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16. Abstract

This report describes the analysis of several intercity corridors for the selection of one candidate for study for the feasibility of providing an exclusive truck facility (ETF). Several alternative designs for ETF are considered for the I-10 freeway corridor from Houston to Beaumont. The existing condition of traffic, geometric designs, land development, truck services and pavement structures were inventoried, and the impacts of ETF options were determined.

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METRIC CONVERSION FACTORS

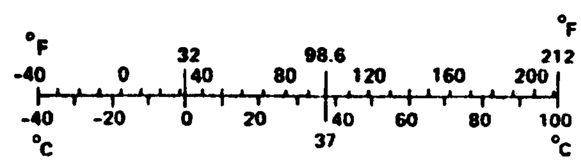
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



THE FEASIBILITY OF EXCLUSIVE TRUCK LANES FOR THE HOUSTON-BEAUMONT CORRIDOR

by

J.T. Lamkin

and

W.R. McCasland

Research Report 393-3F

Research Study Number 2-10-85-393

Feasibility, Design Criteria, and Demonstration of Exclusive Truck Facilities

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DISCLAIMER

The material presented in this paper was assembled during a research project sponsored by the Texas State Department of Highways and Public Transportation and the Federal Highway Administration. The views, interpretations, analyses and conclusions expressed or implied in this report are those of the authors. They do not represent a standard, policy or recommend practice established by the sponsors.

ABSTRACT

This report describes the analysis of several intercity corridors for the selection of one candidate for study for the feasibility of providing an exclusive truck facility (ETF). Several alternative designs for ETF are considered for the I-10 freeway corridor from Houston to Beaumont. The existing condition of traffic, geometric designs, land development, truck services and pavement structures were inventoried, and the impacts of ETF options were determined.

SUMMARY

The deregulation of the trucking industry has intensified competition. There are economic incentives that encourage both the development of large truck technology and smaller fuel efficient passenger cars. As both general and commercial traffic grows, there are serious concerns of safety of roadways shared by vehicles such dissimilar characteristics. Other operations and design issues such as capacity and pavement conditions are impacted by these trends in traffic. This report describes the analysis of one major intercity freeway corridor to determine the feasibility of constructing some type of exclusive roadway facility to separate the large trucks from the smaller vehicles.

Several freeway corridors in the Houston area were considered for the study, with the I-10 freeway, between Houston and Beaumont being selected because of the high volumes of truck traffic. Three major design options for exclusive truck facilities (ETF) were investigated: truck lanes in the median; truck roadways within the highway right-of-way; and truck roadways on new locations. A computer program, developed in study 331 to identify candidate sections that warrant the addition of truck lanes, was used in the analysis.

The project examined the right-of-ways for the I-10 freeway and an alternative route along US-90. The conclusion of that study was that a non-freeway facility that passes through a number of small communities could not feasibly be converted to a high-type roadway for large trucks. The environmental impacts to the non user could not be off-set by the benefits to the users. The alternate route required longer travel distances and would have required very high speeds to gain travel time benefits.

The conclusions of the study of the I-10 right-of-way were that there are a number of short sections 10 to 12 miles that can geometrically accommodate exclusive truck facilities. Major structures would be required to obtain continuous facilities. The construction of the ETF within the freeway median was preferred to other locations in the right-of-way. Some locations outside of the right-of-way were feasible, but problems of acquiring the right-of-way

and providing for truck roadside services, local traffic circulations and freeway to ETF interconnections are complicated.

The overall conclusion of the study is that existing and future trends in traffic volumes do not warrant the construction of an exclusive truck facility on I-10. However, the construction of additional travel lanes that can be shared by non-trucks is the preferred option. The additional lanes should be designed to handle the potentially high truck loads and tire pressures.

IMPLEMENTATION STATEMENT

The findings of this investigation suggest that complete separation of trucks and passenger vehicles in intercity corridors is not feasible, at this time. There is a need to provide stronger pavements and wider lanes for the heavier and larger sized vehicles that will be developed. This study recommends that a short test section (2.5 miles) be developed as an ETF demonstration project to parallel the existing roadway. This section should be instrumented with the most comprehensive electronic systems for measuring truck weights, tire pressures, pavement stresses and other pertinent information. A program of pavement research would be developed to determine the benefits of relieving the old pavements of truck loads, as well as the design needs for new pavements.

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1.0 INTRODUCTION

1.1 BACKGROUND

The deregulation of the trucking industry has intensified competition. Empirical evidence shows that the number of new trucking firms that have opened since the passage of the Motor Carrier Act of 1980 has greatly increased. In addition, the Surface Transportation Act of 1982 has provided the economic incentive that has encouraged the development of large truck technology. Industry demand is high for the larger and heavier trucks, as they have proven to be economically efficient. The safety aspects of the large combinations are only now being documented; current pavement geometrics may not be adequate to safely accommodate large trucks.

Both general and commercial traffic volumes are increasing, the inevitable by-products of the phenomenal growth of Texas. The traffic increase is impinging upon the ability of the current highway system to meet the future needs of the State's economy and the mobility of its residents in a safe and efficient manner. This situation of high traffic densities coupled with larger and heavier trucks can lead to vehicle conflicts and congested driving conditions. Also, current trends toward more compact, fuel-efficient passenger cars raise serious safety considerations due to the sharing of roadways by vehicles of such dissimilar characteristics.

Increased concern in dealing with these problems as they relate to intercity truck traffic has brought about the consideration of segregating trucks from other traffic, either by establishing exclusive lanes on existing roadways, or by constructing new facilities intended exclusively for trucks. Separating trucks from passenger vehicles should improve traffic safety and reduce conflicts for all vehicles, provide an opportunity to design and construct adequate pavement and bridge structures that will accomodate a concentration of heavy vehicles, and substantially reduce maintenance costs on the truck facility and the facility from which trucks would be excluded. Furthermore, many of the more heavily travelled highways are due for extensive rehabilitation. The rehabilitation costs could be scaled down if trucks could be excluded from these facilities and the subsequent savings could be directed towards the construction of exclusive facilities.

1.2 STUDY OBJECTIVES

The objectives of this study are to determine the economic feasibility, safety aspects, and design criteria of providing separate truck facilities for truck traffic between major urban areas. Issues of lesser impact to be investigated are legal aspects, motor carrier issues, and State Agency issues.

1.3 RELATED RESEARCH

1.3.1 Georgia/Florida Study

In April 1979, the Florida and Georgia Departments of Transportation jointly proposed construction of a two-lane, 444-mile long exclusive heavy vehicle facility on I-75 and I-475 from Atlanta to Tampa (1). The objectives of the project were to investigate the following:

1) Improvements in safety and operating characteristics which might be realized by separating trucks, buses, and other heavy vehicles from lighter traffic using the interstate system;
2) Improvements in energy consumption and highway capacity which might be realized if preferential heavy vehicle lanes are constructed on the interstate system;
3) The extension of the lifetime of the interstate facility which might be realized by effective management of the traffic and improved construction, rehabilitation, and maintenance procedures;
4) The suitability of construction materials and improvements to design and operating techniques under actual traffic conditions to handle current and projected traffic on the interstate system; and
5) The accurate identification of the impacts of trucks, buses, and other heavy vehicles on the interstate system.

It was proposed that in Florida the exclusive heavy vehicle lane project be developed on Interstate 75 between Tampa and the Georgia State line (approximately 209 mi.). At that time, the facility had two traffic lanes in each direction separated by at least a 64 foot median. The facility, primarily through rural areas, had 1978 average daily traffic ranging between 10,000 and 25,000 vehicles. Truck traffic was frequently more than 20% of the total traffic. Traffic projection, based on past trends along the facility, indicated that the year 2000 traffic could be between 35,000 to 65,000 vehicles per day (1).

Two lanes would be constructed in the median from Tampa north to the Georgia line. From the intersection of the Interstate with the Florida Turnpike, north to the Georgia line, the exclusive heavy vehicle lanes would be operated on the median side of the facility. The construction and evaluation of a variety of test sections under heavy truck loadings would permit the accurate determination of the impact of the heavy vehicles on these new sections and ascertain what potential design changes might be appropriate to accommodate these loadings (1).

South of the Florida Turnpike, the exclusive heavy vehicle lanes would be operated in the outside lane. This would permit a comparative assessment of the operational characteristics with exclusive lanes on both the inside (northern segment) and outside (southern segment). Placing the preferential heavy vehicle lanes on the outside lanes south of the Florida Turnpike would also permit the research offices to develop methodologies to properly handle heavy vehicles on rehabilitated existing pavements (1).

It was proposed that in Georgia, the preferential heavy vehicle lanes project be developed on Interstates 75 and 475 between the Florida State line and Interstate 285, south of Atlanta (235 mi). The facility would have two traffic lanes in each direction separated by a 40 to 64 foot or greater median. The facility, primarily through rural areas, had 1978 average daily traffic ranging between 19,000 and 76,000 vehicles (1).

Truck traffic on some segments exceeded 20% of the total traffic. Projections based on past trends along the facility, indicated that the year 2000 traffic could be between 35,000 to 163,200 vehicles per day (1).

Two lanes would be constructed in the median for the entire route in Georgia. The preferential heavy vehicle lanes would be operated in the median lanes from the Florida State line to I-475 and on the outside from I-475 to I-285 (1).

The estimated costs for the project, summarized in Table 1-1, indicate an average roadway cost of $1.4 million/mile for the proposed two-lane truck facility.

1.3.2 National Network Study

In 1979, Hansen and Associates conducted a study (2) on 15 representative links of a national freight network for the purposes of identifying truck traffic problems and evaluating several types of improvements oriented toward improving traffic operations and safety. Improvements analyzed on the selected links included:

1) Lane reservation for trucks during peak hours, off-peak hours, or full-time on existing facilities;
2) One additional lane for each direction of travel;
3) One additional lane for each direction and its reservation for trucks during peak periods, off-peak periods and full-time (3 conditions);
4) Construction of a separate 4-lane truckway;

Costs and benefits used in the analyses were limited to the following:

1) Cost of constructing, implementing and maintaining the modifications;
2) Vehicle operations costs due to either changes in operating speed or level of service;
3) Highway user time savings due to reduced travel time; and
4) Accident costs.

Table 1-1. Estimated Costs Georgia/Florida Exclusive Truck Lanes

Florida's I-75 Cost Measures, Tampa to Florida/Georgia Line[a]	
Cost Measures - Including Engineering and Contingencies	
Right-of-Way	None
Bridges	$ 33,660,000
Roadway	$303,980,000
Total Initial Cost	$337,640,000
Annual Cost	
Right-of-Way	None
Bridges (40 yrs. at 7%)	$ 2,520,000
Roadway (20 yrs. at 7%)	$ 28,690,000
Total Annual Cost	$ 31,210,000
Georgia's I-75 and I-475 Cost Measures, Florida/Georgia Line to Atlanta[b]	
Cost Measures - Including Engineering and Contingencies	
Right-of-Way	None
Bridges	$ 30,000,000
Roadway	$300,000,000
Total Initial Cost	$330,000,000
Annual Cost	
Right-of-Way	None
Bridges (40 yrs. at 7%)	$ 2,435,000
Roadway (20 yrs. at 7%)	$ 28,314,000
Total Annual Cost	$ 30,749,000

[a] Length = 209 mi., no. of lanes = 2.

[b] Length = 235 mi., no. of lanes = 2.

Source: (1).

Table 1-2 summarizes the initial cost estimates for the truck facility options evaluated by Hansen and Associates. Of particular interest to the present study are the cost estimates given for the "add one lane" and "separate truck facility" options. The data in Table 1-2 suggest average construction costs of $1.0 million and $2.2 million per mile, respectively, for these two options.

Table 1-3 shows the present worth of total costs and benefits of the options considered for five representative links in the nationwide network. Based on the benefit/cost analysis, Hansen (2) drew the following general conclusions:

1) The most cost-effective type of improvement involved the addition of two new lanes--one in each direction--without full-time reservation during peak hours.
2) Reservation of the additional lanes full-time or during peak hours provided essentially the same cost-effectiveness values. In each case, such reservation reduced the cost-effectiveness of additional lanes but still left this type of improvement second in general cost-effectiveness.
3) Separate truckways on new rights-of-way were cost-effective on 4 of the 5 links showing cost-effectiveness with additional lanes. However, the cost-effectiveness of separate truckways was substantially less than additional lanes in every case.
4) Reservation of existing lanes, full-time or during peak or off-peak hours, was consistently not cost-effective.
5) Typically, changes in accident costs were as follows:
    - o a slight increase when an additional lane was added; and
    - o a small decrease for a separate truckway.

1.3.3 Texas Studies

Mason et al. (3) have described five typical truck lane cross-sections which may be constructed within an existing right-of-way (ROW). Figure 1-1 illustrates these basic cross-sections. The first two place trucks in the median area, with the only difference in the two being the lane and shoulder

Table 1-2. Initial Per-Mile Cost[a] Estimates of Modifications (Thousands of 1979 Dollars)

States	One Additional Lane in Each Direction		Separate Truck Facility		Maintenance (Per Lane)	Reservation Cost
Terrain	Flat	Rolling	Flat	Rolling		
Wisconsin	641	775	1285	1378	8.357	22
Washington	1500	1500	3650	3650	10.098	22
Illinois	860	882	3500	3500	19.615	22
Indiana	443	526	2060	2210	8.009	22
Texas	650	650	1330	1330	5.107	22
Florida	1600	1600	3200	3200	7.428	22
Georgia	717	868	1438	1543	5.455	22
So. Carolina	712	712	3000	3000	3.946	22
No. Carolina	919	1109	1838	1972	4.875	22
Virginia	1217	1472	2441	2619	9.986	22
Massachusetts	959	959	1796	1927	18.222	22
Connecticut	1200	1200	2500	2500	16.249	22
New Hampshire	841	1017	1687	1809	11.258	22
Maine	1440	1440	1000	1000	9.634	22
New York	1155	1397	2316	2484	4.875	22
Pennsylvania	1246	1508	2500	2682	15.553	22
Average	1006		2220			

[a]Costs include construction, maintenance, administrative, and terminal value.

Source: (2).

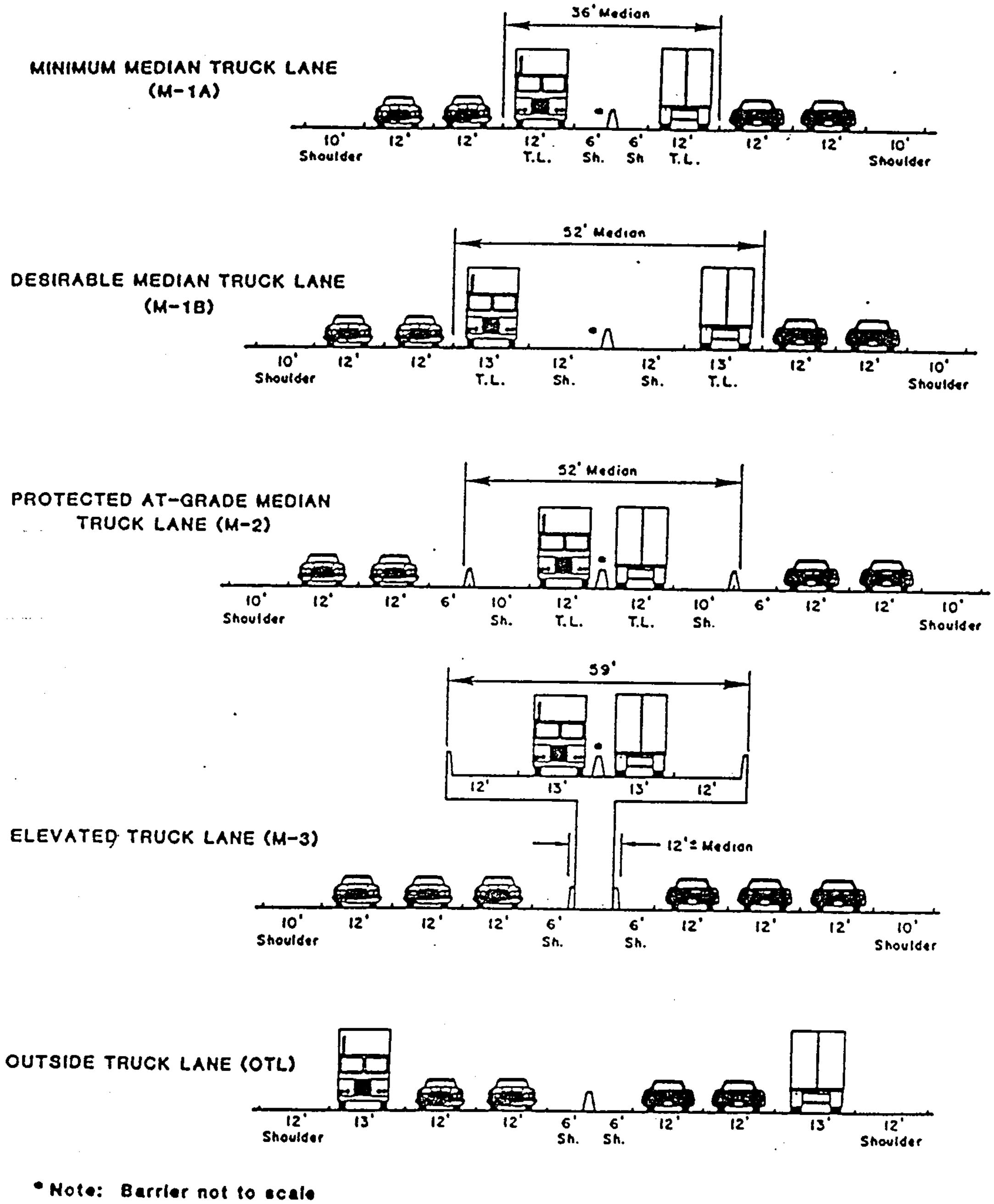
Table 1-3. Total Benefits and Costs for Cost-Effective Links (Present Worth in Thousands of Dollars for 20 Year Period at 10% Interest)

		Reserve One Existing Lane[b]				Add One Lane Each Direction With No Reservation		Add One Lane Each Direction And Reserve One Lane				Add One Lane Each Direction And Reserve Two Lanes[b]				Construct Separate 4-Lane Truckway	
			Peak Hour Reservation	Off-Peak Reservation	Full Time Reservation				Peak Hour Reservation	Off-Peak Reservation	Full Time Reservation		Peak Hour Reservation	Off-Peak Reservation	Full Time Reservation		
Link	Mileage[a]	Cost	Benefit	Benefit	Benefit	Cost	Benefit	Cost	Benefit	Benefit	Benefit	Cost	Benefit	Benefit	Benefit	Cost	Benefit
Atlanta to Chattanooga	73.3	N/A	N/A	N/A	N/A	65,750	124,025	68,022	111,517	124,025	111,517	N/A	N/A	N/A	N/A	109,584	130,600
Atlanta to I-10 & I-75	210.9	139 (4.2)	-6,135 (4.2)	0 (4.2)	6,135 (4.2)	183,493	438,369	190,068	401,182	435,698	398,540	4,032 (4.2)	3,060 (4.2)	11,945 (4.2)	1,616 (4.2)	333,513	448,904
Dallas to Houston	128.2	400 (11.1)	-40,153 (11.1)	1,898 (11.1)	-38,255 (11.1)	86,663	110,603	90,766	110,646	110,603	110,646	8,203 (11.1)	-29,057 (11.1)	18,367 (11.1)	-29,871 (11.1)	177,301	150,713
Richmond to Alexandria	79.0	1,088 (32)	-24,950 (32)	0 (32)	-24,950 (32)	118,188	238,159	120,646	230,221	238,159	230,221	48,506 (32)	84,780 (32)	124,206 (32)	76,956 (32)	213,524	285,538
Greensboro to Atlanta	156.8	971 (28.1)	-17,763 (28.1)	-1,381 (28.1)	-19,143 (28.1)	160,439	530,208	165,382	523,353	528,069	521,251	36,769 (28.1)	63 (28.1)	44,890 (28.1)	-3,467 (28.1)	286,153	573,241

[a] Mileage shown and used in calculations is for rural sections only.

[b] Numbers in parentheses represent mileage over which the modification is possible, and for which benefits and costs were calculated.

Source: (2).



Source: (3).

Figure 1-1. Typical Truck Lane Cross-Sections widths. The first (designated M-1A) exhibits minimum widths while the second (M-1B) shows desirable widths. These two configurations do not physically separate trucks from other traffic by positive barriers. Special lane designations and unique raised pavement markers could be used to define the authorized lane. Option (M-2) shows trucks separated from other traffic by barriers thereby controlling access to the truck lanes. Cross-section (M-3) and the outside truck lane (OTL) pertain to urban areas with restricted right-of-way. These options are discussed on detail in other sections of the report.

1.3.4 Italian Study

In Italy concern about the ever increasing traffic flow, and congestion caused by heavy vehicles has prompted a 40 mph cap on truck speeds on all roads. This is seen as a further hindrance to truck transportation beyond the inconvenience of the existing congestion. To remedy this situation, widening of roadways for additional lanes was first considered, but was proven to be too expensive or impossible to accomplish (possibly for lack of available right-of-way.) The alternative was to design and construct an exclusive truck highway to bypass the areas of greatest congestion and thereby enhance the overall flow of traffic. This study documents the decision process used to develop plans for implementing an exclusive truck highway on the Bologna-Firenze freeway (4).

The Bologna-Firenze Freeway, selected as the initial demonstration of the exclusive truck highway, is a direct link from Northern to Southern Italy (Figure 1-2). This freeway exhibits several problems that made it attractive for this project. A crucial stretch of the existing roadway, from Sasso Marconi to Barberino del Migello, passes through the Appennine Mountains where trucks are particularly prone to difficulty in ascending and descending the steep grades; the existing roadway experiences heavy traffic volumes with a high percentage of truck traffic; and carrying out even routine maintenance causes severe restrictions on traffic flow.

Table 1-4 presents traffic volumes for the major highways in the Italian traffic network, as well as trucks as a percentage of total traffic volume.

Figure 1-2. Exclusive Truck Facility in Italy

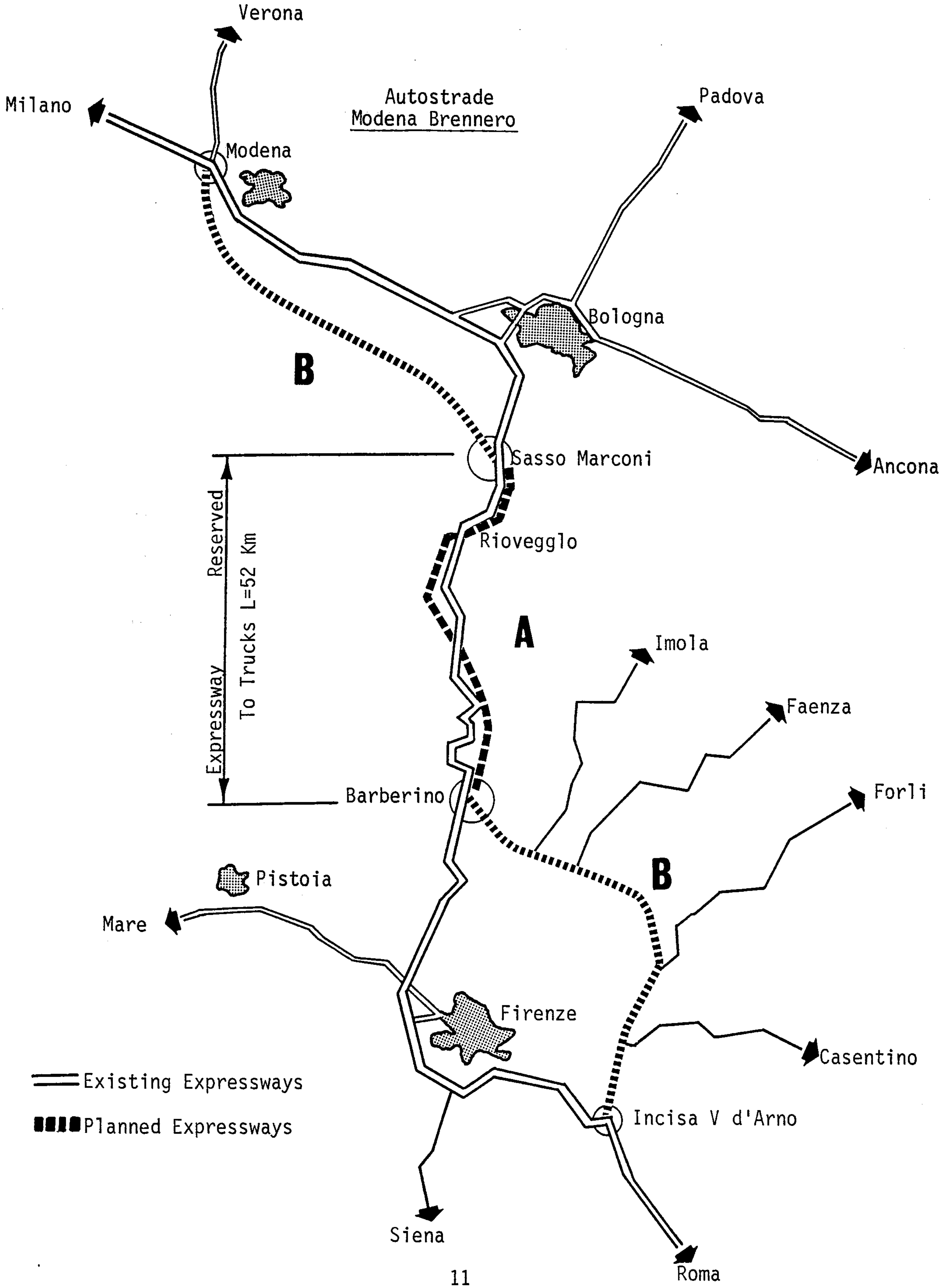


Table 1-4. Traffic Volumes on Main Expressways, 1984

	Average Daily Traffic		
Trunk	Total	Trucks	Percent
Bologna-Florence	33,316	12,321	37%
Milan-Bologna	44,639	15,102	34%
Florence-Rome	29,964	9,496	32%
Rome-Naples	35,300	10,013	28%
Florence-Pisa	27,592	4,790	17%
Turin-Milan	27,774	9,242	33%
Milan-Brescia	52,291	15,860	30%
Padua-Venice	43,675	12,146	28%

A 52 km bypass was designed to reflect the characteristics of the admissable vehicles and the geographic area traversed. Vehicles considered admissable are the traditional truck and trailer combination (most common), the tractor and semitrailer, the extraurban motorbus, and miscellaneous vehicles of exceptional size and weight.

The design features of the truck facility are:

1) Design speed of 80-100 km/h;
2) No sharp curves or longitudinal undulation that limit sight distance (the distance a driver must be able to see to operate his vehicle effectively and safely at the roads design speed);
3) Longitudinal slope with a maximum value of 2.0%;
4) Peak elevation of 490 m as opposed to the 750 m of the existing freeway. This was accomplished by an 8000 m tunnel;
5) Extensive use of viaducts and tunnels (80% of freeway length);
6) Vehicle capabilities were incorporated in the design of the natural ground base, viaducts, and tunnels. The natural ground base is a 4 lane highway with a barrier separating opposing lanes plus a shoulder for emergency stops; the viaduct is of similar construction, with the addition of side barriers to prevent overtopping. The tunnels are the same as the natural ground base with the exception of shoulder space, and are built one tunnel in each direction.

1.3.5 Summary of Related Research

A review of the limited number of studies conducted on exclusive truck facilities provided some general information relevant to the objectives of this study. The key findings of the literature review are summarized below:

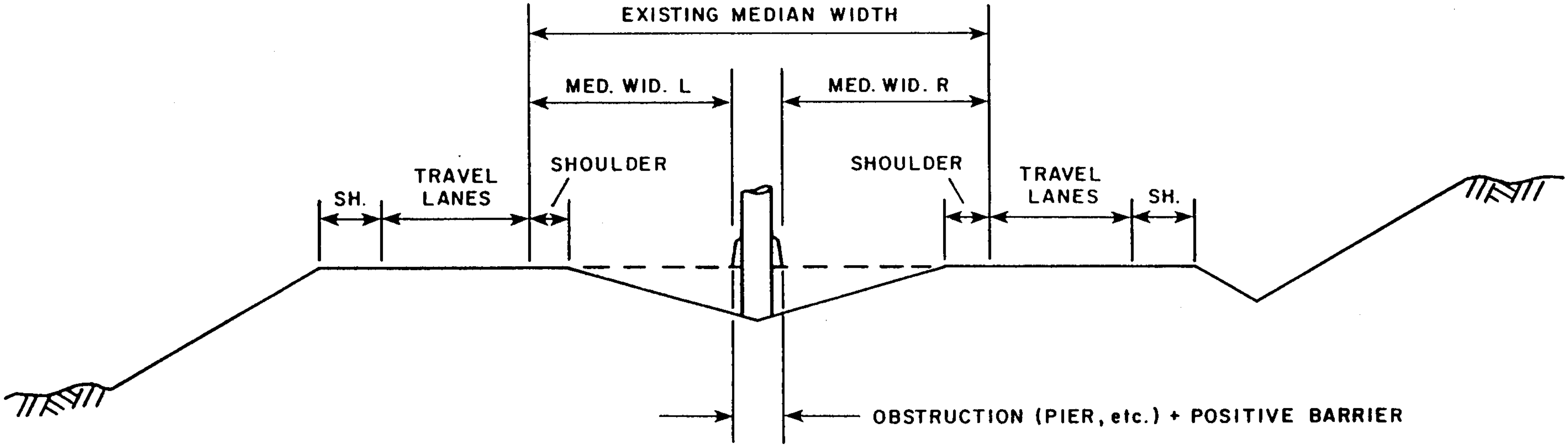
1) In terms of the costs associated with the construction of truck facilities, only some very general values were found. The Florida/Georgia study reported an average roadway cost of $1.4 million/mile for a proposed two-lane truck facility located within an existing freeway ROW. Hansen

Associates reported a comparable cost of $1.0 million/mile for a similar facility (one lane per direction). Hansen Associates estimate the cost of a four-lane truck facility located in a separate ROW as $2.2 million/mile. However, it appears that the Hansen Associates' estimate for separate facilities does not include ROW costs. It should be noted that the Florida/Georgia and the Hansen Associates cost estimates are in 1979 dollars. Discussions with SDHPT construction engineers, and a review of construction costs for recent transitway projects in Houston, suggest that a more realistic estimate of the costs of truck lanes would be in the range of 3-$5 million/lane-mile in 1986 dollars.

2) The limited information available on the potential cost-effectiveness of various truck facility options suggests that the addition of two new lanes for the exclusive use of trucks during peak hours is the most cost-effective means of improving truck operations and safety. The cost-effectiveness of separate truck facilities was found to be lower than the provision of additional lanes within the existing cross-section. Reservation of existing lanes for use by trucks was consistently not cost-effective (2).

3) There appears to be very little information regarding the design and operational requirements for exclusive truck facilities located in a separate ROW. However, Mason et al. suggest that lane widths for exclusive truck facilities should be at least 12 feet in width, preferably 13 feet (5). The wider lane widths may be used if sufficient funds permit the increased costs associated with increased pavement widths. Shoulder widths should be about 10 to 12 feet where possible to allow 1 to 2 feet of clearance between a stopped vehicle and the pavement edge. These criteria would appear to be applicable to exclusive truck facilities in general. Additionally, it would seem reasonable to assume that in order to serve existing travel demands and needs, exclusive truck facilities constructed in a separate ROW should parallel the roadway(s) they are intended to replace. The option of a "parallel facility" has the advantage that, in the case of interstate roadways, the existing ROW may be sufficient to accommodate the exclusive truck facility. A disadvantage of this option is that closely paralleling an existing roadway may require construction of elaborate and expensive grade separated interchanges at roadways which intersect with the truck facility.

