A CASE STUDY APPLICATION OF A COMPUTERIZED FULL-COST ANALYSIS MODEL FOR EVALUATING URBAN PASSENGER TRANSPORTATION

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by

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16. Abstract

Transportation improvement alternatives on the US 59 Southwest Freeway corridor are evaluated from the full-cost, life-cycle perspective for the Houston/Galveston Area Council (HGAC). The alternatives involve facility improvements as well as vehicle occupancy improvements. Findings suggest that the current facility will not be able to service the projected peak-hour traffic demand; and after running MODECOST - a computer model based on the full-cost analysis concept, developed by the authors - the results showed that travelers bore a significant amount of external costs, including congestion costs and air pollution costs. The annual life-cycle cost savings from the reduction of external costs and users/agency costs can more than offset the cost of initial investment for expansion of the current facility.

This case study shows that in many instances, external costs and user/agency costs are more relevant than the initial capital investment in the facility. Expanding the current facility to add general purpose lanes or HOV lanes to accommodate ride-sharing and special transit service reduces the external costs and user/agency costs, which in turn reduces the system life-cycle costs of the facility.

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EXECUTIVE SUMMARY

Transportation improvement alternatives on the US 59 Southwest Freeway corridor are evaluated from the full-cost, life-cycle perspective for the Houston/Galveston Area Council (HGAC). Constructing additional HOV lanes or general purpose lanes to an existing highway does increase the annual life-cycle cost for construction, rehabilitation, and operation & maintenance of the roadway facility. The "HOV Build" scenario is predicted to increase highway agency life-cycle costs by about 8 percent (about $3 million annually for this corridor), while the "General Purpose Lane Build" scenario is predicted to increase the agency life-cycle costs by about 2 percent (about $1 million annually for this corridor). The implication is that adding lanes, even when not considering Right-Of-Way (ROW) costs, requires a significant amount of public funds. When additional transit agency costs are incurred (Travel Behavior Alternative 2) owing to the need to provide additional buses, park-and-ride lots, and transit centers, there is a further increase in required public funds.

However, consideration of total system life-cycle costs, which include private vehicle expenses as well as costs for such externalities as travel time and air pollution, yields a different result. The total annual system life-cycle cost for the "HOV Build" scenario in this corridor is estimated to be about 7 percent *less than* the "No-Build" scenario under existing transit and ridesharing conditions (or about $390 million annually for this corridor). Under conditions of greater transit use and more ridesharing, the "HOV Build" scenario is estimated to have an annual system life-cycle cost about 25 percent *less than* the "No-Build" scenario (or about $930 million annually for this corridor).

Under the "General Purpose Build" scenario, the total system annual life-cycle cost savings are estimated to be even greater. Under existing transit and ridesharing conditions, this scenario is estimated to cost about 40 percent *less than* the "No-Build" scenario (or about $2.5 billion annually for this corridor). Under conditions of greater transit use and more ridesharing, the general purpose lane scenario is estimated to have a system annual life-cycle cost about 40 percent *less than* the "No-Build" scenario (or about $1.5 billion annually for this corridor). The "General Purpose Build" scenario is more effective at reducing costs of travel time and air pollution owing to the under-utilization of the HOV lanes in the "HOV Build" scenario.

The full-cost approach used by MODECOST takes into account not only facility investment, but also external costs and user expenditures. The case study reported in this paper shows that, in many cases, the latter is more important than the former. The full-cost analysis results reported are very effective not only in comparing alternatives, but also in enhancing qualitative assessments and planning/engineering judgment. The intensive numerical analysis involved in this case study was made possible by the availability of a computerized full-cost analysis tool.

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INTRODUCTION

Within Texas, a vast 467,000-km transportation network has been developed to address mobility and accessibility needs of state travelers (Ref. 1). Today, more than 70 percent of local travel occurs within Texas cities having populations over 200,000 (Ref. 2), with most of these trips made by travelers using personal vehicles. The dependence on personal vehicles 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 high energy use. The Federal Highway Administration (FHWA) reported that 25 percent of Texas' urban Interstate highways exceeds 95 percent of capacity, and that 43 percent are operating at over 80 percent of their carrying capacity. Houston, one of the largest cities in the nation, is classified as a non-attainment area. Thus, the main purpose of this paper is to discuss how policymakers should proceed in evaluating investment alternatives for the improvement of transportation along a given corridor from a full-cost analysis perspective.

Until the 1990s, transportation policy focused primarily on the development of the Interstate system. Cost evaluations of transportation alternatives in the urban environment typically considered initial capital investments only. However, the passage of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and the Clean Air Act Amendments of 1990 (CAAA) prompted a more comprehensive approach to evaluating transportation options. ISTEA and CAAA shifted traditional planning and decision-making to a multimodal transportation perspective, a process which examines highway, transit, and rail issues in combination. In this approach, the transportation planning process looks at the problem from the perspective of an integrated system, emphasizing efficient and productive transfer of people and goods. Costs, including indirect social and environmental costs, must be fully accounted for in comparing 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 significantly. A transportation system is composed of several components. Therefore, the costs of a transportation system involve much more than the public agency's costs associated with building and maintaining highways, or purchasing and maintaining transit vehicles. Figure 1 outlines the elements of the full costs associated with a transportation system from the perspective of the automobile users. Bus users, and rail users present a different cost structure that encompasses the full costs associated with the each transportation mode.

