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16. Abstract

Vehicular traffic moving through rural sections of Interstate 35 in Texas is growing at a dramatic rate. For example, in the rural areas between San Antonio and Dallas, traffic grew between 4 and 8 percent annually between 1983 and 1992. Some rural sections exhibited traffic growth rates as high as 10 percent between 1970 and 1993. And as traffic grows, so does travel time — an inevitable consequence of congestion. Thus, a trip from San Antonio to Dallas, which took approximately 4.5 hours in 1972, will require 8 hours by the year 2006, given a modest 4 percent traffic growth annually. Other disturbing, congestion-related consequences include rising pollution levels and greater operating costs for passenger cars and trucks, not to mention more accidents. If the problems associated with increasing traffic demand in the state are not resolved, Texans can expect higher costs of living and greater losses in productivity.

The primary objective of this report, the final for this project, was to demonstrate the future loss of personal mobility on rural sections of the Interstate in Texas. A second objective was to lay the groundwork for a comprehensive economic analysis of the problems associated with large traffic flows by using rural IH-35 as an example of a high-traffic corridor. Additionally, this report will provide a foundation for suggesting alternative solutions to the problem of traffic congestion on high-traffic corridors.

By demonstrating the problems of growing traffic demand on rural high-traffic corridors in Texas, and by building on the findings of an earlier study, we suggest that a supercorridor — also known as a managed transportation system (MTS) — continues to be a feasible option for mitigating the growing traffic congestion problems on rural corridors in Texas.

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Supercorridor, managed transportation system, IH-35, Texas traffic congestion, levels of service, traffic growth predictions

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by

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Project 0-1326:
Preliminary Economic Evaluation of the Supercorridor Concept

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

May 1996

IMPLEMENTATION RECOMMENDATION

This report presents a method for assessing the loss of mobility on rural highways — a method that can be applied to any corridor in Texas. Focusing on a specific case study, this report examines traffic trends on rural sections of Interstate 35 between San Antonio and Dallas. For this case study, we recorded average daily traffic data and then forecast traffic patterns for the locations along the Interstate. Using the *Highway Capacity Manual* and the forecast average daily traffic data, we made predictions as to when flow capacity would be reached. Overall, this report is intended to illustrate the problems associated with growing traffic congestion on rural corridors, and to serve as a guide in whatever statewide policy responses are prompted by the need to address the problems described herein.

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

DISCLAIMERS

B. F. McCullough, P.E. (Texas No. 19914)
Research Supervisor

TABLE OF CONTENTS

SUMMARY

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By demonstrating the problems of growing traffic demand on rural high-traffic corridors in Texas, and by building on the findings of an earlier study, we suggest that a supercorridor — also known as a managed transportation system (MTS) — continues to be a feasible option for mitigating the growing traffic congestion problems on rural corridors in Texas.

CHAPTER 1. INTRODUCTION

GENERAL OVERVIEW

In Texas, as in the rest of the U.S., urban travelers are experiencing a growing loss of personal mobility — an alarming trend that began in the 1980s after almost 25 years of increasingly improved mobility. More recently, there has been a growing concern among Texans that this mobility loss is now reaching into the non-urban segments of our key intercity links. And along with the growing congestion, there is a perceived lack of the kind of public vision needed to resolve these problems.

This report summarizes the activities undertaken for Project 1326, "*Preliminary Economic Evaluation of the Supercorridor Concept.*" It shows that the loss-of-mobility problem is not one that can be resolved by merely adding capacity, and that some alternative solutions, particularly those involving new technologies, are typically both complex and expensive. And, as the report indicates, state departments of transportation (DOTs) are finding that they lack adequate funding to meet even current needs. For example, the Texas Department of Transportation (TxDOT) can provide only about 40 cents for each dollar's worth of current needs with respect to highway provision.

In an effort to address this escalating problem, the Center for Transportation Research of The University of Texas at Austin evaluated the economic feasibility of what it has termed a "Managed Transportation System" (MTS). In a scheme presented as part of this study, the MTS was proposed as a way of supplementing the Interstate over critical links of its network to provide high levels of user service to intercity motorists, motor-carriers, and other suppliers of transport services.

BACKGROUND

In 1956, President Eisenhower signed legislation that began construction of the largest public works enterprise ever undertaken in the United States, namely, the National System of Interstate and Defense Highways, now more commonly referred to as the Interstate Highway (IH) system. This massive undertaking, ultimately costing over $120 billion and comprising 74,000 kilometers (46,000 miles) of separated highway, together with over 40,000 structures, was completed in the early 1990s. Arguably, its impact on U.S. economic development has been far greater than that achieved by the railways that created the east-west networks that still exist today.

The Interstate network, which links all communities having a population greater than 50,000 residents, had defense as its key strategic objective. Accordingly, whether or not actual demand for such a facility existed, each state was linked by a network of high quality, high strength highways that profoundly enhanced not only the distribution of wealth, but also the frequency and quality of personal mobility. This in turn created new cities and markets (Ref 1). Vehicle kilometers of travel (VKT) increased dramatically, both for individuals and for freight movements. Previously constrained to operating on regular highways that passed through narrow and over-crowded urban networks, motor-carriers were presented with a rapid, efficient, and inexpensive new network. Thus, the working range of intercity trucking increased from around 300 kilometers (190 miles) to over 650 kilometers (400 miles) per day, revolutionizing the productivity of the trucking industry and ultimately the location of its clients. (Its competitors faired badly, particularly rail, which lost market share to the new trucking industry.) The post-Interstate period now sees a shifting demographic pattern, with the traditional Northeastern areas giving way to a Southern-Midwest locus — a shift that is once again changing the way the nation's goods are planned, assembled, and distributed.

In Texas, the Interstate system was viewed not only as a way of increasing personal and defense mobility, but also as a catalyst for the economic development of the state. Thus, frontage roads (and their interchanges) provided access to a controlled access facility. The achievement of the latter objective can be viewed as a major success story, since it has changed in a major way where we live, work, shop, travel, and play, to a degree that is almost incomprehensible to those not familiar with the pre-Interstate conditions. Unfortunately, the success of the Interstate has now, ironically, led to a *decrease* in mobility within Texas' major urban areas. Moreover, the large increase in vehicle-miles on the system is also beginning to affect the personal mobility of travelers in Texas' rural areas.

Interstate Development

The development of the Interstate system can be viewed with respect to the typical phases of a product's life cycle. In the first phase, an idea is transformed through planning to an implementation phase. After acceptance by users, the product proceeds through a substantial growth period until it enters a "mature" phase, where it is then seen as no longer providing value to all the market. Finally, after a period of varying length, a product will begin to decline unless substantial efforts are made to improve its performance. Table 1.1 uses this concept to examine the life cycle of the Interstate system.

Table 1.1. Interstate system life cycle

PHASE	CHARACTERISTIC	ISSUES
Planning	Mobility	Speed, Safety
Implementation	Access	Connections, Spatial Impacts
Growth	Demand	a. Land Use, Auto, Trucks (Freight) b. Additional Lanes, ROW
Maturity	Congestion	Environment, Safety, User Costs, Externalities
Enhancement	Efficiency	Intelligent Transportation Systems, Demand Mgmt., Tolls, Time Dependency, Retro vs. New Facility

Following its planning, the implementation of the system entailed a massive effort to link all U.S. continental states. Within a state, access to the system was critical, since it was to link all major cities. Again, once in place, the system substantially impacted national growth. As the economy grew, automobile ownership increased, VKT increased, land use patterns altered, cities grew in response to system access, and companies located with respect to their connections to the

Interstate. Trucking companies significantly altered their operations, notwithstanding the constraints of regulation. Trucking deregulation in the 1980s promoted greater efficiency and accelerated the trucker's share of U.S. surface freight transportation such that it is now the pre-eminent transport mode.

At some point on key links within the network, the traditional Interstate configuration — a four-lane divided system — became incapable of meeting existing demand, particularly where the use of the facility was changing from its original objectives to that of urban mobility.

While this inadequacy is seen most clearly in southern California, where intestates became urban arterials, it is also mirrored somewhat along sections of the Interstate system linking key cities in the so-called Texas Triangle (an area defined by Houston, San Antonio, and Dallas-Ft. Worth). The initial solution to the problem of increased demand was to add capacity, either through purchasing right-of-way or by reducing median widths. However, these solutions provided only temporary relief, since such remedies then encouraged additional use; indeed, there seemed to be no limit to latent demand, particularly at peak periods, for highway space. On segments where additional capacity was not provided quickly, the peaks extended over longer periods until the system was in demand virtually over a 24-hour period. Thereafter, the system simply became congested.

What we are dealing with, then, is an Interstate system that has reached its "mature" phase — a phase in which planners increasingly concede that additional capacity cannot simply be added to the existing system. Not only is it extremely expensive to purchase additional land and to design construction schemes to fit in with these constraints, but the adverse impacts on existing traffic while such construction activities are underway can be substantial. Highway budgets are simply unable to address the total needs of the mature system. In addition to these financial constraints, there are concerns regarding environmental impacts (particularly air quality in urban areas) and vehicle safety. Many of these costs, traditionally ignored in the economic evaluation of highways, are termed "external costs." There is now widespread recognition that these costs are legitimate elements that should be weighed in any highway investment decision (Refs 2, 3). Accordingly, the new methods of evaluation that incorporate these costs are prompting different solutions.

Almost as a result of its own success, the Interstate system faces a vexing dilemma. Those responsible for its management can either tinker with the system and let it move slowly toward decline (which will be characterized by a continuing reduction in service levels, increasing travel times, and higher costs), or they can enhance the system and build efficiency into highway operations.

An Alternative: The Managed Transportation System (MTS) Concept

Urban transportation planners have invested heavily in research on intelligent transportation systems (ITS) and on demand management and traffic signaling schemes. A concept developed at the Center for Transportation Research (CTR), which it terms a "managed transportation system" (MTS), mirrors these activities and would incorporate its alignment to fit into specific ITS schemes. It would have limited access, be designed to deter rapid spatial development in existing communities, and would maintain high levels of service, potentially on a variety of transportation modes, for both people and goods. The key term *managed* underscores the need for continuous supervision and control of the facility's operations, including the monitoring of maintenance and emergency activities, as a means to enhance its efficiency. In this context, the present report examines whether such features can be retrofitted into the existing system, or whether they are best served by building a new facility parallel to critical links.

LITERATURE REVIEW: INITIAL MTS EVALUATION

CTR's initiatives in the area of MTS corridor analysis date back to the late 1980s. Such initiatives were prompted by the (then) statewide debate regarding proposed new surface transportation modes, specifically the Texas high-speed rail system. For a time, it seemed as though planners sought to insure that personal mobility was first maintained, and that this was more appropriately achieved through modes and systems other than vehicles on highways. In focusing on the Interstate network, the CTR team recognized that key links in the system were carrying large traffic loads, and that emphasizing these links would be an effective way of concentrating resources to improve efficiency. Moreover, since many city agencies and authorities were developing ITS systems in response to congestion and clean air initiatives, CTR determined that it would be appropriate to examine a potential corridor with respect to intercity travel, and to insure that it linked to ITS activities within the relevant cities.

CTR reported its findings in this early study on Texas corridors in 1992 (Ref 4). Because speed was initially considered an important variable in the study, this element was accordingly emphasized in the implementation and operation of an intercity MTS corridor. Subsequent analysis, however, has emphasized the delivery of reliable levels of service.

