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16. Abstract In 1991, with the passage of the Intermodal Surface Transportation Efficiency Act (ISTEA), the U.S. Congress established the objective to develop a national intermodal system to move people and goods efficiently. In the freight sector, exclusive truck roads, railroads, barges, and pipelines are seen as part of the intermodal solution to divert truck traffic away from the highways to the benefit of both freight and passengers. Ten years after ISTEA, challenges and barriers in the freight sector remain. Public agencies are challenged with demonstrating and contrasting the benefits of multimodal investments with the benefits of traditional highway spending. This report summarizes the development and use of the Multimodal Analysis Freight Tool (MAFT) as a sketch planning tool to appraise multimodal freight investment alternatives.		
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A SKETCH PLANNING TOOL FOR THE APPRAISAL OF FREIGHT MODAL INVESTMENTS

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Table of Contents

List of Figures

List of Tables

1. INTRODUCTION

The transportation sector undoubtedly has brought about numerous economic benefits in the past 100 years. Over the last two decades, however, freight transportation in the U.S. has changed dramatically as a result of increased globalization and the container revolution that facilitated growing international trade. At the same time, the deregulation of the freight transportation modes resulted in increased truck modal share. By the end of the 20th century public agencies increasingly were becoming aware of the cost associated with increased highway travel. Public agencies point to increasing costs associated with expanding and maintaining the highway system as roadways become more and more congested, while others point to the impact of congestion on the efficiency of goods movements, which has direct regional economic impact. Lastly, environmentalists speak about a lurking environmental crisis and point to the growing demand for fossil fuels and the deterioration of air quality associated with increased highway travel.

These concerns culminated in the passage of the Intermodal Surface Transportation Efficiency Act (ISTEA) in 1991 with the objective to develop a national intermodal system to move people and goods efficiently. Efficiency was envisioned to translate into less energy consumption, reduction in negative transportation externalities such as air pollution, and the promotion of the economy. In the freight sector, railroads, barges, and pipelines are often seen as part of the intermodal solution to divert truck traffic away from the highways to the benefit of both freight and passengers.

A number of innovative multimodal projects have been funded in the U.S. providing evidence of the societal benefits associated with multimodal freight investments. One of the best-known examples is the $2.4 billion Alameda Corridor that connects the Port of Los Angeles and Long Beach by rail to the transcontinental rail network east of downtown Los Angeles. The Alameda Corridor improved the efficiency of cargo distribution by diverting truck traffic from the Los Angeles highway system to the corridor with obvious benefits to highway users: reduced congestion, reduced traffic conflicts at 200 rail crossings, enhanced safety, and mobility. Freight shippers are benefiting from faster travel speeds, thus reducing inventory costs. Broader societal benefits include: significant reductions in train- and truck-idling emissions, reduction in noise pollution, and job creation (http://www.acta.org). These benefits, although widely recognized, have never been quantified in monetary terms, which make it difficult to determine whether the project increased the economic welfare of society in that the discounted benefits exceed the discounted costs associated with the investment. Thus, although innovative multimodal options exist, public agencies are challenged to demonstrate and contrast the benefits associated with such investments with the benefits from traditional highway spending.

In 2002, the Texas Department of Transportation contracted with the Center for Transportation Research (CTR) at The University of Texas at Austin, to develop a sketch planning methodology to quantify and evaluate the benefits associated with multimodal freight investments. In this project, a sketch planning spreadsheet application founded in cost-benefit analysis was developed to appraise multimodal freight transportation projects.

This report is structured as follows. Chapter 2 discusses changes that occurred in the freight sector, highlights the challenges experienced in freight transportation, and identifies the benefits of multimodal freight projects that have been funded to address these challenges in Texas, the U.S., and internationally. Chapter 3 provides a brief overview of cost-benefit analysis as applied to transportation appraisal. Chapter 4 discusses the development of the Multimodal Analysis Freight Tool (MAFT), with specific emphasis on the embedded models and necessary assumptions to reduce the complexity of the tool. Chapter 5 presents the results of two case studies that were used to test MAFT: an urban and rural highway corridor. Finally, Chapter 6 presents the main conclusions of this research and recommends future research that will improve MAFT and similar tools.

2. SOCIAL BENEFITS OF MULTIMODAL PROJECTS

This chapter discusses changes that have occurred in the freight sector, highlights the challenges experienced in freight transportation, and identifies the benefits of multimodal freight projects that have been funded to address these challenges in Texas, the U.S., and internationally. Additional information on each of the funded multimodal freight projects can be found in Appendix A (international multimodal examples) and Appendix B (U.S. multimodal examples).

2.1 Changes in Freight Transportation

Over the past two decades, the U.S. has witnessed dramatic increases in freight volume and movement:

- *Rail volumes hauled* increased from 1,034 billion ton-miles in 1990 to 1,495 billion ton-miles in 2001 (BTS 2002);
- The number of interstate motor carriers increased from 216,000 in 1990 to 592,909 in 2001 (BTS 2002); and
- *Airfreight moved* increased from 3.5 million tons in 1980 to 15.7 million tons in 2001 (BTS 2002).

This section highlights some of the factors that contributed to these increases.

2.1.1 Increased Globalization

In recent decades, increased globalization has highlighted inefficiencies in the production processes and logistics chains of the manufacturing, agriculture, and retail sectors. As these sectors' philosophies changed from inventory-supply–based to just-in-time demand-driven processes, traditional distribution systems became too rigid. Requirements for flexible, reliable, and timely service resulted in smaller and more frequent shipments (Harris 1994). Freight transportation patterns have become increasingly complex as efficient systems are required to meet customer expectations.

2.1.2 Containerization

The container innovation had a direct impact on freight logistics and the cost of moving international trade. To achieve economies of scale, container ship capacity has increased from 1,700 twenty-foot equivalent units (TEUs) in the 1960s to more than 5,000 TEUs in the 1990s (Maritime Administration 2002). To accommodate these vessels and to enhance port capacity, ports have invested in cranes and yard equipment that can efficiently handle large volumes of containers. The result has been a dramatic reduction in the cost per mile of transporting and handling containerized cargo (ICF Consulting et al. 2001). Furthermore, containers provide additional benefits by protecting cargo from damage and pilferage, and allowing general break-bulk cargo to be transferred relatively easily among different modes.

2.1.3 Trade Geography

Changes in the geography of international trade flows have been observed. Trade corridors in the U.S. traditionally stretched east to west, with higher volumes entering through East Coast ports. Growth in Pacific Rim trade altered the importance of U.S Pacific ports,[1] but not necessarily the trade corridors. More recently, however, the North American Free Trade Agreement (NAFTA) has highlighted the need for north-south corridors. The growth in freight truck movements between Mexico and the U.S. and Canada and the U.S. through land border crossings has been dramatic. For example, northbound Mexico-Texas border crossings in Laredo increased from 366,781 in 1994 to 1,493,073 in 2000 (BTS 2002).

2.1.4 Regulation

The deregulation of rail, trucking, and air in the 1980s brought about price reductions, flexibility to serve new routes and to abandon existing routes, the merging of companies (in the case of rail), and the entry of new operators (in the case of trucking). The 1990s introduced the concept of intermodalism. In 1991, the U.S. Congress presented a new vision for transportation policy and planning with the passage of the Intermodal Surface Transportation Efficiency Act (ISTEA). The intent was to change the emphasis on individual modes and to embrace the intermodal concept. Intermodalism focuses on the optimization of goods and passenger movements by using the most efficient mode on a given link and by ensuring seamless transfers at nodes. ISTEA also enhanced the roles of metropolitan planning organizations (MPOs) and state governments in determining transportation priorities. Authority is therefore given to the implementers of transportation plans. Finally, ISTEA required transportation planners to pay more attention to freight planning (Westin et al. 1996) and emphasized that transportation plans must address air quality. Robert Martinez of the Intermodal Office of the U.S. Department of Transportation believes that ISTEA could be considered the most revolutionary approach to transportation

[1] The Pacific ports are now ranked first in volumes handled.

systems in the U.S. since the creation of the interstate highway system (Steering Committee for Intermodal Planning Issues Conference 1993).

Although it is widely recognized that the efficient movement of freight is crucial to the U.S. economy, transportation planners tend to have limited knowledge about freight movements and the planning needs of the sector. The result is that freight has not been adequately considered in metropolitan and regional transportation plans.

2.2 Freight Transportation Challenges

Currently, a number of challenges are faced by the U.S. freight transportation sector. These challenges are discussed in this section under the following headings: operational and capacity challenges, planning and financing challenges, and safety and environmental challenges. Examples of best practice multimodal projects to address these challenges in Texas, the U.S., and internationally are highlighted.

2.2.1 Operational and Capacity Challenges

Increased globalization and the growth in international trade have resulted in capacity concerns at major ports, airports, border crossings, and surface corridors. Ports, airports, and intermodal rail yards are critical transfer points that can become major bottlenecks in the freight transportation system. Luberoff and Walder (2000) reported that capacity constraints in terms of the surface connections to the port can disrupt the flow of goods (Luberoff and Walder 2000). High-volume container ports will therefore require adequate landside access (usually rail and trucks), sufficient land to transfer cargo, and adequate channel depth to receive large megacontainer vessels. As a result, some ports have eliminated noncontainer terminals to expand their container business.

Ports are usually connected to the interstate system by state highways and local streets. Most of these access roads, however, were never designed for the current volumes of truck traffic or the current truck size and weights. Since ISTEA, state agencies can designate roads connecting ports, airports, and intermodal rail yards as part of the National Highway System (NHS). NHS roads may be eligible for 80 percent federal funding (Steering Committee for Intermodal Planning Issues Conference 1993). Ports are, however, usually located in large urban areas and proposals to add capacity to access roads have encountered severe opposition from residents in adjacent neighborhoods. Residents have raised concerns that increased truck traffic will reduce their quality of life by increasing noise and pollution levels and reducing safety.

Improved landside access ultimately impacts the relative competitiveness of a port. One way to address landside capacity constraints is by investing in improved rail connections. The Port of Rotterdam, for example, remains an important container port in Europe through investments in its container handling capabilities, the channel depth of the North Sea that enables the port to accommodate container vessels that move more than 10,000 TEUs (Port of Rotterdam 2002), and its investments in various multimodal projects to enhance its landside access (Appendix A-1). The Betuwe rail, an exclusive freight rail and the first double-stack rail service in Europe, will link the Port of Rotterdam with Germany. This increases the hinterland of the Port of Rotterdam to include Germany by lowering the transportation costs between Rotterdam and Germany (Betuwe Project Organization 2002). The Alameda Corridor in California provides another example of how rail can be used to address landside access concerns. The Alameda Corridor is considered one of the most successful multimodal transportation solutions to alleviate access concerns to a U.S. port. The Ports Advisory Committee (PAC) proposed the Alameda Corridor to solve capacity constraints imposed on the Los Angeles and Long Beach Ports by the inland transportation network (Luberoff and Walder 2000). The Alameda Corridor consists of a 20-mile depressed trench for rail traffic that is separated from road traffic and links the San Pedro Bay ports to the transcontinental rail yards near downtown Los Angeles (Appendix B-1). The corridor currently handles about 100 trains per day. The Alameda Corridor allowed the elimination of 200 at-grade rail crossings, increased average train speeds from 12 mph to 30 mph, and reduced travel times from 2.5 hours to 45 minutes (Alameda Corridor Transportation Authority 2002).

In situations in which port expansion is prohibited by, among other factors, limited land, expensive land, or environmental concerns, port access and capacity can be increased by transporting cargo—without storage and classification—to inland terminals. At these terminals, containers can be sorted for local, regional, and national distribution. If the inland terminals are located away from dense urban developments, access roads to these terminals can be designed appropriately to accommodate large volumes of trucks and to minimize at-grade rail crossings. The Port Inland Distribution Network (PIDN), developed by the Port Authority of New York and New Jersey, is an example of how the development of a number of inland container terminals can increase port capacity and alleviate landside access concerns. The Port of New York and New Jersey forecasted that its cargo storage capacity would be reached in 2004. In the absence of available land for terminal improvements, the ports developed a network of container terminals at the Port of New York and New Jersey's primary markets. PIDN consists of a network of nine satellite terminals 75 miles from the ports with barge and rail connections to the ports (Wakeman 2001). The anticipated benefits of the plan include a 20 percent reduction in the inland distribution costs, improved air quality owing to the use of more environmentally friendly modes, and the alleviation of congestion on roads that provide access to the ports. PIDN will also improve the ports' efficiency and enhance its competitiveness on the East Coast (Appendix B-5 for additional detail).

Finally, the lack of multimodal solutions can be partly attributed to the fact that planning and investments tend to be mode specific. Alliance in Texas is an example of the benefits associated with the planning of a multimodal international trade and logistics center. Alliance, located in Fort Worth, was a master-planned development, thereby allowing Alliance planners to design the facility without the restrictions imposed by existing facilities and infrastructure. Alliance provides multimodal freight access through its Fort Worth Alliance freight airport, a major Burlington Northern Santa Fe (BNSF) rail hub, and its close proximity to IH-35W and SH170. Multimodal transportation access convinced a number of large industrial tenants, such as Nokia, to locate their assembling facilities at Alliance (Leitner and Harrison 2001). It has created more than 20,000 jobs between 1990 and 2001. The economic impact of the facility during the same time period is estimated at more than $19 billion (Hillwood Development Corporation 2003).

2.2.2 Planning and Financing Challenges

Historically, metropolitan and state transportation agencies have focused on passenger and highway transportation planning. Because the benefits of freight investments are not necessarily perceived at a local level, MPOs have been more interested in improving mobility in their metropolitan areas (Westin et al. 1996). At the same time, responsibilities and programs at state and federal transportation agencies have been traditionally organized by mode. As a result, research and training have often focused on specific modes. This situation has been aggravated by a lack of intermodal data and limited dialogue between the public and private sectors. Recently, however, a limited number of agencies have developed successful regional freight plans by creating special committees composed of local and state transportation agencies, and the private sector. One such an example is the Freight Action Strategy (FAST), initiated in 1996, by a coalition of public agencies and private transportation interests to improve freight mobility through the central Puget Sound Region of Washington state. In phase I of FAST, a group of fifteen priority projects that consisted of a series of overpasses and underpasses to reduce at-grade crossings have been identified (Appendix B-3). These projects are intended to eliminate conflicts between trucks and railroads along the I-5 corridor and to improve the efficiency, safety, and reliability of freight traffic to and from the ports of Everett, Seattle, and Tacoma (Beaulieu 2001). Internationally, the European Union (EU) has embarked on a comprehensive planning effort to develop an intermodal transportation network for Europe (Appendix A-2). The initial Trans-European Transport Network (TEN-T) consisted of roads, railways, airports, seaports, inland waterways, and intelligent transportation technologies. The proposed TEN-T network was, however, impossible to build due to a lack of resources. The EU Transportation Commission subsequently identified a list of priority projects called the "Essen Projects" (Sichelschmidt 1999). In terms of the Essen Projects, the European Commission will give priority funding to those projects that favor the expansion of an exclusive freight rail network independently—where possible—of passenger services, the use of inland and short sea-waterway routes for freight services to enhance port hinterlands, the development of "freight villages" to facilitate cargo transshipments, and connections between airports, and high-speed rail to enhance passenger and time-sensitive cargo movements (European Commission of Transportation 2002).

Funding for intermodal projects can be problematic, requiring agencies to enter into agreements in developing intermodal projects. The funding procedures become even more complicated when the project involves several countries. TEN-T required the governments and political unions of fifteen nations to work together in conceptualizing the European transportation network. European governments tend to conduct planning more centrally than the U.S., because of the historical development of the continent and the size of the countries. Although the budget is limited, a public budget and financing mechanisms for funding freight projects exist in the EU. The required funds for the Essen projects were collected proportionately from each country involved and included public and private funds and loans granted from the European Investment Bank (Caldwell et al. 2002). In the U.S., many states, local jurisdictions, port authorities, and even federal agencies have joined efforts to fund innovative multimodal freight transportation projects. The Alameda Corridor and the United Parcel Service (UPS) Chicago Area Consolidation Hub (CACH) are two examples in which various funding sources were used to achieve a common objective. The Alameda Corridor was funded by federal, state, rail, and port funds. The total cost amounted to $2.4 billion and was funded as follows (Evans and Kelley 1999):

- $1.2 million in revenue bonds were sold by the port authority;
- $400,000 was loaned from the U.S. Department of Transportation;
- $394,054 in right-of-way was donated by the railroads;
- $347 million was provided by the Los Angeles County Metropolitan Administration Authority; and
- $154 million came from other state and federal sources.

The UPS CACH, which opened in 1995, consolidates, sorts, and distributes 1.3 to 1.9 million packages daily, representing approximately 10 percent of UPS's daily domestic packages (Appendix B-8). Following are four access-improvement projects funded by the public and private sectors to enhance access to CACH (Evans and Kelley 1999).

1. The construction of an interchange on I 294 at a cost of $15.65 million was funded by UPS, the Illinois Department of Transportation (IDOT), the Illinois State Toll Highway Authority, the Department of Commerce and Community Affairs, and local agencies.
2. The construction of the BNSF intermodal facility adjacent to the UPS CACH at a cost of $75 million was funded entirely by BNSF.
3. The rail grade separation project at Willow Springs Road at a cost of $10 million was funded equally by BNSF and IDOT.
4. UPS funded a number of smaller intersection improvements along Archer Avenue at a total cost of $1.3 million.

One of the most-flexible funding programs is the Congestion, Mitigation and Air Quality Improvement program (CMAQ), established under ISTEA, to reduce harmful emissions from transportation projects in nonattainment areas. Traditionally, CMAQ funds have been used for passenger transit investments. The Red Hook Container Barge was the first freight project funded with CMAQ funds (Delaware Valley Regional Planning Commission 2002). Red Hook is one of the marine terminals of the Port of New York and New Jersey. The Red Hook terminal previously could be accessed only by truck via the Gowanus expressway in Brooklyn. Owing to the need to reconstruct the Gowanus expressway over a ten-year period, the New York Department of Transportation instituted restrictions on the use of the expressway by trucks, thereby threatening the operation of the terminal. The Port Authority of New York and New Jersey thus developed a project to divert the container truck traffic to barges. Today more than 90 percent of the containerized cargo handled by the terminal is moved on barges. These barges offer an alternative for moving containers by truck, as well as the environmental benefits of reduced air emissions. The CMAQ program provided funds for both the barge infrastructure and operation. The project received \$9.7 million from the CMAQ program, \$2 million from the Surface Transportation Program (STP), and \$3.8 million from other Transportation Equity Act for the 21st Century (TEA-21) funds (Appendix B-6).

2.2.3 Safety and Environmental Challenges

The vehicle size disparity between passenger vehicles and freight trucks on roads has raised concern about safety. Generally, in truck-car accidents, car occupants suffer the more severe consequences. In 2002, it was reported that of the 5,280 fatalities associated with accidents involving trucks, only 759 (approximately 14 percent) were truck occupants (National Transportation Statistics 2002). Truck-only lanes have thus been proposed to reduce the risk of accidents involving trucks in mixed traffic situations and, possibly, associated reductions in emissions and agency maintenance costs (Fisher et al. 2003). The Portway International Intermodal Corridor program is an example of a truck-only road in a defined freight corridor that will provide access to the Port of New York and New Jersey. The Portway corridor will extend north from the Newark/Elizabeth Seaport and Airport Complex to rail and trucking distribution facilities in Essex, Hudson, and Bergen Counties, and on the Bayonne Peninsula (Appendix B-4). The project will be developed in four phases. The first phase includes eleven road improvement projects to create a truck-only road. These projects will reduce bottlenecks and separate truck traffic from other vehicles (James 2001).

Domestic transportation safety and security measures traditionally have focused mainly on the transportation of hazardous materials. Hazardous materials transportation regulations require the identification of alternative routes, because a hazardous incident can cause major disruptions to the transportation system. An example is the closure for several days of the Howard Street Tunnel in Baltimore after a train carrying hazardous materials derailed (Sedor and Caldwell 2002). The Joe Fulton Trade corridor, planned along the Inner Harbor of the Port of Corpus Christi, is an example of improvements aimed at reducing the impacts of a hazardous incident (Appendix B-2). The corridor will consist of two projects linking I-37 to US-181, including a link to the existing rail lines. The corridor will provide a safer route for the transportation of hazardous materials and an alternative to the Harbor Bridge corridor in the event of spills (Texas Department of Transportation 2001).

Several freight transportation security initiatives have emerged since transportation vehicles were used for terrorism—a rental truck in the Oklahoma City bombing and commercial aircraft in the September 11 tragedy. National security challenges involving freight transportation include protecting the nation's transportation assets from attacks and preventing the use of freight trucks as weapons in terrorist attacks. Because the freight transportation system can be impacted severely by responses to security initiatives, a major challenge of how to enhance security while keeping commerce moving remains. At ports and surface border crossings, security measures have focused on carefully screening container movements (Sedor and Caldwell 2002).

Freight transportation imposes environmental concerns relating to declining air quality, wetland deterioration, and noise pollution. Heavy-duty diesel truck engines are major producers of nitrogen oxides (NOx), which contribute to the formation of ozone and particulate matter (McCubbin and Delucchi 1996). The Skypass Bridge project is an example of a freight investment aimed at alleviating emissions at the Port of Palm Beach in Florida. U.S. Highway 1 originally divided the Port of Palm Beach in two sections—east and west. This barrier interrupted the port's normal operations. Congestion was caused by drayage trucks, which operate between the dock area and the rail and storage area, waiting on each side of the road. The Skypass Bridge Project was proposed to elevate U.S. Highway 1, allowing the physical connection of the two sections of the Port of Palm Beach. The bridge alleviated drayage truck congestion and commuter traffic congestion on U.S. Highway 1 (Appendix B-7).

2.3 Concluding Remarks

This chapter discussed various factors that contributed to changes in freight transportation in the U.S. and some of the remaining challenges in the sector. It also highlighted various multimodal freight investments aimed at addressing these challenges in Texas, the U.S., and internationally. Chapter 3 reviews the fundamentals of cost-benefit analysis—the approach adopted in this study to illustrate the costs and benefits associated with multimodal freight projects.

3. COST-BENEFIT ANALYSIS: A PRIMER

Transportation planners and decision makers must use evaluation techniques to evaluate and prioritize projects that best meet their objectives. The evaluation of projects involves assessing the costs and benefits that these projects impose on society. The economic appraisal of transportation projects thus involves the quantification of the impacts (benefits and costs) of different investment alternatives. The objective of this chapter is to discuss the economic framework used to quantify the benefits and costs of multimodal freight investment alternatives and to highlight uncertainties in the quantification of these impacts.

3.1 Cost-Benefit Analysis: Important Concepts

Cost-benefit analysis (CBA) is used to evaluate the benefits to society of alternative solutions to a particular problem or need, or to take advantage of an opportunity, for example, to improve the efficiency of the transportation system (Transport Canada 1994). Simply stated, CBA involves the comparison of monetary benefits and costs in the same base year. A discount rate is applied to convert the monetary values in different time periods to the same base year. Overall the standard criterion is to establish whether a project will increase the economic welfare of society. In other words, do the discounted benefits exceed the discounted costs associated with a particular investment.

The valuation of the costs and benefits attempts to produce a parameter for comparing different solutions to the same problem. The first step is to identify the base case, which describes the current and future characteristics of the transportation system if no additional investments are made. The second step is to identify the alternatives. The third step is to evaluate the alternatives relative to the base case. All incremental costs and benefits need to be accounted for. However, a number of benefits and costs will remain unquantified because of a lack of data, complex evaluation methodologies, or the scale of the study does not justify the effort to measure them. Finally, there are four methods of comparing costs and benefits (Quinet 2000):

1. The net present value (NPV) of the project, which measures the difference in the present value of the benefits and costs.
2. The internal rate of return (IRR), which is the rate at which the discounted costs and benefits are equal.

3. The benefit cost ratio, which would be higher than 1 for projects where the benefits exceed the costs.
4. The payback period, which is defined as the number of years needed for annual net benefits to equal investment costs.

Depending on the purpose of the analysis, the appropriate method should be selected. In this study the NPV and benefit cost ratio are used to determine if a project is economically beneficial to society. The rest of this section defines some of the important concepts in CBA.

3.1.1 Pareto Optimality

Pareto optimality is central to CBA. It requires that a project will be deemed beneficial to society only if society will be better off without harming anyone. In reality, any transportation project produces "winners" and "losers," but the principle is potentially preserved when the winners are in a position to compensate the losers, to the extent that the losers are at least indifferent and the winners are still better off (Varian 1992). It is, however, necessary to note that no actual compensation is prescribed—just the ability of the winners to compensate the losers. In practice, compensation is seldom part of a transportation project—partly because it is difficult to identify the individual winners and losers—and also because these compensation schemes can involve a significant administrative cost burden.

3.1.2 Discount Rates

The rationale behind discounting is that benefits and costs that are incurred now receive a higher weight than those that are incurred further in the future. The discount rate therefore reflects the opportunity cost of money or the "time preference value" of money. In other words, a dollar received 5 years into the future is not as valuable as the same dollar received today, because the dollar could have been invested in the meantime.

Although economists have debated the calculation and use of an appropriate discount rate for infrastructure projects, no general consent exists about the discount rate. Some suggested rates include (Luskin 1999):

- the social time preference rate, i.e., the real rate that is attached to receiving a dollar now rather than in the future;
- the real rate of return on private investment; and
- the real interest rate on foreign debt, i.e., the cost of borrowing by the public sector.

A detailed discussion of the appropriate calculation of discount rates falls beyond the scope of this project. In the HERS-ST literature, it was reported that the "real opportunity cost of withdrawing resources from the economy is generally regarded as about 3–5 percent (per year), with a high rate of 7 percent used for sensitivity testing" (HERS_ST Overview 2002). The federal highway tools thus use a discount rate of 7 percent.

3.1.3 Time Frame

Costs and benefits are considered over the economic (useful) life of the investment. Few investments, however, would require an analyses time frame of more than 20 years. This is partly attributable to the fact that most investments have a useful life of less than 20 years, but more importantly the discounting of benefits and costs reduces their significance in present value terms as the time frame lengthens (Transport Canada 1994).

3.1.4 Timing of Benefits and Costs

The research team adopted the end-of-year convention that assumes that all transactions occur on the last day of the year. Therefore, the NPV is expressed in terms of the last day of year zero—the analysis year.

3.1.5 Taxes/ Subsidies

In CBA it is critical to distinguish between impacts and transfers. Taxes or tax revenues do not represent a social cost or benefit, but rather a transfer from the taxpayer to government. The best-known example is the fuel tax. An adjustment is required for fuel prices to exclude the fuel tax component, because this tax does not represent a resource consumed. Similarly, subsidies have to be accounted for and added to the price of the resources consumed to reflect the cost to society of using a particular resource.

3.1.6 Sunk Costs

Past expenditures related to a transportation investment are not considered in CBA and as such are treated as sunk costs. In CBA, the analyst considers only future cost streams. However, if a past investment (i.e., capital asset) has an alternative use, the opportunity cost of the asset in the alternative use needs to be considered in the CBA. For example, the price that a piece of equipment purchased earlier (e.g., a locomotive engine) can attract in the resale market becomes the opportunity cost of the equipment when conducting the CBA (Transport Canada 1994).

3.1.7 Depreciation

Resource costs are accounted for in CBA through the expenditures incurred in future years. If the expenditures and a depreciation allowance of the assets are included in the analyses, the capital costs would be double-counted.

3.1.8 Inflation

Ideally, costs and benefits should be forecasted in nominal dollars and converted to constant dollars by removing the inflation effects. The research team adopted a simplified approach by assuming that the costs and benefits would remain the same in constant dollar terms. "Where values are material and there is a degree of confidence that specific price increase forecasts are likely to be more accurate than general inflation forecasts, estimates should be made in nominal dollars" (Transport Canada 1994). It is, however, very important to state the year for the constant dollars chosen.

3.1.9 Interest

"The interest payable on the capital funds required to implement a project should not be included in a CBA. Interest costs are implicitly taken into account, by means of the discount rate, in the computation of net present value …" (Transport Canada 1994).

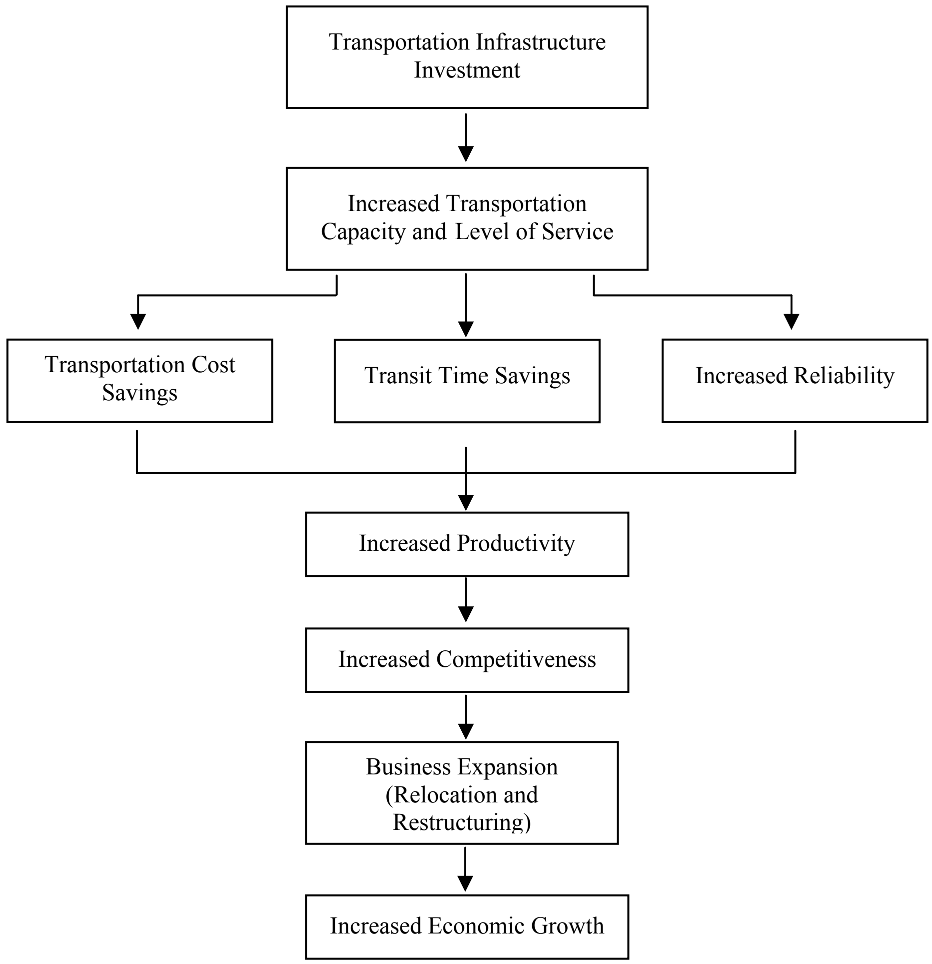
3.2 Benefit Considerations

3.2.1 What Are Benefits?

Three types of benefits are usually associated with a transportation investment: direct benefits, secondary benefits, and indirect benefits. In CBA, only the direct benefits that result from a transportation investment are counted—resource savings and a benefit for which the beneficiary is willing to pay.

Economists (Luskin 1999) have shown that the consumer and producer benefits attributable to costsavings from a transportation investment can be estimated from the transportation outcome; that is, the direct savings in the costs of moving freight considering the change in unit transport cost and the transport output. To illustrate, infrastructure investments that reduce the costs of moving freight have economic benefits (Figure 3.1). In essence, this is because a reduction in the cost of freight transportation directly affects the costs of goods, and thus the profits of producers, which can contribute to economic growth as displayed in Figure 3.1 (ICF Consulting & HLB Decision-Economics 2002).

While the transport costsavings, transit timesavings, and reliability improvement should rightly be included in the CBA, any inclusion of producer profits or the additional income to individuals would result in double counting.



Source: ICF Consulting & HLB Decision-Economics 2002, Adapted

Figure 3.1 Transportation and the Economy

Typically, the benefits included for multimodal freight investments in CBA include:

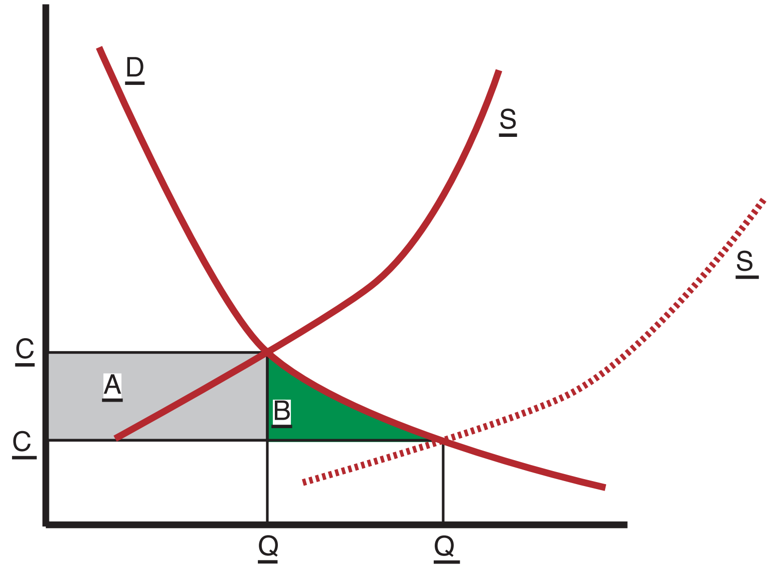
- efficiency improvements (e.g., savings in vehicle-operating costs);
- safety benefits (reduced number and severity of accidents);
- environmental effects; and
- agency cost-savings.

3.2.2 Who Benefits?

Before quantifying the identified benefits, it is important to first understand who benefits. In the case of a transportation investment, such as adding capacity to a congested highway facility, three categories of beneficiaries (demand) needs to be considered:

1. existing users of the facility;
2. the diverted users—those that shift from other modes, change their schedules (nonpeak hour to peak hour), or change their routes (from arterial to the new facility); and
3. induced demand—the new traffic that is generated because of the improvement.

Transportation investments improve the transportation system. In Figure 3.2, S represents the "supply curve" for the base case and S' represents the "supply" curve given the transportation investment. The downward sloping demand function D is the transportation amount users are willing to purchase at various costs. For the supply function S, consumers are willing to purchase Q at cost C. With the transportation investment, the cost per trip is reduced as the supply function moves from S to S'. The reduction in the trip cost will encourage other drivers to use the facility, thereby generating additional traffic that would not have otherwise occurred. Thus, the reduction in the cost from C to C', results in an increase in the number of users from Q to Q' (Transtech Management Inc 2000). Simply stated, area A presents the time and costsavings to the current users of the facility, while area B represents the benefits attributable to "new" demand attracted to the facility (HERS-ST 2002). HERS-ST makes no distinction between diverted and induced demand (i.e., trips not previously taken or longer trips). As seen in Figure 3.2, the benefits received by the induced demand are less than the benefits to current users, because these travelers decide on the margin. The net benefits perceived by the induced traffic fluctuate between zero and the benefit perceived by existing users. The benefits can be estimated using the "rule of half." Consumer surplus analysis allows the calculation of the benefits: the benefits to the current users are valued using the full-cost reduction (area A), while the benefits to induced users are assumed to equal half the cost reduction (area B) (Lee 2000).