Focus on any singular 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.

After reviewing the literature and current practice of full-cost transportation system planning, the computer model MODECOST was developed by the authors (Refs. 3,4,5). MODECOST has the ability to assist Metropolitan Planning Organizations (MPOs) and regional and municipal authorities in comparing multimodal transportation alternatives by accounting for the full cost of 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 is estimating the direct and indirect costs from the perspective of how much society (or the taxpayer) is paying for that mode of transportation.

MODECOST allows the transportation planner to compare the full costs of three major urban transportation modes -- auto, bus, and rail. MODECOST is an easy-to-implement, interactive and menu-driven, user-friendly software for comparing transportation alternatives. All cost components are converted to per passenger-mile (PMT) costs to allow comparisons on a common basis. In addition, MODECOST reports the costs in the form of total costs and average costs for the different modes. The software can be run on any IBM-PC or compatible computer

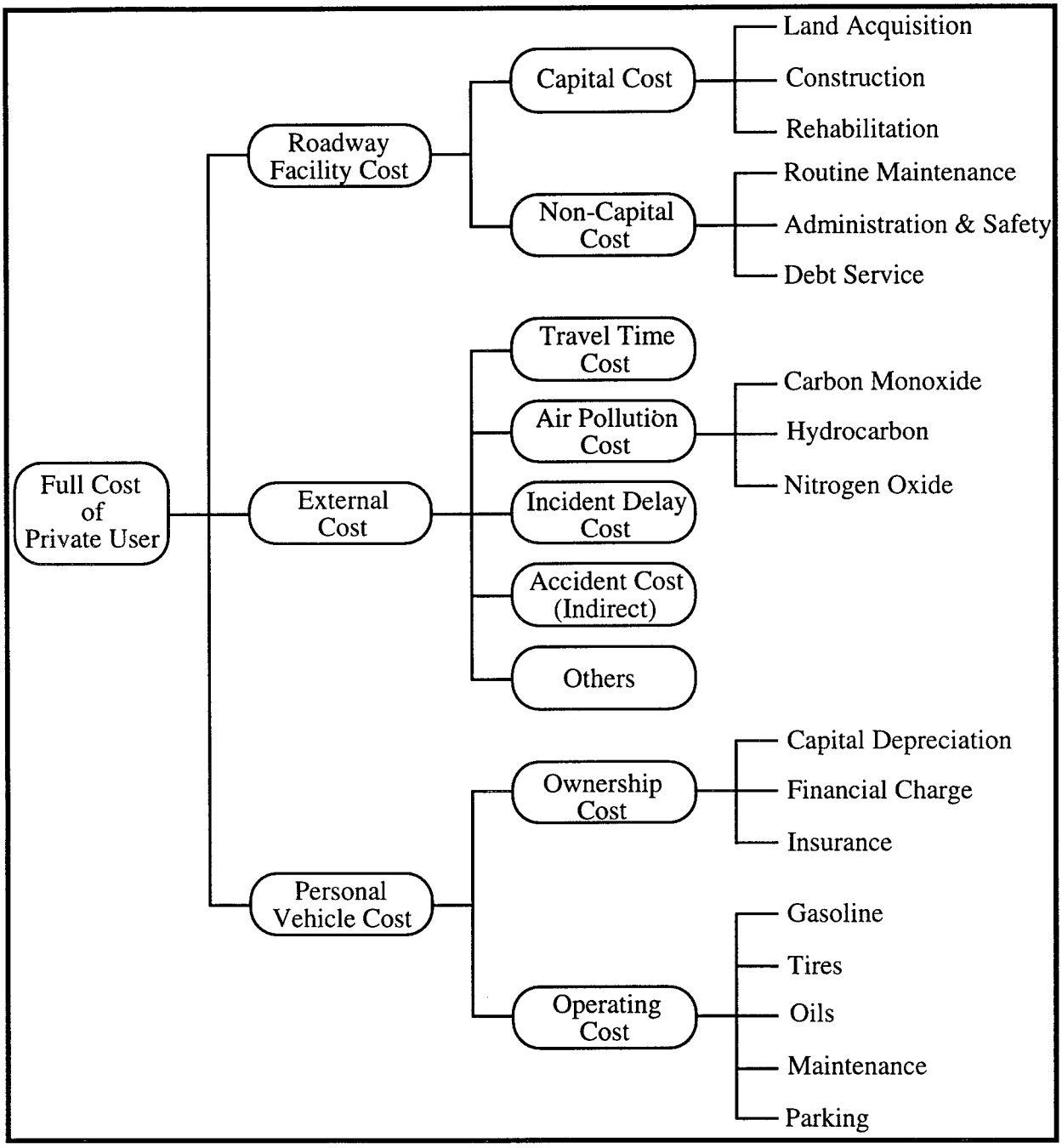

Figure 1. Elements of Full Costs for Private Vehicle Users

under Microsoft Windows 3.0 or higher version. All of the analyses reported in this paper was performed using MODECOST, which allowed for the comparison of several investment and demand scenarios.