4) Mason et al. note that a key consideration when evaluating the feasibility of a truck lane in an existing ROW is the minimum "effective median width". The effective median width is the available clear width of median measured from the nearest edge of each inside travel lane. Any barriers such as piers for overhead structures are subtracted from this clear width. The width of a positive barrier such as the concrete "safety shape" is also subtracted from the total median width to establish the effective median width. Figure 1-3 illustrates these measurements.



TOTAL EFFECTIVE MEDIAN WIDTH = EXISTING MEDIAN WIDTH MINUS (OBSTRUCTIONS + BARRIER)

Effective Median Width

Figure 1-3

Source: (3).

2.0 STUDY CORRIDOR DESCRIPTION

2.1 CORRIDOR DEFINITION

Initially, four corridors were examined for a more detailed evaluation. Houston was selected as one of the hubs because of the large and increasing volume of intercity trucks with an origin or destination in the city. Also, a large volume of through trucks transit Houston on a daily basis. This section of the report presents a general description of the counties within the corridor selected. Requirements for the study were that the corridor would be of moderate length, have significant truck volumes, have hubs with high commercial and industrial activities, and not be confined within urban or highly developed areas. Figure 2-1 shows the route of the four corridors considered. The Houston-Beaumont corridor was selected for a more detailed evaluation.

2.1.1 I-10 Corridor, Houston to Beaumont

The Houston to Beaumont corridor passes along I-10 through Harris and Chambers counties and ends in Jefferson county. It is approximately 75 miles in length. 1984 daily average truck volumes were between of 4600 and 6600 trucks per day, or approximately 15% to 25% of total traffic. A discussion of the economic and industrial base of the counties in the Houston-Beaumont corridor is presented below. Information on other counties for the routes considered and the truck and total traffic volumes are found in Appendix A.

Harris County

Harris County has a total population of over 2.5 million, most of which is accounted for by the cities of Houston (population 1.6 million), Pasadena (population 112,500), and Baytown (population 57,000). It is highly industrialized, although in 1980 agriculture did account for $69,000,000 in annual income. In 1977, 3.707 manufacturing operations shipped over $23.2 billion worth of goods, 5,134 wholesale establishments had total sales of $29.9 billion, 17,324 retail firms has total sales of $9.4 billion, and sales of minerals topped $438 million.

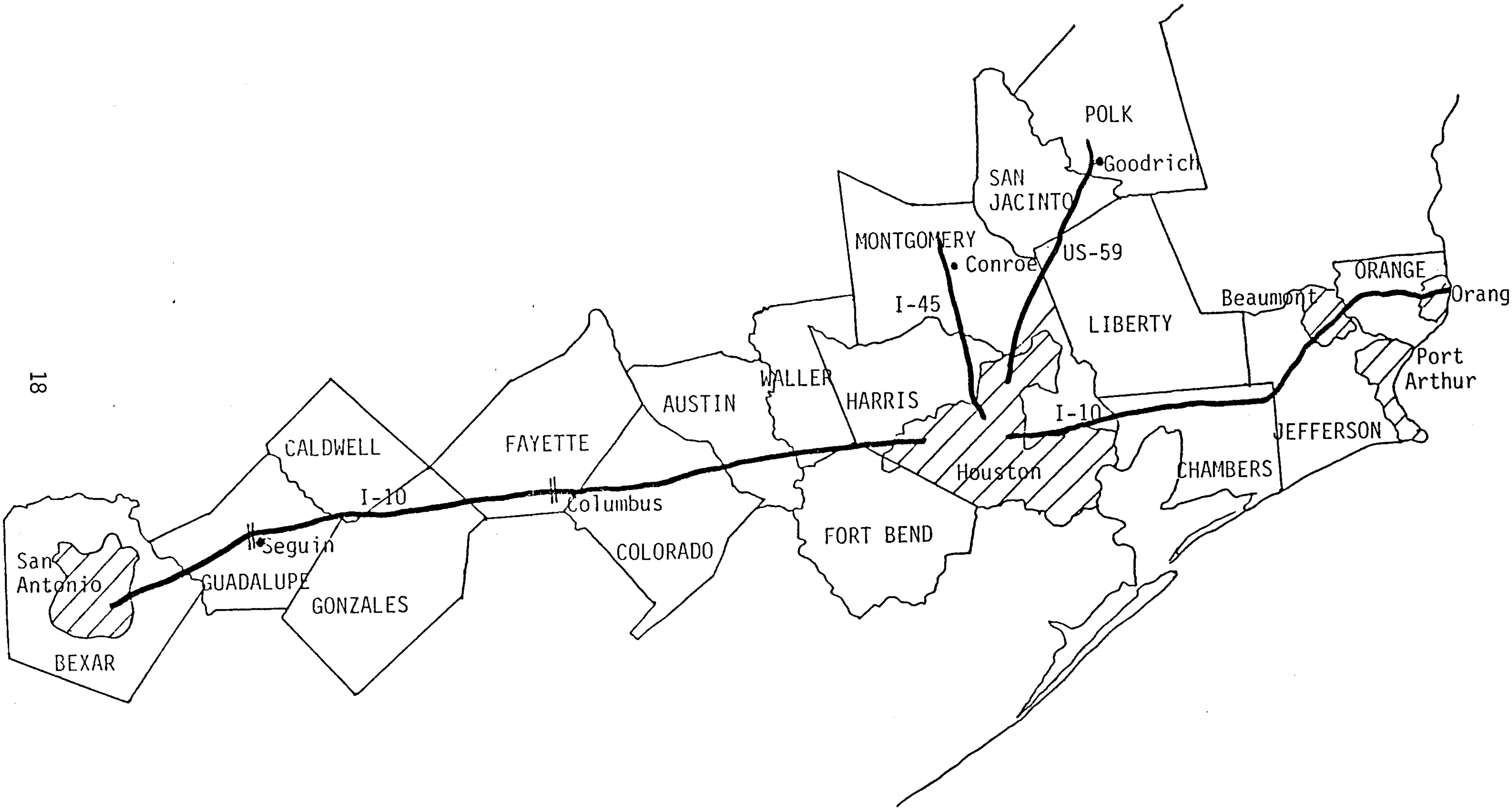


Figure 2-1. Candidate Routes for Study

This county is among the leading oil, gas, and petrochemical areas: it is at the center of a multicounty petrochemical, development that are the worlds' largest. Businesses produce petroleum, cement, natural gas liquids, natural gas, salt, lime, sand and gravel, clays, stone, chemicals, food and kindred products, primary metals, scientific instruments, paper and allied products, and are involved in petroleum refining.

Harris County is a center for space, medical, and energy research; it also contains the second largest seaport in the United States. More than 1.45 million people are employed, earning total wages in excess of thirty billion dollars. The majority of these are employed in the trade, service, manufacturing, and construction industries.

The county seat is Houston, which with a population of over 1.6 million people is the largest city in the state. Houston ranks as first among the nation's cities in annual value of building permits; first in the manufacture of petroleum equipment, agricultural chemicals, fertilizers, pesticides, and oil and gas pipeline transmissions; fifth in the manufacture of machinery; and sixth in the manufacture of fabricated metals.

Plants in Houston make apparel, lumber and wood products, furniture, paper and publications; chemical, petroleum, and coal products; stone, clay, and glass products; electrical and electronic products; and various textiles.

In 1977 it had 4,454 wholesale establishments produced total sales of $27.1 billion, 12,808 retail firms recorded over $7.2 billion in total sales, and 2,994 manufacturing operations shipped over $11.5 billion in goods.

Since 1970 over 200 firms have moved their headquarters to Houston, making it a large corporate nucleus. It is also a leading hub of scientific and engineering research. Most importantly for this study, it is the major distribution and shipping center for the region.

Chambers County

Chambers County has a population of 18,500, 8,400 of whom are employed and earning wages of $172.6 million. The chief businesses are petroleum, chemicals, steel plants, agribusiness, and a variety of manufacturing. In 1977 there were 7 manufacturing operations, 21 wholesale establishments with total sales of $142.8 million, and 150 retail firms with total sales of $42,616 million.

Jefferson County

Jefferson County has a population of over 250,000, 116,000 which are employed and earning wages totaling $2,177.8 million. They are concentrated in the manufacturing, trade, and service industries, and the state government.

The economy is supported by petrochemicals, other chemicals, ship building, steel mills, and port activity; oil field supplies dominate. Agriculture contributes about $30 million average income, over 80% from crops. In 1977 240 manufacturing operations shipped $975 billion worth of goods, 403 wholesale trade establishments produced total sales of $1.9 billion, and 2,221 retail trade firms had total sales of $982.2 billion. Minerals, particularly oil, gas, sulphur, salt, sand, and gravel accounted for over $124 million in sales.

Beaumont, the county seat, has a population of 118,000. It has a variety of chemical and petrochemical plants, oil refineries, ship builders, extensive port activities, and steel mill, and is a rice milling center.

Port Arthur, population 16,855, is a center for oil and chemical plants. Other industries are shipping, rice milling, and tourism.

2.1.2 Selected Study Corridor

The study corridor extends from I-610 in Houston to Beaumont; a distance of approximately 75 miles. Travel demands in the corridor are served by US-90 and I-10 (Figure 2-2). The I-10 Freeway is a typical 4-lane divided

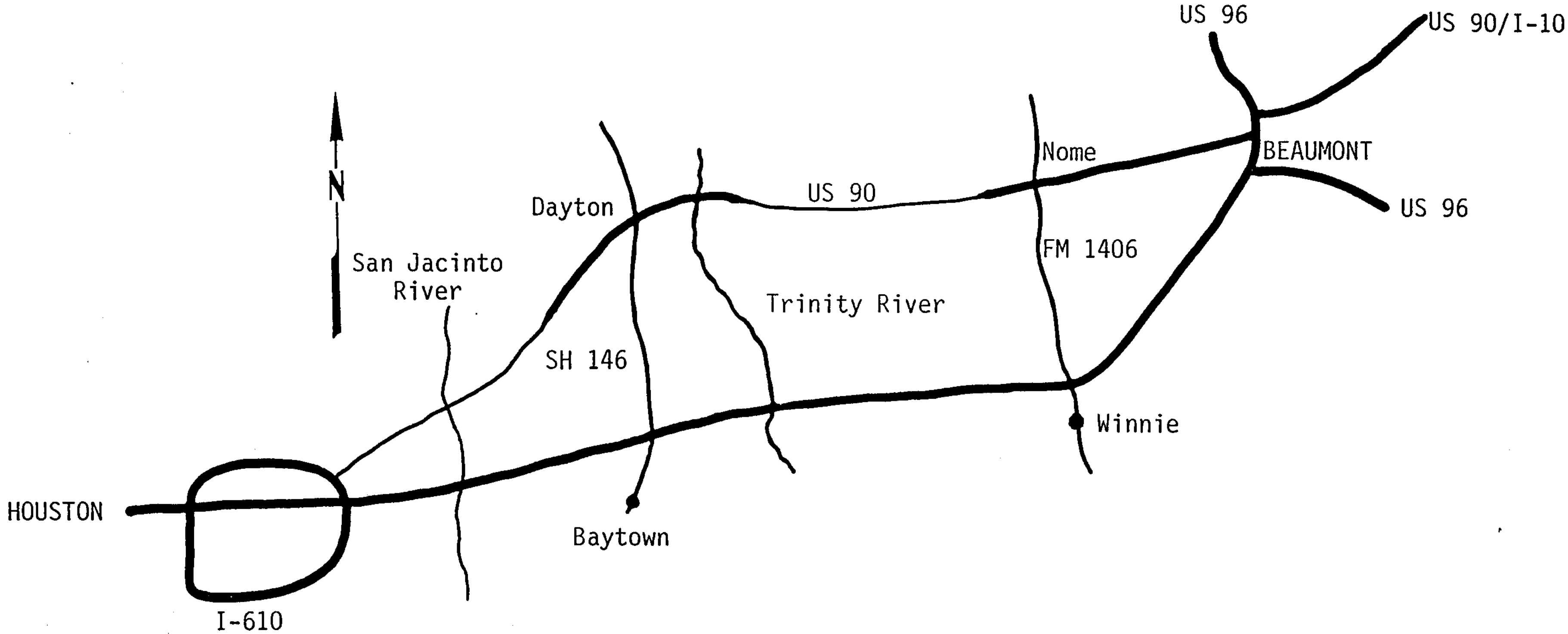


Figure 2-2. Beaumont-Houston Study Corridor

interstate highway. The US-90 cross-section consists of 2-lane sections along the western and central segments of the facility, and 4-lane divided sections on the central and eastern segments of the facility. Both highways were considered as candidates for exclusive truck facilities (ETF).

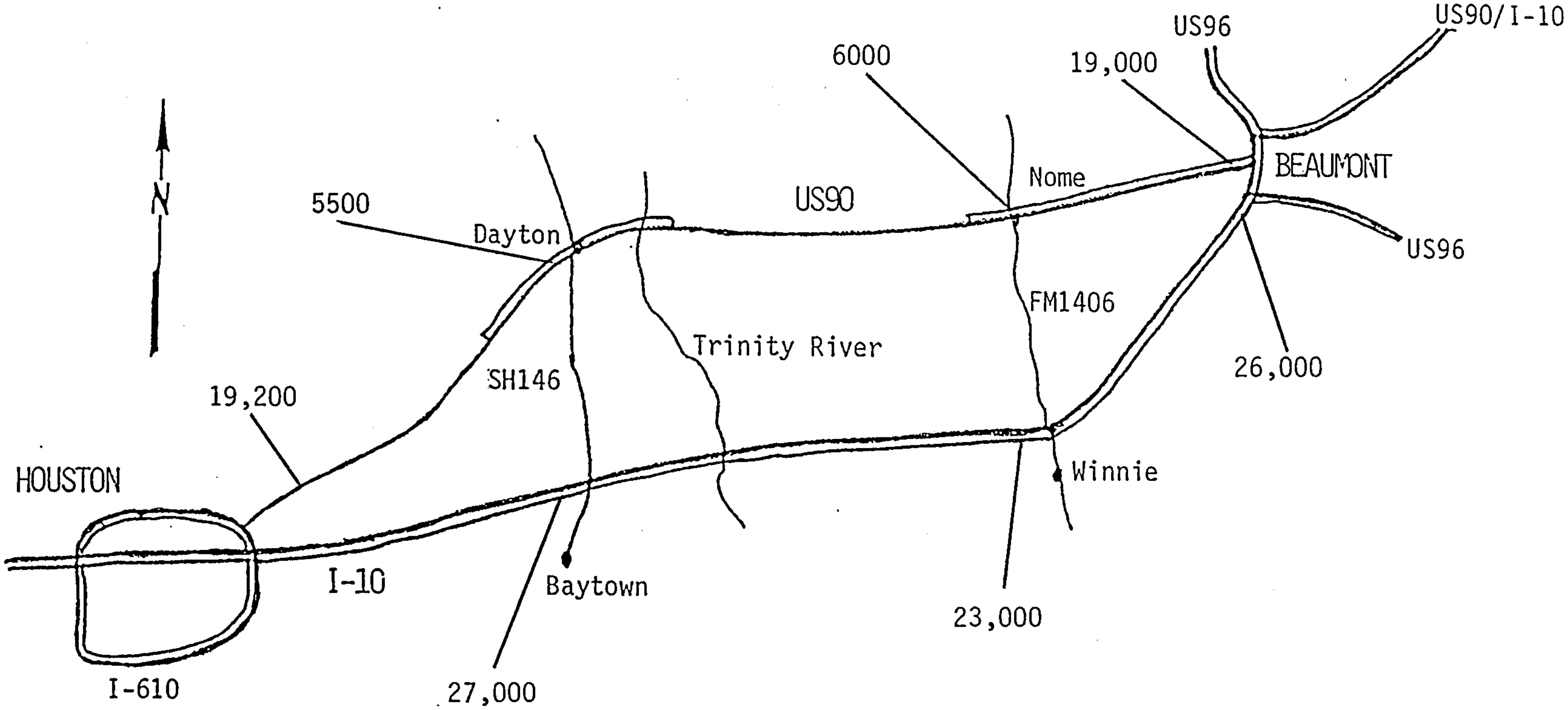
The northeast area of Houston has a large number of freight-related facilities, and as might be expected, both I-10 and US-90 serve relatively large volumes of truck traffic. As a result, a number of measures oriented toward improving truck operations and safety in the corridor have been discussed in recent years. One alternative for improving safety and capacity along a heavily traveled truck corridor is to provide exclusive truck facilities. While no widely accepted warrants concerning the need for exclusive truck facilities exist, safety and capacity would certainly appear to be key considerations in assessing the need for such facilities.

This section of the report presents a general overview of the traffic and safety conditions along the two roadways located in the study corridor. Subsequent sections will assess, in general terms, how the various exclusive truck facility options under consideration might effect traffic and operating conditions within the corridor.

2.2 TRAFFIC VOLUMES

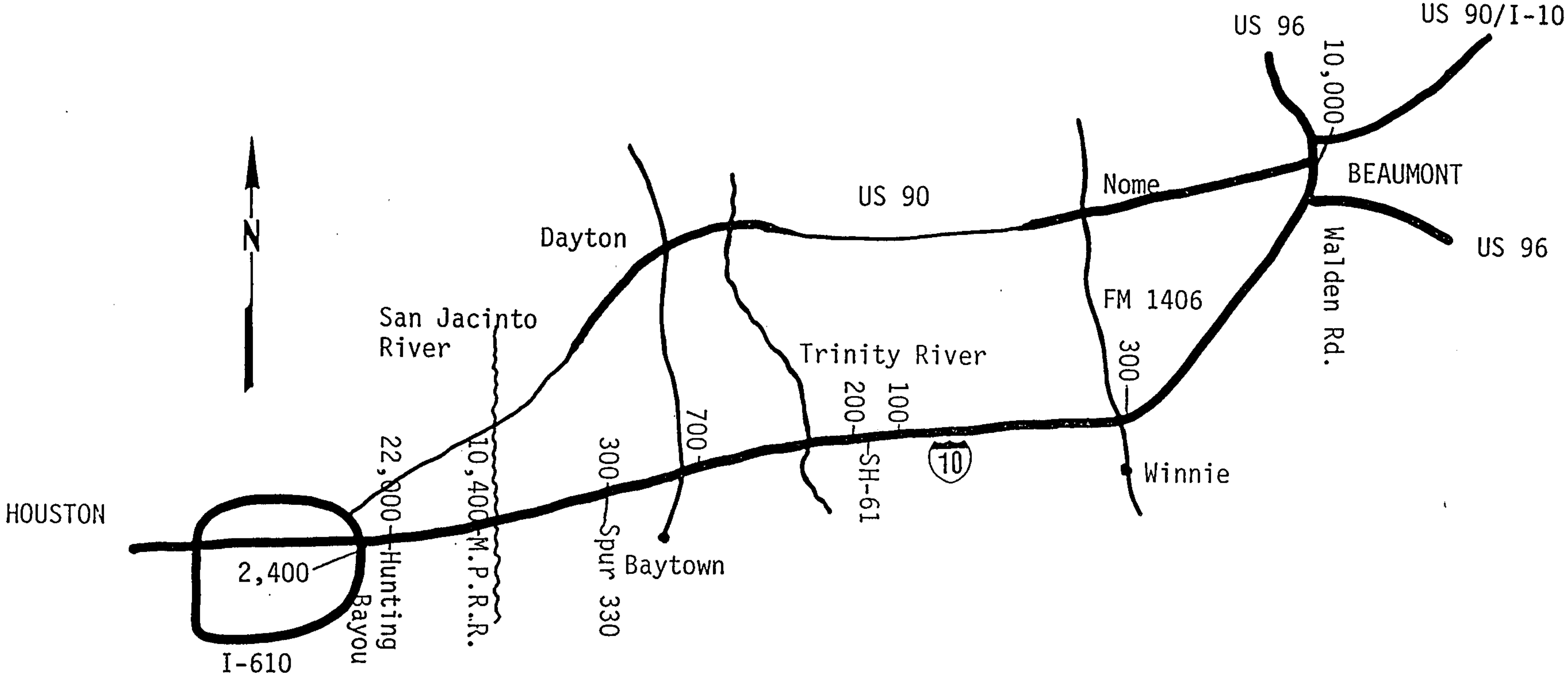
Average daily traffic (ADT) volumes at several locations on I-10 and US-90 main lanes are shown on Figure 2-3. Traffic volumes on I-10 between Houston and Beaumont are fairly uniform, with average daily traffic volumes in the range of 23-27,000 vehicles per day (vpd). Average daily traffic volumes on US-90 range from a low of 5500-6000 vpd on rural segments, to a high of 19-19,500 vpd on those segments near Houston and Beaumont. On I-10 frontage roads, the ADT volumes ranged from 22,000 vpd in urban areas to 100 vpd in rural areas (Figure 2-4).

Preliminary surveys by the Texas Transportation Institute (TTI) suggest that trucks may account for roughly one-third of the total daily traffic on I-10 (Table 2-1). In terms of directional and hourly characteristics, eastbound truck traffic on I-10 tends to peak in the mid- to late afternoon hours



Source: District Highway Traffic Maps, SDHPT.

Figure 2-3. Annual Average 24-Hour Traffic Volumes (1984) for Main Lanes on I-10 and US-90



Source: State Department of Highways and Public Transportation (SDHPT)

Figure 2-4. Average Daily Traffic Volumes (1984) Frontage Roads

Table 2-1. 24-Hour Traffic Volumes I-10 (1985) Main Lanes

Location and Direction	Total Traffic	Truck[a] Traffic Number	Truck[a] Traffic % Total
SH 146 - Baytown (WB)	11,164	3953	35%
SH-146 - Baytown (EB)	10,698	2724	26%
FM 1406 - Winnie (WB)	8,362	2686	32%
FM 1406 - Winnie (EB)	8,494	2749	32%

[a] Truck defined as vehicle with 3 or more axles.

Source: TTI Survey (2/86).

Table 2-2. Peak-Hour Traffic Volumes US-90 (1986)

Location	Peak Hour Vehicles (Total)	Truck[a] Traffic Number	Truck[a] Traffic % Total
East of I-610	1,450	210	15%
West of Dayton	710	45	6%
West of Beaumont	1,400	50	4%

[a] Truck defined as vehicle with 3 or more axles.

Source: TTI Surveys (2/86).

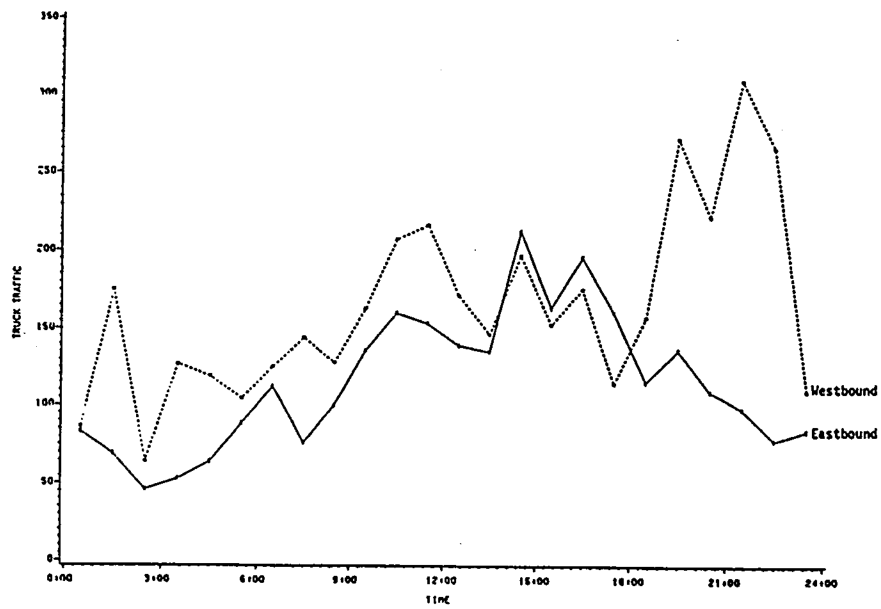
(Figure 2-5). Westbound truck traffic on I-10 tends to peak in early morning and late night hours.

"Spot checks" on US-90 suggest that on those segments near Houston, trucks may account for about 15 percent of peak-hour traffic (Table 2-2). Notice that the peak-hour truck volumes observed on US 90 near I-610 are not substantially lower than the hourly truck volumes observed on I-10 (Figure 2-5). Truck traffic on US 90 near Dayton and Beaumont appears to constitute 4-6 percent of peak-hour traffic.

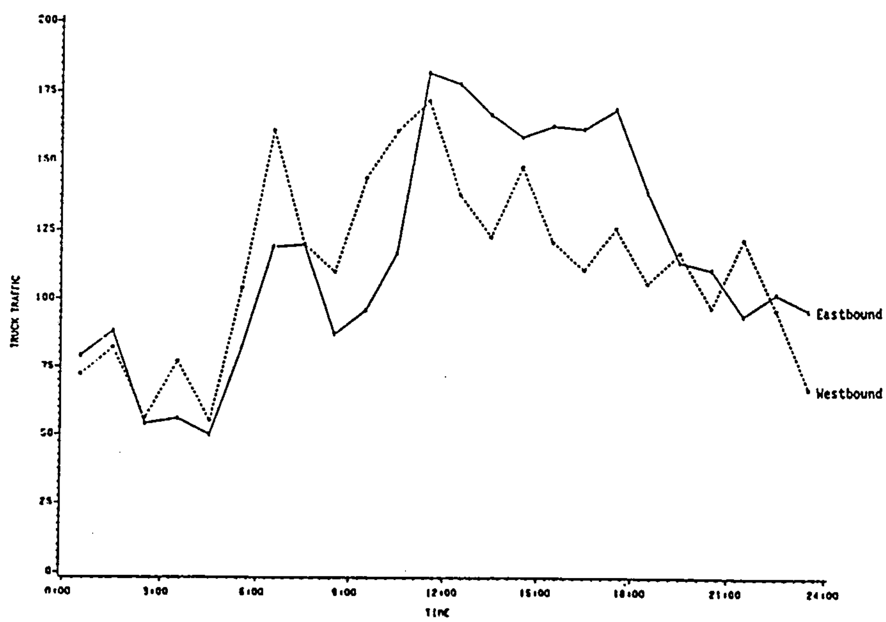
2.3 ACCIDENT EXPERIENCE

Table 2-3 summarizes 1984 truck accident data for the study corridor and all Interstate and US/State highways in Texas. Table 2-4 presents the results of preliminary statistical analyses of the accident data. The basic rationale of the statistical tests summarized in Table 2-4 is that the ratio of corridor accidents to statewide accidents (accident ratio) should not be significantly different than the ratio of corridor vehicle miles of travel (VMT) to statewide VMT (VMT ratio). For example, I-10 accounted for only 5 percent of the statewide Interstate VMT in 1984, but accounted for over 12 percent of the statewide Interstate truck accidents. The accident ratios for the two roadways in the study corridor are significantly larger than would be expected on the basis of their contributions to the statewide VMT (Table 2-4).

Truck accident data for the Houston-Beaumont study corridor on the I-10 frontage roads is summarized in Table 2-5. The percent of truck-accidents is less than the percent of trucks in the area and there are no significant changes in accident experience over the last three years.



(a) Baytown



(b) Winnie

Figure 2-5. Hourly Truck Traffic Volumes I-10 (1985)

Table 2-3. Truck Accidents for Rural Sections of I-10, US-90, and All Interstate and US/State Highways in Texas (1984)

Roadway	Truck[a] Accidents	Annual Vehicle Miles of Travel (VMT) (Millions)	Accidents per Million VMT
I-10E	120	522	0.23
US 90	44	137	0.32
Subtotal	164	659	0.25
All Interstates	972	10,802	0.09
All US/State	3521	23,999	0.15
Total	4493	34,801	0.13

[a] Large trucks (over 10,000 pounds, excludes vans and pickups).

Source: Texas DPS Accident Files (1984) and District Highway Traffic Maps (1984).

Table 2-4. Statistical Test of Hypothesis $p = p_0$

Roadway	Accident Ratio[a] (p)	VMT Ratio[b] (p_0)	Z Statistic[c]
I-10E	0.123	0.048	10.938[d]
US90	0.012	0.006	6.000[d]

[a] p = corridor accidents/statewide accidents.

[b] p_0 = corridor VMT/Statewide VMT.

[c] $Z = (p-p_0)/(p_0(1-p_0)/N)^{1/2}$; where N = total number of accidents.

[d] Significant at 5% level.

Table 2-5. Truck Accidents on I-10 Frontage Roads -- I-610 to US-90

	1983			1984			1985		
	Total	Trucks	% Total	Total	Trucks	% Total	Total	Trucks	% Total
Eastbound	249	44	18	226	53	23	194	34	18
Westbound	278	60	22	245	62	25	245	46	19
Total	527	104	20	471	115	24	440	80	18

2.4 LAND USE CHARACTERISTICS

Land use characteristics along the study corridor vary considerable. The potential for an exclusive truck facility outside the existing highway depends on the availability and costs of new right-of-way. In those areas of the corridor where large scale development (commercial, industrial or residential) has taken place, the potential for obtaining additional rights-of-way is greatly diminished and any exclusive type facility must be accommodated within the existing highway by added lanes, lanes designation, use of median or some other means.

An examination of aerial photographs of the study corridor indicated that approximately 75 percent of the land adjacent or within one half mile of the existing facility is undeveloped and may be suitable and available for right-of-way for an exclusive truck facility. Table 2-6 shows that undeveloped land is available on both the north and south sides of I-10.

The majority of highway developed land is located between the junction of I-610 and I-10 and the San Jacinto River/Baytown exit area. Additional developed land is located at Winnie and near the Beaumont terminus of the study corridor.

From the Baytown exit to SH-146 to the Trinity River, approximately 12 miles, there is considerable undeveloped land on the south side of the existing facility. East of the Trinity River to near Winnie, considerable undeveloped land is found on both sides of I-10. This section is approximately 20 miles in length and is primarily undeveloped with only occasional small areas of development.

From northeast of Winnie to Beaumont, there is also considerable undeveloped land. The southeast side of I-10 is somewhat more developed. The northwest side is basically undeveloped to the junction of I-10 and US-90.

Table 2-6: Land Use Adjacent to I-10 Study Corridor

Land use	Number of Miles (approx)
Developed: North Side	17
Developed: South Side	19
Undeveloped: North Side	58
Undeveloped: South Side	56

Within the study corridor there is available land for exclusive truck facility adjacent or in close proximity to the existing facility. However, not all of the undeveloped land is contiguous. The suitability of the land was not determined. There are several rivers and low areas in the study corridor and the potential problems they may pose need to be determined.

2.5 TRUCK SUPPORT FACILITIES

There are several truck stop facilities within the study corridor which could be adversely impacted by a truck facility. The extent of impact tends to vary with the type of facility considered. The designation or addition of lanes, either exclusive or non-exclusive would have limited impact on their operations. An exclusive facility on a new right-of-way would have significant impact on the existing truck stops and result in closure and/or relocation.