Source: Transtech Management Inc. 2000

Figure 3.2 Equilibrating Demand Given a Change in Transportation Supply

From Figure 3.2, it is evident that the consumer surplus to the induced demand is a function of the change in the cost of the trip (both out-of-pocket cost and the travel time costs) and the elasticity of demand. The perceived change in the cost of the trip is therefore highly dependent on the preexisting level of congestion. The calculation of induced benefits is, however, problematic because the increases in accident risks, environmental costs, and operating costs owing to the induced demand's impact on travel time have to be accounted for. For existing users of the facility, the time saved on the "new facility" will be reduced due to the induced demand (DeCorla-Souza and Harry Cohen 1999).

Guidance exists on the calculation of the diverted and induced demand for highway travel associated with travel timesavings based on the travel time elasticity of demand. No guidance, however, exists on the travel time elasticity of demand for the nontraditional modes (rail and barges). Published studies uncovered during the literature review suggest that the travel time elasticity of demand for highway travel ranges between –0.2 and –1.0. An elasticity of –0.5 means that if travel time reduces by 10 percent, demand will increase by 5 percent.

The issue is that the development of freight mode choice models[2] has lagged behind that of passenger mode choice models. Estimating the demand of alternative facilities over the analysis period is, however, critical to the calculation of benefits.

3.3 Quantifying the Benefits and the Costs

The estimation and quantification of the benefits and costs associated with freight investments require (a) information about the demand for the facility (current, diverted, and induced demand) discussed in Section 3.2, (b) the magnitude of the impacts (reduced costs or increased benefits), and (c) values to quantify these impacts.

In CBA, the cost should reflect the opportunity cost of the resource—in other words, the value of the resource in the best alternative use. In competitive markets, generally market prices are used to measure the costs and benefits to society of transportation projects. As an example, the resource cost of vacant land required for the building of a rail terminal would be the market value of the land as determined by the most valuable alternative use of the land (Transport Canada 1994). Many costs and benefits, however, are not traded in the market and do not have a market price, such as timesavings, pain resulting from accidents, or environmental air quality. These nonmarket costs, however, still impose a cost to society and the different approaches to estimate nonmarket costs are discussed in Section 3.4.

In this study, the research team adopted the concepts used in HERS-ST to measure benefits and costs of transportation projects. The two concepts are price to the user (Price Function (0) in Figure 3.3) and average social cost (AVC_0 in Figure 3.3) to reflect the cost to society. Whether the price function is below or above the average social cost function depends on the user costs and externalities (HERS-ST 2002). Table 3.1 attempts to clarify these concepts.

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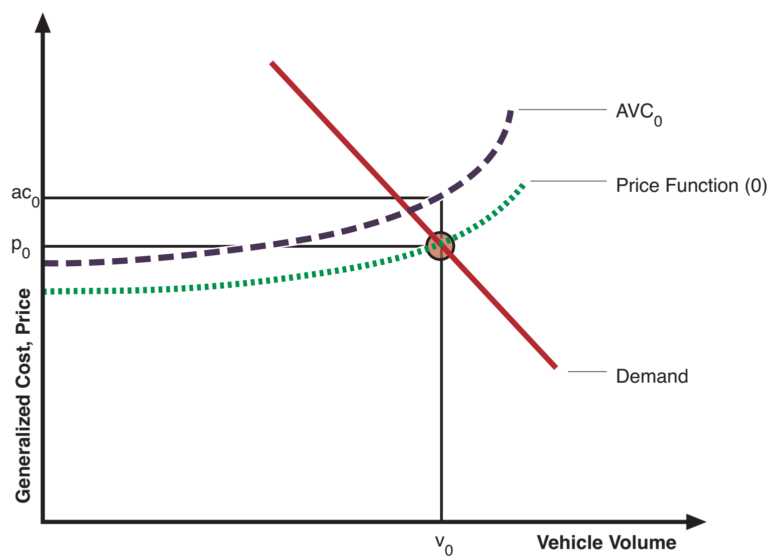
2 Given the lag in the development of freight mode choice models, agencies are often required to conduct expensive studies when evaluating multimodal freight investments. The New York City Economic Development Corporation funded a $5 million study to "develop a strategy for improving the region's movement of goods across New York Harbor." Two of the objectives of the study were to create "a more modally-balanced goods movement system" and to support "rail and marine alternatives" (Edwards and Kelcey Engineers, Inc. 2000). A significant component of the study was the estimation of the truck-to-rail diversion under three rail scenarios. The consultants surveyed approximately 300 shippers. The survey results were combined with data from Reebie Associates, the U.S. Department of Transportation, Standard & Poor's/DRI, and regional rail service attributes to assess the demand for each of the rail alternatives.

Table 3.1 User and Social Costs

	Included in User Price	Included in Social Cost
Travel time	Yes	Yes
Vehicle-operating costs	Yes	Yes
Accidents	Yes	Yes
Agency costs		Yes
User fees and excise taxes	Yes	
Emissions		Yes

Source: HERS-ST 2002

The price to the user determines the vehicle volume, the intersection between the demand curve and the price function. Resource costs/benefits used in CBA are, however, determined from the average cost curve (HERS-ST 2002).



Source: HERS-ST 2002

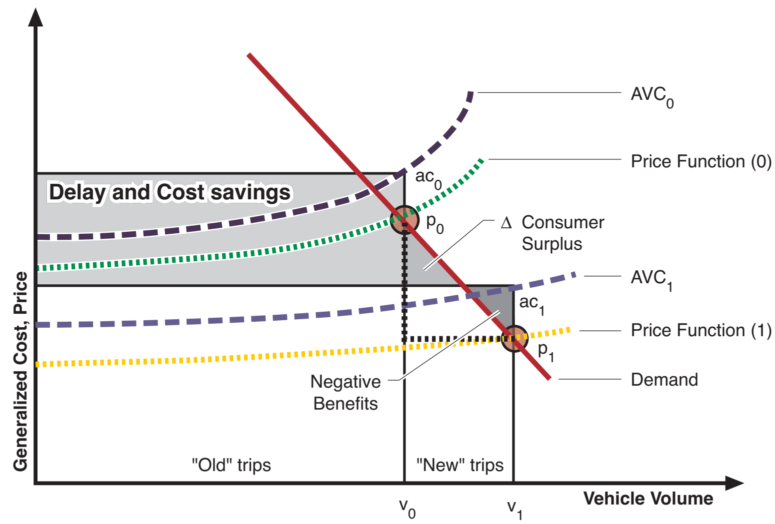
Figure 3.3 Measuring Benefits and Costs

To illustrate the concept of estimating costs and benefits in CBA, Figure 3.4 highlights the example of calculating the net operating benefits:

- AVC_0 represents the social costs incurred (i.e., travel time, vehicle-operating costs, accidents, agency costs, and emissions) under the base case alternative;
- Price function (0) represents the costs incurred by the user (i.e., travel time, vehicle-operating costs, accidents, user fees, and excise taxes) under the base case alternative;

- AVC_1 represents the social costs incurred (i.e., travel time, vehicle-operating costs, accidents, agency costs, and emissions) under the improvement alternative;
- Price function (1) represents the costs incurred by the user (i.e., travel time, vehicle-operating costs, accidents, user fees, and excise taxes) under the improvement alternative; and
- D represents the demand curve (HERS-ST 2002).

It is assumed that the improvement will lower travel time and operating costs, which will benefit not only existing users, but will also attract "new" users. As indicated, the intersection between the price function and the demand curve determines the traffic volume.



Source: HERS-ST 2002

Figure 3.4 Calculation of Net-Induced Benefits (HERS-ST 2002)

As evidenced in Figure 3.4, at price P_0, the demand will be V_0 and the average cost to society will be ac_0. With the improvement, the price to the user will decrease to P_1, resulting in a demand of V_1 and an average cost to society of ac_1. In the CBA framework, the benefits to society in the form of reduced delays and costs to the existing users of the facility can be calculated from the area of the rectangle (ac_0 minus ac_1 multiplied by V_0).

Valuation of the "new" induced demand needs to consider both the benefits of additional travel and the cost to society of additional externalities. The benefits of additional travel are estimated based on the change in price and the increased traffic volume (P_0 minus P_1 multiplied by v_1 minus v_0 multiplied by 0.5). This value, however, has to be adjusted for the increase in societal costs associated with the increase in travel.

The societal costs associated with increased travel are represented by the rectangle with height P_1 minus ac_1 and length V_0 minus V_1. In Figure 3.4, the positive area is labeled "consumer surplus" and the negative area is labeled "negative benefits" (HERS-ST 2002).

3.4 Methodologies for Measuring Nonmarket Impacts

Determining the social costs discussed above can be very problematic, because as indicated earlier many costs and benefits are not traded in the market. In a situation in which competitive markets do not exist, analysts calculate shadow prices[3] to better reflect the true value of resources or benefits (University of Leeds, undated).

The valuation of many of these nonmarket benefits and costs is very controversial, but considerable progress has been made in estimating these values. A number of methods are starting to gain acceptance for estimating nonmarket values: revealed preference, stated preference, and the alternative/opportunity or damage cost approach. The different approaches are briefly discussed below.

3.4.1 Revealed Preference Methods

The revealed preference method estimates the implicit value of time by observing the actual choices made by observing the location of businesses, residences, and services or the choices between modes of which one might be faster, but more expensive, than the other. Existing trade-offs have to be identified, which require extensive sample sizes. Two revealed preference methods that have been widely used to determine implicit environmental values by observing actual choices/ market decisions are the hedonic pricing and the Clawson or travel cost approach. The hedonic pricing method determines a relationship between property values and their environmental characteristics, assuming all else is constant (University of Leeds, undated). For example, if two similar houses in terms of the neighborhood, architectural design, and amenities differ only in that one is located next to a freeway and the other is located on a residential street, then the price differential can be used to estimate the negative costs associated with freeway noise (Greene et al. 1997). The hedonic pricing method has been criticized severely, because it assumes a perfect market in which buyers have perfect knowledge and can buy any combination of characteristics they prefer. Also, it assumes that buyers have perfect knowledge and can consider the effect of the environmental characteristics of the property on themselves, such

[3] Shadow prices are also calculated to account for subsidies or taxes that distort the true costs of resources.

as the health impacts of air pollution. However, it has been used to measure noise pollution impacts (University of Leeds, undated).

The Clawson or travel cost approach has been used widely to value the benefits of visiting nature reserves, forests, beaches, and other tourist attractions. This approach involves estimating a demand curve based on the number of visits and the travel costs incurred. One of the main criticisms of this approach is how to account for multipurpose trips (of which only one of the purposes was to visit a specific facility). Also, this approach might underestimate the benefits of the site — by ignoring the scientific benefits, for example (University of Leeds, undated).

3.4.2 Stated Preference Methods

In stated preference surveys, such as the contingent valuation approach, respondents are asked to respond to hypothetical questions on how much they are willing to pay to achieve or avoid a particular outcome (University of Leeds, undated). Willingness to pay refers to the amount society would pay to reduce negative effects associated with a transportation investment, and willingness to accept refers to the amount that society would accept as financial compensation for the negative effects caused by the transportation investment (Litman 2002). For example, a person might be willing to pay $20 per month to reduce noise caused by a freeway. Alternatively, a person would be willing to receive $20 in compensation for the negative impacts associated with freeway noise. Considerable economies of scale in sample size can be achieved, because respondents can be asked to choose among options that involve a number of tradeoffs (University of Leeds, undated). It is, however, critical that respondents are familiar with the issues at hand. Otherwise, partial and inconsistent results could be gathered. Also, biases remain a concern, especially regarding very controversial issues (University of Leeds, undated) and in practice it has been found that the hypothetical choices could be quite different from observed choices (Greene et al. 1997).

3.4.3 Prevention Cost Methods

The abatement/alternative/opportunity/prevention cost approach involves determining the expenditure needed to prevent or offset a particular effect or outcome. Examples are (a) to provide rare animal species with tunnels to cross new roadways in an effort to protect them; (b) the construction of noise barriers to alleviate noise pollution (Wang and Santini 1996); (c) calculating the financial losses avoided in the form of fishing revenue by implementing measures to prevent an oil spill; or (d) the cost of relocating rare animal species.

3.4.4 Damage Cost Methods

The damage cost method estimates the total economic losses associated with an impact. For example, to determine the value of an accident, the vehicle damage, medical and emergency expenses, loss in productivity for anyone disabled or killed, and some nonmarket costs, such as the pain and suffering caused by the accident, need to be quantified. This method requires the use of other methods, such as revealed or stated preference, to determine some of the costs (Wang and Santini 1996).

3.4.5 Compensation Methods

The compensation method uses the settlement amounts granted in legal judgments to compensate for similar damages in the past. For example, the cost of water pollution can be estimated by previous trials in which victims have been compensated for their illnesses, pain, and suffering (Litman 2002).

3.5 Cost Considerations

Project costs can be divided into:

- planning (i.e., all costs incurred prior to procurement and construction);
- the construction costs (i.e., land acquisition or opportunity cost of land used, construction costs, equipment purchase, vehicle purchase, project-related training, construction delays impacting travel time on the facility, decommissioning costs, construction management, and contingencies); and
- operation and maintenance costs of the transportation facility (Transport Canada 1994).

The total cost of a project should be taken into account, including congestion costs during the construction period. State departments of transportation have considerable expertise and resources to determine the costs associated with the construction, maintenance, and operation of highways. In addition, the federal government has funded numerous studies concerning all aspects of road infrastructure.

In contrast, state departments of transportation have recently expanded their mandates to include “alternative modes of transportation” and freight movements. Resources devoted to freight movements on “alternative modes of transportation” are comparatively limited. The cost of constructing a mile of rail track, for example, is the privilege of railway engineers and a few consultants in the industry. The situation is being aggravated by the confidentiality concerns surrounding rail and barge costs. The situation has been found to be very different in Europe. The European Transportation Commission (2002), for example, publishes estimates of the cost components associated with rail, inland waterway barges, and short sea vessels. Differences in the characteristics of rail and barge operations between the U.S. and Europe prevent the use of these values as U.S. proxies.

3.6 Benefit Considerations

Benefits can be broadly categorized into transportation system efficiency benefits, safety benefits, user operating costsavings, and agency costsavings. Projects may also have certain impacts that are unintended. Typically, third parties experience unintended impacts, which are usually negative, so that benefits can also relate to reductions in negative externalities.

3.6.1 Efficiency-Related Benefits

Transportation investments, in general, improve the efficiency of the transportation system. Efficiency benefits can be measured in terms of reductions in travel time, reduced vehicle-operating costs, and increases in reliability and accessibility. This section discusses some of the considerations in valuing efficiency benefits.

Valuing Travel Timesaving

One of the main motivations for many road projects has been a reduction in the actual trip time because travel timesaving have in many cases constituted the most significant benefit associated with a highway project (Luskin 1999). Transportation investments can reduce travel time by creating shorter routes, increasing the operating speed, or alleviating congestion. The valuing of timesavings is founded in the opportunity cost of the travel time—in other words, it is assumed that the time saved could be productively employed.

Estimating Travel Timesaving

A number of challenges surround the estimation and valuation of travel time. Travel timesavings on highways can be deducted from the average speeds with and without the investment. Litman (2002), however, has claimed that any reduction in urban vehicle miles reduces congestion delays by a factor of two on congested roads. Because trucks require more road space and time to accelerate, a reduction in truck vehicle miles conceivably will have an even more significant congestion benefit. Average speeds of rail and barges are typically lower than those of highway travel, with the result being that it is believed that diverted users will incur a travel time penalty. To some extent, this calculation is influenced by the focus of the analysis, i.e., door-to-door or only the line-haul component. In general, a substantial amount of time can be spent at rail yards. Single rail tracks also means that trains can spend a considerable amount of time stopped on sidings to allow faster trains or trains in the opposite direction to pass. Limited guidance and published information exists to inform multimodal appraisals on estimating travel times on rail and barges.

Valuing Travel Timesaving

When valuing timesavings, trip purpose (i.e., working or nonworking), time of day, and trip length have to be distinguished. Business trips, peak-hour trips, and intercity trips have a higher hourly value than recreational trips, nonpeak hour trips, and local trips. Working or business trips apply to bus and truck drivers, and business travelers, while nonworking trips refer to time spent commuting and traveling for leisure. The "loaded" hourly wage rate (including an allowance for benefits, such as retirement plans) is commonly used to value time during working hours (Quinet 2000; Lee 2000; Bristow and Nellthorp 2000). These benefits are usually calculated as a percentage of the direct labor costs. In the case of trucks and buses, the wage rate of all personnel has to be considered, not only the driver. Also, overhead costs (i.e., office space, administrative support, technical support, etc.) must be quantified. Similar to fringe benefits, overhead costs are usually estimated as a percentage. In addition, travel timesavings can result in lower operating costs (discussed later) and can increase the capacity of the vehicles in that potentially more trips can be made with the same vehicle. Therefore, it is feasible that fewer vehicles are required to achieve the same objective resulting in savings in capital costs (Luskin 1999). Timesavings can also bring about benefits such as less damage of freight in transit, lower inventory stocks in transit, lower requirements for buffer stocks, and increased scope for time-sensitive operations. Lower inventory stocks in transit have been calculated by applying the interest rate to the value of the cargo in transit over the time period saved. This value is highly dependent on the types of commodities transported. Agriculture/fresh produce and time-sensitive commodities can have a very high inventory cost. Valuing these other logistical benefits is, however, often limited by a lack of data and some have argued that the benefits associated with induced traffic include, among other benefits, these logistical benefits.

Using the wage rate of the crew to estimate the value of travel timesavings for freight vehicles seems to suggest an undercalculation of the benefits. The U.S. Department of Transportation (U.S. DOT) recommends the use of a national average driver wage rate ($16.50 per hour) to estimate the value of truck time (Lee 2000). ICF Consulting and HLB Decision-Economics, however, reported a much higher value for truck transit savings of between $144 and $192 per hour (ICF and HLB 2002). A more significant challenge is valuing the time benefits/penalties associated with barges and trains.

In most of the literature reviewed, the value of nonworking time has been expressed as a percentage of the value of working time. Not much explanation has been given for the percentages chosen, which makes this approach questionable. It is conceivable that the value of nonworking travel can vary substantially by mode and income (Transport Canada 1994). The estimation of the nonworking value of time requires the use of the nonmarket techniques reviewed earlier. The valuation of nonworking timesavings requires additional research.

Finally, it has to be noted that the implicit assumption in the use of wage-rate to quantify travel timesavings is that the time spent traveling is entirely unproductive. No clear guidance exists for what percentage of the wage rate needs to be used for work-related travel if it is conceivable that at least some of the business travel time can be used productively (Transport Research APAS Strategic Transport 1996). Also, it is not clear how to handle small travel-timesavings. The question persists whether the same value should be assigned to 200 one-minute savings as to 10 twenty-minute savings because many doubt whether small timesaving (for example, five minutes) can be used productively in the freight transportation sector (Transport Research APAS Strategic Transport 1996). Transport Canada (1994) recommends that "the value of small travel-timesaving should be clearly identified [travel timesavings of less than five minutes per one-way trip] but not included in the Net Present Value (NPV) calculation."

Valuing Reliability

Researchers have found that in many cases increased reliability is more important to transportation users than savings in travel time. Reliability refers to the degree of certainty and predictability associated with travel times on the transportation system. Reliability is often expressed as the standard deviation from the average travel time (Weisbrod et al. 2001).

Unreliability in travel times imposes a logistics cost as manufacturers and distributors have to carry more inventory to reduce the probability of disruptions to their production processes or out-of-stock situations. The size of the required inventory determines the amount of warehouse space required and capital tied up in stock (ICF Consulting et al. 2002). The measurement of improved predictability or reliability benefits, however, presents a major challenge to economists. Unexpected delays imposed by accidents, abandoned vehicles, debris, weather, and security alerts are the main causes of variability in truck travel times. However, trucking services are usually considered more convenient than rail services in terms of predictability, reliability, speed, and flexibility. An investment that aims to divert trucks to rail will usually be accompanied by a loss in convenience for those truck users that switched to rail. At the same time, existing users of the system will experience an increase in convenience. Most CBAs, however, do not attempt to predict or value the increase in reliability associated with road investments or the loss in convenience associated with diversions to rail. The exception is Kenneth Small, who found that trucks value savings in transit time at $144.22 to $192.83 per hour and savings in scheduled delays at $371.33 per hour (Small 1999). Most studies, however, focus on the average travel timesavings while ignoring the random element associated with freight transportation. To estimate reliability, it is necessary to predict the frequency and severity of unexpected delays, to predict the delay imposed by each type of event, and finally to value the effect. Usually no records exist on the delay imposed by incidents and the valuation has to be done using nonmarket techniques. Forkenbrock and Weisbrod (2001) have claimed that the latter requires a vast amount of resources and does not always produce relevant information.

Valuing Accessibility

Transportation investments can translate into improved access to desired goods, services, activities, and destinations, but transportation projects can also reduce accessibility. It is often necessary to determine the areas where accessibility is enhanced and where it is reduced. Accessibility can be defined as (Forkenbrock and Weisbrod 2001):

- access to basic services such as health, school, and public safety;

- access to quality of life destinations such as shopping centers, churches, parks, museums, and other cultural sites;
- access to markets such as employees to jobs and customers and suppliers to businesses; and
- local access such as sidewalks and parking provision.

Improved access associated with an investment alternative can take the form of reduced travel time and user operating costs. Travel timesavings enable current users to access new destinations — a benefit users might be willing to pay for. Reductions in time and operating costs also attract new users to the transportation service—the access benefits accruing to induced demand. Improved access can also enhance business competitiveness and economic development by improving access to new customers and suppliers (Section 3.6.4 for a discussion on valuing economic development benefits). The analyst should be cautioned against double-counting the time and operating costs savings associated with improved access because accessibility can be valued by estimating changes in travel time and operating costs. Accessibility can be considered qualitatively through a series of "yes or no" questions or by applying one of the nonmarket techniques discussed earlier.

Valuing Vehicle-operating Costs

Forkenbrock, Benshoff, and Weisbrod (2001) claimed that in some situations "higher [travel] speeds may … increase the per-mile cost of operating a vehicle." Generally, vehicle-operating costs usually are reduced if a transportation investment alleviates the "stop-and-go" traffic situation experienced on congested facilities. Typically, vehicle-operating cost calculations consider the cost of fuel, oil, tires, and maintenance. These costs vary considerably depending on the traffic conditions (average speed, number of stops, accelerations and decelerations required), the vehicle characteristics (model, maintenance record), and driver characteristics. National averages exist for vehicle-operating costs (cars and trucks) and are expressed per mile. HERS considers the costs of fuel and oil consumption, tires, maintenance, and a depreciation value. STEAM, SPAMS, and IMPACT do not include depreciation of the vehicle, but include parking costs.

Rail and barge operating costs are regarded proprietary by the respective industries. Rail consultants, such as Randy Resor of Zeta Tech Associates, have developed rail cost allocation software that is available commercially and can provide some insights into rail operating costs. No published cost information could be found for barge operations in the U.S.

3.6.2 Valuing Safety

The second most important objective of a transportation project is usually to improve safety. Safety benefits are measured as reductions in property damage costs, the number of injuries, and fatalities.

Concern has been expressed over the number of fatal and injury incidents involving trucks. Trucks represent 3 percent of all registered vehicles, but account for 9 percent of all vehicles involved in fatal crashes. The Bureau of Transportation Statistics reported that in 2001, 86 percent of the fatalities involving an incident with a truck were occupants of the vehicles or people outside the truck. The separation of truck and passenger vehicles[4] or diverting truck shipments to alternative modes can have substantial safety benefits. Estimating these safety benefits is, however, extremely challenging. "The measurement of safety benefits per se requires an analysis of the safety risks that are associated with the project. Risk is a composite measure of the probability and the severity of an adverse occurrence…." (Transport Canada 1994).

The U.S. DOT and most of the Federal Highway Administration's tools evaluated express accidents as a function of vehicle miles, thus not accounting for the composition of the traffic or the average speed of the traffic. The number of injuries and the number of fatalities is also given as a percentage of the total number of accidents. Better guidance is needed to assess the impact of enhanced safety than an accident factor expressed in terms of vehicle miles traveled. No models were uncovered to estimate barge and rail incidents on line-haul rail lines or barge channels. Existing rail incident models focus on estimating the number of incidents at railroad crossings. Rail incident models estimate the number of incidents that will be reduced when constructing a railroad grade separation. In a CBA of multimodal rail investments, however, it is required to estimate the number of at-grade conflicts resulting from increased rail traffic and reduced truck traffic under various assumptions of demand.

Accident costs have market and nonmarket components (Table 3.2). Market costs can be valued directly and include damage to property and vehicles, health services,

[4] The accident history on the New Jersey Turnpike that has designated inner lanes for cars and barrier-separated outer lanes with high volumes of trucks confirms that the separation of trucks and passenger vehicles enhances safety (Douglas 1999).

ambulance and police costs, and loss of production because victims' inability to work (University of Leeds, undated). Nonmarket costs include pain, grief and suffering caused by death or injury for victims and their families, reduction of mobility, and loss of quality of life (Litman 2002).

Table 3.2 Market and Nonmarket Effects of Accidents

Market	Nonmarket
Property damages to vehicles and other objects	Pain and suffering for crash victims
Lost income	Lost quality of life for crash victims
Emergency response services	Uncompensated grief and lost companionship for crash victims' family and friends
Medical treatment costs	Reduced nonmotorized mobility
Crash prevention and protection expenditures	

Source: Litman 2002

Nonmarket costs can be estimated using either revealed or stated preference methods (see Section 3.4 for more details). These estimates, however, show more variation than values of times. In addition, assigning a monetary value to a human life is an ethical and sometimes very controversial issue. By valuing injuries and fatalities, a trade-off can be established between reductions in the risk of accidents and monetary costs (see text box below). In order words, the value of a life is the amount that society is willing to pay for a reduction in the probability of dying in a traffic accident. Studies value fatalities and injuries based on potential years of life lost or disability-adjusted life years to account for age differences of victims (Greene et al. 1997).

The Value of a Statistical Life

"Assigning a dollar value to fatalities avoided reflects a widespread recognition of a need for guidance on what should be spent to reduce the risks of transportation accidents … i.e., to determine the amount that society is willing to invest to reduce the statistically predicted number of accidental deaths in transport. Of course, this is a different concept from what would be spent to save a particular individual whose life might be at risk at a particular time" (Transport Canada 1994).

3.6.3 Valuing Environmental Effects

Environmental impacts associated with transportation projects include: air and water pollution, noise, vibration, community severance, visual intrusion, land degradation, and disposal of contaminated soil. These impacts that affect individuals and society at large are termed externalities when those affected are not responsible for the decisions that give rise to the impacts (e.g., the investment or using the investment) (University of Leeds, undated). Externalities are challenging to quantify, but it is important to consider these impacts in transportation investments.

Air Quality

The U.S. Environmental Protection Agency (EPA) and others have done a substantial amount of research in estimating the air pollution impacts associated with motorized vehicles, but admittedly emissions' research associated with heavy-duty trucks has lagged behind that of passenger vehicles (see text box below). Heavy-duty diesel vehicles are notorious for their contribution to high ambient levels of ozone[5] and fine particulate matter. With the development of EPA's MOBILE 5 and 6 models, which calculate the emissions produced by model year and average speed for different categories of vehicles, heavy-duty diesel engines are increasingly targeted by the EPA to meet more stringent and costly emissions standards. In practice, the quantity of emissions from a truck is a function of (1) the type of fuel consumed, (2) age and condition of the equipment, (3) model, (4) weight, (5) technology, and (6) tampering occurrences with the engine or emissions technologies.

Generally, it is assumed that the freight alternative modes—rail and barges—are more benign environmentally than heavy-duty diesel trucks. EPA provides guidance on the emissions factors associated with rail locomotives built up to 2005. In the future, it is foreseen that rail locomotive engines will emit less pollutants than previously. Emissions factors for the barge mode, however, remain a concern. Available barge emissions information dates back to a U.S. DOT study conducted in 1994 entitled "Environmental Advantages of Inland Barge Transportation." Although the study is dated, the emissions factors were expressed in terms of pounds of pollutants (HC, CO, and N_2O) produced in moving one ton of cargo 1,000 miles.

[5] From an air-quality perspective NOx and particulate emissions emitted by heavy-duty diesel trucks are of greatest concern. Ground-level ozone is formed by a series of reactions between NOx and VOC in the presence of sunlight. Heavy-duty diesel VOC emissions are less of a concern because the emissions levels are usually much lower than the prescribed emissions standards.

Emissions Associated with Transportation

Volatile Organic Compounds (VOC) consist mainly of hydrocarbon (HC), which is emitted primarily as unburned components of petroleum. HC is associated with worsening heart problems for at-risk populations.

Carbon Monoxide (CO) is formed when carbon in fuel is not burned completely. Vehicles produce almost 60 percent of all CO emissions. CO in the blood reduces its capacity to carry oxygen. Exposure to CO was proven to increase the risk of heart failure for people over 65 years old and to cause headaches in the general population (McCubbin and Delucchi 1996).

Nitrogen Oxides (NOx) are formed in the atmosphere and give smog its brown color. NOx is an important component in the formation of ozone and particulate matter. Automobiles and power plants are the major sources of NOx, because of high temperature combustion. NOx has been linked to minor respiratory symptoms and eye irritation (McCubbin and Delucchi 1996).

Ozone is formed by a complex chemical reaction involving VOC and NOx in the presence of sunlight and heat. Ozone is linked to eye irritation, asthma attacks, and increases in respiratory symptoms (Small and Kazimi 1995).

Particulate Matter ten microns in diameter (PM_{10}) are a heterogeneous mix of liquid and solid compounds. PM_{10} emissions are emitted directly and form indirectly from emissions of HC, NOx, and SOx. PM_{10} is generated from diesel engines, power plants, wood stoves, and industrial processes. PM emissions from motor vehicles are estimated to account for 10.6 percent of total PM_{10} emissions (Small and Kazimi 1995). Particulates that are very small (less than 10 microns in effective diameter) penetrate the lungs, causing numerous and severe health problems. Particles originating from acid sources are even more damaging. These particles are linked to a variety of adverse health effects, including reduction in lung function, asthma attacks, and aggravation of respiratory and heart conditions.

In terms of valuing environmental impacts, substantial research exists to value emissions impacts, most notably by McCubbin and Delucchi (1996) and Wang and Santini (1995). Emission values generally are estimated using one of two approaches: a damage-value method or a control cost method. The damage cost method requires information about the relationship between transportation, emissions, distribution, and impacts. This method involves seven steps: "[1] identify emission sources, [2] estimate emissions, [3] simulate air pollutant concentrations in the atmosphere, [4] estimate exposure of humans and other objects to air pollutant concentrations, [5] identify physical effects of air pollutant concentrations on humans and other objects, [6] value physical effects[6], and [7] calculate emission values in dollars per ton" (Wang and Santini 1995). Calculating the damage done to human health thus requires placing values on human mortality, morbidity, discomfort, and restricted physical activity using stated or revealed preference methods. Most of these steps are fraught with uncertainties, making the results rather speculative.

[6] Value of adverse health effects of air pollution can be related to medical expenses, loss of work, discomfort, and inconvenience that result from such effects.

Researchers differ in the assumptions and simplifications adopted to deal with the uncertainties, which can result in a wide range of estimates. Delucchi, Murphy, and McCubbin (2002) estimated that the costs attributable to anthropogenic air pollution in the U.S. ranged between $55 and $670 billion in 1990 using the damage cost method.

In terms of the control cost method, costs are based on expenses for preventing an impact or the effect of an impact. The calculation requires information on costs and emission reductions over the entire life of the control measure, including initial capital costs, operation costs, maintenance costs, and the deterioration rate of the measure. Also, if the control measure reduces a number of pollutants, the cost of the measure has to be allocated among the pollutants reduced. The control cost method requires fewer steps than the damage cost method and is thus generally regarded easier to undertake. Estimating emission values by using either method remains, however, time-consuming and resource-intensive (Wang and Santini, 1995).

Noise

Noise affects communities by disturbing residents' sleep and by increasing stress levels. People, however, become accustomed to noise exposure and after a period of time the degree of annoyance decreases. Some modes, such as rail, also have proven to be less annoying than trucks, especially if tasks are performed that require concentration (Forkenbrock 2001). At low speeds, engine noise is the dominant source of noise; at high speeds, rolling noise and aerodynamic noise is more of a concern (Brons et al. 2003).

Noise pollution tends to be a function of local conditions, duration, frequency, and regularity, which makes it complicated and expensive to estimate. The information needed to model noise pollution is seldom collected. One method to value noise pollution is to equate the effect to the cost of constructing sound barriers or other devices to mitigate noise pollution. In cases where noise pollution has been valued, it was found that the results were negligible compared to air pollution, for example (Quinet 2000).

Visual Quality

Transportation projects can intrude visually on the surrounding environment and it is thus important to determine the level of intrusion that the investment would impose on the community (Forkenbrock and Weisbrod 2001). The use of simulators can help residents to visualize and evaluate the impact of a planned transportation project. In some cases, once the alignment of the project is decided, mitigation measures can be implemented to reduce the visual impact.

Community Effects

Community cohesion can be described in terms of the social links within a community. A transportation project can impact community cohesion positively or negatively. Transportation projects might divide neighborhoods, isolate a group or portion within a neighborhood, or change property values among other effects. To measure potential impacts on community cohesion, it is necessary to identify the current social links and to forecast the disruptions that might be caused by the transportation improvement. The study area must be defined and information must be gathered about the existing social arrangements and the importance of these arrangements. Finally, the analyst must identify possible disruptions caused by the transportation investment (Forkenbrock and Weisbrod 2001).

Other Environmental Effects

Other environmental effects include damage to water sources, endangered species, plant and animal habitats, and native prairie. Although some concern has been expressed about the impacts of barge traffic on water quality, no evidence exists in the literature to support these concerns. Research conducted involving the water quality of the Illinois River concluded that water quality was not adversely affected by barge traffic (U.S. DOT 1994). Limited quantitative data exists on the remaining externalities identified.

