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16. Abstract

Using a full-cost perspective, this report evaluated the different transportation improvement alternatives available for the IH-10 Katy Freeway corridor in Houston, Texas. Through MODECOST — a computer model based on the full-cost analysis concept — we found that the current facility cannot meet future traffic demands. As a result, travelers on this facility will continue to bear substantial external costs, including congestion and air pollution costs. The results clearly show that, in order to satisfy the predicted travel demand on the section running from downtown Houston to Katy, the current facility and/or the current traveler's behavior characteristics (i.e., mode splits) will need to improve. As our investigation revealed, the savings that will accrue from the reduction of external costs and users/agency costs exceed the cost of initial investment.

The case study conducted in this report shows that, in many cases, external costs and user/agency costs are more relevant than the initial investment in the facility. Expanding the current facility to add HOV lanes to accommodate ride-sharing and special transit service reduces the external costs and user/agency costs, which, in turn, reduces the full cost of the facility.

The study also shows that full-cost analysis is a very effective tool for valuing transportation investment alternative comparisons. It is capable of enhancing qualitative assessments and planning/engineering judgment. The actual value calculated by the full-cost analysis sometimes can be used as an assessment indicator to policy-makers and transportation professionals.

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FULL-COST ANALYSIS OF THE KATY FREEWAY CORRIDOR

by

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Research Report Number 1356-3

Research Project 0-1356

Development of an Urban Transportation Investment Model

conducted for the

TEXAS DEPARTMENT OF TRANSPORTATION

in cooperation with the

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

by the

CENTER FOR TRANSPORTATION RESEARCH
Bureau of Engineering Research
THE UNIVERSITY OF TEXAS AT AUSTIN

March 1996

IMPLEMENTATION RECOMMENDATION

This report, one of the six case studies assessing the full cost of urban passenger transportation alternatives, evaluates the different transportation improvement alternatives available for the IH-10 Katy Freeway corridor in Houston, Texas. Given its effectiveness for valuing transportation investment alternative comparisons, full-cost analysis represents a critical element in developing a multimodal transportation investment plan. In terms of implementation, the findings in this report prove that full-cost analysis is capable of enhancing qualitative assessments and planning/engineering judgment.

Prepared in cooperation with the Texas Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration.

DISCLAIMERS

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration or the Texas Department of Transportation. This report does not constitute a standard, specification, or regulation.

NOT INTENDED FOR CONSTRUCTION,
BIDDING, OR PERMIT PURPOSES

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SUMMARY

Using a full-cost approach, this report evaluated the different transportation improvement alternatives (developed by Parsons Brinckerhoff Quade & Douglas, Inc.) available for the IH-10 Katy Freeway corridor. Through MODECOST — a computer model based on the full-cost analysis concept — we found that the current facility cannot meet future traffic demands. As a result, travelers on this facility will continue to bear substantial external costs, including congestion and air pollution costs. The results clearly show that, in order to satisfy the predicted travel demand on the section running from downtown Houston to Katy, the current facility and/or the current traveler's behavior characteristics (i.e., mode splits) will need to improve. As our investigation revealed, the savings that will accrue from the reduction of external costs and users/agency costs exceed the cost of initial investment.

Indeed, the case study described in this report shows that, in many cases, external costs and user/agency costs are more relevant than the initial investment in the facility. Expanding the current facility to add HOV lanes to accommodate ride-sharing and special transit service reduces the external costs and user/agency costs, which in turn reduces the full cost of the facility.

The study also shows that full-cost analysis is a very effective tool for valuing transportation investment alternative comparisons. (The full-cost analysis concept and the MODECOST model are described in previous reports 1356-1 and 1356-2.) It is capable of enhancing qualitative assessments and planning/engineering judgment. The actual value calculated by the full-cost analysis sometimes can be used as an assessment indicator to policy-makers and transportation professionals.

CHAPTER 1. INTRODUCTION

The main objective of this report is to assist Texas policy-makers in evaluating the various investment alternatives available for improving mobility within the IH-10 Katy Freeway corridor in Houston, Texas. Using full-cost analysis, we have calculated costs for five specific transportation alternatives for the Katy Freeway corridor. This chapter reviews the background of full-cost analysis and outlines key elements of the report.

1.1. THE CONCEPT OF FULL-COST ANALYSIS

Over the past several decades, a vast transportation network has been developed to address mobility and accessibility needs in Texas. This state transportation network is dominated by more than 466,900 km of public roads (Ref 1), with more than 70 percent of local travel occurring within Texas cities having populations of 200,000 or more (Ref 2). Most of these trips are made by personal vehicles. And as is well known, such dependence on personal vehicles in Texas has created new problems for transportation professionals, environmentalists, and the public. These problems include congestion in many major metropolitan areas, air pollution and global weather change, noise, accidents, and energy depletion. The Federal Highway Administration (FHWA) reported that 25 percent of Texas' urban interstate highways exceeds 95 percent of their capacity, and that 43 percent are operating at over 80 percent of their carrying capacity. Moreover, Houston, one of the largest cities in the nation, is classified as a non-attainment area.

Until the 1990s, transportation policy focused primarily on the development of the interstate system, with cost evaluations of urban transportation alternatives typically considering only initial capital investments. However, the passage of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 and the Clean Air Act Amendments (CAAA) of 1990 provided an opportunity to take a more comprehensive approach to evaluating transportation options. ISTEA and CAAA shifted traditional planning and decision-making to a broader, multimodal transportation perspective, a process that examines highway, transit, and rail issues in combination. This process looks at the problem from the perspective of an integrated system, emphasizing efficient and productive people and goods transfer from one location to another. Costs, including indirect social and environmental costs, must be fully accounted for in a comparison of modes and management strategies to identify the most cost-effective options.

Transportation full-cost analysis is the first step in developing a multimodal transportation investment plan. Full-cost analysis takes into account not only infrastructure costs, but also user and external costs, thus enhancing transportation planning decisions significantly. Focus on any single cost may result in an inefficient system and can lead to reduced long-term economic investment. The full-cost approach provides a stronger platform from which to evaluate transportation investment decisions without modal bias. It identifies least-cost alternatives and promotes efficient use of the system.

1.2. A BRIEF REVIEW OF MODECOST MODEL

Previous reports (Refs 3, 4) have identified current practices relating to full-cost transportation planning. And in a previous effort, the Center for Transportation Research (CTR) of The University of Texas at Austin developed MODECOST, a computer model capable of comparing multimodal transportation alternatives by accounting for the full cost for each mode. MODECOST incorporates many aspects of modal costs that have not traditionally been accounted for, such as air pollution cost, accident cost, and personal vehicle user cost. These costs are not usually included in decision matrices for transportation investment. By taking costs such as these into account, MODECOST can estimate the direct and indirect costs from the perspective of how much society or the taxpayer is paying for that mode of transportation.

In summary, MODECOST allows the transportation planner to compare the full cost of three major urban transportation modes — auto, bus, and rail — along a particular corridor. It is based on the full-cost and life-cycle-cost concepts discussed in previous reports (Refs 3, 4). MODECOST is an easy-to-operate, interactive, and menu-driven software program for comparing transportation alternatives. The software can be run on any IBM-PC or compatible computer using Microsoft Windows (Ref 5).

1.3. SCOPE OF THE REPORT

This report summarizes and compares the five transportation alternatives for the IH-10 Katy Freeway corridor developed in the Major Investment Study (MIS) prepared by Parsons Brinckerhoff Quade & Douglas, Inc. (Parsons Brinckerhoff). Comparing costs among alternatives can determine under what circumstances one alternative is more efficient than another in terms of the resources it uses to provide a given service. Accordingly, cost comparisons — particularly full-cost comparisons — can aid policy-makers in planning for new transportation infrastructure.

Chapter 2 is concerned with the background and development of the five alternatives for the IH-10 Katy Freeway. Chapter 3 describes the data inputs and assumptions made in the analysis. Chapters 4 and 5 build on the calculations of MODECOST to present the full cost of urban passenger transportation for different investment alternatives. Chapter 4 presents the results for the base case, "No Build," which serves as the comparison basis. Chapter 5 describes the results obtained through other investment alternatives, some of which may result in overall full-cost savings. Chapter 6 presents the development and full-cost results of the alternative recommended by the CTR team. The last chapter summarizes the findings of this report.

CHAPTER 2. BACKGROUND

2.1. A BRIEF INTRODUCTION TO HOUSTON

Houston is located on the upper Gulf Coast prairies of Texas. The Houston metropolitan area includes development in three counties: Harris, Fort Bend, and Montgomery. Houston, founded in the first half of the 1800s, was named after Sam Houston, an early leader of the Republic. In 1836, the city was little more than a muddy crossroads on the banks of the Buffalo Bayou, its population hovering around 3,000. Over the next 160 years, Houston grew to become the fourth largest city in the nation, trailing New York, Los Angeles, and Chicago; it is presently the largest city in Texas, its population totaling some 1.6 million. While the city layout is expansive, mobility within the city is quite effortless, due in large part to an ever-expanding freeway/thoroughfare system and transit service.

The freeway system provides numerous well-maintained east-west and north-south corridors. Motor travel in and out of Houston is expedited by IH-610 around the city, IH-10 (east to west), IH-45 (north to south), Hwy 59 (southwest to northeast), Hwy 290 (northwest to southeast), Hardy Tollroad (downtown north to the Woodlands), Sam Houston Tollroad (Hwy 59 on the southwest side of the city to IH-45 on the north), and Beltway 8, which encompasses the Sam Houston Tollroad. Several other large arteries assist traffic flow within the city.

The Houston area encompasses the largest transitway system in the country. Currently, the city has 102 km of high occupancy vehicle (HOV) lanes in operation, with an additional 65 km under construction or design. The Metropolitan Transit System (METRO) operates 22 park-and-ride routes that carry more than 288,000 passengers daily. It also offers express service to the downtown area and other business centers, as well as one-day matching service for carpool participants. Six freeways, including Katy (IH-10), are undergoing transitway (HOV) development (Ref 6).

2.2. THE CHOICE OF CASE STUDY SITE

In early 1992, the Houston District of the Texas Department of Transportation (TxDOT) undertook (with Parsons Brinckerhoff) a comprehensive transportation study. The primary objective of that study was to provide TxDOT with a framework for evaluating the future transportation needs of the IH-10 Katy Freeway, particularly that portion running from the Houston Central Business District to the Brazos River.

Because sections of the current Katy Freeway corridor were constructed several decades ago, planners fear that the corridor will be unable to accommodate future traffic growth. In addition, the escalating frequency of accidents has led to safety and mobility problems.

The study (dubbed a Major Investment Study, or MIS) is designed to comply with federal guidelines under the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 (Ref 7). Specifically, the preliminary study by Parsons Brinckerhoff accomplished the following tasks:

1. Develop an initial set of transportation improvement alternatives for the corridor from the perspective of a multimodal transportation concept (highway, bus, rail, etc.).
2. Based on input from the public and from the participating transportation agencies, perform an initial evaluation and screening of the alternatives.

Based on the above guidelines, Parsons Brinckerhoff identified six broad investment strategies for the Katy Freeway corridor. These included:

1. No investment*
2. Minimum investment, (i.e., TSM/TDM)
3. Moderate investment in both transit and SOV lanes
4. High investment in SOV lanes
5. High investment in transit
6. High investment in transit and SOV lanes

Based on these criteria, eleven alternatives were developed, including

1. A base case comparable to "No investment" above
2. A minimum investment alternative (i.e., TSM/TDM alternative)
3. Nine major investment build alternatives (ranging from moderate to high)

The above options offer a varying degree of capacity enhancements meant to achieve study goals and objectives. In order to accommodate varying travel and physical characteristics along the full length of the corridor, the 64.4-km stretch of IH-10 was divided into six segments by Parsons Brinckerhoff. Those segments included:

Segment 1:	Downtown Houston to IH-610
Segment 2:	IH-610 to Beltway 8
Segment 3:	Beltway 8 to SH-6
Segment 4:	SH-6 to Katy
Segment 5:	Katy to Brookshire
Segment 6:	Brookshire to the Brazos River

The initial screening of each alternative was based on comparing only the alternatives within a particular investment strategy. In comparing the alternatives within each investment strategy, it became clear that the alternatives under the same category had many similar characteristics. Differences among the alternatives occurred only across the investment strategies.

After comparing each investment category, Parsons Brinckerhoff eliminated six alternatives that did not perform well (based on the initial screening criteria). The remaining five alternatives,

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*Alternative I in the MIS actually does call for constructing some improvements.

including the base case, are shown in Figures 2.1 through 2.5. The details of these alternatives are summarized below (Ref 7):

Alternative 1: Base Case (Alternative I in the MIS)

This alternative assumes that the current roadway configuration plus enhancements can meet future traffic demands. The programmed enhancements include: (1) adding a reversible HOV connection from IH-10 east of Studemont to the downtown area near Franklin, (2) providing an HOV direct connection involving the Northwest Transit Center/Inner Katy connector, and (3) improving localized interchange/intersection along IH-10. These enhancements for Alternative I in the MIS are not evaluated in our full-cost analysis. For our purposes, Alternative 1 represents a "no-build" option.

Alternative 2: Moderate HOV/Moderate SOV (Alternative III-1 in the MIS)

This alternative includes a modest investment in HOV lanes and a modest investment in SOV lanes. These investments include: (1) adding a two-lane, two-way HOV facility from downtown Houston to IH-610 that will connect with the HOV direct connector that provides service to the downtown area near Franklin; (2) adding one SOV lane in each direction from IH-610 to Katy, providing a total of eight SOV lanes; (3) upgrading the existing reversible HOV to a two-lane, two-way HOV facility from IH-610 to Katy; (4) adding one SOV lane in each direction from Brookshire to the Brazos River, providing a total of three SOV lanes in each direction; and (5) upgrading the frontage road to three lanes in each direction from downtown Houston to Brookshire.

Alternative 3: Moderate HOV/High SOV (Alternative IV-2 in the MIS)

This alternative includes a modest investment in HOV lanes and a high investment in SOV lanes. These investments include: (1) providing a two-lane, two-way HOV facility from downtown Houston to Katy; (2) adding two SOV lanes in each direction from IH-610 to Katy, bringing the total SOV lanes to ten; (3) adding one SOV lane in each direction from Brookshire to the Brazos River, giving a total of three SOV lanes in each direction; and (4) upgrading the frontage road to three lanes in each direction from downtown Houston to Brookshire.

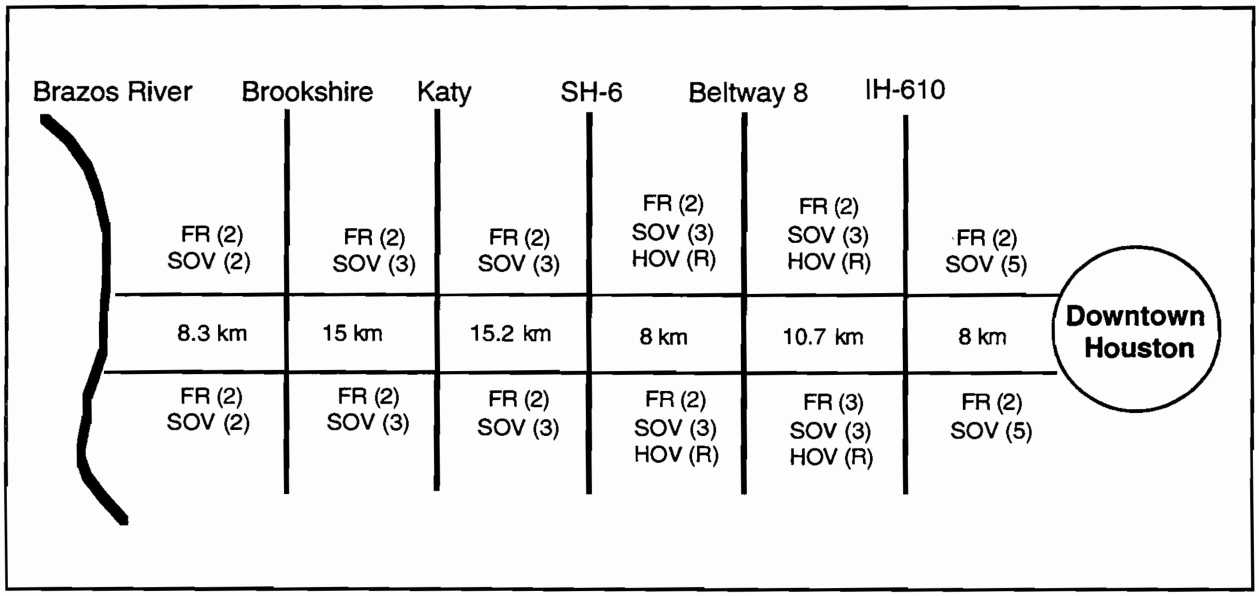
Alternative 4: High HOV/Moderate SOV (Alternative V-2 in the MIS)

This alternative includes a high investment in HOV lanes and a moderate investment in SOV lanes. These investments include: (1) adding a two-lane, two-way HOV facility from downtown Houston to Katy and from SH-6 to Katy; (2) upgrading the existing reversible HOV to a four-lane, two-way HOV facility from IH-610 to SH-6; (3) adding one SOV lane in each direction from IH-610 to Katy, bringing the total SOV lanes to ten; (4) adding one SOV lane in each direction from Brookshire to the Brazos River, giving a total of three SOV lanes in each direction; and (5) upgrading the frontage road to three lanes in each direction from downtown Houston to Brookshire.

Alternative 5: High HOV/High SOV (Alternative VI-1 in the MIS)

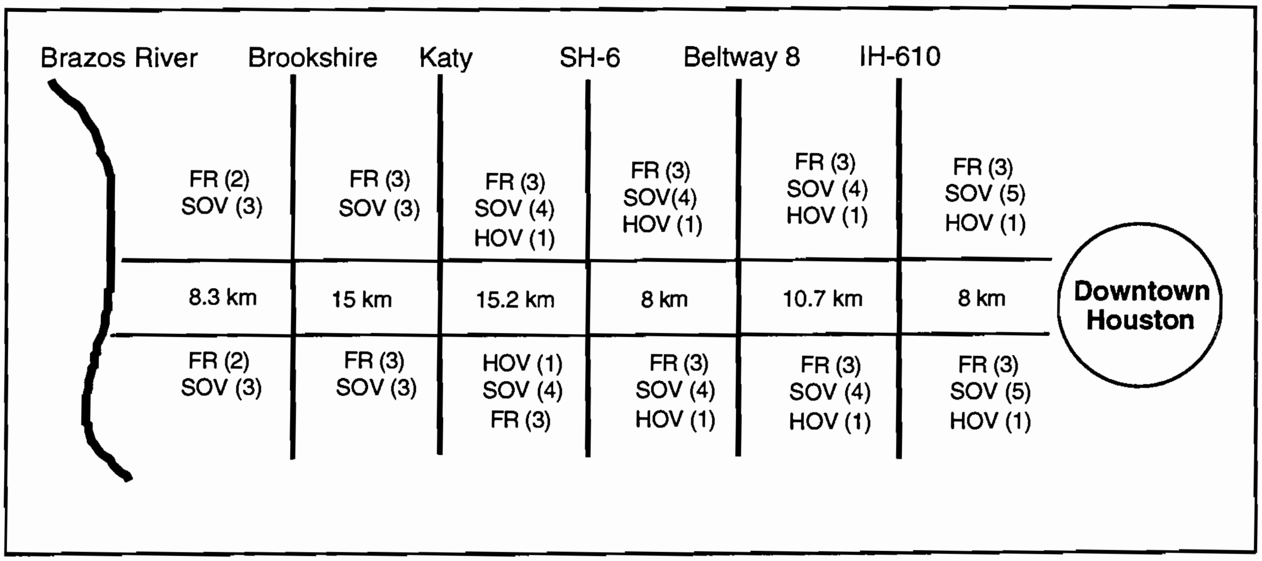
This alternative includes a high investment in HOV lanes and a high investment in SOV lanes. These investments include: (1) adding a two-lane, two-way HOV facility from downtown Houston to Katy and from SH-6 to Katy; (2) upgrading the existing reversible HOV to a four-lane, two-way HOV facility from IH-610 to SH-6; (3) adding two SOV lanes in each direction from IH-610 to Katy, bringing the total SOV lanes to ten; (4) adding one SOV lane in each direction from Brookshire to the Brazos River, giving a total of three SOV lanes in each direction; and (5) upgrading the frontage road to three lanes in each direction from downtown Houston to Brookshire.

The next step in the study process, and the focus of this report, is to "screen" these five alternatives using a full-cost perspective to determine the alternative that performs best.