Five truck stops were identified within the study corridor. These firms provide a broad range of services and provide various supplies to both truck and automobile traffic on I-10. According to truck stop operators interviewed, up to 90 percent of gross revenue may to attributed to motor trucks. Only one of the truck stops provided a full range of services for trucks.* The other provided a combination of service station and convenience store services.

During discussions with the truck stop operators it was indicated that up to 600 vehicles per day use the services provided by the truck stops. As high as 80 percent of the total traffic may be trucks. Long haul (intercity/interstate) trucks tended to use truck stops which provided a full range of services. Local cartage, sand and gravel carriers, delivery vehicles, and trucks operating within a relatively small area used the service station/ convenience store - usually on a daily basis.

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*This includes shower and rest facilities, truck supplies, overnight parking, restaurant, mechanic, gift shop, and other items and services.

The impact on the truck stops in the study corridor as a result of a truck facility relates to their current type operation. The service station/ convenience stores which derive most of their business from local truck operations may not be significantly impacted. Short haul and local trucks may not be able to use an exclusive truck facility due to their operating characteristics. These carriers tend to require frequent access which may not be compatible with an exclusive truck facility on a separate right-of-way. The implementation of an exclusive or non-exclusive truck lane would also have negligible impacts as long as access was maintained.

Truck stops providing a full range of services and catering primarily to long haul intercity/interstate trucks would be severely impacted if through truck traffic was rerouted to an exclusive facility. The use of the available median would also have negative effects unless interchange facilities are provided at truck stop locales. An exclusive or non-exclusive truck lane with access facilities maintained should have no effects on the full service truck stop.

Since truck stops provide a necessary service to truck operators, the decision to develop an exclusive truck facility on separate right-of-way should recognize these needs. These needs (for both truck and automobile traffic) are provided on toll type highways at designated intervals. Regardless of what type facility might be eventually adopted, the need for the services provided by truck stops will be required.

3.0 EVALUATION OF ALTERNATIVES

3.1 GENERAL

For any freeway corridor, the options for an exclusive truck facility (ETF) include a combination of the following locations: within the median of the freeway, within the right-of-way of the freeway, on a new right-of-way, within the right-of-way of an adjacent roadway. For the Beaumont to Houston corridor, the median areas for two roadways (I-10 and US-90) were examined. For the interstate facility, the area within the right-of-way, normally used for the frontage roads was considered. New locations were considered only in terms of availability of land. The assumption is that if it is feasible to build an ETF within the right-of-way, and if land is available for new locations, it is feasible to build an ETF outside the existing right-of-way.

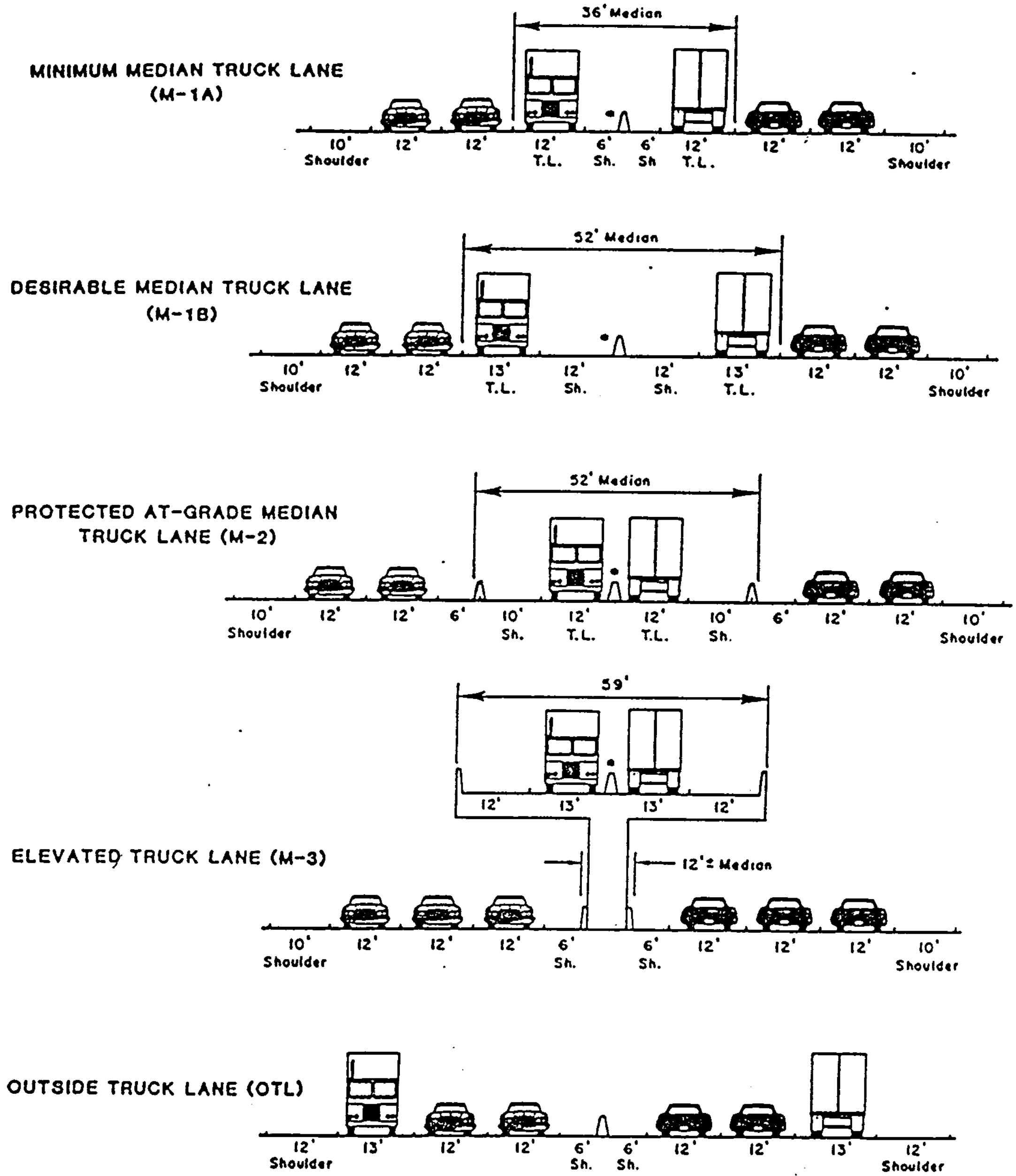
The evaluations are based primarily on the physical and design requirements for upgrading an existing facility and for constructing a new facility. The impacts of the alternatives on the users and non-users of the facilities are considered.

3.2 EXCLUSIVE TRUCK FACILITIES IN THE HIGHWAY MEDIAN

The opportunities and constraints offered by the existing roadway cross-section are key considerations in assessing the feasibility of an ETF within existing right-of-ways. The alternative designs for median truck facilities are compared to the effective median widths of the roadways in the study corridor, I-10 and US-90, to determine the feasibility of median truck lanes. For a more detailed discussion of the median options presented in this section, please refer to the report, Operational and Geometric Evaluation of Exclusive Truck Lanes, by Mason and others (3).

3.2.1. Authorized At-Grade Median Truck Lane, M-1A and M-1B

To accommodate the continuous "through" truck nature of traffic along rural segments, cross-sections M-1A and M-1B and M-2 appear feasible (Figure 3-1). The first two cross-sections are best suited for rural areas with



* Note: Barrier not to scale

Source: (3).

Figure 3-1. Typical Truck Lane Cross-Sections effective median widths of 36 feet or greater. M-1A should be considered as a minimum cross-section. The travel lanes are 12 feet wide with shoulder widths of only about 6 feet. The second option, M-1B, depicts the desirable cross-section, with 13 foot travel lanes and 12 foot shoulders. Both directions of travel are separated by a positive barrier. The designer should consider the use of taller, more sturdy barriers to withstand the impact of large vehicles.

One advantage of this cross-section is its application in narrow medians. Further, the pavement structure would be specifically designed to carry the anticipated truck traffic. The existing travel lanes would experience a longer service life due to the reduced heavy axle load repetitions. This option is the most economical in comparison to the other alternative schemes.

There are several disadvantages to the M-1 designs: (1) limited control of entering/exiting maneuvers, (2) no provision for truck passing maneuvers, (3) insufficient inside shoulder for a stalled truck, and (4) long weaving distances necessary near interchanges. The M-1 design does not completely separate the trucks from other traffic.

3.2.2 Separated At-Grade Median Truck Lane, M-2

Separation of trucks from smaller vehicles is achieved by positive barriers on each side of the exclusive truck facility as shown in Figure 3-1. Again, the designer should consider the use of the taller barrier to withstand impact by these larger vehicles. Minimum travel lanes and shoulders are 12 feet and 10 feet, respectively; 13 feet and 12 feet widths are desirable.

Advantages of this option include: (1) total control of entering/exiting movements; and (2) this option can be easily used with the separate truck intersection or interchange and with the elevated truck lane, M-3.

Disadvantages include: (1) greater required median width; and (2) insufficient clear width for some wide loads.

3.2.3 Elevated Median Truck Lane, M-3

In urban areas where available median width is at a premium, this cross-section is a viable option. Cost effectiveness is the primary consideration. However, the facility could also be used by line-haul transit or by express bus from outlying park-and-ride lots. Buses have operating characteristics which are compatible with large trucks. Special consideration must be given for pavement drainage, lighting and vertical clearance for vehicles at ground level, and the problem of icing during winter months. A combination of this cross-section and M-2 is appropriate near the urban fringe.

Advantages of M-3 are: (1) minimum median width required; (2) control of access of large vehicles; (3) potential use by transit vehicles; and (4) compatibility with the M-2 cross-section.

Disadvantages are: (1) high cost; (2) difficulty in future expansion; (3) icing in winter months; (4) insufficient clearance for wide loads; and (5) noise problems near environmentally sensitive areas.

3.2.4 Authorized Outside At-Grade Truck Lane, (OTL)

In this case, the median is not used for trucks per se, but autos are shifted toward the median so that trucks can be accommodated in the outside lane(s). This is a suitable arrangement for both urban and rural settings and is particularly beneficial in urban areas in that trucks are not required to weave across two or more lanes of heavy traffic to enter or exit the truck lane as in M-1. Since some trucks move slower than autos, this arrangement allows slower vehicles to remain to the right; faster trucks have the opportunity to pass slower vehicles where appropriate.

Advantages include: (1) lower cost than M-2 or M-3; (2) smoother operation of traffic with slower vehicles to the right; (3) overall weaving is minimized; (4) median barrier can be the standard safety shape for autos; and (5) wide loads can be accommodated without special provisions.

Disadvantages to the outside truck lane configuration include: (1) existing pavement design may be insufficient for total truck loading; (2) enforcement problems due to trucks using unauthorized lanes for passing; (3) lack of capacity near interchange ramps for all trucks plus entering/exiting traffic; and (4) generally provides a small incremental improvement in operations.

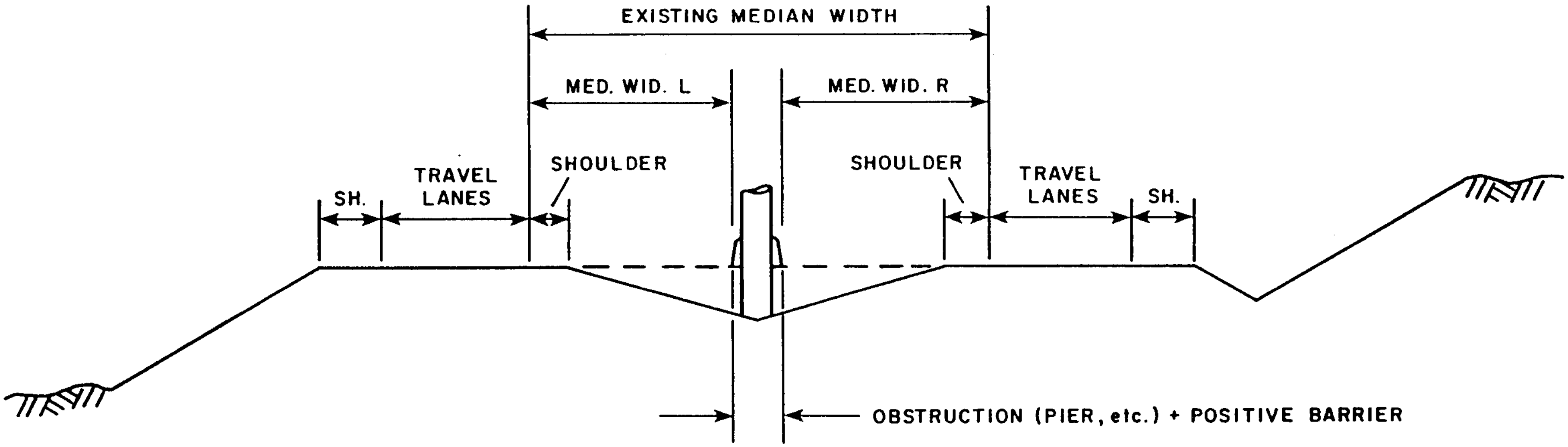
3.2.5 Computer Program for Analyses

The feasibility of using existing median areas for ETF was presented by Mason et. al. (3) for typical Texas State Department of Highways and Public Transportation (SDHPT) median widths of 36 feet, 44 feet, 48 feet, 60 feet, and 76 feet. The critical dimension in median ETF's was the "effective median width". This effective median width is the available clear width of median measured from the nearest edge of each inside travel lane. Any obstructions such as piers for overhead structures were subtracted from this clear width. The width of a positive barrier such as the concrete "safety shape" was also subtracted from the total median width to establish the effective median width. Figure 3-2 illustrates these measurements.

3.2.5.1 Study Procedure

Following selection of the corridor for evaluation, information was gathered in the form of traffic classification counts, existing and predicted population growth along the corridor, size of affected urban areas, horizontal and vertical alignment information about the roadway, and aerial photographs of the corridor.

A strip map was developed showing a schematic plan view of the roadway at a scale of 1 inch equals 1 mile. Figure 3-3 illustrates the general concept. Additional information included: milepost at 10 mile increments, bridges, overpasses interchanges and their ramp configurations, median obstructions, county lines, city limit boundaries, rivers, and other pertinent geographic features. This information was positioned on the top one-third of the strip map.



TOTAL EFFECTIVE MEDIAN WIDTH = EXISTING MEDIAN WIDTH MINUS (OBSTRUCTIONS + BARRIER)

Effective Median Width

Figure 3-2

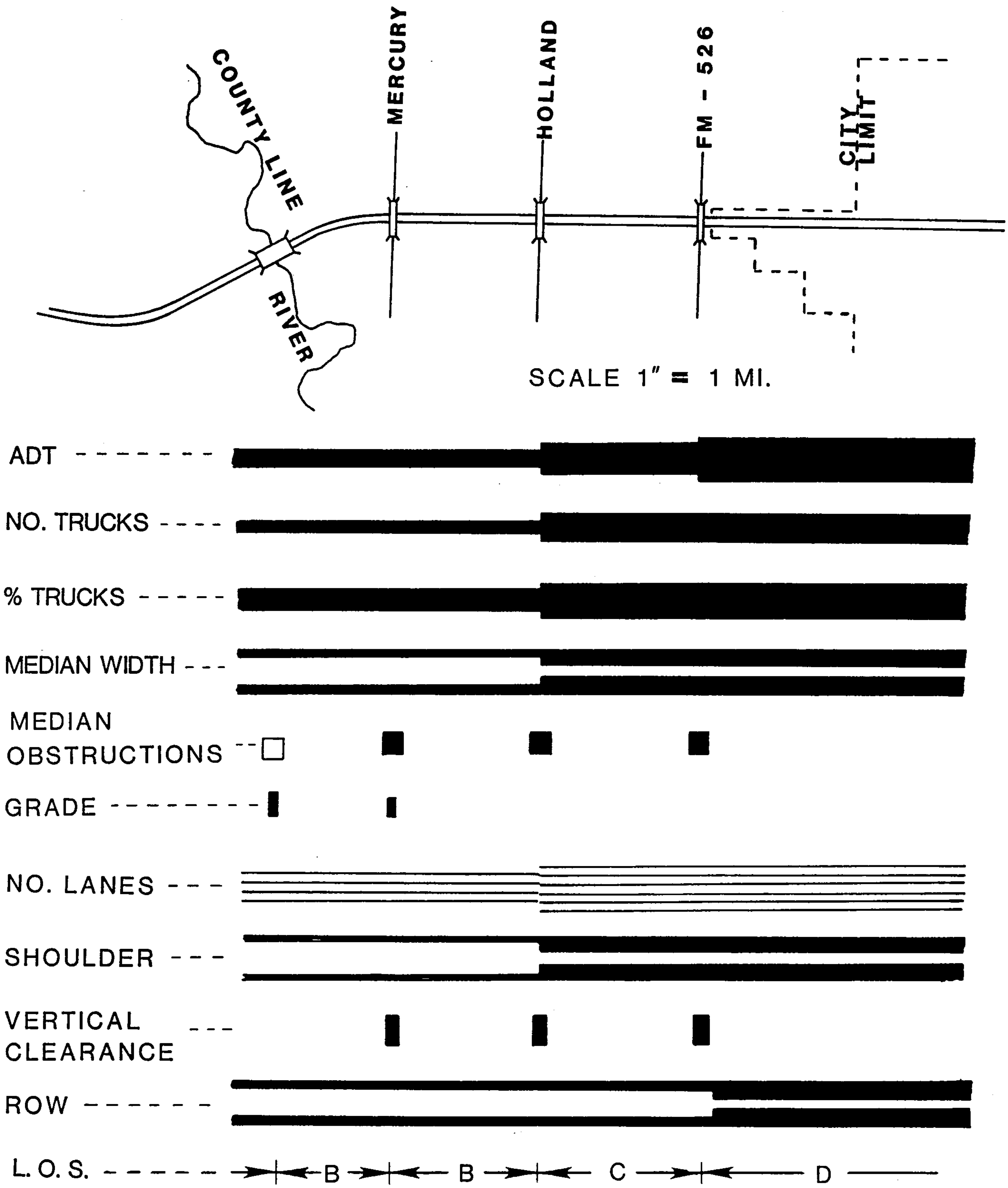


Figure 3-3. Strip Map

Information contained on the lower two-thirds of the map was plotted to scale to pictorially identify "problem areas" at a glance. The items of concern include: ADT, number of trucks, percent trucks, median width, median obstructions, grade, number of lanes, shoulder width, vertical clearance, right-of-way, and level of service. The thickness of the black bands is an indicator of the severity of each of the aforementioned eleven criteria. Specific information came from the detailed design and "as-built" drawings.

Particular geometric information gathered from other sources was verified by aerial photographs (scale: 1 inch equals 1,000 feet) of the entire study corridor. The aerials were helpful in determining changes made since the original construction of the corridor.

Since the strip map provided a means of visually evaluating many factors along a selected highway corridor, it was decided that this same concept of pictorial evaluation should be maintained. A more efficient method to expedite the process was devised by applying computer analyses. A computer program was developed for the truck lane evaluation process, since each segment of highway must be individually examined to determine the practicality and benefits of truck lane construction. A methodology was developed which would consider appropriate variables of each roadway segment in terms of accepted criteria.

3.2.5.2 <u>The Computer Program</u>

A "moving analysis" program was chosen to effectively evaluate each individual segment and display and/or print the results in an easily-interpreted format. The program logic follows a recently developed program for the Amdahl computer written in FORTRAN computer language by Mason et. al. (3). It was modified in this study for use on the microcomputer using TURBO-PASCAL programming language. A description of the program is provided in Appendix B.

Data input in half-mile segments were: milepost, peak hour volume, number of trucks or percent trucks, percent grade, grade length, terrain factor, number of lanes, distance to lateral obstructions, total median width, and effective median width. The program evaluates each half-mile segment independently and calculates a volume-to-capacity ratio (v/c). Two v/c ratios are computed by the Highway Capacity Manual (6) method: v/c with total traffic and v/c without trucks. This comparison was used to determine the impact of removing trucks from the main stream of traffic. Two key parameters are determined by the program: effective median width (Figure 3-2), and improvement in v/c ratio by removing trucks.

3.2.5.3 Evaluation of Base Year Traffic

A portion of the computer program output for I-10 is reproduced in Table 3-1. This information represents the base year (1985) traffic demand. Input variables printed with the associated output are: milepost (MP), peak hour volume (PHV), number of trucks (TRUCKS) or percent trucks (%T), percent grade (%GRADE), grade length (L), terrain factor (T), number of lanes in each direction (N), and distance to lateral obstructions (LAT). The evaluation criteria (actual computer-generated output) are: shoulder to shoulder median width (MEDW), effective median width (TW), volume-to-capacity ratio for all traffic (V/C), for traffic without trucks (V/CA), and level of service at 70 mph design (LOS70) with and without trucks, each printed out by half-mile segment.

The effective median width is evaluated according to the following categories: less than 36 feet, between 36 feet and 52 feet, and over 52 feet. Exclusive truck facilities can be built at grade if the effective median width is at least 36 feet. If the width is less than 36 feet and if other messages are not called, a message is printed under the heading "IMPROVEMENT IN V/C" which overrides the actual plot of change in v/c.

3.2.5.4 Evaluation of Future Traffic

A second model was developed which is similar to the first in that it also focuses on the median area, and it uses the same input criteria for a particular half-mile segment as the first model. It is different, however, in that it applies a growth factor to existing traffic data so that various traffic growth scenarios can be evaluated over time. This model also differs

ANALYSIS OF I-10 PEAK HOURLY DAT

MP	PHV	TRUCKS	%T	%GRADE	L	T	N	LAT	MEDW	TW: -36 36-52 52+		V/C	V/CA	LOS70	IMPROVEMENT IN V/C 0% 50% 100% 150% 200%	OBS	COMMENTS
34.0	3200	160	5	0	0	1	4	10	0	17	: * . . :	0.49	0.45	B:B	: MEDIAN TOO NARROW :	0	
34.5	3200	160	5	0	0	1	4	7	0	14	: * . . :	0.49	0.45	B:B	: MEDIAN TOO NARROW :	0	MERC PED
35.0	3200	160	5	0	0	1	4	10	0	17	: * . . :	0.49	0.45	B:B	: MEDIAN TOO NARROW :	0	
35.5	3200	160	5	0	0	1	4	10	0	17	: * . . :	0.49	0.45	B:B	: MEDIAN TOO NARROW :	0	
36.0	3200	160	5	0	0	1	4	7	0	14	: * . . :	0.49	0.45	B:B	: MEDIAN TOO NARROW :	0	PED OPASS
36.5	2600	160	6	0	0	1	4	10	0	17	: * . . :	0.40	0.36	B:B	: MEDIAN TOO NARROW :	0	
37.0	2600	160	6	0	0	1	4	10	0	17	: * . . :	0.40	0.36	B:B	: MEDIAN TOO NARROW :	0	
37.5	2600	160	6	0	0	1	4	10	0	17	: * . . :	0.40	0.36	B:B	: MEDIAN TOO NARROW :	0	
38.0	2200	180	8	0	0	1	4	10	0	17	: * . . :	0.34	0.30	A:A	: MEDIAN TOO NARROW :	0	
38.5	2200	180	8	0	0	1	4	10	0	17	: * . . :	0.34	0.30	A:A	: MEDIAN TOO NARROW :	0	
39.0	2200	180	8	0	0	1	4	10	0	17	: * . . :	0.34	0.30	A:A	: MEDIAN TOO NARROW :	0	
39.5	2200	180	8	0	0	1	4	10	0	17	: * . . :	0.34	0.30	A:A	: MEDIAN TOO NARROW :	0	
40.0	1800	180	10	0	0	1	3	20	0	17	: * . . :	0.38	0.32	B:A	: MEDIAN TOO NARROW :	0	MPRR
40.5	1800	180	10	0	0	1	3	10	0	17	: * . . :	0.38	0.32	B:A	: MEDIAN TOO NARROW :	0	
41.0	1800	180	10	0	0	1	3	10	0	17	: * . . :	0.38	0.32	B:A	: MEDIAN TOO NARROW :	0	
41.5	1800	180	10	0	0	1	3	10	0	17	: * . . :	0.38	0.32	B:A	: MEDIAN TOO NARROW :	0	
42.0	1800	180	10	0	0	1	3	10	0	17	: * . . :	0.38	0.32	B:A	: MEDIAN TOO NARROW :	0	
42.5	1800	180	10	0	0	1	3	7	0	14	: * . . :	0.38	0.32	B:A	: MEDIAN TOO NARROW :	0	CROCKETT
43.0	1800	180	10	0	0	1	3	7	0	14	: * . . :	0.38	0.32	B:A	: MEDIAN TOO NARROW :	0	CEDAR BAY
43.5	1800	180	10	0	0	1	3	10	0	17	: * . . :	0.38	0.32	B:A	: MEDIAN TOO NARROW :	0	
44.0	1600	180	11	0	0	1	3	7	0	14	: * . . :	0.34	0.28	A:A	: MEDIAN TOO NARROW :	0	MAGNOLIA
44.5	1600	180	11	0	0	1	3	10	0	17	: * . . :	0.34	0.28	A:A	: MEDIAN TOO NARROW :	0	
45.0	1600	180	11	0	0	1	3	10	0	17	: * . . :	0.34	0.28	A:A	: MEDIAN TOO NARROW :	0	
45.5	1600	180	11	0	0	1	3	10	4	21	: * . . :	0.34	0.28	A:A	: MEDIAN TOO NARROW :	0	SAN JACIN
46.0	1600	180	11	0	0	1	3	0	4	1	: * . . :	0.36	0.30	B:A	: MEDIAN TOO NARROW :	0	SAN JACIN
46.5	1200	180	15	0	0	1	2	0	38	32	: * . . :	0.43	0.33	B:A	: MEDIAN TOO NARROW :	0	LYNCBG CR
47.0	1200	180	15	0	0	1	2	10	38	55	: . . * :	0.39	0.30	B:A	:- - . - -I- - . - -:	0	
47.5	1200	180	15	0	0	1	2	10	38	55	: . . * :	0.39	0.30	B:A	:- - . - -I- - . - -:	0	
48.0	1200	180	15	0	0	1	2	10	38	55	: . . * :	0.39	0.30	B:A	:- - . - -I- - . - -:	0	
48.5	1200	180	15	0	0	1	2	10	38	55	: . . * :	0.39	0.30	B:A	:- - . - -I- - . - -:	0	
49.0	1200	180	15	0	0	1	2	10	38	55	: . . * :	0.39	0.30	B:A	:- - . - -I- - . - -:	0	
49.5	1200	180	15	0	0	1	2	10	38	55	: . . * :	0.39	0.30	B:A	:- - . - -I- - . - -:	0	
50.0	1200	180	15	0	0	1	2	10	38	55	: . . * :	0.39	0.30	B:A	:- - . - -I- - . - -:	0	
50.5	1200	180	15	0	0	1	2	10	38	55	: . . * :	0.39	0.30	B:A	:- - . - -I- - . - -:	0	
51.0	1200	180	15	0	0	1	2	10	38	55	: . . * :	0.39	0.30	B:A	:- - . - -I- - . - -:	0	
51.5	1200	180	15	0	0	1	2	10	38	55	: . . * :	0.39	0.30	B:A	:- - . - -I- - . - -:	0	
52.0	1200	180	15	0	0	1	2	10	38	55	: . . * :	0.39	0.30	B:A	:- - . - -I- - . - -:	0	
52.5	1200	180	15	0	0	1	2	10	38	55	: . . * :	0.39	0.30	B:A	:- - . - -I- - . - -:	0	

Table 3-1

in that it prints a single page of output for each (half-mile) segment selected for application of growth factors. For the IH-10 corridor, only the worst half-mile segment (highest existing v/c) in each county was chosen for analysis, calculating traffic growth from the year 1985 to the year 2010. A single line is printed for each year.

In calculating traffic projections with this model, it was possible to calculate a v/c ratio of greater than 1.0, indicating that capacity of the highway segment had been exceeded; this was flagged with the message "LOS = F". Finally, those locations where median width was inadequate for exclusive truck facilities were flagged with a printed message.

Table 3-2 shows a sample of the output of this model which is very similar in format to the base year tabulation described earlier. The output headings are exactly the same except the first, which is "YEAR" instead of "MP". For each roadway, the current roadway geometry (number of lanes, etc.) is held constant. As the traffic volumes increase over time, the v/c ratios increase indicating a need for expanded roadway capacity. Other values were held constant over the projection period (percent trucks, driver population characteristics, and truck operating characteristics).

3.2.5.5 Analysis of Methodology

Two evaluations are possible from the above procedure:

1. A comparison of changes in level of service on the existing facility with and without trucks.

2. A comparison of the length of time until traffic conditions reach undesirable levels.

The study procedure can be adapted to other locations where truck traffic poses unique demands on the system. Additionally, candidate sections of roadway can be readily identified using the computer program to examine alternative traffic scenarios.

Table 3-2

November 5, 1986 — TTI TRUCKLANE ANALYSIS PROGRAM OUTPUT — PAGE 1

ANALYSIS OF I-10 PEAK HOURLY DAT: ADT * K AT MILEPOST 851.0 GROWTH FACTORS USED : 0.86% 1985 - 1989: 1.47% 1990 +

JEFFERSON COUNTY: CRITICAL (HIGHEST) V/C PHV OCCURRS BETWEEN MP 851.0 & MP 851.5

YEAR	PHV	TRUCKS	%T	%GRADE	L	T	N	LAT	MEDW	TW:	-36 36-60 60+	V/C	V/CA	LOS70	IMPROVEMENT IN V/C 0% 50% 100% 150% 200%	OBS	COMMENTS
1985	2500	130	5	0	0	1	2	0	4	0	: * . . :	0.85	0.77	D:D	: MEDIAN TOO NARROW :	0	
1986	2521	131	5	0	0	1	2	0	4	0	: * . . :	0.85	0.78	D:D	: MEDIAN TOO NARROW :	0	
1987	2543	132	5	0	0	1	2	0	4	0	: * . . :	0.86	0.79	D:D	: MEDIAN TOO NARROW :	0	
1988	2565	133	5	0	0	1	2	0	4	0	: * . . :	0.87	0.79	D:D	: MEDIAN TOO NARROW :	0	
1989	2587	134	5	0	0	1	2	0	4	0	: * . . :	0.88	0.80	D:D	: MEDIAN TOO NARROW :	0	
1990	2609	135	5	0	0	1	2	0	4	0	: * . . :	0.88	0.81	D:D	: MEDIAN TOO NARROW :	0	
1991	2647	137	5	0	0	1	2	0	4	0	: * . . :	0.90	0.82	D:D	: MEDIAN TOO NARROW :	0	
1992	2686	139	5	0	0	1	2	0	4	0	: * . . :	0.91	0.83	D:D	: MEDIAN TOO NARROW :	0	
1993	2725	141	5	0	0	1	2	0	4	0	: * . . :	0.92	0.84	D:D	: MEDIAN TOO NARROW :	0	
1994	2765	143	5	0	0	1	2	0	4	0	: * . . :	0.94	0.86	E:D	: MEDIAN TOO NARROW :	0	
1995	2806	145	5	0	0	1	2	0	4	0	: * . . :	0.95	0.87	E:D	: MEDIAN TOO NARROW :	0	
1996	2847	147	5	0	0	1	2	0	4	0	: * . . :	0.96	0.88	E:D	: MEDIAN TOO NARROW :	0	
1997	2889	149	5	0	0	1	2	0	4	0	: * . . :	0.98	0.90	E:D	: MEDIAN TOO NARROW :	0	
1998	2931	151	5	0	0	1	2	0	4	0	: * . . :	0.99	0.91	E:D	: MEDIAN TOO NARROW :	0	
1999	2974	153	5	0	0	1	2	0	4	0	: * . . :	1.01	0.92	F:D	: #### LOS = F #### :	0	
2000	3018	155	5	0	0	1	2	0	4	0	: * . . :	1.02	0.94	F:E	: #### LOS = F #### :	0	
2001	3062	157	5	0	0	1	2	0	4	0	: * . . :	1.04	0.95	F:E	: #### LOS = F #### :	0	
2002	3107	159	5	0	0	1	2	0	4	0	: * . . :	1.05	0.96	F:E	: #### LOS = F #### :	0	
2003	3153	161	5	0	0	1	2	0	4	0	: * . . :	1.07	0.98	F:E	: #### LOS = F #### :	0	
2004	3199	163	5	0	0	1	2	0	4	0	: * . . :	1.08	0.99	F:E	: #### LOS = F #### :	0	
2005	3246	165	5	0	0	1	2	0	4	0	: * . . :	1.10	1.01	F:F	: #### LOS = F #### :	0	
2006	3294	167	5	0	0	1	2	0	4	0	: * . . :	1.11	1.02	F:F	: #### LOS = F #### :	0	
2007	3342	169	5	0	0	1	2	0	4	0	: * . . :	1.13	1.04	F:F	: #### LOS = F #### :	0	
2008	3391	171	5	0	0	1	2	0	4	0	: * . . :	1.15	1.05	F:F	: #### LOS = F #### :	0	
2009	3441	174	5	0	0	1	2	0	4	0	: * . . :	1.16	1.07	F:F	: #### LOS = F #### :	0	
2010	3492	177	5	0	0	1	2	0	4	0	: * . . :	1.18	1.08	F:F	: #### LOS = F #### :	0	

3.2.6 Summary of Median Width Assessment

A minimum effective median width of 36 feet is recommended for a median truck lane. Tables 3-3 and 3-4 summarize the existing effective median widths for I-10 and US-90 (7).