3.6.4 Valuing Regional Economic Development Effects

Improved access provided by a transportation investment can bring about significant economic development benefits in the form of employment creation, increased income, property values, and business activity attributable to a savings in transportation costs. "From a social perspective, analysts and decision-makers are interested in the economic development impacts of a transportation project measured in terms of job creation and changes in personal income and wages, changes in the types of jobs available, changes in property values, and net changes in business activity and investment corridors where new business development is a goal" (Forkenbrock, Benshoff, and Weisbrod 2001). But economists warn that the inclusion of economic impacts can result in double counting that skews the results from traditional CBA calculations. "Such double counting would occur if, for example, we were to count both the transportation costsavings to a producer and the increased profit from the plant or the increased property value of the land on which the plant is located, for the latter effects are simply a reflection of reduced travel time and costs" (Weisbrod and Weisbrod 1997).

In broad terms, a transportation investment that produces costsavings (e.g., time, out-of-pocket cost for the trip) will result in an increase in the demand for transportation. In other words, assuming a more efficient rail link, shippers will divert some of their shipments from truck to rail because of the savings in freight costs, i.e., diverted traffic. And some shippers will ship more, because the freight cost is reduced, i.e., induced traffic[7]. The additional number of shipments represents the induced demand. The induced demand benefit is thus considered a proxy for regional development effects because, for example, the stimulation of industry associated with a transportation improvement will be reflected in increased traffic.

The calculation of net-induced benefits (or the transport consumer surplus to the induced traffic) is problematic, because increased time, accident risks, environmental costs, and operating costs have to be accounted for. For example, for existing users of the facility, the time saved on the "new facility" will be reduced due to the induced demand (DeCorla-Souza and Cohen 1999).

Two methodologies exist to estimate induced demand: the first is asking potential users about their intention to use a transport facility, and the second is estimating a model of transport demand using historical data and calculating demand elasticities. Studies, however, have shown that the increase in transport demand will be marginal unless the demand is highly cost sensitive (Luskin 1999). In the Cross Harbor Freight Movement Major Investment Study, prepared by Edwards and Kelcey Engineers (2000), a shipper choice survey was conducted to determine the potential modal diversion from truck to rail given three potential rail alternatives. The results from this survey together with estimated commodity flows and regional rail service attributes were used to estimate the diversion from truck to rail, the potential reduction in regional truck miles traveled, and the number of truck trips.

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7 HERS makes no distinction between diverted and induced demand.

3.6.5 Valuing Employment Creation

When building an infrastructure project, employment opportunities are created at both the construction phase and the operation of the infrastructure phase. Economists, however, have argued that the employment benefits of transportation projects are exaggerated. A number of factors can temper the number of additional jobs being created at the construction phase:

- the supply of labor, especially skilled labor, potentially will result only in a transfer of labor from one area/project to another;
- collective bargaining organizations can create an artificial scarcity of labor, thereby increasing the cost of unskilled labor;
- businesses might respond to temporary increases in demand by increasing overtime or employing temporary workers;
- government budget constraints might cause the government to fund a transportation project by shifting funds from other more labor-intensive projects; and
- increased taxes, when used to fund transportation projects, may impact employment through decreased consumer spending and decreased levels of savings (Luskin 1999).

Conversely, because production costs will decrease and profits will increase, businesses will have an incentive to produce and invest more, thereby increasing the demand for labor (Luskin 1999).

The effect of infrastructure projects on employment is, however, extremely difficult to estimate, but some evidence does suggest that such projects can create employment in circumstances of high unemployment. Also, the number of jobs created depends on the geographic area of interest. If narrowly focused, such as in a Texas region, the region might benefit from a transfer of employment to the region, while another state might suffer the displacement effects (Luskin 1999).

3.6.6 Valuing Residual Value

The residual value or remaining service life (RSL) of a capital investment can be defined as "the capital value remaining at the end of the analysis period" (HERS-ST 2002). The preferred option to estimate the residual value is to determine the market price of the asset at the end of the analysis period—but this is usually impossible. Consequently, the RSL can be calculated with the following formula:

$$RSL_t = C_0 x \frac{n-t}{n}$$

t = length of the CBA period
C_0 = initial cost of the improvement
n = normal or expected lifetime of the improvement

This calculation provides the RSL value at time *t,* which subsequently has to be discounted to the beginning of the analysis period (HERS-ST 2002).

The introduction of RSL, however, introduces the following caveats:

- It is likely that transportation improvements that have very long lifetimes will suffer a bias against them, because the net benefits after the analysis period are implicitly assumed to be zero. The RSL calculation attempts to account for only the remaining capital portion of the investment.
- It is necessary to specify the analysis period to be at least the length of the life of the investment with the shortest lifetime.

3.6.7 Valuing Agency Costsavings

The life of a highway/pavement typically is expressed in terms of the number of standard axles that would result in failure. The standard axle is defined as a single dual-wheeled axle with a load of 18,000 lbs (80kN). Assuming a highway is designed for one million standard axles over a period of 10 years, the potential exists to increase the life of the pavement if trucks can be diverted to an alternative mode (i.e., rail, barge, or dedicated truck route). In addition, significant maintenance savings are conceivable. The calculation of the agency's costsavings depends on an accurate assessment of the amount of diverted traffic.

3.7 Multi Criteria Attributes

In CBA, the analyst has to identify all the benefits and costs that distinguish an alternative from the base case option. It is, however, not always possible to quantify all the benefits and costs. Multi Criteria Attribute analysis does not require all benefits, impacts, or effects to be expressed in monetary terms. This type of analysis can be used to supplement CBA in an effort to consider those impacts that are not easily quantifiable. Impacts that are unquantifiable or quantifiable only in physical units include:

- loss of wetlands;
- visual impact of a transportation structure (e.g., bridge, railway line, major highway);

- traffic noise;
- increased water pollution;
- increased rainfall runoff;
- loss of wildlife and wildlife habitat;
- loss of threatened and endangered species;
- loss of floodplains;
- loss of wild and scenic rivers;
- loss of parkland;
- danger to pedestrians and cyclists;
- community disruption;
- need to relocate residents; and
- distributive effects, i.e., how a transportation investment impacts different societal groups, specifically low-income or minority groups.

Table 3.3 provides an illustrative example of how CBA parameters can be supplemented to account for unquantifiable impacts and those that can be quantified in physical units. As shown, weights can be assigned to different benefits, impacts, or effects to reflect their relative importance to the decision maker (Luskin 1999). The analyst should, however, take care not to double-count impacts.

Table 3.3 Illustrative Example of Socioeconomic Analysis

Type of Impact	Impact	Option 1 (Base Case)	Option 2	Option 3
Quantified in Monetary Terms	Expected Economic NPV	0	$150	**$300**
	Score	0	2	**4**
	Weighted Score (25%)	0	0.5	**1**
Quantified in Physical Units	Increase in noise levels along new road (average)	10dB	30dB	**60dB**
	Score	0	-1	**-4**
	Weighted Score (10%)	0	-0.10	**-0.40**
	Decrease in pollution to local homes (average)	0%	8%	**5%**
	Score	0	+3	**+2**
	Weighted Score (20%)	0	0.60	**0.40**
Unquantifiable	Aesthetic improvement to local area	No change	Some new greenery etc.	**Significant planting of trees, etc.**
	Score	0	+1	**+3**
	Weighted Score (20%)	0	0.40	**0.60**
	Consistent with government's May 1995 neighborhood policy	Does not address May 1995 statement	Addresses May 1995 statement in full	**Addresses items 2 & 3 of May 1995 statement**
	Score	0	+4	**+2**
	Weighted Score (25%)	0	1.00	**0.50**
Aggregate score of all socioeconomic impacts (100%)		**0**	**2.4**	**2.1**

Note: 1. The "recommended" scoring scale runs from +4, through 0 to -4 as "very much better (than the base case), much better, moderately better, little better, no change, little worse, moderately worse, much worse, very much worse."

Source: Victorian Department of Treasury and Finance (1996, Section 7.5, p.10 in Luskin 1999, Adapted).

3.8 Sensitivity Analyses

Because of uncertainties in the assumptions, values, and magnitudes when calculating benefits and costs, it is necessary to conduct a sensitivity analysis.

3.8.1 Calculating Switching Values

The first step is to identify the key benefits and costs in the analysis, which are uncertain, and to determine what percentage change in these key variables will result in the NPV becoming zero. In addition, it is necessary to determine the likelihood that this percentage change might occur. Some of the key variables include: demand (traffic forecasts), cost estimates, standard values of fatalities, injuries, environmental damage and time, the discount rate, etc.

3.8.2 Timing of the Investment

The timing of an investment is an important consideration. Upon completing the estimation of the costs and benefits, it is important to determine the "timing that results in the most cost-beneficial outcome for individual options" (Transport Canada 1994). Through a sensitivity analysis of different dates, the optimal timing of the alternative can be determined.

3.8.3 Concluding Remarks

This chapter provided an overview of the many dimensions of CBA—the foundation upon which the Multimodal Analysis Freight Tool (MAFT) was developed. Chapter 4 discusses the structure of MAFT and the embedded models, parameters, and assumptions that are used to estimate the costs and benefits associated with freight investment alternatives.

4. MULTIMODAL ANALYSIS FREIGHT TOOL

The objective of Multimodal Analysis Freight Tool (MAFT) is to provide a cost-benefit analysis (CBA) framework with default values that the Texas Department of Transportation (TxDOT) can use to calculate and demonstrate the societal benefits associated with nontraditional highway spending. This chapter summarizes the analysis steps required, the structure of MAFT, and documents the embedded models and necessary assumptions to analyze alternative freight investments.

4.1 Step-By-Step Analysis

The following steps are required to evaluate alternative freight investments in MAFT:

- Identify the problem/need or opportunity;
- Identify the base case option;
- Identify the traditional highway option;
- Identify alternative options; and
- Evaluate the options.

MAFT is a spreadsheet application developed with the objective to allow sketch planning analysis of alternative freight projects. In comparing various alternative investments, the analyst should take care to include all benefits and costs that differ between options. However, given the sketch planning nature of the tool, the analyst is advised to evaluate these costs and benefits only to the degree necessary to distinguish between the alternatives (Transport Canada 1994).

How much accuracy can I afford?

The appropriate amount of time/effort spent in quantifying the costs and benefits is largely a function of

- "how much uncertainty is there concerning … the best option; and
- how much could the possibility of a loss from a wrong decision be reduced by better information or more extensive analysis." (Transport Canada 1994)

4.2 MAFT Structure

MAFT is structured to analyze different modal investments relative to a specified base case alternative. MAFT consists of a number of worksheets: Global Assumptions, Summary, Summary_graphics, Graphics, Input Data, Base Case, and a worksheet for each of the potential types of freight infrastructure investments (i.e., highway expansion, managed lane, rail or barge/short sea).

4.2.1 Global Assumptions Worksheet

The Global Assumptions worksheet contains the "best estimates" and "model parameters" used in the models embedded in MAFT. These values are provided to the analyst upfront and can be changed as research provides new information and estimates. In addition, the literature sources for the default values are provided to allow for verification and subsequent updating.

The values are categorized by impact measured in MAFT (e.g., travel time, safety, environment, etc.). Figure 4.1 provides a screen shot of the Global Assumptions worksheet. The GA codes specified in the Global Assumptions worksheet are used to name the values and to provide easy reference. These codes are used to explain the calculations in the investment alternative worksheets.

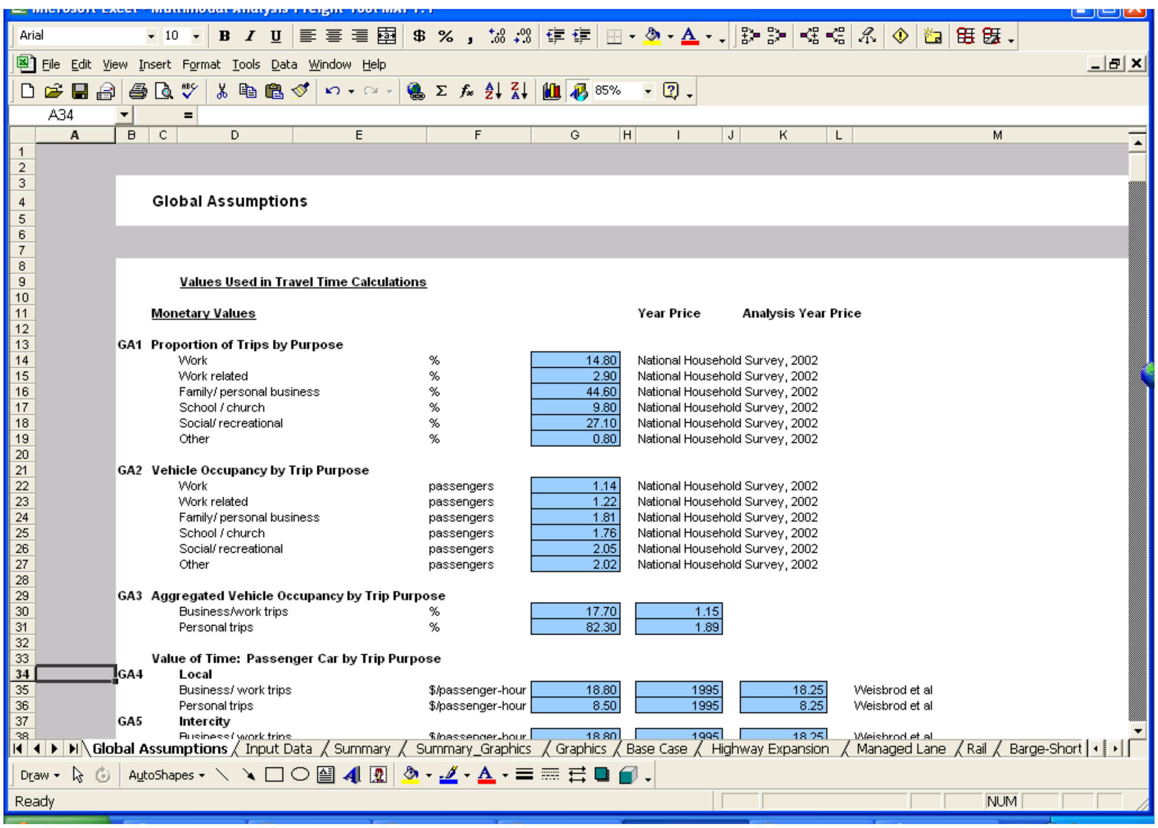


Figure 4.1 Global Assumptions Worksheet

4.2.2 Input Data Worksheet

Required data must be entered in the Input Data Worksheet for all the investment alternatives considered. The required input information is organized as follows:

- **General Information:** The information required in this category summarizes the values that are common to all the investment alternatives considered. The required input includes the analysis year, the discount rate, the consumer price index, the primary TxDOT district responsible for the investment, and the days of the week that are considered in the analyses (i.e., weekdays, weekends, etc).
- **Geometric Characteristics:** The information entered under this category relates to the geometric characteristics of the investment alternatives and are used to determine the design capacity of each alternative. For highway alternatives, the required information includes the length of the link, the number of lanes, the lane width, shoulder width, interchange density, type of terrain (i.e., level, rolling and mountainous), and type of area (i.e., rural and urban). For the non-highway alternatives, barges and rail, the information required includes the length of the link, number of rail cars/barges per locomotive/pusher tug, the maximum number of railcars per train/containers per barge, and the number of truck trailers/containers per railcar/barge.
- **Costs:** Project costs are divided into right-of-way acquisition costs, construction costs, and maintenance and operation costs associated with the investment alternatives. The data required are the cost per year or total investment, the year that this cost was determined, and the year in which this amount is expected to be spent for each of the investment alternatives.
- **Benefits:** The analyst must provide certain information needed to calculate the impacts associated with each alternative investment. The data required are categorized by type of impact calculated, for example, the calculation of the travel-time impact requires data in terms of the Annual Average Daily Traffic, number of trucks diverted, traffic growth rates, travel-time elasticity (short and long term).
- **Nonmonetary Inputs:** MAFT includes a qualitative scoring system (nonmonetary) for impacts (benefits and costs) that are difficult to quantify given the sketch planning level of accuracy intended by this tool. These impacts include noise, travel-time reliability, accessibility, community cohesion, bicycle and pedestrian travel patterns, regional development or economic effects, visual quality, equity, and environmental

considerations (e.g., impact on water resources and wetlands, the habitat of endangered or threatened species, or native prairie). The analyst is asked to score each impact statement on a scale of 1 to 5, with 1 indicating either very high cost or low benefit and 5 indicating either very low cost or high benefit. Each of the impact categories can be weighed differently to reflect different priorities. The scores are summed for all the impact categories and the investment alternative with the highest score can be regarded as the most beneficial in terms of the nonmonetary impacts.

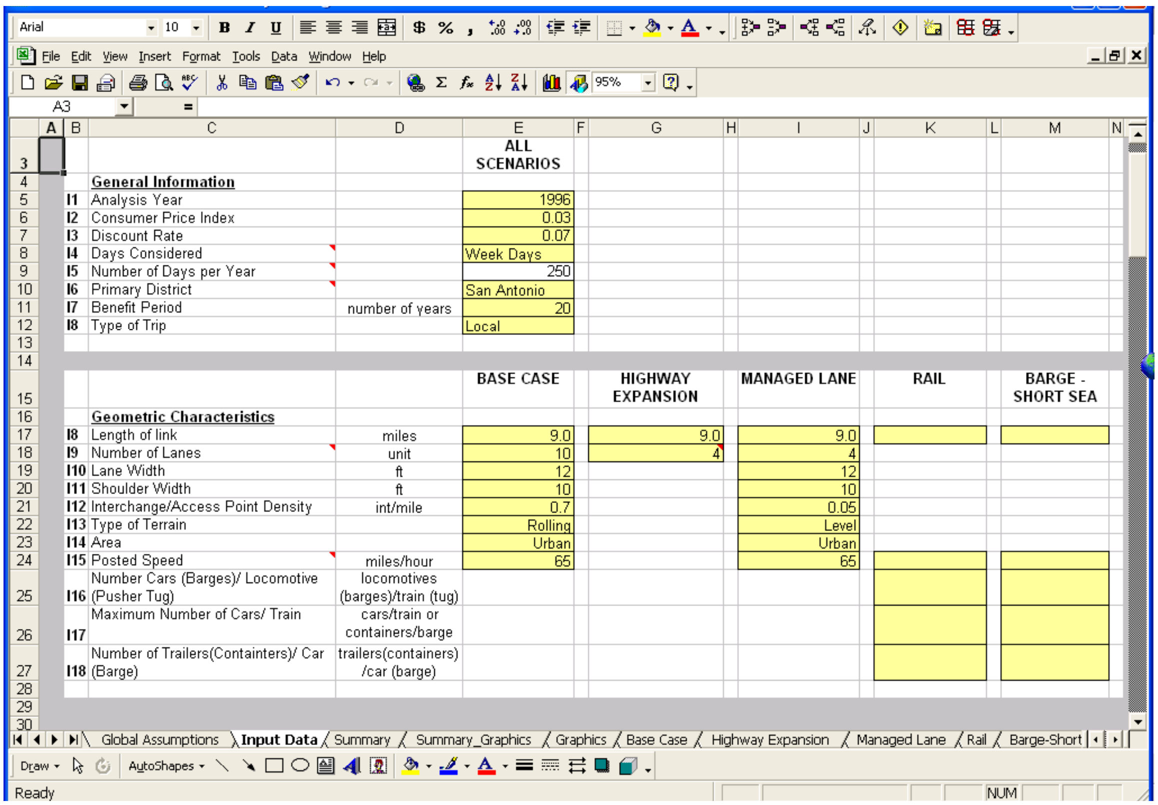


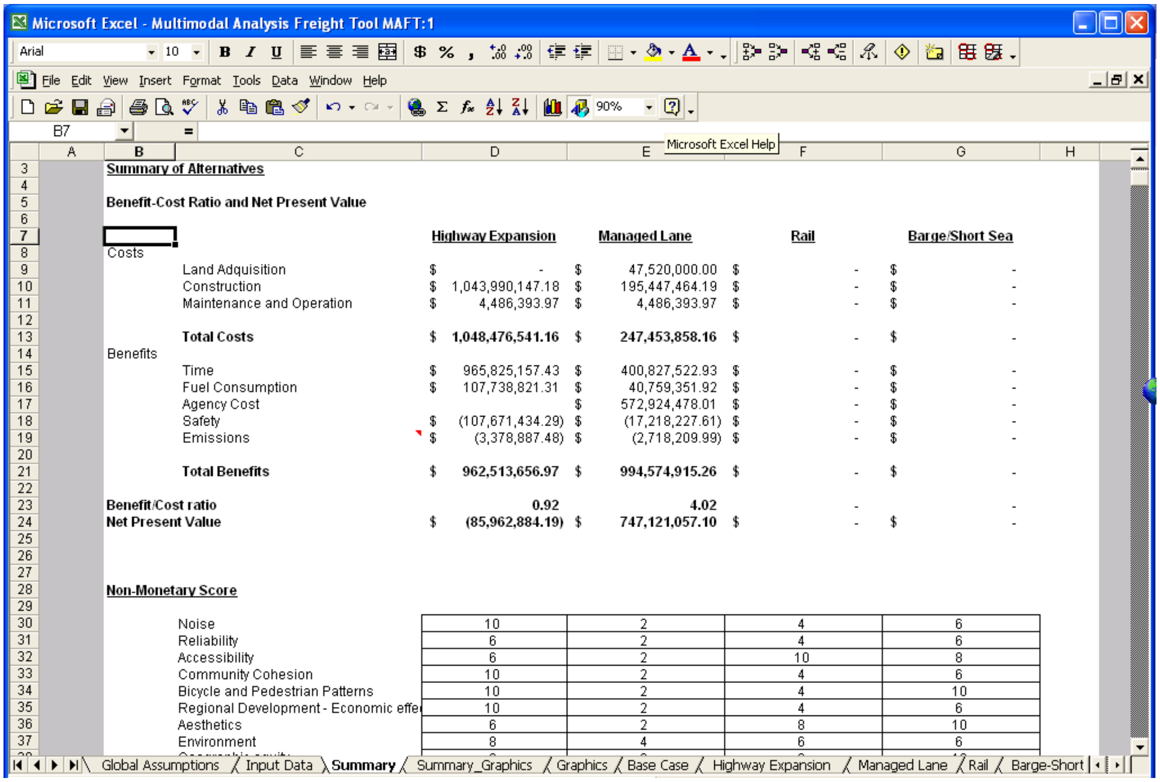
Figure 4.2 Input Data Worksheet

Figure 4.2 provides a screen shot of the Input Data Worksheet. The information required, shown by the cells highlighted in yellow, is organized into columns labeled by investment alternative. The data required under the general and geometric characteristics headings are shown.

4.2.3 Output

The results of the output analysis are summarized in three worksheets: summary, summary graphics, and graphics. Each of these is briefly discussed below.

- **Summary:** This worksheet provides a summary of the calculated costs and benefits by category, as well as the scores by nonmonetary impact for each investment alternative studied (Figure 4.3). Two calculations are included in the worksheet to determine if a project is economically beneficial to society: benefit cost ratio and net present value (NPV).



Microsoft Excel - Multimodal Analysis Freight Tool MAFT:1

Summary of Alternatives

Benefit-Cost Ratio and Net Present Value

		Highway Expansion	Managed Lane	Rail	Barge/Short Sea
Costs					
	Land Adquisition	$ -	$ 47,520,000.00	$ -	$ -
	Construction	$ 1,043,990,147.18	$ 195,447,464.19	$ -	$ -
	Maintenance and Operation	$ 4,486,393.97	$ 4,486,393.97	$ -	$ -
	Total Costs	**$ 1,048,476,541.16**	**$ 247,453,858.16**	**$ -**	**$ -**
Benefits					
	Time	$ 965,825,157.43	$ 400,827,522.93	$ -	$ -
	Fuel Consumption	$ 107,738,821.31	$ 40,759,351.92	$ -	$ -
	Agency Cost		$ 572,924,478.01	$ -	$ -
	Safety	$ (107,671,434.29)	$ (17,218,227.61)	$ -	$ -
	Emissions	$ (3,378,887.48)	$ (2,718,209.99)	$ -	$ -
	Total Benefits	**$ 962,513,656.97**	**$ 994,574,915.26**	**$ -**	**$ -**
Benefit/Cost ratio		**0.92**	**4.02**	**-**	**-**
Net Present Value		**$ (85,962,884.19)**	**$ 747,121,057.10**	**$ -**	**$ -**

Non-Monetary Score

Noise	10	2	4	6
Reliability	6	2	4	6
Accessibility	6	2	10	8
Community Cohesion	10	2	4	6
Bicycle and Pedestrian Patterns	10	2	4	10
Regional Development - Economic effe	10	2	4	6
Aesthetics	6	2	8	10
Environment	8	4	6	6

Global Assumptions / Input Data / Summary / Summary_Graphics / Graphics / Base Case / Highway Expansion / Managed Lane / Rail / Barge-Short

Figure 4.3 Output Summary Worksheet

- **Summary Graphics:** This worksheet displays in graphics the aggregated impacts associated with each investment alternative (Figure 4.4).

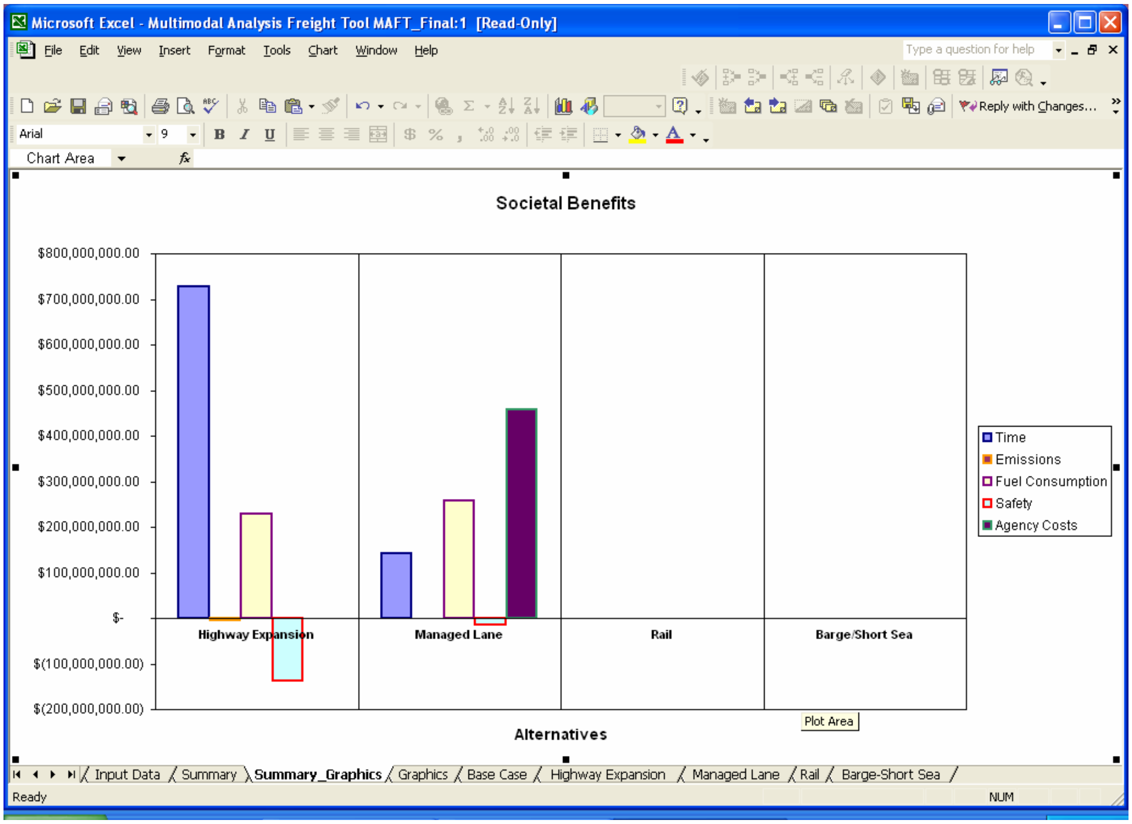


Figure 4.4 Output Summary Graphics Worksheet

- **Graphics:** This worksheet graphically displays the individual impacts associated with each investment alternative for each year of the analysis period. It provides the analyst with a visual overview of the magnitude of each impact associated with each alternative for each year of the analysis period (Figure 4.5).

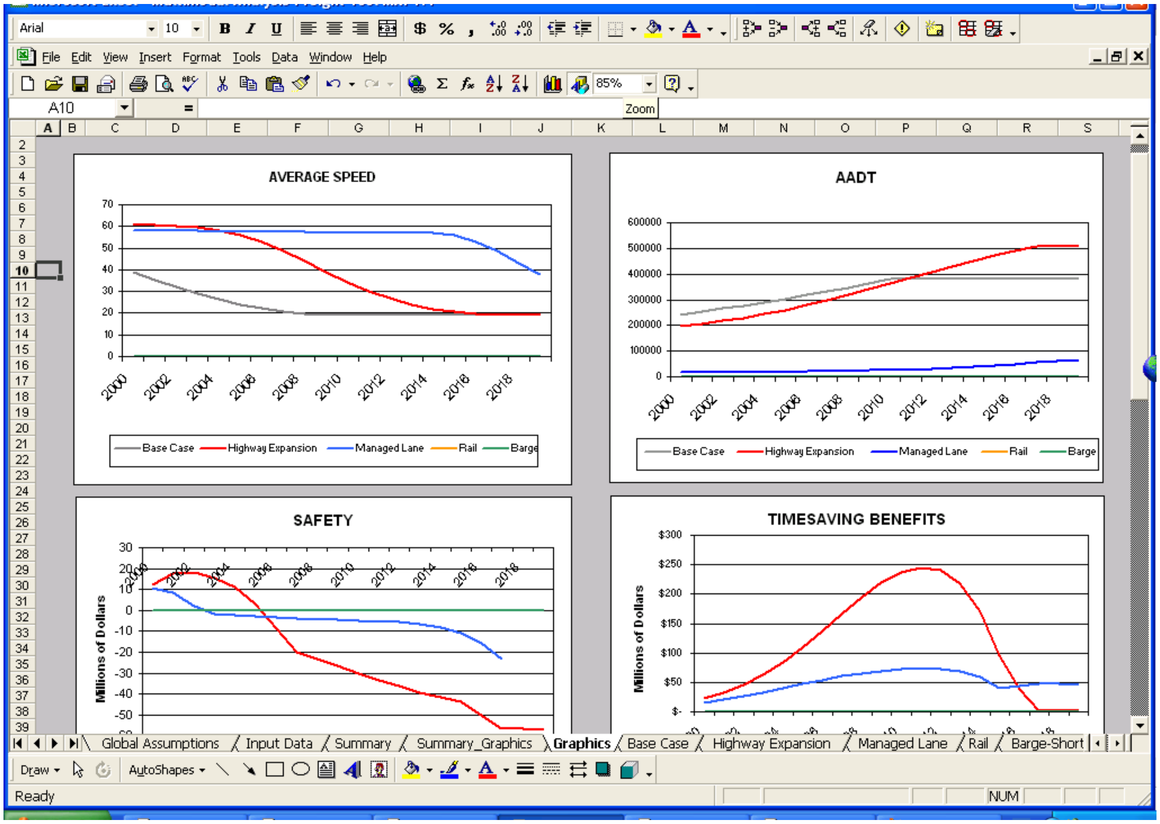


Figure 4.5 Output Graphics Worksheet

4.2.4 Investment Alternatives

All of the formulas and models necessary for the calculation of the cost and benefit impacts associated with the base case and each of the investment alternatives—highway expansion, managed lane, rail, and barge short sea—are embedded in the respective investment alternative worksheets. Therefore, the investment alternative worksheets provide the detailed results for each of the cost and benefit calculations by year for the analysis period. This section provides an overview of the embedded formulas and models used for calculating the cost and benefit impacts.

Costs

MAFT accounts for three broad categories of cost: right-of-way acquisition, construction and maintenance, and operations.

Right-of-way acquisition costs

Right-of-way acquisition costs refer to the cost of the land on which to build the transportation facility. The amount of land required depends on the type of facility and the minimum design standards and special features required, such as on-street parking, weigh-in-motion facilities, and rest zones. The right-of-way acquisition costs are calculated by multiplying the amount of land required with the cost of the land. All costs need to be accounted for.

Construction costs

Highway construction costs can be divided into construction and rehabilitation of pavements, bridge construction and rehabilitation, and miscellaneous costs. Among other factors, these costs are a function of the type of facility and the number of equivalent single-axle loads (ESAL) for which the pavement is designed (Castaño-Pardo and Garcia-Diaz 1995). Most pavement design procedures account for the expected traffic volume growth over the design life of the pavement. State departments of transportation (DOTs) have considerable expertise in estimating construction costs for roads. For example, the Houston District has a spreadsheet model that can be used to estimate the construction costs associated with a highway investment. The analyst is required to enter the calculated construction costs per lane-mile into MAFT. For simplification, it is assumed that all construction costs are incurred at the midpoint of the construction period.

Right-of-way acquisition and construction costs vary significantly for all modes of transportation as they depend on a number of factors that relate to the type of facility, the terrain, the existing use of the land, and the availability of local materials. The estimated maintenance and operation costs and the total expected life of the project are also important variables in the calculation of the costs associated with an investment alternative. The analyst also needs to state the construction period and the year of opening to determine when the benefits would be realized by the users.

Rail track costs refer to the costs associated with planning, designing, constructing, and upgrading rail tracks. For barge and short sea operations, the infrastructure investments may include dredging, environmental impact mitigation measures, and terminal buildings, including structures associated with operating locks, barrages, and pumping stations. State DOTs have less expertise in estimating the construction costs associated with rail and barge investments. Agencies thus have to rely on the private sector to obtain construction cost estimates. Because the useful life of rail track and barge infrastructure usually exceeds that of a highway investment, MAFT considers the residual value as well.

Maintenance and operation costs

Maintenance and operation costs include costs associated with maintaining and operating the facility, such as preventative maintenance, policing, emergency services, traffic management centers, and lighting. Agencies and the private sector will have to provide these cost estimates to the analyst.

Benefits

Five benefit categories are quantified in MAFT: timesavings, safety, agency costsavings, user costsavings, and air quality benefits. The NPV of the estimated annual benefits/costs is calculated over the analysis period, usually 20 to 30 years. MAFT assumes that the benefits begin to accrue in the opening year of the facility. The incremental changes in the benefit categories are calculated by contrasting the benefits calculated for the alternatives to a "do-nothing base case." The objective of the following sections is to discuss the formulas and models used to quantify these benefits.

Timesavings benefits

One of the main motivations for many highway expansion projects in the past has been a reduction in trip travel time. In many cases, travel timesaving had constituted the most significant benefit associated with highway projects. Simply stated, the calculation of the travel-time benefit comprises two stages: the calculation of the amount of time saved and the application of a unit value of time to quantify the savings.