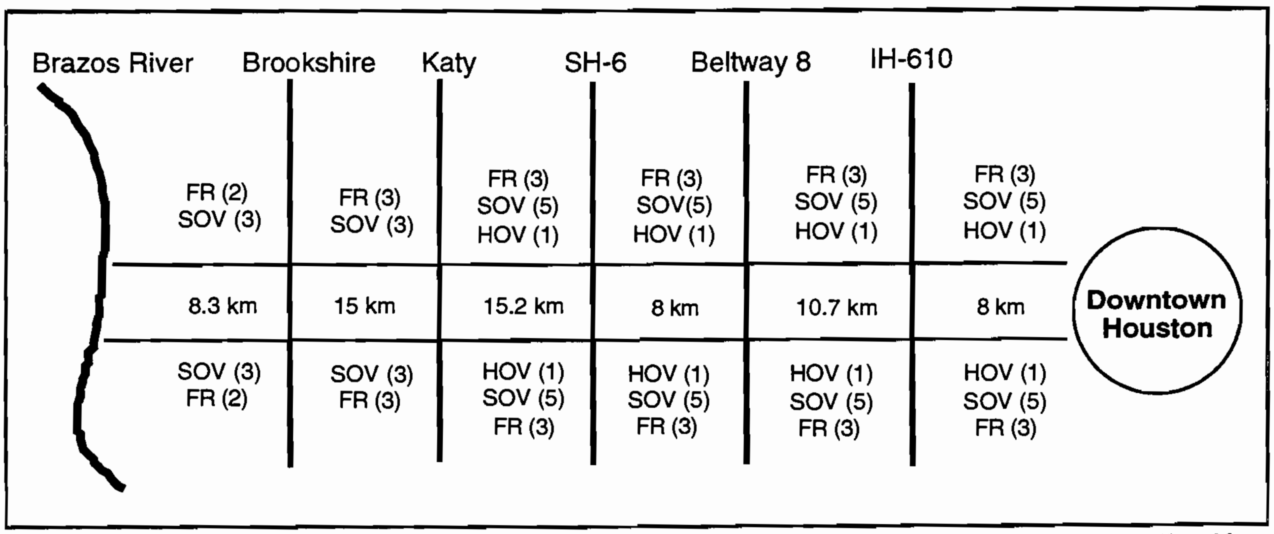
Alternative I in the MIS. The number of lanes of frontage road between downtown Houston and IH-610 is not available in the original graph. Two-lane frontage road is assumed in this study. Number of lanes in each direction is shown in parentheses. (R) indicates a shared reversible HOV lane. Source: Ref 7.

Figure 2.1 Alternative 1: Base Case



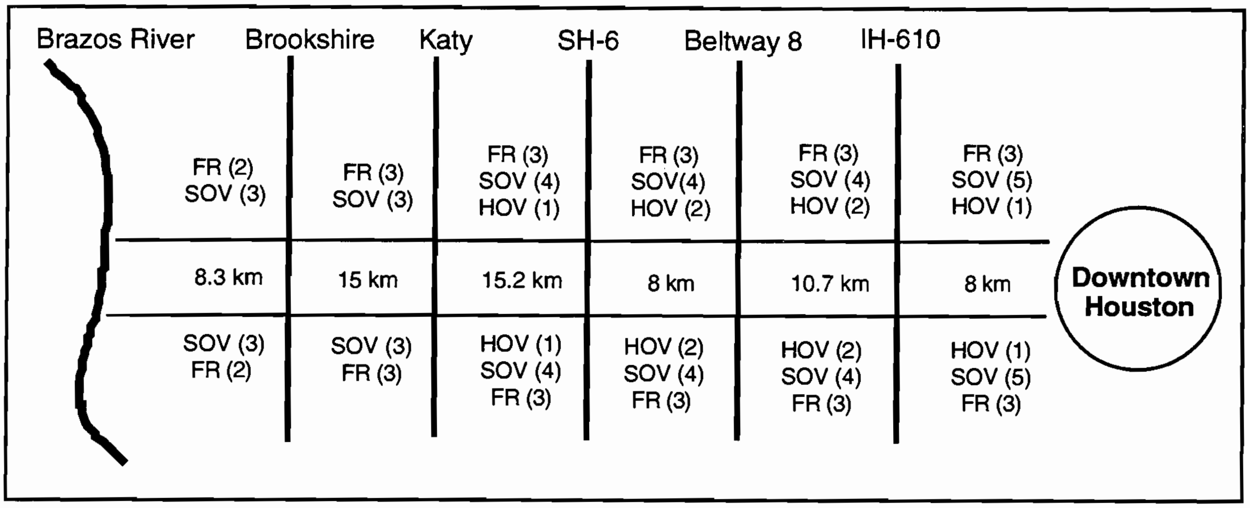
Alternative III-1 in the MIS. This alternative (1) incorporates all elements of the TSM/TDM alternatives; (2) adds one SOV lane in each direction from IH-610 to Katy and from Brookshire to the Brazos River; and (3) provides a two-lane, two-way HOV facility from downtown to Katy. Number of lanes in each direction is shown in parentheses. Source: Ref 7.

Figure 2.2 Alternative 2: Moderate Transit (HOV)/Moderate SOV



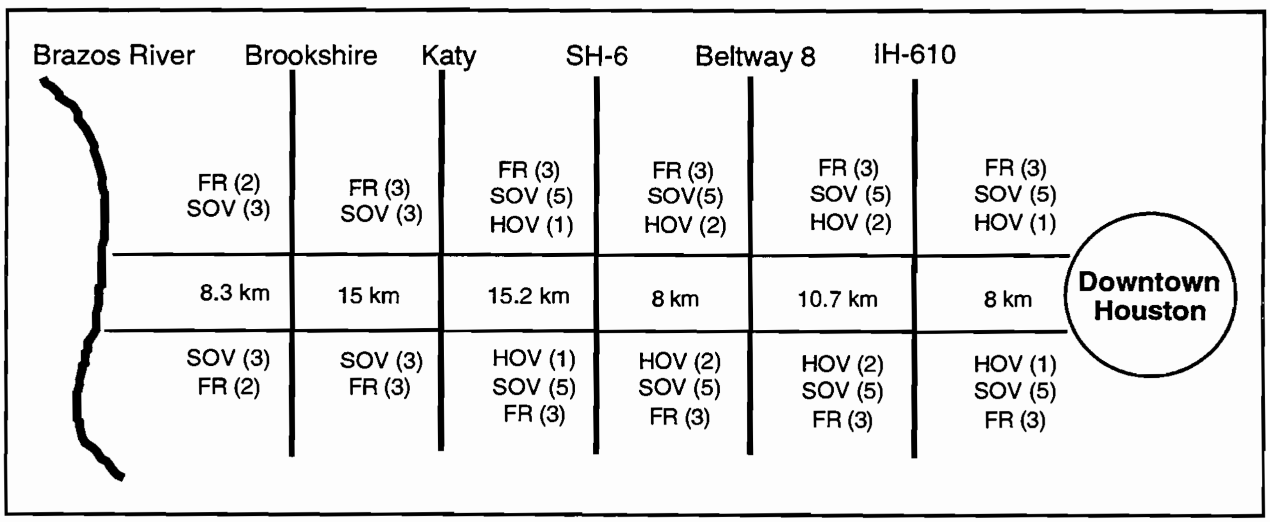
Alternative IV-2 in the MIS. This alternative (1) incorporates all elements of the TSM/TDM alternatives; (2) adds two SOV lanes in each direction from IH-610 to Katy and one SOV lane in each direction from Brookshire to the Brazos River; and (3) provides a two-lane, two-way HOV facility from downtown to Katy. Number of lanes in each direction is shown in parentheses. Source: Ref 7.

Figure 2.3 Alternative 3: Moderate Transit (HOV)/High SOV



Alternative V-2 in the MIS. This alternative (1) incorporates all elements of the TSM/TDM alternatives; (2) adds one SOV lane in each direction from Brookshire to the Brazos River; and (3) provides a two-lane, two-way HOV facility from downtown to IH-610; a four-lane, two-way HOV/Special Use facility from IH-610 to SH-6; and a two-lane, two-way HOV facility from SH-6 to Katy. Number of lanes in each direction is shown in parentheses. Source: Ref 7.

Figure 2.4 Alternative 4: High Transit (HOV)/Moderate SOV



Alternative VI-1 in MIS study. This alternative (1) incorporates all elements of the TSM/TDM alternatives; (2) adds two SOV lanes in each direction from IH-610 to Katy and one SOV lane in each direction from Brookshire to the Brazos River; and (3) provides a two-lane, two-way HOV facility from downtown to IH-610; a four-lane, two-way HOV/Special Use facility from IH-610 to SH-6; and a two-lane, two-way HOV facility from SH-6 to Katy. Number of lanes in each direction is shown in parentheses. Source: Ref 7.

Figure 2.5 Alternative 4: High Transit (HOV)/High SOV

CHAPTER 3. DESCRIPTION OF INPUT DATA

The objective of this study is to evaluate the future transportation needs of the IH-10 Katy Freeway corridor. Unlike the Major Investment Study, which examines only the transportation needs to the year 2020, we assume the planning horizon for the IH-10 Katy Freeway corridor to be from the year 2000 to the year 2030. It is the purpose of this study to identify the investment that represents the best transportation alternative during this period, rather than that for a single year. In this chapter we discuss the data and assumptions used in our calculation.

3.1. PERSON-TRIP DEMAND

One of the most critical factors affecting final results is the person-trip demand. And while the Houston Galveston Area Council (H-GAC) and TxDOT have already estimated future person-trip volumes on the corridor, the data are in average- and maximum-daily-trip format. Table 3.1 shows the average and maximum 24-hour person-trip volumes for the year 2000. These data are estimated by H-GAC from the year 2020 projection, assuming a 2 percent average annual growth rate during the analysis period (Ref 8). In order to convert the average and maximum daily trip into weekday and weekend trip format, we assume maximum 24-hour person volumes as our weekday demand. The weekend demand for each section, which is shown in Table 3.2, is calculated based on the difference between the maximum and average demand.

Table 3.1 Average and maximum person-trip demand (year 2000)

Section on Katy Freeway	Avg. 24-hour Person Volumes		Max. 24-hour Person Volumes	
	Inbound	Outbound	Inbound	Outbound
CBD - IH-610	104,697	100,182	114,005	110,231
IH-610 - Beltway 8	115,440	117,470	129,254	129,621
Beltway 8 - SH-6	111,376	112,271	133,639	130,406
SH-6 - Katy	70,946	75,499	89,217	97,055
Katy - Brookshire	33,063	33,367	47,277	50,371
Brookshire - Brazos*	14,435	14,435	14,462	14,462

*Since directional factor of the inbound and outbound demand on this section is not available, we assumed it as 0.50.
Source: H-GAC - 9/95; The demand on Brookshire–Brazos is based on TxDOT traffic projections.

3.2. FREIGHT TRUCK DEMAND

While the preliminary Major Investment Study does not estimate the corridor freight truck demand, it is the intention of our study to combine both person and freight movements. Our estimation of truck movement on IH-10 Katy Freeway is based on the data obtained from a manual classification study that focused on an area west of the Harris County line (Sta: MS-1200). In a two-day study period, 93.5 percent of the vehicles were classified as cars, pickups, and vans; 0.2 percent were categorized as buses; and the remainder was classified as freight trucks (Ref 14).[1] Converted to a vehicle–trip basis, the truck demand at each section during weekday and weekend is described in Table 3.3. Table 3.4 shows the truck mix on the corridor. The details of the calculation can be found in Appendix A.

Table 3.2 Weekday and weekend person-trip demand (year 2000)

Section on Katy Freeway	Weekday		Weekend	
	Inbound	Outbound	Inbound	Outbound
CBD - IH-610	114,005	110,231	81,427	75,057
IH-610 - Beltway 8	129,254	129,621	80,906	87,091
Beltway 8 - SH-6	133,639	130,406	55,720	66,932
SH-6 - Katy	89,217	97,055	25,268	21,610
Katy - Brookshire*	47,277	50,371	23,639	25,186
Brookshire - Brazos	14,462	14,462	14,370	14,370

*The weekend demand on this segment is assumed as 50 percent of the weekday demand.

Table 3.3 Weekday and weekend truck demand (year 2000)

Section on Katy Freeway	Weekday		Weekend	
	Inbound	Outbound	Inbound	Outbound
CBD - IH-610	6,270	6,063	4,478	4,128
IH-610 - Beltway 8	7,109	7,129	4,450	4,790
Beltway 8 - SH-6	7,350	7,172	3,065	3,681
SH-6 - Katy	4,907	5,338	1,390	1,189
Katy - Brookshire	2,600	2,770	1,300	1,385
Brookshire - Brazos	795	795	790	790

1 Based on the data provided by Jim Heacock at the Texas Department of Transportation, Houston District.

Table 3.4 Freight truck mix

Truck Category	Number of Trucks	Percentage (%)
2-axle Single Unit	304	18.0
3/4-axle Single Unit	77	4.6
3/4-axle Semi-Trailer	78	4.6
5-axle Semi-Trailer	1,125	66.6
6-axle Semi-Trailer	56	3.3
5-axle Trailer	39	2.3
6-axle Trailer	10	0.6
Total	1,689	100.0

3.3. TRAFFIC DISTRIBUTION FOR FRONTAGE ROADS

The previous estimation of person and freight demand included movements on both main lanes (SOV/HOV lanes) and frontage roads. To capture different characteristics of these movements, it is necessary to divide the volumes into separate categories. Most traffic on the main lanes is "through traffic." On the other hand, the frontage road is primarily for access. Because of a lack of adequate data to predict the distribution, in this report it is assumed that 20 percent of traffic movements are on the frontage roads from Katy to the Brazos River, and 10 percent from downtown Houston to Katy. This estimation is based approximately on future facility capacity.

3.4. MODE SPLIT ON MAIN LANE (SOV/HOV/BUS) AND VEHICLE OCCUPANCY

The Major Investment Study does not estimate the mode splits of SOV users, HOV users, or bus users. In assessing the capacity adequacy, only the total demand and capacity of the facility were compared, which implied that the mode split of the demand equals the split of the capacity. In reality, however, the mode split of demand differs from that of capacity, a fact that could result in inadequate capacity for a mode. The estimates made by the H-GAC show that, in the Houston area for 1992, on average, 91.9 percent of the travelers drive single-occupancy vehicles, 6.4 percent take carpools, and 1.7 percent use bus transit (Ref 9). These figures may not be appropriate to the IH-10 Katy Freeway, since the special bus service and HOV lanes along the corridor can boost the mode split of carpool and transit users. In order to compare alternatives, this study used mode split of the capacity of a facility, with one HOV lane and four SOV lanes in each direction as mode split during weekdays, and H-GAC figures during weekends, as shown in Table 3.5.

One of the sensitive factors affecting the final results is vehicle occupancy. Higher vehicle occupancies reduce the total full cost of the facility. In this report, the vehicle occupancies for drive-alone and carpool and vanpool on the Katy Freeway are 1.11 and 3.00 passengers per vehicle, respectively (Ref 8). The bus occupancy, derived from the average occupancy of transit buses on the Katy Freeway, totals 39.00 passengers per bus.[1]

Table 3.5 Mode split and vehicle occupancy

Transportation Mode	Mode Split		Average Occupancy
	Weekday	Weekend	
Drive-Alone	53.3%	91.9%	1.11
Carpool and Vanpool	27.7%	6.4%	3.00
Bus Transit	18.0%	1.7%	39.00
Total	100.0%	100.0%	-

3.5. TRAFFIC DISTRIBUTION IN PEAK AND NON-PEAK PERIOD

The most reliable data on peak-hour person movement during weekdays on the Katy Freeway come from the H-GAC (Ref 8). Based on these data, we have calculated the peaking characteristics of traffic on each section of IH-10 Katy Freeway. The calculation shown in Table 3.6 is in terms of percent of total movements, representing simply the traffic for each direction as a fraction of total person-trips on that section. The share during the "Night" period (10:00 p.m. – 6:00 a.m.) in each direction is assumed to be 3.0 percent of the total trips, based on the national average derived by Hu (Ref 10). The remaining trips are assumed to occur during the "Day" period.

Since there were no data collected for weekends, it is assumed that there is no peak hour period on the weekend. Ninety-four percent of weekend traffic is assumed to travel through the Katy Freeway during the "Day" period (6:00 a.m. – 10:00 p.m.) and the remaining during the "Night" period, as shown in Table 3.7.

3.6. VALUE OF TIME

Although the inclusion of travel time costs in the analysis renders the results more meaningful, it also introduces questions about some of the assumptions. Passenger travel-time values are difficult to measure, and various studies have disagreed regarding the appropriate estimate for the value of travel time. Furthermore, some planners are skeptical of methods that rely on a single assumed value for travel time. However, from the perspective of alternative comparisons, the single value method is adequate. In this analysis we assume a value of $5.00 per passenger per hour for travel time. The value equals to one-third of the average wage rate (Ref 11), which is assumed as $15.00 per passenger per hour.

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1 Based on the data sent by Imad Ismail at Houston METRO about the average daily boarding and number of bus trips on Katy Freeway.

Table 3.6 Weekday distribution during peak and non-peak period (in % of total person trips)

Section on Katy Freeway	AM Peak (1 hour)		PM Peak (1 hour)		Day (14 hour)		Night (8 hour)		Total
	Inbound	Outbound	Inbound	Outbound	Inbound	Outbound	Inbound	Outbound	
CBD–IH-610	5.6	4.7	4.7	5.6	37.5	35.9	3.0	3.0	100
IH-610–Beltway 8	4.9	4.3	4.3	4.9	37.7	37.9	3.0	3.0	100
Beltway 8–SH-6	5.2	4.5	4.5	5.2	37.9	36.7	3.0	3.0	100
SH-6–Katy	5.1	4.0	4.0	5.1	35.8	40.0	3.0	3.0	100
Katy–Brookshire	4.5	4.1	4.1	4.5	36.8	40.0	3.0	3.0	100
Brookshire–Brazos	12.3	3.5	3.5	12.3	31.2	31.2	3.0	3.0	100

Table 3.7 Weekend distribution during peak and non-peak period (in % of total person trips)

Section on Katy Freeway	AM Peak (0 hour)		PM Peak (0 hour)		Day (16 hour)		Night (8 hour)		Total
	Inbound	Outbound	Inbound	Outbound	Inbound	Outbound	Inbound	Outbound	
CBD–IH-610	0.0	0.0	0.0	0.0	49.0	45.0	3.0	3.0	100
IH-610–Beltway 8	0.0	0.0	0.0	0.0	45.2	48.8	3.0	3.0	100
Beltway 8–SH-6	0.0	0.0	0.0	0.0	42.4	51.6	3.0	3.0	100
SH-6–Katy	0.0	0.0	0.0	0.0	50.9	43.1	3.0	3.0	100
Katy–Brookshire	0.0	0.0	0.0	0.0	45.4	48.6	3.0	3.0	100
Brookshire–Brazos	0.0	0.0	0.0	0.0	47.0	47.0	3.0	3.0	100

3.7. FACILITY COST DATA

Most data on facility unit costs have been taken from the "General Guidelines for Estimates" provided by the Texas Department of Transportation. The typical cross-sections reported by Parsons Brinckerhoff (Ref 8) are used for the estimation. We assume the existing right-of-way is large enough to accommodate either the expansion of the facility or the addition of a new facility; therefore the purchase of right-of-way is not included in this study.

3.8. EMISSION VALUE DATA

The emission values, which are based primarily on damage value estimates of stationary source emissions, are found in the literature (Ref 12). In the Houston metropolitan area, the values are \$6,890 per ton for nitrogen oxides (NO_x), \$3,540 per ton for hydrocarbons (HC), \$5,190 per ton for microfine dust (PM10), \$2,910 per ton for sulfur oxides (SO_x), and \$2,000 per ton for carbon monoxide (CO).

3.9. TRANSIT AGENCY DATA

The bus fleet running on the Katy Freeway consists of the Low-Floor, 12m, New Flyer, which has an initial capital cost of \$257,000 per bus, and a life span of 12 years.[1]

1 Based on the data provided by Bill Peterson, Houston METRO.

There are a total of 39 park-and-ride lots and 42 transit centers constructed or under construction in Houston. The average initial capital cost of a park-and-ride lot is $3,900,000, while the initial capital cost of a transit center is $4,900,000.[1] These costs were used in the analysis.

3.10. CAPITAL AND OPERATING DATA FOR PERSONAL VEHICLE

The cost of owning and operating a motor vehicle is of major significance. The data listed in Table 3.8, provided by the FHWA, trace selected vehicles in personal use and their costs through a 12-year lifetime (Ref 13). The costs were based on operation of typical vehicles.

3.11. OTHER DATA

In 1992, the annual vehicle-miles of travel (AVMT) in Houston was 26 million, 42 percent of which was on expressways (Ref 1). By using a TxDOT-projected VMT growth rate,[2] it is expected that the AVMT will grow to 31.7 million by the year 2000.

Concerning the value of money over time, the discount rate used in the study to convert all costs into 1995 dollars is 10 percent. Also, we have conducted a sensitivity analysis of discount rates by using 5 percent and 15 percent in each of the alternatives.

Table 3.8 Auto capital and operating data

Cost Category	Cost
Average Vehicle Price ($/vehicle)	13,534
Average Pickup and Van Price ($/vehicle)	15,813
Percent being Financed	75%
Loan Period (year)	5
Loan Rate	10.0%
Salvage Value ($/vehicle)	1,000
Vehicle Life (year)	12
Average Annual Driven Miles (mile)	10,700
Annual Scheduled Maintenance ($/vehicle)	232
Annual Unscheduled Maintenance ($/vehicle)	195
Annual Oil Change ($/vehicle)	59
Annual Tire Change ($/vehicle)	97
Annual Insurance ($/vehicle)	600
Annual Parking ($/vehicle)	360
Enhanced I/M ($/vehicle)	55
Average Gasoline Price without Taxes ($/gallon)	0.70

Source: *Cost of Owning & Operating Automobiles, Vans & Light Trucks 1991.* U.S. Department of Transportation, Washington, D.C., 1992.

[1] Based on the data provided by Katherine F. Turnbull, Texas Transportation Institute.

[2] Statewide VMT projection by Texas Department of Transportation.