An examination of the data in Table 3-3 indicates that along I-10 about 34 miles of the facility have sufficient minimum median widths to accommodate a truck lane. This is less than one-half the total length of the study section. Also, those sections of I-10 which do not have sufficient median widths are not contiguous sections.

In the case of US-90, only about one-third of the total length of the study section has sufficient median width to accommodate a median truck lane (Table 3-4).

3.2.7 Cost Estimates - Median Facilities

The most cost effective modification to the median area to provide an exclusive truck facility in both directions would have a pavement width of 36 feet. The estimated costs for the pavement to accommodate truck traffic is two million dollars per mile. Structures and access facilities will add approximately two million dollars per mile, for an estimated cost of four million dollars per mile.

This type of facility would require the truck traffic to use the normal roadway lanes for passing and the normal traffic to use the shared inside shoulder with trucks. Since the truck lanes would not be enclosed by traffic barriers, this design would not necessarily be designated as an exclusive facility for trucks.

Table 3-3. Effective Median Width[a] I-10

Mile Posts	Distance (Miles)	Effective Median Width (ft)	Sufficient[a] for Median Truck Lane
34.0-45.5	12.5	17-21	No
47.0-61.0	14.0	42-55	Yes
61.5-66.0	4.5	9	No
66.5-74.5	8.0	37	Yes
75.0-85.0	10.0	34	No
85.5-87.5	2.0	36-38	Yes
88.0-94.5	6.5	34	No
95.0-105.0	10.0	38	Yes
105.5-111.0	5.5	0-5	No

[a] Minimum sufficient median width = 36 ft (see Figure 3-1).

Table 3-4. Effective Median Widths US-90

Mile Posts	Distance (Miles)	Effective Median Width (ft)	Sufficient[a] for Median Truck Lane
22.5-46.0	23.5	0	No
46.5-53.0	6.5	57	Yes
53.5-55.0	1.5	11-75	No
55.5-61.0	5.5	45-57	Yes
61.5-81.5	20.0	0	No
82.0-82.5	0.5	53	Yes
83.0-83.5	0.5	7	No
84.0-97.0	13.0	37-53	Yes
97.5-101.5	4.0	0	No

[a] Minimum sufficient median width = 36 ft (see Figure 3-1).

3.3 EXCLUSIVE TRUCK FACILITIES IN FREEWAY OUTER SEPARATION

The area of the freeway between the mainlanes and the right-of-way boundaries is normally used for access ramps and frontage roads. This section of the study examines the options for constructing an exclusive truck facility on one or both sides of the freeway (8).

3.3.1 Designation of Existing Frontage Roads as Truck Facility

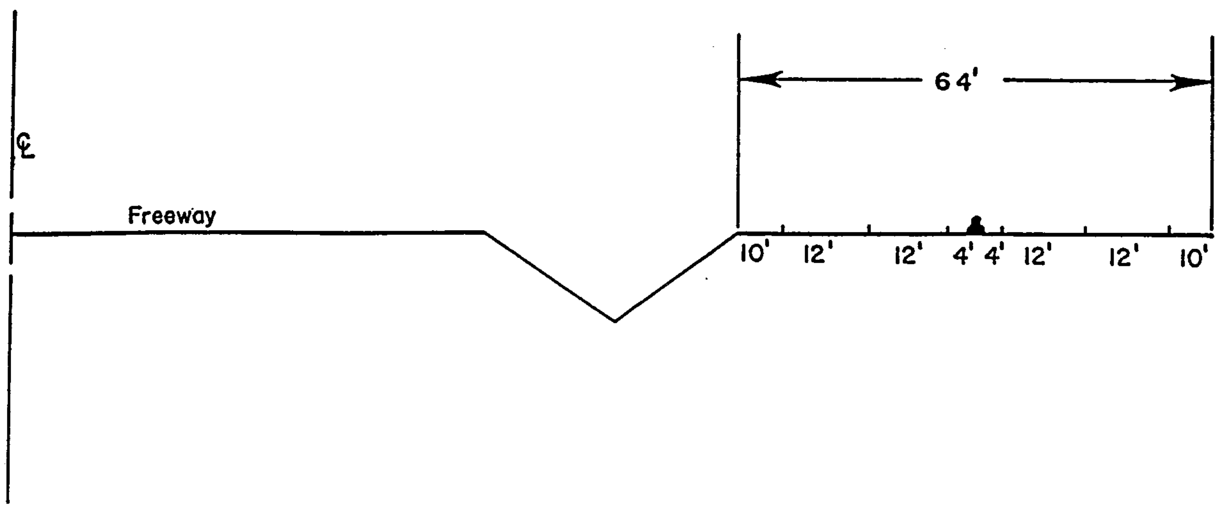
The conversion of the existing frontage roads to a truck facility is unacceptable for several reasons; the existing pavement design is inadequate for heavy truck loads; the geometric design is inadequate to provide a high level of service; and the truck volumes would be in mixed flow with non-truck traffic. Major reconstruction would be required.

3.3.2 Construct an Exclusive Truck Facility on One Side of the Freeway for Two Way Truck Operations

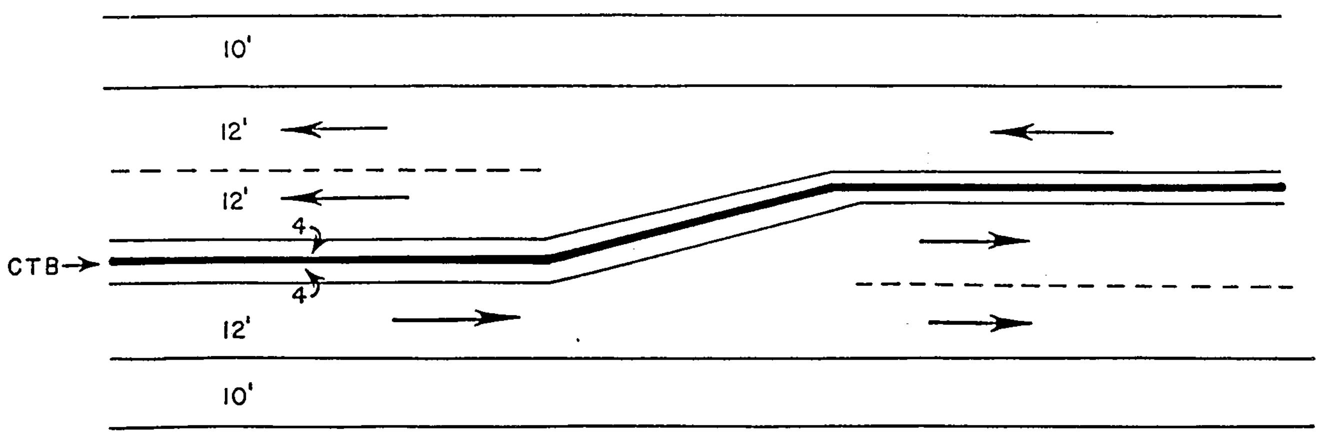
This option requires a minimum of 64 feet width for the truck pavement (Figure 3-4). The truck lanes would replace the existing frontage road on one side of the freeway. Special ramps would be constructed to provide access between the truck facility and the freeway mainlanes. Provisions would have to be made to replace the functions served by the frontage road and all conflicting movements would be grade separated. The truck facility would have one travel lane in each direction with one passing lane that alternates between directions. A full outside shoulder would be provided, along with a minimum median width of 8 feet.

3.3.3 Construct an Exclusive Truck Facility on One Side of the Freeway for One Way Truck Operations

This option requires only 30 feet of width for the truck pavement (Figure 3-5). The one way operation simplifies the design of the access ramps and improves the traffic flow characteristics. Depending on the available right-of-way, the frontage roads may not have to be eliminated completely. The

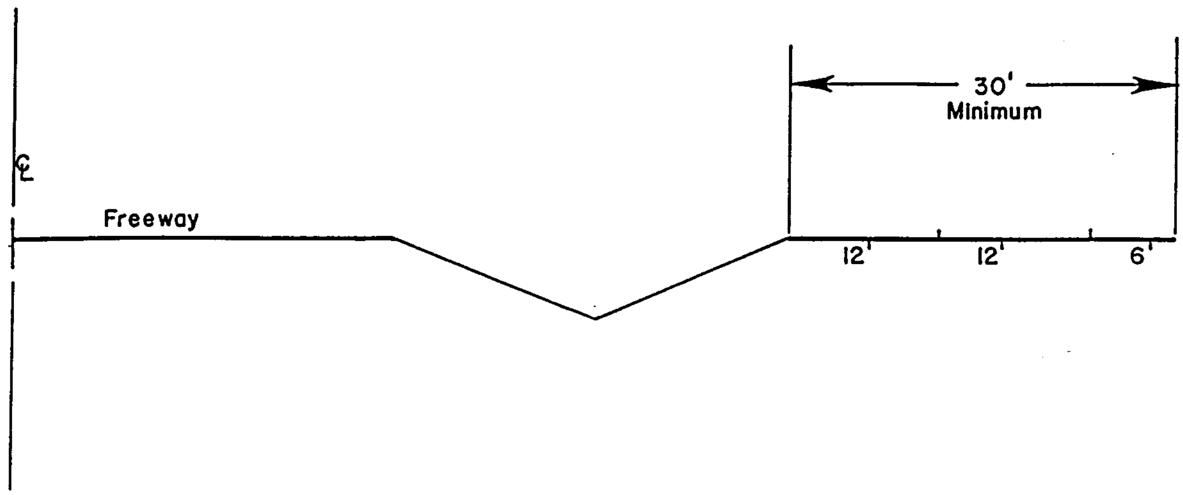


Two Way Frontage Road
Truck Facility with Passing Lane

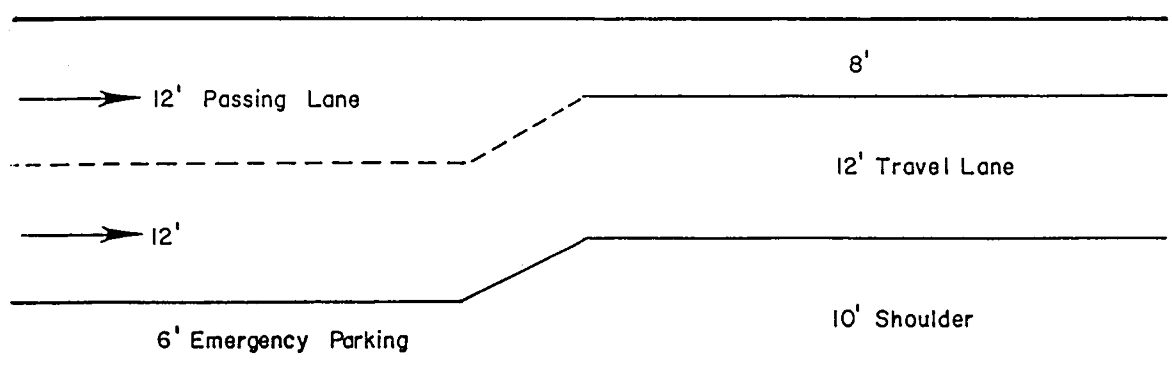


Transition Area

Figure 3-4



One Way Frontage Road
Truck Facility with Passing Lane/Shoulder



Transition from Passing Zone
To Shoulder Lane for Passing

Figure 3-5

cross section provides for one continuous travel lane, with passing lanes provided at frequent intervals.

3.3.4 Discussion of Alternatives within Freeway Right of Way

3.3.4.1 One Way vs Two Way Operation

The smaller one way facility is the more feasible design to retrofit into an existing freeway right-of-way. The roadway can vary in width so that in critical sections, the width can be reduced by eliminating the passing lane and reducing the lateral clearances and in non critical sections, a continuous passing lane and an emergency shoulder can be provided. Bridge structures may be reduced by combining with the freeway mainlane structures. The facility can be easily terminated by merging with the freeway mainlanes and or the frontage road lanes.

The potential for truck accidents is lessened by the one-way design by the reduction in the complexity of interchange designs and the elimination of conflicting movements.

The exclusive truck facilities could be implemented in stages with the smaller one way design, by constructing the facility on only one side of the freeway, or by constructing short sections that can easily be terminated in the mainlanes.

3.3.4.2 Implementation Requirements

In those sections that have frontage roads, the new truck facility would probably encroach on or entirely replace the existing frontage road pavement. The roadway would be replaced with a heavy duty pavement that could support the high volumes of heavy loads. If the total frontage road was eliminated, the access rights to the adjacent properties and the circulation for local traffic would have to be restored. Businesses that would be adversely impacted by the change in traffic access would have to be compensated.

The truck facility must provide a high level of service in terms of high continuous speeds and overall trip travel times that would equal those on the freeway lanes. Therefore, grade separations would be constructed to eliminate conflicts with freeway ramps, cross-streets, and other man made or natural barriers.

In those sections where sufficient space is not available to satisfy all of these requirements, there are several alternatives: purchase additional right-of-way, elevate the truck facility on a structure, shift the freeway mainlanes, or discontinue the truck facility until sufficient width is available.

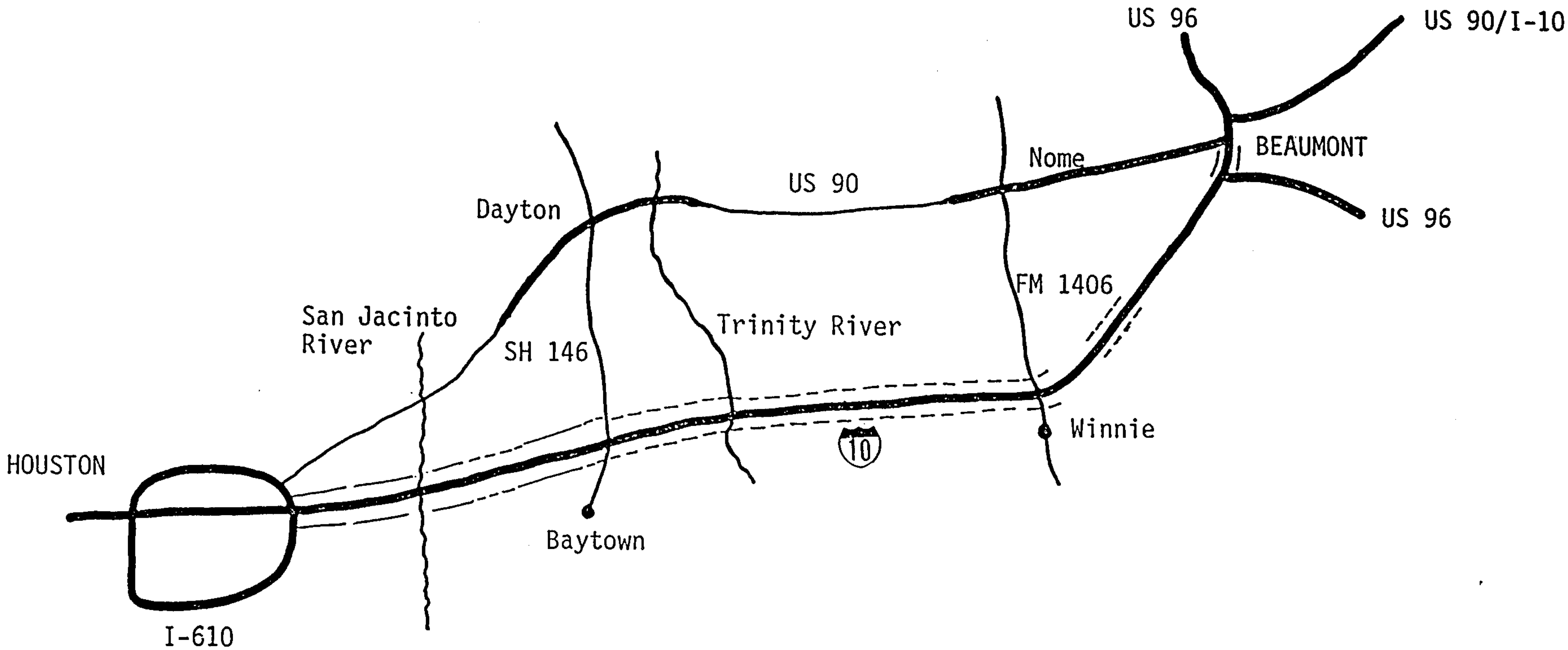
3.3.4.3 Summary

The most feasible solution is the single truck lane with provisions for passing and/or emergency parking. A minimum of 30 feet is recommended with a 12 foot travel lane, a 12 foot passing/emergency parking lanes and 6 feet for clearances to traffic barriers on both sides. For short sections at crossovers and ramp connections, the roadway width could be reduced to 20 feet. The exact cross section to be used would vary considerably with the availability of space.

The frontage road should be retained if possible, but other options such as two way frontage roads on one side with frequent access by cross streets or overpasses could be used.

3.3.5 Candidate Sections in I-10 Corridor

To further illustrate the implementation requirements for an exclusive truck facility in the existing freeway right-of-way, an extensive inventory was conducted over the entire 75 mile study corridor. The frontage road barriers and conflicts that require special designs were determined (Figure 3-6). The number and types of traffic control devices, ramps and roadside access facilities were identified (Tables 3-5, 3-6 and 3-7). Finally, the opportunities and constraints offered by the dimensions and uses of the existing cross-section were surveyed (Figure 3-7).



—— One-way two-lane frontage road

– – – Two-way one-lane frontage road

*Only major frontage road discontinuities shown.

Figure 3-6. I-10 Frontage Road Operations

Table 3-5. I-10 Frontage Road Intersection Traffic Control Devices

Traffic Control Device	Number	% Total
Signal	26	42%
Stop Sign	28	45%
Yield Sign	8	13%
Total	62	100%

Source: TTI Survey (7/86).

Table 3-6. I-10 Types of Ramp Design

Type	Number	% Total
Buttonhook	18	12%
Braided	2	1%
Slip	132	87%
Total	152	100%

Source: TTI Survey (1986).

Table 3-7. I-10 Frontage Road Access Points by Segment and Economic Activity

			Commercial			Driveways			
	Segment	Industrial/ Manufacturing	Strip	Mall	Warehouse	Business	Private	Street	Office
EASTBOUND	I-610 to Thompson	4	5	6	4	51	15	40	8
	Wade to SH-146	4	1	4	0	8	12	6	2
	SH-146 to SH-124	0	0	0	0	18	9	14	0
	Brushkland to US-90	1	1	0	0	20	0	9	0
WESTBOUND	US-90 to Brushkland	0	0	0	0	22	7	19	0
	SH-124 to SH-146	0	0	0	0	4	12	11	0
	SH-146 to Wade	2	0	0	0	18	11	8	0
	Thompson to I-610	0	19	4	0	90	13	30	14

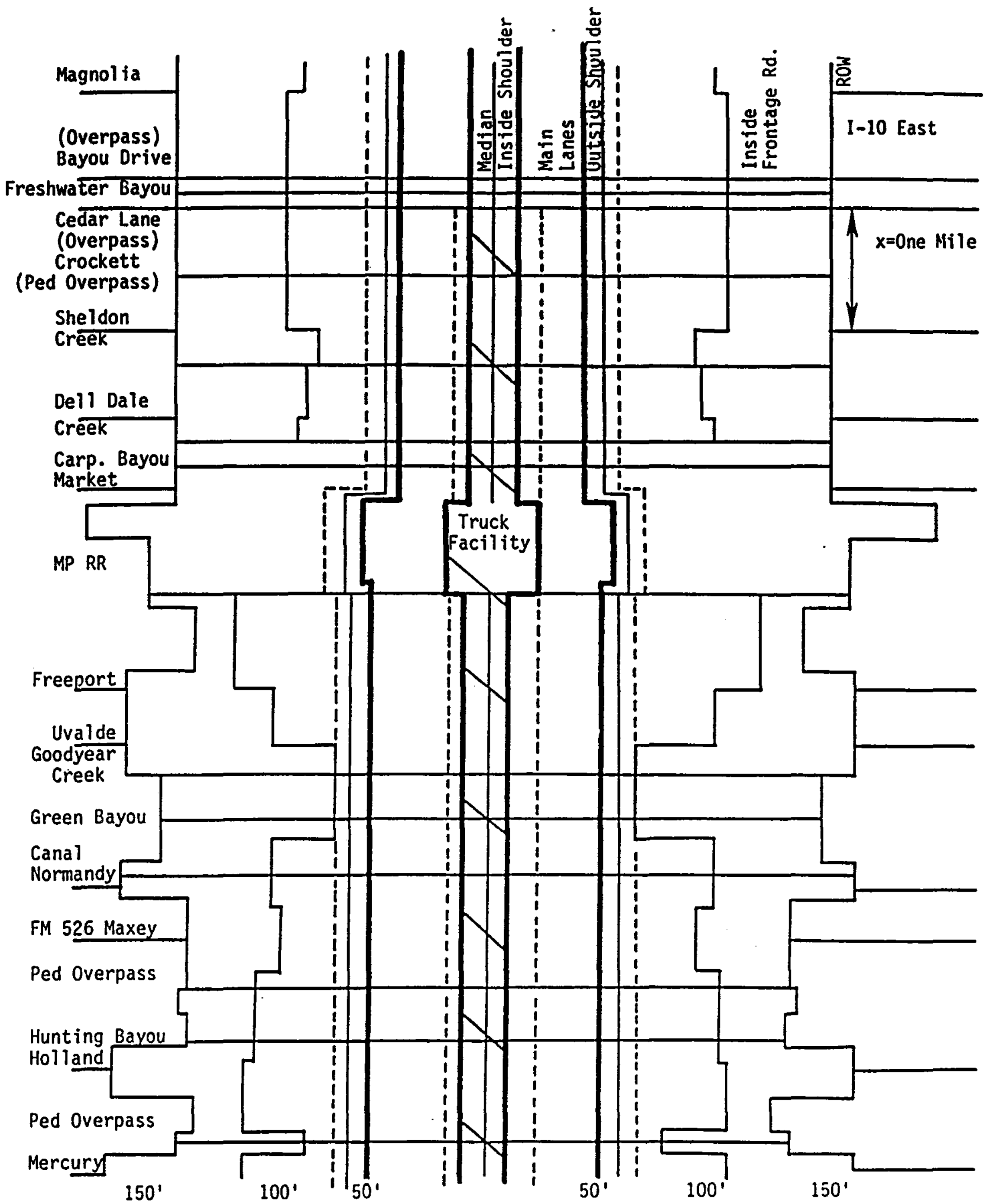


Figure 3-7

Inventory of Right-of-Way Widths
I-10 Freeway - Magnolia to Mercury

One major problem with the utilization of the I-10 frontage road as an exclusive truck facility is access control. Control of access is the condition where the right of owners or occupants of abutting land or other persons to access light, air or view in connection with a highway is fully or partially controlled by public authority. A conflict exists between effectively serving the through movement or providing access to local residents and abutting property business. The movement-access function and the roles of the various roadway types is illustrated in Figure 3-8.

Control of driveways and roadside developments is an integral part of access control. When entrances are adequately spaced and traffic volumes using them are light, the highway will function efficiently. However, where the entrances are numerous and have heavy traffic volumes, particularly those serving industrial and commercial establishments, the capacity and safety of the highway are adversely affected (9).

The number of access points on the I-10 frontage road are numerous near Beaumont and Houston and few in the rural areas as shown in Table 3-7. If an exclusive truck facility was constructed the degree of access to the facility by pedestrians, private driveways, industrial and commercial establishments, as well as crossroad intersections will have to be addressed.

The opportunities and constraints offered by the existing cross-section are key considerations in assessing the feasibility of an exclusive truck facility within the existing right-of-way. As shown in Figure 3-9, the cross-section of an existing typical section in the I-10 frontage road study corridor appears to have available right-of-way in the outer separation of roadway to retrofit a parallel exclusive truck facility. This subject is examined further in subsequent sections.

In order to examine the physical and economic feasibility of utilizing the existing I-10 freeway right-of-way to construct an exclusive truck facility, two candidate sections were analyzed. These candidate sections were

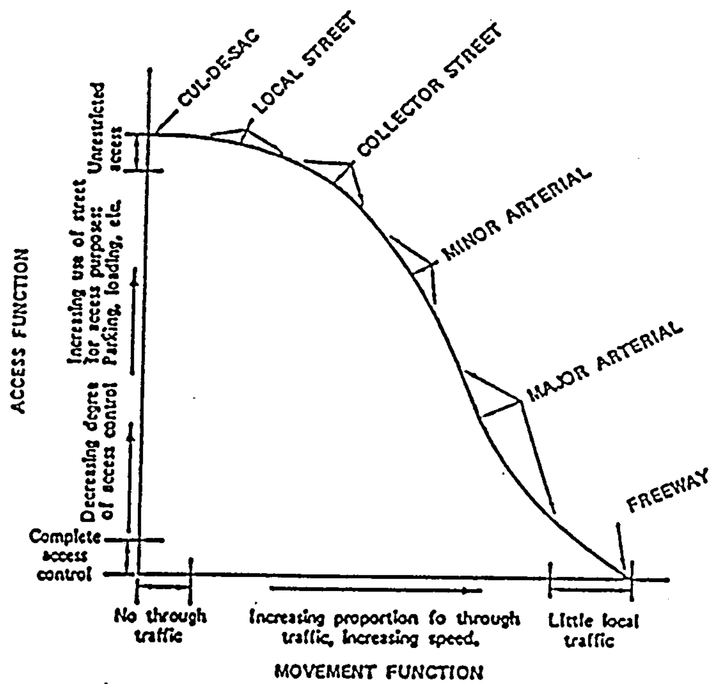


Figure 3-8. Movement Access Function of Roadway Types Ref (8)

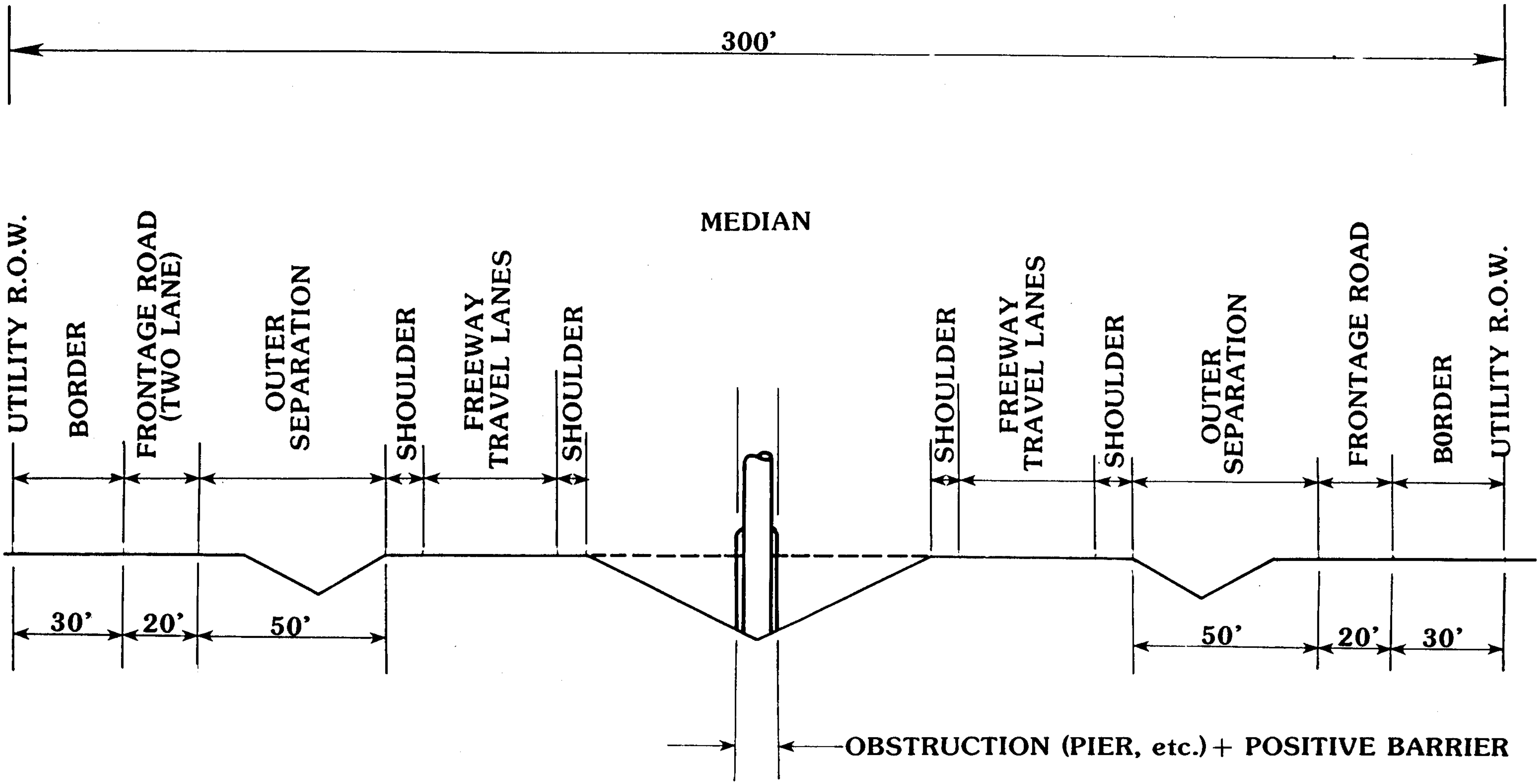


Figure 3-9. I-10 Existing Typical Cross Section

selected on the basis of their rural or urban location, frontage road operations and continuity, and representative typical design problems associated with constructing an exclusive truck facility within existing freeway right-of-way.

