1. Report No. SWUTC/06/167868-1	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Enhanced Freight Sketch Planning Tool for Assessing Multimodal Investment Strategies		5. Report Date September 2006	
		6. Performing Organization Code	
7. Author(s) Jordan Botticello and C. Michael Walton		8. Performing Organization Report No. Report 167868-1	
9. Performing Organization Name and Address Center for Transportation Research University of Texas at Austin 3208 Red River, Suite 200 Austin, TX 78705-2650		10. Work Unit No. (TRAIS)	
		11. Contract or Grant No. 10727	
12. Sponsoring Agency Name and Address Southwest Region University Transportation Center Texas Transportation Institute Texas A&M University System College Station, TX 77843-3135		13. Type of Report and Period Covered Research Report September 2005 – August 2006	
		14. Sponsoring Agency Code	

15. Supplementary Notes
Supported by general revenues from the State of Texas

16. Abstract

In recent years, there have been dramatic changes in the volume and movement of freight within the US and internationally. Traditional distribution systems have been replaced by just-in-time driven processes and freight transportation patterns have become much more complex. Innovations in containerization as well as changes in trade geography have directly influenced international trade movements. NAFTA and the deregulation of rail, trucking and air in the latter part of the twentieth century also had a large impact on freight movement. Given these changes, it has become increasingly necessary for transportation planners to look to modes other than traditional highways as solutions for congestion and other transportation problems. However, public agencies have been challenged to demonstrate and contrast the benefits of these modal investments with traditional highway spending.

During the first phase of the research a spreadsheet based tool, entitled Multimodal Analysis Freight Tool (MAFT) was developed to quantify and evaluate the benefits associated with multimodal freight investments. However, the tool needed to be further developed to accurately account for the rail and barge components and data regarding these modes was not readily available during the first phase of the project. This study addresses that issue as well as develops and analyzes a case study involving the rail mode and one involving the barge mode using MAFT. Additionally, given the uncertainty of assumptions made in the tool, a sensitivity analysis to determine the critical input values is needed. A critical examination of the output from several case studies was studied to determine the overall effect of these factors on the results. An assessment of the oversimplifications in the tool, due to its sketch planning nature, was undertaken and possible solutions identified.

17. Key Words Multimodal Freight Analysis Tool, MAFT, Freight, Multimodal, Rail	18. Distribution Statement No restrictions. This document is available to the public through the NTIS: 5285 Port Royal Road Springfield, Virginia 22161		
19. Security Classif. (of report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of pages 91	22. Price

Form DOT F 1700.7 (8-72)   Reproduction of completed page authorized

ENHANCED FREIGHT SKETCH PLANNING TOOL FOR ASSESSING MULTIMODAL INVESTMENT STRATEGIES

by

Jordan Botticello

and

C. Michael Walton

Research Report SWUTC/06/167868-1

September 2006

DISCLAIMER

The content of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the information presented herein. This document is disseminated under the sponsorship of the Department of Transportation, the University Transportation Centers Program in the interest of information exchange. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

ACKNOWLEDGMENTS

ABSTRACT

In recent years, there have been dramatic changes in the volume and movement of freight within the US and internationally. Traditional distribution systems have been replaced by just-in-time driven processes and freight transportation patterns have become much more complex. Innovations in containerization as well as changes in trade geography have directly influenced international trade movements. NAFTA and the deregulation of rail, trucking and air in the latter part of the twentieth century also had a large impact on freight movement. Given these changes, it has become increasingly necessary for transportation planners to look to modes other than traditional highways as solutions for congestion and other transportation problems. However, public agencies have been challenged to demonstrate and contrast the benefits of these modal investments with traditional highway spending.

During the first phase of the research a spreadsheet based tool, entitled Multimodal Analysis Freight Tool (MAFT) was developed to quantify and evaluate the benefits associated with multimodal freight investments. However, the tool needed to be further developed to accurately account for the rail and barge components and data regarding these modes was not readily available during the first phase of the project. This study addresses that issue as well as develops and analyzes a case study involving the rail mode and one involving the barge mode using MAFT. Additionally, given the uncertainty of assumptions made in the tool, a sensitivity analysis to determine the critical input values is needed. A critical examination of the output from several case studies was studied to determine the overall effect of these factors on the results. An assessment of the oversimplifications in the tool, due to its sketch planning nature, was undertaken and possible solutions identified.

EXEUCTIVE SUMMARY

In recent years, there have been dramatic changes in the volume and movement of freight within the US and internationally. Traditional distribution systems have been replaced by just-in-time driven processes and freight transportation patterns have become much more complex. Innovations in containerization as well as changes in trade geography have directly influenced international trade movements. NAFTA and the deregulation of rail, trucking and air in the latter part of the twentieth century also had a large impact on freight movement. Given these changes, it has become increasingly necessary for transportation planners to look to modes other than traditional highways as solutions for congestion and other transportation problems. However, public agencies have been challenged to demonstrate and contrast the benefits of these modal investments with traditional highway spending.

In 2002 the Texas Department of Transportation (TxDOT) contracted the Center for Transportation Research at The University of Texas at Austin to develop a sketch planning methodology to quantify and evaluate the benefits associated with multimodal freight investments. During the first phase of the research a spreadsheet based tool, entitled Multimodal Analysis Freight Tool (MAFT) was developed to quantify and evaluate the benefits associated with multimodal freight investments. However, the tool needed to be further developed to accurately account for the rail and barge components and data regarding these modes was not readily available during the first phase of the project. A case study involving the rail mode and one involving the barge mode were developed and analyzed using MAFT. Additionally, given the uncertainty of assumptions made in the tool, a sensitivity analysis to determine the critical input values is needed. A critical examination of the output from several case studies was studied to determine the overall effect of these factors on the results. An assessment of the oversimplifications in the tool, due to its sketch planning nature, was undertaken and possible solutions identified.

Based on the experiences during the first phase of the project, the research team felt that neutral organizations may be the best source of industry data since they would not have the same confidentiality concerns. The ability of such groups to collect national level data was also considered to be an asset as the values obtained would be averages rather than very specific figures. Since the data obtained is intended to be used as reference or "ballpark" figures,

national averages are appropriate and could even be more useful since MAFT is concerned with order of magnitude calculations. Data was collected from the Association of American Railroads and from the United States Army Corps of Engineers, for the rail and the barge modes respectively. The data collected was embedded in the tool as general industry information or as cost data.

The rail case study compared building a truck only toll facility with making a moderate investment in an already existing rail facility. Both facilities were quite long, in the range of 600- to 650-miles. The MAFT analysis showed that the managed lane alternative has a much higher net present value ($819 million) compared to the rail alternative ($178 million). Also, for every dollar invested in the managed lane facility society stands to gain a benefit of $1.49, while in the case of the rail alternative society gains $1.23. The barge case study compared building a truck only toll facility with a barge route. The managed lane facility was 15-miles long and the barge route was 7-miles. Both the manage lane and barge alternatives imposed a net cost on society of approximately $1.4 million and $76 million, respectively. The benefit/cost ratio showed that for every dollar invested, a societal return of $0.96 will be realized in the case of the manage lane alternative.

The sensitivity analyses performed on the rail and the barge case study show that the characteristics of benefit cost analysis and the model parameters embedded in the tool which drive the results in MAFT. For all five benefit categories, regardless of the alternative being assessed or the case study, the input values affecting the timing of the project were very significant. The characteristics of benefit cost analysis are such that the timing of a project is often very significant due to the discounting of values to an analysis year. The model parameters embedded in MAFT in the general assumptions sections also drive many of the calculations in MAFT, these values are "best estimates" and their significance in the results shows the importance of updating MAFT as more research becomes available. While the input values are influential in certain cases, it is often values that the analyst cannot control, such as the number of lanes in the base case scenario that are most significant. While the input values are important in terms of running MAFT successfully, small changes in these values will not produce very much of a change in the overall results of the project. This is not to say that projects with very different characteristics will return the same results, but to say that a small or moderate change in one or more input value will not have a profound effect on the results produced by the tool.

The sketch planning nature of MAFT is its greatest strength. Projects can be evaluated in a timely manner and order of magnitude results can be obtained to make basic comparisons between modes. In addition, the completely transparent calculations and the relatively few data inputs needed to run MAFT keep the tool from being cumbersome and difficult to use. Lastly, the ability to print, save and export the data and results make it easy for the analyst to share results.

During the period of this research project MAFT has been tested on four different case studies. However, the tool needs to be tested on a real scenario. The application of the tool on real projects can only help to identify issues that need to be resolved. In addition, a lack of research related to freight movement has led to a number of limitations. As this research becomes more prominent and data becomes available, the tool can be improved and more accurate appraisals of modal investments can occur.

The oversimplifications addressed in Chapter 6 should be looked at and addressed where possible. It is important not to make the tool too cumbersome and eliminate the benefits associated with its sketch planning nature. However certain limitations can be addressed without changing the format and purpose of MAFT. It seems especially important to address the limitations of the barge and rail modes, such as the capacity restraints and the current traffic, since there is little information in the public domain to compare results to. The more accurate the results for these two modes can be the easier it will be for analysts to realistically present these modes as alternatives to traditional highway spending.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1: INTRODUCTION

The interstate highway system, which was first conceived in the 1950s, is being faced with numerous issues related to capacity constraints. Many of the roads that were built in the early part of this program have reached the end of their design life and public agencies are faced with increasing costs to rebuild and maintain these facilities. As the number of vehicle miles traveled (VMT) increases each year, public agencies are faced with having to build new facilities as well. Congestion has become a costly problem for both passenger and commercial vehicles. The Texas Transportation Institute estimated in its 2005 Urban Mobility Study that the cost of congestion (based on wasted time and fuel) in the 85 largest US cities was in excess of $61 billion.[1] In addition, society is increasingly concerned with the air quality and land use issues that accompany such facilities.

The passage of the Intermodal Surface Transportation Efficiency Act (ISTEA) in 1991 had the objective of developing a national intermodal system to move both people and goods efficiently. This was the first time that transportation legislation had the specific goal of coordinating different modes into an efficient intermodal system. Subsequent transportation legislation, the Transportation Equity Act for the 21st Century (TEA-21) in 1998 and more recently the Safe, Accountable, Flexible, Transportation Equity Act: A Legacy for Users (SAFETEA-LU) in 2005 have built on the ideas in the ISTEA legislation.

The diversion of truck traffic to railroads, barges, and pipelines is often seen as a part of this efficient system for the freight sector. However public agencies are challenged to determine the benefits of such alternatives and compare them to traditional highway spending.

This chapter discusses the changes that have occurred in freight transportation over the past several decades, states the objectives of the research and outlines the remainder of this report.

CHANGES IN FREIGHT TRANSPORTATION[1]

In recent years, there have been dramatic changes in the volume and movement of freight within the US and internationally. Traditional distribution systems have been replaced by just-in-time delivery processes and freight transportation patterns have become much more complex.

---

[1] This section draws from TxDOT Research Report 0-4058-1 entitled "A Sketch Planning Tool for the Appraisal of Freight Modal Investments."

Innovations in containerization as well as changes in trade geography, due in part to NAFTA have directly influenced international trade movements. The deregulation of rail, trucking and air in the latter part of the twentieth century also had a large impact on freight movement.