CHAPTER 4. RESULTS OF BASE ALTERNATIVE

Alternative 1 was considered as the base case in our analysis. The analysis for this alternative consists of cost calculations for each of the six previously defined sections along IH-10 Katy Freeway. The cost summary reflects the impact of future traffic on the current facilities. The details, summarized in Table 4.1, are divided into eight cost categories, namely, facility costs, transit agency costs, travel time costs, air pollution costs, incident delay costs, accident costs, other external costs, and user costs.

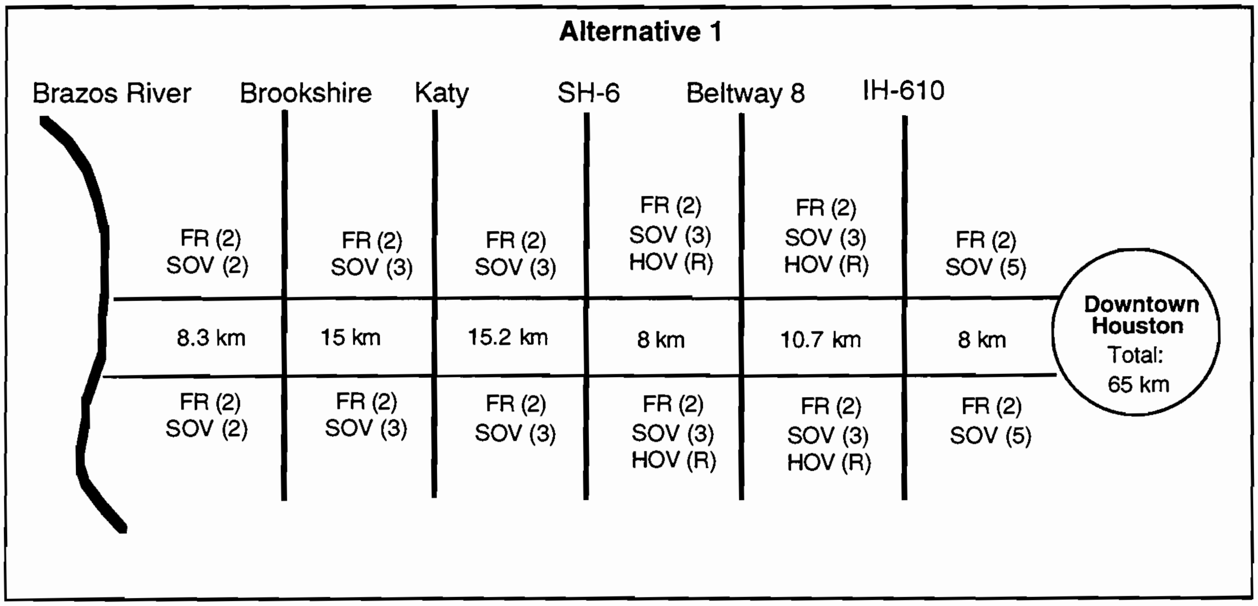
Facility costs include roadway construction, rehabilitation, routine maintenance, and administration costs. Transit agency costs consist of the capital and operating cost paid by transit agencies if there is a transit service running on the corridor. Travel time costs are the time costs expended on the road by users. This part of the costs includes non-incident, congestion-related time costs. Air pollution costs, which are closely related to the congestion levels of the facility, are the result of tailpipe emissions. Incident delay costs result from the delay caused by incidents, while accident costs are those costs not covered by insurance — the part paid by society. Other external costs include energy security, weather change, water pollution, and noise costs. Finally, user costs include the costs paid by private vehicle owners to operate and maintain their vehicles.

As shown in Figure 4.1, the travel time costs on IH-10 Katy Freeway for the 30-year analysis period is a dominant force among all the cost categories. The annual user travel time and incident delay costs will account for more than one half of the total annual cost. The pollution costs, which are closely related to the dimension of the facility, rank third with $187 million a year. Auto users spend about $782 million per year, or slightly less than three-tenths of the total cost, to own and operate their vehicles. The facility costs, which include all the labor and material costs to maintain the current roadway facility, occupy only 2 percent of the pie.

Looking at the annual cost by section, the section from SH-6 to Katy has the largest share — about 40 percent of the total cost occurring within this segment. The travel time cost within section 3 is about 50 percent of the total travel time cost of the entire corridor, though its person-miles of travel (PMT) is only 23 percent of the total PMT, a result of the insufficient capacity in this section. The v/c ratio during peak hours in this section is 1.24 in year 2000, almost one-fourth over the current capacity. It will quickly reach 1.52 in the year 2010 and 1.86 in the year 2020. The inadequate capacity causes excessive delay to through traffic and local traffic. The frequent stop-and-go caused by large v/c ratio results in a tremendous amount of tailpipe emissions from the traffic, which in turn leads to large air pollution costs. This suggests that the expansion of the capacity on this section is very urgent and necessary.

The analysis of the section between IH-610 and Beltway 8 and the section between Beltway 8 and SH-6 shows that the current reversible HOV lane is not capable of alleviating the congestion during peak periods. The presence of a reversible HOV lane is usually recommended with unbalanced directional traffic. The peak hour demand distribution data in Table 3.6, however, show almost equal traffic volumes in both directions during the peak hour on these two sections. As a result, the facility cannot handle the traffic in one direction during the peak hour, causing a large amount of delay and air pollution.

Table 4.1 Annual life-cycle cost of Alternative 1 (in millions of dollars)



Annual Cost	**Agency**	**6.03**	**10.53**	**11.95**	**13.13**	**18.34**	**10.05**	**70.03**
	Highway Facility	6.03	10.53	11.95	6.64	9.77	10.05	54.96
	Transit Agency	0.00	0.00	0.00	6.50	8.57	0.00	15.07
	Auto User	**22.20**	**116.20**	**206.00**	**118.38**	**168.03**	**151.61**	**782.42**
	External	**15.87**	**79.31**	**846.68**	**268.68**	**395.08**	**158.21**	**1763.82**
	Travel Time	6.81	33.45	696.74	204.16	301.07	93.53	1335.77
	Air Pollution	2.97	14.00	92.44	21.66	34.08	22.37	187.52
	Incident Delay	2.05	10.73	20.05	16.10	22.42	14.76	86.10
	Accident	0.60	3.13	5.56	3.27	4.63	4.09	21.27
	Other External	3.44	17.99	31.89	23.50	32.88	23.47	133.16
	Total	**44.09**	**206.04**	**1064.63**	**400.20**	**581.45**	**319.87**	**2616.27**

Initial Investment†	42.88	71.79	83.09	42.76	61.67	71.39	373.57

†Initial investment, as estimated by MODECOST, is the initial lump-sum highway facility cost, excluding mobilization and traffic control cost. This initial investment cost includes existing facilities as well as any facility improvements.

In the next chapter, we will evaluate the alternatives proposed by Parsons Brinckerhoff and the potential of these alternatives in terms of alleviating congestion and reducing total cost.

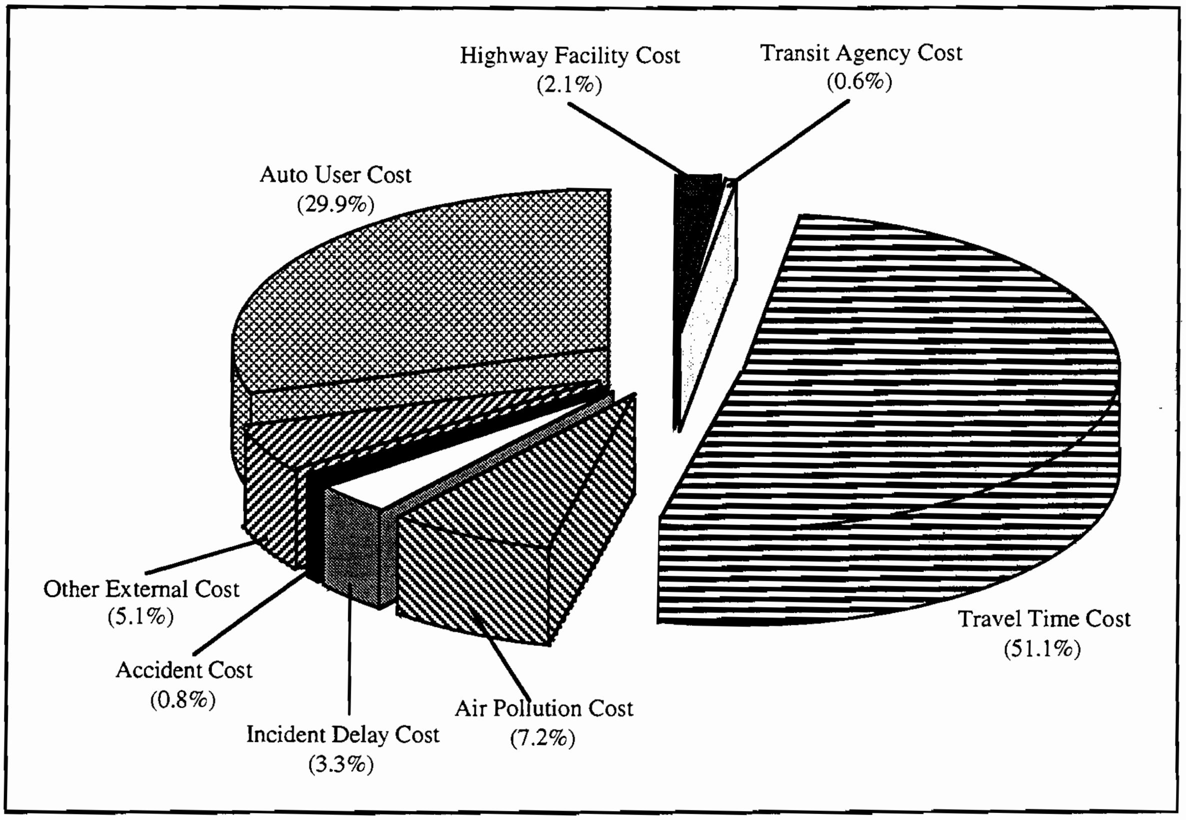


Figure 4.1 Annual cost by categories of Alternative 1

CHAPTER 5. FULL COST OF ALTERNATIVES

5.1. INTRODUCTION

The major objective of this report is to identify and evaluate the alternatives available for reducing total transportation costs on the IH-10 Katy Freeway corridor throughout a planning horizon of 30 years. The base alternative presented previously provides the baseline to compare the other four alternatives. The base alternative reflects the current situation for the Katy Freeway, as well as the future trend based on no additional investment. In this chapter, we discuss four other alternatives:

Alternative 2: Moderate Investment in HOV and Moderate Investment in SOV;
Alternative 3: Moderate Investment in HOV and High Investment in SOV;
Alternative 4: High Investment in HOV and Moderate Investment in SOV; and
Alternative 5: High Investment in HOV and High Investment in SOV.

The analysis was completed using both the MODECOST program and the same assumptions as for the base case reported previously. The analysis includes not only facility costs, but also external costs as well as user and agency costs. The costs are categorized according to eight cost groups, as described in the last chapter. In addition, we also estimated the initial capital cost for each alternative, based on the output from MODECOST.

5.2. COST RESULTS FOR THE DIFFERENT ALTERNATIVES

The four alternatives, discussed in Chapter 2, proposed the expansion of the current facility, which was shown clearly in the previous chapter as being unable to handle future traffic growth. The four investment strategies include building HOV lanes from downtown Houston to Katy and expanding the existing SOV facility and frontage roads. The results for the analysis are presented in Tables 5.1 through 5.4.

Table 5.1 lists the annual life-cycle cost of Alternative 2, which shows a clear improvement from the base alternative. The annual total cost drops almost two-thirds from $2.6 billion to $1.4 billion. Among eight cost categories, the travel time cost has the largest drop, from over $1.3 billion a year to $288 million a year. The next is air pollution cost, which drops by more than one half a year. This implies that the traffic flow on the corridor has been dramatically improved.

Looking at the results by section, the travel time and pollution costs on sections from downtown Houston to Katy show tremendous improvement, which implies that the congestion level is eased significantly. The remainder of the sections from Katy to the Brazos River, however, shows minimum gains. Furthermore, close examination of the segment from Katy to Brookshire shows that the expansion of frontage roads on this section is not effective in reducing costs. Adding a one-lane frontage road in each direction results in minimum gain in travel time and air pollution. In turn, the total cost on this segment is increased owing to the expansion of the facility.

In addition, the expansion of the HOV facility can increase the mode split of HOV users and bus users by attracting more people to ride-sharing programs or to a special bus system. As a result, the total automobile user cost is reduced by almost $100 million a year.

Table 5.2 shows the cost results for Alternative 3. Compared with the base alternative, Alternative 3 has the same impact as Alternative 2 in alleviating congestion on the corridor from downtown Houston to Katy. The travel time savings of Alternative 3 top $1.1 billion a year, while the annual air pollution savings total almost $100 million.

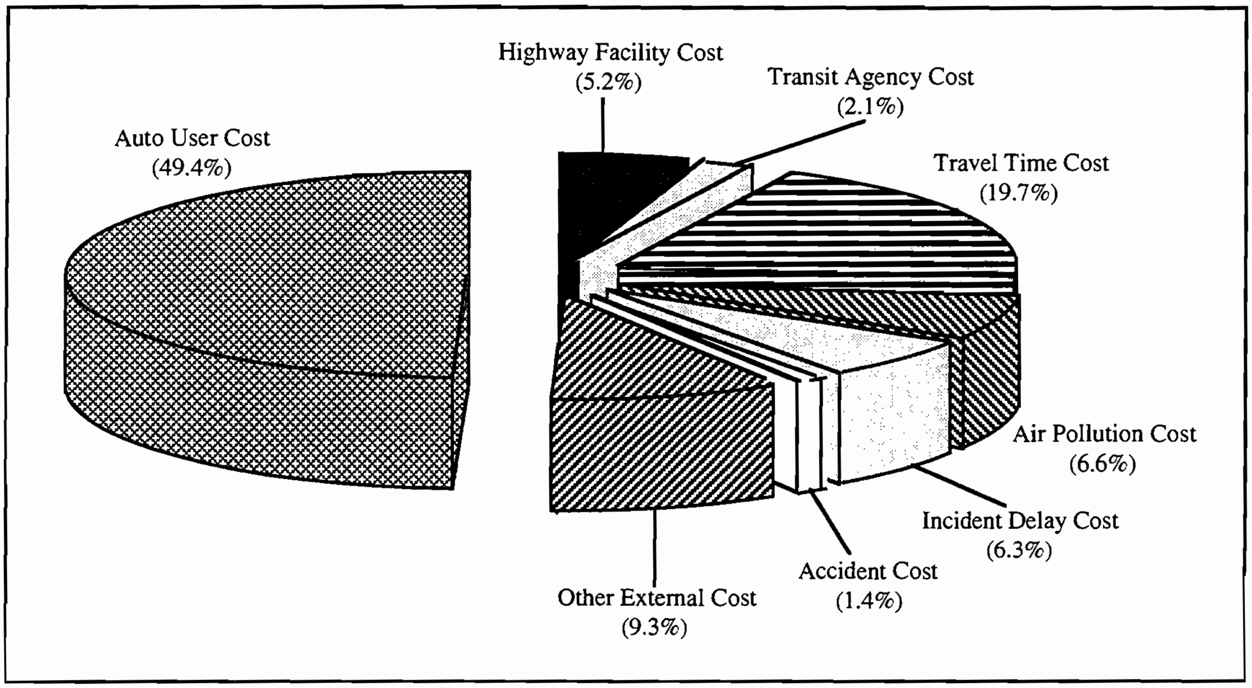


Figure 5.1 Annual cost by categories of Alternative 3

Breaking down the cost by categories, as shown in Figure 5.1, we can see that auto user costs are a major contributor to the total cost, reaching almost 50 percent of the annual cost. Comparing this with the base scenario, travel time cost is down, from 51 percent to 20 percent. This illustrates that the current facility is incapable of handling future traffic growth. Although Alternative 3 increases annual agency costs by $30 million, the tremendous savings on external costs and automobile user costs reduce the total annual cost by 47 percent from the base scenario.

The results for Alternative 4 and Alternative 5 are presented in Tables 5.3 and 5.4, respectively. Both alternatives can effectively reduce travel time cost and air pollution cost, achieving the same goal as did Alternatives 2 and 3.

As discussed above, all four alternatives have a tremendous positive impact on the total future transportation cost. Although Alternative 5 has a higher initial investment than does

Alternative 3, their overall costs are almost the same. This is largely due to the trade-off between capacity and travel time. In Alternative 5, the HOV facility from IH-610 to SH-6 is increased from one lane in each direction to two lanes, but the overall travel time costs do not improve dramatically because of the fixed demand of HOV users. Compared with Alternatives 3 and 5, Alternatives 2 and 4 are less attractive.

The results presented in Tables 5.1 through 5.4 show that Alternatives 3 and 5 are more attractive than Alternatives 2 and 4, yielding some $30 million in annual savings. While Alternative 5 has a slight edge over Alternative 3 in terms of total cost, its construction cost is 5 percent higher.

Table 5.1 Annual life-cycle cost of Alternative 2 (in millions of dollars)

Alternative 2 Moderate HOV & Moderate SOV	Brazos River – Brookshire	Brookshire – Katy	Katy – SH-6	SH-6 – Beltway 8	Beltway 8 – I-610	I-610 – Downtown Houston	**Total**
	FR (2) SOV (3)	FR (3) SOV (3)	FR (3) SOV (4) HOV (1)	FR (3) SOV (4) HOV (1)	FR (3) SOV (4) HOV (1)	FR (3) SOV (5) HOV (1)	
	5.15 miles	9.31 miles	9.44 miles	4.96 miles	6.63 miles	4.96 miles	40.45 miles
	SOV (3) FR (2)	SOV (3) FR (3)	HOV (1) SOV (4) FR (3)	HOV (1) SOV (4) FR (3)	HOV (1) SOV (4) FR (3)	HOV (1) SOV (5) FR (3)	

Annual Cost	**Agency**	**6.44**	**12.88**	**27.10**	**15.13**	**20.75**	**16.98**	**99.28**
	Highway Facility	6.44	12.88	18.45	8.64	12.18	11.41	70.00
	Transit Agency	0.00	0.00	8.65	6.50	8.57	5.57	29.29
	Auto User	**22.20**	**116.20**	**143.71**	**118.38**	**168.03**	**111.10**	**679.61**
	External	**15.30**	**79.27**	**135.56**	**118.94**	**159.65**	**101.52**	**610.23**
	Travel Time	6.16	33.42	62.48	60.21	78.27	47.00	287.54
	Air Pollution	3.05	14.00	19.97	15.87	21.45	15.04	89.38
	Incident Delay	2.05	10.73	20.05	16.10	22.42	14.75	86.10
	Accident	0.60	3.13	3.97	3.27	4.63	3.06	18.66
	Other External	3.44	17.99	29.09	23.50	32.88	21.67	128.56
	Total	**43.94**	**208.35**	**306.37**	**252.45**	**348.43**	**229.59**	**1389.13**

Initial Investment†	44.73	88.15	147.44	66.31	95.09	93.92	535.64

†Initial investment, as estimated by MODECOST, is the initial lump-sum highway facility cost, excluding mobilization and traffic control cost. This initial investment cost includes existing facilities as well as any facility improvements.

Table 5.2 Annual life-cycle cost of Alternative 3 (in millions of dollars)

	Brazos River	Brookshire	Katy	SH-6	Beltway 8	I-610	Downtown Houston
Alternative 3 Moderate HOV & High SOV	FR (2) SOV (3)	FR (3) SOV (3)	FR (3) SOV (5) HOV (1)	FR (3) SOV (5) HOV (1)	FR (3) SOV (5) HOV (1)	FR (3) SOV (5) HOV (1)	**Total**
	5.15 miles	9.31 miles	9.44 miles	4.96 miles	6.63 miles	4.96 miles	40.45 miles
	SOV (3) FR (2)	SOV (3) FR (3)	HOV (1) SOV (5) FR (3)	HOV (1) SOV (5) FR (3)	HOV (1) SOV (5) FR (3)	HOV (1) SOV (5) FR (3)	

Annual Cost	**Agency**	**6.44**	**12.88**	**27.86**	**15.53**	**21.29**	**16.98**	**100.98**
	Highway Facility	6.44	12.88	19.21	9.04	12.71	11.41	71.70
	Transit Agency	0.00	0.00	8.65	6.50	8.57	5.57	29.29
	Auto User	**22.20**	**116.20**	**143.71**	**118.38**	**168.03**	**111.10**	**679.61**
	External	**15.30**	**79.27**	**135.56**	**118.94**	**159.65**	**101.52**	**610.23**
	Travel Time	6.16	33.42	61.66	52.15	71.33	47.00	271.72
	Air Pollution	3.05	14.00	20.75	15.82	22.03	15.04	90.69
	Incident Delay	2.05	10.73	20.05	16.10	22.42	14.75	86.10
	Accident	0.60	3.13	3.97	3.27	4.63	3.06	18.66
	Other External	3.44	17.99	29.09	23.50	32.88	21.67	128.56
	Total	**43.94**	**208.35**	**307.09**	**244.75**	**342.60**	**229.59**	**1376.32**

Initial Investment†	44.73	88.15	150.84	68.10	97.48	93.92	543.22

†Initial investment, as estimated by MODECOST, is the initial lump-sum highway facility cost, excluding mobilization and traffic control cost. This initial investment cost includes existing facilities as well as any facility improvements.