In 1993 CTR explored the potential of the MTS concept to link the cities of Dallas/Fort Worth, San Antonio, and Houston, an area known as the "Texas Triangle" and which generates two-thirds of the state gross domestic product (Ref 5). It was recognized that freight needed to be incorporated into highway planning, and that it was not sufficient to merely concentrate on automobile mobility. Furthermore, the study also investigated segregating trucks and passenger cars for capacity and safety reasons, reflecting the trend toward heavier trucks and lighter autos. A thorough preliminary cost evaluation was undertaken, and the cost of the Texas Triangle network (a total of some 900 kilometers) was calculated to be $4.6 billion at 1991 prices. This suggested an average system cost of around $5.1 million per kilometer, or about twice that of current Interstate rural expenditures. However, the system was to differ from current Interstate construction in that it would involve a large right-of-way and would build in features that would enable it to change modes and incorporate enhanced technology to maintain high levels of service.

As the cost evaluation developed, it became clear that other transportation modes should be incorporated (a consequence of the state's high-speed rail study). Landowners concerned about the rail alignment crossing through their property frequently argued that it should be linked to the highway system. This would accord with a number of planning decisions made in other international studies, where multimodal corridors were recommended as a way to maximize economic efficiency (Ref 6). With the recognition that other products and services needed to be incorporated into the network, the idea shifted direction: Rather than concentrating on a key characteristic for a single mode (e.g., high-speed highways), the concept broadened to encompass a corridor designed according to the highest environmental standards and monitored for all modes on a constant basis. Thus, such a corridor would accommodate not only wheeled traffic (both rubber and steel), but also electricity, gas, fiber optics, and other utilities that link Texas cities. All surface traveler and freight needs could be transmitted through a "managed" transportation corridor that focused on efficiency, equity, safety, and environmental sensitivity.

OBJECTIVE OF PRESENT STUDY

In 1994, TxDOT contracted with CTR to investigate the multimodal transportation corridor concept in more detail. This report is a product of that investigation. While examining the full range of corridor activities, the present study concentrates chiefly on highways and attempts to link the existing Interstate system. Of critical interest is the ability to retrofit existing Interstates with some of the technologies examined by the study team; thus, comparisons with retrofitting costs versus an entirely new facility are explored. In addition, the more conventional approach of adding traffic lanes has been included, as well as a "do-nothing" scenario as a base reference. Thus, a preliminary full-cost evaluation is conducted for these four different alternatives, with the main objective being the determination of *broad* directions of action and magnitudes of investment. In this regard, costs from the previous work are revised and compared.

To examine the impact of demand over a typical, heavily affected Interstate link, we selected IH-35 to serve as a case study (Figure 1.1). We anticipate that our findings with respect to IH-35, one of the busiest corridors in the state, will be applicable to other Interstates within and outside Texas.

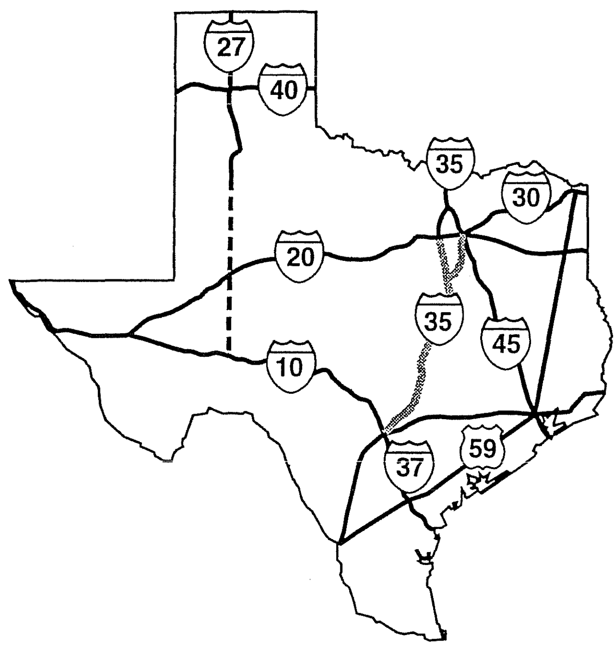

Figure 1.1. Heavy traffic corridors within Texas

REPORT SCOPE

The present document, the third in a series of reports under the current study, brings together the findings reported in previous project documents and provides final conclusions and recommendations. Please note: Because this project proceeded as a preliminary prefeasibility study, many details are necessarily omitted from this and earlier reports. For example, such issues as how much ROW would be needed for interchanges/service facilities, or where the beginning and ending points of the MTS would be located are matters that would be addressed during detailed follow-up planning. Also note that, because the project was a preliminary review only, the analysis included herein is of a deterministic nature, as against a more precise probabilistic one. We recommend that any future studies approach the concept of a managed transportation system probabilistically. In this way, more precise costs could be identified.

REPORT ORGANIZATION

Chapter 2 provides an overall characterization of traffic conditions under the selected case study, and elaborates on the potential impact of future traffic growth scenarios. Chapter 3 discusses the potential alternatives available to meet the projected traffic demand, and establishes the base capacity requirements under each one. With these, a general full-cost evaluation of the alternatives is presented in Chapter 4, to provide a measure of desirability and magnitude of investment. Finally, Chapter 5 presents overall conclusions of the study and recommends future actions.

CHAPTER 2. TRAFFIC CHARACTERIZATION

PREVAILING CONDITIONS

The first step in this case study was to establish the general characteristics of the intercity highway traffic moving along IH-35. Accordingly, we obtained traffic count data dating back to 1970 from automatic traffic recording (ATR) stations in Texas counties through which the highway passed. An initial review of these data showed that the segment having the highest traffic has perennially been that section connecting San Antonio and Dallas-Fort Worth (DFW), which currently handles an average daily traffic (ADT) of over 30,000 vehicles in the non-urban areas. In contrast, the Laredo-San Antonio segment, as well as sections north of the DFW area, show current ADTs below 10,000 vehicles. Hence, we focused our evaluation efforts on the rural segments of the San Antonio-DFW link. Table 2.1 shows recent ADT values for rural areas within this segment.

Table 2.1. ADT over rural IH-35 between Dallas and San Antonio (1992)

COUNTY	ADT
Comal	40,000
Hays	40,000
Travis	57,670
Williamson	34,000
Bell	32,360
Falls	33,000
McClennan	39,910
Hill	33,440

In an effort to ensure the segregation of rural traffic volumes, we excluded the primarily urban counties of Bexar (San Antonio), Ellis, Dallas, and Tarrant (Ft. Worth). Further analysis revealed linear traffic growth rates between 4.7 percent and 7.4 percent since 1983 (see Table 2.2).

With respect to the hourly distribution of traffic, we observed two distinct patterns within the IH-35 data (Ref 7), corresponding to what could be characterized as weekday (or mid-week) rural traffic and weekend rural traffic. In this regard, Friday to Sunday was the range characterized for the weekend, even though Saturdays in some instances showed patterns similar of those typical of weekdays.

The hourly distribution of weekday traffic shows a fairly constant pattern over a 12-hour period, approximately from 7:00 a.m. to 7:00 p.m. On the other hand, over the weekends, traffic slowly builds up, creating a smooth slope until it reaches a distinct peak of about two to three hours in the early evening. Figure 2.1 shows an example of this traffic behavior on IH-35 in Bell County.

Table 2.2. Traffic growth rates for rural IH-35 between Dallas and San Antonio (1983-92)

COUNTY	GROWTH RATE (%)
Comal	7.41
Hays	7.41
Travis	6.21
Williamson	7.29
Bell	5.23
Falls	5.56
McClennan	4.73
Hill	5.04

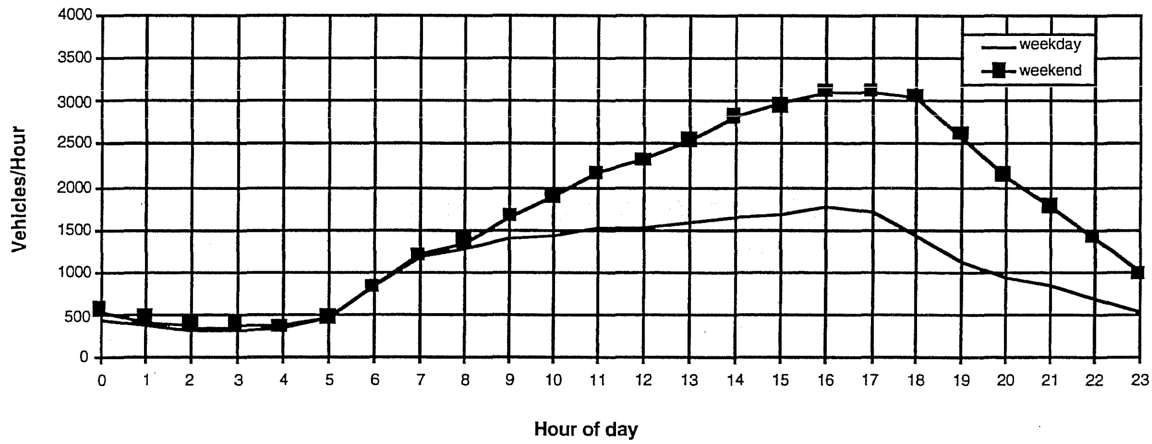

Figure 2.1. Typical hourly distribution of traffic on rural IH-35 (Bell County, 1992)

Figure 2.1 also illustrates the higher volumes that take place on weekends, compared with the weekdays. In fact, both daily and hourly volumes are up to 75 percent higher on weekends. Hourly traffic can also be depicted by the K-factor, which expresses the ratio of hourly volume to daily volume. Figure 2.2 presents the same information with respect to Bell County, but now as a function of the K-factor.

In addition to these data, ATR records provide a "design" K-factor for each traffic count station, one that depicts the 30th highest hourly volume in the year as a function of the annual average daily traffic (AADT). This value is also known as the design hourly volume (DHV), which in this chapter is used to identify the threshold at which traffic meets the design level of service (LOS). The average value of the design K-factor for the studied counties was determined to be around 11 percent. In addition, the directional distribution factor (Dd) for the peak demand was determined to be 0.56.

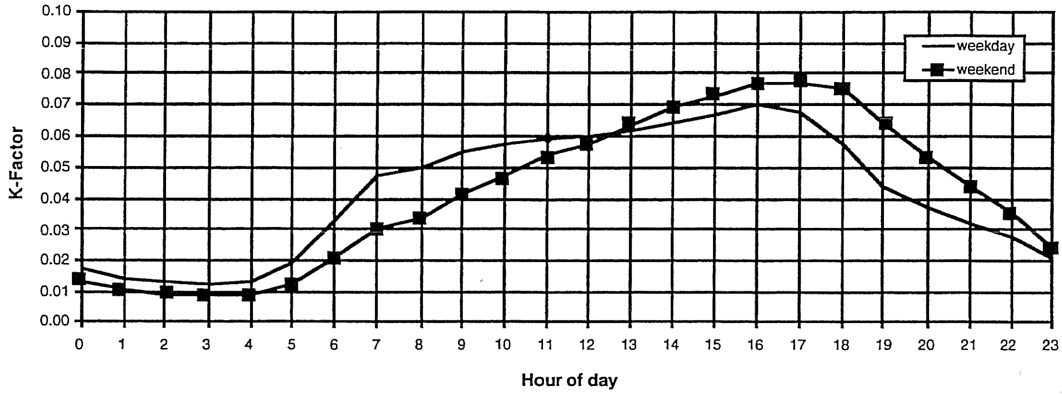

Figure 2.2. Hourly distribution of traffic on IH-35 expressed as K-factor (Bell County, 1992)

Finally, we determined the traffic mix in this segment of IH-35. On average, 14 percent of the traffic is composed of heavy vehicles (mostly 18-wheeled trucks).