Growth

During the past decade there has been enormous growth in the value and volume of freight moved. The total value of freight activity for all modes in 2002 was $8.5 trillion, an increase of 45 percent from 1993.[2] In 2002:

- The truck share accounted for 1,311 trillion ton-miles of freight, up 50 percent from 1993 volumes;

- The rail share accounted for 1,199 billion ton-miles, an increase of 27 percent over 1993 volumes;

- The water share accounted for 323 billion ton-miles, an increase of 19 percent over 1993 volumes.[3]

Globalization

The increased globalization of trade has changed the way in which freight systems operate. As the philosophy of many industries has changed from inventory-supply based to just-in-time demand based processes, traditional distribution systems no longer meet customer needs. Transportation patterns have become more complex as smaller, more frequent shipments become the trend. In addition US international trade has more than doubled from $891 billion in 1990 to $2,068 billion in 2001.[4]

Containerization

The containerization trend has had a large impact on the international movement of goods and on freight logistics in general. Not only are more goods being moved, they are increasingly being moved in containers. In 1980, the Port of Houston moved 300,395 twenty-foot equivalent units (TEUs), compared with 1,437,585 in 2004.[5] In addition, as the size of ships has grown to accommodate increasing numbers of containers, ports around the world have been forced to invest in newer terminals and yard cranes which can handle large volumes of containers. As a result of these changes, there has been a reduction in the cost of transporting containerized

goods. The container innovation has also allowed for more efficient transfers between modes; containers can easily be moved from ship to railcar to truck without unloading the cargo.

Geography

Historically trade routes within the United States were focused on moving goods in east-west patterns, mainly from the East Coast inland. However, the North American Free Trade Agreement (NAFTA), signed in 1994, has increased the need for north-south trade routes spanning from Mexico to Canada.   In 2004 alone, 6.9 million trucks and 2 million rail cars crossed the border from Canada to the United States[6] and 4.5 million trucks and 675,000 rail cars crossed the border from Mexico to the United States. Of the crossings from Mexico, 1.4 million used Laredo, and the I-35 corridor as a gateway.[7] In addition, with the emergence of China and India as major exporters of goods to the United States, intermodal facilities along the West Coast have increased in importance, but trade routes have not necessarily changed.

Deregulation

The deregulation of rail, air, and trucking in the 1980s not only led to a reduction in prices but also allowed companies the flexibility to change their service routes and their business structures. Changes in service routes resulted in new routes being established or older routes being abandoned. The railroads abandoned or sold almost 91,000 miles of rail line during this period, resulting in the emergence of distinct rail corridors.[8] Rail companies also began a complex series of mergers which resulted in the 36 Class I railroads that existed in 1980 to consolidate into the seven[2] that exist today.[9] In the case of trucking companies deregulation allowed the entry of many new companies into the market. The number of interstate trucking companies increased from 15,000 in 1976 to more than 500,000 in 2000.[10]

OBJECTIVE

Given the changes in the freight industry, it has become increasingly necessary for transportation planners to look to modes other than traditional highways as solutions for

---

[2] The seven US Class I railroads are: Burlington Northern Santa Fe Railway (BNSF); CSX Transportation (CSX); Grand Trunk Corporation, which is the US operation of Canadian National (CN); Kansas City Southern (KCS); Norfolk Southern (NS); Canadian Pacific (CP); and Union Pacific (UP).

congestion and other transportation problems. However, public agencies have been challenged to demonstrate and contrast the benefits of these modal investments with traditional highway spending.

In 2002 the Texas Department of Transportation (TxDOT) contracted the Center for Transportation Research at The University of Texas at Austin to develop a sketch planning methodology to quantify and evaluate the benefits associated with multimodal freight investments. During the first phase of the project (2002-2003) a spreadsheet based tool, entitled Multimodal Analysis Freight Tool (MAFT), was developed. The objective of the tool is to provide a framework based in cost benefit analysis which can be used to determine the societal benefits of intermodal investments, specifically managed lane facilities, railroads and barges. The tool is structured to compare different modal investments to a specified base case alternative. The methodology uses five categories of benefits: (1) travel time benefits, (2) vehicle operation cost savings, (3) agency operation cost savings, (4) safety benefits, and (5) emissions benefits and weighs them against the construction, capital and maintenance costs associated with a given alternative.

The second phase of this research, which was conducted during 2004 and 2005, has the following objectives:[3]

- Further develop MAFT to accurately consider the rail and barge modes;

- Collect cost and industry data for both the rail and barge modes;

- Undertake a sensitivity analysis, looking at the models used in MAFT and determine which input values are most critical;

- Develop and critically examine case studies involving the rail and barge modes;

- Examine the oversimplifications which exist within the tool due to its sketch planning nature and identify possible solutions.

ORGANIZATION OF THE REPORT

Chapter 2 discusses the development of MAFT which occurred during phase two of the project. Background information about the tool, including which models are embedded in the

---

[3] The TxDOT project also included the following deliverables: a ten page research report, a training manual which outlined how to use MAFT and a training seminar, lead by the research team which would instruct TxDOT personnel on how to use MAFT.

tool and why they were chosen, is presented. The data collection process that was undertaken, including a description of the data manipulation that was needed to obtain useful input values, is described. In addition, a detailed description of the changes that were made to the tool is included. Chapter 3 outlines the rail case study that was developed and Chapter 4 outlines the barge case study that was developed. Each chapter includes a description of the input values and an analysis of the results, which contains a sensitivity analysis. Chapter 5 contains observations about MAFT, including limitations and oversimplifications of the tool due to its sketch planning nature. A discussion of how said limitations can affect the results that are obtained for a project is included. Chapter 6 outlines the strengths of the tool and provides a brief summary of the research as well as some recommended further steps.

2: MULTIMODAL ANALYSIS FREIGHT TOOL

BACKGROUND

The Multimodal Analysis Freight Tool (MAFT) is a sketch planning tool, which uses cost-benefit analysis to evaluate the benefits of alternative modal investments. Cost-benefit analysis is used to compare the societal benefits to the costs of a particular project; using the same base year, a comparison of the monetary costs and benefits is made and a ratio can be determined. There are four accepted methods for comparing costs and benefits: the net present value of the project, the internal rate of return, the benefit cost ratio, and the payback period. MAFT uses both the net present value and the benefit cost ratio to compare the specified modal investments.

Costs and benefits are considered over the benefit period of the project – the useful life of the investment. The analyst must specify the benefit period during analysis and fro any investment with a longer life, a residual value will be calculated. In addition to considering the useful life of a project, the timing of costs and benefits must also be considered. MAFT uses the end-of-year principle which assumes that all transactions occur on the last day of the year. Therefore when the net present value of a project is determined it is expressed in terms of the last day of the analysis year (year zero).

In order to determine the net present value of a project in the analysis year a discount rate must be applied to costs and benefits incurred in the future. The discount rate reflects the time preference value of money. For instance, a dollar received today is worth more than a dollar received ten years in the future because it could be invested during that time period. Therefore, benefits and costs that are incurred now receive a higher weight than those that are incurred in the future. There is much debate about what the appropriate discount rate for infrastructure projects is, however the current federal highway tools use a discount rate of 7 percent.

The quantification of the benefits and costs associated with freight modal investments requires:

- information about the demand for the facility,
- the magnitude of the impacts, such as increased benefits or reduced costs,
- and values to quantify these impacts.

The costs should reflect the opportunity costs of the resource. In competitive markets, market prices can be used. However many costs related to transportation projects are not traded in the market and therefore are more difficult to quantify. For example, the construction cost of building a mile of roadway can easily be quantified based on market costs, but it is more difficult to quantify travel time savings or environmental air quality. The way in which these non-market costs are determined was discussed in the findings from phase one of this project. Please refer to Research Report 0-4058-1 for more information on this topic.

The next section explains the models that were used in MAFT to calculate the costs and benefits.

MODELS

This section is in essence a summary of the information contained in Chapter 4 of Research Report 0-4058-1 entitled "A Sketch Planning Tool for the Appraisal of Freight Modal Investments". For additional information about the models embedded in MAFT, the reader is referred to this report.

Costs

MAFT considers three categories of costs: land acquisition costs, construction costs and operations and maintenance costs. Note that equipment acquisition costs for the rail and barge modes, including locomotives, rail cars, pusher tugs, and barges, is considered in the operations and maintenance costs section.

Land Acquisition Costs

Land acquisition costs refer to the costs associated with purchasing the right-of-way on which the transportation facility will be built. The amount of land required will depend on the facility being constructed as well as minimum design standards. The total land acquisition cost is determined by multiplying the cost of the land by the amount of land required.

Construction Costs

Construction Costs can vary widely based on the type of facility being built. Terrain, existing use of the land, and availability of materials all have a large influence on the overall

construction costs. The total construction costs are calculated by multiplying the cost of construction (per mile) by the total length of the roadway, track or channel being constructed.

Operations and Maintenance Costs

Operations and maintenance costs include costs associated with maintaining the roadway, track or channel. Costs such as paving the roadway, replacing a section of rail track, or dredging a channel should all be considered. The operations and maintenance costs for a particular mode are calculated by adding all of the costs associated with maintenance operations and then multiplying the overall cost by the length of the roadway, track, or channel. For the rail and barge modes the equipment acquisition costs are also assessed in this calculation.

Benefits

MAFT considers five categories of benefits: travel time benefits, vehicle operations benefits, agency operations benefits, safety benefits, and emissions benefits.

Travel Time Benefits

Generally, travel time savings are considered to be the most important benefit associated with highway projects. Travel time savings calculations can be separated into two sections: the calculation of time saved and the calculation of value of time. These two values are multiplied to determine the dollar amount of travel time savings.

The amount of time saved is calculated by finding the difference in the average speed of traffic before and after the facility is built. The average speed equations embedded into MAFT consider the initial AADT, the induced traffic, and the estimated capacity of the highway. The initial AADT is specified by the analyst based on the existing conditions of the roadway. The induced traffic is calculated based on travel time elasticities which are specified in the assumptions section of the tool. The road capacity is calculated using the geometric characteristics of the roadway identified by the analyst and the equations in the Highway Capacity Manual (HCM)[11]. In addition, the average delay is calculated using the equations developed by Margiotta et al. (1994)[12], which predict the overall daily delay. The model is composed of three different calculations: one for weekdays, one for weekends, and one for all days.

The value of time is the dollar amount an hour of time is worth. For non-commercial vehicles MAFT considers trips that have one of two purposes: business trips, which include work trips and work-related trips; and personal trips, which include family, school, church, social, and recreational trips. Personal trips are further segregated into local and intercity trips, where intercity trips are assigned a higher value of time. MAFT considers the value of time for commercial vehicles based on the cost of the vehicle, the cost of labor and the cost of inventory, as well as the number of hours a vehicle is in service during the year. The value of time for the rail and barge modes is based on the same costs; however it is assumed that the average crew for a locomotive is two people and a barge is nine people.

Vehicle Operations Benefits

Vehicle operations benefits are considered to be the out-of-pocket cost savings of the road user. MAFT considers the fuel, maintenance and tire costs of a vehicle. MAFT calculates fuel consumption for both commercial and non-commercial vehicles as well as locomotives and pusher tugs based on values from the United States Department of Energy.[13] The maintenance and tire costs for the highway modes are taken from a study done at the Minnesota Department of Transportation.[14]

Agency Operations Benefits

Agency operations benefits refer to the maintenance cost savings accrued by the transportation agency if trucks are diverted to managed lanes or other modes. Highways are typically built to handle a predetermined number of equivalent standard axle loads (ESALs) before reconstruction is needed. If trucks are diverted to other facilities then the design life of the highway is increased. The model developed by Luskin et al. (2001)[15], to determine maintenance costs is embedded in MAFT. The model considers the climatic region, number of ESALs, and type of road when calculating the maintenance costs. The agency cost savings due to the truck traffic diversion from the base case to one of the modal alternatives is determined by subtracting the maintenance costs after the investment from the maintenance costs in the base case scenario.