ANALYSIS SCENARIOS

The Houston-Galveston Area Council (HGAC) is evaluating a mobility plan for Fort Bend County. Fort Bend county is adjacent to Harris county and is part of the eight-county Houston-Galveston Transportation Management Area, (Ref. 6). Population in the county is expected to double from 257,000 in 1995 to 525,000 by the year 2020. US 59 is considered a key transportation facility linking Fort Bend County with the Houston-Galveston area.

Several alternative transportation scenarios for US 59 are assessed in this study. This approach provides for a sensitivity analysis, made possible by the computerized MODECOST procedure, by varying both facility improvements such as adding a High Occupancy Vehicle (HOV) lane or a general purpose lane, and by varying travel behavior characteristics such as person trip mode splits and vehicle occupancies. Owing to varying existing roadway geometric characteristics and traffic volume levels, the corridor was divided into thirteen segments from Loop 610 to State Highway 36 bypass.

The transportation facility alternatives considered in this study (TFAs) as well as travel behavior alternatives (TBAs) are described below and where analyzed for a forty year planning horizon.

Transportation Facility Alternatives

TFA 1: No Investment

This alternative does not provide for any transportation facility improvements on the existing freeway. The existing facility under study is 43.5-km in length (27-mile) and extends from Loop 610 west of downtown Houston in Harris County westward into Fort Bend County.

The number of general purpose lanes varies from 12-lanes to 4-lanes, with an additional reversible 1-lane HOV facility extending for 13.7-km (8.5-mile) of the corridor. Weekday Average Annual Daily Traffic (AADT) levels in the year 2000 are estimated to vary from 300,000 to 20,000 along the corridor.

TFA 2: HOV Facility Investment

This alternative calls for an HOV facility to extend from for a distance of about 26 km (over 16 miles). The HOV facility is a two-lane facility running along the existing US 59 corridor and designated for two modes: buses and carpools/vanpools. Three additional park-and-ride lots and two transit centers are assumed to be constructed along the corridor. Currently, six park-and-ride lots are estimated to be servicing the study corridor.

The reader should note that the current version of MODECOST distributes the costs of park-and-ride lots and transit centers on an areawide basis — *not* directly to the specific corridor under study. In other words, the transit agency's total cost for providing services in the specific study corridor being analyzed will include only a portion of the total cost of the park-and-ride lots and transit centers.

TFA 3: General Purpose Facility Investment

This alternative calls for the addition of one lane of highway capacity in each direction for a distance of about 26 km (over 16 miles) without an HOV facility, except for the existing one-lane reversible HOV facility located in the first 13.7 km (over 8.5 miles) of the corridor.

Travel Behavior Alternatives

The study scenarios being evaluated are dependent not only upon various transportation facility improvements as described above, but also upon varying travel behavior characteristics, such as mode split and vehicle occupancy. Given the lack of data available on US 59, the following Travel Behavior Alternatives (TBAs) were proposed as mode split and vehicle occupancy alternatives. It was assumed that TBA 1 represents existing conditions and that the mode splits are constant throughout the entire study period. Also, carpools were classified as a separate mode. The passenger vehicle classifications and occupancies were as follows:

- TBA 1: 93.74% SOV (1.0), 6.00% Carpool (2.2), 0.26% Bus (11)
- TBA 2: 87.48% SOV (1.0), 12.00% Carpool (2.2), 0.52% Bus (22)

TBA 1 results in an overall passenger vehicle occupancy of 1.10, while the second travel behavior alternative results in an overall passenger vehicle occupancy of 1.25 (an increase of 14 percent).

Scenario 1.1 represents the existing-conditions scenario. The remaining scenarios represent facility and/or mode split improvements to the existing conditions. Scenario 1.2 represents the no-build alternative, one where the share of buses and carpools in the vehicle stream doubles, increasing from 0.26 percent to 0.52 percent for buses and from 6 percent to 12 percent for carpools. Bus occupancy also doubles from 11 passengers per vehicle to 22 passengers per vehicle.

Scenario 2.1 represents an "HOV Build" scenario, one in which there is no increase in the existing number of higher occupancy vehicles in the traffic stream. Scenario 2.2 represents an "HOV-Build" scenario, which is accompanied by an increase in the share of higher-occupancy vehicles using the freeway.

Scenario 3.1 represents a "General Purpose Build" scenario that has no increase in the overall passenger vehicle occupancy, while Scenario 3.2 represents the "General Purpose Build" scenario, in which the overall passenger vehicle occupancy increases to 1.25 (from 1.10).

Table 1, a matrix of transportation facility alternatives and mode split alternatives, summarizes the six scenarios that are evaluated in this study.

Scenario 1.1

Total annualized agency cost, including highway and transit, is $39.0 million, or 0.7 percent of the total system annual cost. The auto-user cost, which includes the cost of purchasing and operating an automobile, is $451.8 million, or 7.7 percent of the total system annual cost. The MODECOST analytical models assume that transit riders do not incur automobile ownership and operation costs and therefore do not contribute to the total system annual cost for auto users.

Total external costs are estimated to be $5.3763 billion, or 91.6 percent of the total system annual cost. External costs include monetary estimates of travel time under recurring congestion, air pollution, accidents, incident delay, and other external costs. The total annualized costs are the addition of the previous figures to a total of 5.8671 billion. Figure 2 summarizes the shares of the various cost components.