Table 5.3 Annual life-cycle cost of Alternative 4 (in millions of dollars)

Alternative 4 High HOV & Moderate SOV	Brazos River – Brookshire	Brookshire – Katy	Katy – SH-6	SH-6 – Beltway 8	Beltway 8 – I-610	I-610 – Downtown Houston	Total
	FR (2) SOV (3)	FR (3) SOV (3)	FR (3) SOV (4) HOV (1)	FR (3) SOV (4) HOV (2)	FR (3) SOV (4) HOV (2)	FR (3) SOV (5) HOV (1)	
	5.15 miles	9.31 miles	9.44 miles	4.96 miles	6.63 miles	4.96 miles	40.45 miles
	SOV (3) FR (2)	SOV (3) FR (3)	HOV (1) SOV (4) FR (3)	HOV (2) SOV (4) FR (3)	HOV (2) SOV (4) FR (3)	HOV (1) SOV (5) FR (3)	

Annual Cost	**Agency**	**6.44**	**12.88**	**27.10**	**15.82**	**21.67**	**16.98**	**100.90**
	Highway Facility	6.44	12.88	18.45	9.33	13.10	11.41	71.61
	Transit Agency	0.00	0.00	8.65	6.50	8.57	5.57	29.29
	Auto User	**22.20**	**116.20**	**143.71**	**118.38**	**168.03**	**111.10**	**679.61**
	External	**15.30**	**79.27**	**135.56**	**118.25**	**159.00**	**101.52**	**608.89**
	Travel Time	6.16	33.42	62.48	59.30	77.33	47.00	285.69
	Air Pollution	3.05	14.00	19.97	16.09	21.74	15.04	89.89
	Incident Delay	2.05	10.73	20.05	16.10	22.42	14.75	86.10
	Accident	0.60	3.13	3.97	3.27	4.63	3.06	18.66
	Other External	3.44	17.99	29.09	23.50	32.88	21.67	128.56
	Total	**43.94**	**208.35**	**306.37**	**252.45**	**348.70**	**229.59**	**1389.41**

Initial Investment†	44.73	88.15	147.44	74.57	106.13	93.92	554.93

†Initial investment, as estimated by MODECOST, is the initial lump-sum highway facility cost, excluding mobilization and traffic control cost. This initial investment cost includes existing facilities as well as any facility improvements.

Table 5.4 Annual life-cycle cost of Alternative 5 (in millions of dollars)

Alternative 5 High HOV & High SOV	Brazos River – Brookshire	Brookshire – Katy	Katy – SH-6	SH-6 – Beltway 8	Beltway 8 – I-610	I-610 – Downtown Houston	Total
	FR (2) SOV (3)	FR (3) SOV (3)	FR (3) SOV (5) HOV (1)	FR (3) SOV (5) HOV (2)	FR (3) SOV (5) HOV (2)	FR (3) SOV (5) HOV (1)	
	5.15 miles	9.31 miles	9.44 miles	4.96 miles	6.63 miles	4.96 miles	40.45 miles
	SOV (3) FR (2)	SOV (3) FR (3)	HOV (1) SOV (5) FR (3)	HOV (2) SOV (5) FR (3)	HOV (2) SOV (5) FR (3)	HOV (1) SOV (5) FR (3)	

Annual Cost	**Agency**	**6.44**	**12.88**	**27.86**	**16.23**	**22.21**	**16.98**	**102.60**
	Highway Facility	6.44	12.88	19.21	9.73	13.64	11.41	73.31
	Transit Agency	0.00	0.00	8.65	6.50	8.57	5.57	29.29
	Auto User	**22.20**	**116.20**	**143.71**	**118.38**	**168.03**	**111.10**	**679.61**
	External	**15.30**	**79.27**	**135.52**	**110.15**	**152.64**	**101.52**	**594.38**
	Travel Time	6.16	33.42	61.66	51.24	70.38	47.00	269.86
	Air Pollution	3.05	14.00	20.75	16.04	22.33	15.04	91.20
	Incident Delay	2.05	10.73	20.05	16.10	22.42	14.75	86.10
	Accident	0.60	3.13	3.97	3.27	4.63	3.06	18.66
	Other External	3.44	17.99	29.09	23.50	32.88	21.67	128.56
	Total	**43.94**	**208.35**	**307.09**	**244.75**	**342.87**	**229.59**	**1376.59**

Initial Investment†	44.73	88.15	150.84	76.35	108.52	93.92	562.51

†Initial investment, as estimated by MODECOST, is the initial lump-sum highway facility cost, excluding mobilization and traffic control cost. This initial investment cost includes existing facilities as well as any facility improvements.

CHAPTER 6. REVISED ALTERNATIVE

6.1. DESCRIPTION OF THE REVISED ALTERNATIVE AND INPUT DATA

In this chapter, we will explore a revised alternative that includes the light rail mode in the analysis. The revised alternative, referred to as Alternative 6, is described below:

Alternative 6: Moderate HOV/Moderate SOV/Moderate Rail

This revised alternative includes a modest investment in HOV lanes, a modest investment in SOV lanes, and a modest investment in light rail. The investment includes: (1) adding a two-lane, two-way HOV facility from downtown Houston to IH-610 that will connect with the HOV direct connector that provides service to the downtown area near Franklin; (2) adding one SOV lane in each direction from IH-610 to Katy, providing a total of eight SOV lanes; (3) upgrading the existing reversible HOV to a two-lane, two-way HOV facility from IH-610 to Katy; (4) adding one SOV lane in each direction from Brookshire to the Brazos River, giving a total of three SOV lanes in each direction; (5) upgrading the frontage road to three lanes in each direction from downtown Houston to Katy; and (6) adding a high-level fixed guideway between downtown Houston and Katy.

Input data similar to those described in Chapter 3 are used for this scenario, except for the mode split, which is listed in Table 6.1. The decrease in the number of auto, carpool, and bus users is largely due to the construction of a fixed guideway along the corridor. The share of auto, carpool, bus, and rail modes during weekdays is designed to provide a balance between the facility capacities. It is assumed that there is no rail service during weekends. The average vehicle occupancies are derived from the MIS report (Ref 8).

Table 6.1 Mode split and vehicle occupancy of Alternative 6

Transportation Mode	Mode Split		Average Occupancy
	Weekday	Weekend	
Drive-Alone	48.0%	91.9%	1.11
Carpool and Vanpool	25.5%	6.4%	3.00
Bus Transit	15.9%	1.7%	39.00
Rail Transit	10.6%	0.0%	85.00
Total	100.0%	100.0%	—

Table 6.2 reports the additional data (provided by Parsons Brinckerhoff in their Major Investment Study) used to calculate the capital cost of the fixed guideway system. All rail facilities are assumed to have 40-year life spans in this study. The rehabilitation costs and maintenance costs of the facilities, as well as the operation data of the rail system, are detailed in Appendix D.

Table 6.2 Capital cost data of fixed guideway

Guideway	Unit Cost (per mile)	$2,850,000
	Length	27.7 miles
Stations	Unit Cost (per Station)	$9,000,000
	Number	7 Stations
Yards and Shops	Cost	$13,250,000
	Number	1 Yard
Rail Car	Unit Cost (per Car)	$2,000,000

1 mile=1.61 km

6.2. RESULTS

Table 6.3 lists the full-cost results obtained from MODECOST for Alternative 6, the revised alternative. The results show that by including a fixed guideway option, we can achieve a savings of at least $56 million per year with respect to any alternative described in the previous chapter, though the initial investment will increase by at least $250 million. The increased initial capital cost will be offset by the savings associated with future external costs and user costs.

Figure 6.1 shows the cost comparison of Alternative 6 with Alternative 3, which has the lowest cost result among all alternatives described in the previous chapter. Although Alternative 6 has a higher annual facility cost (because of the addition of a fixed guideway system from downtown Houston to Katy, rather than a five-lane SOV lane from IH-610 to Katy), both auto user costs and external costs are significantly reduced, owing to the assumed travelers' mode shift to the high occupancy transit system.

In the revised alternative introduced in this chapter, we did not add capacity to the frontage roadway system from Katy to Brookshire. The results show that this can achieve approximately $2 million a year in total savings on this section, which are largely attributed to the savings on the highway facility cost. As future traffic is expected to be light on this section, the expansion of the frontage roadway system does not represent a cost-effective alternative.

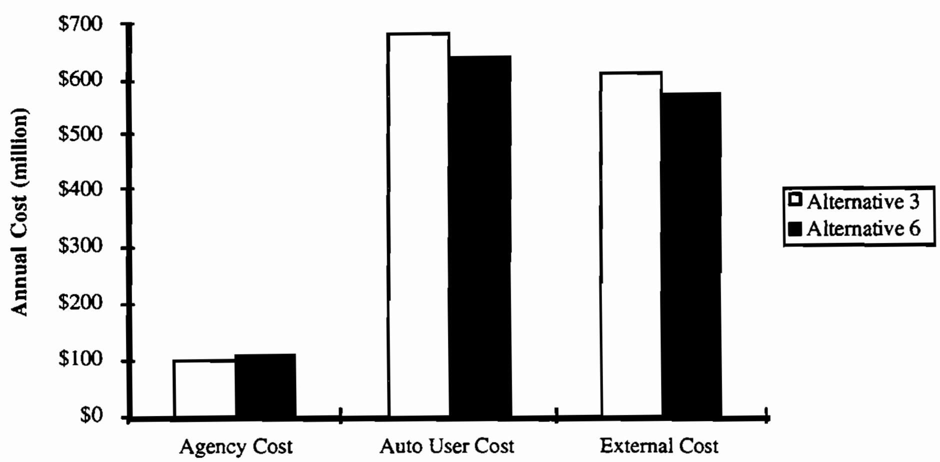


Figure 6.1 Cost comparison of Alternatives 3 and 6

Table 6.3 Annual life-cycle cost of Alternative 6 (in millions of dollars)

Alternative 6 Moderate HOV, Moderate SOV & Moderate Rail	Brazos River – Brookshire	Brookshire – Katy	Katy – SH-6	SH-6 – Beltway 8	Beltway 8 – I-610	I-610 – Downtown Houston	**Total**
	FR (2) SOV (3)	FR (2) SOV (3)	FR (3) SOV (4) HOV (1)	FR (3) SOV (4) HOV (1)	FR (3) SOV (4) HOV (1)	FR (3) SOV (5) HOV (1)	
	5.15 miles	9.31 miles	9.44 miles	4.96 miles	6.63 miles	4.96 miles	40.45 miles
	SOV (3) FR (2)	SOV (3) FR (2)	HOV (1) SOV (4) FR (3)	HOV (1) SOV (4) FR (3)	HOV (1) SOV (4) FR (3)	HOV (1) SOV (5) FR (3)	

Annual Cost	**Agency**	**6.44**	**10.53**	**29.26**	**18.20**	**23.76**	**18.95**	**107.13**
	Highway Facility	6.44	10.53	18.45	8.64	12.18	11.41	67.65
	Transit Agency	0.00	0.00	10.81	9.56	11.58	7.54	39.49
	Auto User	**22.20**	**116.20**	**132.86**	**110.30**	**157.44**	**104.24**	**643.24**
	External	**15.30**	**79.31**	**125.78**	**107.46**	**146.75**	**95.74**	**570.33**
	Travel Time	6.16	33.45	56.83	52.88	70.57	44.46	264.35
	Air Pollution	3.05	14.00	19.09	14.84	20.37	14.45	85.80
	Incident Delay	2.05	10.73	18.32	14.81	20.73	13.66	80.30
	Accident	0.60	3.13	3.70	3.06	4.36	2.89	17.73
	Other External	3.44	17.99	27.85	21.88	30.73	20.28	122.16
	Total	**43.94**	**206.04**	**287.90**	**235.96**	**327.95**	**218.92**	**1320.70**

Initial Investment	Highway†	44.73	71.79	147.44	66.31	95.09	93.92	519.28
	Rail*	0.00		266.14				266.14

†Initial investment, as estimated by MODECOST, is the initial lump-sum highway facility cost, excluding mobilization and traffic control cost. This initial investment cost includes existing facilities as well as any facility improvements.

*Initial investment of rail facility includes the initial lump-sum costs of rail vehicles, guideway, stations, ROW, yards, and shops.

6.3. SENSITIVITY ANALYSIS

As described earlier, time cost and mode split are not the only parameters used here whose values are uncertain. Another such parameter is the discount rate. The discount rate assumed can have a significant effect on the results of life-cycle cost comparisons, mainly because different modes use capital and other factors in different schedules and proportions. Transit bus and rail transportation are relatively capital-intensive modes, and a low discount rate is likely to make transit appear favorably in a cost comparison with automobile transportation. In addition, a low discount rate will tend to increase future external costs, in terms of current dollars. The discount rate controversy, which centers on the question as to what figure best represents the opportunity costs of capital for government investments, cannot be resolved here. Rather, we assume a lower and a higher value, 5 percent and 15 percent, in addition to the 10 percent used previously. This should reasonably cover the range considered appropriate by most economists.

The detailed results of the sensitivity analysis are provided in Appendix B and Appendix C. Tables B.1 through B.5 show the results of Alternatives 2 through 6 with a 5 percent discount rate, while Tables C.1 through C.5 list the cost results of Alternatives 2 through 6 with a 15 percent discount rate. The results show that, in both cases, Alternative 6 has a clear advantage over the other alternatives. The savings obtained by adding a light rail option in Alternative 6 (rather than adding one more SOV lane or one more HOV lane in each direction) range from $56 million a year to $68 million a year, depending on the discount rate.

Figure 6.2 shows that while the discount rate goes up, the agency cost, including highway facility cost and transit agency cost, of Alternative 6 increases significantly. As the discount increases from 5 percent to 15 percent, the agency cost increases by more than two-thirds. As shown in Figure 6.3, an increasing discount rate will increase vehicle owners' costs for automobile maintenance and operation. It is able, however, to reduce future external costs in terms of current dollar values. The total full cost, as shown in Figure 6.4, increases slightly as a result of the offset of decreasing external costs and increasing other costs.

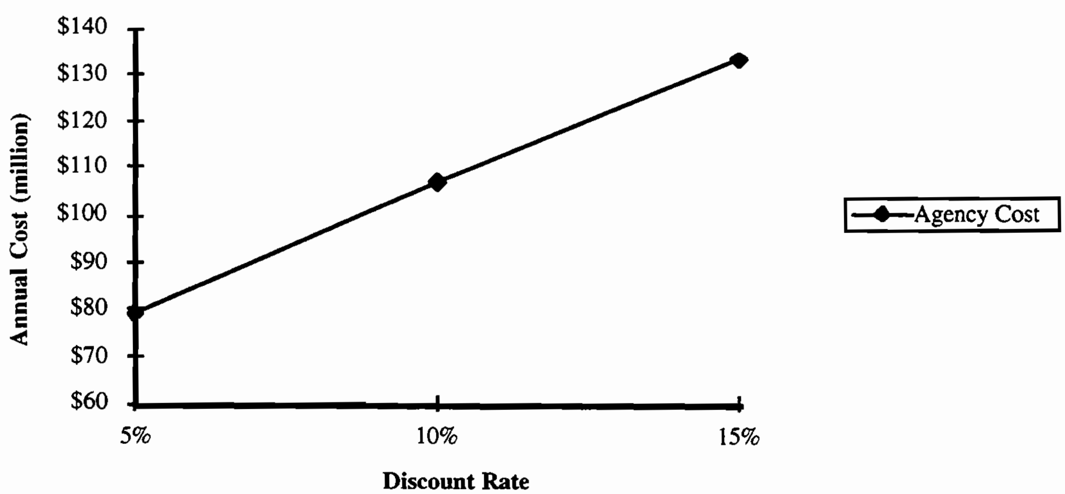


Figure 6.2 Annual agency cost of Alternative 6

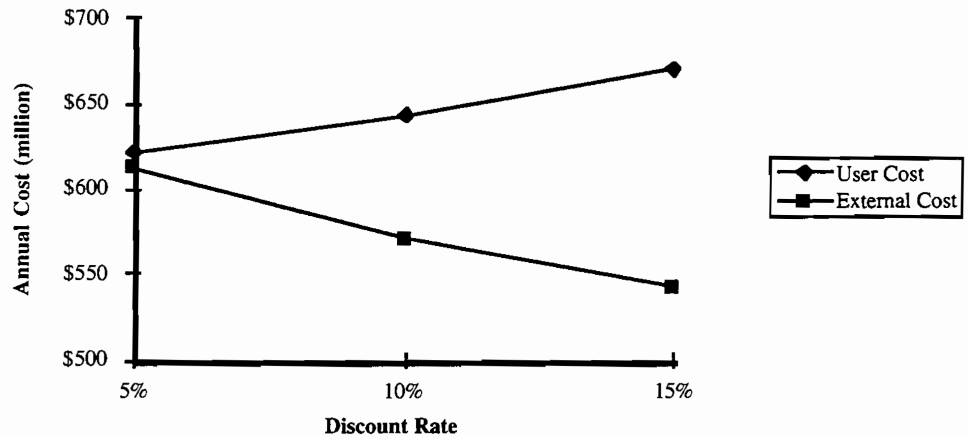


Figure 6.3 Annual user and external cost of Alternative 6

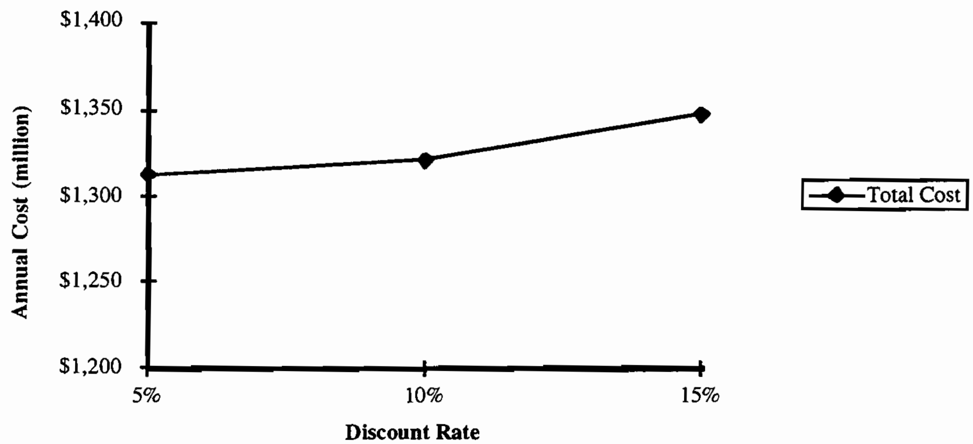


Figure 6.4 Annual total cost of Alternative 6

CHAPTER 7. CONCLUSION

This case study followed the development of MODECOST, a computer model capable of estimating the total costs of transportation alternatives for a given corridor. The estimations are based on the characteristics of the corridor, the characteristics of traffic on the corridor, the transportation modes to be evaluated, and the modal split. Appendix D contains sample screen captures of MODECOST's pull-down menus, as well as a printout from the model.

Our analysis of several transportation improvement alternatives indicates that as much as a 50 percent decrease in total transportation costs on the IH-10 Katy Freeway is possible relative to the base case alternative. This decrease in total transportation costs is relative to the current facility being used from the years 2000 through 2030. Compared with the potential total savings, including time savings and air pollution savings from easing congestion, the initial capital investment is relatively small.

As reported in a previous chapter, the current facility from downtown Houston to Katy cannot accommodate future traffic growth. The section from SH-6 to Katy is the poorest in terms of traffic delay and air pollution costs. The demand on the section will exceed the current capacity by 25 percent by the year 2000, and 80 percent by the year 2020; adding SOV and HOV lanes can result in tremendous savings.

We should point out that the current capacity of the section from Katy to Brookshire can adequately meet future demand. Adding a one-lane frontage road in each direction on this section improves travel time and air quality only slightly — too little in fact to offset the increased facility cost.

In their "Summary of Findings" (Ref 7), Parsons Brinckerhoff (PB) ranked the best transportation improvement alternative within each of four levels of investment strategies proposed (Moderate Investment, High Investment in SOV, High Investment in Transit, and High Investment in Transit and SOV). These four alternatives (Alternative 2 through Alternative 5), along with the base case alternative (Alternative 1), form the basis of this MODECOST case study. In addition, we added a sixth alternative (Alternative 6), which involved a rail option as well as improvements for HOV and SOV facilities. Alternative 6 is in fact based on a combination of PB alternatives described in their report (Ref 7).

In the base alternative, travel time and delay costs dominated the cost categories owing to the insufficient capacity of the facility. In alternative 2 through alternative 5, the user/agency costs account for the largest share, being responsible for almost 50 percent of the total cost.

Alternative 6, proposed by the CTR team in Chapter 6, includes the expansion of SOV and HOV facilities on the Katy Freeway, and the construction of a new fixed guideway system along the corridor. The calculation shows that this alternative provides the best results among all scenarios, based on the mode split used in the previous chapter. The sensitivity analysis illustrates that the annual full cost will increase as the discount rate climbs up.

As discussed earlier, full-cost analysis allows us to look at the transportation planning process from the perspective of an integrated system. Full-cost evaluations of urban transportation alternatives take into account not only initial capital investments, but also indirect social and environmental costs. If we use only initial investment as our "screen" criteria, we will obviously choose Alternative 2 as our final recommendation, as shown in Figure 7.1. From the perspective of full cost, however, Alternative 6 is the best choice, as shown in Figure 7.2. Compared with Alternative 1, Alternative 6 has an initial investment of $250 million more than Alternative 1, but it is capable of saving travelers $68 million per year over the next 30 years. Even compared with Alternatives 3 or 5, which have the best results among all alternatives proposed by Parsons Brinckerhoff, Alternative 6 has a clear advantage, based on its $56 million annual savings obtained largely from reductions in user and external costs. Figures 7.1 and 7.2 illustrate that when evaluating transportation alternatives, a full-cost approach has an obvious advantage over traditional transportation planning. Emphasizing initial capital investment could, over the long-term, create an inefficient transportation system.