Amount of time saved

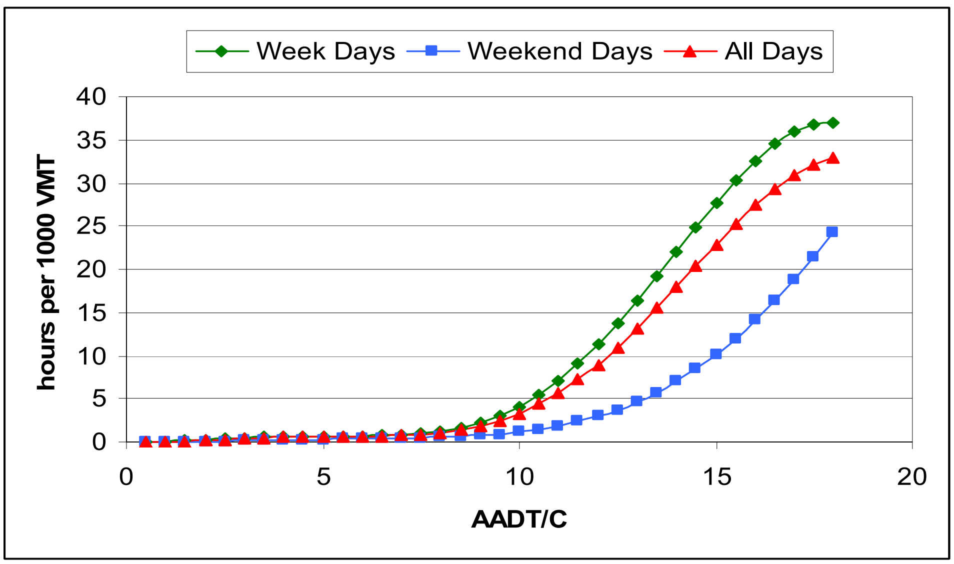
The amount of time saved can be calculated from the difference in the average traffic speed with and without the investment. The delay models developed by Margiotta et al. (1994) were embedded in MAFT to estimate the magnitude of the travel-time benefit. The models—developed using simulated data in CORSIM under saturated conditions—estimate the average speed on the facility and predict the effects of delays caused by congestion on an entire day's traffic (Margiotta et al. 1994). The dependent variable (delay) is measured in hours per 1,000 passenger car equivalents (PCE). The independent variables are the average annual daily traffic (AADT) and the capacity (C) of the road. The use of the AADT/C ratio allows for the calculation of overall daily delay, not only peak hour delay, which usually uses volume-to-capacity ratios. According to the researchers, the AADT/C ratio can be used to estimate what portion of a day in which the volume reaches capacity. As a result, the effect of queuing is argued to be more realistic.

Table 4.1 Delay Model Coefficients

AADT/C	Weekday	Weekends	All Days
$(AADT/C)^3$	0.0551	0.00966	0.0462
$(AADT/C)^4$	-0.0189	-0.00233	-0.0154
$(AADT/C)^5$	0.00233	0.000193	0.00186
$(AADT/C)^6$	-0.000113	-0.0000044	0.0000888
$(AADT/C)^7$	0.0000019		0.0000015

Source: Margiotta et al. 1994

Margiotta et al. (1994) developed three models for predicting delays on freeways: one for weekdays, one for weekends, and one for all days. The model coefficients for each of the three models are given in Table 4.1.



Source: Margiotta et al. 1994

Figure 4.6 Estimated Delay Experienced by Type of Day

Figure 4.6 illustrates the predicted delay on a road facility with the AADT/C ratio values ranging from 1 to 18 using the Margiotta models.

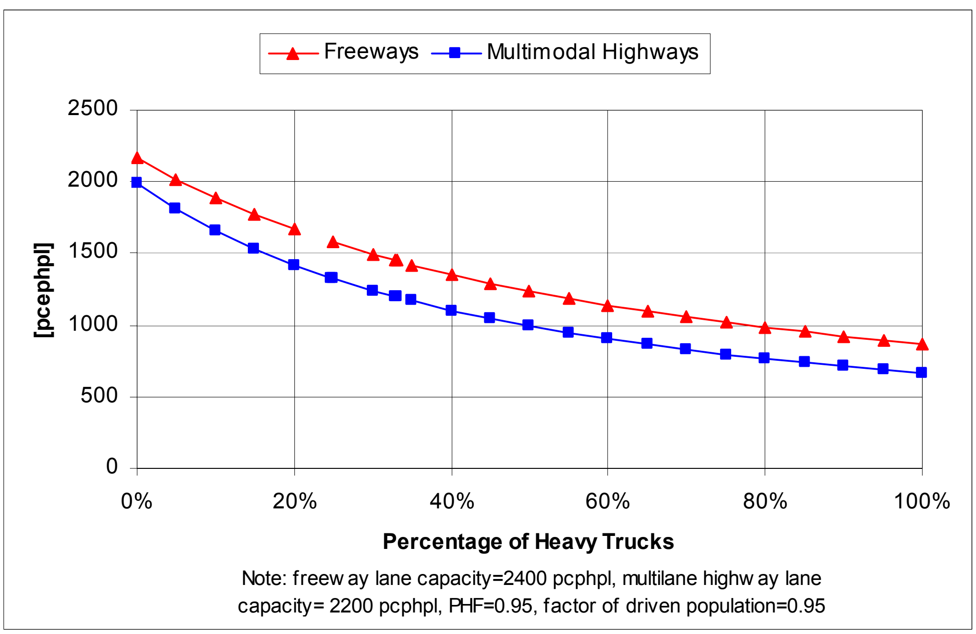
The road capacity is calculated in MAFT using the Highway Capacity Manual (HCM 2000) and the geometric characteristics of the road specified by the analyst. MAFT can consider the impacts of decreased truck traffic volume on road capacity. Because trucks require more space when traveling and more time to accelerate or decelerate, it is arguable that large and heavy freight vehicles have a larger impact on congestion than small and light vehicles. This is particularly relevant in the benefit calculations for investments in non-highway modes that result in truck diversion to these modes. In terms of the Highway Capacity Manual (HCM 2000), the road space required by trucks can range from 1.5 to 6.0 PCEs, depending on the type of terrain and road (Table 4.2).

Table 4.2 Passenger Car Equivalents per Truck

	Level Terrain	Rolling Terrain	Mountainous Terrain
Suburban - Rural Multilane Highways	1.5	3.0	6.0
Freeways	1.5	2.5	4.5

Source: Highway Capacity Manual 2000

The capacity of a road segment can be reduced significantly given increased truck traffic as a percentage of total traffic. Peak-period lane capacity can be reduced by one-third of the design capacity when the traffic stream constitutes 32.8 percent and 24.6 percent trucks for freeways and multilane highways, respectively. Figure 4.7 illustrates the impact on road capacity per lane assuming various percentages of trucks. MAFT can thus be used to quantify the capacity benefit of diverting trucks from general-purpose roads to dedicated truck facilities or rail.



Source: Highway Capacity Manual 2000

Figure 4.7 Impact of Heavy Truck Traffic on Lane Capacity

When capacity is added to a highway facility, it is expected that the average speeds will be higher at the opening of the facility compared to the base case scenario. Improvements in average speed will, however, encourage others to use the facility, generating additional traffic by shifting from other modes or from parallel roads, and by encouraging new or longer trips. MAFT determines the average speed experienced in the base and alternative case for existing users of the facility (base case traffic = existing users) and estimates the annual traffic induced, as well as the travel speed and delay implications of the additional traffic. The induced traffic is calculated using Equation 4.1, given the travel-time elasticity specified in the Global Assumptions worksheet.

$$V_i = \frac{H_0}{M - \frac{1}{E_d \times S_{av}}}$$

Where:
V_i is the induced VMT,
H_o is the initial time saving for previous users due to the investment,
M is added hours of congestion delay imposed to vehicles per added vehicle mile,
E_d is the elasticity of demand for highway travel with respect to travel time, and
S_{av} is the average speed.
Source: DeCorla-Souza and Cohen 1998

Equation 4.1 Induced Traffic

Therefore, the MAFT equations consider the initial AADT, the induced traffic, and the estimated capacity of the road to calculate the average speed and average delay. For each of the analysis years, the perceived timesaving is conservatively equated to the difference in the average speed in the base case and alternative investment case.

Rail and barges generally exhibit significantly lower average travel speeds and thus higher total travel time compared to trucks. For rail, the average operating speed for freight trains is typically 23 miles per hour (Cox 1999). The principal reason for the slower speeds is that the majority of railways operate on single tracks. Freight trains thus spend a significant amount of time stopped on sidings when faster, high-priority trains or trains from the opposite direction need to pass on the track. Depending on the type of analysis, total trip time can also be significantly impacted by transit time for sorting and classification at rail yards. Grades can force heavier trains to operate at even slower speeds (Cox 1999). Like trains, barges are also slow. The average speed of barges ranges from 7 to 9 miles per hour. Each barge usually carries 1,500 tons, which is equivalent to 50 to 75 containers, and one pusher tug can move 15 barges. The average speeds are slow because each pusher tug is moving about 22,500 tons (Homburger et al. 1982).

MAFT estimates the average speed for rail and barge by calculating the total trip time and distance. The total time per trip can be estimated considering the load and unload time, the time for car classification, and the total time from platform to platform. The analyst must input the average time for loading/unloading per truckload, sorting time per train-car, and the total time from platform to platform per train trip or barge trip.

Value of time

After estimating the change in travel time attributable to the investment, the value of an hour of time needs to be decided to quantify the time impact. Passenger vehicle travel time is valued considering the trip purpose and specified trip type (intercity/local). Data to characterize the traffic stream in terms of trip purpose were obtained from the 2001 National Household Travel Survey (Table 4.3).

Table 4.3 Vehicle Occupancy per Trip Purpose (2001)

Trip Purpose	Proportion of Trips (%)	Trip Occupancy
Work	14.80	1.14
Work related	2.90	1.22
Family/ personal business	44.60	1.81
School / church	9.80	1.76
Social/ recreational	27.10	2.05
Other	0.80	2.02

Source: National Household Travel Survey 2002

MAFT distinguishes two trip purposes. Business trips include work and work-related trips. Personal trips include family and personal business, school, church, and social recreational trips. For personal trips, MAFT distinguishes two trip types: intercity and local. Intercity travel time for nonbusiness trips has a higher value (70 percent of wage rate) than local nonbusiness travel time (50 percent of wage rate). The values of time for passenger vehicles are shown in Table 4.4.

Table 4.4 Value of Time for Passenger Vehicles

Trip Purpose	%	Average Occupancy	Intercity/Local	Value of Time	Year Price
Business/work [1]	17.7	1.15	Intercity/Local	18.8	1995
Personal [2]	82.3	1.89	Intercity	11.9	1995
Personal [2]	82.3	1.89	Local	8.5	1995

Notes: [1] work and work-related trips
[2] school, church, social, recreational, and family/personal business trips

Source: BTS 2002 and Weisbrod et al. 2001

For commercial vehicles (trucks), the value of time was taken from the study entitled "Economic Implications of Congestion" (Weisbrod et al. 2001), which estimated the time cost per hour for different types of trucks by dividing the average truck cost per year (considering labor, the vehicle, and inventory) by the number of hours the trucks are in service per year. Values for the time costs of the cargo were calculated by applying a discount rate to a composite average shipment.

No clear guidance exists in the literature regarding the value of time for freight rail and barges. The value of time for these modes was estimated for MAFT based on the value of time calculations for trucks by Weisbrod et al. (2001). The labor component was estimated based on an average crew of two for rail freight and nine for barges (Homburger 1982). The wage rate for barges was assumed to be the same as for truck drivers. The rail wage rate was obtained from data published by the Association of American Railroads (2003). The other two components (vehicle and inventory) are determined when the analyst inputs the rail and barge configurations. Table 4.5 shows the value of time for trucks, rail, and barges, assuming a rail configuration of 100 containers moved by two locomotives and a barge configuration of 750 containers moved on fifteen barges by one pusher tug. The value of time per container or truckload is obtained by dividing the total by the number of truckloads or containers moved.

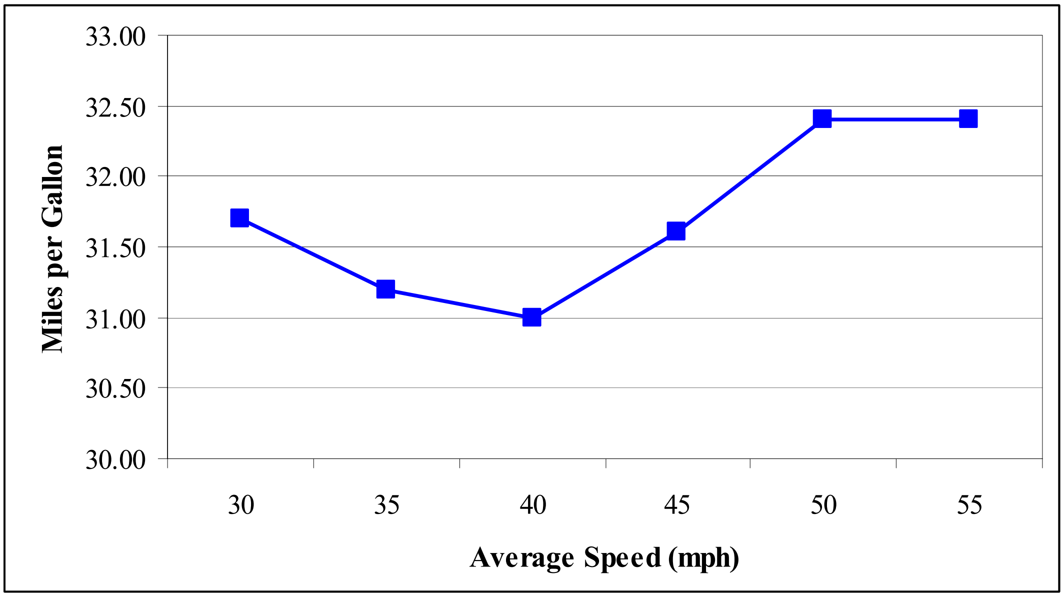
Table 4.5 Value of Time/ Truck Load (Container) Equivalents

	Truck	Rail	Pusher Tug/ Barge
Crew	1	2	9
Number of Truck Loads/ Containers	1	100	750
Labor	21.95	37.98	197.55
Vehicle	7.98	798	5,985
Inventory	1.65	165	1,237.5
Value of Time Per Truck/Train/Barge	31.58	1,000.98	7,420.05
Value of Time Per Truck Load/ Container	**31.58**	**10.01**	**9.89**

Operating costsavings

Vehicle-operating costsavings refer to a reduction in the out-of-pocket costs of the road user. It varies depending on the type of vehicle, road conditions, and average travel speeds. In addition, vehicle-operating cost per mile is a function of the maintenance of the vehicle and the driver's driving behavior. MAFT accounts for the reduction in costs of fuel consumption, maintenance, and tires of passenger cars and trucks associated with alternative infrastructure investments.

Figure 4.8 illustrates the fuel consumption of passenger vehicles by average speed based on data published in the Transportation Energy Data Book (U.S. Department of Energy 2003). The passenger vehicle fuel consumption by travel speed was included in the Global Assumptions worksheet. As can be seen from Figure 4.8, fuel consumption tends to be higher at speeds over 45 mph and under 30 mph. MAFT calculates the annual fuel consumption (gallons) benefits associated with alternative investments given associated changes in the average travel speed compared to the base case.



Source: U.S. Department of Energy 2002

Figure 4.8 Passenger Vehicle Fuel Consumption

Daily truck diesel fuel consumption is calculated in MAFT based on the diesel fuel consumption by truck class information (Table 4.6) published in the Transportation Energy Data Book (U.S. Department of Energy 2002) and the truck class traffic distribution information (Table 4.7) published in a Center for Transportation Research study entitled "Effects of Truck Size and Weight on Highway Infrastructure and Operations" (Luskin and Walton 2001).

Table 4.6 Fuel Consumption per Truck Class

Truck Class	Miles per gallon
Class 6	13.60
Class 7	9.40
Class 8	9.30
Class 9	8.70
Class 10	7.30
Class 11	6.40
Class 12	5.70
Class 13	5.70

Source: U.S. Department of Energy 2002

Table 4.7 Percentage of Truck Class on Texas Roads

Truck Vehicle Class	Gross Weight	% Truck Class on Texas Roads
Class 6	48,000	7.44
Class 7	56,000	0.00
Class 8	80,000	7.16
Class 9	80,000	79.42
Class 10	88,000	0.59
Class 11	101,000	4.21
Class 12	122,000	1.18
Class 13	129,000	0.00

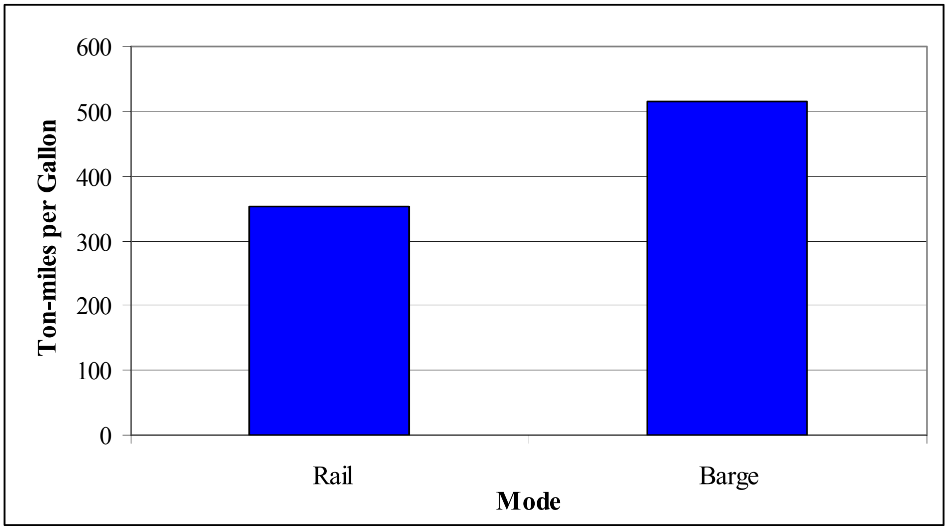
Source: Luskin and Walton 2001

The equation used to calculate daily truck diesel fuel consumption has the following functional form:

$$A = \sum_i (B \times C \times ADTT \times L)$$

Where:
A is the daily truck diesel fuel consumption,
B is the percentage of the truck class on Texas roads (Table 4.7),
i represents the truck class, $i = 1....13$,
C is the fuel consumption per truck class (Table 4.6),
ADTT is the average annual daily truck traffic, and
L is the length of the corridor.

In addition, information on the fuel consumption rates of rail and barge were obtained from the Transportation Energy Data Book (U.S. Department of Energy 2002). For example, a ton of cargo can be carried by barge 514 miles per gallon of diesel as compared to 352 miles by train (U.S. Department of Energy 2002). These fuel consumption rates (Figure 4.9) for rail and barge were embedded in MAFT to evaluate rail and barge investments.



Source: U.S. Department of Energy 2002

Figure 4.9 Fuel Consumption by Mode

The maintenance/repair and tire costs for passenger cars and trucks (Table 4.8) embedded in MAFT were obtained from a study undertaken by the University of Minnesota for the Minnesota Department of Transportation entitled "The Per-mile Costs of Operating Automobiles and Trucks" (Barnes and Langworthy 2003).

Table 4.8 Operating Cost of Passenger Cars and Trucks

Category	Passenger Car (cents per mile)	Truck (cents per mile)
Maintenance/Repair	3.2	10.5
Tires	0.9	3.5

Source: Barnes and Langworthy 2003

Agency costsavings

Roads are typically designed for a predetermined number of equivalent standard axle loads (ESALs). Table 4.9 illustrates the number of ESALs per truck class on flexible and rigid pavements, respectively. Shifting trucks to managed lanes or alternative modes (i.e., rail and barge) can increase the design life of the road and reduce the rehabilitation and maintenance costs of the road.

Table 4.9 Number of ESALs per Truck Class

Truck Class	Gross Weight	Number of ESALs	
		Flexible Pavements	Rigid Pavements
Class 6	48,000	1.48	2.1
Class 7	56,000	1.11	1.78
Class 8	80,000	2.37	4.07
Class 9	80,000	4.05	4.09
Class 10	88,000	1.88	3.57
Class 11	101,000	2.57	3.56
Class 12	122,000	2.97	5.52
Class 13	129,000	2.66	4.43

Source: Luskin and Walton 2001

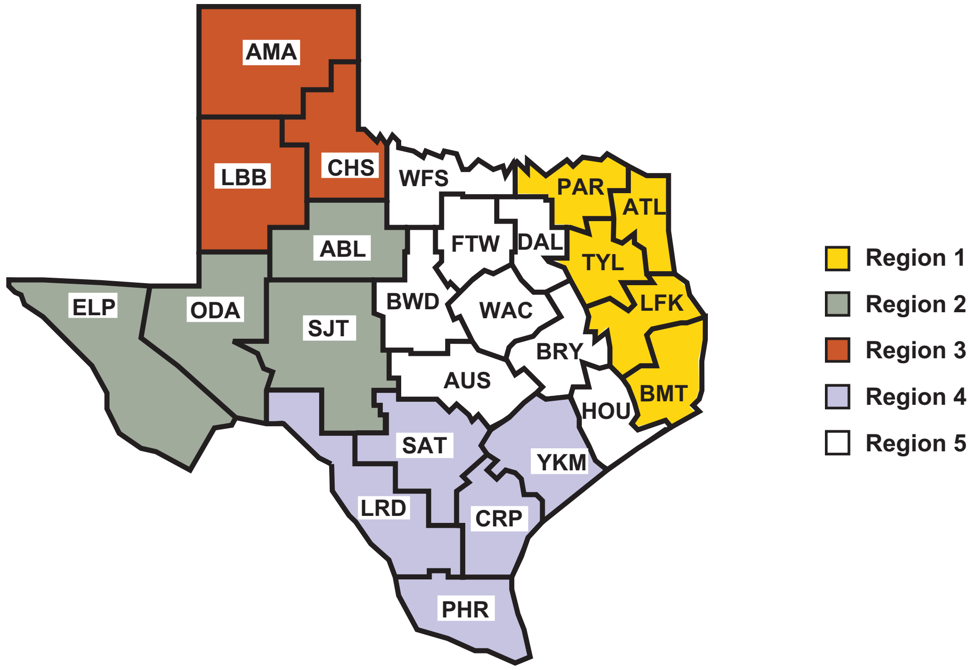
MAFT can be used to calculate the maintenance costsavings accumulated by the transportation agency if trucks are diverted to managed lanes or alternative modes. The maintenance cost model developed by Luskin et al. (2001) as part of the TxDOT research study entitled "Highway Cost Allocation Study" was embedded in MAFT. The model estimates incurred maintenance costs in dollars per square yard as a function of the TxDOT climatic region, the number of ESALs per year (million), type of road, and lane distribution factor. The model has the following functional form:

$$Y = l(a + b\ X\ F(l))$$

Where:
Y is the maintenance cost in dollars per square yard,
X is million of ESALs per year,
$F(l)$ represents the lane distribution factors (Table 4.5), and
a and b depend on the type of road and the climatic region (Table 4.6).
Source: Luskin et al. 2002

Equation 4.2 Flexible Pavement Maintenance Cost

Weather can have a significant impact on the durability of highways, affecting maintenance costs associated with the base case and the highway investment and managed lane alternatives. Texas generally can be divided into five climatic regions as shown in Figure 4.10.



Source: Luskin et al. 2002

Figure 4.10 Texas Climatic Regions

The lane distribution factors are summarized in Table 4.10.

Table 4.10 Distribution Factors According to Number of Lanes

Distribution Factors	
Number of Lanes in One Direction	***F(l)***
1 – 2	1.0
3	0.7
4 or more	0.6

Source: Luskin et al. 2002

The parameter values for *a* and *b* for each of the climatic regions and highway types (i.e., interstate highways and high traffic U.S. or state highways, low traffic U.S. or state highways, and farm-to-market roads) are summarized in Table 4.11.

Table 4.11 Parameters *a* and *b* by Type of Road and Weather Region

Region		Interstate & High Traffic US/State Highways	Low Traffic US/State Highways	Farm-to-Market Roads
1	*a*	0.65	0.28	0.26
	b	1.70	2.52	3.55
2	*a*	0.18	0.00	0.09
	b	6.09	6.75	3.85
3	*a*	0.01	0.08	0.13
	b	1.98	0.81	0.05
4	*a*	0.51	0.23	0.21
	b	1.46	2.14	3.04
5	*a*	0.67	0.32	0.31
	b	1.44	2.16	3.02

Source: Luskin et al. 2002

The agency costsavings attributable to the diversion of truck traffic from the base case to the managed lane or non-highway alternative is calculated by subtracting the maintenance cost after the investment (thus considering induced and diverted traffic) from the maintenance cost in the base case.

Safety benefits

Traffic safety impacts typically are expressed in terms of the number of fatalities, injuries, and financial losses associated with incidents of property damage only. The valuation of safety benefits is similar to that of timesaving benefits. Safety benefits can be determined by multiplying the number of accidents expected on the new facility with the average cost per accident relative to the base case.

Number of accidents

Accidents can have three types of consequences: injuries, fatalities, and economic losses. An understanding of the relationship between traffic speed and accident risk is necessary to determine the number of accidents that could be expected on a transportation facility. Considerable evidence exists to demonstrate that higher traffic speeds are associated with more severe accidents (Aljanahi et al. 1998; Persaud and Dzbik 1993). Furthermore, accident rates tend to increase with traffic density (Persaud and Dzbik 1993), but the number of fatalities tends to be fewer at high levels of congestion (Zhou and Sisiopiku 1997).

For the highway investment alternatives, the models developed by Zhou and Sisiopiku (1997) were embedded in MAFT to calculate accident rates per 100 million vehicle miles traveled. Two accident models were developed: one for casualties (fatalities and injuries) and the other for property damage only (PDO) accidents. The two independent variables for estimating the number of accidents in the Zhou and Sisiopiku models are: traffic volume and capacity (Equation 4.3 and 4.4).

$$CA = 346\left(\frac{v}{c}\right)^2 - 452\left(\frac{v}{c}\right) + 210$$

Where:
CA is the average hourly casualty accident rates per 100 million VMT,
V is the traffic volume on the facility, and
C is the capacity of the facility.
Source: Zhou and Sisiopiku 1997

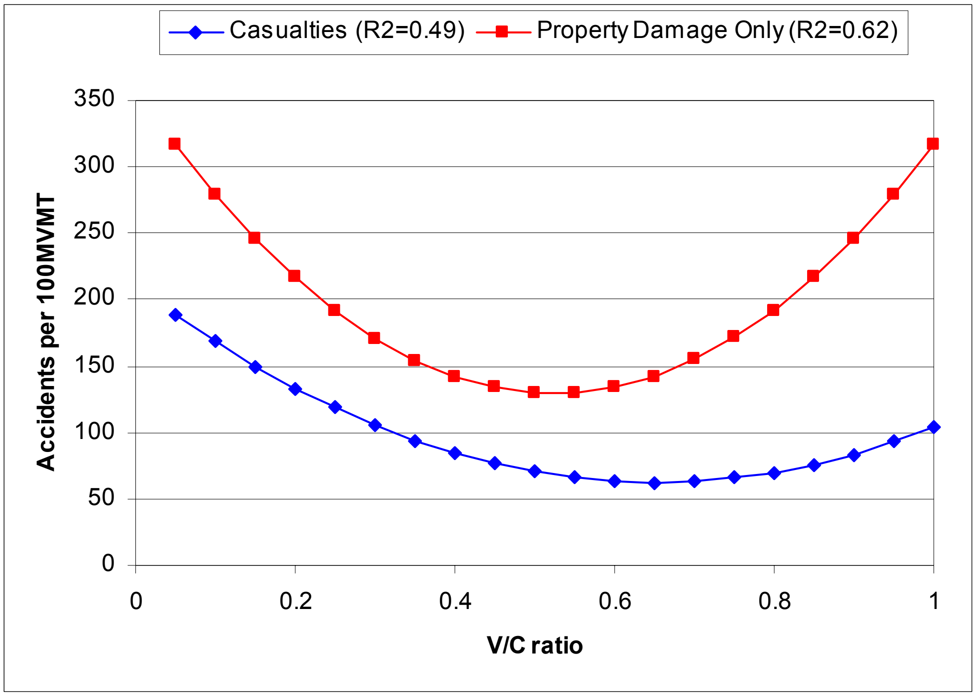
Equation 4.3 Casualties Model (Injuries and Fatalities)

$$PDO = 831\left(\frac{v}{c}\right)^2 - 872\left(\frac{v}{c}\right) + 358$$

Where:
PDO is the average hourly PDO accident rates per 100 million VMT,
V is the traffic volume on the facility, and
C is the capacity of the facility.
Source: Zhou and Sisiopiku 1997

Equation 4.4 Property Damage Only Model

These accident models were developed using data from a highly congested road segment of I-94 in Detroit. The road segment contains 79 merging and exit ramps (approximately 2.5 ramps per mile). The Zhou and Sisiopiku models revealed a U-shape relationship between the number of PDO accidents and the volume-to-capacity ratio (Figure 4.11). In other words, at lower traffic volumes, higher average speeds result in increased accident rates, but at the same time higher traffic volumes—i.e., congestion—result in more interference among vehicles and ultimately higher accident rates. Zhou and Sisiopiku (1997) also found that the number of casualties is lower in congested traffic (v/c close to 1) compared to traffic conditions where the v/c ratio is close to zero. Accident rates (for casualty and PDO incidents) are lowest on roads experiencing "moderate" congestion (a v/c ratio between 0.5 and 0.7).



Source: Zhou and Sisiopiku, 1997

Figure 4.11 Accident Models Embedded in MAFT

When quantifying the safety impacts, however, it is necessary to estimate the number of injuries and fatalities (associated with casualty incidents) for the highway alternatives—not only the number of casualty accidents. Chang and Mannering (1999) examined 1996 Washington State data in an attempt to identify factors that increase accident severity. Models were developed for accidents that did and did not involve trucks. The researchers concluded that the level of severity of an accident is reduced if trucks were not involved in the accident. Accidents that involve trucks have an increased likelihood of producing a severe injury or fatality owing to the truck-car size disparity and other factors (Kwean and Kockelman 2003; Chang and Mannering 1999). Table 4.12 summarizes the findings of Chang and Mannering (1999) and the assumptions embedded in MAFT to estimate the number of fatalities and casualties associated with truck and non-truck accidents.

Table 4.12 Percentage of Injuries and Fatalities

	Non-Truck Accidents	**Percentage Used in MAFT**	**Truck-Involved Accidents**	Percentage used in MAFT
Property Damage Only	83.9%		64.5%	
Injury	11.4%	70%	23.5%	**66%**
Fatality	**4.8%**	**30%**	**12%**	**34%**

Source: Chang and Mannering 1999

To summarize, the number of accidents and the severity of the accidents are calculated in three steps for the highway alternatives:

- the number of casualty and property damage only accidents are calculated using the Zhou and Sisiopiku models,
- the number of truck accidents are assumed to be proportional to the percentage of trucks in the traffic stream, and
- the number of injuries and fatalities are estimated based on the research of Chang and Mannering (1999). For the managed lane alternative, i.e., truck-only road, the severity of the incidents was assumed to be the non-truck accident rates.

For the rail alternative, the summary data published by the Federal Railroad Administration (2003) on the number of rail accidents and casualties, rail accident rates, total train miles traveled by type of rail carrier, and total cost of rail accidents was included in MAFT (Table 4.13). Burlington Northern Santa Fe (BNSF) and Union Pacific (UP) are the two most important rail freight carriers in Texas. Accident rates (including number of accidents, fatalities, and injuries) for BNSF and UP, published by the Federal Railroad Administration, were thus included in MAFT. If a railroad other than BNSF or UP provides the rail service, MAFT calculates the average of the values determined for BNSF and UP to present the number of accidents, fatalities, and injuries for the other railroad. These rates are included in the Global Assumptions worksheet and can be updated if the rail carrier provides better estimates.

Table 4.13 Rail Accident Rates

Accident Cost or Factor	**BNSF**	**UP**	**Average**
Train accident rate per million train miles	3.28	4.41	3.85
Fatalities per million train miles	0.915	1.18	1.05
Injuries per million train miles	7.607	8.34	7.97

Source: Federal Railroad Administration 2003.

The fatality and injury rates for barges (Table 4.14) were derived from data published in the "National Transportation Statistics" (BTS 2002) and a document entitled the "Environmental Advantages of Inland Transportation" (U.S. DOT 1994). These rates were embedded in the Global Assumptions worksheet. It should be noted, however, that data on barge and short sea accidents are particularly scarce.

Table 4.14 Barge Fatality and Injury Rates

	Rates/Million Ton-Barge
Fatalities	0.0195
Injuries	0.039

Source: BTS 2002 and U.S. DOT: Marine Administration 1994

Valuing safety

The National Safety Council estimated the monetary costs of a fatality, injury, and PDO accident using the "willingness to pay" concept. These values are included in the Global Assumptions worksheet and are summarized in Table 4.15.

Table 4.15 Monetary Costs of Accidents

	Monetary Costs
Property damage only	**$3,470,000**
Injury	**$44,200**
Fatality	**$2,000**

Source: National Safety Council 2002

The cost of a PDO train accident, excluding the damage to highway vehicles, is estimated at $108,246 for BNSF and $105,381 for UP (Federal Railroad Administration 2002). These costs were embedded in MAFT.

Emissions impacts

The emissions impacts are calculated similarly to the travel time and safety impacts. First, the amount of emissions with and without the transportation investment is calculated for each pollutant and then these quantities are multiplied by the cost per ton of the respective pollutants. MAFT can be used to calculate the impacts associated with HC, CO, and NOx for all of the modal investment alternatives. The particulate emissions impacts can be calculated for the traditional highway, managed lane, and rail alternatives only. A lack of data prevented the calculation of the particulate emissions associated with barge investments.

Amount of Emissions

The emission equations for each of the pollutants included in MAFT were based on the EPA MOBILE 5 model. The MOBILE 5 emissions equations account for the following variables: estimated basic emissions rate given the age of the vehicles (i.e., passenger cars and trucks), vehicle miles traveled, and travel speed. The basic emission rates for passenger cars and trucks embedded in MAFT are summarized in Table 4.16 and 4.17, respectively.