Scenario 1.2

Scenario 1.2 represents the existing facility attributes, but with an "improved" mode split on US 59, which results in the average passenger vehicle occupancy increasing to 1.25 on the general purpose lanes (from an occupancy of 1.1).

Total annualized agency cost, for this scenario, including highway and transit, is $46.9 million, or 1.3 percent of the total system annual cost. The auto-user cost, which includes the cost of purchasing and operating an automobile, is $381.2 million, or 10.1 percent of the total system annual cost.

TRANSPORTATION FACILITY ALTERNATIVES	TRAVEL BEHAVIOR ALTERNATIVES	
	TBA 1	TBA 2
TFA 1	Scenario 1.1	Scenario 1.2
TFA 2	Scenario 2.1	Scenario 2.2
TFA 3	Scenario 3.1	Scenario 3.2

TABLE 1. US 59 CASE STUDY SCENARIOS

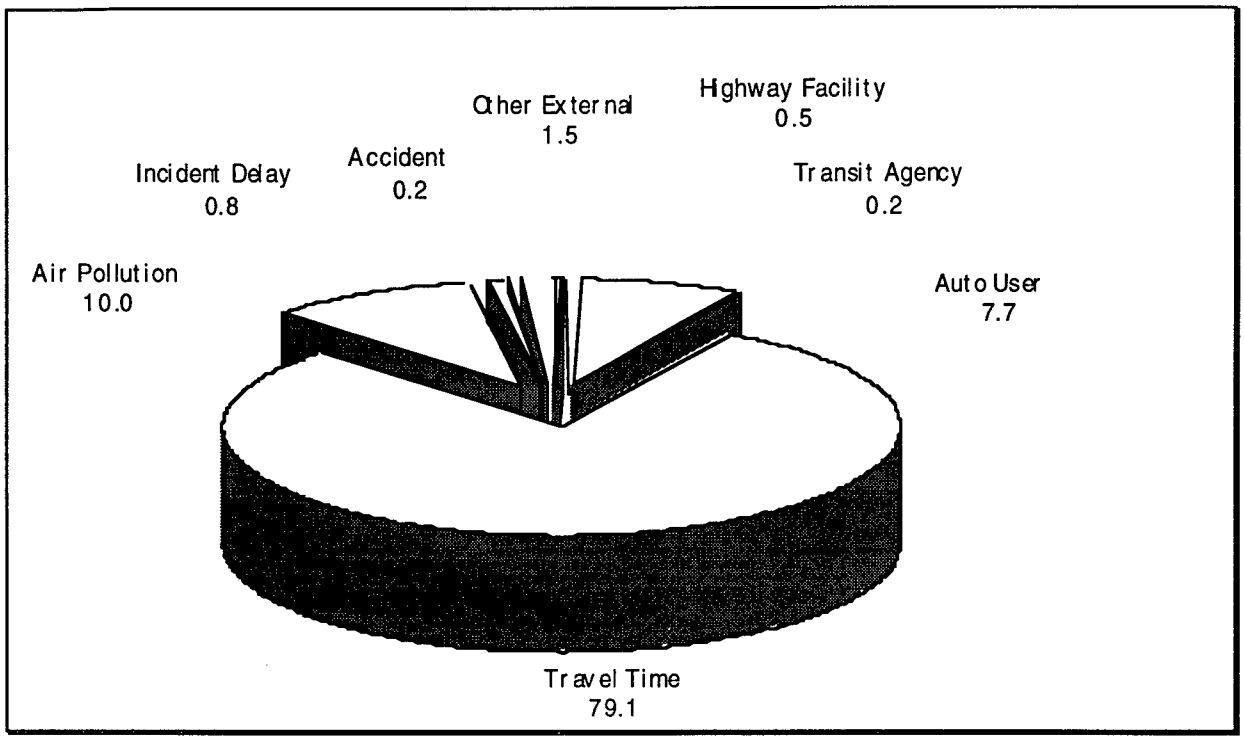

Figure 2. Annual Shares of System Cost — Scenario 1.1

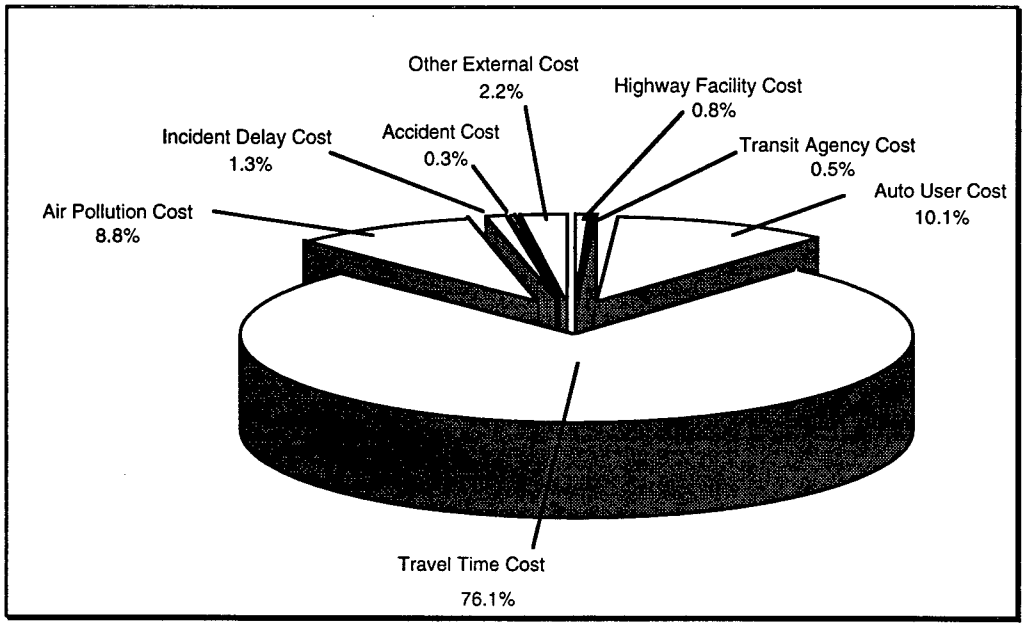

Figure 3. Annual Shares of System Cost Scenario 1.2

Total external costs are estimated to be $3.349 billion, or 88.7 percent of the total system annual cost. External costs include monetary estimates of travel time under recurring congestion, air pollution, accidents, incident delay, and other external costs. The total annualized costs for this scenario are 3.7768 billion. Figure 3 summarizes the shares of the various cost components in more detail.

Scenario 2.1

Scenario 2.1 represents an "HOV Build" scenario along US 59, but under existing mode split conditions. Under Scenario 2.1, the existing 13.7-km (8.5-mile) one-lane reversible HOV lane is assumed to be replaced with a 26.4-km (16.4-mile) two-lane HOV facility.

Total annualized agency cost, for this scenario, including highway and transit, is $42.1 million, or 0.8 percent of the total system annual cost. The auto user cost, which includes the cost of purchasing and operating an automobile, is $456.5 million, or 8.3 percent of the total system annual cost. MODECOST assumes that transit riders do not incur automobile ownership and operating costs and therefore do not contribute to the total system annual cost for auto users.

Total external costs are estimated to be $4.98 billion, or 90.9 percent of the total system annual cost. External costs include monetary estimates of travel time under recurring congestion, air pollution, accidents, incident delay, and other external costs. The total annualized costs for this scenario are 5.4788 billion. Figure 4 summarizes the shares of the various cost components in more detail.