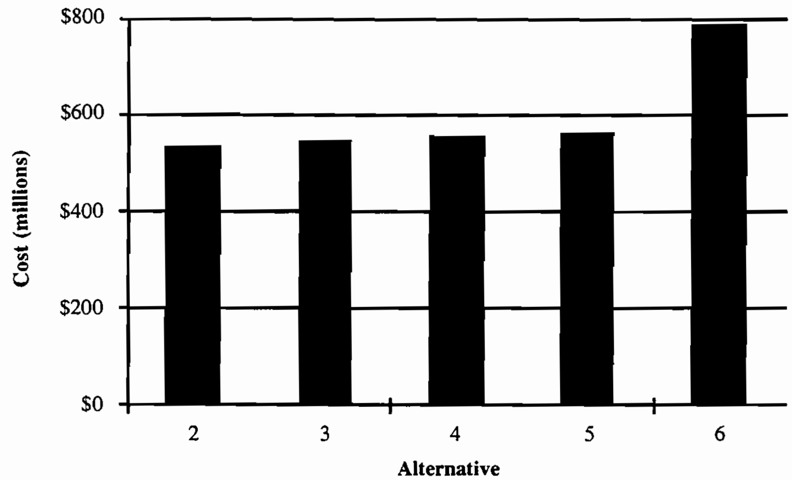


Figure 7.1 Initial investment by alternatives

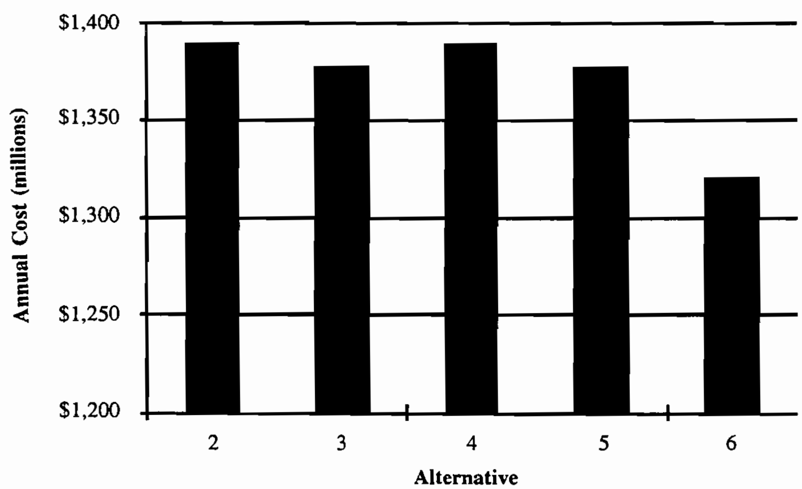


Figure 7.2 Annual cost by alternatives

The full-cost approach takes into account not only facility investment, but also external costs and user expenditures. The case study conducted in this report shows that, in many cases, the latter is more important than the former. The full-cost analysis results reported are effective not only in comparing alternatives, but also in enhancing qualitative assessments and planning/engineering judgment. The full-cost values calculated for the several alternatives can thus be used by policy-makers and transportation professionals as an assessment indicator.

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APPENDIX A

ESTIMATION OF FREIGHT TRUCK DEMAND AND TRUCK MIX

APPENDIX A

ESTIMATION OF FREIGHT TRUCK DEMAND AND TRUCK MIX

The following table lists the number and classification of vehicles observed on IH-10 Katy Freeway (west of the Harris County line) from August 28–29, 1993.

Table A-1. Vehicles Classified at Manual Count Station (MS-1200)

Vehicle Category		No. of Vehicles	Percentage	Occupancy
Personal Vehicles	Cars & Motorcycles	15,114	56.27%	1.11
	Pickups & Vans	9,994	37.20%	
	Sub-Total	**25,108**	**93.47%**	
Buses	Buses	65	0.24%	40.00
	Sub-Total	**65**	**0.24%**	
Freight Trucks	2-axle Single Unit	304	1.13%	1.00
	3/4-axle Single Unit	77	0.29%	
	3/4-axle Semi-Trailer	78	0.29%	
	5-axle Semi-Trailer	1,125	4.19%	
	6-axle Semi-Trailer	56	0.21%	
	5-axle Trailer	39	0.15%	
	6-axle Trailer	10	0.04%	
	Sub-Total	**1,689**	**6.29%**	
	Total	**26,862**	**100.00%**	

Source: Coastal Oxident Assessment for Southeast Texas, Texas Transportation Institute, 1993.

By using the average vehicle occupancies shown in the table above, we found the ratio of truck movements (in person-trips) to person movement demand (in person-trips) to be:

$$\frac{\text{Truck Demand}}{\text{Person Movement}} = \frac{6.29\% * 1.00}{93.47\% * 1.11 + 0.24\% * 40.00} = 5.55\%$$

The ratio of cars to pickups and vans is 60:40.

APPENDIX B

COST RESULTS OF SENSITIVITY ANALYSIS (5% DISCOUNT RATE)

APPENDIX B

COST RESULTS OF SENSITIVITY ANALYSIS (5% DISCOUNT RATE)

The following tables list the annual life-cycle costs of Alternatives 2 through 6 using the data described in Chapters 3 and 6, with the exception of discount rate, which is assumed to be 5 percent in this analysis.

Table B-1. Annual Cost of Alternative 2 with 5% Discount Rate (in million dollars)

Brazos River — Brookshire — Katy — SH-6 — Beltway 8 — I-610 — Downtown Houston

Alternative 2 Moderate HOV & Moderate SOV	FR (2) SOV (3)	FR (3) SOV (3)	FR (3) SOV (4) HOV (1)	FR (3) SOV (4) HOV (1)	FR (3) SOV (4) HOV (1)	FR (3) SOV (5) HOV (1)	**Total**
	5.15 miles	9.31 miles	9.44 miles	4.96 miles	6.63 miles	4.96 miles	40.45 miles
	SOV (3) FR (2)	SOV (3) FR (3)	HOV (1) SOV (4) FR (3)	HOV (1) SOV (4) FR (3)	HOV (1) SOV (4) FR (3)	HOV (1) SOV (5) FR (3)	

Annual Cost	**Agency**	**4.39**	**8.86**	**21.01**	**12.30**	**16.72**	**13.18**	**76.47**
	Highway Facility	4.39	8.86	12.54	5.94	8.33	7.73	47.80
	Transit Agency	0.00	0.00	8.47	6.36	8.39	5.45	28.67
	Auto User	**21.44**	**112.24**	**138.82**	**114.35**	**162.30**	**107.31**	**656.46**
	External	**16.21**	**84.06**	**144.09**	**132.51**	**174.92**	**108.21**	**660.00**
	Travel Time	6.55	35.69	66.89	69.88	88.49	50.60	318.09
	Air Pollution	3.21	14.61	20.91	17.20	22.91	15.76	94.60
	Incident Delay	2.17	11.37	21.25	17.06	23.76	15.64	91.26
	Accident	0.64	3.32	4.21	3.46	4.91	3.24	19.78
	Other External	3.64	19.07	30.83	24.91	34.86	22.97	136.27
	Total	**42.04**	**205.16**	**303.92**	**259.16**	**353.95**	**228.70**	**1392.93**

Initial Investment†	44.73	88.15	147.44	66.31	95.09	93.92	535.64

† Initial investment is the initial lump-sum highway facility cost, excluding mobilization and traffic control cost.

Table B-2. Annual Cost of Alternative 3 with 5% Discount Rate (in million dollars)

Alternative 3 Moderate HOV & High SOV	Brazos River – Brookshire	Brookshire – Katy	Katy – SH-6	SH-6 – Beltway 8	Beltway 8 – I-610	I-610 – Downtown Houston	Total
	FR (2) SOV (3)	FR (3) SOV (3)	FR (3) SOV (5) HOV (1)	FR (3) SOV (5) HOV (1)	FR (3) SOV (5) HOV (1)	FR (3) SOV (5) HOV (1)	
	5.15 miles	9.31 miles	9.44 miles	4.96 miles	6.63 miles	4.96 miles	40.45 miles
	SOV (3) FR (2)	SOV (3) FR (3)	HOV (1) SOV (5) FR (3)	HOV (1) SOV (5) FR (3)	HOV (1) SOV (5) FR (3)	HOV (1) SOV (5) FR (3)	

Annual Cost	**Agency**	**4.39**	**8.86**	**21.64**	**12.63**	**17.17**	**13.18**	**77.87**
	Highway Facility	4.39	8.86	13.17	6.27	8.77	7.73	49.20
	Transit Agency	0.00	0.00	8.47	6.36	8.39	5.45	28.67
	Auto User	**21.44**	**112.24**	**138.82**	**114.35**	**162.30**	**107.31**	**656.46**
	External	**16.21**	**84.06**	**143.67**	**119.38**	**163.47**	**108.21**	**634.99**
	Travel Time	6.55	35.69	65.64	57.25	76.90	50.60	292.63
	Air Pollution	3.21	14.61	21.74	16.69	23.05	15.76	95.05
	Incident Delay	2.17	11.37	21.25	17.06	23.76	15.64	91.26
	Accident	0.64	3.32	4.21	3.46	4.91	3.24	19.78
	Other External	3.64	19.07	30.83	24.91	34.86	22.97	136.27
	Total	**42.04**	**205.16**	**304.13**	**246.36**	**342.94**	**228.70**	**1369.33**

Initial Investment†	44.73	88.15	150.84	68.10	97.48	93.92	543.22

† Initial investment is the initial lump-sum highway facility cost, excluding mobilization and traffic control cost.

Table B-3. Annual Cost of Alternative 4 with 5% Discount Rate (in million dollars)

Brazos River | Brookshire | Katy | SH-6 | Beltway 8 | I-610 | Downtown Houston

Alternative 4 High HOV & Moderate SOV	Brazos River – Brookshire	Brookshire – Katy	Katy – SH-6	SH-6 – Beltway 8	Beltway 8 – I-610	I-610 – Downtown Houston	Total
	FR (2) SOV (3)	FR (3) SOV (3)	FR (3) SOV (4) HOV (1)	FR (3) SOV (4) HOV (2)	FR (3) SOV (4) HOV (2)	FR (3) SOV (5) HOV (1)	
	5.15 miles	9.31 miles	9.44 miles	4.96 miles	6.63 miles	4.96 miles	40.45 miles
	SOV (3) FR (2)	SOV (3) FR (3)	HOV (1) SOV (4) FR (3)	HOV (2) SOV (4) FR (3)	HOV (2) SOV (4) FR (3)	HOV (1) SOV (5) FR (3)	

Annual Cost	**Agency**	**4.39**	**8.86**	**21.01**	**12.78**	**17.35**	**13.18**	**77.57**
	Highway Facility	4.39	8.86	12.54	6.42	8.96	7.73	48.90
	Transit Agency	0.00	0.00	8.47	6.36	8.39	5.45	28.67
	Auto User	**21.44**	**112.24**	**138.82**	**114.35**	**162.30**	**107.31**	**656.46**
	External	**16.21**	**84.06**	**144.09**	**131.51**	**174.13**	**108.21**	**658.21**
	Travel Time	6.55	35.69	66.89	68.64	87.38	50.60	315.73
	Air Pollution	3.21	14.61	20.91	17.44	23.23	15.76	95.17
	Incident Delay	2.17	11.37	21.25	17.06	23.76	15.64	91.26
	Accident	0.64	3.32	4.21	3.46	4.91	3.24	19.78
	Other External	3.64	19.07	30.83	24.91	34.86	22.97	136.27
	Total	**42.04**	**205.16**	**303.92**	**258.64**	**353.79**	**228.70**	**1392.25**

Initial Investment†	44.73	88.15	147.44	74.57	106.13	93.92	554.93

† Initial investment is the initial lump-sum highway facility cost, excluding mobilization and traffic control cost.

Table B-4. Annual Cost of Alternative 5 with 5% Discount Rate (in million dollars)

Alternative 5 High HOV & High SOV	Brazos River – Brookshire	Brookshire – Katy	Katy – SH-6	SH-6 – Beltway 8	Beltway 8 – I-610	I-610 – Downtown Houston	Total
	FR (2) SOV (3)	FR (3) SOV (3)	FR (3) SOV (5) HOV (1)	FR (3) SOV (5) HOV (2)	FR (3) SOV (5) HOV (2)	FR (3) SOV (5) HOV (1)	
	5.15 miles	9.31 miles	9.44 miles	4.96 miles	6.63 miles	4.96 miles	40.45 miles
	SOV (3) FR (2)	SOV (3) FR (3)	HOV (1) SOV (5) FR (3)	HOV (2) SOV (5) FR (3)	HOV (2) SOV (5) FR (3)	HOV (1) SOV (5) FR (3)	

Annual Cost	**Agency**	**4.39**	**8.86**	**21.64**	**13.11**	**17.80**	**13.18**	**78.98**
	Highway Facility	4.39	8.86	13.17	6.75	9.41	7.73	50.30
	Transit Agency	0.00	0.00	8.47	6.36	8.39	5.45	28.67
	Auto User	**21.44**	**112.24**	**138.82**	**114.35**	**162.30**	**107.31**	**656.46**
	External	**16.21**	**84.06**	**143.67**	**118.38**	**162.68**	**108.21**	**633.21**
	Travel Time	6.55	35.69	65.64	56.02	75.79	50.60	290.27
	Air Pollution	3.21	14.61	21.74	16.93	23.37	15.76	95.62
	Incident Delay	2.17	11.37	21.25	17.06	23.76	15.64	91.26
	Accident	0.64	3.32	4.21	3.46	4.91	3.24	19.78
	Other External	3.64	19.07	30.83	24.91	34.86	22.97	136.27
	Total	**42.04**	**205.16**	**304.13**	**245.84**	**342.78**	**228.70**	**1368.64**

Initial Investment†	44.73	88.15	150.84	76.35	108.52	93.92	562.51

† Initial investment is the initial lump-sum highway facility cost, excluding mobilization and traffic control cost.

Table B-5 Annual Cost of Alternative 6 with 5% Discount Rate (in million dollars)

Alternative 6 Moderate HOV, Moderate SOV & Moderate Rail	Brazos River – Brookshire	Brookshire – Katy	Katy – SH-6	SH-6 – Beltway 8	Beltway 8 – I-610	I-610 – Downtown Houston	Total
	FR (2) SOV (3)	FR (2) SOV (3)	FR (3) SOV (4) HOV (1)	FR (3) SOV (4) HOV (1)	FR (3) SOV (4) HOV (1)	FR (3) SOV (5) HOV (1)	
	5.15 miles	9.31 miles	9.44 miles	4.96 miles	6.63 miles	4.96 miles	40.45 miles
	SOV (3) FR (2)	SOV (3) FR (2)	HOV (1) SOV (4) FR (3)	HOV (1) SOV (4) FR (3)	HOV (1) SOV (4) FR (3)	HOV (1) SOV (5) FR (3)	

Annual Cost	**Agency**	**4.39**	**7.26**	**21.51**	**13.66**	**17.82**	**14.33**	**78.97**
	Highway Facility	4.39	7.26	12.54	5.94	8.33	7.73	46.19
	Transit Agency	0.00	0.00	8.97	7.72	9.49	6.61	32.78
	Auto User	**21.44**	**112.24**	**128.34**	**106.55**	**152.07**	**100.68**	**621.32**
	External	**16.21**	**84.11**	**133.41**	**117.75**	**158.63**	**101.62**	**611.72**
	Travel Time	6.55	35.73	61.64	59.74	77.95	47.47	289.06
	Air Pollution	3.21	14.62	19.97	15.88	21.52	15.11	90.31
	Incident Delay	2.17	11.37	19.42	15.70	21.97	14.48	85.11
	Accident	0.64	3.32	3.92	3.24	4.62	3.06	18.80
	Other External	3.64	19.07	28.46	23.19	32.57	21.51	128.44
	Total	**42.04**	**203.61**	**283.25**	**237.96**	**328.52**	**216.64**	**1312.02**

Initial Investment	Highway†	44.73	71.79	147.44	66.31	95.09	93.92	519.28
	Rail*	0.00		266.14				266.14

† Initial investment of highway facility cost is the lump-sum roadway capital cost, excluding mobilization and traffic control cost.

* Initial investment of rail facility includes the initial lump-sum costs of rail vehicles, guideway, stations, ROW, yards and shops.

APPENDIX C

COST RESULTS OF SENSITIVITY ANALYSIS (15% DISCOUNT RATE)

APPENDIX C

COST RESULTS OF SENSITIVITY ANALYSIS (15% DISCOUNT RATE)

The following tables list the annual life-cycle cost of Alternatives 2 through 6 using the data described in Chapters 3 and 6, with the exception of the discount rate, which is assumed to be 15 percent in this analysis.

Table C-1. Annual Cost of Alternative 2 with 15% Discount Rate (in million dollars)

	Brazos River – Brookshire	Brookshire – Katy	Katy – SH-6	SH-6 – Beltway 8	Beltway 8 – I-610	I-610 – Downtown Houston	
Alternative 2 Moderate HOV & Moderate SOV	FR (2) SOV (3)	FR (3) SOV (3)	FR (3) SOV (4) HOV (1)	FR (3) SOV (4) HOV (1)	FR (3) SOV (4) HOV (1)	FR (3) SOV (5) HOV (1)	**Total**
	5.15 miles	9.31 miles	9.44 miles	4.96 miles	6.63 miles	4.96 miles	40.45 miles
	SOV (3) FR (2)	SOV (3) FR (3)	HOV (1) SOV (4) FR (3)	HOV (1) SOV (4) FR (3)	HOV (1) SOV (4) FR (3)	HOV (1) SOV (5) FR (3)	

Annual Cost	**Agency**	**8.75**	**17.42**	**34.09**	**18.42**	**25.42**	**21.34**	**125.44**
	Highway Facility	8.75	17.42	25.10	11.67	16.51	15.56	95.01
	Transit Agency	0.00	0.00	8.99	6.75	8.91	5.78	30.43
	Auto User	**23.14**	**121.12**	**158.79**	**123.40**	**175.14**	**115.80**	**717.39**
	External	**14.67**	**76.00**	**129.85**	**110.24**	**149.89**	**97.07**	**577.72**
	Travel Time	5.90	31.89	59.60	54.13	71.91	44.66	268.08
	Air Pollution	2.94	13.57	19.33	15.00	20.52	14.55	85.91
	Incident Delay	1.97	10.29	19.22	15.44	21.50	14.15	82.56
	Accident	0.57	3.01	3.81	3.13	4.44	2.93	17.89
	Other External	3.30	17.25	27.89	22.54	31.53	20.78	123.28
	Total	**46.56**	**214.54**	**322.73**	**252.06**	**350.46**	**234.21**	**1420.55**

Initial Investment†	44.73	88.15	147.44	66.31	95.09	93.92	535.64

† Initial investment is the initial lump-sum highway facility cost, excluding mobilization and traffic control cost.

Table C-2. Annual Cost of Alternative 3 with 15% Discount Rate (in million dollars)

Brazos River | Brookshire | Katy | SH-6 | Beltway 8 | I-610 | Downtown Houston

Alternative 3 Moderate HOV & High SOV							Total
	FR (2) SOV (3)	FR (3) SOV (3)	FR (3) SOV (5) HOV (1)	FR (3) SOV (5) HOV (1)	FR (3) SOV (5) HOV (1)	FR (3) SOV (5) HOV (1)	
	5.15 miles	9.31 miles	9.44 miles	4.96 miles	6.63 miles	4.96 miles	40.45 miles
	SOV (3) FR (2)	SOV (3) FR (3)	HOV (1) SOV (5) FR (3)	HOV (1) SOV (5) FR (3)	HOV (1) SOV (5) FR (3)	HOV (1) SOV (5) FR (3)	

Annual Cost	**Agency**	**8.75**	**17.42**	**35.00**	**18.90**	**26.06**	**21.34**	**127.47**
	Highway Facility	8.75	17.42	26.01	12.15	17.15	15.56	97.04
	Transit Agency	0.00	0.00	8.99	6.75	8.91	5.78	30.43
	Auto User	**23.14**	**121.12**	**158.79**	**123.40**	**175.14**	**115.80**	**717.39**
	External	**14.67**	**76.00**	**129.98**	**105.34**	**146.52**	**97.07**	**569.57**
	Travel Time	5.90	31.89	58.99	48.98	67.70	44.66	258.11
	Air Pollution	2.94	13.57	20.06	15.26	21.35	14.55	87.73
	Incident Delay	1.97	10.29	19.22	15.44	21.50	14.15	82.56
	Accident	0.57	3.01	3.81	3.13	4.44	2.93	17.89
	Other External	3.30	17.25	27.89	22.54	31.53	20.78	123.28
	Total	**46.56**	**214.54**	**323.76**	**247.64**	**347.72**	**234.21**	**1414.43**

Initial Investment†	44.73	88.15	150.84	68.10	97.48	93.92	543.22

† Initial investment is the initial lump-sum highway facility cost, excluding mobilization and traffic control cost.