Table 4.16 Basic Emission Rates for Passenger Vehicles

Year	HC	CO	NOx
1990	1.97	25.56	1.77
1991	1.98	25.66	1.77
1992	1.99	25.75	1.76
1993	1.99	25.75	1.76
1994	1.95	25.75	1.68
1995	1.91	25.75	1.57
1996	1.87	25.75	1.52
1997	1.85	25.75	1.52
1998+	1.85	25.75	1.52

Source: Glover and Koupal 1999

Table 4.17 Basic Emission Rates for Trucks

Year	HC	CO	NOx
1991-1997	4.83	18.46	8.13
1998-2000	4.82	18.44	6.49
2001+	4.82	18.43	6.49

Source: Glover and Koupal 1999

To simplify calculations, it is assumed in MAFT that all passenger cars and all trucks have the same average age, respectively. The median ages for U.S. trucks and passenger vehicles were based on the data published in the "National Transportation Statistics" (BTS 2002). Estimates for the average number of miles traveled per vehicle per year were also obtained from National Transportation Statistics (BTS 2002). The median age and vehicle miles traveled estimates are included in the Global Assumptions worksheet, which can be updated each year.

Finally, the average travel speed on the road facilities is accounted for in MAFT through the speed correction factors for light-duty gasoline vehicles (Table 4.18) and heavy-duty diesel vehicles (Table 4.19), respectively.

Table 4.18 Speed Correction Factors for Light-Duty Gasoline Vehicles

SCF = A/s+B S=average speed	HC	CO	NOx
A	9.90	9.49	1.46
B	0.50	0.52	0.93

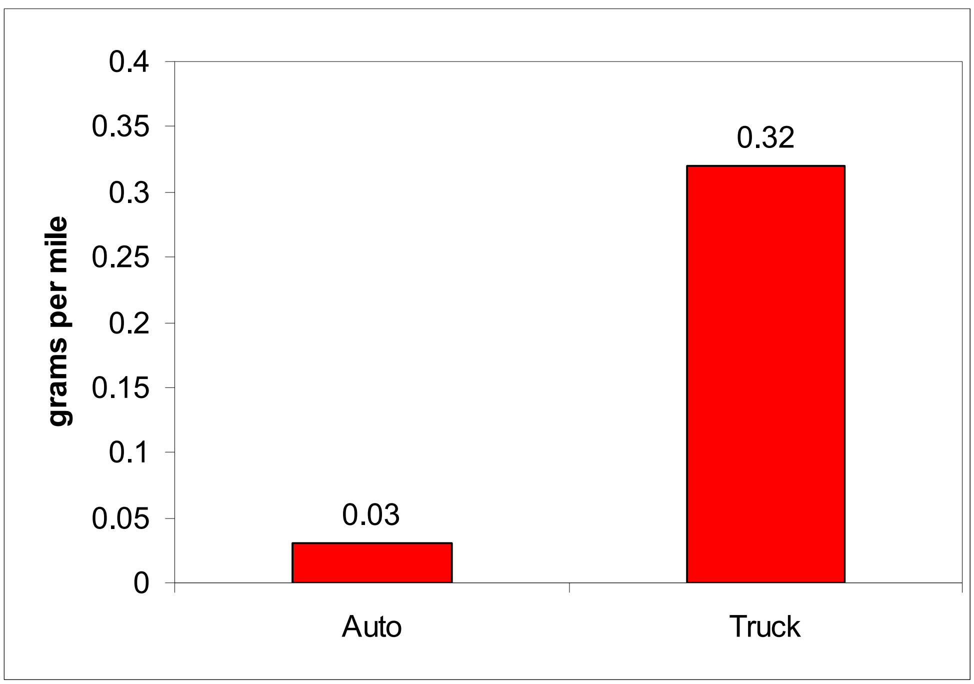
Source: Brzezinski 1999

Table 4.19 Speed Correction Factors for Heavy-Duty Diesel Vehicles

SCF = exp(A+B*s+C*s²) S=average speed	HC	CO	NOx
A	0.924	1.396	0.676
B	-0.055	-0.088	-0.048
C	0.00044	0.0009	0.0007

Source: Brzezinski et al. 1999

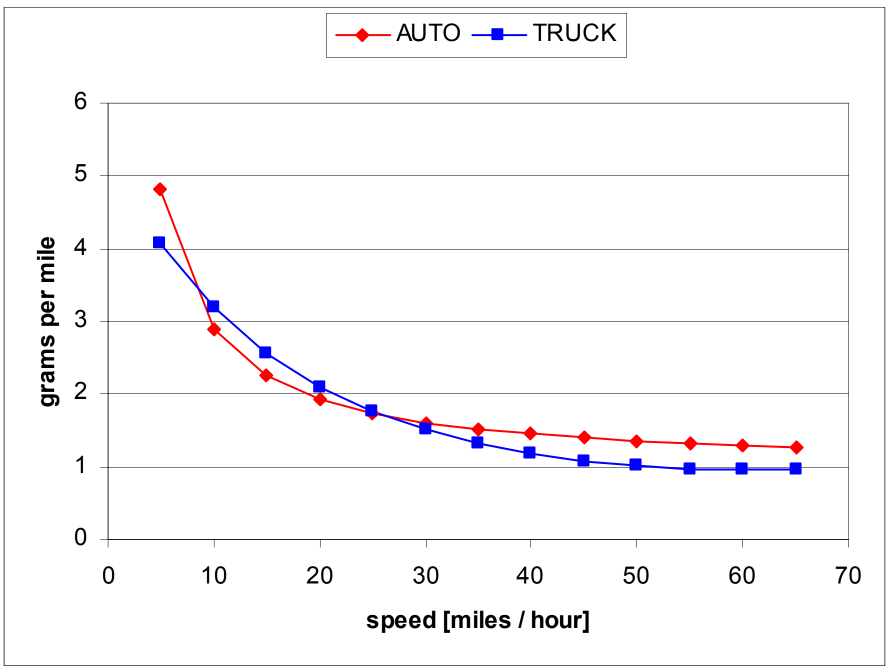
Figure 4.12 illustrates the emissions rates for particulate matter, which were embedded in MAFT.



Source: Glover and Koupal, 1999

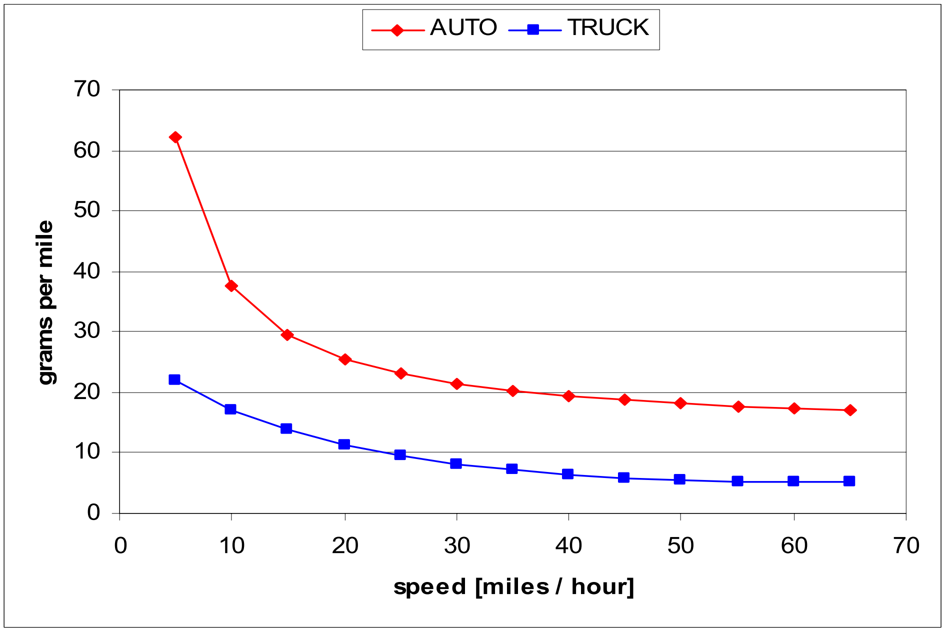
Figure 4.12 Particulate Emission Rates

In general, CO and HC emission rates tend to increase under stop-and-go conditions characteristic of facilities that experience high levels of congestion (Figures 4.13 and 4.14). In the case of NOx, higher emissions rates are experienced at very low and very high speeds for truck movements (Figure 4.15). Changes in average travel speeds therefore result in changes in the overall emissions. Because MAFT assumes a single average travel speed per year on a facility, the overall change in pollutant emissions is roughly approximated. MAFT also does not consider geographical location influences, the distribution of pollutants, or the characteristics of the population at risk. Finally, MAFT does not account for higher emission rates owing to cold-starts or at traffic peaks during the day. More accurate emissions estimates require the use of the EPA MOBILE 6 model.



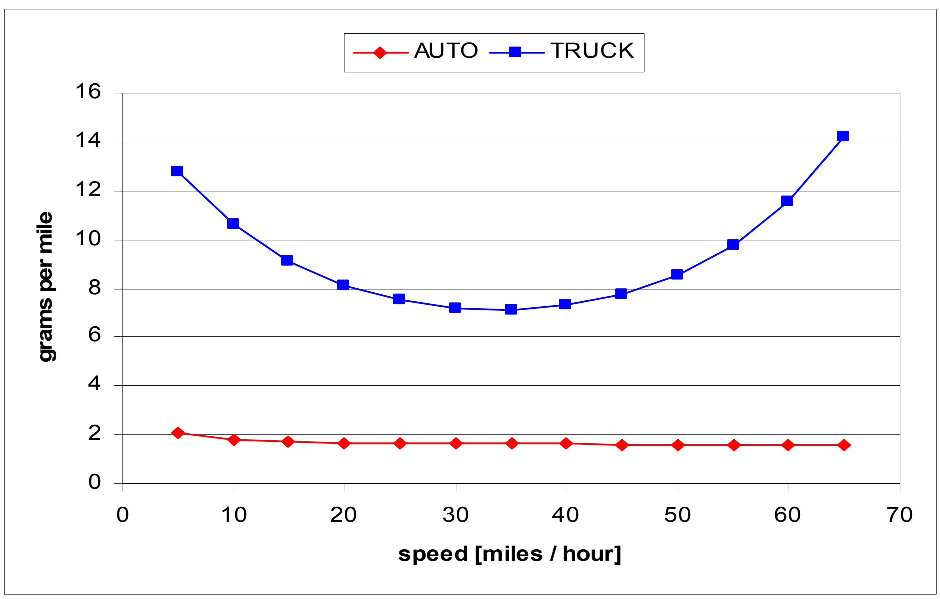
Source: Glover and Koupal 1999

Figure 4.13 Hydrocarbon Emission Rates



Source: Glover and Koupal 1999

Figure 4.14 Carbon Monoxide Emission Rates



Source: Glover and Koupal 1999

Figure 4.15 Nitrogen Oxides Emission Rates

Emission rates for rail and barges were taken from information published by the EPA. Table 4.20 illustrates the emission rates for line haul locomotives embedded in MAFT for the four criteria pollutants: HC, CO, NOx, and PM. Table 4.21 illustrates the basic emission rates for three of the criteria pollutants (i.e., HC, CO, and NOx) for barges. These values were also embedded in the Global Assumptions worksheet in MAFT.

Table 4.20 Emission Rates for Locomotives—Line Haul

Year	HC	CO	NOx	PM
before 1973 (nonregulated)	10.00	26.60	270.00	6.70
1973-2001	10.00	26.60	178.00	6.70
2002-2004	9.80	26.60	139.00	6.70
2005 or later	5.40	26.60	103.00	3.60

Source: Environmental Protection Agency 1997

Table 4.21 Basic Emission Rates for Barges

Pollutant	Ton-miles per gallon
HC	0.00009
CO	0.00020
Nox	0.00053

Source: Environmental Protection Agency 1997

Values Used to Quantify Pollutant Damages

The emissions values embedded in MAFT were taken from a study by Small and Kazimi (1995) entitled "On the Costs of Air Pollution from Motor Vehicles." The emission values were estimated by observing the relationship between increases in the primary pollutants and mortality and morbidity. This study is quoted widely in the literature when researchers attempt to quantify the impacts of emissions in dollar terms. The values summarized in Table 4.22 were embedded in the Global Assumptions worksheet.

Table 4.22 Monetary Costs of Pollutants

Pollutant	Monetary Costs ($/ton)
HC	**$1,710**
CO	**$63**
NOx	**$1,330**
PM-10	**$12,850**

Source: Small and Kazimi 1995

4.3 Concluding Remarks

This chapter provided an overview of the structure, embedded models, and assumptions included in MAFT. Chapter 5 presents the results of two case studies used to test and validate MAFT.

5. MULTIMODAL ANALYSIS FREIGHT TOOL: CASE STUDIES

The Federal Highway Administration and the state departments of transportation of Texas, Oklahoma, Kansas, Missouri, Iowa, and Minnesota funded a study in 1999 to investigate multimodal solutions for congestion experienced on the IH-35 corridor and to ensure adequate capacity to meet future demand in 2025. The "IH-35 Trade Corridor Study" (HNTB Corporation and Wilbur Smith Associates Team 1999) covered the IH-35 corridor between Laredo, Texas, and Duluth, Minnesota. The study proposed three alternative solutions to relieve congestion: (a) widening of the corridor (a highway expansion alternative); (b) building a dedicated truck road between Dallas and Laredo (a managed lane alternative); and (c) adding rail capacity between Kansas and Laredo. Because the study collected most of the needed information to test and validate Multimodal Analysis Freight Tool (MAFT), data published for two sections of the corridor was used to test and validate MAFT. The case studies thus pertained to a highway expansion versus a managed lane alternative for a rural and urban segment of the Texas IH-35 corridor. To test MAFT, data contained in the IH-35 study occasionally had to be supplemented to meet the data input requirements for testing the tool. This chapter presents the case study results used to test MAFT.

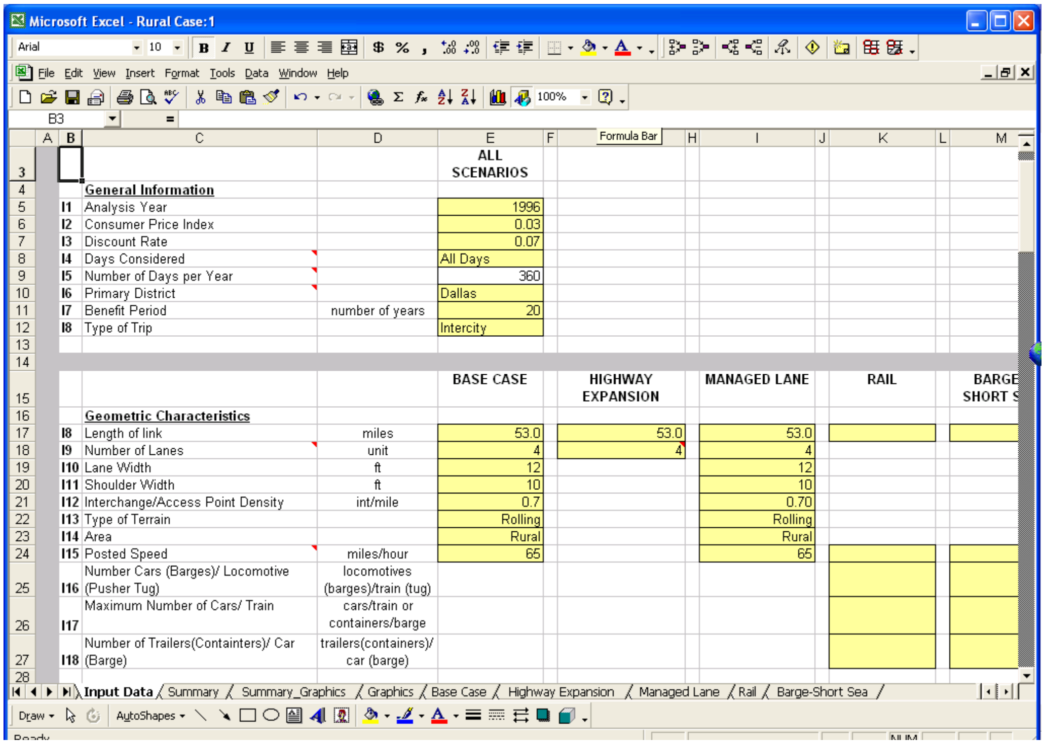
5.1 Rural Case Study

5.1.1 Description of Input Data

General Information and Geometric Characteristics

The rural IH-35 segment stretches between Dallas/Fort Worth and the southern transition (IH-35 East). This segment is a controlled access divided freeway with four 12-foot wide lanes and a length of 53 miles. The rural analysis considered all days of the week, because rural road segments usually experience less of a difference between weekday traffic volumes and weekend day traffic volumes.

The proposed highway expansion and managed lane alternatives consisted of two 12-foot lanes in each direction and 10-foot paved right shoulders. The design speed was 75 mph for both alternatives, with a free flow speed of 70 mph. A rolling terrain was assumed and the interchanges were spaced every 1.5 miles and 20 miles for the highway expansion and managed lane alternatives, respectively. Figure 5.1 summarizes the general and geometric characteristics information that was entered into MAFT.



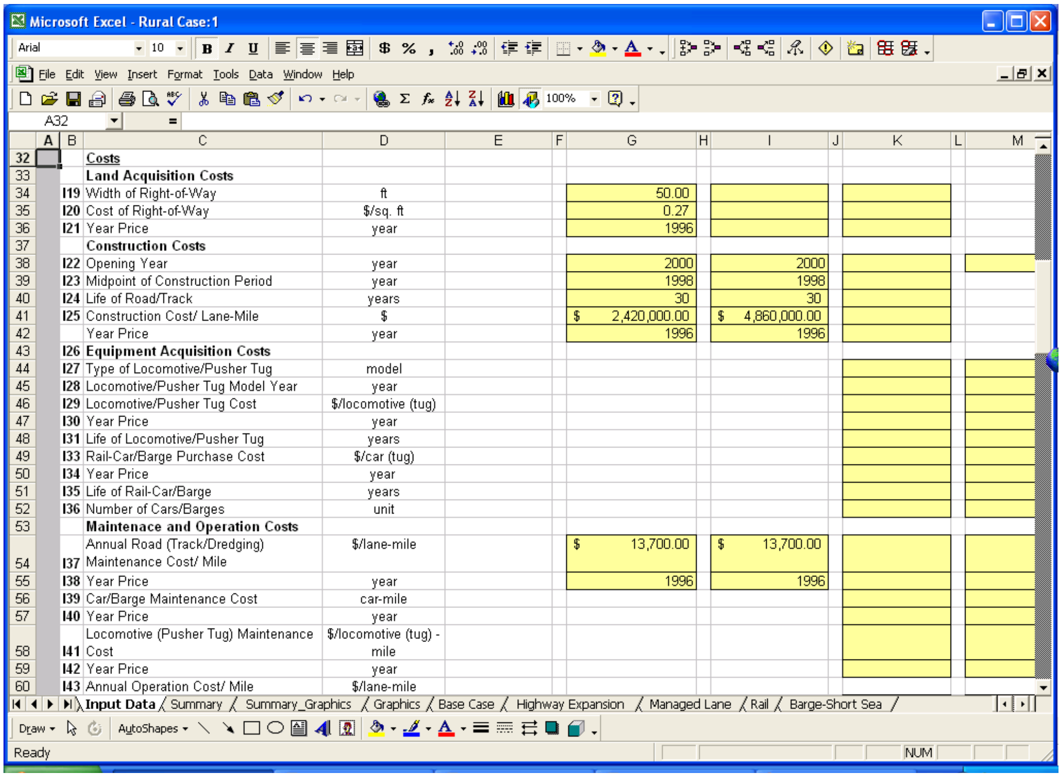
				ALL SCENARIOS				
4		General Information						
5	I1	Analysis Year		1996				
6	I2	Consumer Price Index		0.03				
7	I3	Discount Rate		0.07				
8	I4	Days Considered		All Days				
9	I5	Number of Days per Year		360				
10	I6	Primary District		Dallas				
11	I7	Benefit Period	number of years	20				
12	I8	Type of Trip		Intercity				
15				BASE CASE	HIGHWAY EXPANSION	MANAGED LANE	RAIL	BARGE SHORT S
16		Geometric Characteristics						
17	I8	Length of link	miles	53.0	53.0	53.0		
18	I9	Number of Lanes	unit	4	4	4		
19	I10	Lane Width	ft	12		12		
20	I11	Shoulder Width	ft	10		10		
21	I12	Interchange/Access Point Density	int/mile	0.7		0.70		
22	I13	Type of Terrain		Rolling		Rolling		
23	I14	Area		Rural		Rural		
24	I15	Posted Speed	miles/hour	65		65		
25	I16	Number Cars (Barges)/ Locomotive (Pusher Tug)	locomotives (barges)/train (tug)					
26	I17	Maximum Number of Cars/ Train	cars/train or containers/barge					
27	I18	Number of Trailers(Containters)/ Car (Barge)	trailers(containers)/ car (barge)					

Source: HNTB Corporation and Wilbur Smith Associates 1996

Figure 5.1 Rural Case Study: General and Geometric Characteristics Input Data

Costs

The amount of land required for the right-of-way, the right-of-way costs, and the construction costs for the expansion and the managed lane alternatives is summarized in Figure 5.2. Construction costs include subbase, base, and pavement surface costs. Managed lanes tend to have a stronger pavement structure (16 inches in this example) than general-purpose lanes. In the “IH-35 Trade Corridor Study,” the useful life of the road was stated as 30 years for the pavements and shoulders, and 50 years for the road base (HNTB Corporation and Wilbur Smith Associates Team 1996). For simplicity, a useful life of 30 years was assumed for both the highway expansion and managed lane alternatives. The construction period (5 years) and the opening year of both alternatives were based on data from the “IH-35 Trade Corridor Study.” The midpoint construction year was assumed to be 2002. Operation and maintenance costs of $13,700 (1996) per lane-mile were assumed (HNTB Corporation and Wilbur Smith Associates Team 1996). The latter includes maintenance, highway patrol, engineering and administration, and communications costs.



	B	C	D	G	I
32		Costs			
33		**Land Acquisition Costs**			
34	I19	Width of Right-of-Way	ft	50.00	
35	I20	Cost of Right-of-Way	$/sq. ft	0.27	
36	I21	Year Price	year	1996	
37		**Construction Costs**			
38	I22	Opening Year	year	2000	2000
39	I23	Midpoint of Construction Period	year	1998	1998
40	I24	Life of Road/Track	years	30	30
41	I25	Construction Cost/ Lane-Mile	$	$ 2,420,000.00	$ 4,860,000.00
42		Year Price	year	1996	1996
43	I26	**Equipment Acquisition Costs**			
44	I27	Type of Locomotive/Pusher Tug	model		
45	I28	Locomotive/Pusher Tug Model Year	year		
46	I29	Locomotive/Pusher Tug Cost	$/locomotive (tug)		
47	I30	Year Price	year		
48	I31	Life of Locomotive/Pusher Tug	years		
49	I33	Rail-Car/Barge Purchase Cost	$/car (tug)		
50	I34	Year Price	year		
51	I35	Life of Rail-Car/Barge	years		
52	I36	Number of Cars/Barges	unit		
53		**Maintenace and Operation Costs**			
54	I37	Annual Road (Track/Dredging) Maintenance Cost/ Mile	$/lane-mile	$ 13,700.00	$ 13,700.00
55	I38	Year Price	year	1996	1996
56	I39	Car/Barge Maintenance Cost	car-mile		
57	I40	Year Price	year		
58	I41	Locomotive (Pusher Tug) Maintenance Cost	$/locomotive (tug) - mile		
59	I42	Year Price	year		
60	I43	Annual Operation Cost/ Mile	$/lane-mile		

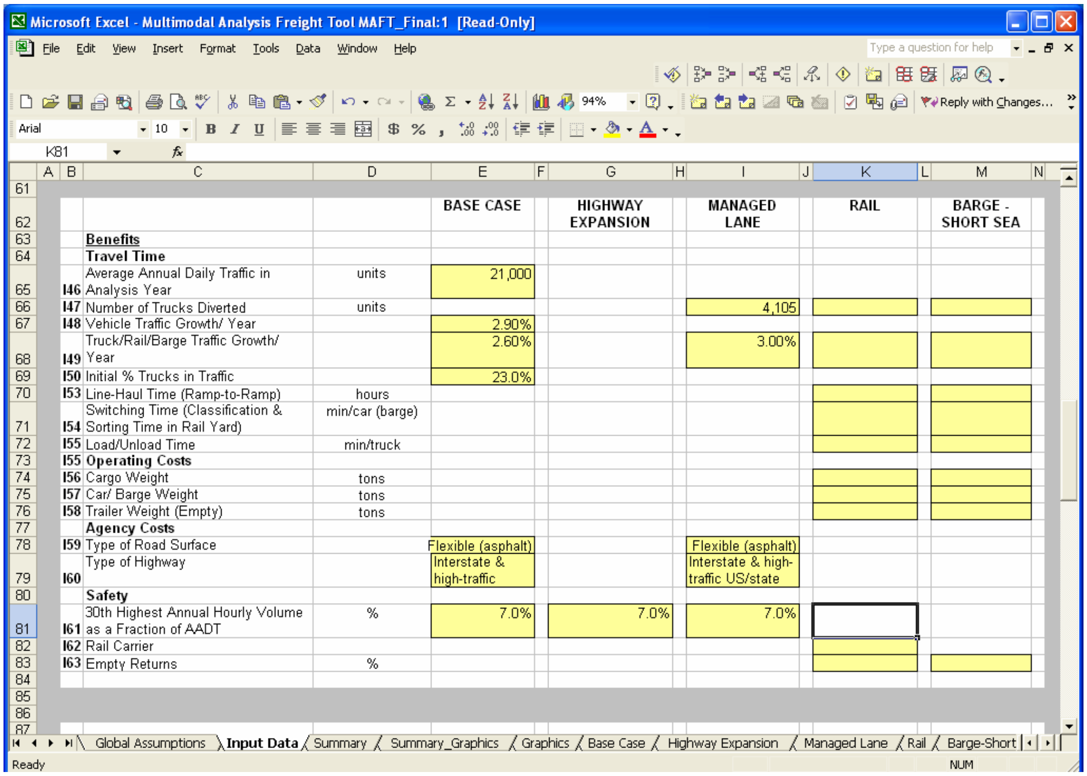
Source: HNTB Corporation and Wilbur Smith Associates 1996

Figure 5.2 Rural Case Study: Cost Input Data

Benefits

The annual average daily traffic was reported as 21,000 vehicles, of which 23 percent were trucks. The "IH-35 Trade Corridor Study" provided the passenger traffic growth between 1970 and 1990, and estimated truck traffic growth at 2.6 percent per year. It was forecasted that when completed, 85 percent of the truck traffic between Dallas and Laredo would be diverted from IH-35 to the managed lane alternative (HNTB Corporation and Wilbur Smith Associates Team 1996).

The safety models embedded in MAFT use the 30th maximum hourly volume to estimate the volume-to-capacity ratio when calculating the safety impacts associated with alternative investments (Zhou and Sisipioku 1997). The 30th maximum hourly volume was not reported in the "IH-35 Trade Corridor Study." A 7 percent ratio of peak hour to daily traffic was assumed based on the basic time-of-day patterns observed by Hallenbec et al. (1997). The benefit input data are presented in Figure 5.3.



Microsoft Excel - Multimodal Analysis Freight Tool MAFT_Final:1 [Read-Only]

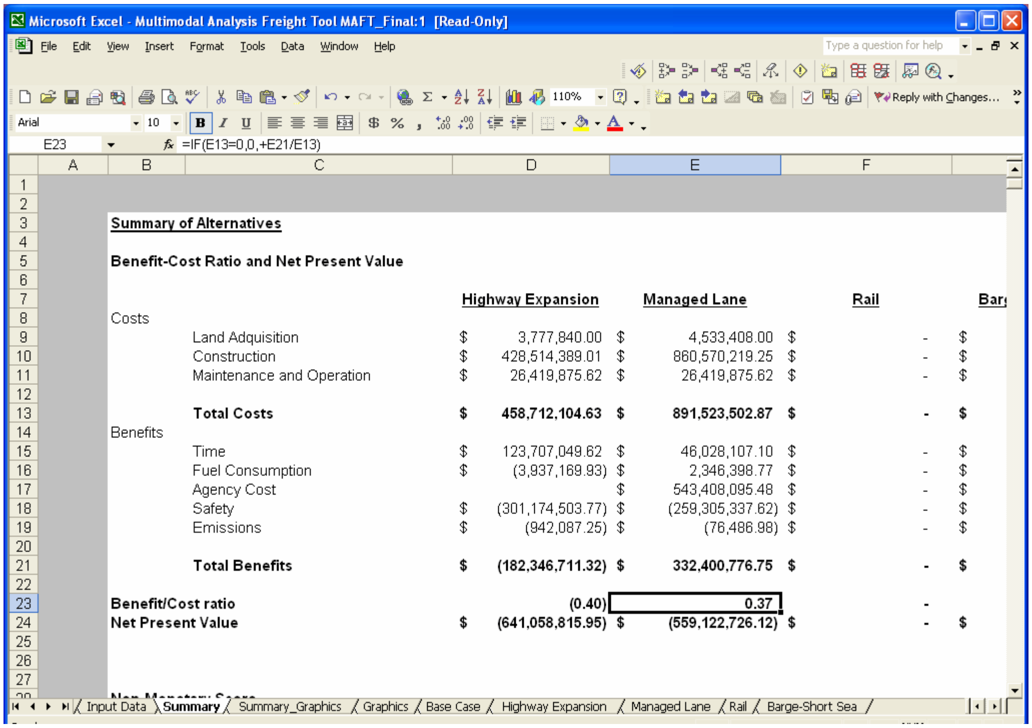
Row				BASE CASE	HIGHWAY EXPANSION	MANAGED LANE	RAIL	BARGE - SHORT SEA
63		**Benefits**						
64		**Travel Time**						
65	I46	Average Annual Daily Traffic in Analysis Year	units	21,000				
66	I47	Number of Trucks Diverted	units			4,105		
67	I48	Vehicle Traffic Growth/ Year		2.90%				
68	I49	Truck/Rail/Barge Traffic Growth/ Year		2.60%		3.00%		
69	I50	Initial % Trucks in Traffic		23.0%				
70	I53	Line-Haul Time (Ramp-to-Ramp)	hours					
71	I54	Switching Time (Classification & Sorting Time in Rail Yard)	min/car (barge)					
72	I55	Load/Unload Time	min/truck					
73	I55	**Operating Costs**						
74	I56	Cargo Weight	tons					
75	I57	Car/ Barge Weight	tons					
76	I58	Trailer Weight (Empty)	tons					
77		**Agency Costs**						
78	I59	Type of Road Surface		Flexible (asphalt)		Flexible (asphalt)		
79	I60	Type of Highway		Interstate & high-traffic		Interstate & high-traffic US/state		
80		**Safety**						
81	I61	30th Highest Annual Hourly Volume as a Fraction of AADT	%	7.0%	7.0%	7.0%		
82	I62	Rail Carrier						
83	I63	Empty Returns	%					

Source: HNTB Corporation and Wilbur Smith Associates 1996

Figure 5.3 Rural Case Study: Benefit Input Data

5.1.2 Analysis of Results

Figure 5.4 summarizes the results of the cost-benefit analysis for the highway expansion and managed lane rural alternatives. As can be seen from Figure 5.4, none of these alternatives results in a net public benefit to society. Both alternatives present negative net present values (NPVs), implying a net cost to society.



Summary of Alternatives

Benefit-Cost Ratio and Net Present Value

	Highway Expansion	Managed Lane	Rail	Bar
Costs				
Land Adquisition	$ 3,777,840.00	$ 4,533,408.00	$ -	$
Construction	$ 428,514,389.01	$ 860,570,219.25	$ -	$
Maintenance and Operation	$ 26,419,875.62	$ 26,419,875.62	$ -	$
Total Costs	**$ 458,712,104.63**	**$ 891,523,502.87**	**$ -**	**$**
Benefits				
Time	$ 123,707,049.62	$ 46,028,107.10	$ -	$
Fuel Consumption	$ (3,937,169.93)	$ 2,346,398.77	$ -	$
Agency Cost		$ 543,408,095.48	$ -	$
Safety	$ (301,174,503.77)	$ (259,305,337.62)	$ -	$
Emissions	$ (942,087.25)	$ (76,486.98)	$ -	$
Total Benefits	**$ (182,346,711.32)**	**$ 332,400,776.75**	**$ -**	**$**
Benefit/Cost ratio	**(0.40)**	**0.37**	**-**	
Net Present Value	**$ (641,058,815.95)**	**$ (559,122,726.12)**	**$ -**	**$**

Figure 5.4 Rural Case Study: Summary Output

The results can be explained in terms of the base case conditions. The calculated average annual daily traffic (AADT) to capacity (C) ratios allow for the estimation of overall delay on a facility. In other words, it provides information about the level of congestion experienced on the facility. Typically, the AADT/C ratio values range from one to eighteen (Margiotta et al. 1994), where one means that the facility is not congested for a significant proportion of the day and eighteen means that the facility experiences congestion for a significant number of hours in the day. From Figure 5.5, it is evident that the AADT/C ratio ranges from approximately four to seven in the base case. Therefore, this rural segment of IH-35 does not experience significant levels of congestion over the analysis period.

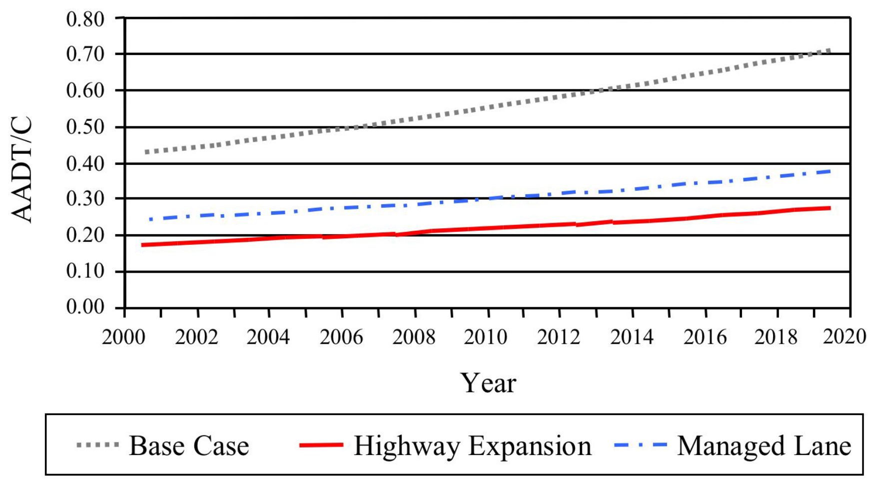


Figure 5.5 Rural Case Study: AADT/C Ratio

In the absence of congestion, however, an increase in capacity results in a large upfront cost, but minor changes in the average travel speed on the facility. As seen in Figure 5.6, the average speed resulting from the highway expansion and managed lane alternatives is only slightly higher than the average speed in the base case over the 20-year analysis period.