Scenario 2.2

Scenario 2.2 represents the "HOV Build" scenario on US 59, along with an assumed increase in the number of higher-occupant vehicles in the traffic stream.

Total annualized agency cost, including highway and transit, is $50.0 million, or 1.8 percent of the total system annual cost. The auto user cost, which includes the cost of purchasing and operating automobiles, is $381.9 million, or 13.4 percent of the total system annual cost.

Total external costs are estimated to be $2.414 billion, or 84.8 percent of the total system annual cost. External costs include monetary estimates of travel time under recurring congestion, air pollution, accidents, incident delay, and other external costs. The total annualized costs for this scenario are 2.8462 billion. Figure 5 summarizes the shares of the various cost components in more detail.

Scenario 3.1

Scenario 3.1 represents a "General Purpose Lane Build" scenario along US 59 under existing mode split conditions. Under Scenario 3.1, 26.4 km (16.4 mi) of the existing general purpose facility have one lane of capacity added in each direction up to a maximum of six lanes.

Total annualized agency cost, including highway and transit, is $39.9 million, or 1.2% of the total system annual cost. The auto user cost, which includes the cost of purchasing and operating an automobile, is $451.8 million, or 13.3% of the total system annual cost.

Total external costs are estimated to be $2.897 billion, or 90.9% of the total system annual cost. External costs include monetary estimates of travel time under recurring congestion, air pollution, accidents, incident delay, and other external costs. The total annualized costs for this scenario are 3.3883 billion. Figure 6 summarizes the shares of the various cost components in more detail.

Scenario 3.2

Scenario 3.2 represents a "General Purpose Lane Build" scenario on US 59, along with an assumed increase in the number of higher-occupant vehicles in the traffic stream.

Total annualized agency cost, including highway and transit, is $47.7 million, or 2.1% of the total system annual cost. The auto user cost, which includes the cost of purchasing and operating an automobile, is $381.2 million, or 16.7% of the total system annual cost.

Total external costs are estimated to be $1.859 billion, or 81.2% of the total system annual cost. External costs include monetary estimates of travel time under recurring congestion, air