Table C-3. Annual Cost of Alternative 4 with 15% Discount Rate (in million dollars)

Alternative 4 High HOV & Moderate SOV	Brazos River – Brookshire	Brookshire – Katy	Katy – SH-6	SH-6 – Beltway 8	Beltway 8 – I-610	I-610 – Downtown Houston	Total
	FR (2) SOV (3)	FR (3) SOV (3)	FR (3) SOV (4) HOV (1)	FR (3) SOV (4) HOV (2)	FR (3) SOV (4) HOV (2)	FR (3) SOV (5) HOV (1)	
	5.15 miles	9.31 miles	9.44 miles	4.96 miles	6.63 miles	4.96 miles	40.45 miles
	SOV (3) FR (2)	SOV (3) FR (3)	HOV (1) SOV (4) FR (3)	HOV (2) SOV (4) FR (3)	HOV (2) SOV (4) FR (3)	HOV (1) SOV (5) FR (3)	

Annual Cost	**Agency**	**8.75**	**17.42**	**34.09**	**19.36**	**26.67**	**21.34**	**127.63**
	Highway Facility	8.75	17.42	25.10	12.61	17.76	15.56	97.20
	Transit Agency	0.00	0.00	8.99	6.75	8.91	5.78	30.43
	Auto User	**23.14**	**121.12**	**158.79**	**123.40**	**175.14**	**115.80**	**717.39**
	External	**14.67**	**76.00**	**129.85**	**109.71**	**149.33**	**97.07**	**576.63**
	Travel Time	5.90	31.89	59.60	53.40	71.07	44.66	266.51
	Air Pollution	2.94	13.57	19.33	15.21	20.79	14.55	86.39
	Incident Delay	1.97	10.29	19.22	15.44	21.50	14.15	82.56
	Accident	0.57	3.01	3.81	3.13	4.44	2.93	17.89
	Other External	3.30	17.25	27.89	22.54	31.53	20.78	123.28
	Total	**46.56**	**214.54**	**322.73**	**252.47**	**351.14**	**234.21**	**1421.65**

Initial Investment†	44.73	88.15	147.44	74.57	106.13	93.92	554.93

† Initial investment is the initial lump-sum highway facility cost, excluding mobilization and traffic control cost.

Table C-4. Annual Cost of Alternative 5 with 15% Discount Rate (in million dollars)

	Brazos River – Brookshire	Brookshire – Katy	Katy – SH-6	SH-6 – Beltway 8	Beltway 8 – I-610	I-610 – Downtown Houston	Total
Alternative 5 High HOV & High SOV	FR (2) SOV (3)	FR (3) SOV (3)	FR (3) SOV (5) HOV (1)	FR (3) SOV (5) HOV (2)	FR (3) SOV (5) HOV (2)	FR (3) SOV (5) HOV (1)	
	5.15 miles	9.31 miles	9.44 miles	4.96 miles	6.63 miles	4.96 miles	40.45 miles
	SOV (3) FR (2)	SOV (3) FR (3)	HOV (1) SOV (5) FR (3)	HOV (2) SOV (5) FR (3)	HOV (2) SOV (5) FR (3)	HOV (1) SOV (5) FR (3)	

Annual Cost	**Agency**	**8.75**	**17.42**	**35.00**	**19.84**	**27.31**	**21.34**	**129.66**
	Highway Facility	8.75	17.42	26.01	13.09	18.40	15.56	99.23
	Transit Agency	0.00	0.00	8.99	6.75	8.91	5.78	30.43
	Auto User	**23.14**	**121.12**	**158.79**	**123.40**	**175.14**	**115.80**	**717.39**
	External	**14.67**	**76.00**	**129.98**	**104.81**	**145.95**	**97.07**	**568.47**
	Travel Time	5.90	31.89	58.99	48.25	66.87	44.66	256.54
	Air Pollution	2.94	13.57	20.06	15.46	21.62	14.55	88.20
	Incident Delay	1.97	10.29	19.22	15.44	21.50	14.15	82.56
	Accident	0.57	3.01	3.81	3.13	4.44	2.93	17.89
	Other External	3.30	17.25	27.89	22.54	31.53	20.78	123.28
	Total	**46.56**	**214.54**	**323.76**	**248.05**	**348.41**	**234.21**	**1415.53**

Initial Investment†	44.73	88.15	150.84	76.35	108.52	93.92	562.51

† Initial investment is the initial lump-sum highway facility cost, excluding mobilization and traffic control cost.

Table C-5 Annual Cost of Alternative 6 with 15% Discount Rate (in million dollars)

	Brazos River – Brookshire	Brookshire – Katy	Katy – SH-6	SH-6 – Beltway 8	Beltway 8 – I-610	I-610 – Downtown Houston	Total
Alternative 6 Moderate HOV, Moderate SOV & Moderate Rail	FR (2) SOV (3)	FR (2) SOV (3)	FR (3) SOV (4) HOV (1)	FR (3) SOV (4) HOV (1)	FR (3) SOV (4) HOV (1)	FR (3) SOV (5) HOV (1)	**Total**
	5.15 miles	9.31 miles	9.44 miles	4.96 miles	6.63 miles	4.96 miles	40.45 miles
	SOV (3) FR (2)	SOV (3) FR (2)	HOV (1) SOV (4) FR (3)	HOV (1) SOV (4) FR (3)	HOV (1) SOV (4) FR (3)	HOV (1) SOV (5) FR (3)	

Annual Cost	**Agency**	**8.75**	**14.22**	**35.94**	**21.74**	**28.42**	**24.16**	**133.24**
	Highway Facility	8.75	14.22	25.10	11.67	16.51	15.56	91.81
	Transit Agency	0.00	0.00	10.84	10.07	11.91	8.60	41.43
	Auto User	**23.14**	**121.12**	**138.49**	**114.97**	**164.11**	**108.65**	**670.48**
	External	**14.67**	**76.04**	**120.70**	**100.90**	**139.11**	**91.75**	**543.17**
	Travel Time	5.90	31.92	55.37	48.62	65.97	42.43	250.20
	Air Pollution	2.94	13.58	18.47	14.17	19.62	14.00	82.78
	Incident Delay	1.97	10.29	17.57	14.20	19.88	13.10	77.00
	Accident	0.57	3.01	3.55	2.93	4.18	2.77	17.00
	Other External	3.30	17.25	25.75	20.98	29.47	19.45	116.19
	Total	**46.56**	**211.38**	**295.13**	**237.62**	**331.64**	**224.57**	**1346.88**

Initial Investment	Highway†	44.73	71.79	147.44	66.31	95.09	93.92	519.28
	Rail*	0.00		266.14				266.14

† Initial investment of highway facility cost is the lump-sum roadway capital cost, excluding mobilization and traffic control cost.

* Initial investment of rail facility includes the initial lump-sum costs of rail vehicles, guideway, stations, ROW, yards and shops.

APPENDIX D

INPUT AND OUTPUT DATA OF MODECOST

APPENDIX D

INPUT AND OUTPUT DATA OF MODECOST

Since we divided the entire corridor into six segments, there are a total of twelve runs for each alternative (main lanes plus frontage roads for each segment). Owing to space limitations, we provide only a sample of the input and output data.

The following are the input and output data from the analysis of the main lanes (SOV and HOV lanes) on segment 2, which runs from IH-610 to Beltway 8, in Alternative 6.