POTENTIAL GROWTH

As a preliminary approach, and based on the discussed historic trends in traffic, we established two basic rates to project future demand. A 4-percent growth rate approximates the lower bound of the trend established since the early 1980s and was used as the base case. To examine for sensitivity, an 8-percent traffic growth rate was used, which represents the upper bound as well as an unexpected growth rate of the sort associated with changes in trade (i.e., Mexico), and the spatial development of metropolitan areas.

Traffic in all the specified counties was projected using both rates. As an example of the results, Figures 2.3 and 2.4 show potential rural traffic demand in Travis and Bell Counties over the next 25 years, assuming that current mode splits and link choices remain constant over this period.

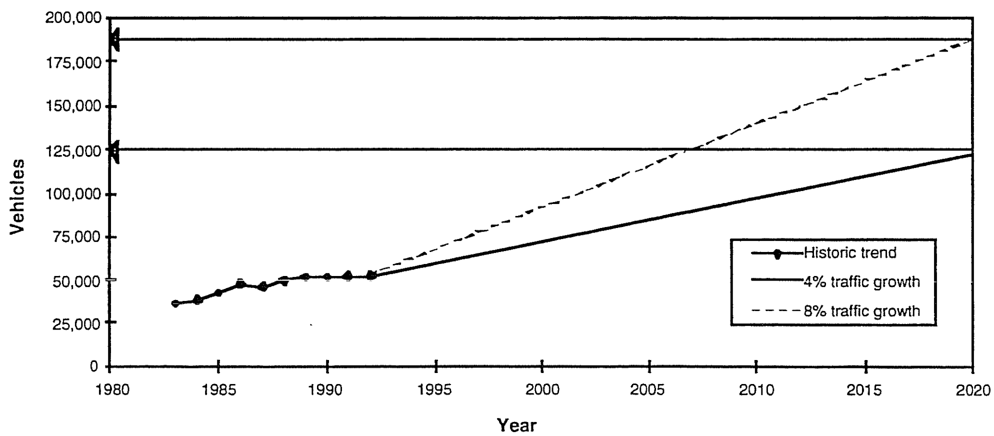

Figure 2.3. Traffic growth projections for rural Travis County

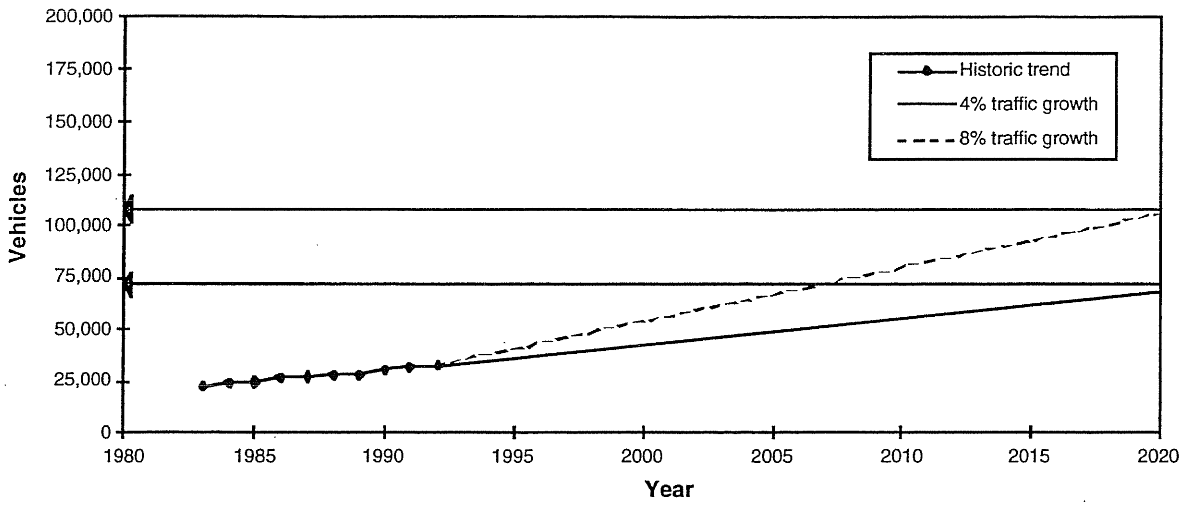

Figure 2.4. Traffic growth projections for rural Bell County

These two cases represent the conditions at the upper and lower limit of IH-35 rural traffic moving between San Antonio and DFW. Again, urban traffic levels are not included in this analysis (given that they represent an issue outside the scope of this work).

For the 4-percent growth rate, the expected annual average daily traffic for Travis County is projected to be nearly 123,000 vehicles by the year 2020. For the same year, the traffic in Bell County is expected to reach 70,000 vehicles per day (vpd), given a 4-percent growth rate. These numbers provide a sense of the potential demand.

IMPACTS OF POTENTIAL CONGESTION

The ability of a highway to provide a satisfactory degree of operation, better known as the level of service (LOS, A to F), is conventionally measured by the density of the traffic stream (Ref 8). Moreover, the density of the traffic stream in turn can be related to a specific range of speeds. In the upper limit, LOS A depicts low traffic densities (6 passenger cars/km/lane), under which free-flow speeds around 105 km/hr (65 mph) generally prevail. In the lower limit, LOS F depicts high traffic densities (up to 28 passenger cars/km/lane), usually associated with unstable flow conditions, breakdowns, and average speeds lower than 56 km/hr (35 mph). Levels of service have been one of the triggers used by TxDOT to add capacity to highways and is a broad surrogate for efficiency. So, using the previously discussed parameters that characterize rural IH-35 traffic (design K-factor, Dd, and the percentage of heavy vehicles), along with predicted ADTs, we calculated levels of service for the different rural segments of IH-35 to determine the impact of increased traffic growth and congestion. Based on this analysis, IH-35 LOS will decline with time unless corrective measures are taken. As shown in Table 2.3, we have already moved below the minimum acceptable level of service for rural segments of the Interstate and will face urban-like gridlock by the year 2010 at a 4-percent growth, or by the year 2001 at an 8-percent growth rate.

Table 2.3 Threshold years for level of service on Interstate 35

GROWTH RATE (%)	YEAR	
	LOS B	LOS F
4	1992	2010
8	1992	2001

The actual impact of falling LOS can be depicted by the change in travel times. Using LOS as speed indicators, travel times were estimated under future congestion patterns and compared to past trends. Figure 2.5 illustrates the change in travel time required for a San Antonio-to-Dallas trip, as well as future projections on the existing system. In the pre-Interstate era, it took approximately 8 hours for a vehicle to travel between these two cities, with motorists required to pass through many communities and signalized intersections. With the development of the Interstate, travel time was cut in half. During the 1970s, travel time increased slightly when the speed limit was lowered to 88 km/hr (55 mph). But as we move toward the next century, we will again face higher travel times because of the tremendous growth in traffic along IH-35. Based on the conservative growth rate of 4 percent, travel time from San Antonio to Dallas will revert to pre-Interstate travel times by the year 2016. A more realistic traffic growth estimate of 8 percent will lead to an 8-hour trip from San Antonio to Dallas by the year 2005, with users certain to face tense urban driving conditions (rather than the more relaxed rural driving conditions represented by a LOS B).

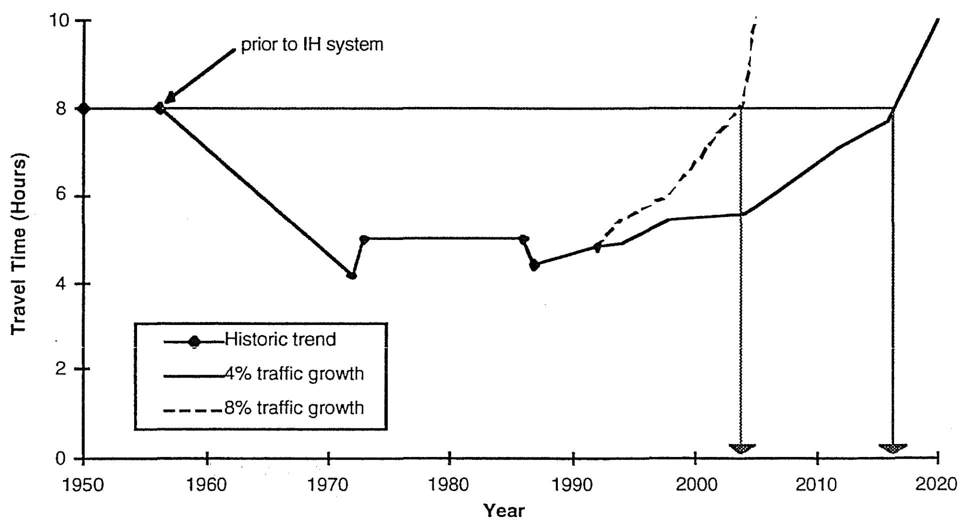

Figure 2.5. Travel time for a San Antonio-to-Dallas trip along IH-35

The growth in traffic along the IH-35 corridor underscores the emerging congestion problem. High traffic corridors in the near- to medium-term will reach operating conditions that motorists have not experienced since the dawn of the Interstate system. The present study provides a preliminary approach to resolving this imminent situation, first by acknowledging the growing crisis, and then by broadly reviewing alternative courses of action.

SUMMARY

The U.S. Interstate Highway system has been an unparalleled success in terms of social and economic impacts. It has dramatically altered urban and city growth, prompted the relocation of industries, and has stimulated the development of new distribution systems that have changed where Americans live and work and how they market products. However, the system has also imposed a significant social cost: In fostering the growth of the automobile in personal mobility and the truck in industrial productivity, the system has led to unrestrained growth in demand over the 40 years of its operation. Moreover, there appears to be substantial latent demand associated with highway use. In other words, increasing capacity to satisfy existing demand typically invites new users to utilize the system. To examine the impact of demand over a typical, heavily affected Interstate link, we examined several rural segments of Interstate 35 within the Texas Triangle, looking in particular at traffic data from 1983 to the present. In addition, we presented forecasts of future traffic growth within these segments using 4- and 8-percent growth rates. Based on this analysis, it has been determined that rural IH-35 service levels will decline sharply with time and could even approach urban-like gridlock conditions in the near future unless corrective measures are taken. Alarmingly, these conditions are not confined to IH-35; they can be replicated over a number of highly trafficked Interstate corridors within Texas.

CHAPTER 3. ALTERNATIVES TO MEET THE DEMAND

INTRODUCTION

As noted in the previous chapter, projected traffic demand for the San Antonio-DFW segment of IH-35 shows that capacity will be reached within a few years. Perhaps even more important, the provision of additional capacity (which cannot now be easily acquired) or other conventional approaches do not represent effective solutions for the crisis rapidly overwhelming links on the Interstate system. Finally, solutions involving new technologies are typically both complex and expensive.