3.3.5.1 Description

The first potential ETF section is located on the I-10 frontage road between Wade Road and FM 565, west of the Old and Lost River, as shown in Figure 3-10. The thirteen mile section is evenly divided between two lane, one way operation and two lane, two way operation. Discontinuous frontage road sections are due to railroad lines and bayous. The candidate section handles 300 to 700 vpd and is located in a predominately rural area, except a one mile segment near the San Jacinto Mall at Garth Road.

As shown previously in Table 3-7 the number of access points along this frontage road section is below the average for the study corridor. The majority of the access points are businesses, private driveways or access to the San Jacinto Mall. The frontage road passes through five intersections, three are signalized and two have stop signs as traffic control devices.

The second potential exclusive truck facility section is located on the I-10 frontage road from SH-61 to Devillier Road, just west of SH-124 (Figure 3-11). The rural 13 mile section carries 100 to 300 vpd with a two lane, two way operation with each lane 10 feet wide. No discontinuous frontage road areas exist in this candidate section. Access points along this section are few. Although this candidate section does not have cross street intersections, the frontage roads pass under four overpasses, and over a bayou, a canal and two ditches.

3.3.5.2 Implementation Requirements

The potential design options for constructing an exclusive truck facility within the existing right-of-way were discussed earlier in this report. Outside of the median the best exclusive truck facility alternative was a one way, two lane roadway on each side of the freeway. The facility would be located in the outer separation of the roadway, usually encroaching on one lane of the frontage road. The cross-section requirements and the operational effects of that type of exclusive truck facility within that existing right-of-way on was examined for the two candidate sections.

The existing cross-section in the two candidate sections, as shown previously in Figure 3-9, has inadequate right-of-way in the outer separation of the roadway to accommodate a full width exclusive truck facility, frontage roads and freeway separation. The adjustments that must be made are shown in Figure 3-12, where the frontage road is reconstructed and the truck facility width is reduced.

In urban areas, where predominately one way, two lane frontage road operations exist, frontage roads function more for access to property rather than circulation of traffic. However, in rural areas, where some two way, two lane operations exist, and where frontage roads may serve as the principal facility to move local traffic parallel to the freeway, removal of the inside frontage road lane would deny access to one direction of travel in rural areas. The removal of the inside lane from an urban one way, two lane operation would affect capacity, but not directional access as shown in Figure 3-13 and 3-14.

Options to avoid access problems for rural residents where two way, two lane frontage road operations previously existed include:

1) Do nothing.
2) Construction of bridges over the mainlanes connecting westbound traffic north of I-10 to eastbound traffic south of I-10, as shown in Figures 3-15 and 3-16.
3) Provide other access for east-west movement of traffic.
4) Businesses that would be adversely impacted by the change in traffic access would have to be compensated.

An additional potential operational problem, when constructing a parallel exclusive truck facility within the existing highway right-of-way is at frontage road intersections. The ability to accommodate truck traffic safety

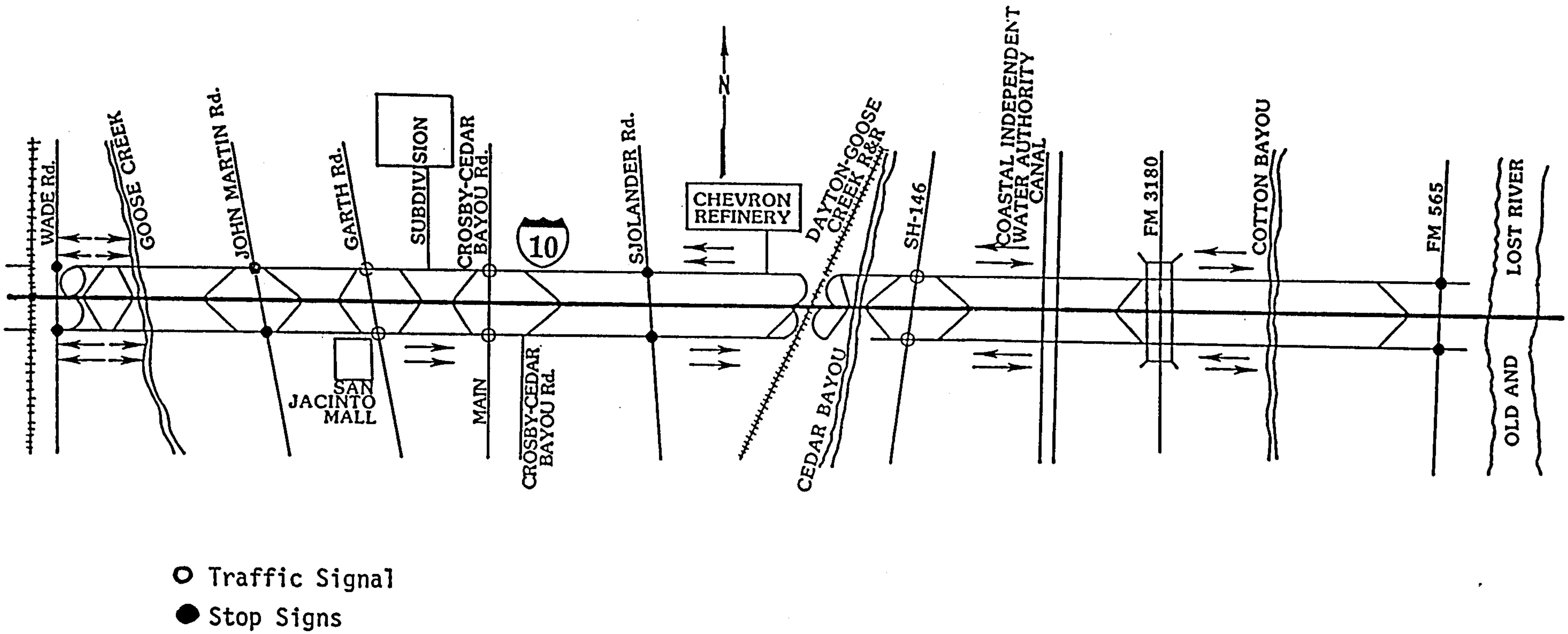


Figure 3-10. Candidate Section One (13 Miles)

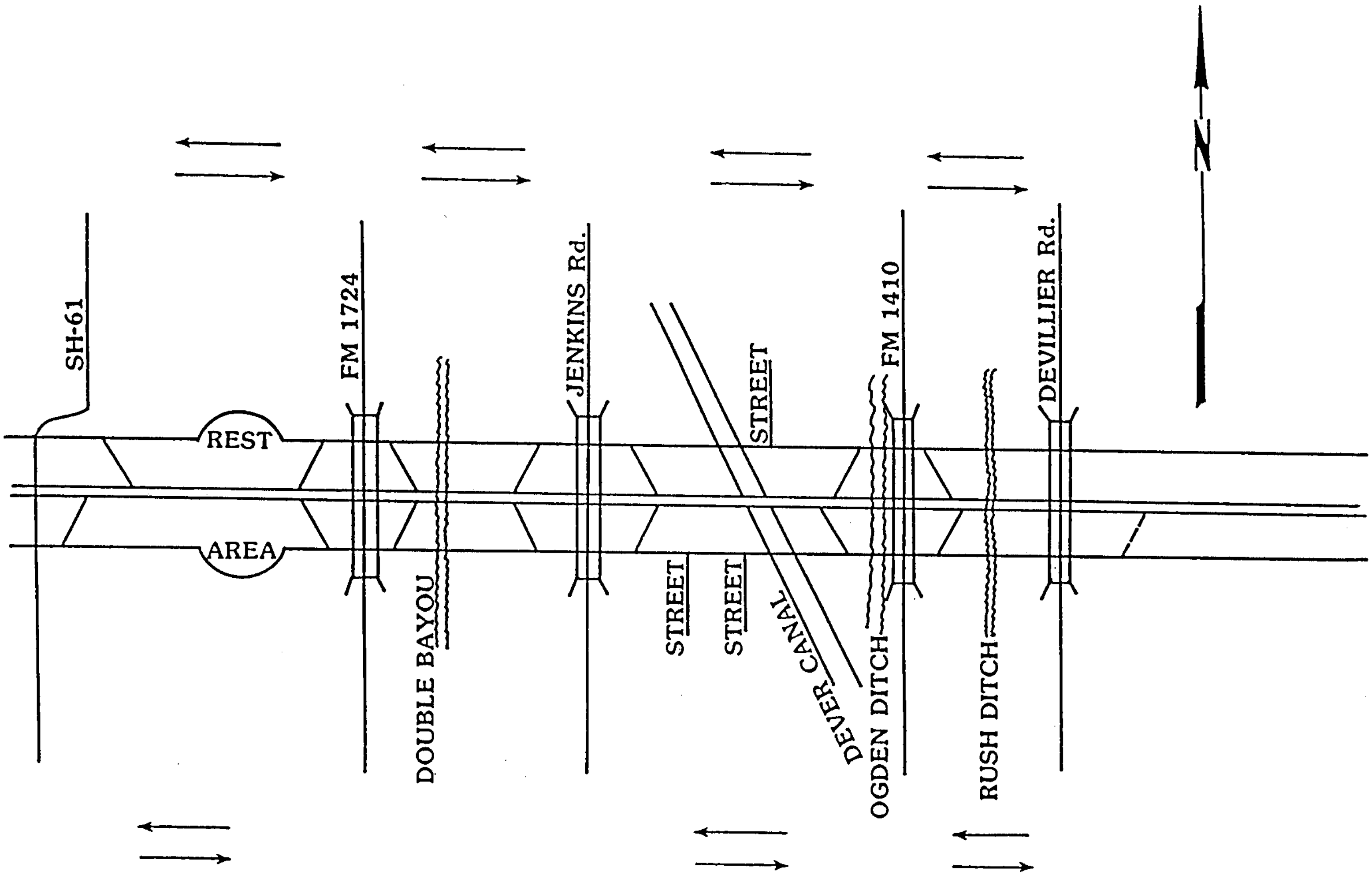


Figure 3-11. Cadidate Section Two (13 Miles)

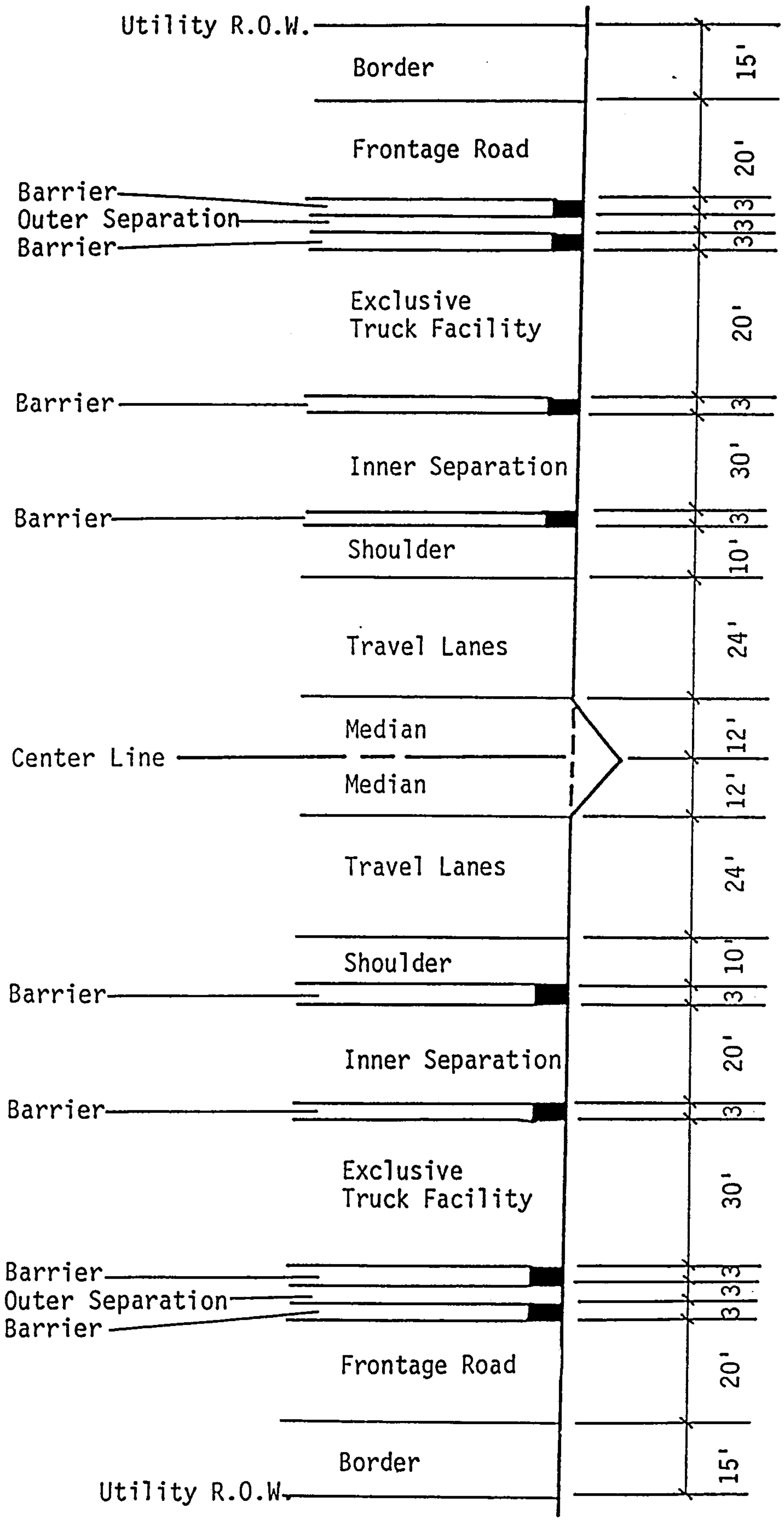


Figure 3-12. Minimum Exclusive Truck Facility Cross-Section

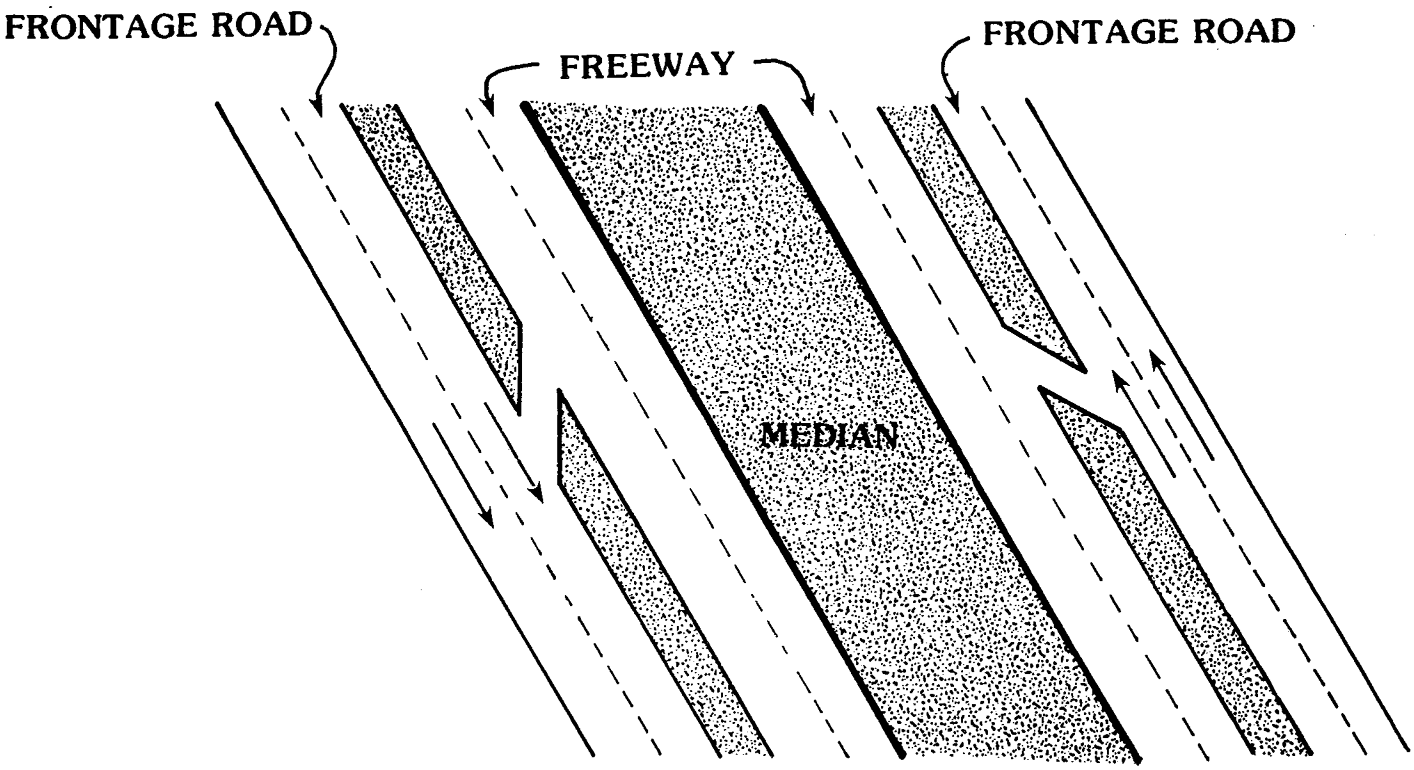


Figure 3-13. Existing One-way, Two-lane Frontage Road

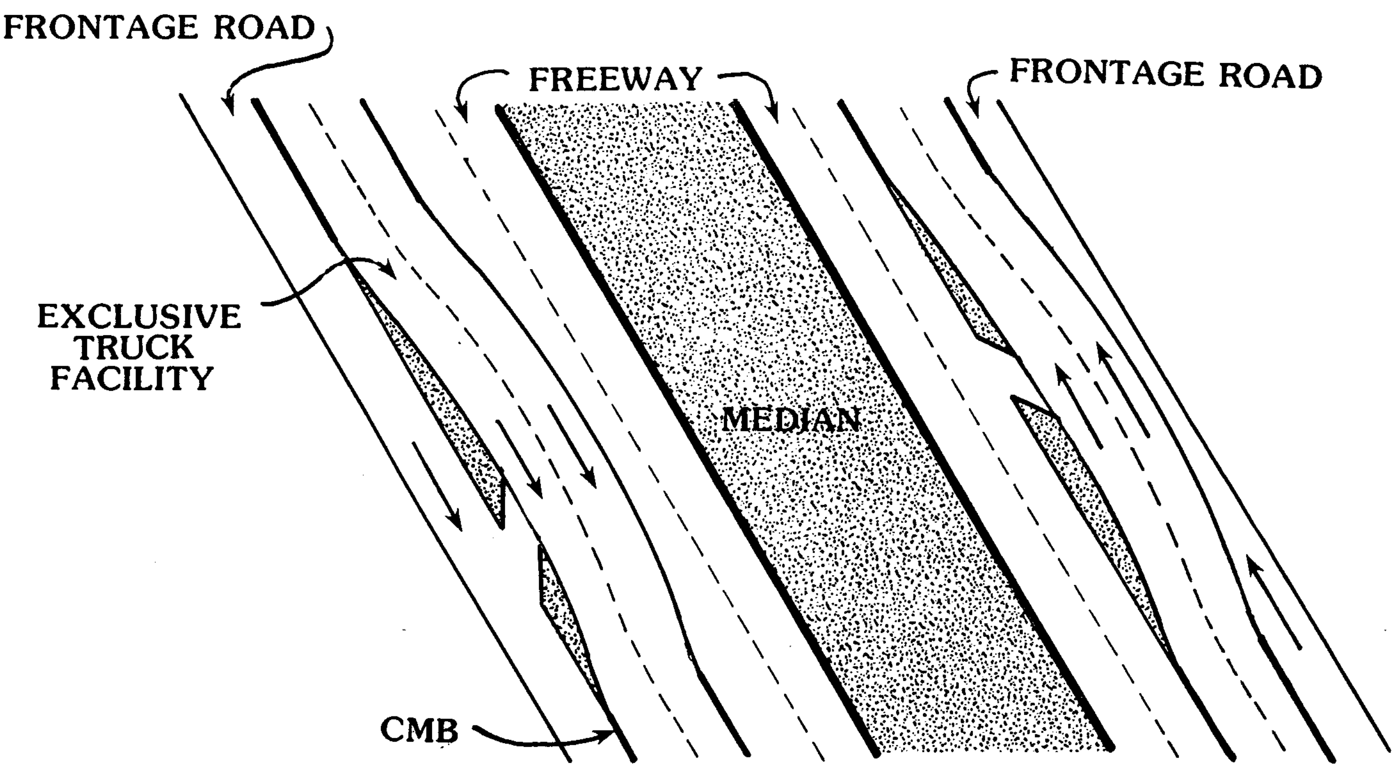


Figure 3-14. Proposed One-way, One-lane Frontage Road with Exclusive Truck Facility

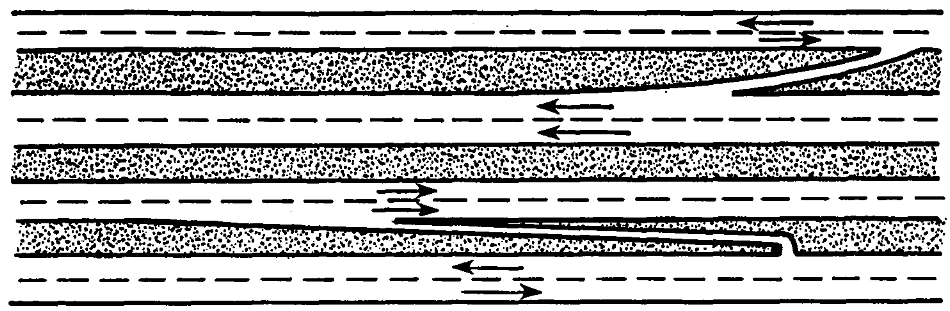


Figure 3-15. Existing Two-way, Two-lane Frontage Roads

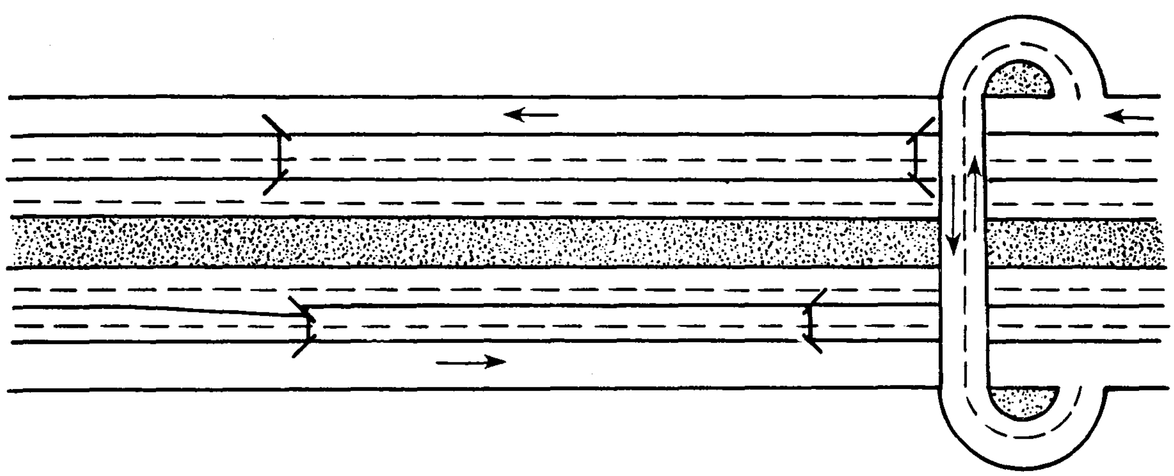


Figure 3-16. Proposed One-way, One-lane Frontage Road with Exclusive Truck Facility

and efficiently through intersections depends largely on what arrangement is provided for handling intersection traffic. The greatest efficiency, safety and capacity are attained when intersecting through-traffic lanes are separated in grades. In order to accommodate the through-truck facility-traffic, avoid unnecessary user-delay and provide for safety grade separated fly-over ramps would be constructed at frontage road intersections as shown in Figure 3-17.

3.3.5.3 Cost Estimates

Conservative estimates by the State Department of Highways and Public Transportation (SDHPT) design engineers have calculated exclusive truck facility grade separated flyover ramps travelling over the I-10 entrance and exit ramps to be $1.0 million each. The same cost figure can be applied to the bridges providing cross access for frontage road traffic north and south of the I-10 mainlanes.

Cost estimates for grade separating an intersection for exclusive truck facility traffic is $1.2 million. A 50 mph design speed was used to arrive at the cost estimates. If a 70 mph design speed was selected for exclusive truck facility traffic, these figures would increase from $1.2 to $1.5 million respectively.

A cost estimate of each potential exclusive truck facility section would have to include grade-separation fly-over ramps at freeway entrance and exit ramps, frontage intersections, creeks or bayous and railroad lines. An inventory of candidate Section One shows 27 entrance or exit ramps, 6 frontage road intersections, 1 bayou and 1 railroad line that would need flyover structures to provide for an exclusive truck facility on the frontage road or $42.3 million. In addition to this figure would be the cost of additional pavement for heavy truck traffic for the 13 mile section. To construct a roadway that would accommodate heavy truck traffic 30 feet wide would cost $3.0 million per mile, bringing the total cost to $81.3 million.

For the entire 75 mile study corridor, there are 76 ramps and 31 intersections on one side of the freeway. This averages out to approximately

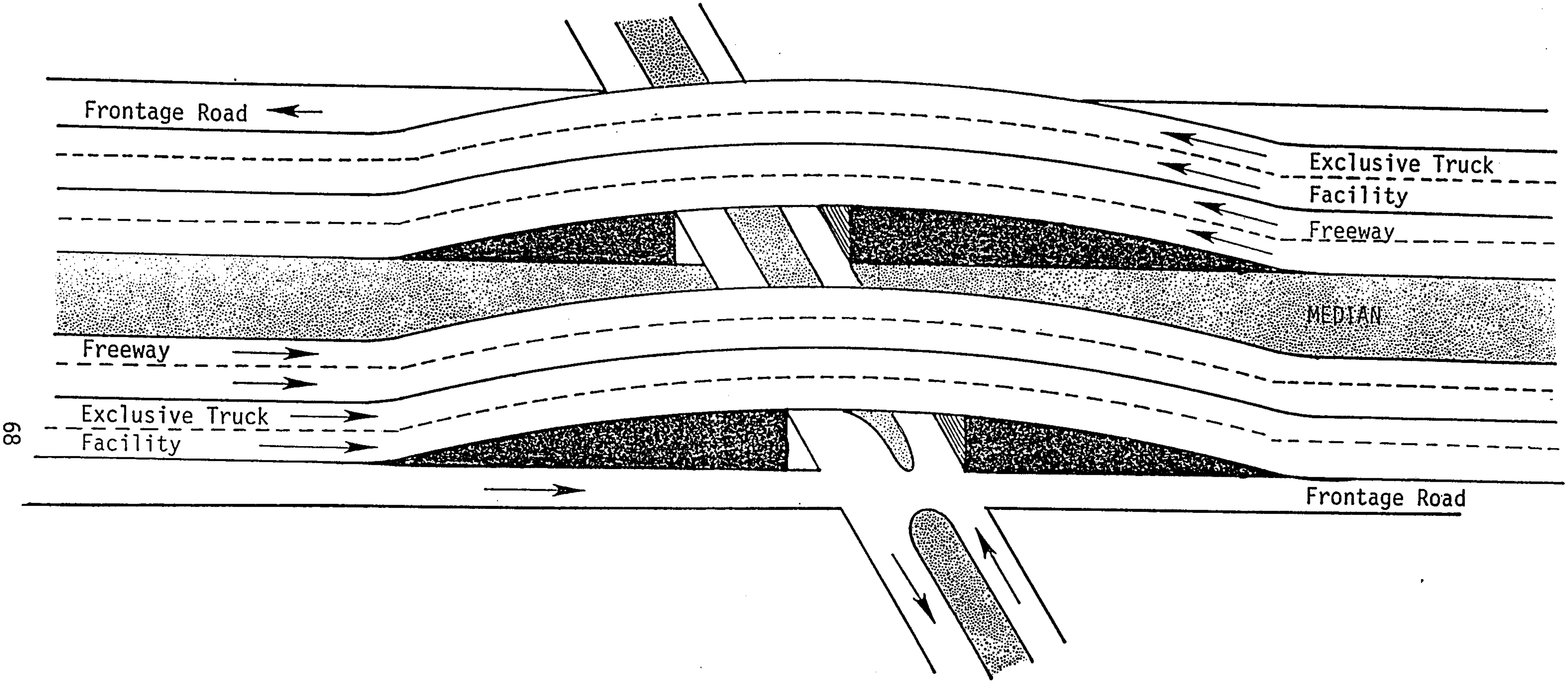


Figure 3-17. Frontage Road Intersection with Exclusive Truck Facility

1 intersection and 2 ramps per 2 miles of freeway. For an average cost of $3.0 million per mile of roadway 30 feet wide that accommodates trucks, and structure costs of $1.0 million each for grade separating the intersection and ramps, the average cost per mile for a truck facility would be $4.5 million. This would provide a one way truck facility 30 feet wide with 1 travel lane, 1 shoulder/passing lane, 3 foot clearance on both sides. Width of the structure would be slightly narrower - 24 to 27 feet.

3.4 BENEFITS AND COSTS OF THE ETF OPTIONS

3.4.1 Safety

Separating trucks from passenger vehicles should improve safety and reduce conflicts for all vehicles. As noted in Chapter 2 the accident rates in the Beaumont-Houston Corridor is low, but in comparison to statewide averages, they are 2 to 3 times the normal rate. The other safety consideration is the severity of the accidents. Large trucks are involved in fatal accidents at a rate that is 3 times that of passenger cars. Another way to state an obvious fact, a car occupant is 35 times more likely than a truck occupant to be killed when the two vehicles crash. This statistic is important when linked with the fact that 65 percent of large truck fatal accidents involve another vehicle (10).

Providing the separate truck facility should reduce truck-automobile accidents, but may also increase truck-truck accidents. Accidents on the frontage roads and at the cross street intersections will probably not be affected since that traffic is local in nature and will not be changed by a additional three lanes.

3.4.2 Capacity

Providing additional express lanes for trucks will improve the capacity of the corridor. Some capacity for local circulation may be lost. However, the traffic demands for the freeway corridor are not a major issue except of small sections near urban areas. Reducing congestion is not a major objective nor a resulting benefit of intercity truck facilities. Most sections of the I-10 corridor operate during peak hours at v/c ratios of less than 0.35. The demand must grow at a substantial rate (3 percent for 15 years) to become a problem.

3.4.3 Travel Time Savings

If the ETF is a separated roadway with high design standards, it is reasonable to expect that speed limits on that facility could be raised 10 to 15 mph to encourage their use. This is only a supposition for the purpose of exploring benefits for the system and does not represent a recommendation of the study.

For each mile, the users of the ETF could save 14 seconds. This would be 17.5 minutes for the entire length of the corridor. A recent study (1985) determined that the value of time for trucks was $19.00 per hour. Therefore, a saving of $5.55 per trip or 7.4 cents per mile could be realized with the ETF. With average daily volumes of approximately 5000 trucks per day in the I-10 corridor, the daily and annual savings in time would be $370/day and $135,000/year per mile of ETF.