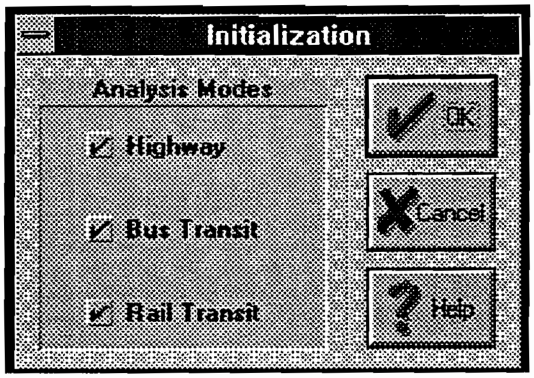

Figure D-1. Input Dialog Box 1 -- Initialization

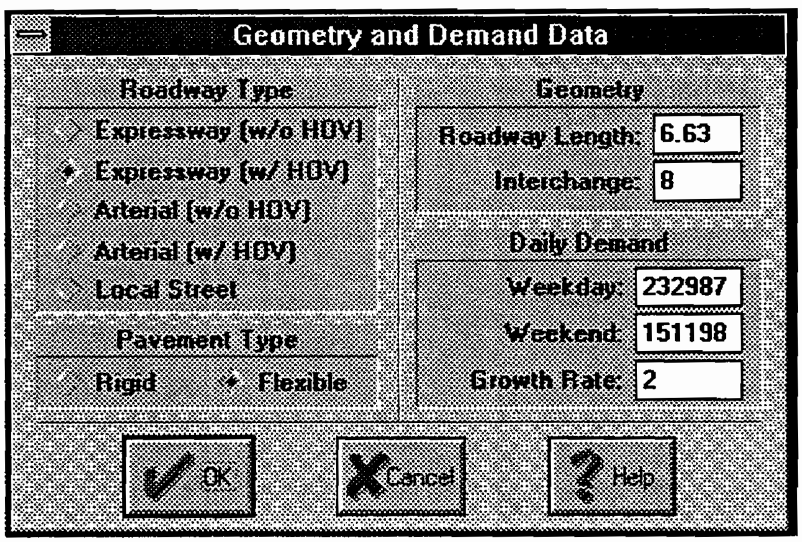

Figure D-2. Input Dialog Box 2 -- Geometry and Demand Data

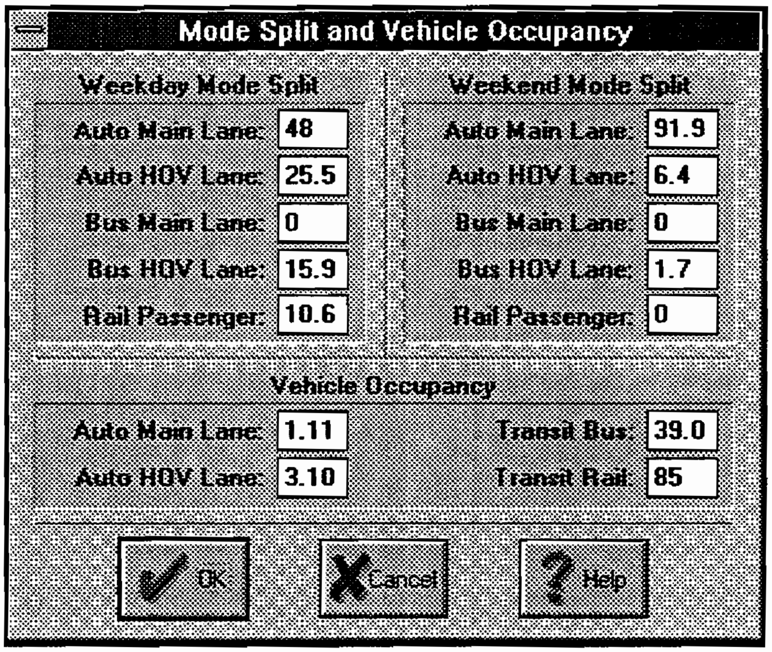

Figure D-3. Input Dialog Box 3 -- Mode Split and Occupancy Data

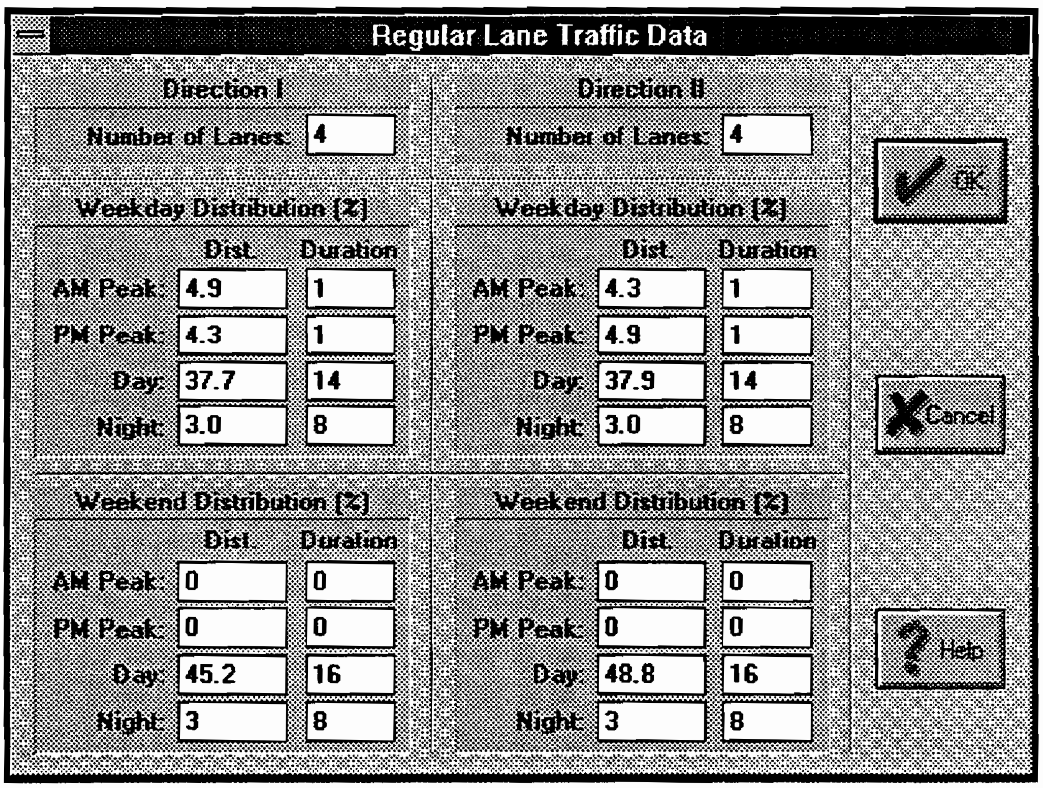

Figure D-4. Input Dialog Box 4 -- Regular Lane Traffic Data

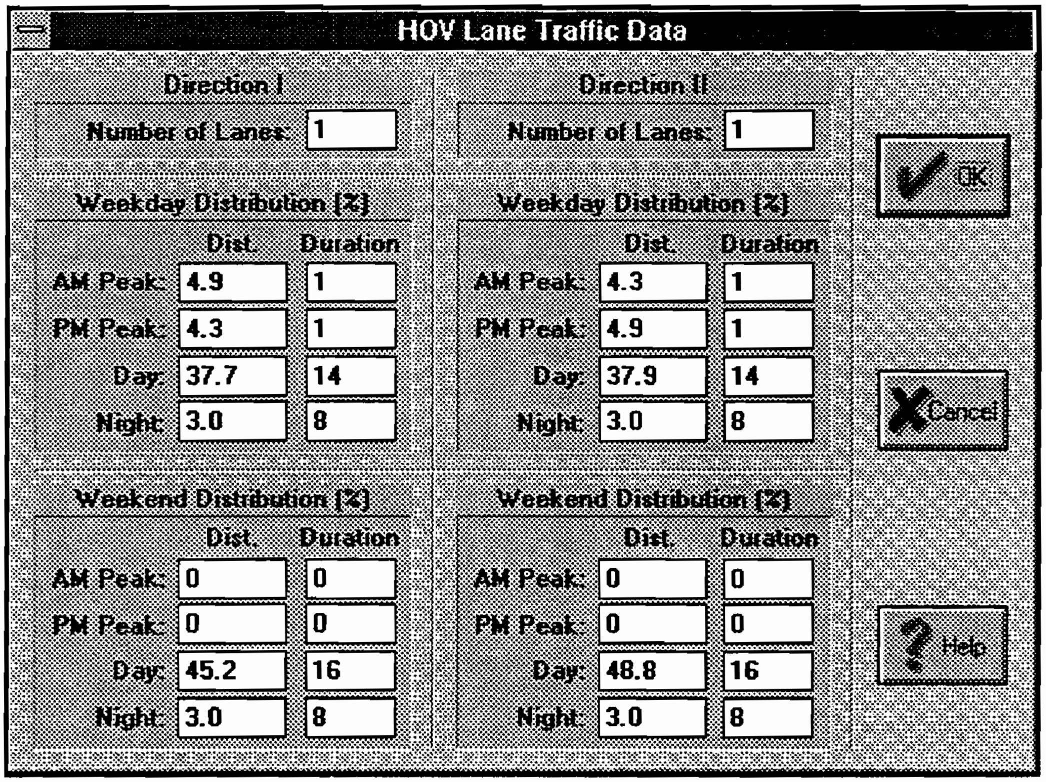

Figure D-5. Input Dialog Box 5 -- HOV Lane Traffic Data

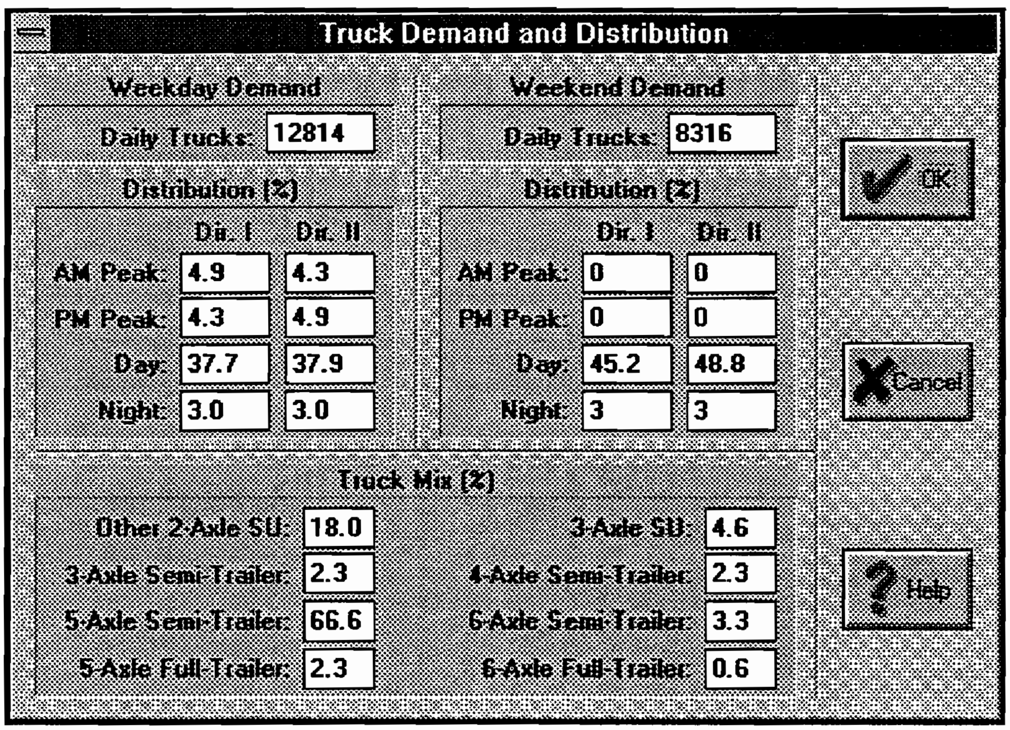

Figure D-6. Input Dialog Box 6 -- Truck Data

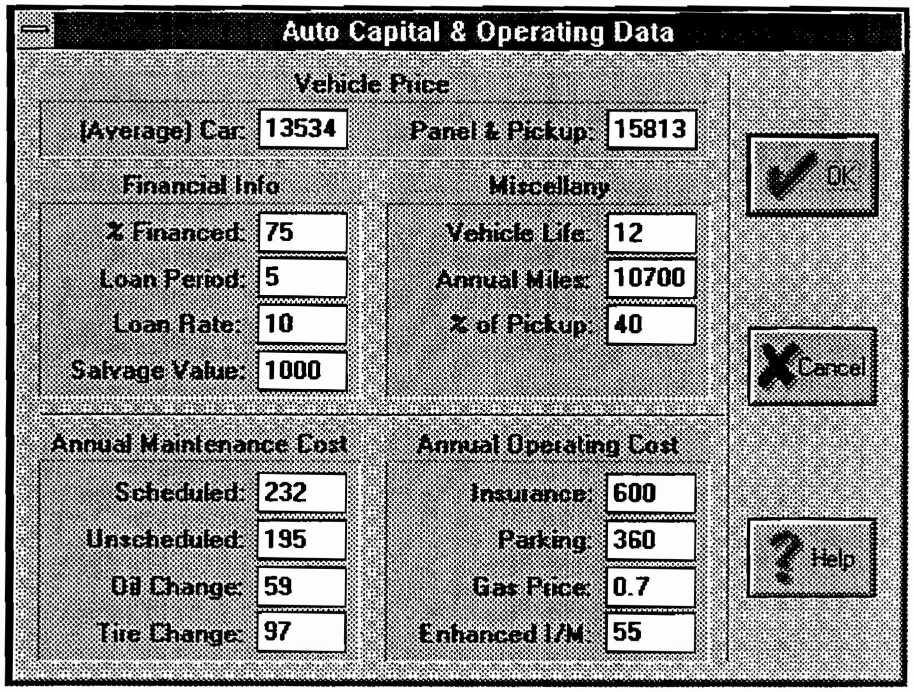

Figure D-7. Input Dialog Box 7 -- Auto Capital and Operating Data

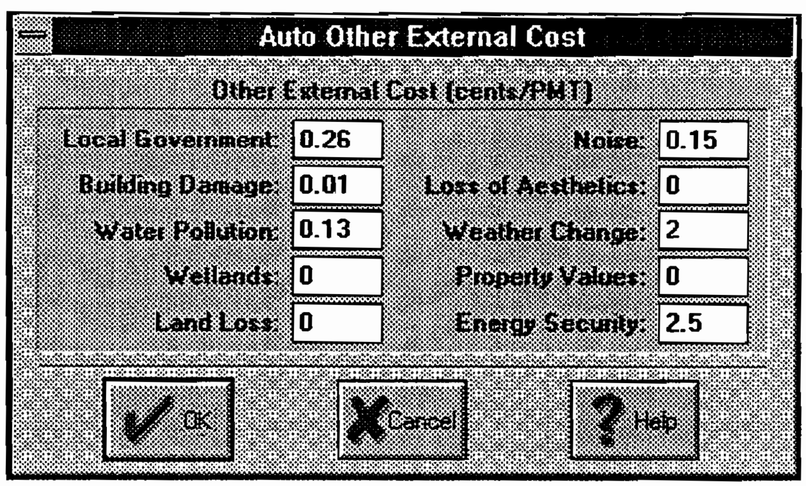

Figure D-8. Input Dialog Box 8 -- Auto External Data

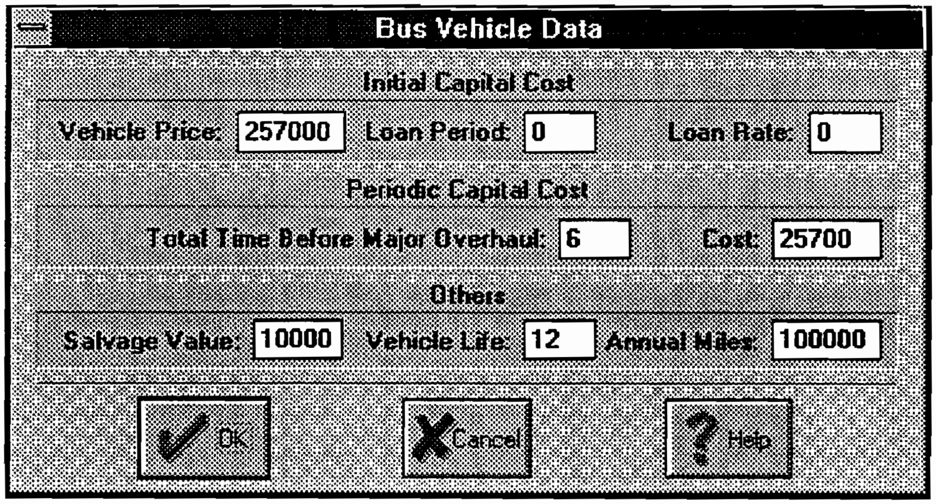

Figure D-9. Input Dialog Box 9 -- Bus Vehicle Data

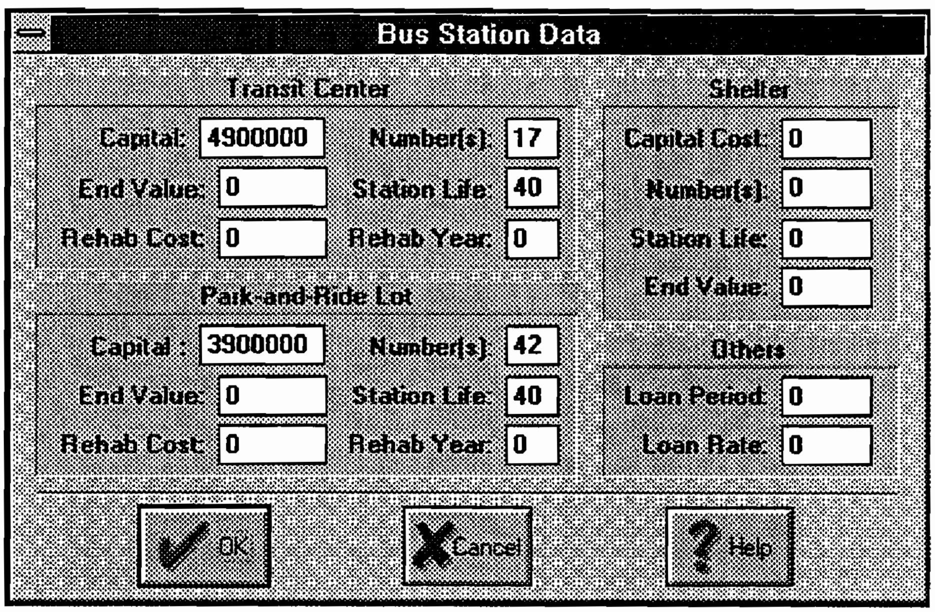

Figure D-10. Input Dialog Box 10 -- Bus Station Data

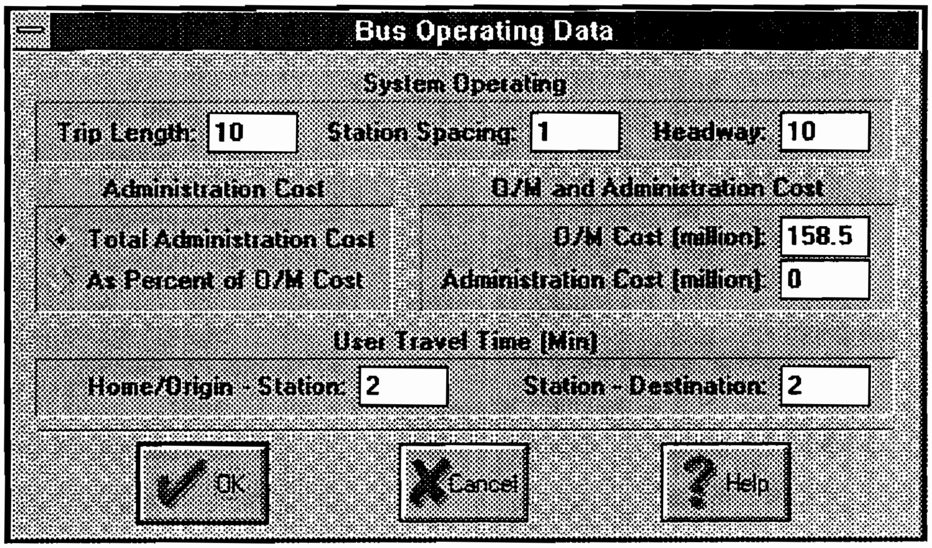

Figure D-11. Input Dialog Box 11 -- Bus Operating Data

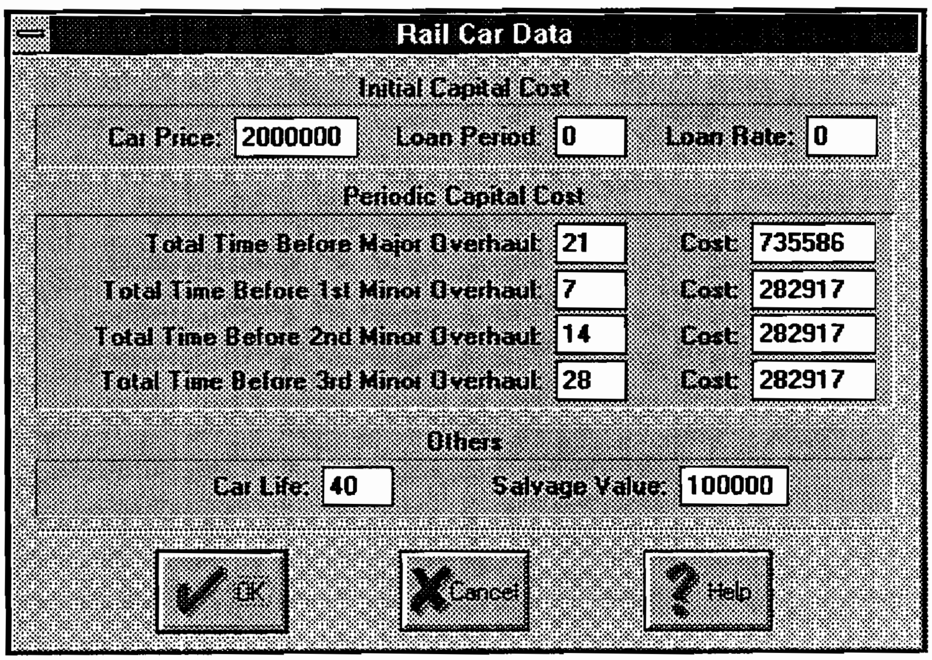

Figure D-12. Input Dialog Box 12 -- Rail Car Data

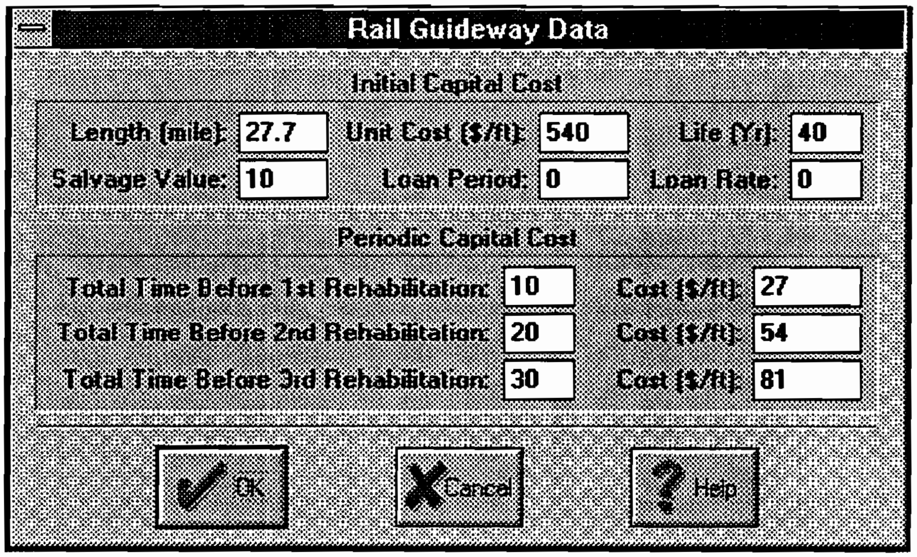

Figure D-13. Input Dialog Box 13 -- Rail Guideway Data

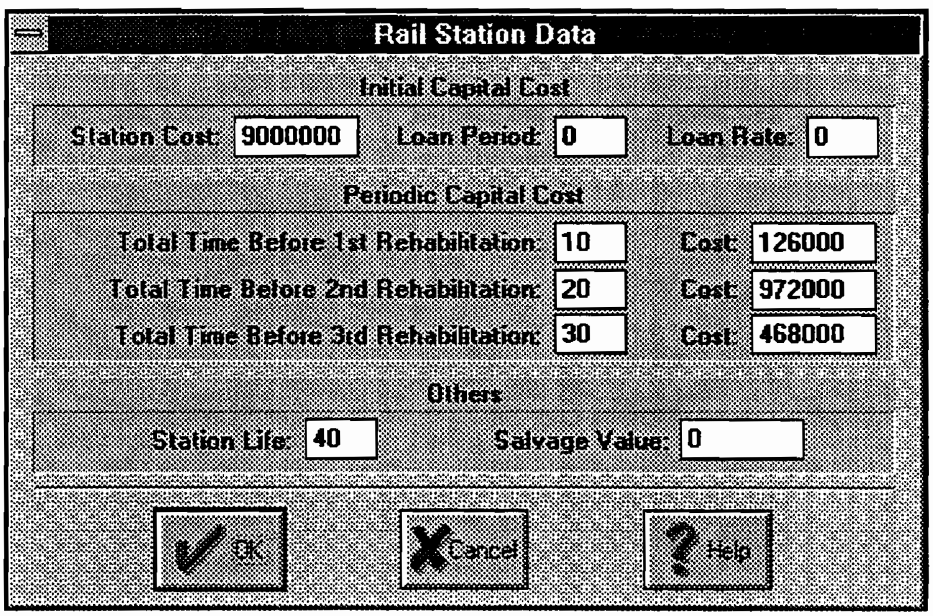

Figure D-14. Input Dialog Box 14 -- Rail Station Data

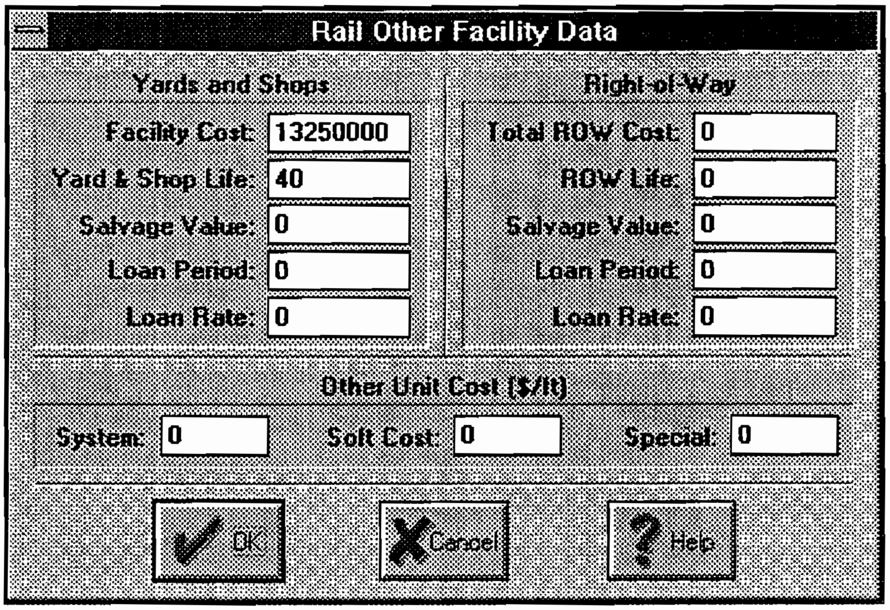

Figure D-15. Input Dialog Box 15 -- Rail Other Facility Data

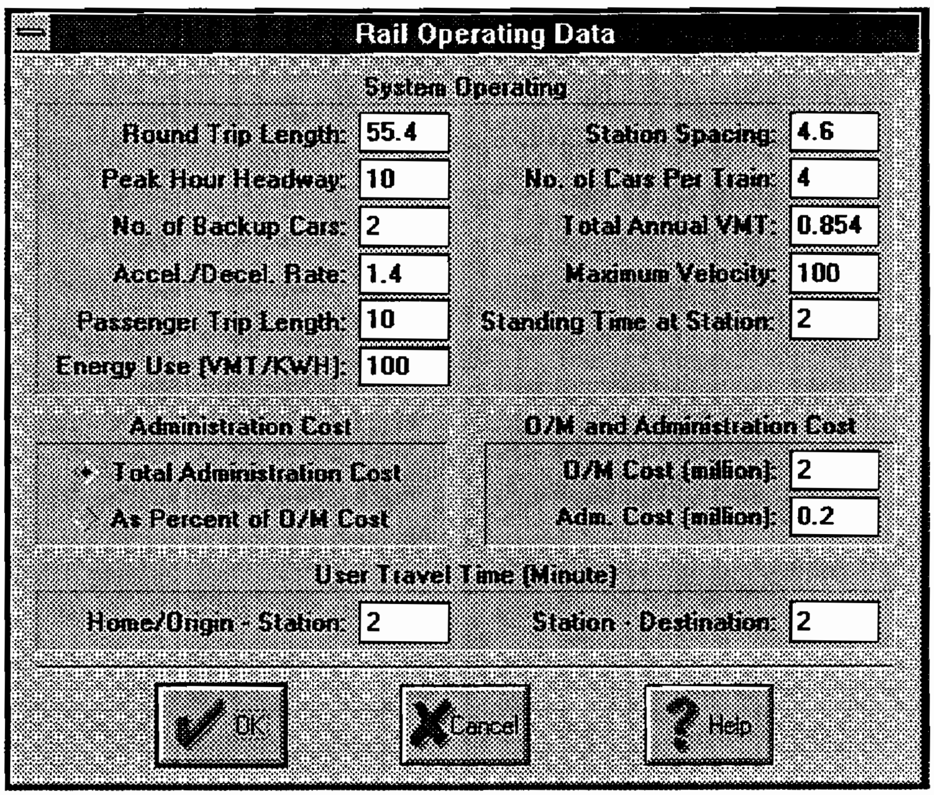

Figure D-16. Input Dialog Box 16 -- Rail Operating Data

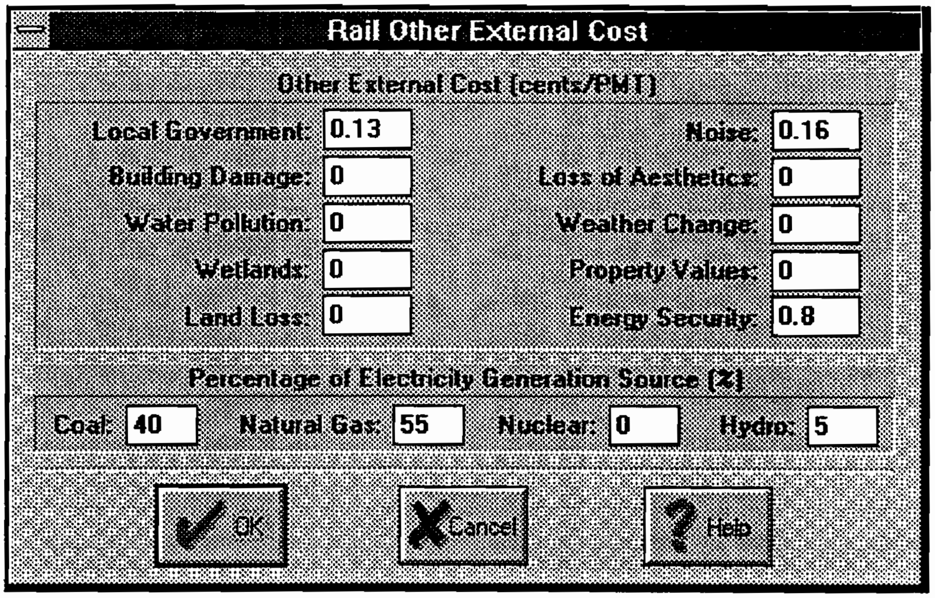

Figure D-17. Input Dialog Box 17 -- Rail External Data

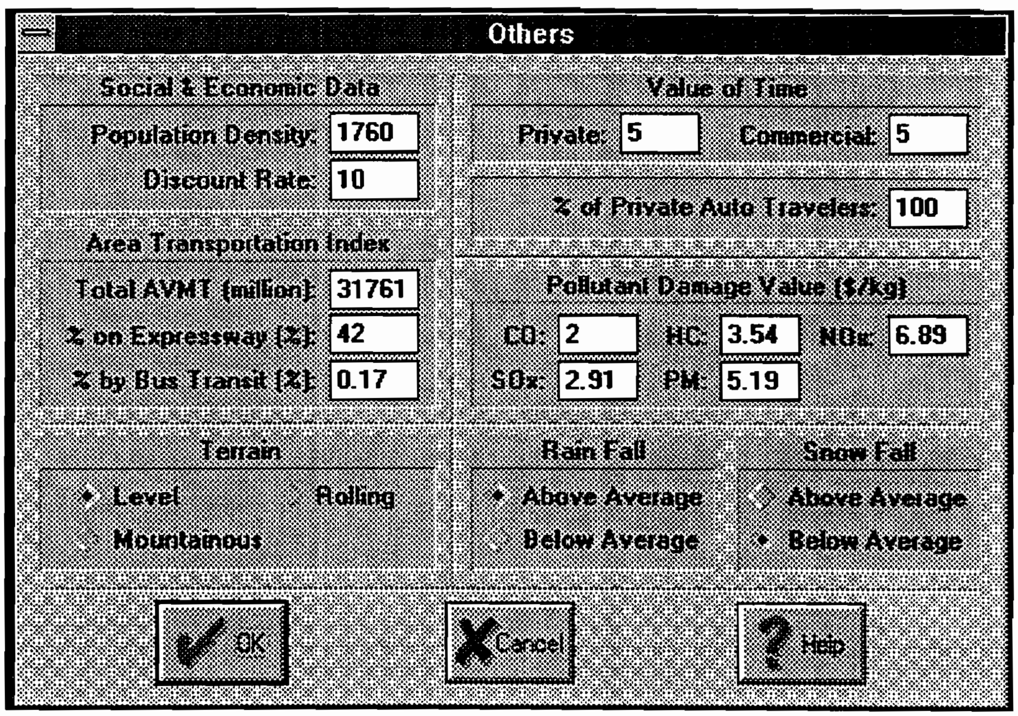

Figure D-18. Input Dialog Box 18 -- Other Data

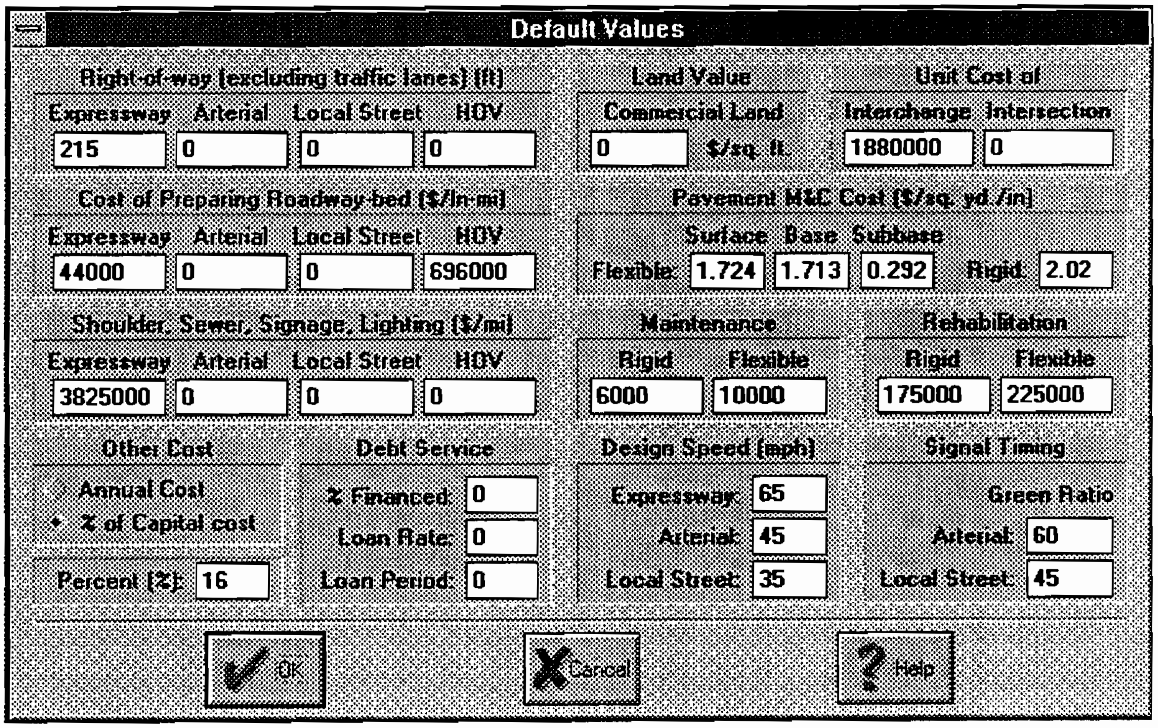

Figure D-19. Input Dialog Box 19 -- Default Data

OUTPUT (E:\FULLCOST\RAIL_2M.OUT)