However, a relatively new concept developed at the Center for Transportation Research over the past years represents a new approach to resolving the intercity ground transport capacity dilemma. Originally termed a "supercorridor," this concept blends a variety of approaches for congestion management that has proved effective in urban settings by capitalizing on the benefits of multimodality and by providing self-sustaining financial mechanisms. Among its features are measures to curb adjacent development and to protect the environment. With the passing of ISTEA (Ref 9), this concept has gained new momentum, particularly among public agencies; similar approaches are now being considered for implementation in other parts of the country as well (Ref 10).

The primary objective of this study is to evaluate the feasibility of potential solutions to highway capacity. As a first step, this chapter provides a brief overview of the approaches being considered, and elaborates on the capacity requirements of each in preparation for the economic comparison discussed later.

DISCUSSION OF CONCEPTS FOR ALTERNATIVE SOLUTIONS

A variety of approaches have been analyzed that could address capacity problems for Texas' roadways. Concepts ranging from the simple addition of traffic lanes on existing facilities (or equivalent construction of parallel routes) to the more complex mechanisms involving mode/link shifts for balancing and optimizing the existing transportation infrastructure are common in both the literature and in practice.

In addition, the financing associated with the maintenance of the current system and the construction of new facilities has now surfaced as a new challenge for both government and the general public (tax payers). In particular, new attitudes toward the use of tolls for highway projects in Texas (Ref 11) have set the stage for a real equitable sharing of transportation costs. The idea that highway users should pay the full cost of highway use has gained increasing currency, especially in the context of achieving better levels of service over increasingly congested links. Yet, as established recently (Ref 12), not all highway projects are compatible with toll implementation.

As an initial attempt to broadly encompass the reviewed concepts for improving highway capacity, three main alternatives have been devised for a preliminary evaluation of economic performance over the IH-35 corridor:

(1) Adding lanes to IH-35
(2) Retrofitting IH-35 with intelligent transportation systems (ITS)
(3) Building a Managed Transportation System (MTS) parallel to IH-35

In addition, a "do nothing" alternative has been included as a control (or reference) element.

Adding Lanes

This is the conventional approach to increasing highway capacity used by DOTs throughout the country. It requires the use of any available space over the existing right-of-way, including medians or safety lateral clearances. Since most highways have been planned to include space for additional traffic lanes, this approach initially appeared as a favorable alternative. Yet continued demand has stretched space reserves to the limit, such that it has become increasingly necessary to purchase additional land in many cases.

Depending on the available space for expansion, another potential difficulty with this approach is the creation of "workzones," which usually cause travel delays over the construction period and, consequently, can be a major inconvenience to road users.

In addition, for IH-35 this approach would require building by-pass routes along major cities to separate urban traffic from intercity traffic passing through. This arrangement was considered less disruptive than building the additional lanes within traffic-intensive urban areas. The facility would operate in its conventional format: mixed traffic at 112 kph (70 mph) maximum legal speed, with typical access control and frontage roads. Current land-use policies need not be modified over abutting areas. Figure 3.1 shows a conceptual layout of the cross-section for the "adding lanes" alternative.

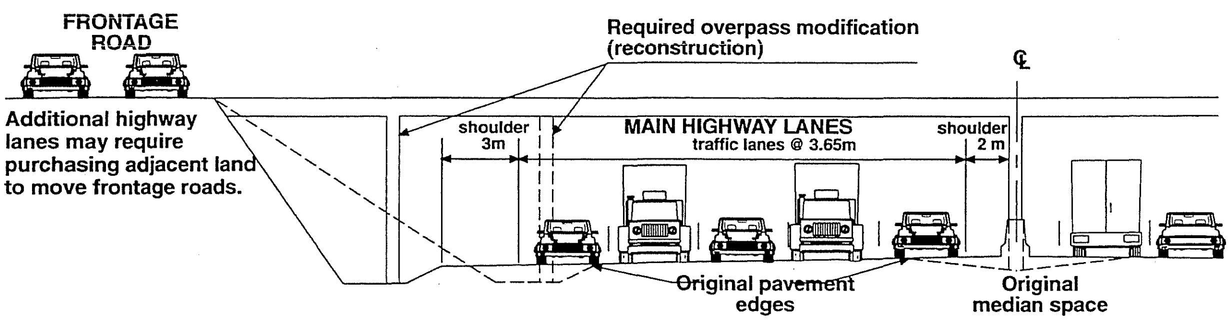

Figure 3.1. Conceptual cross-section of the "adding lanes" approach to capacity

Retrofit with ITS

This alternative would require upgrading IH-35 to operate as a semi-supercorridor, mainly by providing separate traffic lanes to automobiles and heavy trucks, and by increasing the width of these lanes from the current 3.65 meters (12 feet) to a proposed 4.55 meters (15 feet). (The lane width increase would be a way of safely accommodating heavier and larger trucks, and would also furnish auto drivers with the additional space required for a marginal speed increase.) As in the previous approach discussed, these modifications are expected to create workzones along the IH-35 route. Figure 3.2 shows a conceptual layout of the cross-section for the "retrofit" alternative.

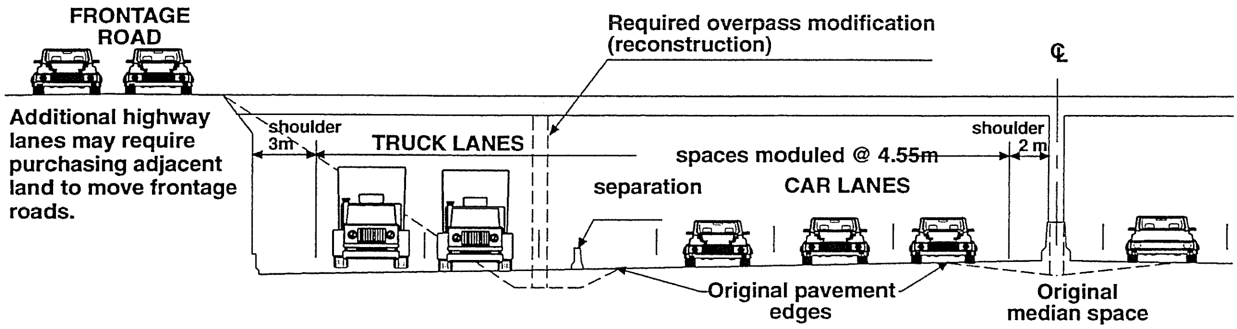

Figure 3.2 Conceptual cross-section of the "retrofit" approach to capacity

Given the geometric constraints of the current alignment, speeds could be increased only to a maximum of 130 km/hr (and maybe to 145 km/hr in some straight segments), and then only after vehicle-control technology and ITS are installed to ensure safety. Again as with the previous approach, this alternative would require building by-pass alignments along major urban areas.

Restricting adjacent development would be met with some degree of opposition, since neighboring landowners already have access to the system and many of them already have taken advantage of it. Thus, further access control for traffic fluidity enhancement doesn't appear to be a feasible feature under this alternative. Finally, the current space restrictions would make it improbable that multimodal capabilities could be built-in without major capital investment. Thus for the present evaluation, this alternative does not provide transportation modes other than the highway element.

A Managed Transportation System

Formerly referred to as a "supercorridor," this facility would be a separate alignment running parallel to IH-35, one that could thus complement its operation. Fully monitored and controlled to provide a highly efficient service throughout all its aspects, this facility has now been more fittingly termed a *Managed Transportation System* (MTS).

The highway element of this MTS would also have separate and wider lanes for automobiles and heavy trucks; its geometric design would incorporate provisions for travel speeds up to 240 km/hr, anticipating future advances in vehicle-control technology and ITS (which would be incorporated).

Specially designed limited access points would be provided to control abutting land development and to ensure a continuous and fluid operation (hence, no frontage roads would be provided). Moreover, sufficient right-of-way would be acquired to reserve additional space for a gradual incorporation of other high-capacity transportation modes within the alignment (including electricity, gas, and fiber optic transmission lines), as depicted in Figure 3.3. For the present evaluation, though, only the highway element costs (including full right-of-way acquisition) are being considered.* Also, since this facility is expected to complement IH-35 in accommodating future traffic demand, rehabilitation expenditures for IH-35 are being considered as part of the overall cost of this alternative.

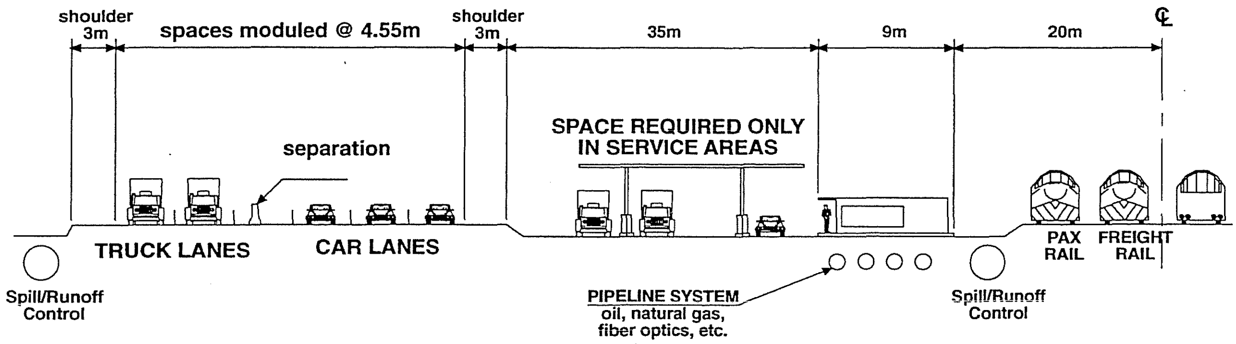

Figure 3.3. Conceptual cross-section of the MTS approach to capacity

CAPACITY REQUIREMENTS

The evaluation process requires that we establish the capacity needs for each of the alternatives under consideration. Since the current analysis concentrates specifically on highway operation, the capacity requirements are described in terms of the number of traffic lanes needed.

As a preliminary step, and following the procedures outlined in the 1994 *Highway Capacity Manual* (Ref 8), we used three traffic composition conditions to obtain service flows (SF) for a minimum level of service C over the design peak period. Using a maximum service flow MSF=1,550pcphpl (passenger cars/hr/lane) for LOS C results in the following:

CONDITION	CHARACTERIZATION	SERVICE FLOW FOR LOS C (SFC)
Only automobiles	0% heavy trucks (fhv=1.00)	1,550 vph per lane
Mixed traffic	20% heavy trucks (fhv=0.71)	1,100 vph per lane
Only heavy trucks	100% heavy trucks (fhv=0.33)	510 vph per lane

* While there are no figures available for projecting rail usage, the researchers are aware that Union Pacific is eager to bypass many IH-35 cities located on its route. For example, Union Pacific has indicated its willingness to move its Austin, Texas, facilities as part of the proposed MoKan alignment, the expectation being a faster and, hence, more efficient system.

In the above table, "fhv" is a capacity reduction factor based on the percentage of heavy vehicles present in the traffic stream.

Using the typical hourly traffic distribution over IH-35 previously discussed, we observed that the travel patterns over IH-35 present a quite beneficial hourly distribution in terms of optimal use of capacity, owing to the fact that a fairly constant demand occurs over a 12-hour period (from about 7:00 a.m. to 7:00 p.m.), thus allowing for a somewhat constant level of service over much of the day. This is in contrast to the characteristic urban travel behavior where two or three prominently high peaks take place over narrow periods, which in turn creates huge gaps of underutilized capacity. In addition, it was observed that critical peaks (or design ADT) take place toward the weekends; thus, if aiming for minimum LOS C, most probably the weekday LOS would go no lower than B.