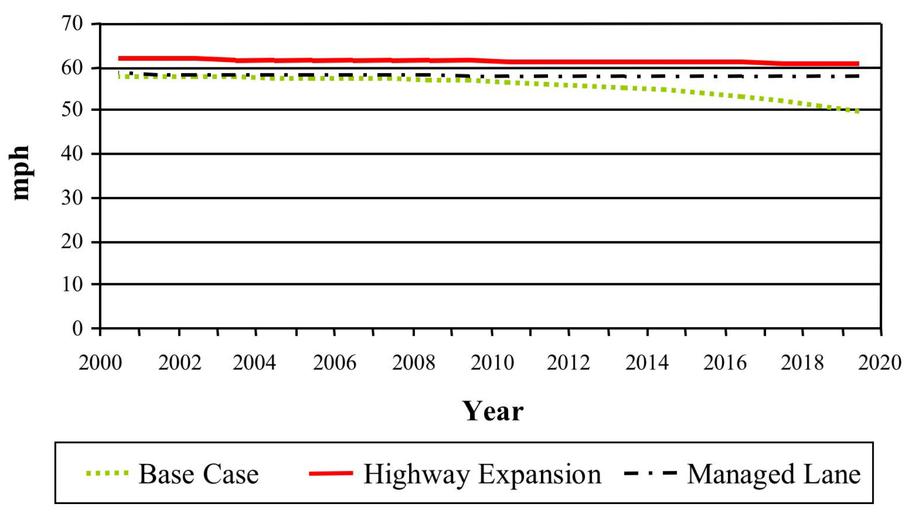


Figure 5.6 Rural Case Study: Average Speeds

Nonetheless, both alternatives result in a reduction in travel times. The value of the travel timesavings for the highway expansion alternative compared to the base case varies between $12 million in 2000 to about $30 million in 2020. The timesaving benefit to trucks on the managed lane alternative compared to the base case is less than $5 million in 2000 and just over $15 million in 2020 (Figure 5.7).

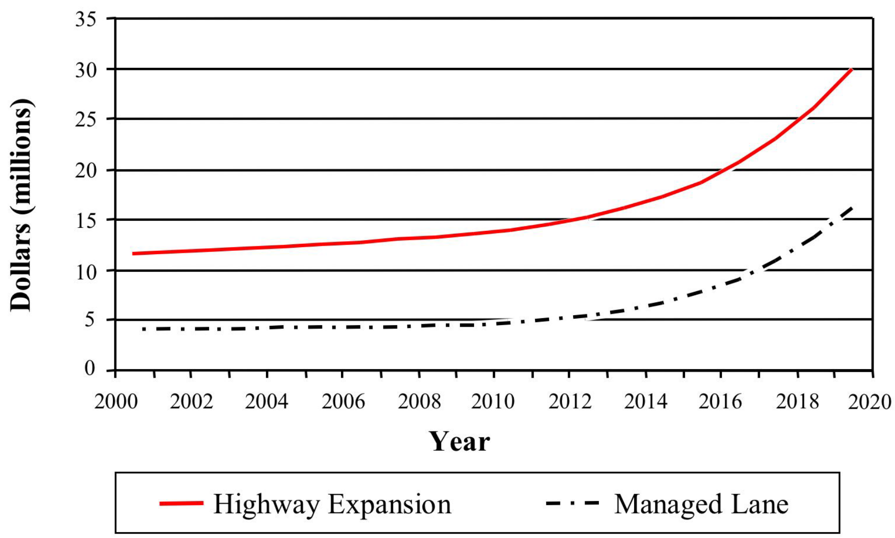


Figure 5.7 Rural Case Study: Timesaving Benefits

Both investment alternatives result in an increase in safety costs (Figure 5.8) that exceeds the travel timesaving (Figure 5.7). As explained in Chapter 4, accident severity increases with increased travel speed. The increase in average travel speed thus results in a larger number of severe accidents, resulting in injuries and fatalities, in the case of both investment alternatives compared to the base case.

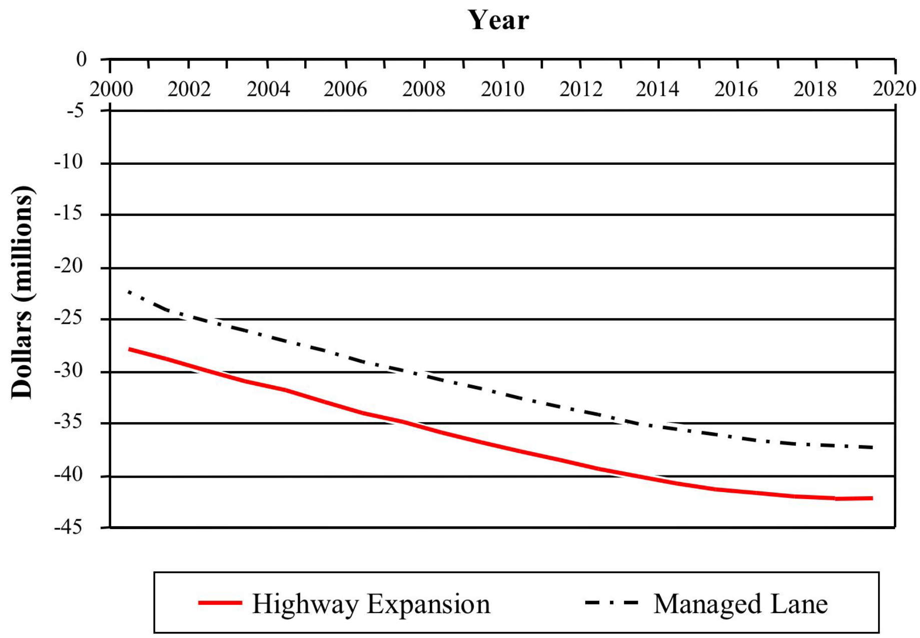


Figure 5.8 Rural Case Study: Safety Benefits

Incremental increases in travel speeds beyond 55 mph result in increased fuel consumption (Chapter 4) in the case of passenger vehicles. In Figure 5.9, the operating costsavings for the managed lane alternative represents the total operating costsavings on the existing highway and the managed lane. Because the increase in average travel speed is only slightly higher than the base case for both alternatives, both the operating cost (Figure 5.9) and emissions impacts (Figure 5.10) associated with the investments are also fairly insignificant over the analysis period.

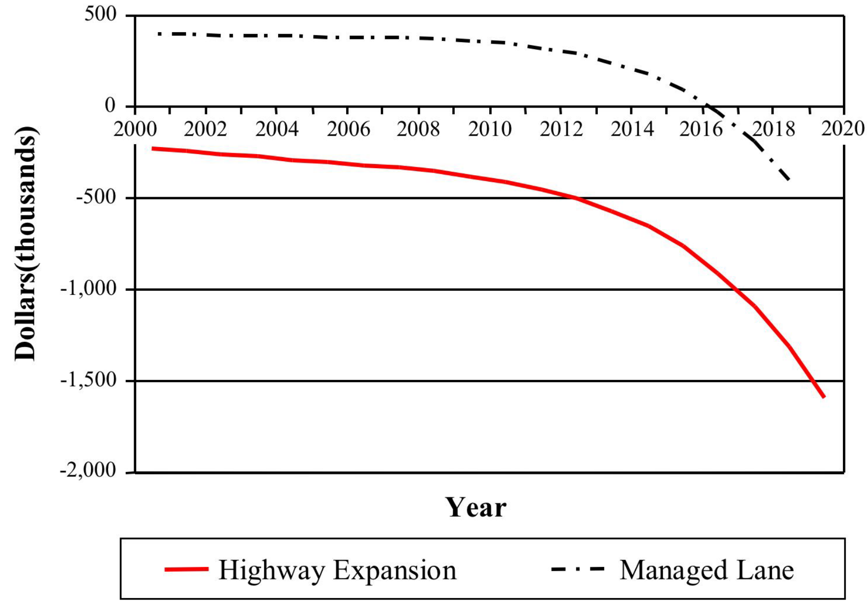


Figure 5.9 Rural Case Study: Operating Benefits

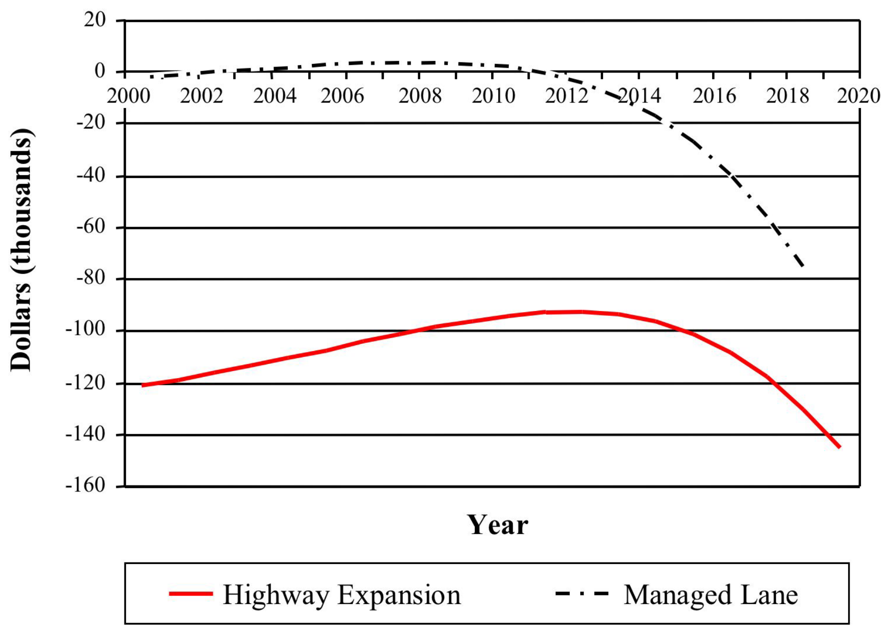


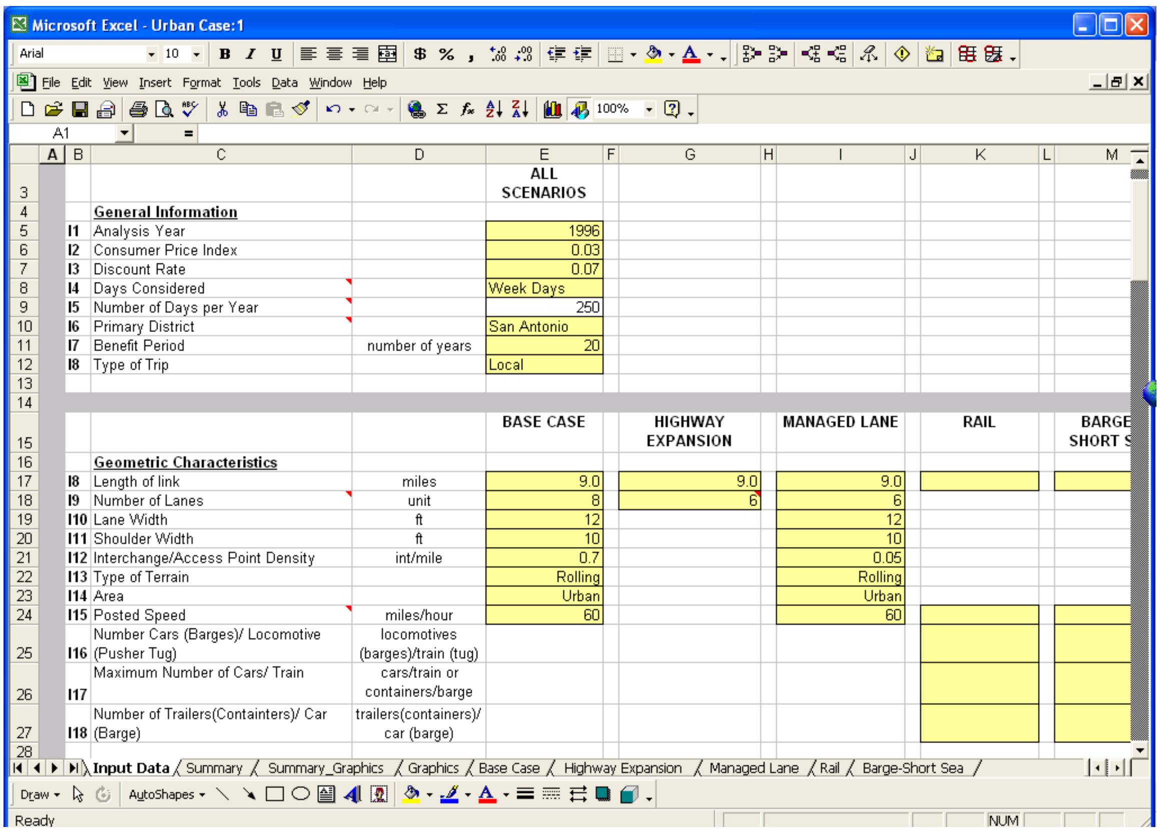
Figure 5.10 Rural Case Study: Emissions Benefits

5.2 Urban Case Study

5.2.1 Description of Input Data

General Information and Geometric Characteristics

The IH-35 segment selected for the urban case study was south of the San Antonio city center. The San Antonio District was responsible for evaluating the investment alternatives. The existing road segment was a 9-mile, controlled access, divided freeway with four 12-foot lanes in each direction. Because congestion is a major consideration in urban areas, the urban analysis was done for weekdays. Figure 5.11 summarizes the general and geometric input data entered into MAFT.



			ALL SCENARIOS
	General Information		
I1	Analysis Year		1996
I2	Consumer Price Index		0.03
I3	Discount Rate		0.07
I4	Days Considered		Week Days
I5	Number of Days per Year		250
I6	Primary District		San Antonio
I7	Benefit Period	number of years	20
I8	Type of Trip		Local

			BASE CASE	HIGHWAY EXPANSION	MANAGED LANE	RAIL	BARGE SHORT S
	Geometric Characteristics						
I8	Length of link	miles	9.0	9.0	9.0		
I9	Number of Lanes	unit	8	6	6		
I10	Lane Width	ft	12		12		
I11	Shoulder Width	ft	10		10		
I12	Interchange/Access Point Density	int/mile	0.7		0.05		
I13	Type of Terrain		Rolling		Rolling		
I14	Area		Urban		Urban		
I15	Posted Speed	miles/hour	60		60		
I16	Number Cars (Barges)/ Locomotive (Pusher Tug)	locomotives (barges)/train (tug)					
I17	Maximum Number of Cars/ Train	cars/train or containers/barge					
I18	Number of Trailers(Containters)/ Car (Barge)	trailers(containers)/ car (barge)					

Source: HNTB Corporation and Wilbur Smith Associates 1996

Figure 5.11 Urban Case Study: General and Geometric Input Data

Costs

The amount of land required for the right-of-way, the right-of-way costs, and the construction costs (including the elevated structures) is shown in Figure 5.12. The construction period for both alternatives was estimated at 10 years with the midpoint construction year being 2000. Also, it was assumed that both investment facilities would be opened to the public in 2005. The remaining information is similar to the information used for the rural case study.

				BASE CASE	HIGHWAY EXPANSION	MANAGED LANE	RAIL	BARGE - SHORT SEA
32		**Costs**						
33		**Land Acquisition Costs**						
34	I19	Width of Right-of-Way	ft		200.00	200.00		
35	I20	Cost of Right-of-Way	$/sq. ft		5.00	5.00		
36	I21	Year Price	year		1996	1996		
37		**Construction Costs**						
38	I22	Opening Year	year		2005	2005		
39	I23	Midpoint of Construction Period	year		2000	2000		
40	I24	Life of Road/Track	years		30	30		
41	I25	Construction Cost/ Lane-Mile	$		$ 5,490,000.00	$ 6,500,000.00		
42		Year Price	year		1996	1996		
43	I26	**Equipment Acquisition Costs**						
44	I27	Type of Locomotive/Pusher Tug	model					
45	I28	Locomotive/Pusher Tug Model Year	year					
46	I29	Locomotive/Pusher Tug Cost	$/locomotive (tug)					
47	I30	Year Price	year					
48	I31	Life of Locomotive/Pusher Tug	years					
49	I33	Rail-Car/Barge Purchase Cost	$/car (tug)					
50	I34	Year Price	year					
51	I35	Life of Rail-Car/Barge	years					
52	I36	Number of Cars/Barges	unit					
53		**Maintenace and Operation Costs**						
54	I37	Annual Road (Track/Dredging) Maintenance Cost/ Mile	$/lane-mile		$ 13,700.00	$ 13,700.00		
55	I38	Year Price	year		1996	1996		
56	I39	Car/Barge Maintenance Cost	car-mile					
57	I40	Year Price	year					
58	I41	Locomotive (Pusher Tug) Maintenance Cost	$/locomotive (tug) - mile					
59	I42	Year Price	year					
60	I43	Annual Operation Cost/ Mile	$/lane-mile					

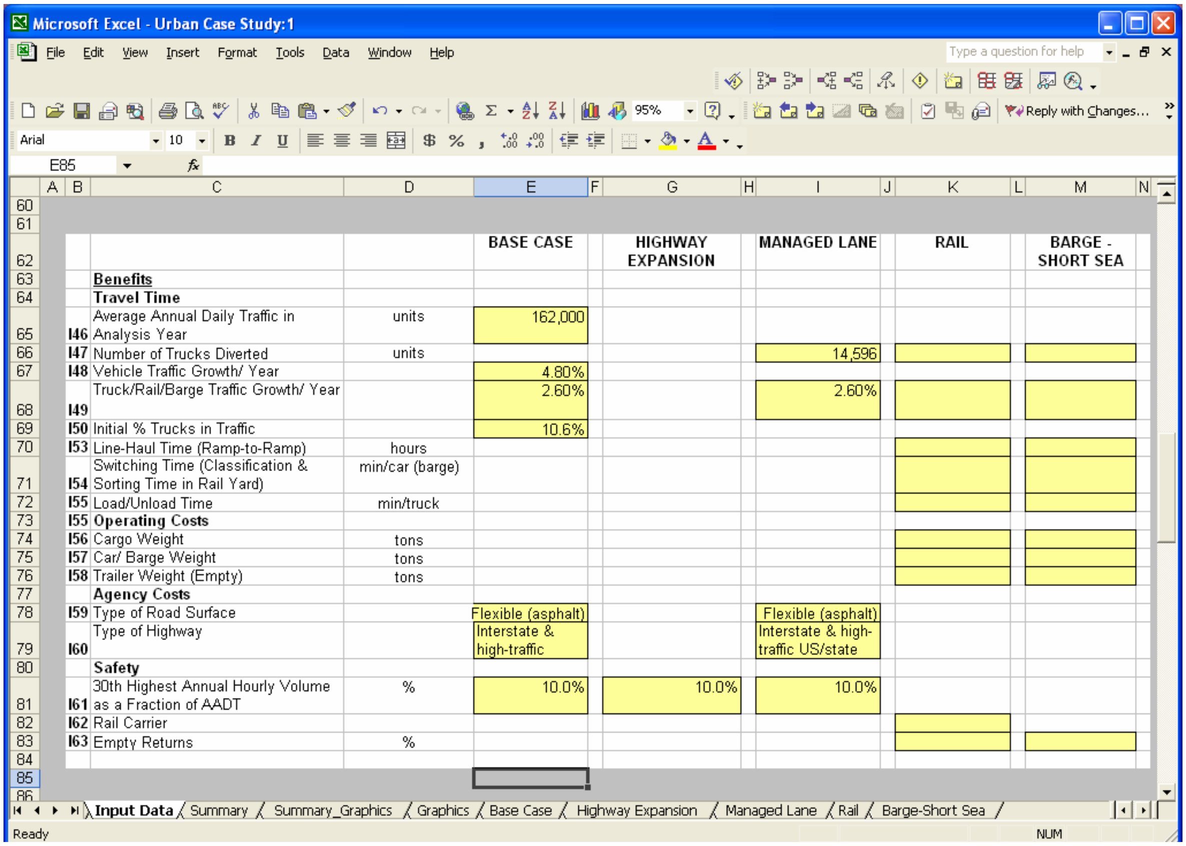
Source: HNTB Corporation and Wilbur Smith Associates 1996

Figure 5.12 Urban Case Study: Cost Input Data

Benefits

The "IH-35 Trade Corridor Study" reported that the AADT on the selected road segment was 162,000, of which 10.6 percent represented trucks. Also, the study forecasted that 85 percent of the truck traffic would be diverted from IH-35 to the managed lane alternative upon completion (HNTB Corporation and Wilbur Smith Associates Team 1996).

Vehicle traffic growth was assumed at 4.8 percent and truck traffic growth was assumed at 2.6 percent for both the highway expansion and managed lane alternatives. The 30th maximum hourly volume was defined as 10 percent of the AADT. The remaining input values are similar to the input values used in the rural case study (Figure 5.13).



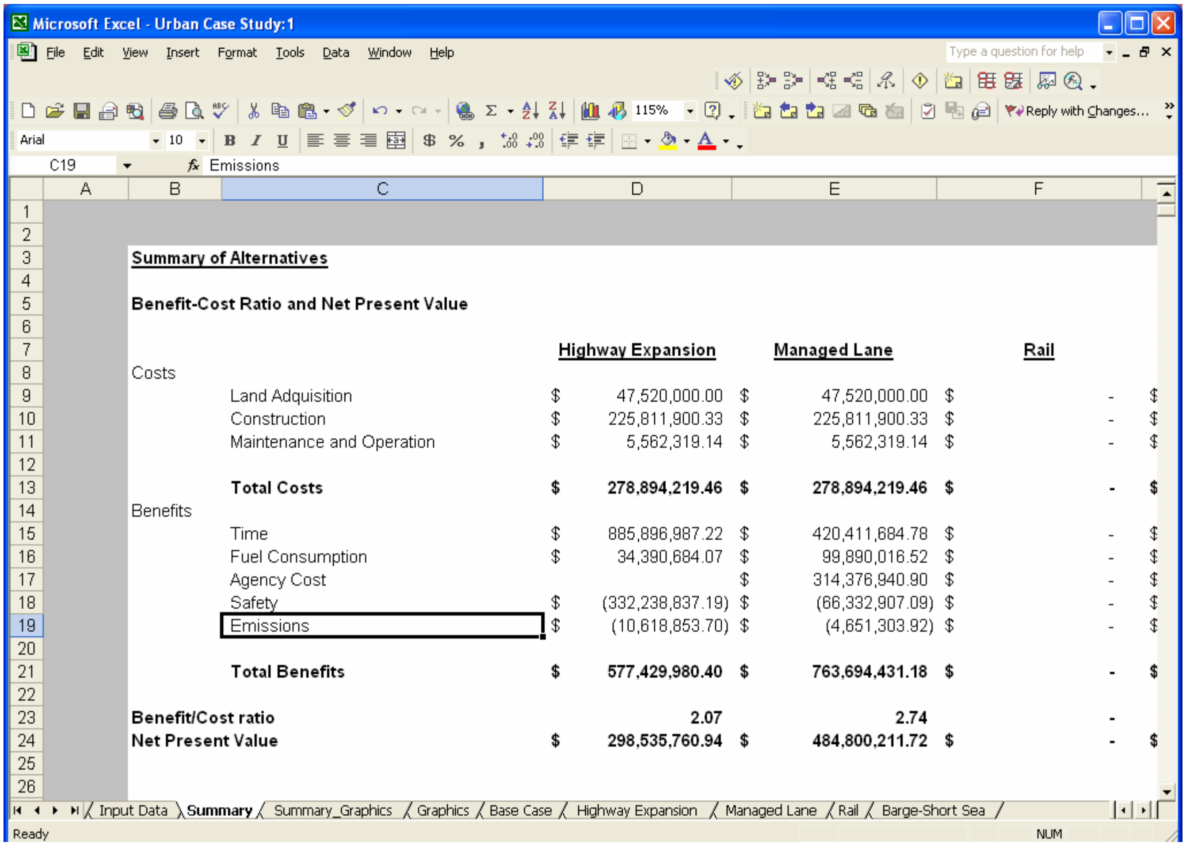
			BASE CASE	HIGHWAY EXPANSION	MANAGED LANE	RAIL	BARGE - SHORT SEA
	Benefits						
	Travel Time						
I46	Average Annual Daily Traffic in Analysis Year	units	162,000				
I47	Number of Trucks Diverted	units			14,596		
I48	Vehicle Traffic Growth/ Year		4.80%				
I49	Truck/Rail/Barge Traffic Growth/ Year		2.60%		2.60%		
I50	Initial % Trucks in Traffic		10.6%				
I53	Line-Haul Time (Ramp-to-Ramp)	hours					
I54	Switching Time (Classification & Sorting Time in Rail Yard)	min/car (barge)					
I55	Load/Unload Time	min/truck					
I55	**Operating Costs**						
I56	Cargo Weight	tons					
I57	Car/ Barge Weight	tons					
I58	Trailer Weight (Empty)	tons					
	Agency Costs						
I59	Type of Road Surface		Flexible (asphalt)		Flexible (asphalt)		
I60	Type of Highway		Interstate & high-traffic		Interstate & high-traffic US/state		
	Safety						
I61	30th Highest Annual Hourly Volume as a Fraction of AADT	%	10.0%	10.0%	10.0%		
I62	Rail Carrier						
I63	Empty Returns	%					

Source: HNTB Corporation and Wilbur Smith Associates 1996

Figure 5.13 Urban Case Study: Benefit Input Data

5.2.2 Analysis of Results

Figure 5.14 summarizes the costs and benefits for the urban alternatives. From the positive NPVs and the fact that both benefit cost ratios are higher than one, it is evident that both alternatives are economically beneficial to society. The managed lane alternative, however, has a higher NPV and cost-benefit ratio compared to the highway expansion alternative. Thus, the economic benefits associated with the managed lane alternative exceed those of the highway expansion project.



Summary of Alternatives

Benefit-Cost Ratio and Net Present Value

		Highway Expansion	Managed Lane	Rail
Costs				
	Land Adquisition	$ 47,520,000.00	$ 47,520,000.00	$ -
	Construction	$ 225,811,900.33	$ 225,811,900.33	$ -
	Maintenance and Operation	$ 5,562,319.14	$ 5,562,319.14	$ -
	Total Costs	**$ 278,894,219.46**	**$ 278,894,219.46**	**$ -**
Benefits				
	Time	$ 885,896,987.22	$ 420,411,684.78	$ -
	Fuel Consumption	$ 34,390,684.07	$ 99,890,016.52	$ -
	Agency Cost		$ 314,376,940.90	$ -
	Safety	$ (332,238,837.19)	$ (66,332,907.09)	$ -
	Emissions	$ (10,618,853.70)	$ (4,651,303.92)	$ -
	Total Benefits	**$ 577,429,980.40**	**$ 763,694,431.18**	**$ -**
Benefit/Cost ratio		**2.07**	**2.74**	**-**
Net Present Value		**$ 298,535,760.94**	**$ 484,800,211.72**	**$ -**

Figure 5.14 Urban Example Summary of Results Output

Figure 5.15 illustrates that significant delay was experienced on the facility in the base case with an AADT ratio close to 18. For a significant period of the day the traffic volume on the facility was reaching the road capacity, resulting in congested travel conditions. Both the highway expansion and managed lane alternatives address the situation through added capacity. Also evident from Figure 5.15, is the latent demand that results in similar congested conditions as the base case for the highway expansion alternative only 10 years after the opening of the facility.

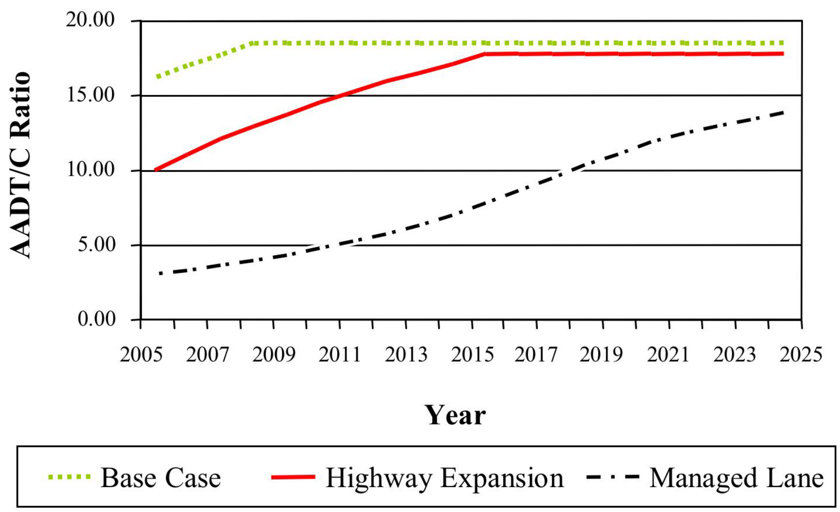


Figure 5.15 Urban Case Study: AADT/C Ratio

An increase in road capacity allows for increases in the average travel speed. Increased travel speeds, however, attract new or diverted users to the facility that ultimately reduces the travel speed. Figure 5.16 illustrates how average travel speed on the expanded highway decreases every year until the facility experiences congested conditions similar to the base case in 2015—10 years after the opening of the facility. Figure 5.16 also shows that as more trucks use the managed lane, the average travel speed on the facility decreases. After 2017, the average truck speed on the managed lane alternative reduces significantly and by 2024 the average speed on the facility is about half of what it was when the facility opened.

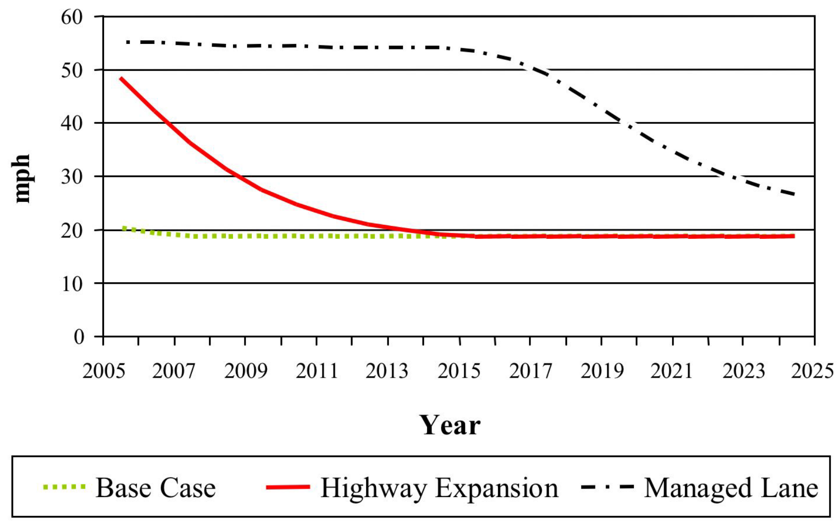


Figure 5.16 Urban Case Study: Average Speed

Both investment alternatives result in timesaving benefits. The timesaving benefit in Figure 5.17 for the managed lane alternative represents the timesaving on the existing highway attributable to the diversion of 85 percent of the truck traffic and the truck travel timesaving experienced on the managed lane relative to the base case. Between 2005 and approximately 2013, a decreasing proportion of the timesaving for the managed lane alternative pertains to the timesaving experienced on the highway facility because of diverted truck traffic. After 2017, travel timesaving on the managed lane decreases as the facility experiences increasing levels of congestion. In the case of the highway expansion alternative, considerable timesaving is experienced up until the facility starts to experience similar levels of congestion as the base case in 2015.

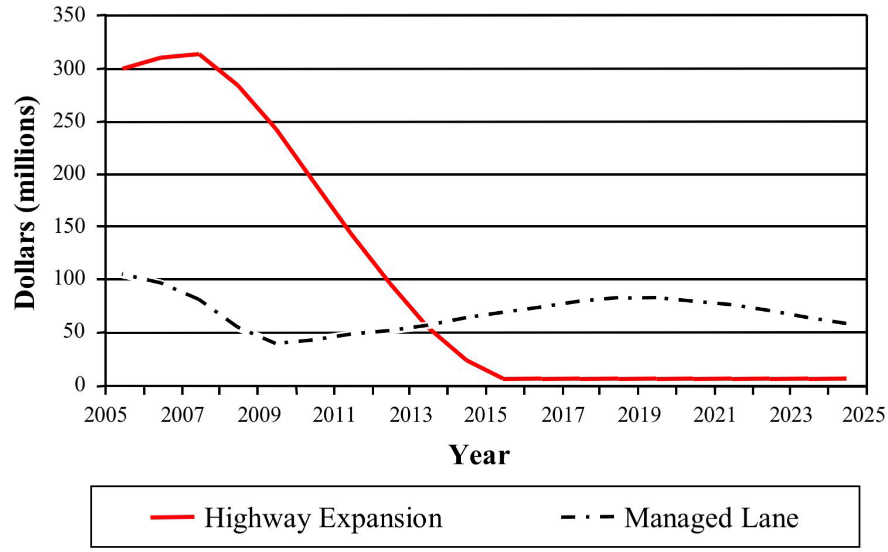


Figure 5.17 Urban Case Study: Timesaving Benefits

Both investment alternatives result in a safety cost to society. As with timesaving benefits, the safety impacts in Figure 5.18 for the managed lane alternative represent the safety impacts on the existing highway attributable to the diversion of 85 percent of the truck traffic and the safety impacts on the managed lane relative to the base case. Initially, the safety benefits associated with the separation of truck and passenger vehicles—85 percent of the highway trucks were diverted to the managed lane—are slightly less than the increase in safety costs associated with increased traffic and travel speeds. Three years after opening the managed lane, however, the safety costs increase, largely because of increased traffic and higher speeds on the managed lane (until 2017) and increased traffic and congestion experienced after 2017 (Figure 5.18). The safety costs associated with the highway expansion alternative worsen each year since the opening of the facility owing to increased demand (AADT) and increased travel speeds until the facility reaches similar levels of congestion as the base case in 2015.

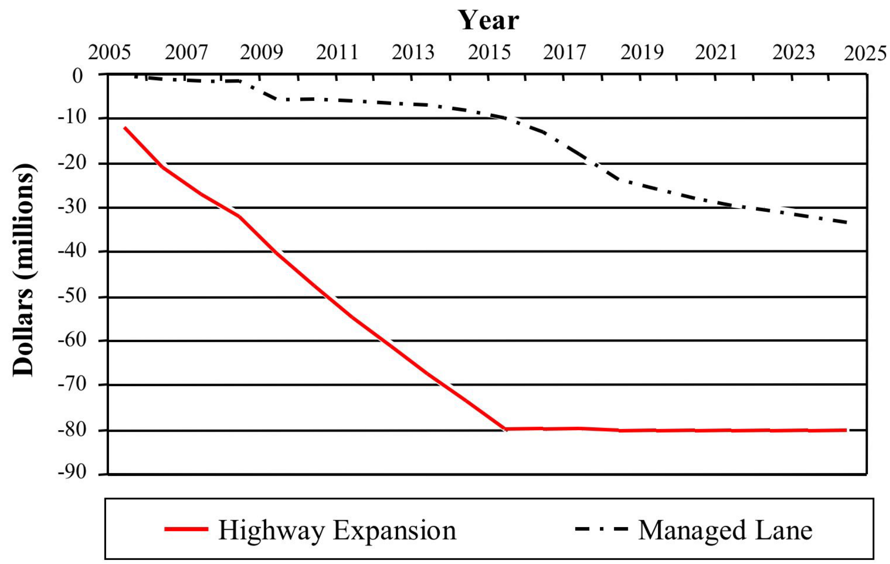


Figure 5.18 Urban Case Study: Safety Benefits

Figure 5.19 illustrates the vehicle-operating benefits associated with the highway expansion and managed lane alternatives (including the operating benefits on the highway owing to diverted truck traffic and the operating benefits on the managed lane). In the case of the highway expansion alternative, improvements in the stop-and-go traffic conditions initially allow the average travel speed on the facility to increase above 30 mph. This results in decreased fuel consumption and an initial vehicle-operating benefit. However, as increased demand starts to impact travel speed on the facility, the vehicle-operating benefits are reduced each year until 2015 when similar congestion levels as the base case are experienced. Similarly, for the managed lane alternative, the vehicle-operating benefits reduce each year with increased truck usage and slower operating speeds.