1. Auto and/or Bus

Roadway Section (Main Lane):

Annual Cost (in $/yr) by Modes

Mode	Auto & Pickup	Bus	Truck	Total
Facility Cost	4,041,802	0	3,072,816	7,114,618
Travel Time Cost	32,841,056	0	3,205,286	36,046,344
Air Pollution Cost	11,517,782	0	4,926,073	16,443,855
Incident Delay Cost	11,482,893	0	1,105,730	12,588,623
Accident Cost	3,009,551	0	321,679	3,331,230
Other External Cost	17,373,878	0	1,672,994	19,046,872
User/Agency Cost	118,415,400	0	0	118,415,400

Highway Facility Cost

	Annual Cost ($/yr)	Initial Lump-Sum ($)
Right-of-way	0	0
Cost of Preparing Roadway-Bed	247,564	2,333,760
Shoulder, Sewer, Signage, Lighting	2,690,143	25,359,750
Cost of Interchange/Intersection	1,595,432	15,040,000
Pavement Cost	766,694	7,227,562
Rehabilitation Cost	303,058	-
Annual Maintenance Cost	530,400	-
Cost of Administration, Safety, etc.	981,327	-

Travel Time Cost (in $/yr) of Different Periods (Unit Cost: $/PMT)

Period (Direction)	Auto & Pickup	Bus	Truck
Weekday AM Peak (1)	2,146,824 (0.168)	0 (0.000)	245,985 (0.168)
Weekday PM Peak (1)	1,179,249 (0.105)	0 (0.000)	135,119 (0.105)
Weekday Day (1)	7,441,607 (0.076)	0 (0.000)	852,665 (0.076)
Weekday Night (1)	535,853 (0.069)	0 (0.000)	61,398 (0.069)
Weekend AM Peak (1)	0 (0.000)	0 (0.000)	0 (0.000)
Weekend PM Peak (1)	0 (0.000)	0 (0.000)	0 (0.000)
Weekend Day (1)	4,604,194 (0.078)	0 (0.000)	275,554 (0.078)
Weekend Night (1)	269,385 (0.069)	0 (0.000)	16,122 (0.069)
Weekday AM Peak (2)	1,179,249 (0.105)	0 (0.000)	135,119 (0.105)
Weekday PM Peak (2)	2,146,824 (0.168)	0 (0.000)	245,985 (0.168)
Weekday Day (2)	7,486,584 (0.076)	0 (0.000)	857,819 (0.076)
Weekday Night (2)	535,853 (0.069)	0 (0.000)	61,398 (0.069)
Weekend AM Peak (2)	0 (0.000)	0 (0.000)	0 (0.000)
Weekend PM Peak (2)	0 (0.000)	0 (0.000)	0 (0.000)
Weekend Day (2)	5,046,047 (0.079)	0 (0.000)	301,998 (0.079)
Weekend Night (2)	269,385 (0.069)	0 (0.000)	16,122 (0.069)

Pollution Cost (in $/yr) of Different Periods (Unit Cost: $/PMT)

Period (Direction)	Auto & Pickup	Bus	Truck
Weekday AM Peak (1)	405,862 (0.032)	0 (0.000)	186,472 (0.127)
Weekday PM Peak (1)	294,423 (0.026)	0 (0.000)	154,909 (0.121)
Weekday Day (1)	2,918,230 (0.030)	0 (0.000)	1,482,794 (0.132)
Weekday Night (1)	320,011 (0.041)	0 (0.000)	139,094 (0.155)
Weekend AM Peak (1)	0 (0.000)	0 (0.000)	0 (0.000)
Weekend PM Peak (1)	0 (0.000)	0 (0.000)	0 (0.000)
Weekend Day (1)	1,624,625 (0.027)	0 (0.000)	447,407 (0.126)
Weekend Night (1)	159,522 (0.041)	0 (0.000)	36,332 (0.155)
Weekday AM Peak (2)	294,423 (0.026)	0 (0.000)	154,909 (0.121)
Weekday PM Peak (2)	405,862 (0.032)	0 (0.000)	186,472 (0.127)
Weekday Day (2)	2,927,512 (0.030)	0 (0.000)	1,489,025 (0.132)
Weekday Night (2)	320,011 (0.041)	0 (0.000)	139,094 (0.155)
Weekend AM Peak (2)	0 (0.000)	0 (0.000)	0 (0.000)
Weekend PM Peak (2)	0 (0.000)	0 (0.000)	0 (0.000)
Weekend Day (2)	1,687,779 (0.026)	0 (0.000)	473,235 (0.124)
Weekend Night (2)	159,522 (0.041)	0 (0.000)	36,332 (0.155)

Roadway Section (HOV Lane):

Annual Cost (in $/yr) by Modes

Mode	Auto & Pickup	Bus	Truck	Total
Facility Cost	1,917,035	75,908	0	1,992,943
Travel Time Cost	10,764,698	12,340,262	0	23,104,960
Air Pollution Cost	1,777,508	210,647	0	1,988,154
Incident Delay Cost	4,329,252	2,603,789	0	6,933,042
Accident Cost	406,279	0	0	406,279
Other External Cost	6,550,259	1,482,222	0	8,032,482
User/Agency Cost	15,985,683	7,595,762	0	23,581,444

Highway Facility Cost

	Annual Cost ($/yr)	Initial Lump-Sum ($)
Right-of-way	0	0
Cost of Preparing Roadway-Bed	979,001	9,228,960
Shoulder, Sewer, Signage, Lighting	0	0
Cost of Interchange/Intersection	1,595,432	15,040,000
Pavement Cost	191,674	1,806,890
Rehabilitation Cost	75,765	-
Annual Maintenance Cost	132,600	-
Cost of Administration, Safety, etc.	475,915	-

Travel Time Cost (in $/yr) of Different Periods (Unit Cost: $/PMT)

Period (Direction)	Auto & Pickup	Bus	Truck
Weekday AM Peak (1)	530,934 (0.078)	609,932 (0.144)	0 (0.000)
Weekday PM Peak (1)	455,593 (0.077)	528,806 (0.142)	0 (0.000)
Weekday Day (1)	3,790,411 (0.073)	4,509,091 (0.139)	0 (0.000)
Weekday Night (1)	283,396 (0.068)	347,448 (0.134)	0 (0.000)
Weekend AM Peak (1)	0 (0.000)	0 (0.000)	0 (0.000)
Weekend PM Peak (1)	0 (0.000)	0 (0.000)	0 (0.000)
Weekend Day (1)	281,314 (0.068)	146,808 (0.134)	0 (0.000)
Weekend Night (1)	18,499 (0.068)	9,698 (0.134)	0 (0.000)
Weekday AM Peak (2)	455,593 (0.077)	528,806 (0.142)	0 (0.000)
Weekday PM Peak (2)	530,934 (0.078)	609,932 (0.144)	0 (0.000)
Weekday Day (2)	3,812,145 (0.073)	4,534,026 (0.139)	0 (0.000)
Weekday Night (2)	283,396 (0.068)	347,448 (0.134)	0 (0.000)
Weekend AM Peak (2)	0 (0.000)	0 (0.000)	0 (0.000)
Weekend PM Peak (2)	0 (0.000)	0 (0.000)	0 (0.000)
Weekend Day (2)	303,982 (0.068)	158,571 (0.134)	0 (0.000)
Weekend Night (2)	18,499 (0.068)	9,698 (0.134)	0 (0.000)

Pollution Cost (in $/yr) of Different Periods (Unit Cost: $/PMT)

Period (Direction)	Auto & Pickup	Bus	Truck
Weekday AM Peak (1)	65,954 (0.010)	10,166 (0.002)	0 (0.000)
Weekday PM Peak (1)	61,486 (0.010)	8,881 (0.002)	0 (0.000)
Weekday Day (1)	630,806 (0.012)	77,144 (0.002)	0 (0.000)
Weekday Night (1)	61,831 (0.015)	6,084 (0.002)	0 (0.000)
Weekend AM Peak (1)	0 (0.000)	0 (0.000)	0 (0.000)
Weekend PM Peak (1)	0 (0.000)	0 (0.000)	0 (0.000)
Weekend Day (1)	60,929 (0.015)	2,569 (0.002)	0 (0.000)
Weekend Night (1)	4,177 (0.015)	170 (0.002)	0 (0.000)
Weekday AM Peak (2)	61,486 (0.010)	8,881 (0.002)	0 (0.000)
Weekday PM Peak (2)	65,954 (0.010)	10,166 (0.002)	0 (0.000)
Weekday Day (2)	633,294 (0.012)	77,558 (0.002)	0 (0.000)
Weekday Night (2)	61,831 (0.015)	6,084 (0.002)	0 (0.000)
Weekend AM Peak (2)	0 (0.000)	0 (0.000)	0 (0.000)
Weekend PM Peak (2)	0 (0.000)	0 (0.000)	0 (0.000)
Weekend Day (2)	65,584 (0.015)	2,774 (0.002)	0 (0.000)
Weekend Night (2)	4,177 (0.015)	170 (0.002)	0 (0.000)

2. Rail

Vehicle Cost:	$ 1,931,510	($0.22/Rail-PMT)
Guideway Cost:	$ 1,790,859	($0.21/Rail-PMT)
Station Cost:	$ 1,604,592	($0.18/Rail-PMT)
ROW Cost:	$ 0	($0.00/Rail-PMT)
Yard & Shop Cost:	$ 288,247	($0.03/Rail-PMT)
Operating Cost:	$ 468,025	($0.05/Rail-PMT)
Pollution Cost:	$ 28	($0.00/Rail-PMT)
Travel Time Cost:	$ 1,508,723	($0.17/Rail-PMT)
Other External Cost:	$ 83,172	($0.01/Rail-PMT)

Cost (million $) by year and by categories: Auto Main Lane

Year	Facility	Time	Air Pollut	Inci Delay	Accident	External	User/Age
1	4.042	24.709	10.140	9.663	2.533	14.620	99.647
2	4.042	25.268	10.270	9.856	2.583	14.913	101.640
3	4.042	25.842	10.400	10.053	2.635	15.211	103.673
4	4.042	26.430	10.530	10.254	2.688	15.515	105.747
5	4.042	27.034	10.660	10.459	2.741	15.825	107.862
6	4.042	27.655	10.790	10.669	2.796	16.142	110.019
7	4.042	28.293	10.920	10.882	2.852	16.465	112.219
8	4.042	28.948	11.049	11.100	2.909	16.794	114.464
9	4.042	29.621	11.178	11.322	2.967	17.130	116.753
10	4.042	30.314	11.307	11.548	3.027	17.473	119.088
11	4.042	31.026	11.436	11.779	3.087	17.822	121.470
12	4.042	31.759	11.564	12.015	3.149	18.178	123.899
13	4.042	32.514	11.691	12.255	3.212	18.542	126.377
14	4.042	33.291	11.818	12.500	3.276	18.913	128.905
15	4.042	34.092	11.945	12.750	3.342	19.291	131.483
16	4.042	36.838	12.267	13.005	3.408	19.677	134.112
17	4.042	39.009	12.636	13.265	3.477	20.070	136.795
18	4.042	41.283	12.979	13.530	3.546	20.472	139.530
19	4.042	43.667	13.305	13.801	3.617	20.881	142.321
20	4.042	46.164	13.626	14.077	3.689	21.299	145.167
21	4.042	48.781	13.946	14.359	3.763	21.725	148.071
22	4.042	51.522	14.272	14.646	3.839	22.159	151.032
23	4.042	56.838	14.902	14.939	3.915	22.603	154.053
24	4.042	61.196	15.477	15.237	3.994	23.055	157.134
25	4.042	65.775	16.041	15.542	4.073	23.516	160.277
26	4.042	70.586	16.607	15.853	4.155	23.986	163.482
27	4.042	75.639	17.183	16.170	4.238	24.466	166.752
28	4.042	80.946	17.776	16.494	4.323	24.955	170.087
29	4.042	86.518	18.391	16.823	4.409	25.454	173.489
30	4.042	92.369	19.031	17.160	4.497	25.963	176.958

Cost (million $) by year and by categories: Auto HOV Lane

Year	Facility	Time	Air Pollut	Inci Delay	Accident	External	User/Age
1	1.917	8.917	1.564	3.643	0.342	5.512	13.452
2	1.917	9.108	1.589	3.716	0.349	5.622	13.721
3	1.917	9.303	1.613	3.790	0.356	5.735	13.996
4	1.917	9.503	1.639	3.866	0.363	5.849	14.275
5	1.917	9.707	1.664	3.943	0.370	5.966	14.561
6	1.917	9.916	1.690	4.022	0.377	6.086	14.852
7	1.917	10.130	1.715	4.103	0.385	6.208	15.149
8	1.917	10.349	1.742	4.185	0.393	6.332	15.452
9	1.917	10.574	1.768	4.268	0.401	6.458	15.761
10	1.917	10.803	1.794	4.354	0.409	6.587	16.076
11	1.917	11.038	1.821	4.441	0.417	6.719	16.398
12	1.917	11.279	1.848	4.530	0.425	6.854	16.726
13	1.917	11.526	1.875	4.620	0.434	6.991	17.060
14	1.917	11.778	1.902	4.713	0.442	7.130	17.402
15	1.917	12.037	1.930	4.807	0.451	7.273	17.750
16	1.917	12.302	1.957	4.903	0.460	7.419	18.105
17	1.917	12.574	1.985	5.001	0.469	7.567	18.467
18	1.917	12.852	2.013	5.101	0.479	7.718	18.836
19	1.917	13.138	2.041	5.203	0.488	7.873	19.213
20	1.917	13.431	2.070	5.307	0.498	8.030	19.597
21	1.917	13.731	2.098	5.413	0.508	8.191	19.989
22	1.917	14.039	2.126	5.522	0.518	8.354	20.389
23	1.917	14.354	2.155	5.632	0.529	8.522	20.797
24	1.917	14.679	2.184	5.745	0.539	8.692	21.213
25	1.917	15.011	2.212	5.860	0.550	8.866	21.637
26	1.917	15.353	2.241	5.977	0.561	9.043	22.070
27	1.917	15.704	2.270	6.096	0.572	9.224	22.511
28	1.917	16.064	2.299	6.218	0.584	9.409	22.961
29	1.917	16.434	2.328	6.343	0.595	9.597	23.420
30	1.917	16.815	2.357	6.470	0.607	9.789	23.889

Cost (million $) by year and by categories: Bus Main Lane

Year	Facility	Time	Air Pollut	Inci Delay	Accident	External	User/Age
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.000	0.000
7	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000
15	0.000	0.000	0.000	0.000	0.000	0.000	0.000
16	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19	0.000	0.000	0.000	0.000	0.000	0.000	0.000
20	0.000	0.000	0.000	0.000	0.000	0.000	0.000
21	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22	0.000	0.000	0.000	0.000	0.000	0.000	0.000
23	0.000	0.000	0.000	0.000	0.000	0.000	0.000
24	0.000	0.000	0.000	0.000	0.000	0.000	0.000
25	0.000	0.000	0.000	0.000	0.000	0.000	0.000
26	0.000	0.000	0.000	0.000	0.000	0.000	0.000
27	0.000	0.000	0.000	0.000	0.000	0.000	0.000
28	0.000	0.000	0.000	0.000	0.000	0.000	0.000
29	0.000	0.000	0.000	0.000	0.000	0.000	0.000
30	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Cost (million $) by year and by categories: Bus HOV Lane

Year	Facility	Time	Air Pollut	Inci Delay	Accident	External	User/Age
1	0.076	10.297	0.177	2.191	0.000	1.247	6.392
2	0.076	10.510	0.180	2.235	0.000	1.272	6.520
3	0.076	10.728	0.184	2.280	0.000	1.298	6.650
4	0.076	10.952	0.188	2.325	0.000	1.324	6.783
5	0.076	11.179	0.192	2.372	0.000	1.350	6.919
6	0.076	11.412	0.195	2.419	0.000	1.377	7.057
7	0.076	11.650	0.199	2.468	0.000	1.405	7.198
8	0.076	11.894	0.203	2.517	0.000	1.433	7.342
9	0.076	12.142	0.208	2.567	0.000	1.461	7.489
10	0.076	12.396	0.212	2.619	0.000	1.491	7.639
11	0.076	12.656	0.216	2.671	0.000	1.520	7.792
12	0.076	12.922	0.220	2.724	0.000	1.551	7.948
13	0.076	13.193	0.225	2.779	0.000	1.582	8.106
14	0.076	13.471	0.230	2.834	0.000	1.614	8.269
15	0.076	13.754	0.234	2.891	0.000	1.646	8.434
16	0.076	14.045	0.239	2.949	0.000	1.679	8.603
17	0.076	14.341	0.244	3.008	0.000	1.712	8.775
18	0.076	14.645	0.249	3.068	0.000	1.747	8.950
19	0.076	14.956	0.254	3.129	0.000	1.781	9.129
20	0.076	15.273	0.259	3.192	0.000	1.817	9.312
21	0.076	15.598	0.264	3.256	0.000	1.853	9.498
22	0.076	15.931	0.270	3.321	0.000	1.890	9.688
23	0.076	16.272	0.275	3.387	0.000	1.928	9.882
24	0.076	16.620	0.281	3.455	0.000	1.967	10.079
25	0.076	16.977	0.287	3.524	0.000	2.006	10.281
26	0.076	17.342	0.293	3.595	0.000	2.046	10.487
27	0.076	17.716	0.299	3.667	0.000	2.087	10.696
28	0.076	18.099	0.305	3.740	0.000	2.129	10.910
29	0.076	18.491	0.311	3.815	0.000	2.172	11.128
30	0.076	18.893	0.317	3.891	0.000	2.215	11.351

Cost (million $) by year and by categories: Rail

Year	Facility	Time	Air Pollut	Inci Delay	Accident	External	User/Age
1	5.615	1.270	0.000	0.000	0.000	0.070	0.394
2	5.615	1.295	0.000	0.000	0.000	0.071	0.402
3	5.615	1.321	0.000	0.000	0.000	0.073	0.410
4	5.615	1.347	0.000	0.000	0.000	0.074	0.418
5	5.615	1.374	0.000	0.000	0.000	0.076	0.426
6	5.615	1.402	0.000	0.000	0.000	0.077	0.435
7	5.615	1.430	0.000	0.000	0.000	0.079	0.444
8	5.615	1.458	0.000	0.000	0.000	0.080	0.452
9	5.615	1.488	0.000	0.000	0.000	0.082	0.461
10	5.615	1.517	0.000	0.000	0.000	0.084	0.471
11	5.615	1.548	0.000	0.000	0.000	0.085	0.480
12	5.615	1.579	0.000	0.000	0.000	0.087	0.490
13	5.615	1.610	0.000	0.000	0.000	0.089	0.499
14	5.615	1.642	0.000	0.000	0.000	0.091	0.509
15	5.615	1.675	0.000	0.000	0.000	0.092	0.520
16	5.615	1.709	0.000	0.000	0.000	0.094	0.530
17	5.615	1.743	0.000	0.000	0.000	0.096	0.541
18	5.615	1.778	0.000	0.000	0.000	0.098	0.551
19	5.615	1.813	0.000	0.000	0.000	0.100	0.563
20	5.615	1.850	0.000	0.000	0.000	0.102	0.574
21	5.615	1.887	0.000	0.000	0.000	0.104	0.585
22	5.615	1.924	0.000	0.000	0.000	0.106	0.597
23	5.615	1.963	0.000	0.000	0.000	0.108	0.609
24	5.615	2.002	0.000	0.000	0.000	0.110	0.621
25	5.615	2.042	0.000	0.000	0.000	0.113	0.633
26	5.615	2.083	0.000	0.000	0.000	0.115	0.646
27	5.615	2.125	0.000	0.000	0.000	0.117	0.659
28	5.615	2.167	0.000	0.000	0.000	0.119	0.672
29	5.615	2.210	0.000	0.000	0.000	0.122	0.686
30	5.615	2.255	0.000	0.000	0.000	0.124	0.699