Safety Benefits

Safety impacts can be broken into one of three categories: number of fatalities, number of injuries, and the cost of property damage only accidents. Safety benefits can then be separated into two sections: the calculation of number of accidents of each type and the value of safety. Multiplying these two values together gives the dollar amount of safety benefits.

For the highway modes, MAFT uses the models developed by Zhou and Sisiopiku (1997)[16] to calculate the casualty and property damage only accident rates based on vehicle miles traveled. Then the number of casualty accidents is divided into injury accidents and fatality accidents using the data developed by Chang and Mannering (1999)[17]. For the rail alternative, average accident rates published by the Federal Railroad Administration (2003)[18] were embedded in the tool. The accident rates for the barge mode were derived from the National Transportation Statistics (BTS 2002)[19].

The National Safety Council estimates the monetary costs of fatality, injury and property damage only accidents. The costs associated with loss of life and injury accidents are used across all modes while the costs associated with property damage only rates are different for each of the modes.

Emissions Benefits

MAFT considers hydrocarbons (HC), carbon monoxide (CO), and nitrous oxides (NOx) for all four modes. However, it is unable to calculate particulate matter (PM-10) emissions for the barge mode. Emissions benefits can be separated into two sections: the calculation of the amount of emissions and the application of a value for pollutant damage. Multiplying these two values together gives the dollar amount of emissions benefits.

The vehicle emission equations embedded in MAFT are based on the Environmental Protection Agency's (EPA) MOBILE 5 model. The MOBILE 5 equations consider the age of the vehicle, vehicle miles traveled, and average travel speeds. MAFT assumes that all passenger vehicles and trucks have the same median age, respectively. This information, along with the national average for vehicle miles traveled was collected from data published in "National Transportation Statistics" (BTS 2002)[20]. The average speed is calculated using speed correction

factors developed by Brzezinski et al. (1999)[21]. The rail and barge emissions rates are also taken from EPA data (1997)[22,23].

The values used to quantify damages produced by pollutants in MAFT are taken from Small and Kazimi (1995)[24]. These values are estimated using the relationship between increases in pollutants and mortality.

The next section explains the data collection process that was undertaken to determine industry and cost data for the rail and barge modes.

DATA COLLECTION

Obtaining cost data from industries is generally very difficult due to confidentiality issues. This is especially true in industries, such as the railroad industry, where companies have historically operated in highly competitive markets with narrow profit margins. During the first phase of this project, some cost data was obtained from Burlington Northern Santa Fe Railway, however strict confidentiality agreements prevented the information from being embedded in the tool or provided to TxDOT for use. In addition, during this phase of the project, cost data could not be obtained for the barge mode.

As a result of this lack of data, although the rail and barge sections of the tool were developed, considerable uncertainty surrounded the results, especially for the barge mode where the tool could not be tested at all. During the second phase of the project, the research team was tasked with obtaining industry data for both of these modes which could be used in MAFT. The values obtained will provide the TxDOT staff with reference values when approached by rail or barge companies to undertake non-traditional highway investments.

Based on the experiences during the first phase of the project, the research team felt that neutral organizations may be the best source of industry data since they would not have the same confidentiality concerns. The ability of such groups to collect national level data was also considered to be an asset as the values obtained would be averages rather than very specific figures. Since the data obtained is intended to be used as reference or "ballpark" figures, national averages are appropriate and could even be more useful since MAFT is concerned with order of magnitude calculations.

Association of American Railroads

The Association of American Railroads (AAR) is a national level organization whose members include all of the Class I railroads in the United States, Canada, and Mexico. The organization is based in Washington. As an advocate for rail industry, the AAR collects industry data from each of the Class I railroads on a yearly basis.

Using the contacts of the Research Supervisor at the Association of American Railroads, the research team was able to obtain both cost data and industry characteristics for the Class I freight railroads that operate in the United States.

United States Army Corps of Engineers

The United States Army Corps of Engineers (Corps) is comprised of both civilian and military members. One of the major responsibilities of the Corps, in addition to providing engineering support to the military, is the planning, designing, building, and operating of water resources and other civil works projects in the United States. This includes navigation, flood control, environmental protection and disaster response for all of the inland waterway systems in the United States.

The Research Supervisor also had contacts at several barge companies, which operate within the Houston Ship Channel and the Gulf Intracoastal Waterway in Texas. However, due to the non-traditional business model of Ingram Barge and the reluctance of companies to part with confidential cost information, the team was referred to the Corps, who was able to provide barge industry data at the national level.

Data Manipulation

The AAR produced and provided the research team with a "University of Texas at Austin Data Request Report" (see Appendix X). The data did not need to be manipulated in any way and were embedded in MAFT "as is".

The Corps provided the research team with the following reports:

- Economic Guidance Memorandum 05-06: FY 2004 Shallow Draft Vessel Operating Costs

- Lock Performance Monitoring System Summary by Division/District: January – December 2000 and 2001

- Lock Characteristics Operational Statistics – 1999

The relevant data were extracted from these reports and embedded in MAFT. Most of the cost data came from the first report listed. Data regarding industry information such as average number of barges per tow came from the second and third reports listed. The data needed to be manipulated as it varied widely depending on the characteristics of the waterway being traversed. The data embedded in MAFT thus pertains only to those vessels operating on the Gulf Intracostal Waterway within Texas. See Appendix X for the data that was finally included in MAFT.

The following section outlines the improvements that were made to MAFT during phase two of this research project.

IMPROVEMENTS TO MAFT

Several improvements were made to MAFT. TxDOT expressed some concern with the user friendliness of the tool and therefore extensive changes were made to the appearance of the tool. In addition important changes were made to the formulas embedded in the tool. Two major changes concerned how initial truck traffic needs to be specified and how the time value of money is considered. In addition a review of all of the formulas embedded in MAFT was undertaken to check for any errors.

Develop User Interfaces

TxDOT was concerned that a consultant would have to be contracted to apply the tool, defeating the purpose of having a sketch planning tool. MAFT was originally developed as a Microsoft Excel application. As such, the tool was easy to understand and completely transparent to the user. However, it was somewhat daunting as each worksheet contained upwards of 100 rows. In addition, helpful hints were included as comments, which were limited in length, in the spreadsheets. This resulted in some confusion about certain input requirements.

The research team thus proposed that the platform be changed to Microsoft Access, but this idea was abandoned because not all potential TxDOT users of the tool had access to the software and there was some concern about the general unfamiliarity of many people with the program. A

standalone application was subsequently discussed, but the desire of TxDOT to save, print and export the results precluded the development of a standalone application. Finally the decision was made to retain the Microsoft Excel platform, but to code interfaces to make the tool more user-friendly, especially when entering the data.

Changes to the Data Input Interface

The most important change was the development of a user-friendly data input interface. Rather than a spreadsheet workbook the user is now presented with a series of forms which outline the analysis process. The forms outline the five step analysis process, sequentially:

1. Input general assumption information;
2. input general project information;
3. choose which modes to analyze;
4. input project information for each mode;
5. run the tool.

Figure 2.1 shows the "home page", from which the analyst works. For each project, the analyst should follow steps one through five to ensure that MAFT runs correctly. Each button on the homepage leads the analyst to another form where data is requested. Once the data is entered and the submit button is clicked on a given input form, the user is brought back to this main page, where he/she can then proceed to the next step. Any confusion concerning what analysis process with the Phase 1 version of MAFT is therefore eliminated.
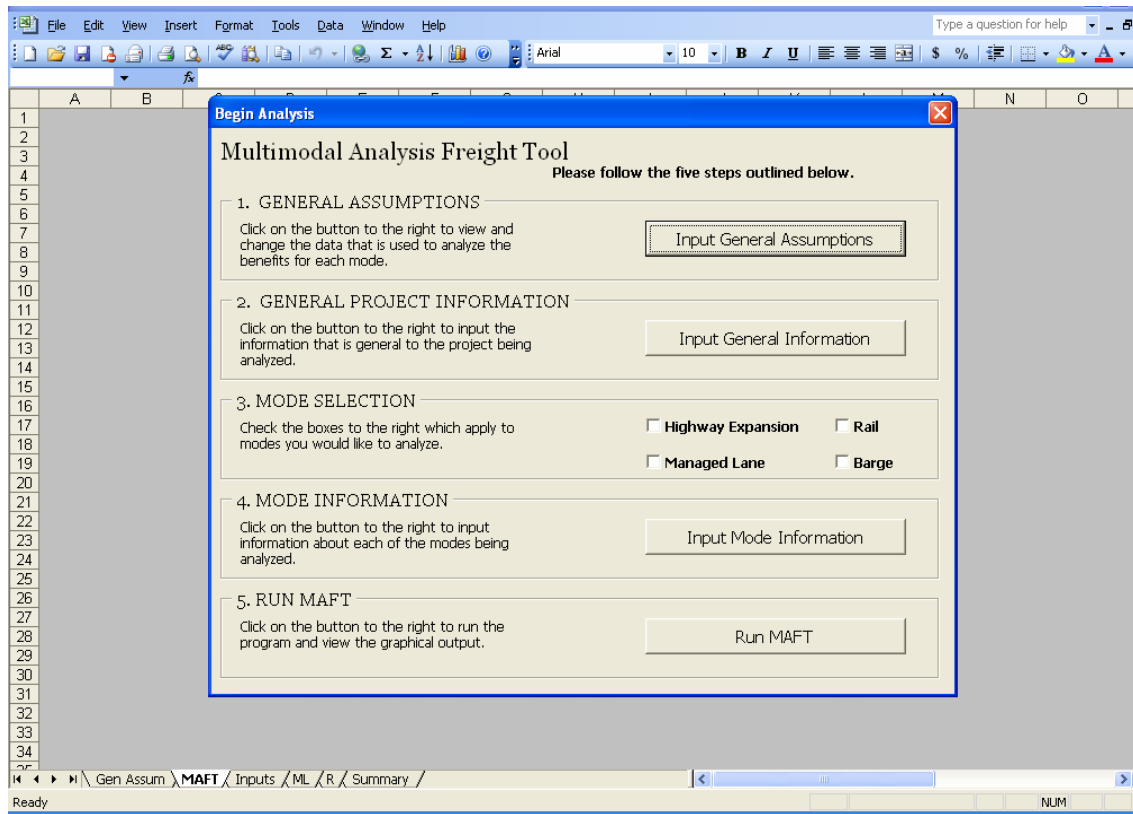
Figure 2.1 – Main User Interface in MAFT