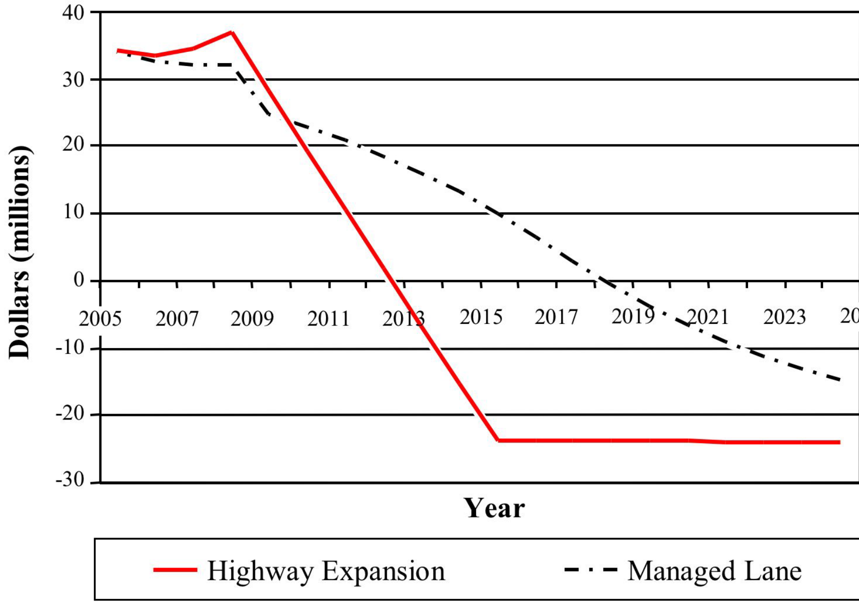


Figure 5.19 Urban Case Study: Vehicle-Operating Benefits

Because the average travel speed is an important determinant in the operating cost and emissions calculations, it follows that these impacts should follow the same general trend. Similar to the vehicle-operating costs (Figure 5.19), the emissions associated with both alternatives increase—thus the emissions costs increases—as demand increases and the facilities become more congested (Figure 5.20).

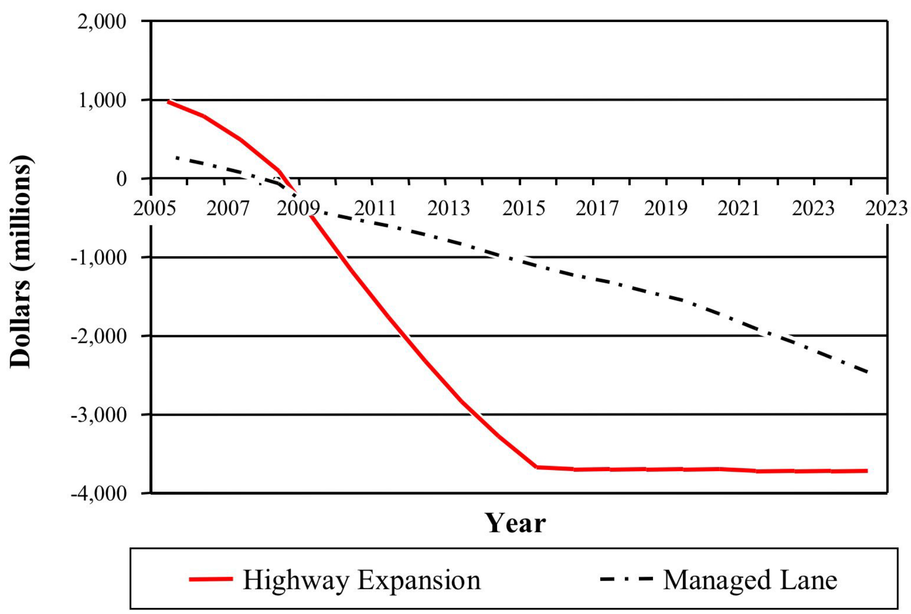


Figure 5.20 Urban Case Study: Emission Benefits

5.3 Concluding Remarks

This chapter summarized the results of the initial testing of MAFT in appraising urban and rural highway and managed lane projects. MAFT showed defensible results. The rural case revealed that congestion levels on the existing facility do not warrant capacity enhancements. Despite the fact that the rural corridor has a high percentage of truck traffic, no significant public benefits will be secured overall through investments in additional capacity or a dedicated truck lane. The urban case, on the other hand, indicates that significant economic and societal benefits will be gained from adding capacity to the existing urban freeway as the corridor is heavily congested for significant parts of the day. Both investment alternatives resulted in significant time and vehicle-operating costsavings, but the managed lane alternative proved to be less costly in terms of safety and emissions. Both the NPV and the benefit cost ratio of the urban managed lane alternative exceeded those of the urban highway expansion alternative, indicating higher societal benefits. Therefore, MAFT provides the transportation agency with a tool to conduct sketch planning appraisals of multimodal freight projects at the initial stages of the project planning process.

6. CONCLUSIONS

This report summarized the development of the Multimodal Analysis Freight Tool (MAFT), a sketch planning tool used to analyze and demonstrate the public sector benefits of multimodal freight investments.

In Chapter 2, the authors highlight the many factors and trends that have impacted and changed the U.S. freight sector, including globalization and associated increases in international trade, containerization, and developments in the U.S. manufacturing and service sectors. These factors and trends have contributed to changes in the geography of U.S. freight movements and a dramatic growth in freight volumes and movements over the past two decades. In 1991, with the passage of the Intermodal Surface Transportation Efficiency Act (ISTEA), the Congress established a new vision for transportation policy and planning. ISTEA aimed to develop an efficient and integrated multimodal transportation system for freight and passengers. Chapter 2 highlights the challenges and barriers that remain in achieving the vision of an integrated multimodal transportation system for freight. Some of the challenges are entrenched in past planning policies, the past focus on passenger movements, and the impediments to funding a multimodal system. In most transportation agencies, responsibilities and programs are internally structured by mode. Each department or program focuses on solutions for a specific mode, with the result that multimodal transportation solutions are seldom promoted. In recent years, metropolitan and regional transportation planning agencies have started to form committees composed of local agencies, state agencies, and the private sector to identify solutions for freight issues that have culminated in the more successful development of regional freight plans.

Chapter 3 provides a primer on the use of cost-benefit analysis (CBA) as a methodology for comparing different transportation alternatives. CBA helps to determine whether a project will increase the economic welfare of society by assigning monetary values to the impacts of transportation investments. Some of the effects of transportation projects do not have a market price. The valuation of nonmarket effects require techniques based on determining what amount people would be willing to pay or accept. Costs include all capital, labor, and other resources required to plan and build the transportation project and all required investments to maintain and operate the facility during its useful life. Benefits can be defined as a reduction in resource costs or a benefit that society will be willing to pay for. Benefits can be related to the efficiency of the transportation system (reducing travel time, operating costs, or both, and increase reliability and accessibility); the safety of the system (reductions in property damage costs, injuries, and fatalities associated with accidents); and the reduction of negative externalities (air pollution, noise, and visual intrusion). The chapter also discusses the impacts of induced traffic caused by a reduction in the travel cost usually associated with an investment alternative.

The objective of this project was to develop a sketch planning tool that can be used to evaluate alternative freight modal investments. In Chapter 4, the structure of MAFT, the general characteristics, the embedded models, and implicit assumptions are highlighted. The transportation alternatives that can be considered in MAFT are highway expansion, managed lane, rail, and barge/short sea. MAFT includes three cost categories: land acquisition, construction, and maintenance and operation costs. MAFT also includes five benefit categories: timesavings, safety, agency costsavings, vehicle-operating costsavings, and emissions benefits. Finally, MAFT includes a qualitative scoring system (nonmonetary) for impacts (benefits and costs) that are difficult to quantify given the sketch planning level of accuracy intended by this tool. These impacts include noise, travel-time reliability, accessibility, community cohesion, bicycle and pedestrian travel patterns, regional development or economic effects, visual quality, equity, and environmental considerations (e.g., impacts on water resources and wetlands, the habitat of endangered or threatened species, or native prairie). The authors reviewed numerous models that aim to quantify the impacts in an effort to identify those models that produce defensible results without imposing undue burdens in terms of complexity, cost, and data requirements. Models developed by Margiotta et al. (1994) were embedded to calculate the average travel speed on the highway alternatives that is required to calculate the travel timesavings, vehicle-operating costs, safety, and emissions impacts. Models included in the Highway Capacity Manual were used to determine the impact on the capacity of a road segment given the diversion of truck traffic to the managed lane, rail, or barge alternatives. The diversion of trucks can also increase the design life of the road and reduce the rehabilitation and maintenance costs of the facility. MAFT calculates the agency costsavings using the highway allocation cost model developed by Luskin et al. (2001). For the highway alternatives (highway expansion and managed lane alternatives), MAFT uses models developed by Zhou and Sisiopiku (1997) to calculate the accident rates and models developed by Chang and Mannering (1999) to estimate the number of fatalities and casualties associated with truck and non-truck incidents. Finally, the emissions rates for four of the criteria pollutants are based on the EPA MOBILE 5 emissions equations. MAFT thus suffers from the limitations and assumptions pertaining to each of these embedded models. In addition, a number of further assumptions were incorporated into MAFT. For example, MAFT considers a single value for average speed in the corridor. This average speed is assumed to be uniformly distributed along the corridor and all the vehicles are assumed to travel along the entire corridor (have the same origins and destinations). Consequently, trip length is equal for all the vehicles and traffic volumes are completely homogeneous along the corridor. Significant uncertainty also surrounds the values included for the barge and rail alternatives.

Three case studies were conducted to determine if MAFT produces defensible results. The results of two of the case studies—urban and rural—were presented in Chapter 5. Rail data was provided to the research team to test and validate the tool, but a confidentiality agreement prevents the publication of this information. In both case studies, MAFT produced defensible results. In the rural case study, MAFT showed that an increase in capacity in the absence of significant congestion did not benefit society overall. On the other hand, the urban case study revealed that the provision of additional capacity in highly congested corridors holds significant societal benefits. Improvements in travel speeds, however, brought about new users that resulted in similar congested conditions as in the base case 10 years after opening the highway expansion alternative. Both the net present value and the benefit cost ratio of the urban managed lane alternative exceeded those of the urban highway expansion alternative, indicating higher societal benefits.

To conclude, a sketch planning analysis tool was developed as part of this research project to assist the Texas Department of Transportation in appraising freight modal investments. Although the tool provides a defensible framework and results to undertake freight project appraisals, the tool has a number of limitations that stem from the lack of freight research (i.e., freight models) and available data. Specifically, data and models pertaining to the rail and barge sectors are not readily available from public sources. In addition, MAFT has been developed to conduct corridor analysis and therefore, extending the tool to appraise efficiency enhancements to intermodal nodes or the elimination of at-grade crossings is beyond the scope of this tool. The tool can thus be enhanced in the future as more reliable freight research and data becomes available to appraise nodal investments.

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APPENDIX A. INTERNATIONAL MULTIMODAL EXAMPLES

A.1 The Port of Rotterdam

The Port of Rotterdam is a very important gateway in Europe. It was ranked first worldwide for bulk cargo handling (84,439 tons of dry bulk and 235,370 tons of liquid bulk) and fourth for containerized cargo handling (approximately 6.51 million twenty-foot equivalent units [TEUs]) in 2002 (Port of Rotterdam 2002).

A.1.1 Geographical Location

Rotterdam is located in Holland (Netherlands) on the North Sea in the estuary of the Rhine and Maas rivers. Recently, the port channel has been deepened to 72 feet to accommodate the largest container vessels that currently have a capacity of more than 10,000 TEUs. The port handles approximately 30,000 sea-going vessels and 130,000 inland vessels annually.

The Port of Rotterdam has connections with the rest of Europe by truck, rail, barge, and sea. Barge transportation is very inexpensive: one barge can carry as much as 15,000 tons. Barges are, however, usually used for bulk cargo transportation because of their slow travel speed.

The Rhine and Maas rivers have more than 50 inland terminals located along them. These rivers connect the Port of Rotterdam to Germany. The Port of Rotterdam moves more cargo to and from Germany than the German ports at Hamburg and Bremen.

The Port of Rotterdam connects to England by short sea. Roll on – Roll off (Ro-Ro) traffic amounts to 10 million truck tons and 1.5 million passengers annually. Ferries depart from Rotterdam every half hour and travel time between Rotterdam and the United Kingdom is approximately 3 hours. The Port of Rotterdam ranks second in cargo volumes handled for England.

In addition to the above-water connections, the Port of Rotterdam is connected by rail to 30 European destinations. On average, 150 shuttle trains operate 24 hours a day to and from the port. Three shuttle trains operate between Italy and Rotterdam, moving approximately one million containerized tons annually. Furthermore, between 1993 and 1996, the containerized tonnage moved by these shuttle trains increased by almost 0.5 million tons.

Global increases in containerized cargo, however, are starting to impact the competitiveness of the Port of Rotterdam. In the past, the Port of Rotterdam was very competitive because of relatively efficient barge access services and rates. The container revolution, however, decreased the cost competitiveness of the port. From Table A.1 it is evident that the number of containers handled by Rotterdam has been decreasing since 1999. During the same period, the number of containers has been increasing in most other European ports listed, including Hamburg, Antwerp, and Felixstowe (Port of Rotterdam Statistics 2001).

Table A.1 Major European Union Container Ports

	Number of Containers ('000 TEUs)			
	2001	**2000**	**1999**	**1998**
Rotterdam	6,096	6,274	6,342	6,012
Hamburg	4,689	4,248	3,738	3,566
Antwerp	4,218	4,082	3,624	3,266
Felixstowe	2,950	2,800	2,697	2,524
Bremen	2,915	2,737	2,181	1,812
Gioia Tauro	2,488	2,653	2,253	2,126
Algeciras	2,152	2,009	1,833	1,826

Source: Port of Rotterdam Statistics 2001.

A.2 The Trans-European Network

The Trans-European Network (TEN) is a modern concept of an efficient transportation system originally developed in the 1990s to facilitate the movement of goods, people, and services in a European community. The objectives of TEN are founded in the principles of interconnection and interoperability to improve or alleviate (a) safety, (b) the connections between peripheral and central areas, (c) traffic operation through the application of intelligent systems, (d) environmental damage, and (e) disruption to transportation flows at the borders (Caldwell et al. 2002).

The first list of TEN projects was approved in November 1993. The defined network included: 70,000 kilometers of rail, of which almost 22,000 kilometers was high-speed rail; almost 58,000 kilometers of roads; and various intermodal terminals, and inland waterway and multimodal facilities, including 267 airports. The financial resources required for the initial list of TEN projects were estimated at €400 billion, which exceeded available funding. The Essen European Council thus defined a list of 14 priority projects: the Essen projects, which consisted of 8,000 kilometers of rail, 4,500 kilometers of high-speed rail, 4,000 kilometers of roads, and one airport. The financial resources required for the Essen projects are approximately €110 billion. The Essen projects are scheduled for completion by 2010.

Over the last 10 years, traffic has increased substantially in Europe. According to information from the European Commission, 10 percent of the road network and almost 20 percent of the rail network has experienced traffic problems because of bottlenecks or technical restrictions, and one out of three flights incur delays in excess of 15 minutes (Sichelscmidt 1999). Increasing the road capacity in Europe is in many instances not feasible, because of limited available space to add road capacity and concerns about air pollution associated with increased road traffic. Therefore, efforts have been focused on "no-road built" solutions and traffic management measures. In May 2001, the European Parliament developed new TEN guidelines specifying additional criteria for the selection of priority projects (European Commission for Transportation 2002). The guidelines included the following four objectives that project appraisers should consider when selecting priority projects:

- Promoting rail freight: The transportation of cargo by rail has decreased in Europe over the last two decades, partly because the European rail network was not designed for high-intensity freight transportation. The European rail system moves both freight and passenger trains. Low clearances on tunnels and bridges prevent the use of double-stack freight trains.[8] Moreover, shipment distances tend to be shorter, making rail transportation less profitable. The building of an exclusive freight rail network is not feasible in the European Union (EU), but one of the objectives in prioritizing projects is to encourage the use of nonroad modes for freight movements. Projects that develop rail freight services or provide innovative intermodal nodes (i.e., freight villages) that facilitate more efficient intermodal connections will be prioritized.
- Promoting short sea shipping and inland waterways: The use of short sea shipping and inland waterways offers a lower cost per ton nonroad alternative with fewer emissions and less energy consumption per ton.
- Integrating rail and air: It is believed that the construction of linkages among airports and high-speed rail lines optimize the capacity on both because time and comfort levels are similar between high-speed rail and air. Such integration will also enable express courier services to provide more reliable service. Planned connections

[8] In contrast, 40 percent of U.S. freight is transported by rail. In most of the country, double-stack freight trains move goods over long distances at very competitive rates.

include railway stations at airports, baggage check-in terminals at railway stations, and linked passenger information services, reservations, ticketing, and baggage handling.

- Using Intelligent Transportation Systems: Traffic operations can be improved through the application of advanced technologies, such as traffic management and satellite navigation and positioning systems.

A.2.1 Essen Projects

From the original list of Essen projects, three have been completed and six others are under construction and scheduled for completion by 2005. This section briefly highlights the priority Essen projects (European Commission for Transportation 2002).

High-Speed Rail: North-South

The north-south rail project consists of a high-speed rail service from Berlin to Verona connecting Germany, Austria, and Italy. The rail infrastructure—designed to serve both passengers and freight—can be divided into two links. The first link from Berlin to Nuremberg of 550 km requires both upgrading (30 percent of the infrastructure) and 70 percent of new construction to allow maximum travel speeds of 200 km/h. The second link from Munich to Verona of 409 km will be upgraded to four tracks. An extension from Verona to Naples, linking the major towns and industrial areas of the Italian Peninsula, has been proposed, but has not yet been approved. The total cost of the project is estimated at €15 billion. German railways fund the sections in Germany, the Austrian government funds the Austrian sections, and the European Investment Bank has granted loans for upgrading the existing rail lines in Italy. The expected benefits from this rail project include a reduction in travel time, sufficient capacity to serve future needs, and incremental increases in the service quality of the rail lines. These benefits will contribute to a shift of cargo from road to rail, which will in turn alleviate some of the environmental concerns in the Alpine region.

High-Speed Rail: PBKAL

The PBKAL project consists of a high-speed rail connecting Paris, Brussels, Frankfurt, Amsterdam, and London. It involves different countries, funding, and management approaches. The Dutch government has involved the private sector in the Dutch rail link. Funds for the Dutch link come from three sources: €2,949 million from the Dutch government, €76 million from the EU, and €834 million from the private sector. The German federal government and the German railways will fund the German connections to the international airports at Cologne and Frankfurt. The United Kingdom contracted with London Continental Railways (LCR) to build the U.K. component. Upon completing 68 percent of the U.K. link, the LCR will receive a grant of €2.7 billion. The funding comes from the revenues of the Eurostar concession. LCR, however, has asked for an advance of €1.8 billion. This has delayed the project and the expected date of completion is uncertain. The Belgium section consists of three links connecting to the French, German, and Dutch borders, respectively. The French link has been in operation since 1997, while the other sections were scheduled for completion in 2002. The expected benefits from this project include travel timesaving for passengers traveling among the main cities served.

High-Speed Rail: South

The south project will connect Spain and France by high-speed rail, including proposed connections to the existing TGV high-speed rail in France. The project consists of two links: the Mediterranean and the Atlantic. The 941 km Mediterranean link connects Madrid, Barcelona, and Montpellier. New rail lines are required for 750 km to upgrade the Spanish track to European standard gauge. This link will eventually be connected to the French TGV enabling service among Paris, Lyon, and Marseille. Initiated in 1996, completion of the Spanish sections is expected in 2005. Some concerns have been raised regarding the international section between Figueres (Spain) and Perpignan (France). The 660 km Atlantic link will connect Madrid, Bilbao, and Dax. This link will require the construction of a new line on the Spanish side and rail upgrades on the French side. Connections to the French TGV will allow for service to Paris and Bordeaux.

The total cost of the project is estimated at €14,072 million. Construction of the Spanish sections has begun, but the French are still determining the availability of funding. Expected project benefits include increased capacity associated with the upgrades and travel timesavings. For example, the travel time between Madrid and Barcelona will reduce from 6 hours 50 minutes to 3 hours (more than 100 percent); the travel time between Madrid and Dax will reduce from 10 hours 30 minutes to 5 hours and between Madrid and Perpignan from 10 hours to almost 4 hours. In addition, by standardizing the

Spanish network, significant economic benefits are expected through the linking of Spain with the central part of the EU.

High-Speed Rail: East

This project will connect the existing high-speed networks of Germany and France. In France, 472 km of new rail line will connect Paris to Metz and Strasburg. This line will be exclusively for passengers. In addition, two branch lines are planned for Germany: from Saarbruken to Mannheim and from Saarbruken to Strasburg. On both branches, the track will be upgraded to allow speeds of 200 km/h.

Competion of the French section is expected in 2005, while the German sections will be completed in 2004. The French government acknowledges the importance of this rail link between Germany and France. Expected project benefits include improved relations and connectivity between two of the most significant economies in the EU and travel timesavings. Travel times between the major French and German cities will reduce significantly. For example, the travel time between Paris and Munich will reduce from 8 hours 35 minutes to 4 hours 45 minutes; between Paris and Frankfurt travel time will reduce from 5 hours 55 minutes to 3 hours 30 minutes and, finally, between Paris and Strasburg travel time will reduce from 2 hours 15 minutes to 1 hour 25 minutes.

High-Speed Rail: France and Italy

This high-speed rail project between France and Italy will consist of 750km of new freight and passenger high-speed rail, linking Lyon, Turin, Milan, Verona, Venetia, and Trieste. The project design speed is 250 to 300 km/hour. The total cost of the project is estimated at €14,200 million. The Italian network will be owned by the state and the government has funded the section from Turin to Milan. Funding for the French section and the Padova to Trieste section still needs to be secured. Although the project has experienced some technical difficulties and financial uncertainty, the European Commission deemed it essential for the development of an intermodal system in the Alps.

Expected project benefits include capacity enhancements to meet future needs and travel time reductions for passengers and freight. For example, travel time between Paris and Milan is expected to decrease from 6 hours 35 minutes to 3 hours 40 minutes. In addition, diverting truck shipments to rail will decrease environmental damage attributable to traffic in the Alpine region.

Greek Motorways

The Greek motorways project consists of the upgrading of two main roads in Greece: the Pathe and the Via Egnatia. The Pathe (800 km) runs north to south, linking Patro, Athens, Thessalonica, Promahonas, and includes a circle road around Athens. Via Egnatia is 780 km long, linking Igoumenitsa, Alexandroupolis, Ormenio, and Kipi. The total project cost is estimated at €9,242 million. Some delays have been experienced in the upgrading of Via Egnatia.

Anticipated project benefits include:

- a reduction in travel time among major cities in Greece,
- improved economic and social relations among these major cities,
- enhanced regional cohesion, and
- improved accessibility to remote regions in Greece, such as Thrace, Epirus, and Macedonia.

Multimodal Link: Portugal–Spain–Central Europe

This project consists of several subprojects aimed at improving the network flow on three main corridors: La Corunna to Lisbon, Irun to Lisbon, and Seville to Lisbon. The subprojects involve the rail, road, and air modes, as well as the interfaces among the modes. The total expected project cost is €6.2 billion. The project will be funded through grants from the Spanish and Portuguese governments, from EU funds, and loans. The expected project benefits include: improved connectivity among various transportation modes in the Iberian Peninsula, enhanced economic development in the region, and the integration of the region with major European economies.

Conventional Rail in Ireland

This project is finished. The objective was to improve the existing rail lines linking the main cities in Ireland. The project resulted in upgrading 502 km of rail infrastructure to accommodate freight and passenger services. The upgrades currently allow passenger train travel speeds of 200 km/hour. The total investment was €357 million.

Airport: Malpensa

The Malpensa Airport is 50 km from the city center of Milan. The airport was completed in 2001 at a cost of €1,047 million. It is expected to handle approximately 21 million air passengers per year. Environmental benefits are anticipated because of the airport's location outside the city of Milan—a major air destination.

Oresund: Linking Denmark and Sweden

The completed Oresund project links Sweden and Denmark. The project consists of a 4 km undersea tunnel, a 4 km road/rail link traveling over an artificial island, and a 7.5 km bridge from the Danish to the Swedish coast. The road/rail link consists of a four-lane road and double-track rail line. The project cost approximately €4,158 million. This link facilitated enhanced integration in the area and resulted in reduced travel times between Sweden and Denmark.

Multimodal Nordic Triangle Corridor

The multimodal Nordic project consists of existing rail and road upgrades, linking Oslo, Copenhagen and Stockholm, and Turku and Helsinki. The total cost of the project is estimated at €10,070 million. The rail line between Copenhagen and Stockholm will be upgraded to enhance freight capacity and accommodate passenger trains traveling at 200 km/hr. Existing rail track between Oslo and Stockholm will be upgraded or constructed to allow trains to travel at 200 km/hr. The expected travel time between Helsinki and St. Petersburg will reduce from 6 hours 30 minutes to 3 hours. Also, it is expected that the number of trips will increase from 0.8 million in 1998 to 2.1 million in 2010.

Road Link: Ireland–United Kingdom–Benelux

This project aims to link the main cities in Ireland, Scotland, and Wales to each other and to the ports of Felixstowe and Hardwick by road and or ferry. The total length of the corridor (in England, Ireland, Wales, and Northern Ireland) to be upgraded is 1,455 km. The total cost of the project is estimated at €3,600 million.

West Coast Main Line

The West Coast project aims to modernize the rail corridor that links Glasgow, Liverpool, Manchester, Birmingham, and London. This project will increase train speeds to 225 km/h and enable the accommodation of freight. The total cost of the project is estimated at €3,000 million.

Betuwe Rail

The Betuwe Rail is a planned 150-kilometer, freight-only rail service from the Port of Rotterdam to the German border. It will be the first double-stack rail service in Europe and will have the capacity to accommodate 10 trains per hour, per direction. Some concern has been expressed, however, that the demand for the service will be lower than what was anticipated during the conceptualization of the Betuwe Rail.

The Betuwe Rail is currently being constructed at an estimated cost of €5 billion. The rail project is partly funded by the European Union Transportation Commission, because the project supports the EU transportation policy adopted to divert cargo from roads to rail or inland water. Social benefits cited include reduced road congestion and air emissions (Van Ierland et al. 2000). Some interesting aspects of this project include mitigation options aimed at reducing landscape impacts and noise pollution. For example, in an effort to mitigate noise pollution, the first 16 kilometers of the route will pass through five tunnels, 1.5 kilometers of the rail passing through the Barendrecht town will be covered by a roof, and 80 percent of the Betuwe Rail will parallel the A15 motorway. The project is scheduled for completion in 2005.

The Dutch government intends to subsidize the rail service during its first years of operation. Because one of the objectives of the project is to improve connections between Rotterdam and Germany, the Dutch government entered into an agreement with the German government that the Germans will fund the connections between the Betuwe Rail and the German rails as explained in the Treaty "Vereinbarig von Warnemunde." The Betuwe Rail will not only improve connections to Germany, but it is also foreseen that the rail service will facilitate just-in-time delivery (Betuwe Project Organization 2002).

A.1.2 Priority Projects Added to the Trans-European Network

The following projects were subsequently defined as priority projects by the EU and were included as TEN projects. These projects will be considered for development in the next 10 years in light of the new guidelines.

The Straubing–Vilshofen Project

The Straubing–Vilshofen project is designed to increase the navigability of the Danube River between Straubing and Vilshofen. This section of the river is too shallow and over 70 km must be dredged to allow for the continuous passage of ships. Removing this bottleneck on the Rhine-Maas-Danube route, which connects the North Sea and the

Black Sea, is regarded as critical because of the potential to shift large volumes of cargo from roads to waterways, thereby decreasing congestion on the roads. It is also anticipated that the project will help to integrate the eastern countries in the EU with the rest of the EU. The project is therefore regarded as strategic to the development of inland waterway transportation on this east-west route.

High-Capacity Rail through the Pyrenees

Currently, more than 15,000 heavy vehicles pass through the Pyrenees each day and this volume is increasing by 10 percent per year. The Pyrenees between the Iberian Peninsula and France has become a major bottleneck impeding the flow of traffic. The planned high-capacity rail line will carry 2.8 million tons, which represents 1.5 percent of the traffic crossing the Pyrenees by 2010–2015. Completion of the project will take between 10 and 20 years.

High-Speed Rail: Eastern Europe

This high-speed rail project will link Eastern Europe with other EU member countries in an effort to facilitate increased traffic stemming from improved commercial relations. The project consists of 713 km of rail track that will be upgraded to allow for a high-speed service among Stuttgart, Munich, Salzburg, and Vienna. At a later stage, this rail line will be linked to the Paris-Strasburg TGV to provide a high-speed rail service between Paris and Vienna. In addition, plans exist to extend the rail track to Budapest, Bucharest, and Istanbul. Although the project will not be completed until 2012, a large component will be built by 2006.

The Fehmarn Belt

The Fehmarn belt project entails a bridge/tunnel that crosses the natural barrier of the Fehmarn Strait between Germany and Denmark. This is considered a strategic project to connect the north-south axis by linking the Nordic countries to Central Europe. One component of this project, the Oresund link, has been completed.

Interoperability of the Iberian High-Speed Rail Network

The project aims to convert the Iberian rail network to EU Standards. The different rail gauge in the Iberian Peninsula compared to the rest of the TEN is considered a major obstacle to the efficient operation of the EU's rail system. This project will thus ensure interoperability. In addition, the development of a network of high-speed rail lines will possibly free up tracks for the movement of freight. Investors are currently being sought to enter into public-private partnerships.

Finally, a number of projects have been considered for extension, such as the extension of the high-speed rail service between Montpellier and Nîmes, and similarly between Verona and Naples.

APPENDIX B. MULTIMODAL U.S. EXAMPLES

B.1 Alameda Corridor

The ports of Los Angeles and Long Beach on the Pacific Coast are strategic to the commercial relations between the U.S. and the Pacific Asian nations—the fastest-growing marketplace in the global economy. Known as the San Pedro Bay Ports, the ports of Los Angeles and Long Beach comprise the largest port complex in the U.S. In 2001, the Port of Los Angeles handled 5,183,519 twenty-foot equivalent units (TEUs) (Port of Los Angeles 2002), while the Port of Long Beach handled 4,462,959 TEUs (Port of Long Beach 2002). Together, these ports make up the third-largest port complex in the world. It is estimated that the number of containers handled at these ports will double by 2020. A major obstacle is, however, the capacity constraints imposed by the inland transportation network. By 1981 there were concerns about the handled trade volume nearing the capacity of the landside modes, i.e., the national railroads and the interstate highway network serving the ports. In 1981, the Port Advisory Committee (PAC) was created to identify solutions to address the transportation system's concerns related to increased traffic originating at or destined for the port area. The Committee focused on the congested highway access routes to the ports and the projected rail capacity constraints. The PAC proposed the Alameda Corridor to address these concerns (Alameda Corridor Transportation Authority 2002).

B.1.1 Project

The Alameda Corridor consists of 20 miles of express railroad that links the San Pedro Bay Ports to the transcontinental rail yards near downtown Los Angeles (Figure B.1). The corridor replaced three railroad lines and can handle 100 trains a day. It can accommodate a third track when it becomes necessary to improve future landside access to the ports (California Department of Transportation 2002).

The Alameda Corridor consists of three sections: north section, midsection, and south section. The north section of the project stretches from Santa Fe Avenue, across the Los Angeles River near Washington Boulevard, to the rail yard east of downtown. A number of projects were completed in this section. First, the old structure over the river was replaced by a three-track railroad bridge structure at a cost of $6.6 million. Second, two bypasses (one underground) were built to separate vehicle and train traffic at

Washington Boulevard and Santa Fe Avenue. Third, the Amtrak and Metrolink railroads over the Alameda Corridor were elevated to separate passenger and rail freight traffic.

Source: Alameda Corridor Transportation Authority (ACTA)

Figure B.1 Alameda Corridor

The midsection is the most significant component of the Alameda Corridor and the most difficult to construct. It consists of a trench for rail traffic that is totally separated from the road traffic. The trench contains two main-line rail tracks and a service road used for maintenance (Figure B.2). This corridor component is located between State Route 91 and 25th Street. This sunken rail has allowed for the elimination of 200 at-grade rail crossings.

The south section of the Alameda Corridor involved a 7-mile extension of the rail lines. Some of the significant projects in this section include:

- The construction of a three-track rail bridge over Compton Creek to replace the track bridge, thereby allowing higher train speeds.

- The construction of three railroad bridges over the Dominguez Channel to increase the capacity of the tracks.

Source: Alameda Corridor Transportation Authority (ACTA)

Figure B.2 Alameda Corridor: Midsection

The capacity of the Alameda Corridor is estimated at 100 trains per day traveling at 40 mph. By traveling at 40 mph, most of the trains have doubled their previous speeds. Both Union Pacific (UP) and Burlington Northern Santa Fe (BNSF) use the corridor (Alameda Corridor Transportation Authority 2002). According to the Port of Long Beach, 33 trains used the Alameda Corridor on the first day.

B.1.2 Public Benefits

Numerous social benefits can be attributed to the Alameda Corridor. Foremost, is the fact that the landside capacity of the multimodal connections to the ports has increased, allowing the ports to handle additional cargo without aggravating congestion, air, and noise pollution.