3.4.4 Pavement Life

The provision of additional travel lanes designed to carry large repetitions of heavy loads is a benefit to the old pavement. The life of the old pavement is extended, reducing the maintenance and replacement costs. However, the condition of the existing pavement for the volumes of truck traffic now projected do not justify a major pavement rehabilitation project for many years (Appendix D).

However, if larger trucks with heavier wheel loads, higher tire pressures and more frequent repetitions are permitted on the interstate system, and I-10 in particular, the good pavement that now exists will quickly deteriorate, and the benefits of ETF will be enhanced.

3.4.5 Cost Comparisons

For the proposed demonstration projects, cost estimates for the various options can be estimated:

For the addition of two truck lanes to the existing roadway in the median, estimated cost is $4 million per mile for a 36 foot pavement.

For the conversion of the frontage road to an exclusive truck facility, the cost is estimated to be $4.5 million for one travel lane and 1 shoulder/passing lane. The cost to provide for the exclusive truck facilities in both directions would be $9 million per mile.

For the provision of a separate four lane truck facility on its own right-of-way, a minimum roadway width would be 684 feet, and a right-of-way width of 100 feet. Using the same construction cost activities as the ETF in the median, the facility would cost approximately $7 to 8 million per mile, including the right-of-way costs.

The differences in the three options are:

1. For the ETF in the median construction, trucks share the shoulder and passing lanes with those for the normal roadway. There are no expensive structures for grade separating ramps or providing connections to the main lanes.

2. For the ETF in the outer separation, the conversion of the frontage road requires more roadway width and more grade separations for ramps and cross streets.

3. For an ETF in a new location, the roadway width is wider, some additional roadway structures may be necessary and right-of-way must be acquired, but the requirements for structures at ramps and drainage facilities are reduced. There may be complication and extra expenses in acquiring the new right-of-way.

4.0 MOTOR CARRIER ISSUES

4.1 INTRODUCTION

The volume, safety and operating characteristics of large trucks on rural and urban freeways is of increasing concern to private citizens, highway departments and the trucking industry in general. Several studies have been directed towards the determination of the feasibility of physically or operationally segregating trucks from other vehicles in the traffic stream. It is expected that by separating trucks and passenger vehicles conflicts would be reduced and safety improved. Also, maintenance costs on those sections of the roadway from which trucks were excluded would be expected to be lower. Roadway sections designated for use by heavy trucks would be designed and constructed at higher levels in order to meet the requirements of additional and concentrated truck traffic.

Two basic type facilities have usually been defined and considered when evaluating separating trucks and passenger vehicles. One method is the designation and/or construction of a freeway lane on a reserved or unreserved basis for trucks. Within this context there are several design alternatives which can be specified including elevation and use of available median. The second method is concerned with physical removal of trucks to an exclusive facility in or contiguous to the existing right-of-way (ROW) or one which is generally parallel to the existing highway. This section is directed to a discussion of truck facility options from the perspective of the motor carrier industry.

4.2 OPERATIONAL ASPECTS

User requirements appear to an important aspect in consideration of truck facilities. Operational characteristics of motor carriers must be recognized and planned for whether the focus of the study is on an inter or intracity facility. In this regard, several large motor carriers with headquarters or major terminals in the Houston Area and involved in intercity operations were contacted. The purpose of the contacts was to document intercity operational characteristics and identify those which are compatible with development of an exclusive or non-exclusive truck facility.

In meetings with motor carrier firms two types of truck facility concepts were discussed:

1) An all new highway facility either contained within the existing rights-of-way or on a new rights-of-way alignment.
2) Improve the existing facility by adding an additional lane for trucks the lane may or may not be reserved or may be reserved only during specific times.

There are several variations of these two concepts which may be considered and implemented, once it has been determined that a truck facility is the preferred alternative to meet specific goals.

In evaluating the alternative concepts there are several areas apart from design engineering that must be addressed:

1) Most programs that have assigned large trucks in urban areas to one or two specific lanes have met with limited success and in some instances had the potential to increase vehicle conflicts. While thru truck traffic may tend to select the lanes of travel which result in minimum conflicts and require fewer lane changes, other truck traffic with origins and/or destinations within the urban area may find that specific lane assignments impede their operations.
2) In an intercity corridor where both congestion and traffic conflicts are significantly reduced and where lane assignment may be predicted on pavement life consideration, voluntary compliance would be difficult to obtain and enforcement expensive to achieve.
3) If an entirely new separate facility in a new right-of-way is constructed or a new lane is constructed within the existing right-of-way specifically for trucks, the question of truck use to remains. Without the assurance of compliance by the trucking industry, either of the two options would be difficult to justify.

Therefore, to obtain the necessary usage of the ETF, the trucks must benefit from operation on the separate facility. Obviously, if adequate entry and exit facilities are not available to meet operational requirements trucks cannot use the facility. The ETF must be long enough to attract trucks. It may be necessary to allow higher highway speeds for trucks using the facility, in order to reduce travel time, a major incentive for trucks to use a separate facility.

A separate facility may be within the existing right-of-way or require new right-of-way. If space is not available within the existing ROW there is the option of going over head. The critical and controlling factor for a separate facility is the availability of land for the facility. For most of the distance in an intercity corridor this condition is usually met. Near urban areas where the interviewed carriers indicate an ETF would be most beneficial - (from their perspective) the condition of available space may not be met or may be lost to development within the next several years.

Most separate truck facility will probably require more miles of travel than the existing route (If the facilities are adjacent or within the existing ROW this would not be the case). These additional miles of travel add to the operating costs of the carriers and reinforce the need for incentive to encourage truck use.

The meetings with motor carrier firms provided insight into their operations and an appreciation of their needs as they relate to a truck facility. The interview process was not intended nor designed for a statistical analysis. However, many of the comments of the carriers interviewed are typical of carrier operations within the specific categories.

4.2.1 General Commodity Carriers

Spokesman for these firms indicated that intercity, long haul operations tended to be scheduled for arrival and/or departure at their Houston terminal between 6 p.m. and 6 a.m. The majority of firms scheduled trucks around peak period traffic. For their purposes an exclusive truck facility should be near the urban area and be 25-50 miles long. They considered the need for intercity truck facilities more important for their pickup and delivery functions within the urban area. There was no consensus from this carrier group on the issue of higher speeds on any type of facility for trucks.

4.2.2 Household Goods Carriers

This carrier group has limited ability to schedule arrivals or departures. Also, they did not view exclusive facility as necessary for this sector of the industry. However, if an exclusive truck facility was available, it was their opinion that it should be near the urban area and not in rural areas. They also did not envision any requirement for differential speeds.

4.2.3 Hazardous Materials Carriers

Interest was shown for constructing a facility to the east between Houston and Beaumont or Port Arthur. A majority of intercity truck arrivals and departures during a 24 hour period arrive from or depart to the east for the larger Houston-based Hazardous Material companies. Intercity truck traffic to the east originated or terminated as close as Baytown or as far as New England, yet approximately 20% of that eastbound traffic traveled to or arrived from Louisiana, without intermediate stops.

All carriers interviewed favored an exclusive truck facility, although none could agree on the length or type of facility. The question that evoked the most response from the larger hazardous material carriers surveyed was "Would the exclusive truck facility enable trucks to reach higher average highway speeds?" Terminal managers were emphatically against any facility or procedure that would allow drivers to reach higher operating speeds, thus potentially sacrificing safety.

Another reason cited for constructing an ETF to the east was to improve driving conditions. On I-10, segments between Loop I-610 to San Jacinto Bridge and Beaumont to Orange, operation managers considered pavement conditions to be unsafe for their drivers. A greater number of accidents were experienced on I-10 east than west by the carriers surveyed. This is to be expected due to the higher volumes of truck traffic.

4.2.4 Pipe and Steel Carriers

Pipe and steel carriers using I-10 try to dispatch trucks to avoid peak traffic periods. However, custom delivery requirements often resulted in this objective to not be reached. This group felt that trucks should be able to increase operating speeds on an exclusive truck facility. They also considered that 25 miles would be a minimum length for such a facility.

4.2.5 Sand and Gravel Carriers

Due to the nature of the Sand and Gravel business, this group could not schedule around commuter peak period traffic. They estimate that 60 mph is the carrier's average operating speed. Those surveyed favored a new 25 mile exclusive truck lane alongside the existing roadway, for which they would consider paying an additional fee to use the facility.

4.3 MOTOR CARRIER OPERATING COSTS

Interviews with selected motor carriers operating in the I-10 (Houston-Beaumont Corridor) determined estimated operating costs at 114 cents per mile. This figure approximates published figures of 115.3 cents per mile presented in Table 4-1. Using these estimates truck operating costs per trip in the 75-mile study corridor approach $85. Therefore, a facility on a new and separate right-of-way would probably be circuitous and more operationally expensive, while an ETF in the available median on the frontage roads would not result in added travel miles or increase carrier operating costs. Thus, in the event of construction of an ETF on a separate right-of-way, speed limits may have to be increased in order for carriers to maintain their current cost per trip expense. The increase in speed necessary is related to the degree of circuitry of the route.

Table 4-1. Truck Costs Per Mile

TRUCK FLEET COSTS, 1984

(cents per mile)

COST ITEMS

FIXED COSTS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AVG
Interest	7.1	7.1	7	7	7.1	7.1	7.1	7.1	7.1	7.1	6.9	6.7	7.0
Depreciation	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
MGMT & O/H	9.2	9.6	9.3	9.3	9.5	9.5	9.5	9.5	9.5	9.7	9.7	9.7	9.5
Insurance	4	4	4	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.2	4.3	4.1
Licenses	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
VAR. COSTS													
Vehicle Depr	13	13.1	11	11	11	11	11	11	11	11	11	11	11.3
Driver Cost	30.4	30.5	30.7	30.3	30.5	30.4	30.3	30.4	30.3	30.5	30.8	30.9	30.5
OP. COSTS													
Fuel	25.3	25.5	25.1	25.2	24.9	25	25	25.8	26	26.3	26.2	26.2	25.5
Maintenance	13.5	13.6	13.5	13.6	13.5	13.6	13.6	13.6	13.7	13.6	13.6	13.7	13.6
Tires	2.9	2.8	2.8	2.9	2.8	2.8	2.8	2.8	2.8	2.8	2.9	2.8	2.8
Misc.	7.3	7.4	7.4	7.4	7.4	7.4	7.4	7.5	7.5	7.6	7.6	7.6	7.5
TOTAL COST	116.1	117	114.2	114.2	114.2	114.3	114.2	115.2	115.4	116.1	116.3	116.3	115.3

In determining necessary speed limit increase the study examined carrier operating costs, value of time estimates and length of the truck facility. The analysis of these factors is found in the Appendix C. It was determined that considerably higher speeds are necessary to effect the costs associated with higher travel miles.

4.4 INDUSTRY BENEFITS

Benefits to the motor carrier industry of an exclusive truck facility appear related primarily to the type, location, and length of the facility. At this time such a facility on a separate right-of-way offers little if any perceived incentive to truckers and has certain negative operating costs aspects.

The addition of exclusive or non-exclusive lanes does not add to carrier costs and appears to be acceptable as long as passing is allowed and entry and exit is not impaired. Most of the carriers interviewed did not require access to intermediate locations in the corridor. Accident experience and safety issues of an exclusive facility do not appear to be a major concern of the carriers.

5.0 AGENCY ISSUES

5.1 IMPACT OF INCREASED TRUCK SIZE

As a result of the Surface Transportation Assistance Act of 1982 the size of trucks on the highways of Texas is expected to change. The shift to longer, wider, and probably heavier trucks over the next several years may result in the need to continually reevaluate the role of an exclusive truck facility in highway design and construction. The long term effects of the legislation are not known. However, the recently completed Twin Trailer Monitoring Study identified some trends and initial effects of the legislation. This section highlights some of the findings reported in Twin Trailer Trucks: Effects on Highways and Highway Safety (11) that relates to an exclusive truck facility. The effects examined and estimated by the monitoring committee were:

1) truck industry use of twins,
2) safety consequences of using twins,
3) pavement wear and other highway features affected by twins, and
4) safety and pavement wear affected by 48-foot long semitrailers and 102-inch wide trucks.

According to the report, the use of twin trailers will account for approximately 11 percent of the total nationwide truck miles of combination vehicles. Common carriers of general commodities are expected to be the primary users of twin trailers. The expected increased use of twins will result in a reduction of combination truck miles by those carriers introducing them to their fleets.

Although twin trailer vehicles tend to have a somewhat higher accident experience per mile than tractor-semitrailer combinations, little overall effect on safety is anticipated. The reduction in miles of travel is expected to offset any increase in accident experience. However, additional experience and data related to highway safety performance is needed to verify this conclusion.

The introduction of twins to replace conventional combination type vehicles is expected to have negative impacts on pavement wear and rehabilitation costs. The monitoring committee reported that increased pavement wear is expected because, 1) twins typically weigh more than tracter-semitrailers, 2) load distribution of twins is less uniform over the axles than tractor-semitrailers, and 3) the transfer of loads to pavement surfaces is different from tractor-semitrailers. By 1990 the additional pavement wear occasioned by twins is expected to cost $50 million to repair.

The Surface Transportation Act of 1982 also authorized the highway use of 48-foot semitrailers with a maximum width of 102 inches. The monitoring committee found no data base to use in assessing the overall impact of these vehicles on highways. It is anticipated, however, that these type trucks will be used by private and truckload carriers that require added capacity. Pavement and shoulder wear will tend to increase and the increased width will probably result in some highway design standards. The report indicates no significant effects on highway safety.

The situation of a changing mix of trucks, especially combinations, on the highways of Texas over the next several years indicates a need to reevaluate the role of exclusive truck facilities in the system. If these types of trucks gain industry acceptance, replace current combinations at the anticipated rate, and prove to have the effects put forth by the committee, the need for exclusive truck facilities may increase. An increase in pavement wear attributable to these vehicles may result in the need for designated truck lanes with improved pavement design standards.

5.2 PAVEMENT CONDITION

The State Department of Highways and Public Transportation is intensifying its study of heavier wheel loads and higher tire pressures and their impact on the life of the pavements. A survey of pavement conditions on I-10 using the measures of Serviceability Indices and Pavement Evaluation Scores are included in Appendix D. The pavement condition becomes a critical factor in determining if and when to build additional lanes or roadways in a freeway corridor. The economic analysis would include the savings that might result from a longer pavement life for the old pavement without the heavier vehicles, and the longer life of the pavement especially designed for truck loads.

In this report the issues of pavement strength and condition are raised, but the impacts that ETF have on design and on maintenance/reconstruction schedules are deferred to those studies of pavement management.

5.3 LEGAL CONSIDERATIONS

During the course of the study several questions of a secondary and non-technical nature arose that need to be addressed prior to implementation of an exclusive truck facility. One of these concerned the legal considerations and consequences of having trucks use the facility. This may not be an issue if the facility is a designated truck lane within the existing roadway. As long as entry and exit is not impaired and passing is allowed at intervals the assignment of trucks to a specific lane of travel seems to pose little, if any, legal concerns. Since designation and assignment does not increase operating costs or occasion an increase in travel time the motor carriers would not be adversely affected. Also, the need to preserve pavement life, higher pavement design in the truck lane or accident experience would seem to justify the assignment.

Several states currently assign or have assigned, trucks to specific lanes of travel on all or part of their roadway system. The assignment is usually to the outside lane or lanes if there are three or more lanes of travel in the same direction. The State of Arkansas has assigned trucks to the inside lane on freeway sections due to pavement deterioration on the outside lane(s). Such lane assignment are usually confined to specific roadways and/or sections to cope with a special situation. Indiana restricts trucks to the outside lane, or lanes, on all interstate system highways (1).

An exclusive truck facility on the separate right-of-way may present legal problems which need to be examined. If the facility is circuitous and increase carrier costs and provides no compensating or off-setting benefits carriers may be reluctant to voluntary use the facility. Some legal mechanisms may be needed to insure truck use. In addition, if the exclusive facility is in any aspect inferior in design or safety standard from the roadway it replaces for trucks there may be questions and concerns regarding liability.

5.4 OTHER

Enforcement of ETF restrictions may pose problems for state highway patrols. If a separate facility is selected additional law enforcement personnel will be required. Signing and enforcement efforts are also necessary in a lane assignment option. An educational program aimed to the motor carrier industry defining the benefits of using a truck lane may be desirable and increase compliance.

Emergency vehicles may encounter certain problems such as access and be hindered in providing services to a separate truck facility. The use of the median, especially if the facility is elevated, may also cause problems in response to accidents and dealing with any incidents involving hazardous materials. The selection of a truck lane option is not anticipated to have negative implications in this regard.

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(1) Information contained in letters to Phillip L. Wilson, State Transportation Planning Engineer (Retired) Texas Department of Highways and Public Transportation. The following states indicate some form of lane assignment for trucks: Arkansas, Indiana, Georgia, Massachusetts, Maryland, Louisiana, Illinois, and Connecticut.

6.0 CONCLUSIONS

6.1 GENERAL

There is growing interest in separating trucks and passenger vehicles. However, the conclusions of this study are that the benefits are more perceived than real for most intercity corridors. The reasons for this observation are: that truck volumes are not high enough to cause significant travel time delays in rural areas; truck accidents on high speed rural sections have a higher mortality rate, but fortunately, the truck accident rates are low; pavement conditions suffer under the heavy truck loads, but the cost to provide extra roadways for trucks can not be justified by pavement benefits alone.

6.2 NEED FOR AN EXCLUSIVE TRUCK FACILITY

The need for exclusive truck facilities (ETF) are greatest in the urban areas where truck volumes are high and traffic congestion is severe, but where space requirements and costs are prohibitive.

The provision of ETF in the rural areas must result in real benefits to the users. Therefore, the designs must meet freeway standards; trip lengths and average speeds must produce shorter travel times; roadside services and emergency facilities must equal or exceed those available on the normal route. Under existing conditions on most intercity freeway corridors, the ETF can serve the trucking industry with the same or slightly better level of service as measured by these lengths, but at high costs.

Special situations in hilly or rolling terrain with high percentages of heavy trucks may warrant special truck facilities for short distances. The provision of truck climbing lanes are not considered a part of this study.

6.3 PRIORITY OF DESIGN OPTIONS

The most cost effective option for accommodating large volumes of trucks on intercity freeways is the widening of the existing roadway, either in the median or in the outer separation, and permitting mixed flow on all lanes, but restricting truck traffic to one lane, except for passing maneuvers. The restricted lane can be constructed to carry the heavier loads, the widened freeway will result in less traffic density and more freedom to maneuver, which results in safer operations. This option is not an exclusive truck facility and does not accomplish the one objective that most proponents desire - to physically separate trucks from passenger cars.

The second most cost effective option provides for two truck lanes in the median with a third lane used for passing. Extremely high speeds may not be advisable for this design, but travel times comparable to the freeway main lanes can be achieved. The costs for this option would be twice that of the added lanes, but total separation of the trucks from passengers can be achieved. This option can be placed in the outer separation or on new right-of-way at higher costs.

The most desired and most costly option is a totally separate facility with 2 or more lanes in each direction. Truck volumes would need to exceed the capacity of one freeway lane to initiate consideration for this type of roadway. Or, truck sizes, weights and tire pressures would have to increase to a point that existing freeway pavements would be destroyed. This condition may become the central issue in determining the justification of a fully designed ETF.

The lease desired option considered in this study was the diversion of trucks to an alternate route, essentially parallel to the freeway. The time loss due to the additional travel time was unacceptable. The conversion of the parallel facility to a freeway type facility resulted in a myriad of problems; including social and environmental concerns as well as costs.

6.4 IMPLEMENTATION ISSUES

The study identified a number of problems that need to be solved prior to initiating ETF projects:

User Requirements - For an exclusive or restrictive lane or roadway, legal definitions of who can or who must use particular parts of the freeway/ETF roadways will have to be developed. There may be special funding requirements and/or user fees to finance the ETF projects.

Safety - The attractiveness of "fitting in" special lanes and roadways in restricted spaces to save money must be measured against the operation difficulties that may result. The barriers that are used to separate types of vehicles also limit accessibility and freedom to maneuver. The effects on safety of concentrating large volumes of trucks, traveling at high speeds in restricted lanes or roadways has not been determined.

6.5 PAVEMENT BENEFITS

There is much research now underway to evaluate the impact of higher loads and tire pressures. The benefits of eliminating the heavy loads from old pavements need to be identified. With the improvements in weigh-in-motion equipment, there are opportunities to determine these benefits, and address some of the other implementation concerns for ETF.

6.6 RECOMMENDATION

This study concludes that wide spread implementation of exclusive truck facilities on interstate city freeway corridors can not be justified at this time. It is the recommendation of this study that a test section of sufficient length (2 to 5 miles) be constructed on I-10 and designated as an exclusive truck facility. This facility should be totally separate from the existing freeway with full shoulders on both sides of two 12 foot lanes. A pavement test program should be developed to examine several pavement cross sections as determined by the Department. A vehicle monitoring station should be installed to detect and measure the type, weight, speed, tire pressure and other pertinent data from all vehicles using the test section. The program should be designed to monitor the roadway from which trucks are being diverted and the opposing roadway that is carrying mixed traffic.

Operational and design issues that have been identified in this and other ETF studies should be included in the research program.

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APPENDICES

A - Alternative Corridors

B - Description of the Moving Analysis Program to Evaluate the Geometric and Operational Feasibility of Truck Lanes

C - Cost Impact on Trucks Using ETF

D - Pavement Condition and Evaluation in the I-10 Study Corridor

APPENDIX A
ALTERNATIVE CORRIDORS

1.0 DESCRIPTION

1.1 I-10 CORRIDOR, HOUSTON TO SAN ANTONIO

The Houston to San Antonio corridor is approximately 200 miles and crosses ten counties - Harris, Fort Bend, Waller, Austin, Colorado Fayette, Gonzales, Caldwell, Guadalupe, and Bexar. In 1982, truck volumes accounted for between 10% and 35% of total traffic.

Harris County

Information on Harris County is found in the section on the Houston-Beaumont Corridor.

Fort Bend County

Fort Bend County is considered part of the Houston metro area and has a population of over 130,000. There are 36,300 people employed, earning total wages of $672 million. Many of these work in Houston.

The economy of Fort Bend County is supported by petrochemicals, sulphur, and sugar refining, as well as by agriculture. Agriculture contributes more than $90 million in average annual income, mostly from rice, cotton, sorghums, soybeans, corn, cattle, poultry, and hogs. In 1977 76 manufacturing operations shipped $506 million worth of goods, 94 wholesale establishments had total sales of $143.5 million, and 631 retail trade firms reported total sales of $216.6 billion. Minerals accounted for sales totaling $153.2 million.

Waller County

Waller County is also considered part of the Houston metro area. It has a population of about 20,000, with 5,200 employed and earning wages in excess of $55 million. The majority of those employed work in the manufacturing and trade industries, and the state government.

The economy is based on oil, agribusiness, and manufacturing. Agriculture contributes about $40 million in average annual income from beef cattle, hogs, goats, sheep, rice, and corn. Minerals, including oil, have average annual sales of about $250 million. According to 1977 Census Data, there are 14 manufacturing operations, 21 wholesale trade establishments with total sales of $11.6 million, and 141 retail trade firms with total sales of $74.3 billion.

Austin County

Austin County has a population of 17,750. There are 5,500 employed, earning wages of $72.8 million. The majority work for mining, trade, service, and construction industries, and the local government.

The economy is based on agribusiness, followed by steel and manufacturing. Agriculture accounts for $35 million in average annual income from livestock, poultry, sorghums, rice and peanuts. Minerals, particularly oil and gas, contribute approximately $21 million per year. In 1977 there was 23 manufacturing operations which shipped goods valued at $28.2 million, 36 wholesale trade establishments had total sales of $43.8 million, 210 retail trade firms posted total sales of $42,720.

Colorado County

Colorado County has a population of 18,800, 6,300 which are employed and earning wages over $86 million. Most of those who work do so for the trade, manufacturing, mining, and service industries.

The economy is based on agribusiness, oil field services and equipment manufacturing, and mineral processing. Agriculture accounts for $66 million average annual income from beef and dairy cattle, poultry, hogs, rice, corn, and cotton. Minerals, particularly gas, oil, sand, gravel, and stone contribute about $97 million per year. In 1977 there were 19 manufacturing establishments which shipped $16.3 worth of goods, 43 wholesale establishments had total sales of $40.3 million and 278 retail trade firms had total sales of $63.5 billion.

The county seat, Columbus, is the cut off point between the corridor segments. It has a population of 4,000, and is the agribusiness center for the county. It has sand and gravel industries, oil and gas servicing, and a variety of manufacturers.

Fayette County

Fayette County has a total population of 19,000. About 7,000 are employed and earn wages of $89 million, with the majority working in trade, service, manufacturing and construction industries, and the local government.

The economy is based on agribusiness, oil production, manufacturing, and tourism. Agriculture accounts for about $35 million annual average income from beef and dairy cattle, hogs, poultry, corn and peanuts.

Minerals, particularly oil, gas, clays, sand, and gravel contribute about $4 million per year. The latest Census data (1977) showed 34 manufacturing operations shipped goods valued at $24.7 million, 50 wholesale trade establishments had total sales of $51.9 million, and 325 retail trade firms had total sales of $56.5 billion.

Gonzales County

Gonzales County has a total population of 17,000, 6,000 which are employed and earning wages of $69 million. The industries with the greatest number employed are manufacturing, trade, service, mining, and the state government.

The economy is based almost entirely on agribusiness. Agriculture accounts for more then $173 million average annual income. It is a top beef, poultry, and egg producing county in the state; crops grown include grain, corn, peanuts, melons, and pecans. Revenues from sale of minerals are approximately $7 million per year.

In 1977 this county had 26 manufacturing operations which shipped $70.9 million worth of goods, 52 wholesale trade establishments had total sales of $74.9 million, and 61 retail trade firms had total sales of $9.6 billion.

Caldwell County

Caldwell County has a total population of 24,000. There are 5,800 people employed, mainly in the trade, service, and mining industries and the state government. They earn $75 million in total wages per year.

The economy is based on petroleum, agribusiness, and a variety of manufacturing. Oil and gas account for $18.6 million per year, while agriculture contributes more the $29 million average annual income. In 1977 15 manufacturing operations shipped goods valued at $30.4 million, 36 wholesale trade establishments had total sales of $41.2, and 199 retail firms had total sales of $48,441 million.

Guadalupe County

Guadalupe County has a total population of 47,000 with 13,000 employed and earning wages of $158.9 million. Most of those employed work for the manufacturing trade, and service industries, and the local government. Many work in San Antonio.

The economy is based on agribusiness and a variety of manufacturing. Agriculture accounts for about $32 million average annual income from the production of beef and dairy cattle, hogs, poultry, sorghums, and corn, while mineral sales average $17 million per year. According to 1977 Census data there are 44 manufacturing operations which shipped goods valued at $175.5 million, 53 wholesale establishments had $60.1 million in total sales, and 429 retail trade firms had total sales of $105.7 billion.

Harris County

Information on Harris County is found in the section on the Houston-Beaumont Corridor.

Montgomery County

Montgomery County, population 128,487, is a center for lumber and oil production as well as gas, sand, and gravel. According to 1977 Census figures, a total of 89 manufacturing operations shipped $161.3 million worth of goods, 85 wholesale establishments produced total sales of $114 million and 723 retail firms reported $268,687 million in total sales. Approximately 32,000 people are employed, earning $504 million in total wages. The industries that employ the most are trade, manufacturing, service, and the local government.

The county seat is Conroe (population 18,034). It is mainly a residential community, with many workers employed in Houston. Plants here make oil, wood, helicopters, oil field equipment, and many other products.

Agriculture provides about $17 million in annual income from beef, dairy cattle, hogs, horses, hay, and vegetables. Timber products also account for substantial income.

1.3 US-59 CORRIDOR, HOUSTON TO GOODRICH

This corridor passes through San Jacinto, Liberty, Montgomery, and Harris Counties along U.S. Highway 59 from Houston to Goodrich, a stretch of over 65 miles. 1984 daily average truck volumes were about 3800, which was approximately 6% of total traffic.

San Jacinto County

San Jacinto County has a total population of 11,400; 950 are employed and earning wages of $11 million. Most of those employed are involved in trade, finance, insurance, real estate, and the local government.

The economy is based on timber and oil, with some $5.5 million average annual income from agriculture. According to Census data, in 1977 there were only 2 establishments involved in wholesale trade, with 462 manufacturing operations shipping $1.4 million of goods, and 71 retail firms achieving total sales of $9,615 million.

Liberty County

Liberty County has a total population close to 50,000, 14,000 of whom are employed and earning total wages of $234 million. Many of these work in Houston. The primary businesses are agribusiness, chemical plants, a variety of manufacturing plants, tourism, and forest industries.

In 1977, 50 manufacturing operations shipped $85.4 million worth of goods, 69 wholesale operations had total sales of $78.1 million, and 445 retail firms had sales of $139,374 million. Agriculture accounts for about $40 million per year in average income, about three-forths from the principal crops of rice and soybeans.

The main town of interest is Cleveland, population 8,000, located at the intersection of U.S. Highway 59 and State Highway 105. Its business activities include processing and shipping forest, farm, and petroleum products.

Table A-1. Traffic Volumes on Selected Corridors, 1984

		Trucks	Total Vehicles	Truck% of Total
I-10	Houston to Orange	3,028	9,680	31.3
I-10	Houston to Columbus	2,139	7,291	29.3
I-10	Columbus to Seguin	6,652	11,700	56.9
I-10	Seguin to San Antonio	1,082	4,155	26.0
I-45	Houston to Conroe	34,964	89,000	39.3
I-59	Houston to Goodrich	25,232	64,000	39.4

SOURCE: Steven Albert, Texas Transportation Institute, The Texas A&M University System.

Table A-2. Average Daily Number of Vehicles, 1981-1984*

I-10 Houston to State Line (Orange):

Year	Station	County	Trucks**	Total Vehicles	Truck% of Total
1980	M-1216	Orange	4,019	18,010	22.3
1981			4,245	21,200	20.0
1982			3,659	18,000	20.3
1983			4,840	21,000	23.0
1984			4,600	20,000	23.0
1980	MS-117	Orange	4,474	46,000	9.7
1981			4,902	47,870	10.2
1982			4,986	49,000	10.2
1983			-	-	-
1984			-	-	-
1980	M-1253	Jefferson	-	-	-
1981			5,435	21,300	25.5
1982			-	-	-
1983			-	-	-
1984			-	-	-
1980	MS-125	Harris	5,238	27,000	19.4
1981			6,337	32,000	19.8
1982			5,882	33,000	17.8
1983			6,723	35,000	19.2
1984			6,632	37,000	17.9

I-10 Houston to Columbus Subcorridor:

Year	Station	County	Trucks**	Total Vehicles	Truck% of Total
1980	M-1200	Harris	5,348	54,000	9.9
1981			7,310	67,000	10.9
1982			7,021	68,000	10.3
1983			-	-	-
1984			9,360	95,000	9.9
1980	M-1249	Colorado	-	-	-
1981			5,948	20,000	29.7
1982			6,682	18,800	35.5
1983			-	-	-
1984			-	-	-

I-10 Columbus to Seguin Subcorridor:

Year	Station	County	Trucks**	Total Vehicles	Truck% of Total
1980	MS-164	Fayette	1,705	10,600	16.1
1981			2,181	11,560	18.9
1982			2,922	11,700	25.0
1983			3,761	11,500	32.7
1984			4,140	11,700	35.4
1980	L-102	Guadalupe	3,272	10,100	32.4
1981			3,264	10,400	31.4
1982			3,074	10,000	30.7
1983			3,064	15,600	19.6
1984			3,598	16,100	22.3

I-10 Seguin to San Antonio Subcorridor:

There are no manual count stations along this subcorridor.