Using the computed service flows, along with traffic growth forecasts generated in Chapter 2, lane requirements over the next 50 years were obtained for each of the alternative approaches. Since at the present time it is difficult to predict preference levels in the case of parallel alignments for IH-35 and an MTS, two attraction scenarios were suggested to establish and compare broad magnitudes of investment: The first one assumes that 55 percent of the traffic would be redirected to the MTS while the rest would continue using IH-35; the second scenario assumes that the traffic attracted to the MTS could grow to 70 percent of the total corridor volume. Table 3.1 summarizes the lane requirements for each alternative solution and for the conditions described herein.

Table 3.1. Total lane requirements for different alternatives and scenarios (year 2045)

Alternative	Growth scenario	Traffic condition	Forecast ADT (year 2045)	Peak flow (K=0.11)	Required Lanes
Add lanes IH35	4%	mixed traffic	106,080vpd	11,700vph	10
	8%	mixed traffic	178,160vpd	19,600vph	18
Retrofit IH35	4%	autos only	84,864vpd	9,300vph	6
		trucks only	21,216vpd	2,300vph	4
	8%	autos only	142,528vpd	15,700vph	10
		trucks only	35,632vpd	3,900vph	8
MTS + IH35 IH35 attraction: 45% MTS attraction: 55%	4%	IH35: mixed	47,736vpd	5,300vph	4
		MTS: autos	46,675vpd	5,100vph	4
		MTS: trucks	11,669vpd	1,300vph	min 4
	8%	IH35: mixed	80,172vpd	8,800vph	8
		MTS: autos	78,390vpd	8,600vph	6 or 4HOV*
		MTS: trucks	19,598vpd	2,200vph	4
MTS + IH35 IH35 attraction: 30% MTS attraction:70%	4%	IH35: mixed	31,824vpd	3,500vph	4
		MTS: autos	59,405vpd	6,500vph	4
		MTS: trucks	14,851vpd	1,600vph	4
	8%	IH35: mixed	53,448vpd	5,900vph	6
		MTS: autos	99,770vpd	11,000vph	8 or 4HOV*
		MTS: trucks	24,942vpd	2,700vph	6 or 4LI**

* HOV lanes considered here for autos with at least 2 pax.

** LI represents here a load increase of 20%.

From the analysis of station traffic counts, Williamson County rural traffic produced the median ADT, with 34,000 vehicles in 1992. This figure was therefore used as a representative rural value for the IH-35 corridor between DFW and San Antonio.

SUMMARY

As noted in Table 3.1, both the "adding lanes" and "retrofit" approaches require a staggering number of traffic lanes, most of which would be constructed on IH-35 over the next 50 years. Depending on the growth scenario, a total of 10 to 18 lanes would be required for any of these two alternatives. It is important to note, though, that for the "retrofit" approach, conventional capacity standards were used to compute the required number of lanes. Because its current commercial stage cannot guarantee major capacity improvements, ITS technology was not included as a factor. Likewise the MTS approach, which would make use of ITS technology, was also forecast using conventional capacity standards.

On the other hand, even though a case can be built around future benefits in increased capacity that ITS can bring to existing roadways, the fact remains that, by itself, this technology can only buy additional time before the corridor again reaches congested conditions (Ref 13). As history has shown, building traffic lanes without incorporating other measures that prompt changes in travel behavior (including traffic demand and vehicle occupancy patterns) has only induced more vehicle traffic, as users identify benefits in trip making with the absence of added cost.

An MTS could serve to bring about these travel behavior changes. Since this would be a "managed" facility, user fees or tolls would be introduced not only as an equity measure to obtain the necessary resources, but also as a control tool. With the use of pricing schemes, for example, travel behavior can be modified considerably to take full advantage of the capacity properties at hand.

From this perspective, and balancing the lane requirements under the conventional capacity estimation procedure, the MTS should be able to operate with a maximum of 10 lanes under the critical 8-percent growth scenario over the next 50 years. Four lanes (two in each direction) could be allocated for exclusive heavy truck use if a 20-percent load increase is allowed, while the other six lanes could be assigned for automobile use; two of these lanes could later be turned into bus-HOV lanes (one in each direction). Built-in multimodal capabilities and continuous improvements in vehicle occupancy patterns can further increase its service life far beyond the 50-year threshold without any additional lane investment.

Using the same reasoning, under this alternative solution, rural IH-35 should not increase its total number of lanes over six for the 8-percent growth scenario, thus requiring only the addition of two lanes from Austin to Fort Worth in the worst case. This is the critical element that must be considered if an MTS is to be implemented successfully. If it is not, this approach could potentially be regarded as doing more of the same thing: just adding extra lanes. Thus, Table 3.2 summarizes the optimal lane allocations to be considered for the cost evaluation of the alternative solutions.

Table 3.2 Optimal lane allocation to be used for cost comparison

Alternative	Growth scenario	Traffic condition	Allocated Lanes
Add lanes IH35	4%	mixed traffic	10
	8%	mixed traffic	18
Retrofit IH35	4%	autos only	6
		trucks only	4
	8%	autos only	10
		trucks only	8
MTS + IH35	4%	IH35: mixed	4
		MTS: autos	4
		MTS: trucks	4
	8%	IH35: mixed	6
		MTS: autos	6
		MTS: trucks	4

CHAPTER 4. A GENERAL FULL-COST EVALUATION OF ALTERNATIVES

ELEMENTS OF A FULL-COST EVALUATION IN TRANSPORTATION

Traditionally, costs are viewed as the expenditures or outlays required to purchase a good or service. However, it is appropriate to also define costs in terms of the value of the alternatives or opportunities relinquished in order to achieve a particular thing. This broader view of costs will harmonize with outlays if, and only if, the factors by which the outlays are calculated correctly reflect the value of the alternative uses of the resources. When costs are used in cost-benefit analyses, the emphasis is on social costs and benefits, with the aim of measuring the losses and gains in economic welfare incurred by society as a whole, in association with a particular action or investment. It seems clear that when measuring the impact of a new element of infrastructure, a full, social cost-benefit analysis is not only desirable but also technically appropriate. For the purposes of holistically evaluating Interstate Highway alternatives, we therefore adopted a full-cost approach.

Full cost by definition implies the complete inclusion of expenditures and impacts associated with a given action (in this case a transportation project). In this regard, and as shown in Figure 4.1, the full cost of a roadway is comprised of (1) agency costs, (2) internal costs, and (3) external costs.

Agency Costs

Agency costs are those costs associated with building and operating a roadway. Agency costs are usually divided into capital and non-capital costs. Capital costs include land acquisition, construction, and rehabilitation. Non-capital costs refer to routine maintenance administration, safety, and debt service.

Internal Costs

These are also called "user costs," insofar as they are borne by the consumer (e.g., tires, gasoline, maintenance, etc.). Accordingly, internal costs are usually divided into ownership costs and operating costs.

External Costs

These are also called "social costs," since they are borne by groups of individuals, by sectors of the population, or even by society as a whole. Owing to the preliminary nature of the present study, only those costs having a significant impact were included in the evaluation. In this regard, we note that, while accident and pollution costs were explored, they were not included in the final economic evaluation, given the inherent complexities in their evaluation and manipulation.

AGENCY COST EVALUATION

Having established a set of potential alternatives available to meet future IH-35 traffic demand, we next sought (as part of our economic evaluation) to determine the total investment cost associated with the implementation of each of the options.

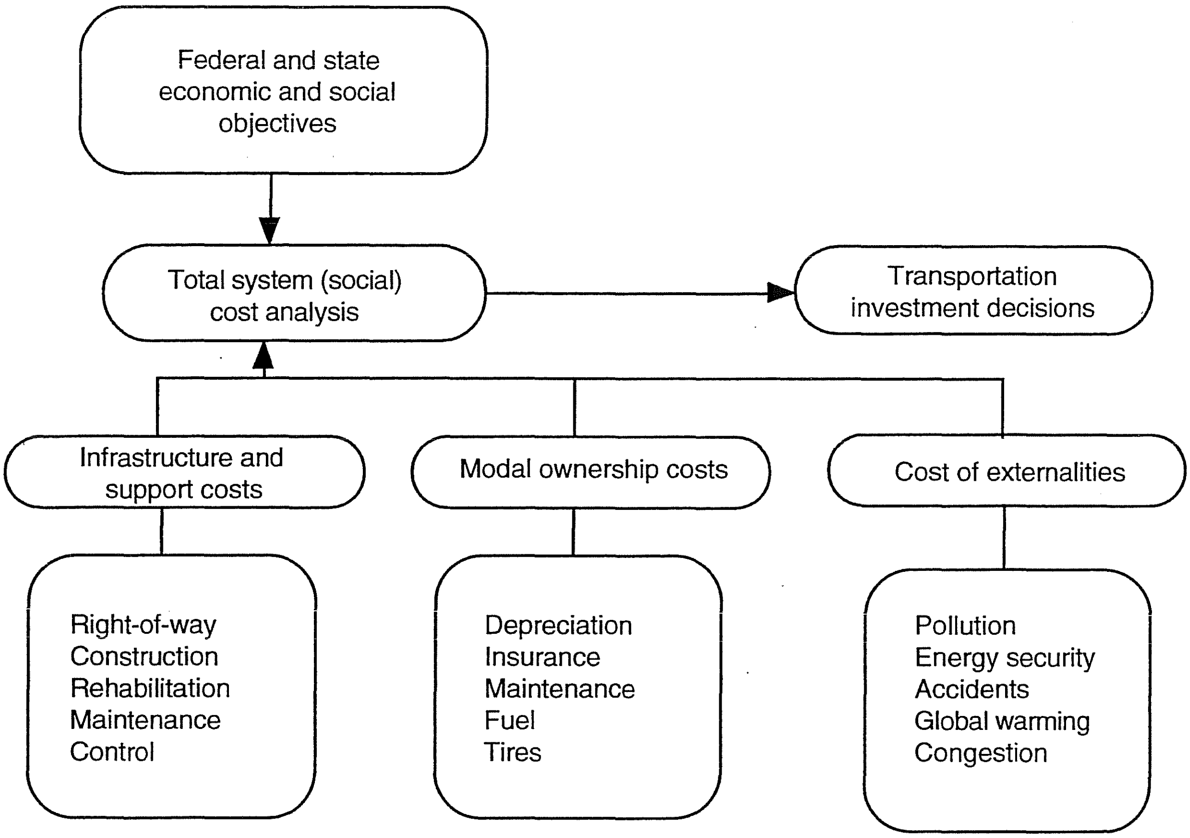

Figure 4.1. Elements of the full cost of a roadway

Pavement Requirements

Since pavement construction and pavement maintenance account for a substantial portion of the total agency cost of highways, the present study examined with special attention the pavement cost variations as a function of the attracted traffic. Accordingly, different conditions observed over the IH-35 corridor and relevant to pavement performance were introduced in a factorial design analysis to obtain a set of pavement solutions and associated costs. These pavement solutions were to include designs for both new construction and major rehabilitation of existing pavement, thus encompassing the range of requirements for the previously discussed alternatives for meeting future traffic demand.