The user interface developed allows the analyst to input information in to forms rather than into the cells of the spreadsheet itself. Figure 2.2 shows the "before" view of the input screen, as it appeared at the end of phase one. Note that information concerning all four modes was entered on the same page. Figure 2.3 shows an "after" view of the input screen for the managed lane construction costs. The area circled in Figure 2.2 corresponds to the data that is requested in the form in Figure 2.3.
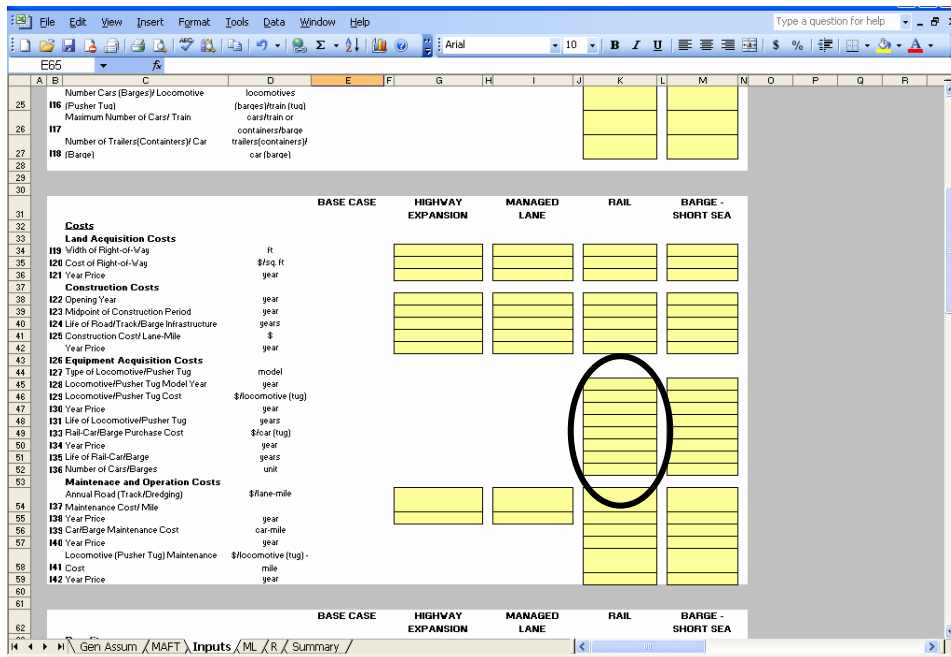
Figure 2.2 – "Before" View of the Input Interface

TxDOT also requested that the clarity of the input labels, which identified data being requested, be addressed. Because information for all four modes was entered in different columns along the same row, the label had to apply to all four modes. Therefore the labels could become quite complex. For example, "Number of Cars (Barges) / Locomotive (Pusher Tug)," related to the number of rail cars per locomotive for the rail mode and the number of barges per pusher tug for the barge mode. This was quite confusing at times. This concern was eliminated in the new version of MAFT since the data for each mode is entered in separate screens.
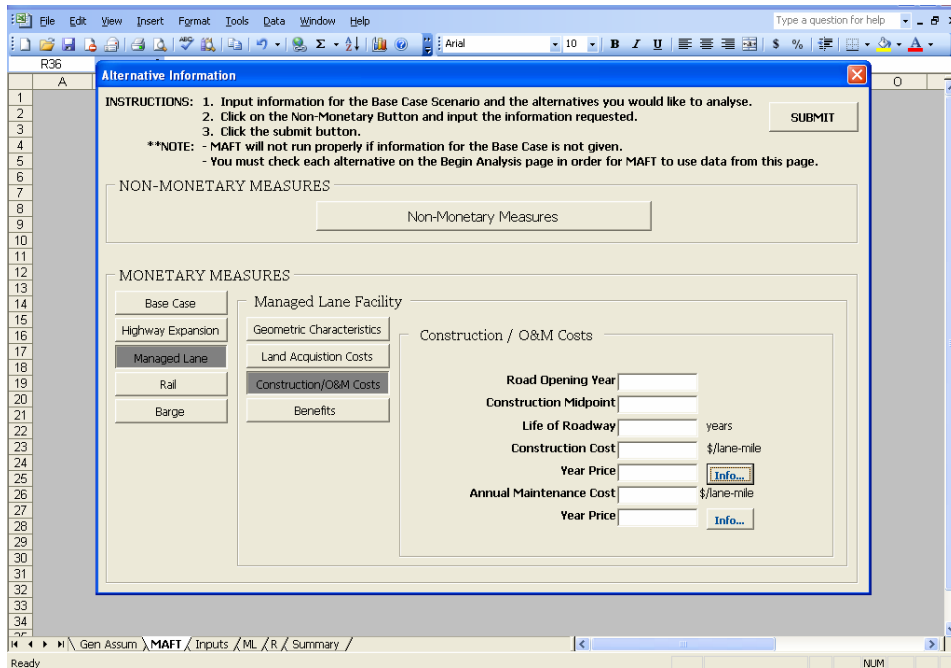
Figure 2.3 – "After" View of the Input Interface

In addition, defining the input variables was somewhat problematic. The previous version of MAFT did not provide information beyond the data label. In the new version, macros allow for information buttons to define and explain the input data required. See Figure 2.4 for how the discount rate is defined.

Information buttons were also used to embed the industry characteristics and cost figures for the rail and barge modes. Figure 2.5 shows an example of industry data for the rail mode.

In addition, it was decided to hide the worksheets that contain the calculations. The analyst can work from the homepage to input the required information and view the results. Should the analyst want to view the worksheets that contain the formulas, calculations and values, they can easily be revealed. This maintains the transparent nature of the tool when desired but hides it when considered unnecessary.
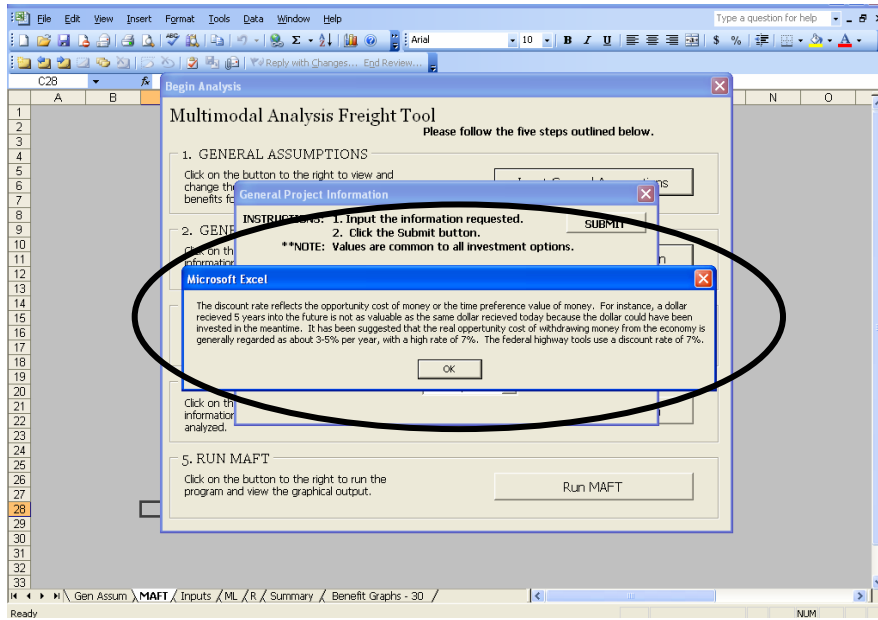
Figure 2.4 – Discount Rate Definition in MAFT
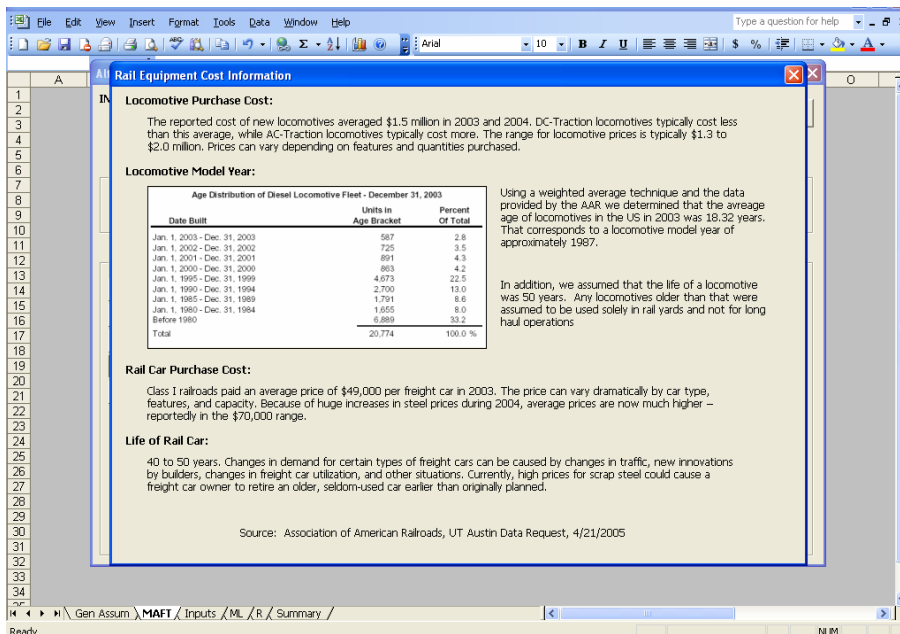
Figure 2.5 – Rail Industry Information presented in MAFT

Changes to the Output Interface

The output interface was also improved. The output interface has two components: (a) a table summarizing the net present value of the costs and benefits associated with each mode and

(b) a series of graphs which illustrate the annual benefits over the benefit period specified. The first version of MAFT always graphed a 30-year benefit period, regardless of the specified benefit period. This was problematic for the analyst interested in the results over a shorter benefit period. The improved version of MAFT addressed this problem and the graphs now show the benefit period specified.

Truck Traffic

The first version of MAFT was unable to assess a situation in which there was 100 percent truck traffic on a roadway, for instance a tolled truck facility. The analyst had to enter at least 0.01 percent passenger vehicles for the tool to run correctly. This was due to an error in many of the formulas: non-truck average annual daily traffic instead of total average annual daily traffic was used to calculate the induced demand the speed on the facility. This resulted in the induced demand and speed being zero if no passenger vehicles used a facility, the situation in a dedicated truck facility. The problem was resolved by replacing the non-truck average annual daily traffic with the total average annual daily traffic (calculated by summing truck and non-truck AADT). Even if the non-truck average annual daily traffic is zero, the truck AADT would have a positive value and MAFT could correctly assess the traffic patterns.

Time Value of Money

The consumer price index (CPI) is used to express all costs in analysis year dollars. In other words, if construction costs are expressed in 1998 dollars and the analysis year is 2000, the CPI is used to account for inflation. However, the first version of MAFT allowed for the entry of only one CPI for all input values. Therefore, if construction costs were in 1998 dollars and maintenance costs were in 1995 dollars both would have been converted using the same specified CPI. This is incorrect, however, requiring a year and a CPI for each cost input would have required too many input values. This problem was addressed by removing the CPI as an input value. All costs have to be entered in analysis year dollars. The analyst is thus required to look up the correct CPI for the year in question and convert the dollar amount accordingly. While this adds to the amount of work that must be done before MAFT can be run, it ensures that monetary values are as accurate as possible.

20

Operations and Maintenance Costs

Due to the lack of data concerning the rail and barge modes during the first phase of the project, the Operations and Maintenance Costs for both the rail and the barge modes were oversimplified. Once data became available it was evident that the calculations did not properly account for cost savings associated with diverting trucks to these modes. For the rail and barge modes, the cost savings should consider both the fuel and maintenance savings due to the diversion of trucks. the savings due to maintenance no longer being performed on the trucks. The first version of MAFT considered the reduction in fuel consumption, but did not consider the maintenance costs. The latter can be significant depending on the length of the route and the number of trucks diverted. The costs saved due to maintaining the diverted trucks was calculated and is now considered in the calculation of the operations and maintenance impacts.

Formula Review

All the formulas embedded in MAFT were reviewed to check for minor errors and redundancies. Minor errors were found in several cases. There were instances where formulas did not properly assess if the value of a cell should be zero. Also, there were cases where a cell was referenced incorrectly or a formula was copied incorrectly across a row.

Examples of this type of error include:

- The formula for the number of empty containers was structured to assume that all containers were empty on the return trip. This was incorrect as the percentage of empty returns was a required input value. The formula was changed to reference the input value.
- The number of daily rail and barge trips was calculated differently for the first year and then all subsequent years. This was changed so that the formula was consistent across all years.

These minor corrections were difficult to detect, because of the large number of formulas within MAFT, but were easy to correct and generally involved only minor corrections.