I-45 Houston to Conroe:

Year	Station	County	Trucks**	Total Vehicles	Truck% of Total
1980	MA-16	Harris	5,593	70,000	8.0
1981			6,292	79,000	8.0
1982			6,154	83,000	7.4
1983			5,877	87,000	6.8
1984			-	-	-
Route 59 Houston to Goodrich:					
1980	MS-174	Montgomery	-	-	-
1981			3,924	51,000	7.7
1982			3,194	57,000	5.6
1983			3,161	60,000	5.3
1984			3,747	64,000	5.9
1980	M-1285	Harris	-	-	-
1981			2,354	10,200	23.1
1982			-	-	-
1983			-	-	-
1984			-	-	-

*Truck counts are being conducted to determine current volumes. This data and any additional information will be provided in separate technical notes.

**Includes 3-axle trucks and all truck-trailer combinations.

State Department of Highways and Public Transportation, Manual Count Annual Report, 1980-1984.

APPENDIX B

DESCRIPTION OF THE

MOVING ANALYSIS PROGRAM TO EVALUATE THE GEOMETRIC AND OPERATIONAL FEASIBILITY OF TRUCK LANES

1.0 INTRODUCTION

The increase in truck traffic on Texas highways led to a study of the feasibility of exclusive truck lane facilities in the median of existing interstate highways. The first two phases of the study established the geometric requirements for exclusive truck lanes and developed a computer program to analyze specific highway segments. The objective of this phase was to provide a user-friendly interactive computer program that would function on an IBM-PC (or compatible) microcomputer.

1.1 PURPOSE OF PROGRAM

Limitations of the previous methodology which used a mainframe computer could be resolved by developing a program which performed the same analyses on a microcomputer. Quite often, there exists a need to run the program on selected portions of the highway (instead of the entire length), to vary some of the traffic assumptions, or to produce study results with data not stored on a mainframe computer.

It is also important to have data related to a specific freeway accessible for easy revision. The primary technique of evaluating each individual segment of the highway was critical to the analysis. This combination of factors resulted in the development of a dual purpose computer program.

1.2 PROGRAM DEVELOPMENT

The computer program evolved from a high-speed train simulation program written in Basic that was reprogrammed in Fortran 77 for a mainframe computer. The highway data was card image with all data in ASCII character format. It was necessary to modify the first two cards of the input data for each run with standard parameters. The modification of the data was normally done with a line editor (such as WYLBUR) or a card punch.

The Fortran 77 program was converted to Turbo Pascal for operation on the IBM-PC with identical computations and methodology. All the subroutine functions of the original program were maintained. Some slight modifications were made to take advantage of the capabilities of the newer language thus increasing speed. The program was redesigned to be a menu driven interactive session with run-time parameters input for each run. A module was created that provides an on-line edit and update capability for the interstate highway data. The capability to maintain several data files and to select any of the existing highway files for evaluation was also added.

1.3 PROGRAM ARCHITECTURE

The micro processor program is designed to be a stand alone system that will run on any IBM-PC (or compatible) operating under PC-DOS equipped with double-sided double-density 360 K-byte disk drive and a printer. When the program is activated (by typing TLANE), the master menu that offers three options will appear. This master menu screen is shown in Figure B-1 as it would appear to the operator. The third option is normally used only for initial installation and for special requirements. These options and the general program layout are shown by Figure B-2.

One of the primary options will provide an on-line interactive real time function by which the operator can add, update or delete an interstate highway data file. Figure B-3 shows this screen as it would appear to the operator. Up to sixteen highway data files may be maintained at any time, each representing the data of a different highway. The data file is designed as a relative record sequential file with one record for each mile of the highway. Each record contains the data for two segments of the mile with each segment representing a half-mile of highway.

The other primary option is to evaluate the geometric and operational feasibility of dedicated truck lanes. This menu driven option will allow the selection of any one of the sixteen highway data files. Once the file is

---

T L A N E
TEXAS TRANSPORTATION INSTITUTE
MASTER MENU

Evaluating the Feasibility of Truck Lanes

1 .... CORRIDOR Data Menu

2 .... EVALUATION Methods Menu

3 .... UTILITY Menu

4 .... EXIT TLANE

Choice:

Option'1' Management of the freeway data files menu The normal Add, Change and Delete functions of file management are available.

Option '2' Evaluation of the freeway. The evaluation menu will be invoked.

Option '3' Performs auxiliary functions.

Option 'X' Terminates TLANE and returns to MS_DOS.

Figure B-2

TLANE PROGRAM OPERATION

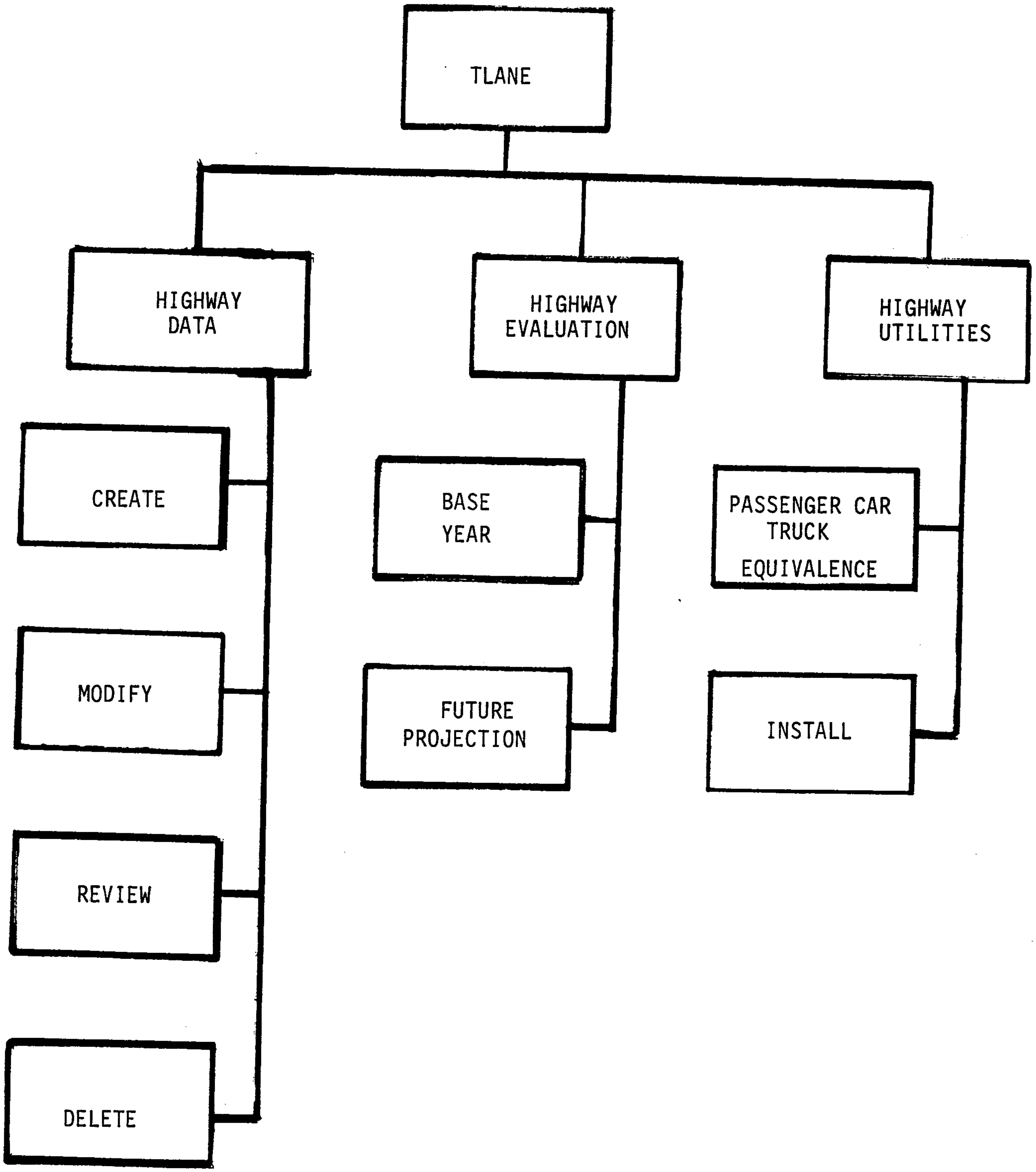

Figure B-3

Corridor Data Menu Screen

```
                T L A N E
      TEXAS TRANSPORTATION INSTITUTE

           CORRIDOR Data Menu

        1 .... Create New Data File

        2 .... Modify Existing file

        3 .... Review Existing file

        4 .... Delete Existing file

        X .... Return to MAIN MENU



         Select Option:
```

Option 1 Create a file for a freeway that does not have a data file. This new file will be added to the list of permissible files contained in the auxiliary file.

Option 2 Modify the data of an existing freeway file. Each half-mile section of the freeway can be displayed and any of the 12 data elements can be modified.

Option 3 Review the data of an existing freeway file. The data for each milepost is displayed on the screen for about 2 seconds. The process can be stopped or terminated at any milepost.

Option 4 Delete a data file for a freeway. This option removes the name from the permissible files and physically removes the file from the disk.

Option 'X' Return to TLANE Master Menu.

selected and the run-time parameters are entered, the program will execute the analysis of either base year or future traffic data. Figure B-4 illustrates this screen. The output from either base year or future traffic analysis will be available on the screen and, if desired, on the printer. More information on the operational features of the program is available in the TLANE User's Manual (__).

1.4 HIGHWAY DATA

The highway data files contain an integer that indicates the milepost of the record, and seven data elements related to each half-mile segment of that mile of interstate. When the highway file is initially created, a record that identifies the highway is written to an auxiliary file. The contents of this auxiliary file is displayed each time an evaluation is desired or a highway data file update is needed (see Figure B-5). Once the highway record is entered in the auxiliary file, the highway data file is available. Changes can be made to any of the highway data elements except the milepost number. Thus, it is not necessary to have all the data for each half-mile segment at the time the highway file is initialized. It is also possible to add records to the highway file either at the beginning or the end of the current file.

The highway data file is a real time environment; thus, if any data element is changed, the new data are immediately available for evaluation. Conversely, once the value is changed, the old data is no longer available.

1.5 RUN-TIME PARAMETERS

Each time an evaluation is run, it is necessary to supply four critical data elements. Each of these data elements are used in the calculation phase of the evaluation and are constant for the particular run. It is possible to evaluate the same highway data several times by entering the evaluation portion of the program and changing the run-time parameters shown on the screen depicted in Figure B-6. The four data elements are:

1. Factor to adjust for restricted lane width and lateral clearance (FWD). When the FWD is not entered, the program will use lane

Figure B-4

Corridor Evaluation Screen

T L A N E
TEXAS TRANSPORTATION INSTITUTE

CORRIDOR Evaluation

1. Volume/Capacity and Effective Median Width

2. Projection of Traffic Growth

X .... Return to MAIN MENU

Choice :

Option 1 Provide a listing of each half mile segment of the highway data. It will calculate the V/C ratio both with and without trucks, and plot the percent improvement in V/C to be obtained by removing the truck traffic.

Option 2 Apply growth factors to the highway data. It will calculate the V/C ratio for increasing traffic over the time period from 1985 through 2010 both with and without trucks, and plot the percent improvement in V/C to be obtained by removing the truck traffic.

Option 'X' Return to TLANE Master Menu.

Figure B-5

Highway Data Screen-Update

```
--------------------------------------------------------------------------------
                                  T L A N E
                         TEXAS TRANSPORTATION INSTITUTE
                            Updating  FULL ADT : I35

                  Updating RECORD for Milepost 168.0        0.0 ==> 0.50
AVERAGE DAILY TRAFFIC ALL LANES BOTH WAYS----    260        !  26000     !
PERCENT OF TRAFFIC VOLUME THAT IS TRUCKS----     11         !  229       !
MEDIAN WIDTH IN FEET------------------------     24         !  24        !
GRADE, IN PERCENT---------------------------     0          !  0         !
GRADE LENGTH IN FEET------------------------     0          !  0         !
NUMBER OF LANES IN SINGLE PEAK DIRECTION-----    2          !  2         !
TOTAL WIDTH OF BOTH INSIDE SHOULDERS---------    16         !  16        !
TERRAIN INDEX-------------------------------                !  0         !
DISTANCE FROM LANE TO LATERAL OBJECT---------    6          !  6         !
LEVEL OF SERVICE INDEX----------------------     3          !  3         !
WIDTH OF MEDIAN OBSTRUCTION (FEET)-----------    0          !  0         !
20-CHARACTER COMMENT ABOUT SEGMENT-----------               !            !


                       Is the data above correct (Y/N)
--------------------------------------------------------------------------------
```

Figure B-6

Run-Time Parameter Screen

```
---------------------------------------------------------------------
                          T L A N E
                TEXAS TRANSPORTATION INSTITUTE
           Volume/Capacity and Effective Median Width

1. Enter Factor for Restricted Lane Width---------------: 0.00
2. Enter type output(0=terminal,1=terminal & printer)---: 0
3. Enter Ratio of Volume to Highest 15 Minute traffic---: 0.85
4. Enter factor for driver population-------------------: 1.00
5. Enter the single lane capacity-----------------------: 2000
6. Enter the starting milepost--------------------------: 168

                 Is the data above correct (Y/N)
---------------------------------------------------------------------
```

width, number of lanes, and distance to lateral object to calculate a FWD for each half-mile segment of the highway.

2. Factor to adjust the hourly demand volume to represent the peak flow requirements (PHF). The service flow rate for each half-mile segment is determined by dividing the hourly volume by the PHF.

3. Factor to adjust the service flow rate for the effect of the driver population (FP).

4. The number of passenger cars that represent the ideal capacity on each lane per hour at a specific design speed.

In addition to the above four factors, the output may be directed to the printer (selection of 2 sizes of paper); the starting milepost may be designated.

1.6 BASE YEAR TRAFFIC EVALUATION

Figure B-7 depicts the general operation of the program for base year traffic evaluation. At the beginning of each run of the program, the highway data file that is to be evaluated is selected. A total of sixteen different data files are possible. After the highway data file is chosen, the run-time parameters outlined above are entered. The program will then evaluate each half-mile segment of the highway and will calculate the volume to capacity ratio (V/C) and level of service (LOS) with and without trucks. The program will also determine the effective median width for the segment. A display of the information for each half-mile segment will appear on the terminal (see Figure B-8, MP 171.0) and on the printer if selected (see Figure B-9, MP 171.0 for printed output comparison with input screen). The program will continue until the end of the highway data is reached or the program is stopped with the 'ESC' key.

Figure B-7

PROGRAM FLOW CHART FOR BASE YEAR TRAFFIC EVALUATION

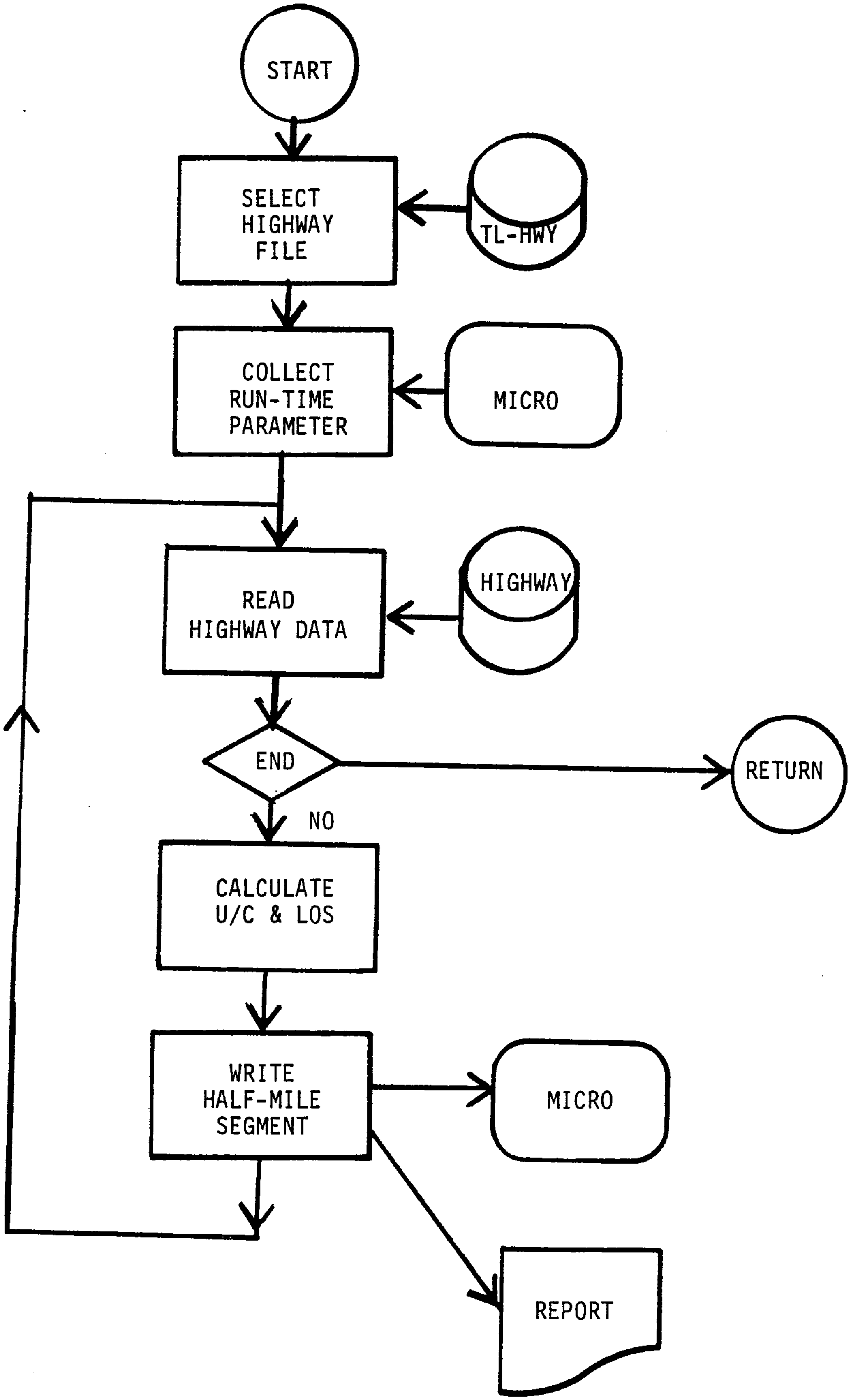

Figure B-8

Highway Data Screen-Review

T L A N E
TEXAS TRANSPORTATION INSTITUTE
Review existing data file
Display of Data for Milepost 171 of FULL ADT : I35

Data item Description	Milepost .00==>.50	.50==>.99
ONE WAY VEHICLE COUNT (PEAK HOUR)------------	2080	1280
NUMBER OF TRUCKS (PEAK HOUR), ONE WAY--------	229	141
MEDIAN WIDTH IN FEET-------------------------	24	24
GRADE, IN PERCENT----------------------------	0	0
GRADE LENGTH IN FEET-------------------------	0	0
NUMBER OF LANES IN SINGLE PEAK DIRECTION-----	2	2
TOTAL WIDTH OF BOTH INSIDE SHOULDERS---------	8	8
TERRAIN INDEX--------------------------------	0	0
DISTANCE FROM LANE TO LATERAL OBJECT---------	6	6
LEVEL OF SERVICE INDEX-----------------------	3	3
WIDTH OF MEDIAN OBSTRUCTION (FEET)-----------	0	6
20-CHARACTER COMMENT ABOUT SEGMENT-----------		2MID

Stop Processing - 'Hit ANY Key'   Abort - 'ESC'

Figure B-9

Base Year Traffic Output

```
--------------------------------------------------------------------------------
                                   T L A N E
                         TEXAS TRANSPORTATION INSTITUTE
                    Volume/Capacity and Effective Median Width
 ###################Analysis of FULL ADT : I35 ##############################
# MP    PHV  TRUC  N  LAT MEDW TW: V/C V/CA %V/C LOS70   0%    50% 100% 150% 200#
#168.0 2080  229   2   6   24  37  0.66 0.54  21 C:C    : *  .     I    .   :  #
#168.5 2080  229   2   6   24  37  0.66 0.54  21 C:C    : *  .     I    .   :  #
#169.0 2080  229   2   6   24  37  0.66 0.54  21 C:C    : *  .     I    .   :  #
#169.5 2080  229   2   6   24  37  0.66 0.54  21 C:C    : *  .     I    .   :  #
#170.0 2080  229   2   6   24  37  0.66 0.54  21 C:C    : *  .     I    .   :  #
#170.5 2080  229   2   6   24  21  0.66 0.54  21 C:C    : MEDIAN TOO NARROW :  #
#171.0 2080  229   2   6   24  29  0.66 0.54  21 C:C    : MEDIAN TOO NARROW :  #
#171.5 1280  141   2   6   24  23  0.41 0.33  21 B:A    : MEDIAN TOO NARROW :  #
#172.0 1280  141   2   6   24  29  0.41 0.33  21 B:A    : MEDIAN TOO NARROW :  #
#172.5 1280  141   2   6   24  23  0.41 0.33  21 B:A    : MEDIAN TOO NARROW :  #
#                                                                              #


                   Hit any Key - STOP        'ESC' - abort

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```

1.7 FUTURE TRAFFIC EVALUATION

Figure B-10 depicts the general operation of the program for future traffic evaluation. At the beginning of each run of the program, the highway data file that is to be evaluated is selected. A total of sixteen different data files are possible. After the highway data file is chosen, the run-time parameters outlined above are entered. Any half-mile segment of the highway may be selected for future projection. Once the segment is selected, the county name to be printed and the growth factors to be applied are entered. If more than sixteen segments are needed, the program should be rerun.

The program will then evaluate the selected segment of highway and will calculate the volume to capacity ratio (V/C) and level of service (LOS) with and without trucks. The program will also determine the effective median width for the segment. A display of the information for the selected segment will appear on the terminal (see Figure B-11 for MP 168.5) and on the printer (if selected). The program will apply the appropriate growth factors to the traffic volume and repeat the process until the data for year 2010 has been displayed. If additional segments have been selected, the process will be repeated until the segment list is exhausted. Each highway segment will appear on a separate printout.

Figure B-10

PROGRAM FLOW CHART FOR FUTURE TRAFFIC EVALUATION

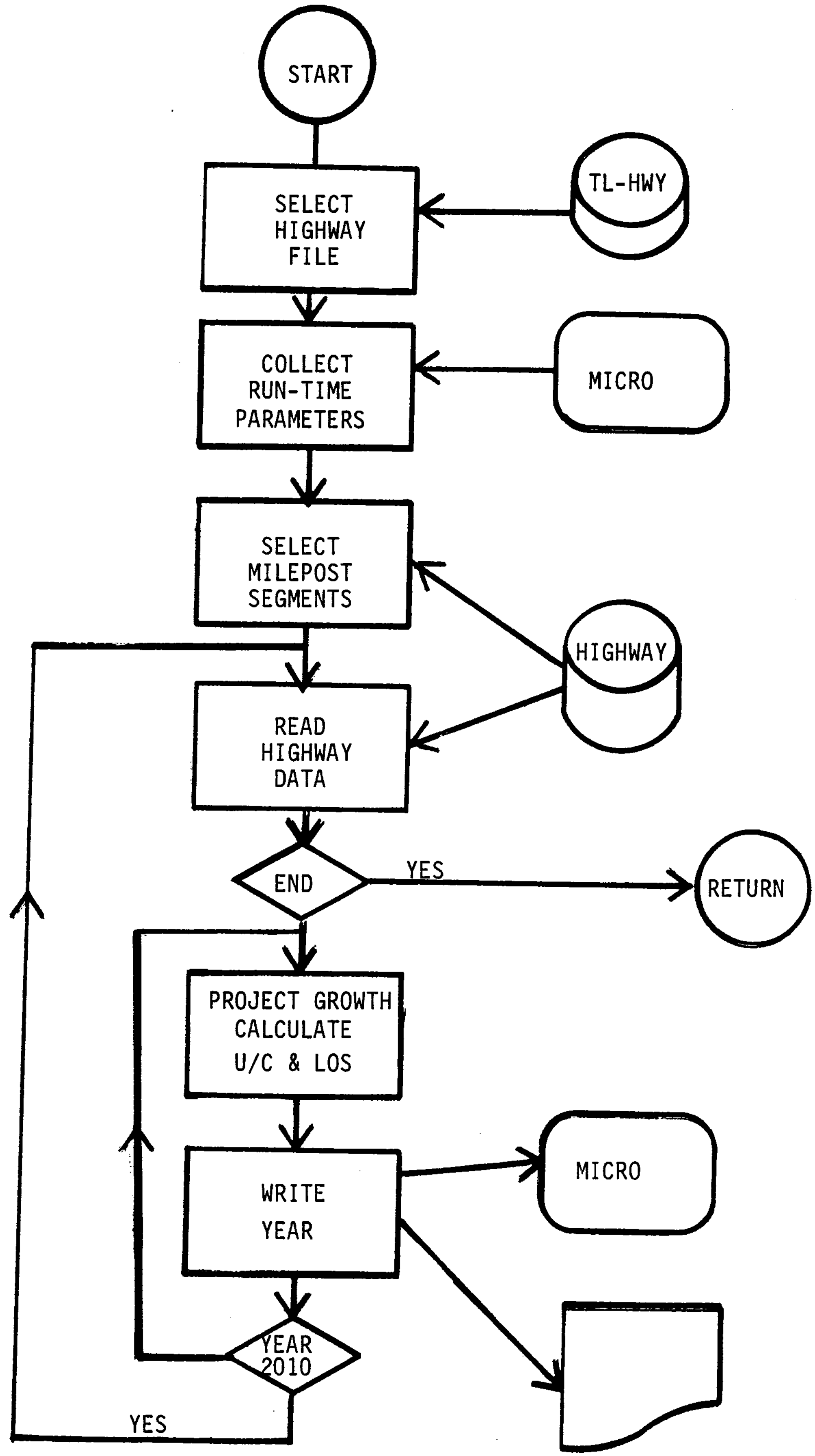

Figure B-11

Future Traffic Evaluation Output

```
--------------------------------------------------------------------------------
                                   T L A N E
                         TEXAS TRANSPORTATION INSTITUTE
                          Projection of Traffic Growth
 ############Analysis of Milepost 168.5 for FULL ADT : I35 ####################
# YEAR  PHV  TRUC  N  LAT MEDW TW: V/C V/CA %V/C LOS70  0%    50% 100% 150% 200#
#1985  2080  229   2   6   24  37  0.66 0.54  21 C:C   : *   .     I    .    : #
#1986  2102  231   2   6   24  37  0.67 0.55  21 C:C   : *   .     I    .    : #
#1987  2125  233   2   6   24  37  0.67 0.56  21 C:C   : *   .     I    .    : #
#1988  2148  236   2   6   24  37  0.68 0.56  21 C:C   : *   .     I    .    : #
#1989  2171  239   2   6   24  37  0.69 0.57  21 C:C   : *   .     I    .    : #
#


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```

APPENDIX C

COST IMPACT ON TRUCKS USING ETF

The Transportation Institute gathered data on average speeds and travel time for selected highway segments. This data includes the segment length, average speed, and travel time during morning peak, off peak, and evening peak hours. Tables C-1 presents the average speeds recorded for I-10.

Assuming that these speeds are representative of the entire length of the study corridor, and that truck speeds equal those of all other vehicles, the total trip length for a truck traveling on I-10 from Houston to Beaumont will be 1 hour 12 minutes (73 miles/61 mph).

It was necessary to determine how sensitive truck costs would be to various kinds of savings. In order to do this, a USDA truck cost report for 1984 was examined[1]. It was found that the average cost per mile for Truck Fleets and Owner-Operators was $1.154 per mile. The cost breakdown is presented in Table C-2. The truck fleet data is based on 1982 annual reports to the Interstate Commerce Commission from 15 long distance haulers of perishable agricultural products and solid refrigerated products, while the owner-operator data is based on a September 1979 survey of light independent truckers. The costs are updated monthly using price indexes from the Bureau of Labor Statistics and diesel fuel prices from the Interstate Commerce Commission.

A survey conducted by TTI confirmed this data. The survey consists of interviews of 19 owner-operators of trucks serving intercity routes connecting Houston. Operating costs per mile were found to average $1.14 for general carriers.

Given the known length of a highway, and the average cost per mile, it is possible to obtain the total cost of one trip by multiplying these two figures together. For I-10, which has a length of 73 miles, the cost per trip is $84.24.