The original strategy with respect to traffic was to assume a current annual traffic volume over IH-35 of 4,800,000 repetitions of 8,000-kg (18-kip) equivalent single axle loads (ESALs), and to use two different ESAL growth rates (compounded yearly), based on previous observations over rural highways in Texas. In addition, for the design of the critical traffic lane, a directional distribution (Dd) factor was kept constant at 0.50, while the design lane factor was used with values of 0.90 and 0.70. Finally, attraction percentages of 100 percent, 45 percent, and 10 percent were used to characterize scenarios of user preference of parallel alignments within the IH-35 corridor.

As a result of combining these traffic factors, a wide spectrum of ESAL applications over the maximum 50-year period was obtained with the associated pavement designs and costs, ranging from a minimum of 10 million ESALs to a maximum of 300 million ESALs.

The use of the previously described factors resulted in the determination of pavement layer thicknesses for the new construction procedure, or asphalt concrete (AC) overlay thicknesses for the rehabilitation procedure. In turn, these thicknesses yielded a unit cost. In an iterative process, the several thicknesses were varied until they produced a minimum cost for a given set of factorial conditions.

Estimated Agency Cost of Alternatives

Having determined the potential costs of pavements, total agency costs were estimated for a 50-year life cycle of the facilities, which was the analysis period established under the current study. In addition, maintenance and rehabilitation costs for the rural segments of the existing roadway were determined as well, as part of the "no build" approach. Figure 4.2 shows the current alignment configuration for IH-35 from San Antonio to Dallas-Fort Worth.

In order to properly determine the present worth of each of the alternatives, it was necessary to establish an approximate implementation schedule. Based on recent IH-35 construction experience, we established an overall construction program composed of three major periods of five years each. These periods were allocated for the construction of three roadway segments similar in length: (1) Austin to Waco, (2) Waco to DFW, and (3) San Antonio to Austin. This order was selected based on priorities for congestion relief. Currently, the segment recording the highest traffic volumes is the San Antonio-Austin section, but, as depicted in Figure 4.2, the recent construction of two additional lanes to this segment should reduce its congestion somewhat. Figure 4.3 shows the general construction stages, which apply to all the alternatives considered.

Agency costs included capital investment for construction, maintenance, and operation of the facility. Based on the prevailing economic conditions, a 4-percent real rate of return was used to obtain the present worth of the cost items, in terms of constant dollars. The real rate of return (also known as "real MARR" or minimum attractive rate of return) represents the time value of capital.

The present evaluation built on a previous estimation of infrastructure requirements for a roadway parallel to IH-35 (Ref 5). Finally, the unit cost for lane additions to IH-35 was obtained from TxDOT (Ref 14). The agency cost investment for each of the alternatives is described below.

a) No-Build option: This is equivalent to a "do nothing" approach, which serves as a control element or performance reference to the alternative solutions. Only future costs for maintenance and rehabilitation of existing pavements were obtained for this case, and only for the rural sections of IH-35.

b) Adding lanes: Figure 4.4 presents the general configuration generated for this alternative. As previously established, by-passes should be constructed around major urban areas to separate urban traffic from through intercity traffic. This arrangement was considered less disruptive (and thus less costly) than building the additional lanes within the traffic-intense urban area. It should be noted that a "bridge overpass reconstruction" item has been included, which considers modifications to transverse overpass crossings required by the additional space needs.

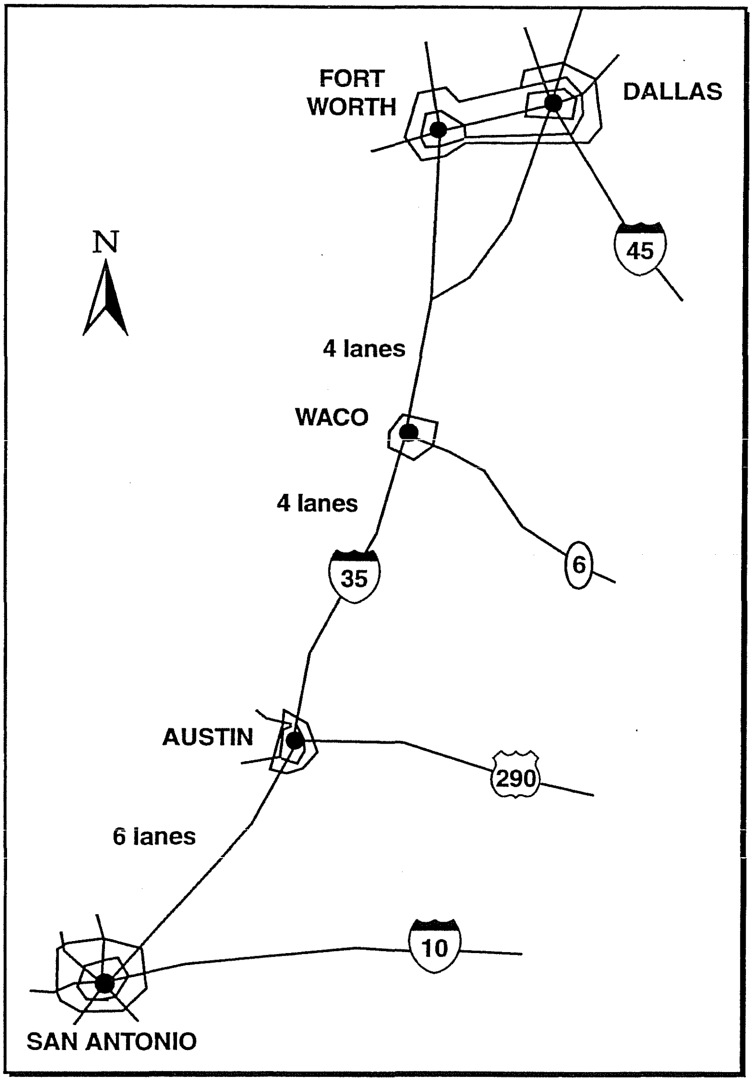

Figure 4.2. Layout of the current IH-35 configuration between San Antonio and DFW

Segment	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Austin-Waco															
Waco-DFW															
SAN-Austin															

Figure 4.3. General construction schedule for solutions to the IH-35 corridor

c) Retrofit with ITS: Figure 4.5 presents the general configuration established for this alternative. Again, by-passes should be constructed around major urban areas. In addition, traffic lane widths of 4.55 meters (15 feet) were considered for pavement costs, bridge structures, and right-of-way requirements. Finally, ITS implementation costs were also estimated. It should be noted, again, that a "bridge overpass reconstruction" item has been included, which considers modifications to transverse overpass crossings needed for the additional space requirements on IH-35.

d) Managed Transportation System: Figure 4.6 shows the general configuration established for this alternative. In addition to the agency costs of the MTS, maintenance costs for IH-35 were included under the overall evaluation of this alternative. Moreover, for the 8-percent growth scenario, the agency cost of upgrading IH-35 from 4 to 6 lanes (from Austin to DFW) was included as well (with IH-35 attracting 30 percent of the traffic and the MTS attracting 70 percent; see Figure 3.1 on page 17). For pavement design, a preliminary traffic attraction split of 55 percent and 45 percent was considered for the MTS and IH-35, respectively.

Table 4.2 summarizes the estimated present worth of the agency costs for each of the alternatives under 4-percent and 8-percent growth scenarios, and for the 50-year analysis period.

As expected, the "no build" option yielded the least cost of all the approaches under consideration; however, it doesn't provide the congestion relief measures that the other alternatives do. The corresponding cost of this approach, therefore, is for merely maintaining the facility.

Table 4.2. Agency cost comparison between alternatives (50-year analysis period)

Alternative	**Agency cost (millions)**	
	4% growth	**8% growth**
No build	\$210	\$229
Adding lanes	\$2,694	\$5,266
Retrofit with ITS	\$3,270	\$6,411
MTS	\$2,859	\$3,622

Of the alternative solutions, the "adding lanes" approach shows the least agency cost under the 4-percent growth scenario. However, for the 8-percent growth scenario, the MTS alternative shows the least agency cost. Overall, even though the MTS is a new facility, reconstruction requirements and the need for by-passes for both the "add lanes" and "retrofit" approaches make all the alternatives comparable with respect to infrastructure costs. Still, for a complete economic evaluation, internal (user) and external (social) costs need to be incorporated.

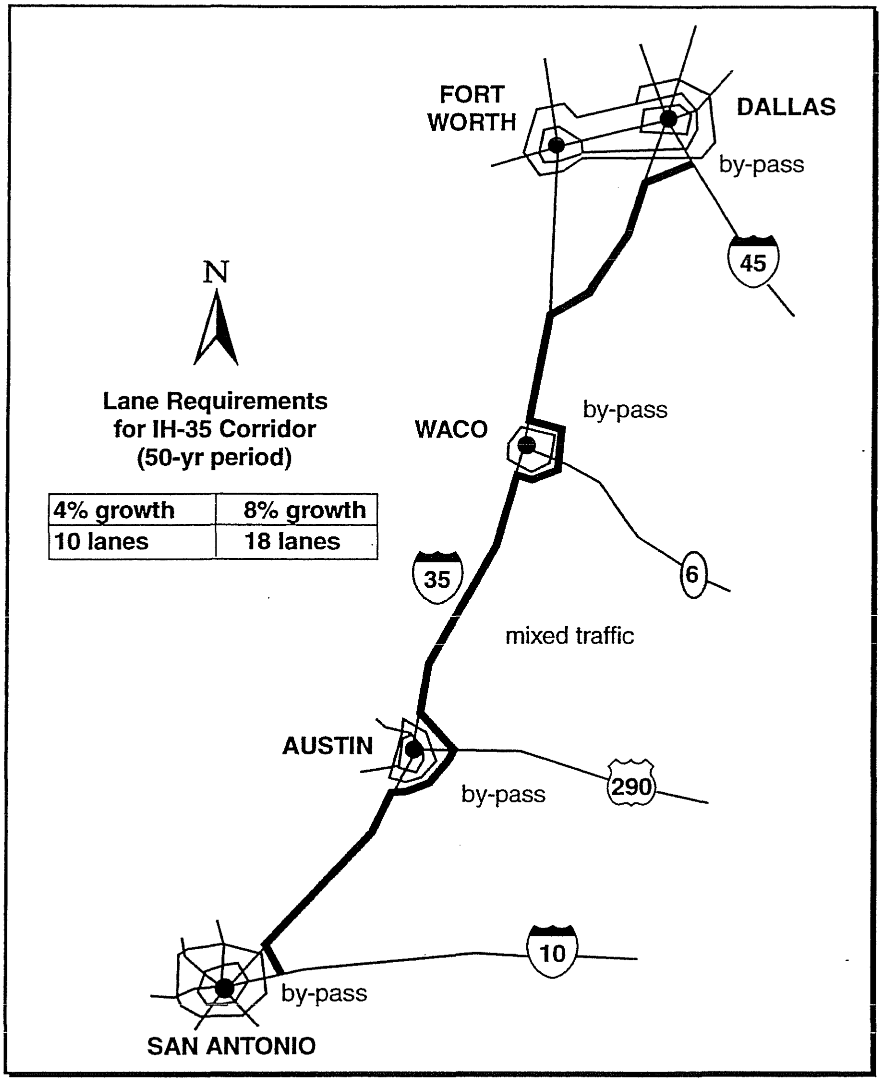

Figure 4.4. "Adding lanes" configuration between San Antonio and DFW

INTERNAL/EXTERNAL COST EVALUATION

As previously established, internal and external costs are those costs borne by individual users of a transportation system or by the society as a whole, and can be correlated to the level of service provided by a particular facility under study. Since the level of service can be associated with a specific range of operating speeds, the main objective here was to determine the internal and external costs related to reductions in operating speeds resulting from increasing traffic congestion and/or disruption.