During this review, several redundancies were also found. For example, several input values were never used in subsequent calculations and several data inputs in the general assumptions section were never referenced. Examples of this include:

- The input value for percentage empty containers returning on barges was never used.

- The general assumptions worksheet included emissions information for both line-haul and switch rail locomotives. However, never referenced the switch data. These values were eliminated from the tool to avoid confusion.

This chapter has provided background information on MAFT. It described the methods used to develop the tool including the models that are embedded in the worksheets. It also discussed the data collection process and the improvements that were made during phase two of the research. Chapter 3 contains a case study which compares the rail and managed lane modes.

3: RAIL CASE STUDY

DESCRIPTION

A private developer has approached the Multimodal office at TxDOT because they are proposing to build a managed lane (i.e. truck toll road) facility from Brownsville to the Oklahoma border.

The existing route between Brownsville and the Okalahoma border is 650 miles and involves traveling on more than one interstate. Over the 650 miles there is an average of two lanes in each direction and the posted speed limit is 60 miles per hour. Interchanges are spaced every 0.7 miles and the lanes are standard 12-foot lanes with 10-foot shoulders. While the route does cross urban areas the majority of the trip would be considered rural and over level terrain.

The managed lane facility would reduce the trip to 600 miles and increase the speed limit to 70 miles per hour. The facility would add one truck lane in each direction and interchanges would be spaced every 20 miles (0.05 interchanges/mile). Assume standard 12-foot lanes and 10-foot shoulders.

The alternative is a rail line that is 620 miles long. If TxDOT invested a moderate amount to improve this corridor, it is expected that the trains could average 25 miles per hour, including terminal times, resulting in a total time of 25 hours. Also, 900 rail cars will need to be purchased to handle the volume of cargo.

The existing average annual daily traffic is 12,000 vehicles per day, of which one quarter are trucks. Truck traffic is expected to grow at an annual rate of 3.2%, vehicle traffic at a rate of 2.5%, and rail traffic at a rate of 2.8%.

The following table shows the expected timeline for planning and construction:

Table 3.1 – Rail Case Study Project Schedule

	Managed Lane	Rail
Analysis Year	2000	2000
Construction Begins	2004	2015
Construction Midpoint	2017	2020
Opening Year	2030	2025
Construction Period	26 years	10 years

INPUT VALUES

Please refer to Appendix X to see the input values for this case study. The next section reviews the results of this case study.

RESULTS

The results are divided into a summary section and then a section for each of the societal benefits.

Summary

From Table 3.2, it is evident that the managed lane alternative has a much higher net present value ($819 million) compared to the rail alternative ($178 million). Also, for every dollar invested in the managed lane facility society stands to gain a benefit of $1.49, while in the case of the rail alternative society gains $1.23.

It is also evident that the costs associated with the rail alternative are almost half that of the managed land facility, due in part to the fact that no land acquisition costs are incurred for the rail alternative. Upgrading the rail track is also far less expensive than constructing the managed lane facility. Maintaining the rail system over the analysis period will, however, cost marginally more ($15 million) than maintaining the managed lane facility.

Table 3.2 – Tabular Summary of Rail Case Study Results

Summary of Alternatives

Benefit-Cost Ratio and Net Present Value

	Highway Expansion	Managed Lane	Rail	Barge/Short Sea
Costs				
Land Acquisition Costs	$ -	$ 47,520,000.00	$ -	$ -
Construction Costs	$ -	$ 1,609,556,460.00	$ 744,000,000.00	$ -
Maintenance and Operation Costs	$ -	$ 31,834,814.32	$ 46,801,965.61	$ -
Total Costs	$ -	$ 1,688,911,274.32	$ 790,801,965.61	$ -
Benefits				
Travel Time Benefits	$ -	$ 126,162,964.65	$ (1,030,226,133.32)	$ -
Vehicle Operating Cost Savings	$ -	$ 90,874,890.73	$ 917,409,458.17	$ -
Agency Cost Savings		$ 2,515,716,036.82	$ 1,046,951,516.54	$ -
Safety Benefits	$ -	$ (221,367,561.50)	$ 12,812,070.44	$ -
Emissions Benefits	$ -	$ (3,230,374.74)	$ 22,169,949.33	$ -
Total Benefits	$ -	$ 2,508,155,955.95	$ 969,116,861.15	$ -
Benefit/Cost ratio	-	1.49	1.23	-
Net Present Value	$ -	$ 819,244,681.63	$ 178,314,895.54	$ -

Non-Monetary Score

|	Highway Expansion	Managed Lane	Rail	Barge/Short Sea
Noise and Aesthetics	0.0	3.0	4.0	0.0
Community Issues	0.0	0.2	0.1	0.0
Accessablity and Reliability	0.0	7.2	7.2	0.0
The Environment	0.0	9.6	8.0	0.0
Regional Economic Development	0.0	16.0	16.0	0.0
Total Non-Monetary Score	0.0	36.0	35.3	0.0

It is also evident that the costs associated with the rail alternative are almost half that of the managed land facility, due in part to the fact that no land acquisition costs are incurred for the rail alternative. Upgrading the rail track is also far less expensive than constructing the managed lane facility. Maintaining the rail system over the analysis period will, however, cost marginally more ($15 million) than maintaining the managed lane facility.

The negative travel time benefit dominates the NPV calculation for the rail alternative and the outcome of the analysis (see Figure 3.1). As can be seen from Table 3.2, the net present value of the travel time benefits for the managed lane facility is approximately $126 million compared to a negative travel time benefit for the rail alternative of approximately $1 billion. This is largely attributable to the fact that the average speed for the rail alternative was 25 mph, while the base case and managed lane alternative resulted in average speeds of approximately 60 mph and 70 mph, respectively.

Societal Benefits
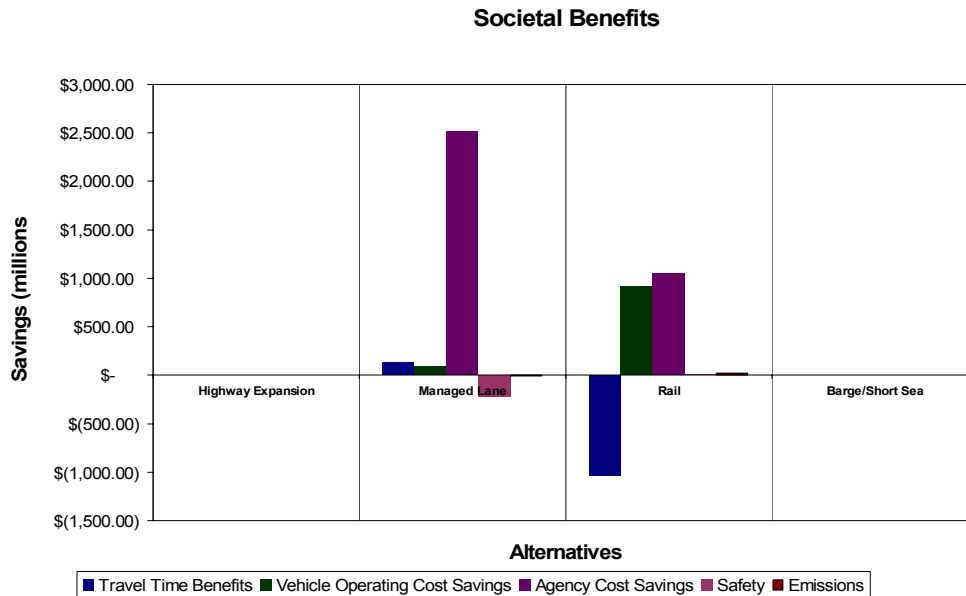
Figure 3.1 – Graphical Summary of Rail Case Study Results

The rail alternative results in substantially higher vehicle operating cost, safety, and emissions benefits. The benefits in terms of vehicle operating costs are higher - by a factor of nine - for the rail alternative compared to the managed lane alternative. This is not unreasonable given that diverting trucks to a managed lane facility will not reduce the fuel consumed or the cost of labor. On the other hand diverting trucks to the rail alternative will reduce vehicle operating costs as each rail car can move three truck trailers and each train can move 100 or more rail cars, resulting in reduced fuel consumption and labor costs. For the same reason, the rail alternative also exhibits higher emissions benefits - i.e., the emissions impacts from the locomotives will be less than the emissions from the diverted trucks. The negative safety benefits associated with the managed lane alternative can largely be attributed to the higher speeds and traffic characteristics of the managed lane alternative. It is important to note that accident severity increases with increased travel speeds and higher truck volumes.

Finally, the managed lane alternative results in higher agency cost savings by a factor of two and a half. This is largely attributable to the fact that twice as many trucks are diverted to the managed lane facility as to the rail alternative.

26

Figure 3.1 illustrates the costs and benefits presented in the Table 3.2. From the figure it is evident that agency cost savings are by far the largest benefit for the managed lane alternative while travel time presents the largest negative benefit for the rail alternative.

Travel Time Benefits

Figure 3.2, illustrates the annual travel time savings associated with each alternative relative to the base case over the analysis period specified. The travel time savings are largely influenced by the level of congestion experienced in the base case. Because congestion did not pose a significant concern in the base case and because average rail speeds, including terminal times, were considerably slower (25 mph) than the base case (60 mph) any traffic diverted to the rail alternative and any subsequent growth in rail traffic experience an increase in travel time. By the same token, the managed lane alternative exhibits consistent and modest benefits until congestion worsens in the base case around 2050, when a significant upturn in travel time savings are realized.
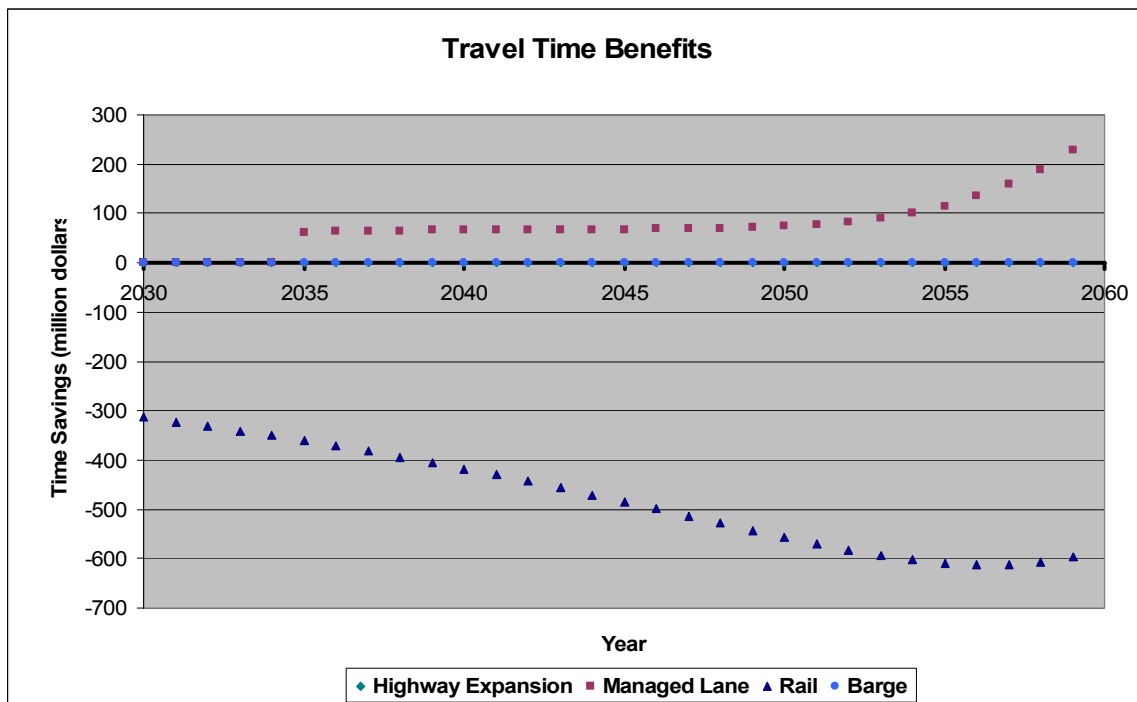
Figure 3.2 – Rail Case Study Travel Time Benefits Graph