The elimination of 200 at-grade railroad crossings and the separation of rail and highway traffic also generated substantial benefits. It allowed an increase in train travel speeds from 5–20 mph to 20–40 mph. Trains can now travel between the ports and the rail yards in about 45 minutes. Also, the existence of two parallel rail tracks decreases the rail waiting time to pass another train by 75 percent. Before the construction, it had taken as long as 2.5 hours to travel between the ports and the rail yards. In addition, truck delays have been reduced because cars and trucks do not have to wait at crossings. It is estimated that 15,000 hours in vehicle delay will be saved, resulting in a 90 percent reduction in vehicle delay. In addition, the risk of accidents will reduce because of the separation of rail and vehicle traffic (Alameda Corridor Transportation Authority 2002).

Associated environmental benefits include a reduction in railroad emissions by 28 percent and truck emissions by 54 percent. The truck emissions benefits are attributable to the elimination of the need to stop at rail crossings. In addition, noise and vibration impacts were reduced.

Indirect benefits include an improved local economy resulting from the creation of approximately 10,000 construction jobs. In addition, the infrastructure improvements provided new opportunities for local businesses along the corridor.

B.1.3 Project Finance

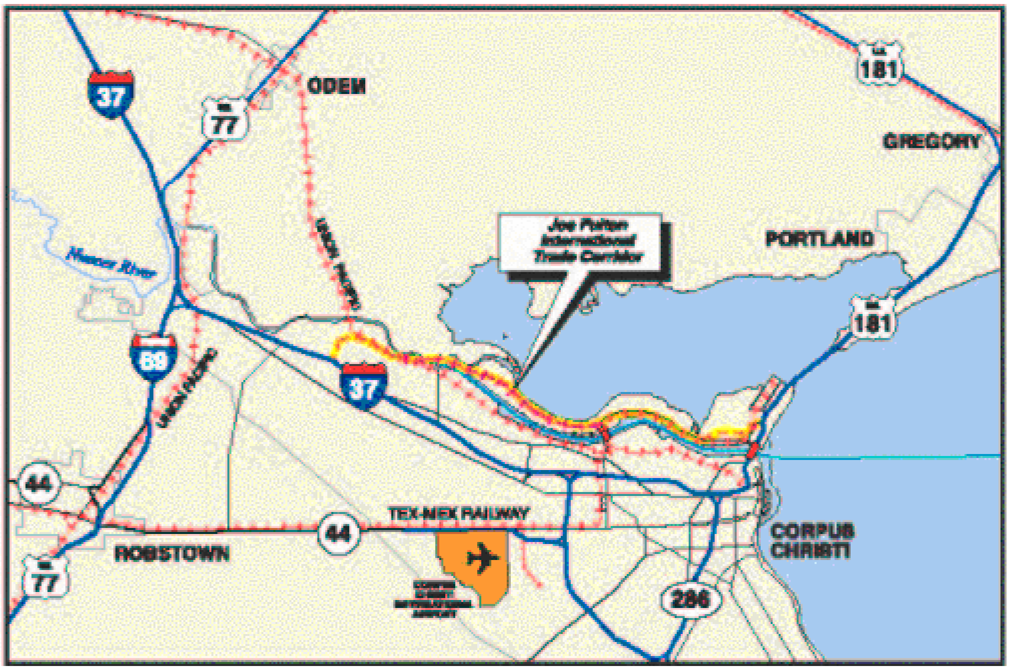
The total cost of the Alameda Corridor was $2.4 billion. It was completed on time and within budget. The funding for this project came from various public and private contributions (Evans and Kelley 1999) including:

- $400,000 loan from the U.S. Department of Transportation;
- $394,054 from the San Pedro Bay Ports in the form of railroad right-of-way;
- Approximately $347 million administered by the Los Angeles County Metropolitan Administration Authority;
- $154 million in other state and federal sources of interest income; and
- $1.2 million in revenue bonds issued by the authority. The bonds will be paid from railroad fees. Because of the revenue bonds, this facility can almost be viewed as a tolled railroad.

C.2 Joe Fulton International Trade Corridor

The Port of Corpus Christi in Texas is the 5th largest port in the U.S. in terms of the number of tons handled. The port moved 89 million tons of bulk cargo, mainly petroleum products, in 2000 (Bureau of Transportation Statistics 2002). It also houses oil refining facilities and an industrial chemical center.

The Port of Corpus Christi has a channel depth of 45 ft. Located 150 miles north of the U.S.-Mexico border, it is an important short sea node in the Gulf Intracoastal Waterway. Three rail companies provide service to the port: BNSF, the Texas Mexican Railway Company (TexMex), and UP (Figure B.3).



Source: Texas Department of Transportation 2001

Figure B.3 Port of Corpus Christi

C.2.1 Project

The original objective of the Joe Fulton International Trade Corridor in 1960 was to connect U.S. Highway 181 to Interstate 37. The Port of Corpus Christi conducted the feasibility study and in 1994, the project was referred to as the "North Side Highway Rail Corridor." In 1995, the project was identified as a priority project and included in the ISTEA High-Priority Corridor on the National Highway System Program. Moreover, the Texas Department of Transportation (2002) directed a study of the project entitled "U.S. 83/Port Roads Study." The proposed route design was completed and submitted to the Federal Highway Administration in November 2000. Currently, the results of the Environmental Impact Statement are outstanding. Once approval is secured, the design of the project can be initiated. The construction of the project was expected to start in 2003 and the project was scheduled for completion by 2006.

The corridor will be located along the Inner Harbor of the Port of Corpus Christi. The corridor will consist of (a) 11.8 miles of two-lane roadway that connects Interstate 37 to U.S. Highway 181, and (b) links to existing rail lines. The corridor will provide both highway and railroad connections. Figure B.4 illustrates the corridor concept.

Source: Texas Department of Transportation 2001

Figure B.4 Joe Fulton International Trade Corridor

The Port of Corpus Christi has three access roads/bridges to the north area of the port. Two of these are the Harbor Bridge and Tule Lake Bridge (Figure B.4). The third option—50 miles to the northwest—is the Nueces River Bridge on U.S. 77 that connects to IH-37. Trucks and trains must, however, wait when the Tule Lake Bridge is lifted for marine traffic. The Joe Fulton International Trade Corridor will provide an alternative route to the Harbor Bridge, whose entrance from IH-37 is steep and narrow. IH-37 is the designated hazardous material route. The Joe Fulton International Trade Corridor will also be designated as a hazardous material route. It is anticipated that it will reduce the risk of spills on the steep incline to the Harbor Bridge.

B.2.2 Public Benefits

Foreseen social benefits associated with the Joe Fulton International Trade Corridor are:

- enhanced access to the Port of Corpus Christi;
- improved commerce at the port; and
- facilitation of future economic development.

The Joe Fulton International Trade Corridor will enhance road and rail access to facilities on the north side of the Corpus Christi Inner Harbor, thus providing access to non-developed[9] land in the port and increasing the potential capacity at the port.

The corridor will connect two major highways, IH-37 and U.S.-181, thereby improving the land connections at the port. The corridor will also provide an alternative route for truck traffic from the port and an alternative route for rail traffic connecting to the north side of the port. The improved geometric characteristics of the Joe Fulton International Trade Corridor will also provide a safer route for the transportation of hazardous materials. Finally, the Port of Corpus Christi is an economic generator in the region and the expansion will facilitate trade and future economic development in the area.

B.2.3 Project Finance

The total cost of the project is estimated at $49.7 million. The Port of Corpus Christi has funded most of the preliminary studies. Federal funds will amount to approximately $10.3 million, the Texas Department of Transportation will contribute $11 million, the Corpus Christi Metropolitan Planning Organization will provide $3 million, and the Port of Corpus Christi submitted a loan request for $16.3 million to the State Infrastructure Bank. These funds will be made available upon completion of the environmental assessment. The Port of Corpus Christi, however, requires an additional $10–15 million in federal funds that have not been secured (Port of Corpus Christi 2002).

B.3 Port of Tacoma Overpass - FAST Corridor Project

The FAST Corridor Strategy for the Everett-Seattle-Tacoma Corridor consists of a series of overpasses and underpasses aimed to reduce conflict points between roadways and railroad tracks along the I-5 corridor (Figure B.5). FAST was initiated in 1996 by a coalition of public agencies and private transportation interests. The main objective is to improve the efficiency, safety, and reliability of freight traffic to and from the ports of Everett, Seattle, and Tacoma. The FAST Corridor program will help to facilitate increasing freight movements through the central Puget Sound region of Washington State (Beaulieu 2000).

Fifteen priority projects from Everett to Tacoma have been identified in the first phase, such as road/rail grade separations and port access projects. Three of these projects have been completed and six are under construction. The first phase of the FAST Corridor program is estimated to cost $400 million, will take 6 years to build, and is scheduled for completion by 2004. The program is funded by both public and private agencies, including the Port of Tacoma, the Port of Seattle, the Port of Everett, the U.S. Department of Transportation, the Washington State Department of Transportation, the Puget Sound

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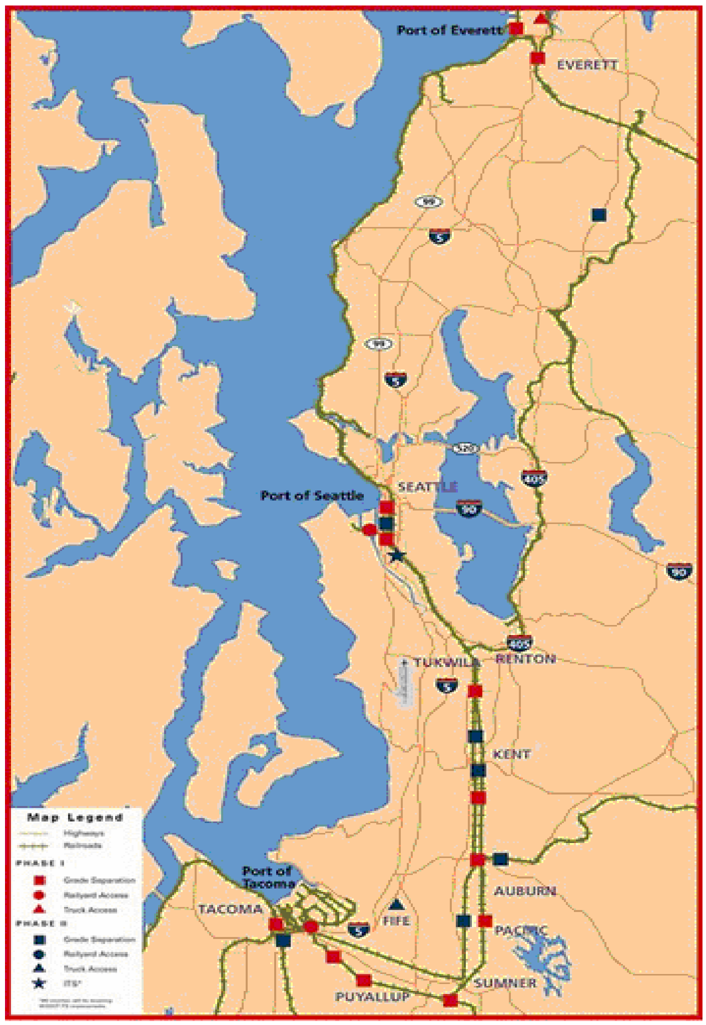
9 About 1,100 acres along the ship channel in the northwest of the port is currently undeveloped.

Regional Council, BNSF and UP railroads, and numerous counties and cities in the Puget Sound area. The second phase will focus on the improvement of regional truck mobility and is expected to cost approximately $160 million (Puget Sound Regional Council 2002).

B.3.1 Project

The Port of Tacoma handled approximately 1.5 million TEUs; 180,173 vehicle units; and more than 14.5 million standard tons of bulk cargo in 2002 (Port of Tacoma statistics). The port was ranked 10th in 2002 in terms of the amount of containerized cargo handled and 32nd in terms of total tonnage handled in 2000 in the U.S (U.S. DOT: Maritime Administration 2003).



Source: Washington Department of Transportation

Figure B.5 FAST Corridor

The first project completed as part of the FAST Corridor program was the Port of Tacoma Road overpass. The overpass elevates the Port of Tacoma Road and Interstate 5 over State Route 509 (Figure B.6). As part of the project, a new interchange was built between the two roadways. New railroad tracks parallel to SR 509 under the overpass were also constructed (Chicolte 2002).

Source: Washington Department of Transportation

Figure B.6 Tacoma Overpass View

B.3.2 Public Benefits

The overpass can potentially increase the capacity and the efficiency of the Port of Tacoma because of improved road and rail connections. The overpass eliminates a number of traffic lights and at-grade rail crossings, thereby improving the flow of rail and truck traffic to and from the Port of Tacoma. The overpass reduced congestion in the area, thereby increasing the average speeds of trucks moving in and out of the Port of Tacoma. It also reduced the travel times of cross-port commuters because of the reduction in the number of traffic lights and improved safety through the elimination of a number of at-grade rail crossings. Finally, by raising the roadway, the port is able to construct three arrival and departure rail tracks under the Tacoma road. These tracks will allow for the movement of intermodal containers and will serve as a link to connect the transcontinental railroads with the local port area rail network. The "double-bubble" portion of the overpass has a height of 24 ft, thus allowing the use of double-stack trains (Figure B.6).

B.3.3 Project Finance

The overpass project cost $33 million. The major funding sources for the project are summarized Table B.1.

Table B.1 Tacoma Overpass Funding Sources

Funding Source	Amount ($)
TEA-21 "High Priority project"	$4.5 million
TEA-21 "Borders and Corridors program"	$3.3 million
Port of Tacoma	$5 million
Burlington Northern Santa Fe	$1.1 million

Source: Port of Tacoma 2002

B.4 Portway International/Intermodal Corridor Program

The Port of New York and New Jersey is the largest port on the East Coast and is ranked third in the U.S. The port handled 21.6 million metric tons of generalized cargo, 48.5 million metric tons of bulk cargo, 3.7 million container TEUs (from which 1.1 million were empty), and almost 589,000 vehicle units in 2002 (Port Authority of New York and New Jersey 2002). The number of containers handled is projected to increase on average by 3.7 percent per year, resulting in 11.8 million containers by 2040 (Rodrigue 2003).

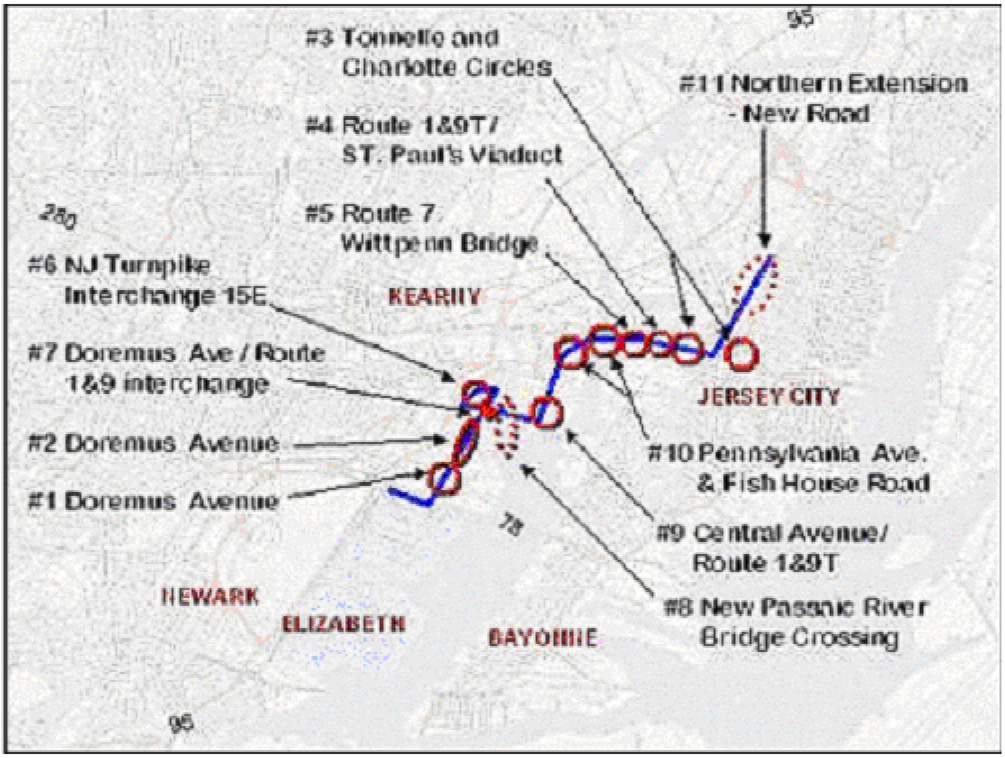
Since the 18th century, the Port of New York was the link between Europe and North America. During the first half of the 20th century, the port was ranked first in the U.S., handling almost half of all U.S. trade. The container revolution in the late 1950s initiated the development of the Elizabeth Port Authority Marine Terminal—the world's first container port. In the 1970s, however, the Pacific Rim began to replace Europe as an important trading partner of the U.S. Most of the trade between the northeastern U.S. and Asia thus moved through West Coast ports. The volume of cargo at the Port of New York and New Jersey continued to increase, albeit at a slower rate. By the 1980s, the Port of New York and New Jersey showed a relative decline, while the San Pedro Bay Ports (Long Beach and Los Angeles) emerged as the leaders in handling U.S. trade. The situation was further aggravated by the new facilities that were developed by other East Coast ports from Halifax to Miami, which resulted in competition with the Port of New York and New Jersey for market share.

Efforts to enhance the competitiveness of the Port of New York and New Jersey resulted in significant cost reductions: from $8.9 per ton in 1984 to $0.50 per ton currently. Approximately half of these savings can be attributed to the introduction of on-dock rail service in 1991 (Port Authority of New York and New Jersey 2002). The Port Authority developed a five-part strategy to alleviate landside access concerns and improve inland transportation. It is anticipated that improved inland transportation will enhance the hinterland of the port and facilitate improvements in productivity (Wakeman 2001). The port is continually seeking opportunities to reduce costs and improve the efficiency of distributing cargo (Port Authority of New York and New Jersey 2002).

B.4.1 Project

Many of the roads serving the Port of New York and New Jersey have not been improved since the 1950s. The Portway International/Intermodal Corridor program consists of a number of intermodal projects in a defined freight intensive corridor to and from Port Newark–Port Elizabeth. The Portway Corridor extends north from the Newark/Elizabeth Seaport and Airport Complex to the rail and trucking distribution facilities in Essex, Hudson, and Bergen Counties, and east to the port facilities on the Bayonne Peninsula (Figure B.7).

The Portway Corridor project will be built in four phases. Only the first phase has been approved, stretching from the port to Kearny and Croxton yards in Jersey City (Figure B.7). This phase will be constructed in 5 years. It consists of eleven independent projects and the estimated cost is approximately \$800 million. Of the eleven projects, three are under construction, two are in the final design stage, and six are at the feasibility assessment stage (James 2000).



Source: New Jersey Department of Transportation 2003

Figure B.7 Portway International/Intermodal Corridor

The three projects under construction are the Doremus Avenue, the Charlotte Circle, and the Tonnelle Circle. The Route 1 and 9T, and the Route 7 Wittpenn Bridge replacements are in the final design stages. Feasibility studies are currently being conducted for a number of interchange projects, including the New Jersey Turnpike interchange, the interchange of Doremus Avenue with Route 1 and 9T, the New Passaic River Bridge crossing, and the interchange of Central Avenue with Routes 1 and 9. In addition, feasibility studies are being conducted for the Pennsylvania Avenue and Fish House Road project, and the northern extension from St. Paul's Avenue to Secucas Road (Delaware Valley Regional Planning Commission 2002).

In the first phase of the Portway Corridor program, the focus has been on the reconstruction of Doremus Avenue, capacity improvements to a number of bridges to accommodate overweight containers, and the replacement of the St. Paul Viaduct for the new "Route 1 and 9T" between Tonnele and Charlotte circles that will be used exclusively by trucks. Construction began in November 2001. These projects are supervised by the New Jersey Department of Transportation.

B.4.2 Public Benefits

Many of the Portway Corridor improvements will alleviate bottlenecks at the port and improve the traffic flow to various inland destinations. Anticipated benefits include improved travel time and reduced congestion on access roads. At the same time, the capacity expansion projects and the dedicated truck road will enhance road safety. Environmental benefits will result from a reduction in congestion with associated benefits of decreased idling emissions. The program has been recognized by the Federal Highway Administration and the U.S. Environmental Protection Agency, and has been selected as one of ten projects nationwide to be included in the Environmental Streamlining Pilot Program. Finally, the Portway Corridor program will promote economic development and job creation, enable the port to increase capacity to serve future demand, and it is expected to reduce the cost of truck trips by half.

B.4.3 Project Finance

The first phase of the Portway Corridor project is expected to cost $750 million (TriState Transportation Campaign 2000). The cost of two of the components of Phase 1 is shown in Table B.2.

Table B.2 Portway International/Intermodal Corridor Funding

Project	Cost ($ million)
Doremus Avenue	13.5
Replacement of Route 1 and 9T	197

Source: New Jersey Department of Transportation 2003

B.5 Port Inland Distribution Network

Assuming the projected increase in container movements (3.7 percent per year), the Port of New York and New Jersey will reach capacity in 2004. The port has 1,280 acres of container terminal space with a capacity of 3.2 million TEUS annually. To address future capacity concerns, the Port Authority of New York and New Jersey developed the Port Inland Distribution Network (PIDN) for the distribution of containerized cargo. The PIDN consists of a network of nine inland container terminals linked to the port by dedicated freight rail or barge services.

Source: Port Authority of New York and New Jersey 2003

Figure B.8 Port Inland Distribution Network

Currently, 80 percent of the cargo handled at the Port of New York and New Jersey is transported by truck. The current modal split between rail and truck in the region is 10/90 in favor of trucking. More than 90 percent of all freight passing through New Jersey arrives at its final destination by truck and 86 percent of New Jersey's communities are served exclusively by truck. This is attributable to the fact that the majority of the port users are located within a 1-day drive from the port. It was felt that the current method of distributing cargo by truck contributes to congestion, compromises the reliability of distributing port cargo, and adds to the cost of cargo movements.

Moreover, the Port of New York and New Jersey Master Plan predicted that port volumes would double between 2000 and 2010 (Access and Mobility 2025). The constraints on increasing port capacity imposed by the land uses surrounding the port resulted in PIDN. PIDN aims to build satellite container terminals at least 75 miles from the port and located at the Port of New York and New Jersey's primary markets. Possible sites identified include: Albany and Buffalo (NY), Camden (NJ), Bridgeport or New Haven (CT), and Fall River (MA) (Figure B.8). As indicated previously, these terminals will be connected to the port by barge or intermodal rail shuttle. From the inland terminals, the cargo will be distributed by truck.

The proposed inland terminals connected by train are: Pittsburgh (PA), Syracuse (Buffalo), Rochester (NY), and Worchester (MA). The proposed inland locations connected by barge are: New England/Bridgeport (CT), New Haven (CT), and Quonset Point (RI), Hudson River Service to Albany (NY), Mid-Atlantic Service to Camden or Salem (NJ), and Wilmington (DE) (Port of New York and New Jersey 2002).

The development of this terminal network is viewed as instrumental in increasing productivity beyond the 3,500 containers per acre level, thereby reducing the need to develop additional acreage at the waterfront.

B.5.1 Public Benefits

Numerous benefits are anticipated, including:

- a 20 percent reduction in the cost of inland distribution, creating new economic development opportunities at the feeder ports;
- a reduction in environmental concerns (reduced air emissions, noise pollution, and energy savings) in the region owing to the use of rail/barge shuttles that emit fewer emissions compared to trucks, and because of a reduction in the number of truck trips generated at the port;
- a reduction in the dwell time of the on-port storage of containers;
- postponing the need for terminal expansions at the port to accommodate future container growth;
- a reduction in congestion at the port attributable to the more-effective use of trucks for shorter trips; and
- improving port efficiency and thereby the competitiveness of the port.

B.5.2 Project Finance

The PIDN concept consists of three elements: maritime terminals, barge and rail services, and inland container terminals. The maritime terminals can be built by port funds. Existing port cranes can be used to load the trains and barges. The freight rail and barge services can be financed initially by the port authority. The investment subsequently can be recovered from charging a user fee. The port authority, however, is limited in its ability to invest in transportation equipment, i.e., barges and trains, moving outside the agency's jurisdiction.

The agency also cannot fund the development and operation of the inland container terminals, because these terminals will be located outside the agency's jurisdiction. The terminals will have to be developed through public/private partnerships. Some federal funds are available, including federal credits for private-sector investments, incentive payments for truck diversions, and loan guarantees.

B.6 Red Hook Container Barge

Red Hook is one of the maritime terminals of the Port of New York and New Jersey (Figure B.9). With a channel depth of 40 feet, it is capable of handling deep draft vessels and offers the shortest sailing time in and out of the harbor.

Source: Port Authority New York and New Jersey

Figure B.9 Red Hook Marine Terminal

The Red Hook marine terminal is a 100-acre facility with four cranes in service. It is the only facility located in Brooklyn and could only be accessed by truck. Access was via the Gowanus expressway (Figure B.10), crossing the Verrazzano-Narrows Bridge, continuing with the Staten Island Expressway, and finally crossing two bridges into New Jersey. When the New York State Department of Transportation announced a project to reconstruct the Gowanus expressway over a 10-year period, some of the port tenants announced that they would leave because access to the port would be affected. The re-construction work began in December 1996. Access concerns heightened when one of the Gowanus expressway lanes was restricted to buses, taxis, and other vehicles with at least two occupants, thereby impacting capacity.

Source: New York State Department of Transportation

Figure B.10 Gowanus Expressway

B.6.1 Project

The Port Authority, in agreement with the City of New York, developed a project to divert the container truck traffic to barges. The main objective of the project was to establish a barge service to transport containers between the Red Hook terminal in New York and the Port of Newark in New Jersey.

The barge service is operated between the Red Hook terminal and the American Stevedore terminal at the Elizabeth Port Authority Marine Terminal in the Port of Newark. This barge service has been operating for 10 years. In 2000, the terminal handled 63,000 containers and 173,000 tons of bulk cargo. More than 90 percent of the containerized cargo handled by the terminal now moves on barges. Between 1993 and 2000, the percentage of cargo handled by barge increased from 34 to 94 percent. On average, eight shuttle barge trips are undertaken between the Red Hook terminal and the American Stevedore terminal per day. Cargo received at the Red Hook terminal on a given day is available for pick up at the Port of Newark after noon the next day. The barges only transport containerized cargo.

B.6.2 Public Benefits

Barges offer an alternative to trucks in the movement of containers with associated emissions reduction benefits. In the future, the service could be expanded to move dry bulk cargo.

B.6.3 Project Finance

The Port of New York and New Jersey Authority and the New York State Development Program made the initial investments ($2.8 million and $300,000, respectively) for operating the barge service only 3 days a week. The barge service was offered free of charge, because the main objective was to retain Red Hook terminal's customers and tenants.

The Red Hook Container Barge was the first freight project funded under the Intermodal Surface Transportation Efficiency Act. The project was funded with Congestion Mitigation and Air Quality (CMAQ) funds. Subsequently, the CMAQ program provided the necessary funds for both the infrastructure required—the barge equipment—and for the barge operation. The project received $9.7 million from the CMAQ program, $2 million from the Surface Transportation Program, and $3.8 million from other Transportation Equity Act for the 21st Century (TEA-21) funds.

During its 10 years of operation, this project received $1.7 million from the New Jersey Transportation Trust Fund, $39.8 million from the Port Authority, and $1.8 million from New York State. The service continues to be free.

B.7 Skypass Bridge Project

Florida's Port of Palm Beach is located halfway between the Port of Miami and Port Canaveral. It is ranked fourth in terms of container cargo handled in Florida and eighteenth in the U.S. The port handled more than one million containerized tons and 112,782 tons of bulk cargo in 2001 (Port of Palm Beach 2002). The major commodities moved by the Port of Palm Beach are molasses, cement, fabrics, and utility fuels.

Compared to other U.S. ports, the Port of Palm Beach experienced significant growth from 1995 to 1997, mainly because of an increase in Latin American trade. In addition, the port is expanding its cruise services. A new cruise terminal has facilitated the simultaneous operation of two cruise passenger vessels.

The port, however, was divided by U.S. Highway 1 into an east and west side. The east side, on the Atlantic Ocean, had all the pier and cargo handling facilities, while the west side housed the rail yards and the storage facilities. This configuration impacted the port's normal operations. The crossing of drayage trucks from the dock area to the rail and storage area aggravated congestion on U.S. 1 (Port of Palm Beach 2002). According to port information, almost 5,000 daily truck crossings occurred between the two sides.

B.7.1 Project

The Skypass Bridge Project is a four-lane bridge elevating U.S. 1 to allow the physical connection of the two sides of the Port of Palm Beach. The Skypass Bridge enhanced safety and reduced congestion with associated environmental benefits. By creating a link between the two sides of the port, port operations (for example, vehicular access, cargo movement, and storage) were optimized, thereby facilitating increased international trade and cruise passenger operations. The elevation of U.S 1 generated new space for storage or rail yard operations. It also improved the flow of traffic and average speed on U.S. 1. Finally, this improvement had a positive impact on the local economy and employment in the area.

B.7.2 Project Finance

The project cost $31.6 million. Half of the project funds came from the Florida Transportation and Economic Development Program, $2 million came from the Florida Governor's Office of Trade, Tourism and Economic Development, and $3 million came from the Florida Department of Transportation. The latter was mainly used for access roads and utility relocations. No private funds or user fees were used to finance this project.

B.8 UPS Chicago Area Consolidation Hub

The UPS Chicago Area Consolidation Hub (CACH) opened in 1995. The 240-acre site is a key midwestern facility for consolidating, sorting, and distributing 1.3 to 1.9 million packages daily, representing approximately 10 percent of UPS's daily domestic packages. The facility is currently operating at 60 percent of its capacity. It is expected that the number of packages will increase to between 2.5 and 2.8 million per day in 5 years. The average time that a package spends in the UPS CACH is 15 minutes. Approximately

50 percent of all packages require the use of intermodal transportation, highlighting the need for efficient multimodal connections.

B.8.1 Project

To meet the UPS CACH requirements for efficient multimodal connections, the public and private sectors funded four access improvement projects. The first project was the construction of an interchange on Interstate 294 at 75th Street. The project was completed in 1994 at a cost of $15.65 million. Of the total cost, UPS funded $3 million, the Illinois Department of Transportation (IDOT) funded $2.5 million, the Illinois State Toll Highway Authority (ISTHA) funded $7 million, the Department of Commerce and Community Affairs (DCCA) funded $2.5 million, and local agencies contributed $650,000 (Evans and Kelley 1999).

The second project was the construction of the BNSF intermodal facility adjacent to the UPS CACH. BNSF agreed to build the intermodal yard to serve UPS by providing a direct connection to the rail system. The project cost $75 million. Currently, approximately 40 percent of the operations at the yard are used to serve UPS. The yard handles an average of twenty-four intermodal trains a day—twelve incoming and twelve outgoing—and 1,850 truck drops and lifts. Every 80 seconds a trailer is lifted on or off a rail flatcar. An electronic data interchange (EDI) system facilitates communication between BNSF and UPS-CACH (Van Hattem 2001).

Source: Van Attem 2003

Figure B.11 CACH Facility

The third project involved the rail grade separation at Willow Springs Road. BNSF built the rail overpass and the road under the overpass was reconstructed by IDOT. BNSF contributed $5 million and IDOT contributed $5 million.

The fourth project consisted of smaller intersection improvements along Archer Avenue to accommodate UPS employees and the increase in truck traffic. This project, funded by UPS, cost $1.3 million.

B.8.2 Public Benefits

The UPS-CACH facility brought important economic benefits to the community by generating employment (8,500 jobs) and tax revenues. The access improvements enhance the daily operation of the UPS facility, thereby generating additional economic benefit to the community.

Source: Van Attem 2003

Figure B.12 Operation of BNSF Facility

The construction of the BNSF railroad yard next to UPS-CACH has limited the impact of daily operations on Chicago traffic. Approximately 1,900 truck movements are generated between these two facilities daily (Van Hattem 2001).

Finally, the rail grade separation project reduced the emissions from idling cars and trucks at the rail crossing. Additionally, it reduced the risk of car-rail accidents.

B.9 Alliance

Alliance, located close to the Interstate 35W corridor, offers various transportation and industrial possibilities at a single site. Alliance was the vision of Ross Perot Jr. Although originally one of the key components was air transportation to serve industrial and freight activities, the Alliance strategy was subsequently adapted to accommodate the needs of their tenants. The vision was broadened to include multimodal transportation options to serve the needs of Alliance's tenants (Hillwood Corporation 2003).

In July 1988, the Fort Worth Alliance airport began operation. In May 1989, Santa Fe Railway became Alliance's first major tenant when it opened a 55-acre loading facility at the site. Today, BNSF operates a 735-acre hub at the complex. In June 1989, American Airlines located a maintenance facility with an estimated worth of $482 million at Alliance. Finally, the construction of State Highway 170 began in 1990. This highway provided additional access to the Texas highway network. These factors marked the beginning of the successful development of this multimodal center (Leitner and Harrison 2001).

Approximately 9,600 acres of the total area are earmarked for commercial, industrial, and transportation development. Currently, more than 7,000 acres are available for future development. The remainder is reserved for community development. Two community projects, Circle T Ranch and Heritage, are in the first stages of development. Circle T Ranch is a 2,500-acre area reserved for luxury housing, golf courses, and recreational activities. A regional shopping center and a 35-acre hospital are also planned. Heritage will be primarily a residential, 2,300-acre community. The area is reserved for 2,700 single-family houses. The first 350 single-family units are currently being developed. Plans for a 54-acre City of Fort Worth park, three elementary schools, and two high schools exist for the Heritage site.

According to Leitner and Harrison (2001), the development of Alliance had a number of distinct phases. The establishment of the transportation components was critical to the development of the distribution facilities. Once the distribution facilities were established, the manufacturing sector began to locate at Alliance. The first manufacturing company to locate at Alliance was Nokia in November 1994. Subsequent suppliers to Nokia also located their industries at Alliance.

Alliance is unique in many ways. Part of its success is attributable to the fact that Alliance was a "green area"[10] development. Alliance planners were thus not constrained in terms of land use and could develop the area in accordance with tenant needs. Also, Alliance was almost completely privately funded, with the result that the developers did not have to deal with the administrative procedures associated with public financing. Total private investment has amounted to more than $4.3 billion, while the public investment has amounted to almost $168 million. Private funding accelerated the development of the facility and allowed the developers to change their vision during the course of the project.

B.9.1 Project Benefits

Alliance clearly demonstrates the importance of (a) transportation reliability offered by multiple transportation modes, (b) the integration of these modes to ensure effective distribution across the U.S., and (c) being close to a large customer base (in this case Dallas and Fort Worth) in the location decisions of manufacturers. Alliance has generated $19.13 billion in economic benefits from 1990 to 2001. Approximately 20,317 employment opportunities have been created during the same time period.

10 The land was used previously for agricultural purposes.