These costs were obtained for the two main users of the highway system: automobiles and heavy trucks. In order to simplify the analysis, one vehicle type was selected as representative for each of these groups. For automobiles, a medium-sized passenger car was selected, and for the heavy trucks, a five-axle (18-wheeled) tractor semi-trailer was considered. An average grade of 0 percent was used as representative of the vertical alignment when considering vehicle/engine wear and maintenance.

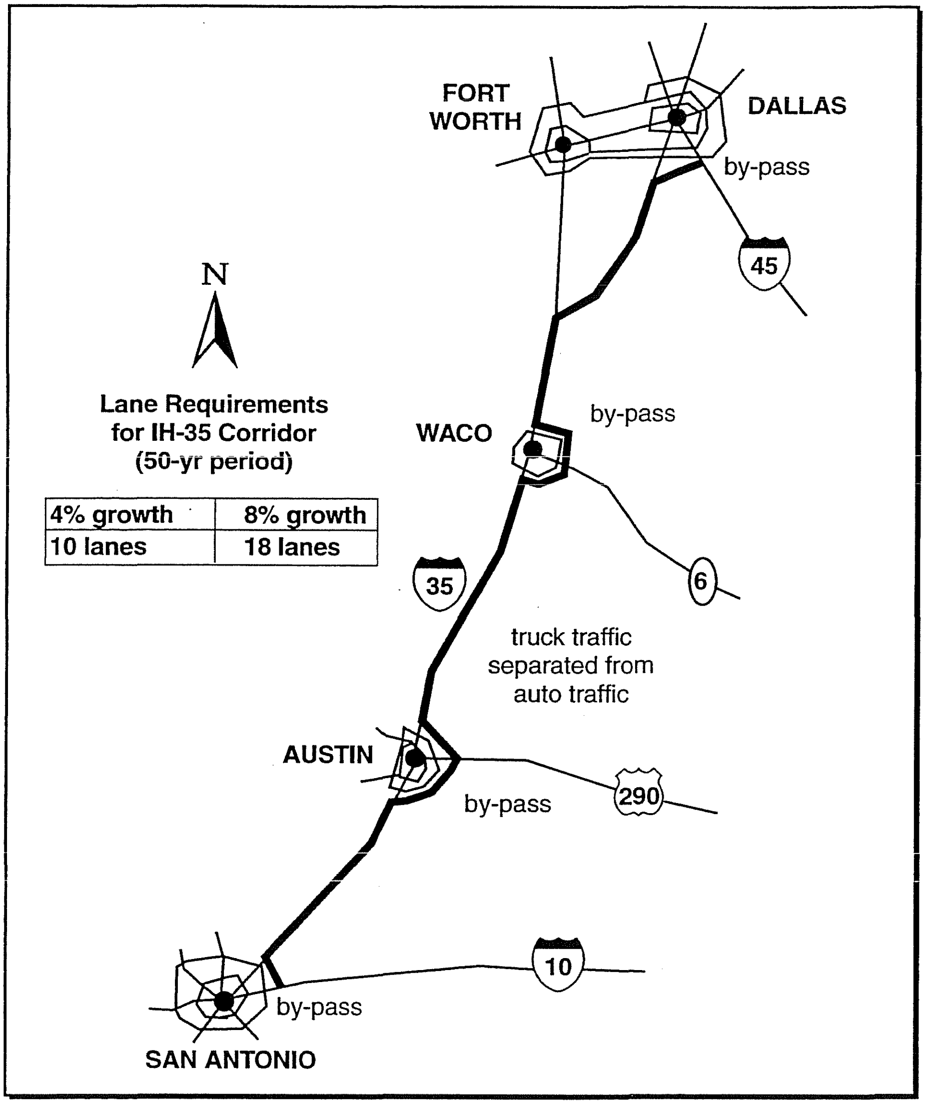

Figure 4.5. "Retrofit with ITS" configuration between San Antonio and DFW

Ownership Costs

Ownership costs are those costs relating to depreciation and insurance/overhead costs (depending on the type of vehicle). Depreciation expense is one of the most difficult of non-fuel costs to estimate accurately. The major area of contention in the debate concerning depreciation expense is what portion of the expense should be assigned to operation on the road. For the present study, two reports published by the Texas Research and Development Foundation (Refs 15 and 16) were used to estimate depreciation.

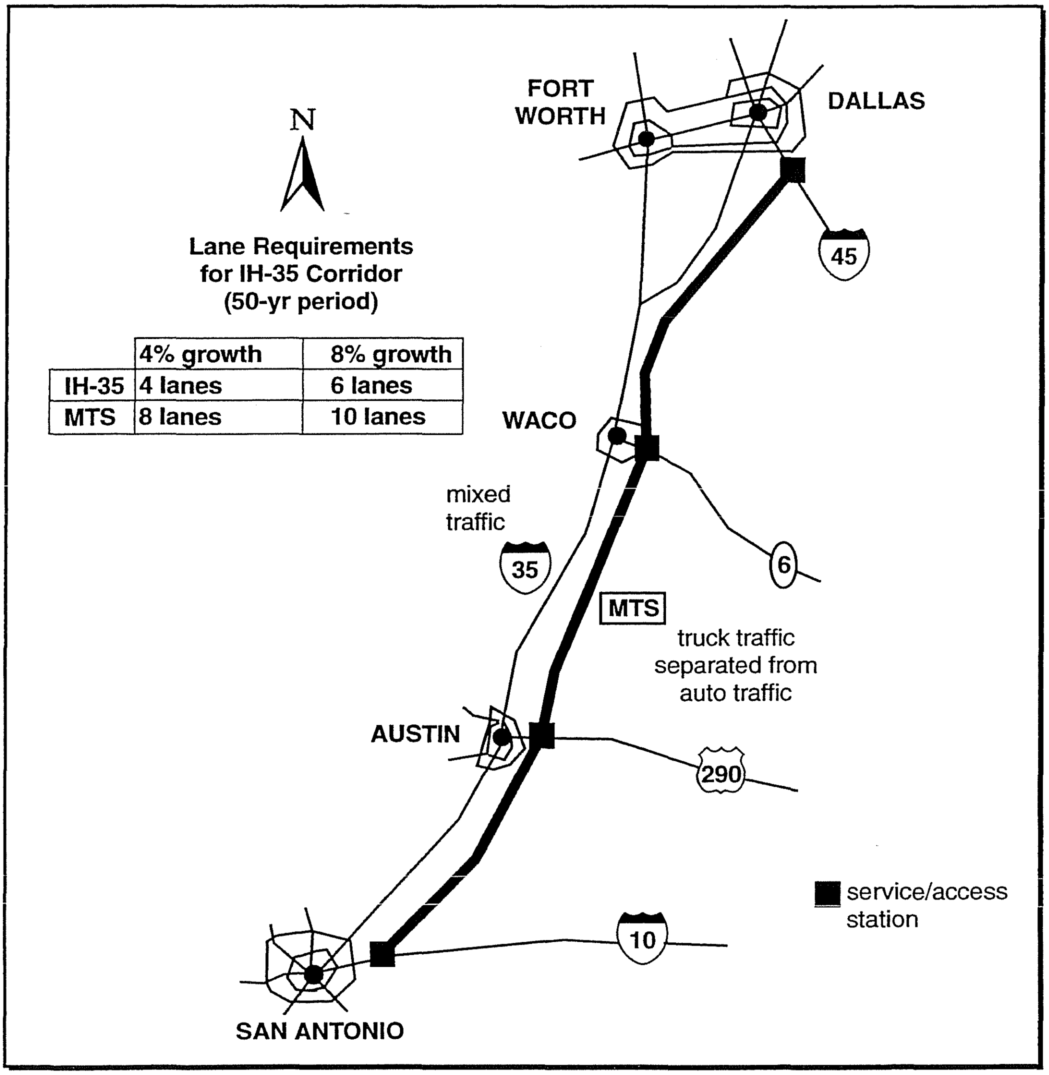

Figure 4.6. "MTS" configuration between San Antonio and DFW

Insurance cost is determined by vehicle type, coverage selected, user's driving record and age, and the region in which the vehicle is used. In addition, it has been documented that as congestion increases, so does the accident rate (Ref 17). Insurance companies include this effect by adding insurance premiums on vehicles being used in large urbanized areas. In the case of automobiles, insurance costs were found to average $0.04 per kilometer (Ref 18).

In the case of trucks, overhead is the estimate of all other indirect costs (administration, regulation, etc.).

Operating Costs

The items in this group included fuel costs, tire wear, and maintenance/repair costs. In the case of fuel costs, fuel price for automobiles was estimated to be $0.20 per liter ($0.76 per gallon) of gasoline, and for trucks, a price of $0.15 per liter ($0.55 per gallon) of diesel, not including state and federal taxes, was used. Tire wear and maintenance/repair costs were estimated using the formulas developed by Zaniewski et al. (Ref 16).

Travel Time Costs

Travel time values vary considerably depending on who is traveling, for what purpose, and under what conditions. The California Energy Commission calculated the value of congestion delay reduction at $10.60 per vehicle per hour, studying a mix of private and commercial vehicles. In the case of automobiles, the Texas Transportation Institute gives to time an average cost of $10.00 per person-hour in 1990 dollars, which translates to about $14.40 in 1995 dollars. In the case of trucks, the time value was considered to be the average salary paid to a truck driver. This of course is a conservative estimate, since it omits the more complex time value that businesses and overall trade stakeholders place on expeditious and reliable freight transportation.

Air Pollution Costs

Air pollution is the contamination of the ambient air by chemical compounds or by solid particulates in a concentration that adversely affects living organisms. In the present study, the main interest is the pollution produced by vehicles. Estimating this cost requires information about the relationships between driving, emissions, and atmospheric conditions. Only recently has the extent of human health damage from airborne particles been recognized; nevertheless, a vehicle's precise contribution to this pollutant remains uncertain.

Pricing air pollution is a difficult task that requires placing dollar values on human mortality, discomfort, loss of recreation, and aesthetic damage. Basically, there are two approaches to calculating air emission unit costs: (1) damage cost, and (2) control cost. The damage cost attempts to quantify in monetary terms the environmental damage caused by the emissions. The control cost is based either on the cost of emission control equipment or on the price needed to reduce emissions to specific levels. Using both approaches, emission costs were obtained from published reports (Ref 19).

To obtain the relation between emissions and speed, we used workzone models for emission prediction (Ref 20). These models were originally developed for urban congestion scenarios and, thus, were modified to represent the rural highway conditions under discussion in the present study.

Accident Costs

Accidents are an unavoidable aspect of transportation. Even though the number of accidents can be obtained for different types of roadway facilities, it is difficult to quantitatively estimate how future vehicle technology, ITS, or a given geometric configuration and operating speed will impact the frequency (and severity) of accidents.

Another difficulty in establishing this cost item is the lack of consensus regarding the loss of productivity resulting from injuries, as well as the value placed on human life. In this regard, only scatter data from a set of reports could be obtained for the present study. A further difficulty was attempting to develop a measure of accident costs related to a given level of service. Thus, a decision was reached to omit this cost item for the time being, until more reliable information could be obtained.