Vehicle Operations Benefits

Figure 3.3 illustrates the annual vehicle operating cost savings for each alternative over the analysis period. The discontinuities for the rail alternative in 2033, 2041, 2048, 2053, and 2058 illustrates when it became necessary to add an additional train trip to handle the growth in traffic. The analyst is required to provide the maximum number of rail cars per train. As soon as one rail car more than the maximum is needed to move the traffic, an additional train trip is added. As can be seen from Figure 3.3, the vehicle operating costs savings for the rail alternative were reduced slightly each time an additional train trip was added. As discussed earlier, the vehicle operating cost savings for the managed lane alternative are more modest, largely because traffic is diverted from the base case to the managed lane facility, resulting predominantly in modest reductions in diesel consumption.
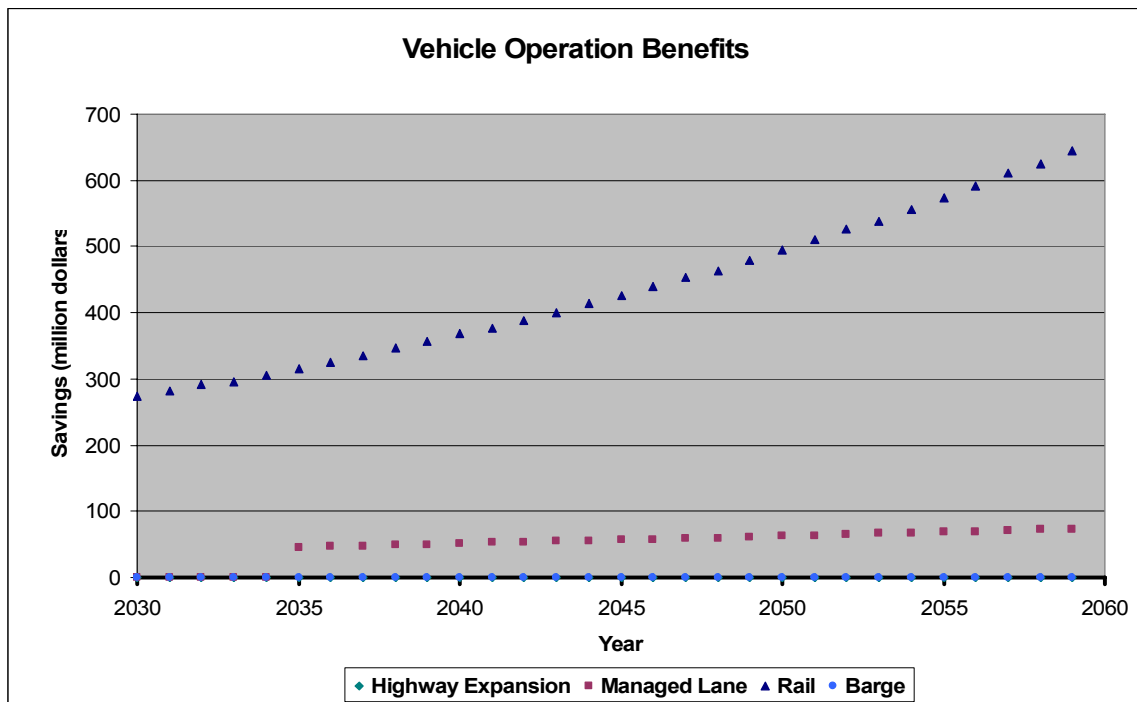
Figure 3.3 – Rail Case Study Vehicle Operations Benefits Graph

Agency Operations Benefits

Figure 3.4 illustrates the savings in maintenance costs incurred by the transportation agency associated with each alternative relative to the base case condition. It is evident that over the thirty year benefit period, both of the alternatives will produce maintenance cost savings. The

managed lane alternative will, however, produce much larger savings that grow non-linear. The driving factor in this calculation is the number of ESALs on the roadway. The number of ESALs is directly related to the number of trucks diverted either to the managed lane or the rail alternative. Simply stated, diverting trucks reduces the number of ESALs on the roadway thereby reducing the maintenance costs to the agency. The difference in the savings produced by the two alternatives is explained by the fact that twice as many trucks are diverted to the managed lane alternative. The difference in the slopes of the two lines (the managed lane increases at a faster rate) is explained by the fact that annual truck traffic growth is larger than annual rail traffic growth.
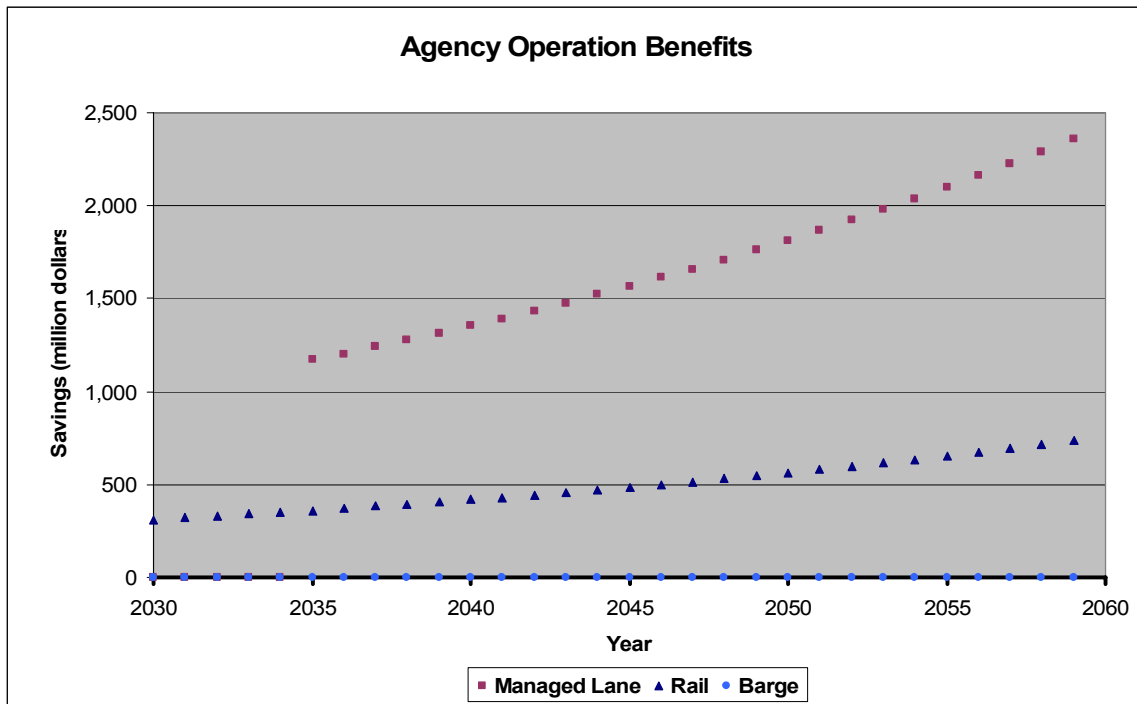
Figure 3.4 – Rail Case Study Agency Cost Savings Graph

Safety Benefits

Figure 3.5 illustrates the estimated annual safety benefits associated with the managed lane and rail alternatives relative to the base case over the analysis period. As indicated earlier, the significant negative annual safety benefits associated with the managed lane alternative can be attributed to the higher travel speeds and the traffic characteristics of the managed lane alternative. The graph also illustrates that the rail alternative presents marginal safety benefits

that reduce each year until 2042. From 2043 to 2055, the safety benefits are negative and by 2056 the safety benefits become positive again. The safety impacts for rail is a function of the rail accident rates assumed, the number of train miles calculated, and the highway conditions with the rail investment relative to the base case.
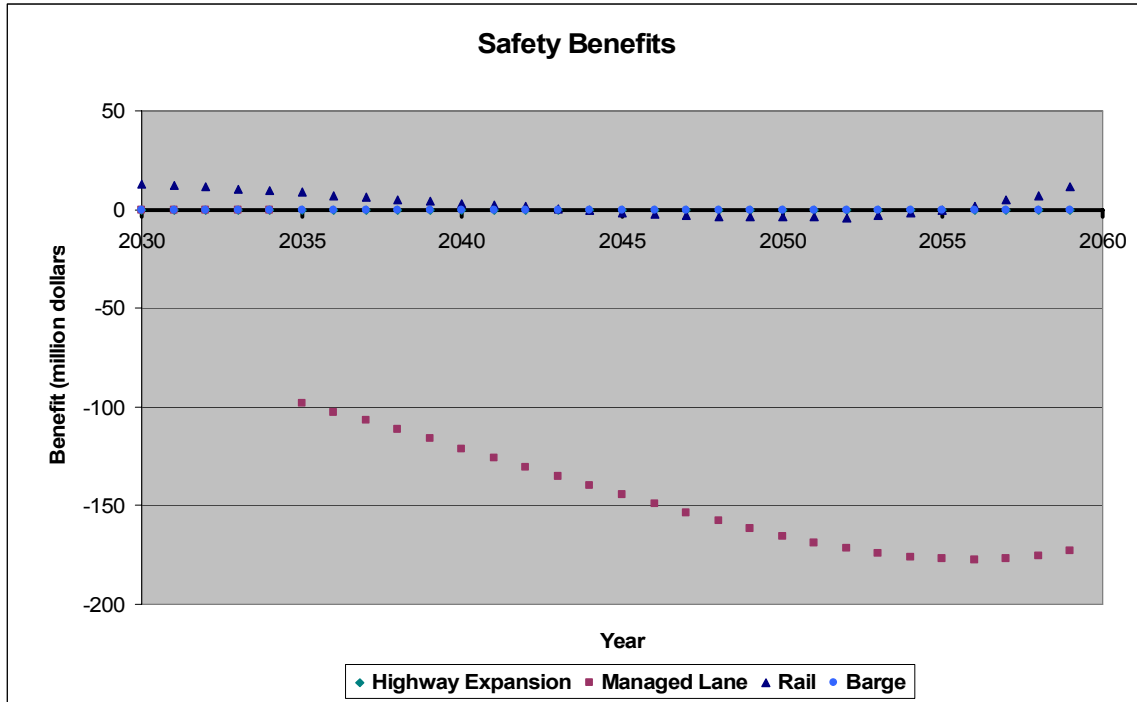
Figure 3.5 – Rail Case Study Safety Benefits Graph

Emissions Benefits

Figure 3.6 shows the annual emission benefits for the rail and managed lane alternatives over the analysis period. It is evident that the emissions benefits associated with the rail alternative are significantly higher than for the managed lane alternative, because each train removes several hundred trucks from the highway whereas the managed lane facility in essence only redistributes the trucks on the system. In addition, as the highway facility becomes more congested around 2050 and travel speeds reduce, the emissions rates and ultimately costs increase, resulting in increasingly negative emissions benefits.