Table C-1. Average Speed, I-10

	Segment Length	A.M. Peak Eastbound	A.M. Peak Westbound	Off Peak EB	Off Peak WB	P.M. Peak EB	P.M. Peak WB
IH 610 to East Belt	6.65	61	56	60	61	56	61
East Belt to Cedar Bayou	15.35	62	62	60	60	60	61
Cedar Bayou to Jeff Co. Line	34.22	63	62	62	62	61	65
Total Length	56.22 Miles						
Average MPH		62	60	61	59	59	61

A.M. Peak 6:30 to 8:30
Off Peak 9:30 to 3:30
P.M. Peak 4:30 to 6:30

Table C-2

Truck Costs Per Mile, USDA

TRUCK FLEET COSTS, 1984
(cents per mile)

COST ITEMS / FIXED COSTS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AVG
INTEREST	7.1	7.1	7	7	7.1	7.1	7.1	7.1	7.1	7.1	6.9	6.7	7.0
DEPRECIATION	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
MGMT & O/H	9.2	9.6	9.3	9.3	9.5	9.5	9.5	9.5	9.5	9.7	9.7	9.7	9.5
INSURANCE	4	4	4	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.2	4.3	4.1
LICENSES	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
VAR. COSTS													
VEHICLE DEPR	13	13.1	11	11	11	11	11	11	11	11	11	11	11.3
DRIVER COST	30.4	30.5	30.7	30.3	30.5	30.4	30.3	30.4	30.3	30.5	30.8	30.9	30.5
OP. COSTS													
FUEL	25.3	25.5	25.1	25.2	24.9	25	25	25.8	26	26.3	26.2	26.2	25.5
MAINTENANCE	13.5	13.6	13.5	13.6	13.5	13.6	13.6	13.6	13.7	13.6	13.6	13.7	13.6
TIRES	2.9	2.8	2.8	2.9	2.8	2.8	2.8	2.8	2.8	2.8	2.9	2.8	2.8
MISC.	7.3	7.4	7.4	7.4	7.4	7.4	7.4	7.5	7.5	7.6	7.6	7.6	7.5
TOTAL COST	116.1	117	114.2	114.2	114.2	114.3	114.2	115.2	115.4	116.1	116.3	116.3	115.3

TRUCK OWNER-OPERATOR COSTS, 1984

COST ITEMS / FIXED COSTS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AVG
INTEREST	8.8	8.6	8.6	8.6	8.7	8.7	8.7	8.7	8.7	8.7	8.3	7.8	8.6
DEPRECIATION	0	0	0	0	0	0	0	0	0	0	0	0	0.0
MGMT & O/H	3.5	3.7	3.6	3.6	3.5	3.5	3.5	3.6	3.6	3.6	3.6	3.6	3.6
INSURANCE	7.1	7.2	7.2	7.3	7.3	7.3	7.3	7.3	7.3	7.4	7.5	7.6	7.3
LICENSES	2.1	2.2	2.2	2.1	2.1	2.1	2.1	2.1	2.2	2.2	2.2	2.2	2.2
VAR. COSTS													
VEHICLE DEPR	14.4	14.4	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.9
DRIVER COST	33.9	34	33.8	33.6	33.9	33.9	33.6	33.6	33.4	33.5	33.3	33.8	33.7
OP. COSTS													
FUEL	25.3	25.5	25.1	25.2	24.9	25	25	25.8	26	26.3	26.2	26.2	25.5
MAINTENANCE	10.4	10.5	10.4	10.5	10.5	10.5	10.54	10.4	10.6	10.6	10.6	10.6	10.5
TIRES	4	3.9	3.9	4	3.9	3.9	3.9	3.9	3.9	3.9	4	3.9	3.9
MISC.	6.2	6.4	6.3	6.2	6.2	6.2	6.2	6.4	6.4	6.5	6.4	6.4	6.3
TOTAL COST	115.7	116.4	114.9	114.9	114.8	114.9	114.6	115.6	115.9	116.5	115.9	115.9	115.5

Table C-2

Truck Costs Per Mile, USDA

TRUCK FLEET COSTS, 1984
(cents per mile)

COST ITEMS													
FIXED COSTS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AVG
INTEREST	7.1	7.1	7	7	7.1	7.1	7.1	7.1	7.1	7.1	6.9	6.7	7.0
DEPRECIATION	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
MGMT & O/H	9.2	9.6	9.3	9.3	9.5	9.5	9.5	9.5	9.5	9.7	9.7	9.7	9.5
INSURANCE	4	4	4	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.2	4.3	4.1
LICENSES	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
VAR. COSTS													
VEHICLE DEPR	13	13.1	11	11	11	11	11	11	11	11	11	11	11.3
DRIVER COST	30.4	30.5	30.7	30.3	30.5	30.4	30.3	30.4	30.3	30.5	30.8	30.9	30.5
OP. COSTS													
FUEL	25.3	25.5	25.1	25.2	24.9	25	25	25.8	26	26.3	26.2	26.2	25.5
MAINTENANCE	13.5	13.6	13.5	13.6	13.5	13.6	13.6	13.6	13.7	13.6	13.6	13.7	13.6
TIRES	2.9	2.8	2.8	2.9	2.8	2.8	2.8	2.8	2.8	2.8	2.9	2.8	2.8
MISC.	7.3	7.4	7.4	7.4	7.4	7.4	7.4	7.5	7.5	7.6	7.6	7.6	7.5
TOTAL COST	116.1	117	114.2	114.2	114.2	114.3	114.2	115.2	115.4	116.1	116.3	116.3	115.3

TRUCK OWNER-OPERATOR COSTS, 1984

COST ITEMS													
FIXED COSTS	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	AVG
INTEREST	8.8	8.6	8.6	8.6	8.7	8.7	8.7	8.7	8.7	8.7	8.3	7.8	8.6
DEPRECIATION	0	0	0	0	0	0	0	0	0	0	0	0	0.0
MGMT & O/H	3.5	3.7	3.6	3.6	3.5	3.5	3.5	3.6	3.6	3.6	3.6	3.6	3.6
INSURANCE	7.1	7.2	7.2	7.3	7.3	7.3	7.3	7.3	7.3	7.4	7.5	7.6	7.3
LICENSES	2.1	2.2	2.2	2.1	2.1	2.1	2.1	2.1	2.2	2.2	2.2	2.2	2.2
VAR. COSTS													
VEHICLE DEPR	14.4	14.4	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.9
DRIVER COST	33.9	34	33.8	33.6	33.9	33.9	33.6	33.6	33.4	33.5	33.3	33.8	33.7
OP. COSTS													
FUEL	25.3	25.5	25.1	25.2	24.9	25	25	25.8	26	26.3	26.2	26.2	25.5
MAINTENANCE	10.4	10.5	10.4	10.5	10.5	10.5	10.54	10.4	10.6	10.6	10.6	10.6	10.5
TIRES	4	3.9	3.9	4	3.9	3.9	3.9	3.9	3.9	3.9	4	3.9	3.9
MISC.	6.2	6.4	6.3	6.2	6.2	6.2	6.2	6.4	6.4	6.5	6.4	6.4	6.3
TOTAL COST	115.7	116.4	114.9	114.9	114.8	114.9	114.6	115.6	115.9	116.5	115.9	115.9	115.5

Because the proposed path of the exclusive truck facility lies in effect on the outside edge of the corridor, it will in all cases be longer than the existing highways. Therefore, in order to be economically advantageous for truckers to divert, this increased trip length must be offset by a corresponding increase in travel time savings. Table C-3 presents projected highway lengths based on a percentage of circuitry over I-10.

In Table C-4 some projected highway lengths of the new facility have been multiplied by the USDA cost per mile of $1.154 to determine the cost per trip on the new truck facility.

DIVERSION POINTS:

Chui and McFarland[3] of the Texas Transportation Institute determined an updated (1985) value of time for trucks to be $19.00 per vehicle hour. This time value accrues from three cost components:

1) vehicle operating costs;
2) accident costs (which entail accident rates and value of life); and
3) traveling speed.

These time values are then used to find the crossover point where the increased length of the exclusive facility is offset by increased operating speed and time value savings. The methodology for finding these points involves several steps:

1) Calculate the new facility length based on percentage circuitry increase over the competing facilities from which it will be diverting traffic. This is shown in Table C-3.
2) Calculate the trip cost for the various new facility lengths by multiplying facility length by cost per mile (see Table C-4).
3) Determine trip time for a range of operating speeds and facility lengths. This is given in Table C-5.
4) Calculate time value savings.

Table C-3. Projected New Facility Lengths

Percent Increase In Length	I-10	US-90
0%	73	75
1%	73.73	75.75
2%	74.46	76.50
3%	75.19	77.25
4%	75.92	78.00
5%	76.65	78.75
6%	77.38	79.50
7%	78.11	80.25
8%	78.84	81.00
9%	79.57	81.75
10%	80.30	82.50

Table C-4. Cost Per Trip for a Range of Facility Lengths

Length in Miles	Cost Per Trip
73	$84.24
74	$85.40
75	$86.55
76	$87.70
77	$88.86
78	$90.01
79	$91.17
80	$92.32
81	$93.47
82	$94.63
83	$95.78

Table C-5. Time Value Savings From I-10 Diversion

	Facility Length (Miles)									
Operating Speed	73.7	74.5	75.2	75.9	76.7	77.4	78.1	78.8	79.6	80.3
62	$0.14	-0.08	-0.30	-0.53	-0.75	-0.98	-1.20	-1.42	-1.65	-1.87
63	$0.50	0.28	0.06	-0.16	-0.38	-0.60	-0.82	-1.04	-1.26	-1.48
64	$0.85	0.63	0.42	0.20	-0.02	-0.23	-0.45	-0.67	-0.88	-1.10
65	$1.19	0.97	0.76	0.55	0.33	0.12	-0.09	-0.31	-0.52	-0.73
66	$1.51	1.30	1.09	0.88	0.67	0.46	0.25	0.04	-0.17	-0.38
67	$1.83	1.62	1.42	1.21	1.00	0.79	0.59	0.38	0.17	-0.03
68	$1.83	1.62	1.42	1.21	1.00	0.79	0.59	0.38	0.17	-0.03
69	$2.14	1.93	1.73	1.52	1.32	1.12	0.91	0.71	0.50	0.30
70	$2.44	2.23	2.03	1.83	1.63	1.43	1.23	1.03	0.83	0.63

5) Calculate the crossover points where the time value savings from increased operating speeds outweighs the cost of the increased new facility length (see Table C-6.)

In Table C-5 steps 3 and 4 have been combined to show the time value savings that occur for a range of various operating speeds over a range of facility lengths.

For example, an exclusive truckway with 6% circuitry over I-10 (length = 77.38 miles) that allows a truck speed of 70 mph has a positive value to truckers of $1.43 per trip due to time value savings over increased trip length.

In Table C-6 the crossover points have been calculated where time value savings outweighs the cost of the increased mileage of the new facility over the length of I-10. These points occur where the operating cost of using the new facility less time value savings is lower than the operating cost of using I-10.

Table C-6. Cost Per Trip Using Operating Costs Less Time Value Savings (I-10)

	Facility Length (Miles)									
Speed	73.7	74.5	75.2	75.9	76.7	77.4	78.1	78.8	79.6	80.3
62	84.94	86.01	87.07	88.14	89.21	90.27	91.34	92.40	93.47	94.54
63	84.58	85.65	86.71	87.77	88.83	89.90	90.96	92.02	93.08	94.15
64	84.24	85.29	86.35	87.41	88.47	89.53	90.59	91.65	92.71	93.77
65	83.90	84.95	86.01	87.07	88.12	89.18	90.23	91.29	92.34	93.40
66	83.57	84.62	85.68	86.73	87.78	88.83	89.89	90.94	91.99	93.05
67	83.26	84.30	85.35	86.40	87.45	88.50	89.55	90.60	91.65	92.70
68	82.95	83.99	85.04	86.09	87.13	88.18	89.23	90.27	91.32	92.37
69	82.65	83.69	84.74	85.78	86.82	87.87	88.91	89.95	91.00	92.04
70	82.36	83.40	84.44	85.48	86.52	87.56	88.60	89.64	90.68	91.72

*Operating Cost on I-10 is $84.24

REFERENCES

C-1. U. S. Department of Agriculture, Office of Transportation, Fruit and Vegetable Truck Rate and Cost Summary, 1984, p. 33-34.

C-2. Texas Transportation Institute, Houston-Galveston Regional Transportation Study, July 1985, p. 3-4.

C-3. Chui, Margaret K. and McFarland, William F., "The Value of Travel Time: New Estimates Developed Using a Speed-Choice Model," Research Report No. 396-2F, Texas Transportation Institute, The Texas A&M University System, Texas, May 1986.

APPENDIX D

PAVEMENT CONDITION AND EVALUATION IN THE I-10 STUDY CORRIDOR

1.0 INTRODUCTION

Increased concern in dealing with intercity truck traffic has brought about the consideration of segregating trucks from other vehicular traffic, either as separate lanes, or as exclusive facilities. Separating trucks from passenger vehicles should improve traffic safety and reduce conflicts for all vehicles, provide an opportunity to design and construct adequate pavement and bridge structures that will solely accommodate a concentration of heavy vehicles, and substantially reduce maintenance costs on the truck facility and the facility from which trucks will be excluded. Furthermore, many of the more heavily travelled highways are due for extensive rehabilitation. The rehabilitation procedure costs may be scaled down and the subsequent savings can be directed towards the construction of truck facilities.

This report presents information regarding the Serviceability Index, Evaluation Score, and Condition Profiles of pavements within the Houston-Beaumont study corridor (I-10). The corridor is approximately seventy-five (75) miles in length. Traffic volumes on I-10 are fairly uniform, with average daily traffic volumes in the range of 23-27,000 vehicles per day (vdp).

1.2 PRESENT SERVICEABILITY INDEX

In North America, riding comfort and vehicle cost data have been related to the Serviceability Index of pavement condition, a concept with origins in the AASHO Road Test. The Serviceability Index is a pavement roughness measure defined in terms of slope variance of the surface profile, mean rut depth, and areas of cracking and patching by statistical correlation. In more common practice, however, this index is subjectively determined by a panel rating of pavement ride quality and maintenance needs. Serviceability Index values

range between 0 and 5, respectively indicating unusable and smooth pavements. A value less than 3.2 is considered critical, and improvements to the pavement are warranted.

In Texas, Serviceability Indices are obtained from roughness measures collected by the Mays Ride Meter. The Mays Ride Meter is a car-mounted device that measures the relative movement between the rear axle and the mass of the car at a speed of 50 miles per hour. Direct instrument readings are transformed into proper serviceability scale through appropriate relationships.

Roughness defined by a slope variance statistic was included as one component of Serviceability Index (SI) function estimated from panel ratings of pavement serviceability at the AASHO Road Test. Some attempts have since been made to relate roughness to serviceability by calibration of the vehicles to slope variance and application of the original SI function. Yet, agencies have more commonly related roughness directly to local panel ratings of serviceability. Ratings, however, tend to vary considerably with the expectation of the users and their previous exposure to very high roughness levels. SI is not defined for unpaved roads.

1.3 PAVEMENT EVALUATION SCORE

The Pavement Evaluation Score can be defined as a composite index that describes the condition of a pavement according to roughness, structural capacity, safety, and visual distress. Pavement evaluation is useful for activities such as maintenance and rehabilitation decisions, budget requirement projections, and pavement performance monitoring. The four major components of the Pavement Evaluation Score are briefly described as follows:

1) Roughness, expressed in terms of a serviceability index as discussed above.
2) Structural capacity, an index that measures the strength of the pavement to carry traffic. The structural capacity evaluation is obtained through the use of the Dynaflect. It is the most commonly used non-destructive test device in the United States. This

instrument is mounted on a two-wheel trailer and produces a dynamic force of 1000 lbs. at a frequency of 8 cycles per second. The resulting deflections are measured by five sensors, each 1 foot apart, with the first one directly between the wheels.

3) Safety, as related to skid resistance, specified by a "skid number". Skid data are collected from tests on wet pavements, since most skid related accidents occur under wet or icy conditions.

4) Distress condition, obtained by visual survey of the pavement surface which rates extension and severity of rutting, raveling, flushing, alligator cracking, longitudinal cracking, transversal cracking, and other pavement failures.

Pavement evaluators determine scores for each distress type by deducting points from a total of 100. The greater the extension or the severity, the more points are deducted. The individual scores are transformed into utility values and combined in a multiplicative model to obtain a global visual distress utility value. This result is further combined with roughness, structural capacity, and safety indices to produce the overall Pavement Evaluation Score, the value of which ranges from zero to one hundred, representing a worst and an excellent pavement condition, respectively. A score of less than 45 is considered critical, and pavement rehabilitation is warranted.

1.4 PAVEMENT CONDITION PROFILES

The information in this section of the report is based on data collected and reported by SDHPT in its pavement evaluation and condition surveys. In the I-10 sections between Houston and Beaumont, the condition of the pavement in the right-hand travel lane is one of the factors to be included in the overall appraisal of the feasibility of an exclusive truck facility.

The data base for the procedure reported here is the SDHPT's Pavement Evaluation System (PES), which contains design and rehabilitation records of pavements on the Texas highway system. The data processing to produce the representative condition profiles for I-10 sections between Houston and Beaumont was done in three stages: selection, sorting, and reporting.

A SAS data file containing the selected records and data items was created from the PES data base tape. This file was further sorted in ascending order of milepost number by highway identification code and traffic lane. Only the rightmost lanes of the thoroughfare in either direction were considered since they accomodate the highest percent of traffic, and therefore receive the most damage. The reporting stage included a list of the sorted file and a set of graphs showing pavement condition profiles, as measured by serviceability index (SI) and PES score, along the Houston-Beaumont corridor.

The graphic profiles of the relevant segments of IH-10 are presented in Figures D-1 to D-4. Both the PES and the serviceability index are plotted for each two-mile section of roadway.

PAVEMENT CONDITION

IH-10

EASTBOUND

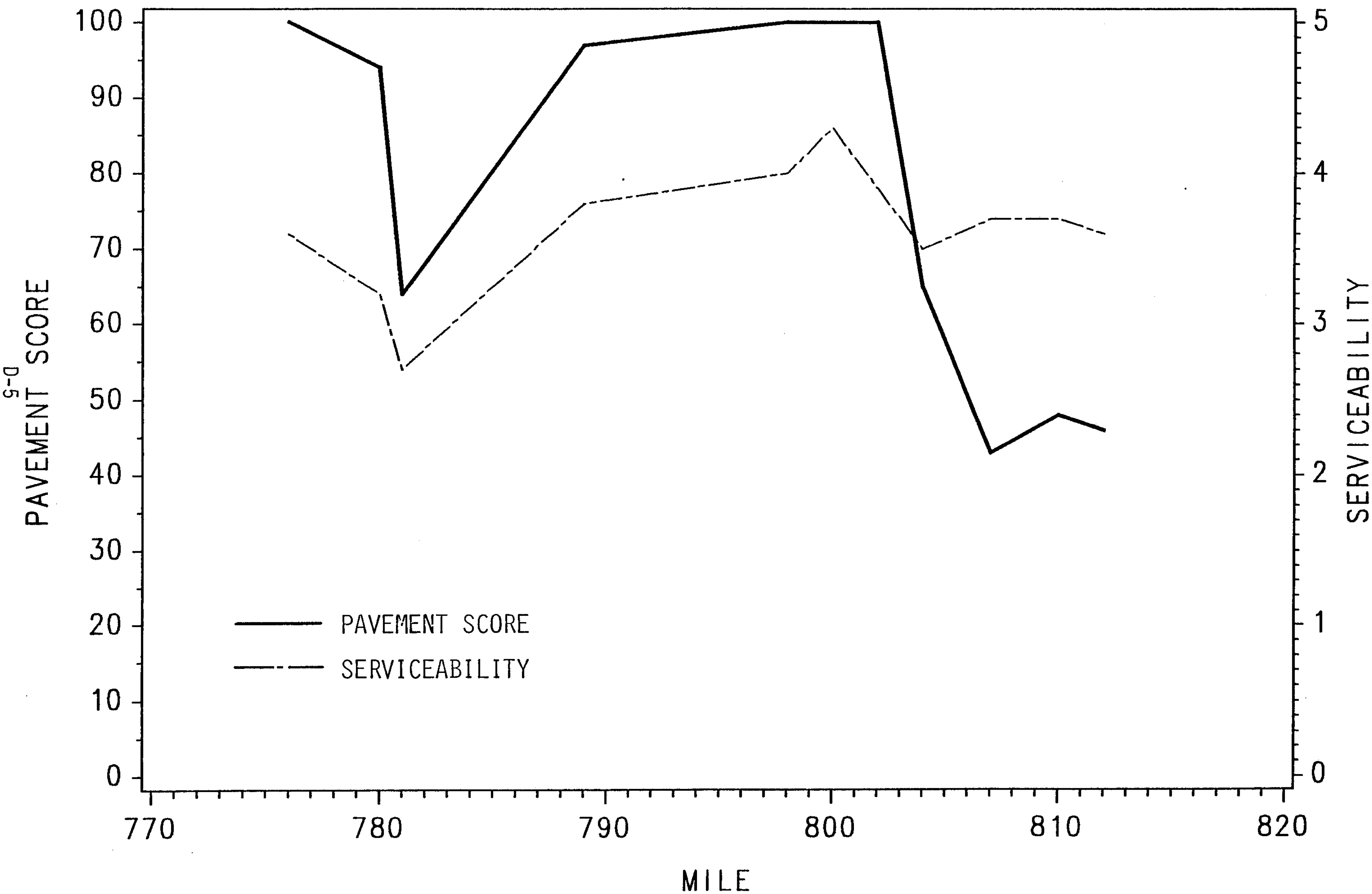
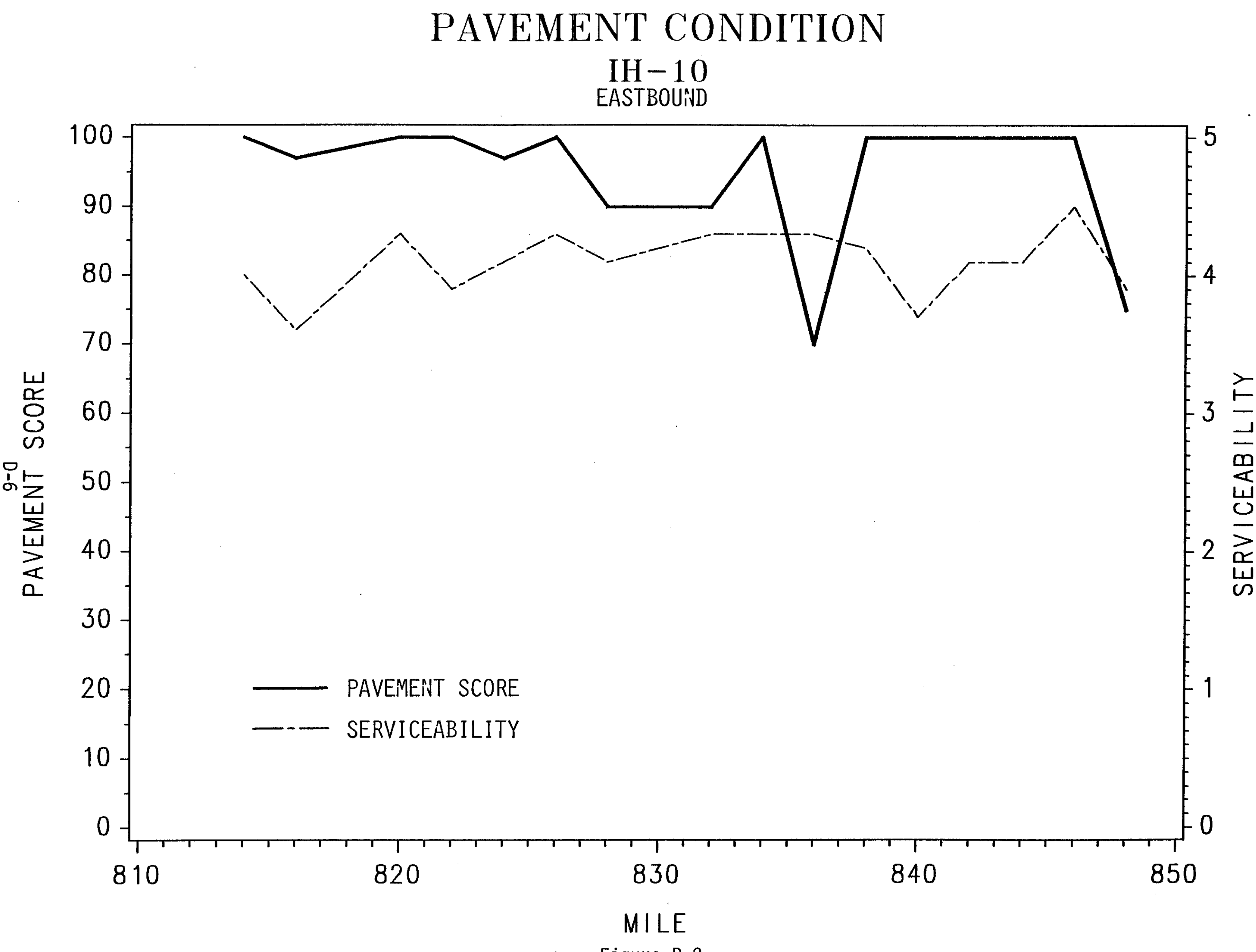


Figure D-1


PAVEMENT CONDITION
IH-10
EASTBOUND
PAVEMENT SCORE
SERVICEABILITY
100
90
80
70
60
50
40
30
20
10
0
5
4
3
2
1
0
810
820
830
840
850
MILE
PAVEMENT SCORE
SERVICEABILITY
Figure D-2

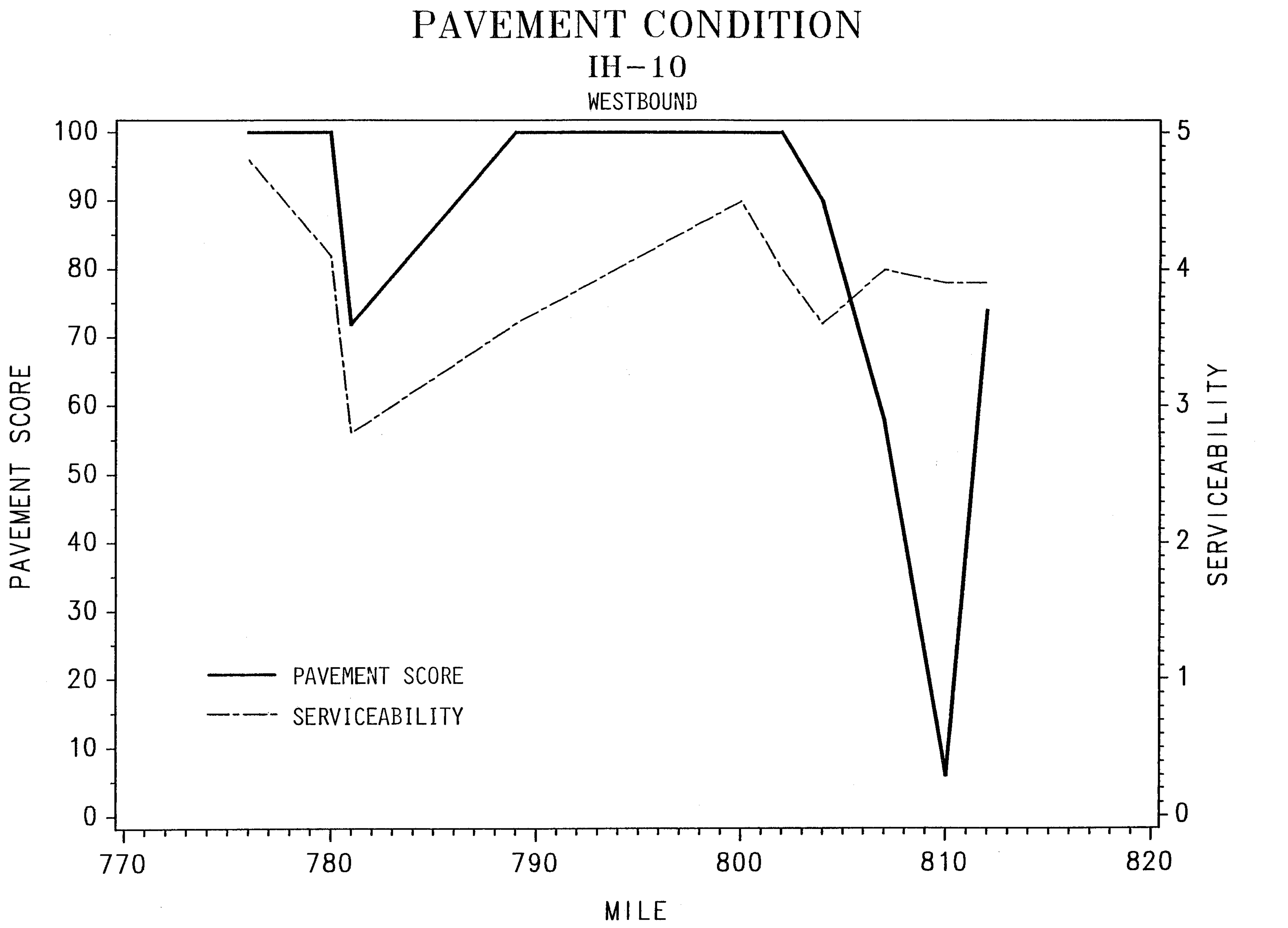

PAVEMENT CONDITION
IH-10
WESTBOUND
PAVEMENT SCORE
SERVICEABILITY
MILE
PAVEMENT SCORE
SERVICEABILITY
100
90
80
70
60
50
40
30
20
10
0
5
4
3
2
1
0
770
780
790
800
810
820

Figure D-3

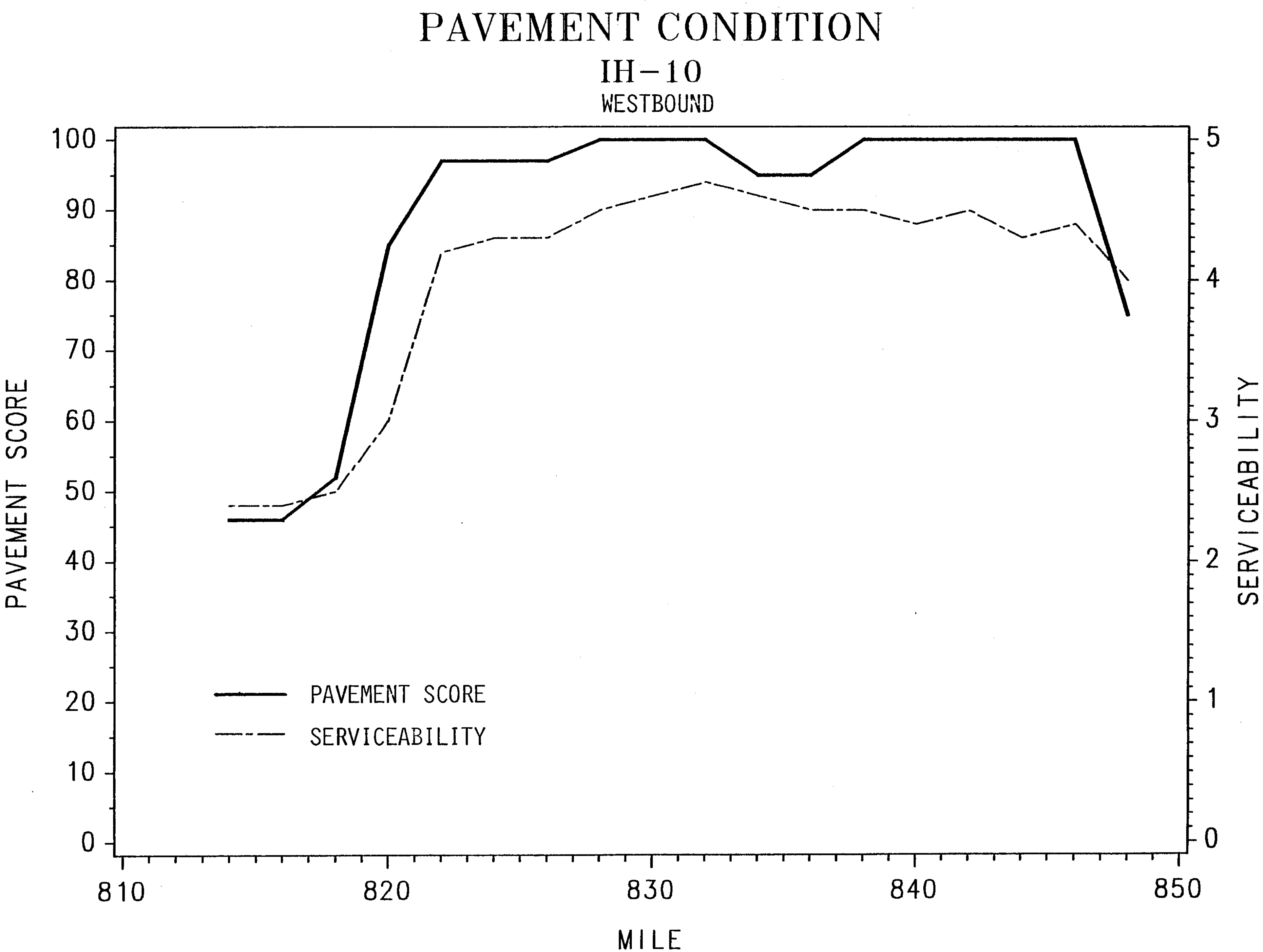

PAVEMENT CONDITION
IH-10
WESTBOUND
PAVEMENT SCORE
SERVICEABILITY
MILE
PAVEMENT SCORE
SERVICEABILITY
0
10
20
30
40
50
60
70
80
90
100
0
1
2
3
4
5
810
820
830
840
850

Figure D-4