In summary, Tables 4.3 and 4.4 present a preliminary estimation of internal and external costs for rural highway use under different levels of service associated with an average operating speed. In this regard, levels-of-service A through D depict constant operating speeds, with minimum acceleration-deceleration effects, while in levels-of-service E and F, the stop-and-go effect was introduced in the cost estimation.

FULL-COST COMPARISON BETWEEN ALTERNATIVES

In order to estimate the total user/social costs generated under each of the respective alternatives, the projected traffic volumes on the IH-35 corridor (using both the 4- and 8-percent growth scenarios) were analyzed to forecast operating levels of service. This task was accomplished for the 50-year analysis period, and according to the procedures outlined by the 1994 *Highway Capacity Manual* (Ref 21). The costs summarized in Tables 4.3 and 4.4 were then assigned to the projected traffic, according to the yielded level of service. Finally, the differential user and social costs obtained for the analysis period were added to the agency costs.

Table 4.3. Summary of internal/external costs for automobiles ($/kilometer)

Item	Level of service					
	LOS A [105km/hr]	LOS B [95km/hr]	LOS C [90km/hr]	LOS D [85km/hr]	LOS E [72km/hr]	LOS F [48km/hr]
Depreciation	0.058	0.059	0.062	0.062	0.065	0.079
Insurance	0.037	0.041	0.044	0.046	0.064	0.135
Fuel	0.021	0.018	0.017	0.016	0.024	0.034
Tire wear	0.001	0.001	0.001	0.001	0.005	0.009
Maintenance & repair	0.022	0.021	0.020	0.019	0.019	0.017
Travel time	0.137	0.152	0.159	0.168	0.235	0.497
Total cost, $/kilometer	0.277	0.291	0.302	0.312	0.411	0.771

Table 4.4. Summary of internal/external costs for heavy trucks ($/kilometer)

Item	Level of service					
	LOS A [105km/hr]	LOS B [95km/hr]	LOS C [90km/hr]	LOS D [85km/hr]	LOS E [72km/hr]	LOS F [48km/hr]
Depreciation	0.080	0.080	0.089	0.089	0.104	0.140
Overhead	0.118	0.130	0.137	0.144	0.201	0.425
Fuel	0.068	0.062	0.058	0.056	0.112	0.170
Tire wear	0.025	0.022	0.019	0.018	0.162	0.323
Maintenance & repair	0.137	0.128	0.119	0.115	0.111	0.091
Driver	0.158	0.174	0.183	0.194	0.270	0.570
Total cost, $/kilometer	0.586	0.596	0.607	0.617	0.960	1.718

Basic Assumptions

To establish congestion conditions for the different alternatives, two important considerations were established to model the disruption effects of workzones and to determine the typical hourly volumes:

1) Lane-narrowing strategy: Capacity requirements presented in Chapter 3 were modified as a result of lane-width reductions over workzones. According to the 94-HCM, a lane reduction from 3.65 meters to 3.05 meters, together with shoulders reduced to less than 1.80 meters, decreases the original capacity by 25 percent. These considerations were introduced for the "adding lanes" and "retrofit" alternatives during construction periods, as depicted by the schedules established previously in the current chapter. The modified capacity can then be expressed as the effective number of traffic lanes, resulting from multiplying the original number by the reduction factor (in this case fw=0.75). While this strategy can account for only a small fraction of the disruption effects created by workzones, the general scope of the present study allows for this simplification.
2) Modeling the K-factor: The K-factor is the fraction of daily vehicles that travel during the peak hour. Since for the present study a single average daily traffic (ADT) is being used as representative for a given year, in order to characterize the variation in hourly volumes (including the peak period), hourly factors have been backcalculated from hourly flows, using the ADT of the base year. These so-called "surrogate K-factors" model hourly traffic flow in two-step periods during average weekdays (K=5% and 3.33%), and in four-step periods during weekends (K=9%, 7.5%, 5.5%, and 1.0%).

Summary of Results

Table 4.5 shows the total user and social costs for each of the alternatives considered. As depicted here, the MTS is the least-cost alternative, owing mainly to the fact that levels of service drop only to a minimum of C. By contrast, the "adding lanes" and "retrofit" alternatives drop in some instances to D and even to E levels as a consequence of workzone disruption during construction periods — and consequently show notably higher user and social costs. Since the "no-build" alternative does not provide any type of congestion relief measure (and as expected levels of service drop considerably), it yields the highest user and social costs of all the options.

Thus, considering the MTS as the only alternative free of congestion effects, the second column of each growth scenario depicted in Table 4.5 shows the congestion/disruption cost of the alternatives computed as the algebraic difference between the user and social costs of the MTS and the other alternatives.

Table 4.5. Total user/social costs under each alternative (billions) for a 50-year analysis period

	8% Growth		4% Growth	
Alternative	Total user+social cost (billions $)	Congestion/ disruption cost	Total user+social cost	Congestion/ disruption cost
No-build	$205.1	$78.2	$105.2	$21.2
Adding lanes	$132.5	$5.5	$88.6	$4.5
Retrofit with ITS	$132.5	$5.5	$88.5	$4.4
MTS	$127.0	$0.0	$84.0	$0.0

Finally, Table 4.6 summarizes the full cost of each of the alternatives, including the agency costs previously estimated.

Table 4.6. Fifty-year full-cost summary (billions)

	8% Growth			4% Growth		
Alternative	Agency cost (billions $)	Congestion/ disruption cost	Total cost	Agency cost	Congestion/ disruption cost	Total cost
No-build	$0.3	$78.2	$78.5	$0.3	$21.2	$21.5
Adding lanes	$5.3	$5.5	$10.8	$2.7	$4.5	$7.2
Retrofit with ITS	$6.4	$5.5	$11.9	$3.3	$4.4	$7.7
MTS	$3.6	$0.0	$3.6	$2.9	$0.0	$2.9

From this last table, two important conclusions can be drawn. First, the agency costs for all the alternatives (excluding the "no-build" option) are quite similar. One reason for this result is that the same capacity standards were used to compute the number of traffic lanes needed, thus yielding similar requirements. Moreover, the added costs of a new facility are being offset by additional ROW requirements on existing alignments, as well as by the extra alignment needed to by-pass major cities. Second, for the "no-build" alternative, the impact of traffic congestion alone drives its total cost way above the total costs of the other options.

Comparing the full costs across the alternatives evaluated reveals that internal/external costs are reduced under the MTS solution. Because it would be a separate facility located away from existing alignments, the MTS would impose no disruption effects on the traffic in the corridor. As a result, it yields the least total cost.

It is important to note again that a conservative approach has been used in the evaluation, with the development of accident costs and meticulous workzone impacts being excluded. Insofar as the purpose of this analysis was to determine broad directions and magnitudes of investment, their inclusion is strongly recommended in any further feasibility studies for such a corridor.

CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

According to the results obtained in the present study, conclusions are offered from both a general (or statewide) view point, as well as from the specific application of the selected case study. Please note: Because this project proceeded as a preliminary prefeasibility study, many details are necessarily omitted from this and earlier reports. For example, such issues as how much ROW would be needed for interchanges/service facilities, or where the beginning and ending points of the MTS would be located are matters that would be addressed during detailed follow-up planning. Also note that, because the project was a preliminary review only, the analysis included herein was of a deterministic nature, as against a more precise probabilistic one. We recommend that any future studies approach the concept of a managed transportation system probabilistically. In this way, more precise costs could be identified.

General

The present study develops a methodology for exploring loss of mobility on rural highways that can be applied to any major corridor in the state. Furthermore, the application of the methodology to the case study demonstrates that the present loss of mobility currently experienced on urban highway sections will eventually expand to the rural sections of key intercity links. Unfortunately, these events will occur much sooner than later. Our findings underscore the need for an immediate policy response, one that would set in motion a major effort to identify the extent of the statewide problem by applying the methodology presented herein to all the major trade corridors in Texas. In addition, public recognition of the problem will provide a window of opportunity for mobilizing public support and resources necessary to address the problem. Otherwise, Texas travelers will rapidly face a loss of personal mobility and a consequent steady erosion of their quality of life. Moreover, industry that would normally be attracted to the state and provide job opportunities for Texans will seek other areas of the country. And because Texas is in competition with all other states for both national and (increasingly) international business, the problems associated with IH-35 and other high-traffic corridors in the state must be addressed decisively, while there is still time.

In determining that conventional solutions do not always offer effective strategies for the crisis rapidly overwhelming key links on the Interstate system, the results of our study suggest that the MTS concept, as a parallel facility to high-traffic links, does present a viable investment alternative. An MTS would provide efficient ground transportation in the future, and would render highly effective solutions to problems associated with traffic demand management and the environment; with the introduction of tolls, the MTS could also proceed as a self-financing and self-sustaining facility. When implemented parallel to a high-traffic, non-tolled link, the MTS will be the facility of choice for those users willing to pay a premium for higher levels of service. Thus, this self-perpetuating feature of the MTS represents an excellent opportunity for relieving the strain on state budgets.

Specific Observations for the Case Study

Applying the methodology developed in this study to the IH-35 segment connecting Dallas and San Antonio (around 450 kilometers), and assuming a conservative 4- to 8-percent annual traffic growth rate, we have determined the following:

1. The capacity analysis indicates that a 3- to 10-year window of opportunity exists before a poor level of service (LOS D) exists along the entire route. Furthermore, only a 2- to 10-year window exists before several counties along the route will be at ultimate capacity (given the present configuration of lanes).
2. If no additional capacity is provided, the travel time for highway trips from Dallas to San Antonio will increase from the approximately 4 hours required at present, to the pre-Interstate time of more than 8 hours. Such an 8-hour trip will be required as soon as the year 2005.
3. If no additional capacity is provided, vehicle operating costs for cars and trucks will increase from 2.5 to 3 times their present value (not including inflation) along the entire 450-kilometer segment within the next ten years, owing to congestion alone.
4. Pollution caused by congested traffic will double over present levels in ten years along the entire route.
5. From the economic analysis of alternative solutions, we conclude that the need for bypasses along major cities, for the reconstruction of transverse overpasses along IH-35, and for additional and more expensive right-of-way — all make the "adding lanes" and "retrofit" alternatives comparable in agency costs to building a separate facility.
6. The added user and social costs resulting from traffic disrupted by construction makes a parallel MTS the most viable of the studied alternatives by far. Including all possible costs, adding lanes to IH-35 and/or retrofitting ITS would result in costs 3 times the full cost of building a separate MTS. Doing nothing but maintaining IH-35 will yield a full cost 20 times higher than that required to build a separate MTS.

RECOMMENDATIONS

In general, we recommend that the methodology developed in this report be applied to every major transportation corridor in the state of Texas, with a view toward identifying the extent of mobility problems and their consequences over a given analysis period. Included in such a recommendation is the following:

1. A priority listing of corridors suitable for application of the economic analysis should be developed. This effort would assist in identifying feasible alternative solutions to alleviate non-urban traffic congestion.
2. A policy should evolve from the implementation of Item 1 to develop solutions.
3. The proposed solution should consider multiple modes of transportation, such as adding passenger rail, intermodal combinations of trucks and trains, and special lanes for cars and trucks. In addition, other transmission agencies, including vendors of oil, gas, electricity, and fiber optics, could be operational partners.

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