30
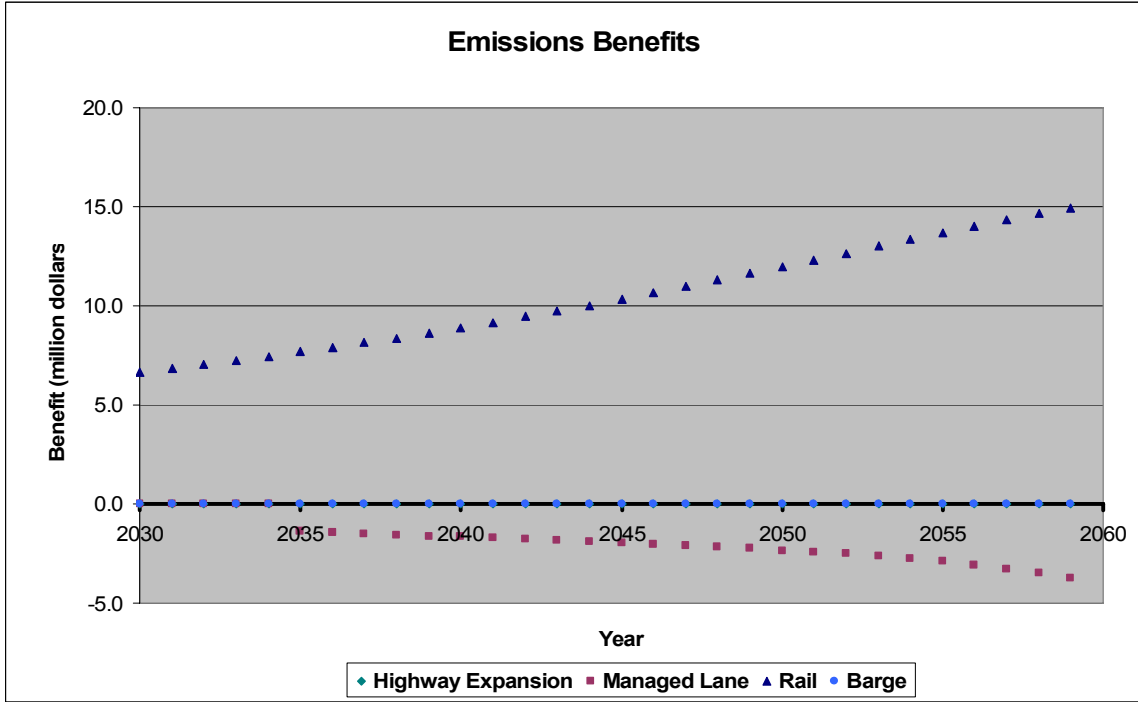
Figure 3.6 – Rail Case Study Emissions Benefits Graph

This chapter has outlined the rail case study that was run in MAFT. The results were presented and discussed. Chapter 4 discusses the second intermodal case study, which looks at the barge mode.

4: BARGE CASE STUDY

DESCRIPTION

A prominent discount store is building a large distribution center near the Port of Houston. They have approached the Multimodal office at TxDOT because they would like to either build a managed lane facility for trucks traveling from the ship terminals to the distribution center or dredge a channel in Galveston Bay so that containers can be moved by barge.

The existing route is 20 miles with two lanes in each direction and it is estimated that travel speeds are 50 miles per hour. Assume that interchanges are every 0.7 miles and that there are standard 12-foot lanes and 10-foot shoulders. The route is through an urban area and over level terrain.

The managed lane facility would reduce the trip to 15 miles and increase the travel speed to 65 miles per hour. The facility would add one truck lane in each direction and there would be no interchanges along the route. Again, assume standard 12-foot lanes and 10-foot shoulders.

The barge route will reduce the trip to 7 miles. It is expected that the barges will average 8 miles per hour, including all terminal times, completing the trip in approximately 70 minutes. It is expected that 25 barges will need to be purchased to handle the volume of cargo.

The existing average annual daily traffic is 1,000 trucks per day; assume that the vehicle traffic per day is negligible. Truck traffic is expected to grow at an annual rate of 1.0%, vehicle traffic growth is zero and barge traffic is expected to grow at a rate of 1.0%.

The following table shows the expected timeline for planning and construction:

Table 4.1 – Barge Case Study Project Schedule

	Managed Lane	Barge
Analysis Year	2005	2005
Construction Begins	2008	2008
Construction Midpoint	2012	2012
Opening Year	2015	2015
Construction Period	8 years	8 years

INPUT VALUES

Please refer to Appendix X to see the input values for this case study. The next section reviews the results of this case study.

RESULTS

The results are divided into a summary section and then a section for each of the societal benefits.

Summary

From Table 4.2, it is evident that both the manage lane and barge alternatives will impose a net cost on society of approximately $1.4 million and $76 million, respectively. It is also clear from the benefit/cost ratio that for every dollar invested, a societal return of $0.96 will be realized in the case of the manage lane alternative. In the case of the barge alternative, however, the negative benefits far outweigh the modest investment required.[4] Also, the maintenance and operation costs of the barge alternative (mainly dredging costs) are much lower than the managed lane alternative.

---

[4] It was assumed that no land acquisition or construction costs would be required for the barge alternative.
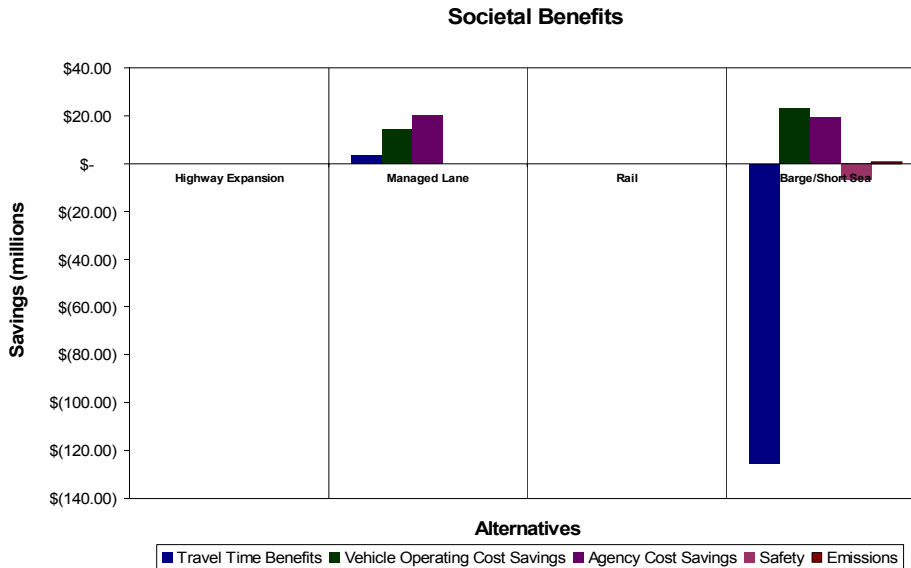
Table 4.2 – Tabular Summary of Barge Case Study Results

Summary of Alternatives

Benefit-Cost Ratio and Net Present Value

	Highway Expansion		Managed Lane		Rail		Barge/Short Sea	
Costs								
Land Acquisition Costs	$	-	$	1,267,200.00	$	-	$	-
Construction Costs	$	-	$	35,873,275.08	$	-	$	-
Maintenance and Operation Costs	$	-	$	2,629,300.42	$	-	$	52,777.86
Total Costs	$	-	$	39,769,775.50	$	-	$	52,777.86
Benefits								
Travel Time Benefits	$	-	$	3,607,992.65	$	-	$	(125,380,943.80)
Vehicle Operating Cost Savings	$	-	$	14,328,736.81	$	-	$	36,560,213.39
Agency Cost Savings			$	20,314,378.86	$	-	$	19,245,201.03
Safety Benefits	$	-	$	(10,932.14)	$	-	$	(7,149,436.32)
Emissions Benefits	$	-	$	90,638.21	$	-	$	724,470.50
Total Benefits	$	-	$	38,330,814.39	$	-	$	(76,000,495.21)
Benefit/Cost ratio		-		0.96		-		(1,440.01)
Net Present Value	$	-	$	(1,438,961.11)	$	-	$	(76,053,273.06)

Non-Monetary Score

	Highway Expansion	Managed Lane	Rail	Barge/Short Sea
Noise and Aesthetics	0.0	10.0	0.0	11.0
Community Issues	0.0	0.5	0.0	0.5
Accessablity and Reliability	0.0	9.6	0.0	9.6
The Environment	0.0	12.8	0.0	12.8
Regional Economic Development	0.0	8.0	0.0	10.0
Total Non-Monetary Score	0.0	40.9	0.0	30.0

Note that in the case of the barge alternative, it is the travel time penalty associated with barge movements that drives the calculations (see also Figure 4.1). The net present value of the travel time benefits for the manage lane facility is almost $4 million and -$125 million for the barge alterative. Given that the line haul time for the barge alternative was 1.15 hours (an average of 8 mph) while the base case allowed travel speeds of 50 mph, it is understandable that the barge alternative results in a negative travel time benefit.

The barge alternative, however, results in two and half times the vehicle operating and eight times the emissions benefits compared to the manage lane alternative. This is not unreasonable given that diverting trucks from the base case facility to the manage lane facility will not reduce the fuel consumed or the cost of labor. On the other hand, diverting trucks to the barge alternative will reduce both these costs since each barge can move the equivalent of 36 trucks and each pusher tug can move four barges. This results in comparatively significant reductions in the fuel required and thus ultimately a relative reduction in the vehicle operating costs and emissions.

Societal Benefits

Figure 4.1 – Graphical Summary of Barge Case Study Results

The agency cost savings are similar for both alternatives – approximately $20 million. This can be explained by the fact that a similar number of trucks will be diverted to the manage lane (95 percent of the base case trucks) and barge alternatives (90 percent of the base case trucks).

The managed lane alternative produces a marginal increase in safety costs to society – approximately $11,000 – compared to the base case. This can be attributed mainly to the increase in travel speed on the manage lane and the existing highway compared to the base case. In the case of the barge alternative, safety impacts are calculated as a function of tons moved by barge and the speed on the highway (i.e., "with barge alternative") compared to the base case condition (i.e., "without barge alternative"). The significant safety impacts are thus attributable to the increase in barge tonnage moved and the increase in highway travel speeds resulting from diverting 90 percent of the trucks to barges.

Travel Time Benefits

Figure 4.3 illustrates the annual travel time savings associated with each alternative relative to the base case over the analysis period specified. This graph clearly illustrates the negative travel time benefits imposed by the barges traveling at eight mph, which is considerably slower than the speeds in the base case and those anticipated for the manage lane alternative. It also illustrates the marginal travel time benefits for the manage lane alternative. Slightly higher

travel speeds on the manage lane facility combined with a slightly shorter trip are the main factors resulting in the marginal incremental travel time benefits.