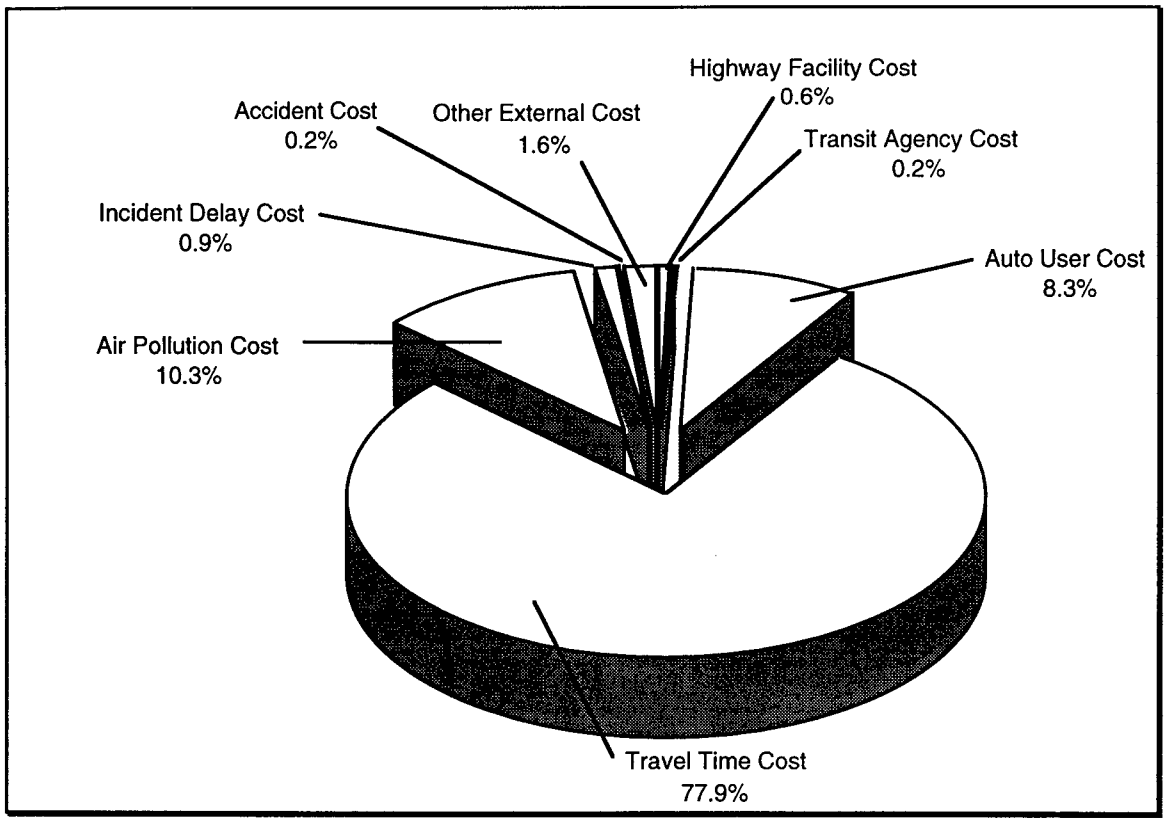

Figure 4. Annual Shares of System Cost Scenario 2.1

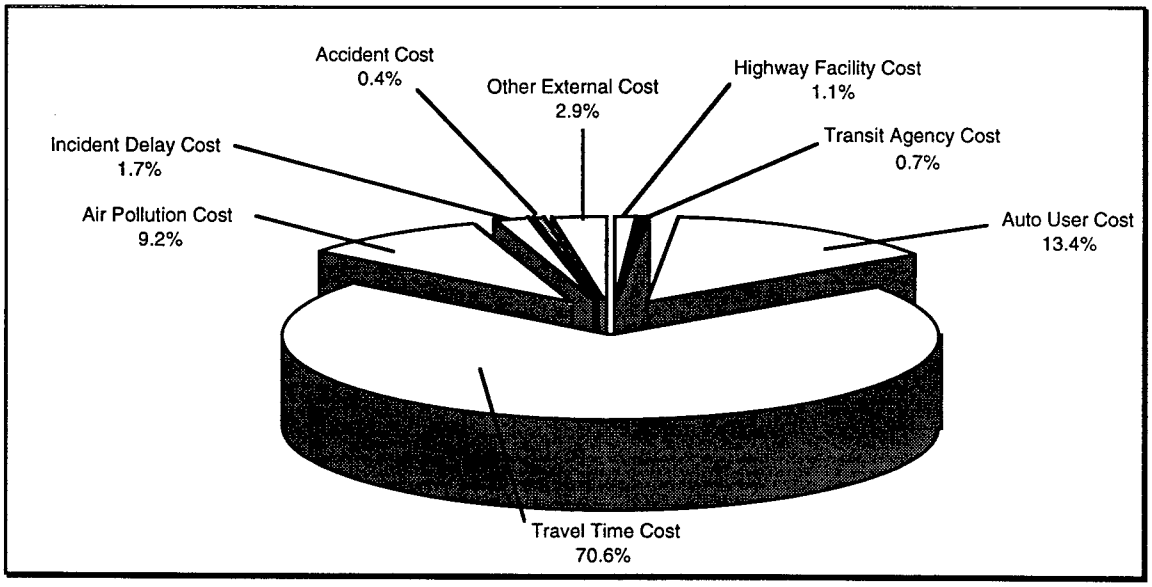

Figure 5. Annual Shares of System Cost Scenario 2.2

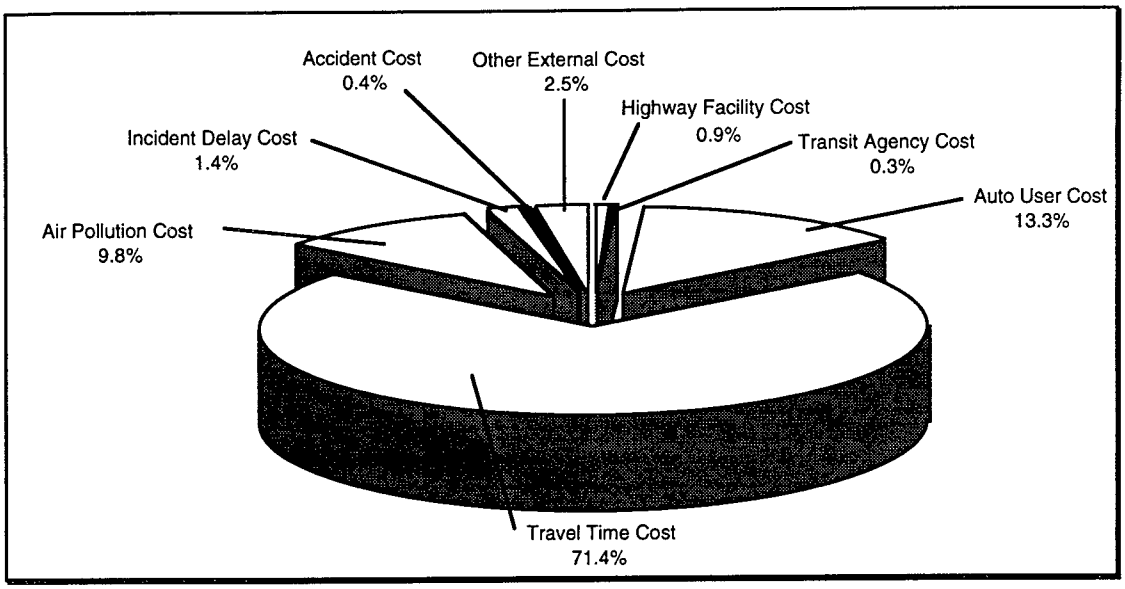

Figure 6. Annual Shares of System Cost Scenario 3.1

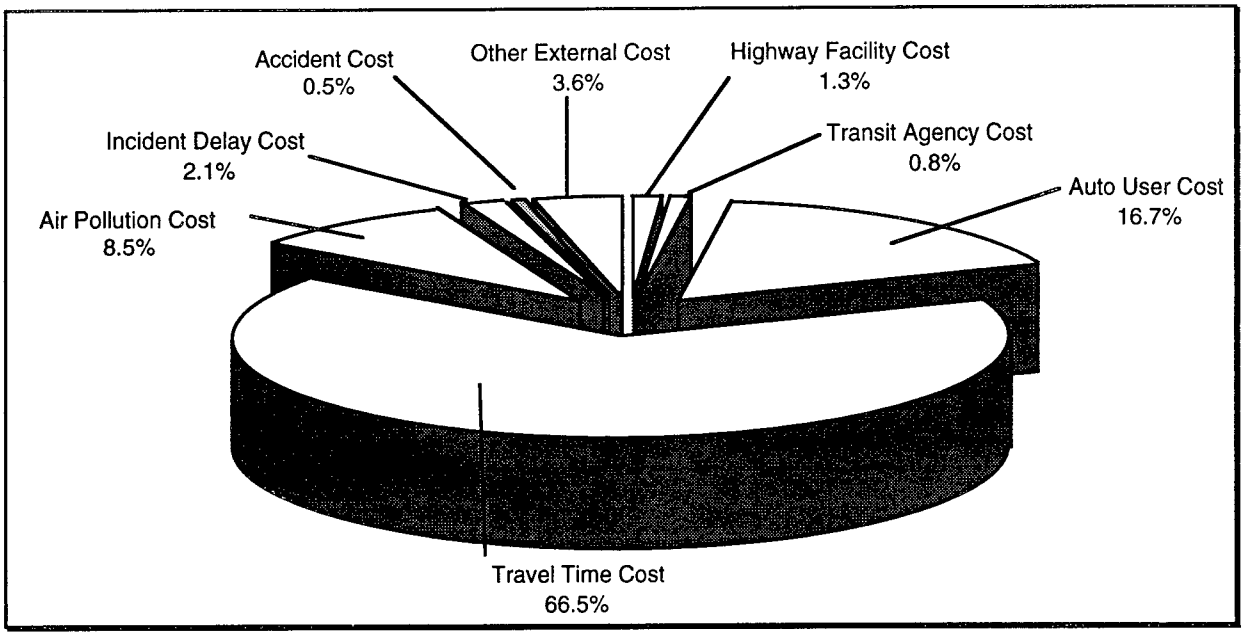

Figure 7. Annual Shares of System Cost Scenario 3.2

pollution, accidents, incident delay, and other external costs. The total annualized costs for this scenario are 2.2877 billion. Figure 7 summarizes the shares of the various cost components in more detail.

Comparison Of Facility Alternatives Under Travel Behavior Alternative #1

Scenario 1.1 vs. Scenario 2.1 vs. Scenario 3.1

Under these scenarios, the facility improvements change while the proportion of high-occupancy vehicles in the traffic stream remains constant at what is estimated to be existing mode splits and occupancies. We would expect that the estimate of the total life-cycle system cost under Scenario 3.1 would be less than that for Scenario 1.1, given the additional capacity added to the general purpose lanes in Scenario 3.1.

The results obtained under Scenario 2.1 are less predictable. While two lanes of capacity are added in Scenario 2.1 (as in Scenario 3.1) the use of the lanes added in Scenario 2.1 is restricted to high-occupant vehicles (carpools and buses). The estimated existing mode splits on US 59 might not be adequate to make full use of the HOV lanes and, therefore, may leave unused capacity on the HOV lanes, resulting in external cost reductions smaller than would occur if the HOV lanes were used to a fuller extent.

Actual inspection of the results verifies these expectations. The total system life-cycle cost under Scenario 3.1 is approximately 42 percent less than that for existing conditions, as estimated under Scenario 1.1. Scenario 2.1 results are less significant, with the total system life-cycle cost reduction (relative to Scenario 1.1) being about 7 percent. This is due to the fact that the estimated existing mode splits and occupancies may not be adequate to fully make use of the available HOV facility capacity.

The limited effects on the total system life-cycle cost of Scenario 2.1 can also be attributed to a second issue, namely, that mode splits for the year 2020 have been input into the model for the entire life-cycle period (year 2000 to year 2040). This has the effect of not assigning as much traffic to the HOV facility as HOV capacity would allow because, as total traffic volumes increase owing to estimated growth rates, the percentage of this total traffic that can "fit" into the HOV facility becomes smaller.

Thus, in the preceding years up to 2020, the percentage of the total traffic assigned to the HOV facility could have been higher than the percentage used for the year 2020, assuming that the HOV facility would be filled to capacity. By utilizing the lower 2020 percentage for the preceding years, we are in effect assuming that the "demand" for the HOV facility is less than capacity up to the year 2020.

One anomaly in the results is the slight increase in the system auto-user cost under Scenario 2.1 (about 1 percent greater) relative to Scenario 1.1 or Scenario 3.1. This apparent increase should be disregarded. It is due to a round-off error of the average vehicle occupancy input for the general purpose lanes, as well as to using the weekday's average auto occupancy on the general purpose lanes for the weekend.

Comparison Of Facility Alternatives Under Travel Behavior Alternative #2

Scenario 1.2 vs. Scenario 2.2 vs. Scenario 3.2

A similar comparison of these scenarios as those discussed in the previous section can be made. Scenario 3.2 (the "General Purpose Lane Build" scenario) offers the largest reduction in total system life-cycle cost from Scenario 1.2, with a 39 percent reduction. As in the Scenario 3.1 and Scenario 1.1 comparison, the reduction is attributable to a reduction in external costs, specifically travel time and air pollution costs.

Scenario 2.2 (the "HOV Build" scenario) offers a 25 percent reduction in the total life-cycle system cost from Scenario 1.2, the "No-Build" scenario. As explained in the previous section, there are several issues involved in the analysis of the "HOV Build" scenario that potentially restrict its effectiveness.

CONCLUSIONS

Constructing additional HOV lanes or general purpose lanes to an existing highway does increase the annual life-cycle cost for construction, rehabilitation, and operation & maintenance of the roadway facility. The "HOV Build" scenario is predicted to increase highway agency life-cycle costs by about 8 percent (about $3 million annually for this corridor), while the "General Purpose Lane Build" scenario is predicted to increase the agency life-cycle costs by about 2 percent (about $1 million annually for this corridor). The implication is that adding lanes, even when not considering Right-Of-Way (ROW) costs, requires a significant amount of public funds. When additional transit agency costs are incurred (Travel Behavior Alternative 2) owing to the need to provide additional buses, park-and-ride lots, and transit centers, there is a further increase in required public funds.

However, consideration of total system life-cycle costs, which include private vehicle expenses as well as costs for such externalities as travel time and air pollution, yields a different result. The total annual system life-cycle cost for the "HOV Build" scenario in this corridor is estimated to be about 7 percent *less than* the "No-Build" scenario under existing transit and ridesharing conditions (or about $390 million annually for this corridor). Under conditions of greater transit use and more ridesharing, the "HOV Build" scenario is estimated to have an annual system life-cycle cost about 25 percent *less than* the "No-Build" scenario (or about $930 million annually for this corridor).

Under the "General Purpose Build" scenario, the total system annual life-cycle cost savings are estimated to be even greater. Under existing transit and ridesharing conditions, this scenario is estimated to cost about 40 percent *less than* the "No-Build" scenario (or about $2.5 billion annually for this corridor). Under conditions of greater transit use and more ridesharing, the general purpose lane scenario is estimated to have a system annual life-cycle cost about 40 percent *less than* the "No-Build" scenario (or about $1.5 billion annually for this corridor). The "General Purpose Build" scenario is more effective at reducing costs of travel time and air pollution owing to the under-utilization of the HOV lanes in the "HOV Build" scenario.

The full-cost approach used by MODECOST takes into account not only facility investment, but also external costs and user expenditures. The case study reported in this paper shows that, in many cases, the latter is more important than the former. The full-cost analysis results reported are very effective not only in comparing alternatives, but also in enhancing qualitative assessments and planning/engineering judgment. The intensive numerical analysis involved in this case study was made possible by the availability of a computerized full-cost analysis tool.

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