Travel Time Benefits
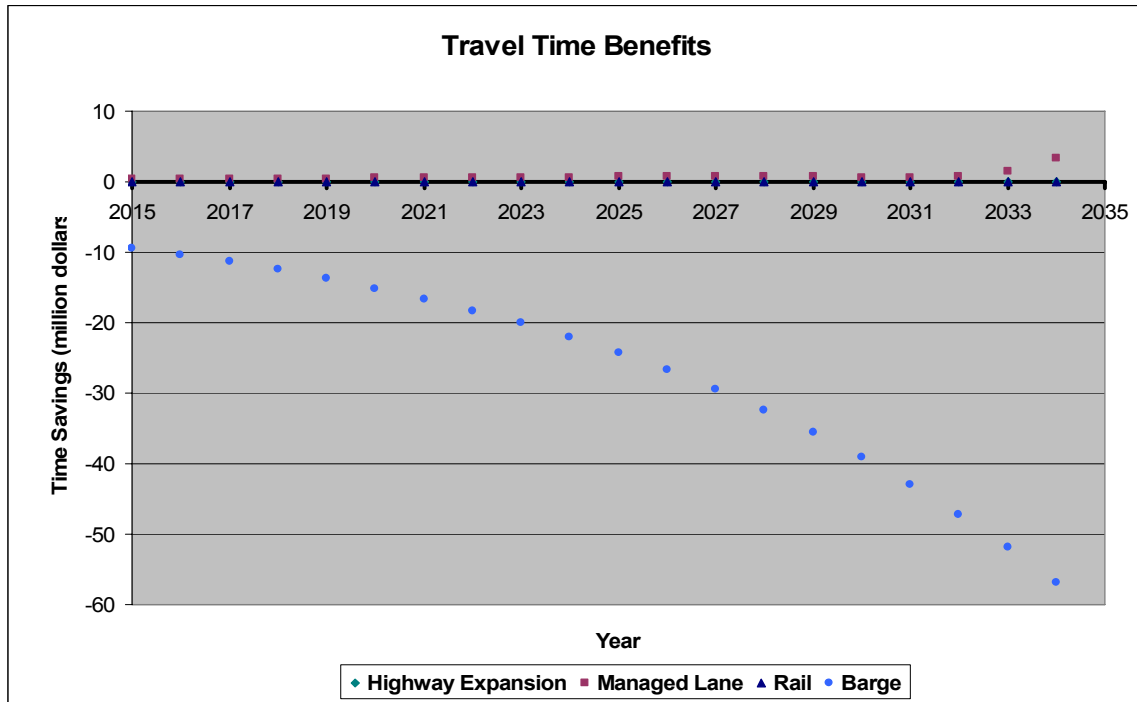
Figure 4.2 – Barge Case Study Travel Tim Benefits Graph

Vehicle Operations Benefits

The Vehicle Operations Benefits graph (see Figure 4.3) illustrates the annual operating cost savings for each alternative over the analysis period. As can be seen, both alternatives show increasing savings in vehicle operating costs over the analysis period. As explained before, the barge alternative results in larger savings because each pusher tug can move cargo equivalent to that moved by 144 trucks, resulting in savings in labor and fuel costs relative to the base case condition and manage lane alternative. The vehicle operation cost calculation for the manage lane alternative considers fuel consumed, labor, and maintenance and tire costs. The latter is calculated as a function of distance traveled. The slightly higher travel speeds given the manage lane alternative together with the shorter trip distances result in the illustrated vehicle operation cost benefits.
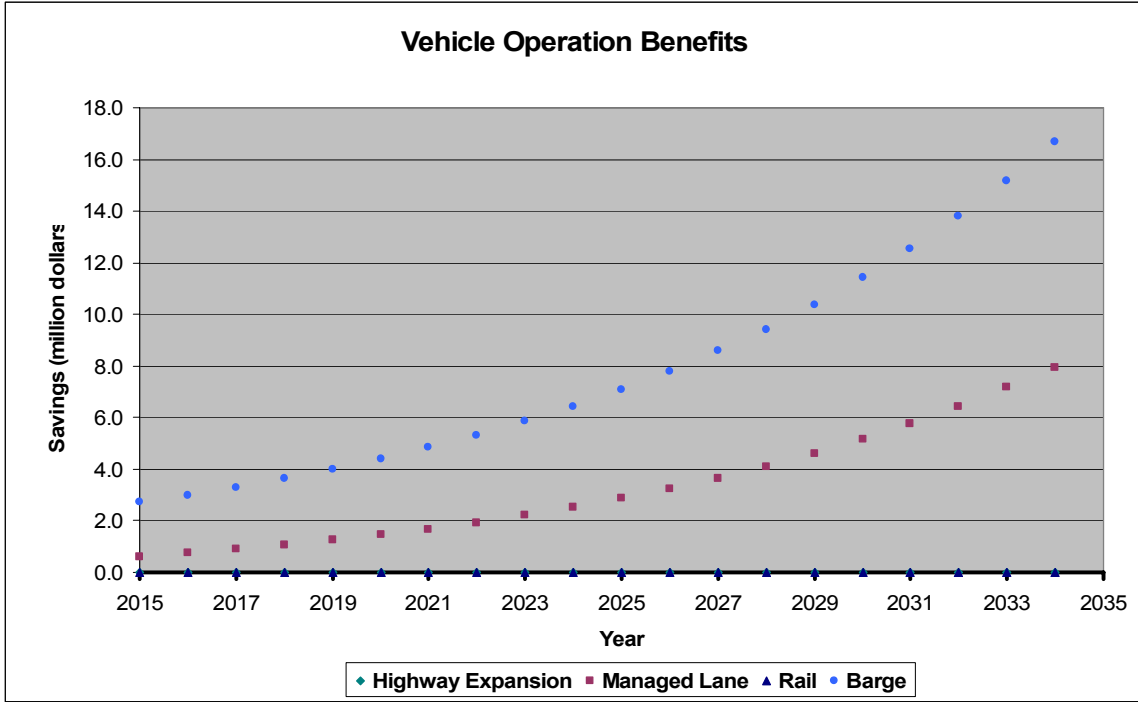
Figure 4.3 – Barge Case Study Vehicle Operations Benefits Graph

Agency Operations Benefits

Figure 4.4 illustrates the annual savings in maintenance costs to a transportation agency associated with each alternative relative to the base case condition. This graph highlights the fact that the two alternatives produce very similar maintenance costs savings over the analysis period. The fact that the manage lane results in slightly higher annual maintenance costs savings is largely attributable to the fact that 5 percent more of the initial truck traffic is diverted to the manage lane compared to the barge alternative.
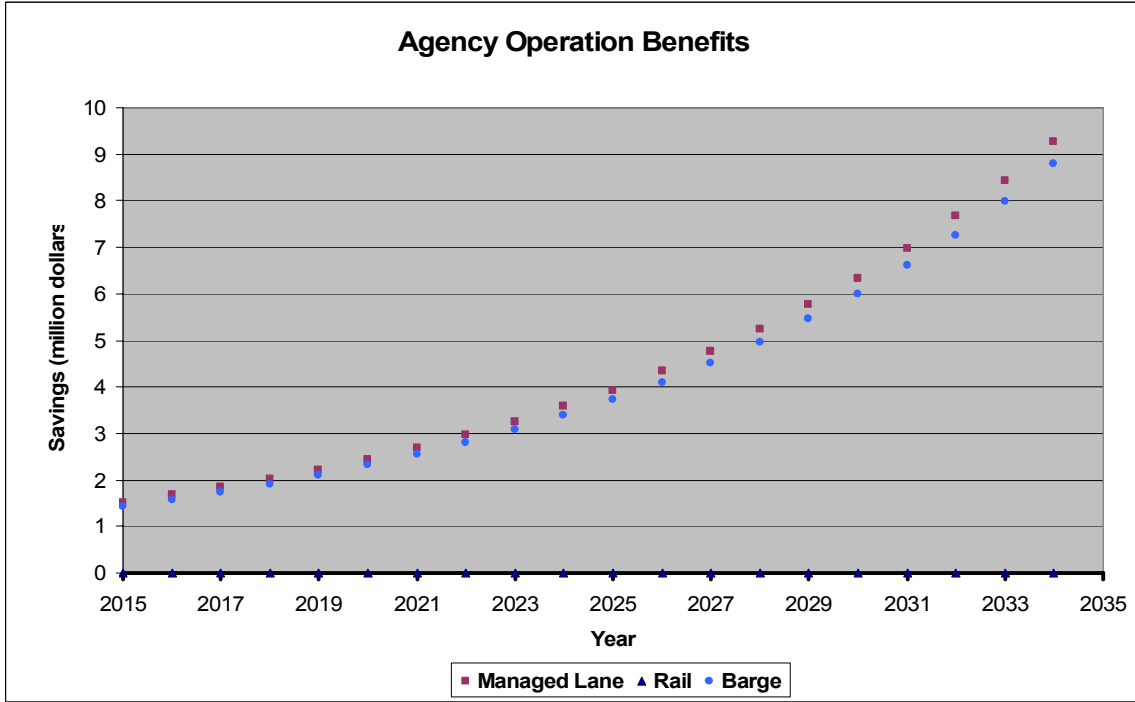
Figure 4.4 – Barge Case Study Agency Operations Benefits Graph

Safety Benefits

Figure 4.5 illustrates the calculated annual safety benefits associated with the manage lane and rail alternatives relative to the base case over the analysis period. As observed earlier, the manage lane alternative produces a marginal increase in safety costs to society – approximately $11,000 – over the analysis period compared to the base case. This can be attributed mainly to the increase in travel speed on the manage lane and the existing highway compared to the base case. As mentioned earlier, the safety impacts for the barge alternative are calculated as a function of tons moved by barge and the speed on the highway (i.e., "with barge alternative") compared to the base case condition (i.e., "without barge alternative"). Therefore as the tonnage moved by barge increases, the safety costs to society associated with barge incidents will increase. Finally, diverting 90 percent of the initial truck traffic to barges will result in higher highway speeds, further aggravating the safety impacts of the barge alternative.
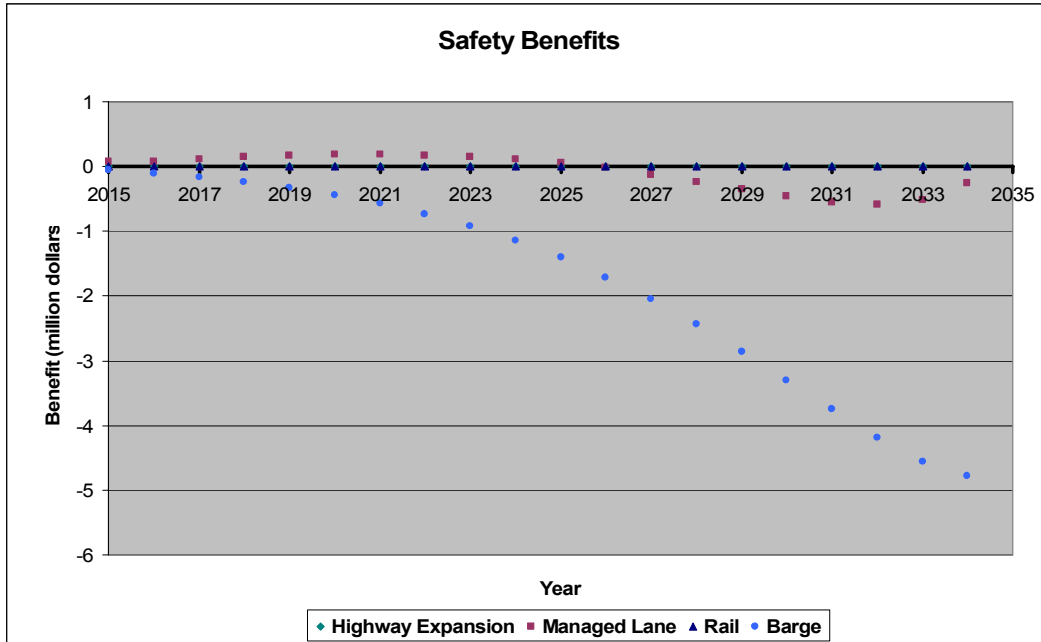
Safety Benefits

Figure 4.5 – Barge Case Study Safety Benefits Graph

Emissions Benefits

Figure 4.6 shows the annual emissions benefits for the rail and managed lane alternatives over the analysis period. From the graph, it is evident that the emissions benefits associated with the barge alternative is significantly higher compared to the manage lane alternative. This is because each barge removes 144 trucks from the road, whereas the manage lane facility in essence only redistributes the trucks on the system. In the case of the manage lane facility, the shorter trip length partially results in the emissions benefits illustrated in Figure 4.6.

Emissions Benefits
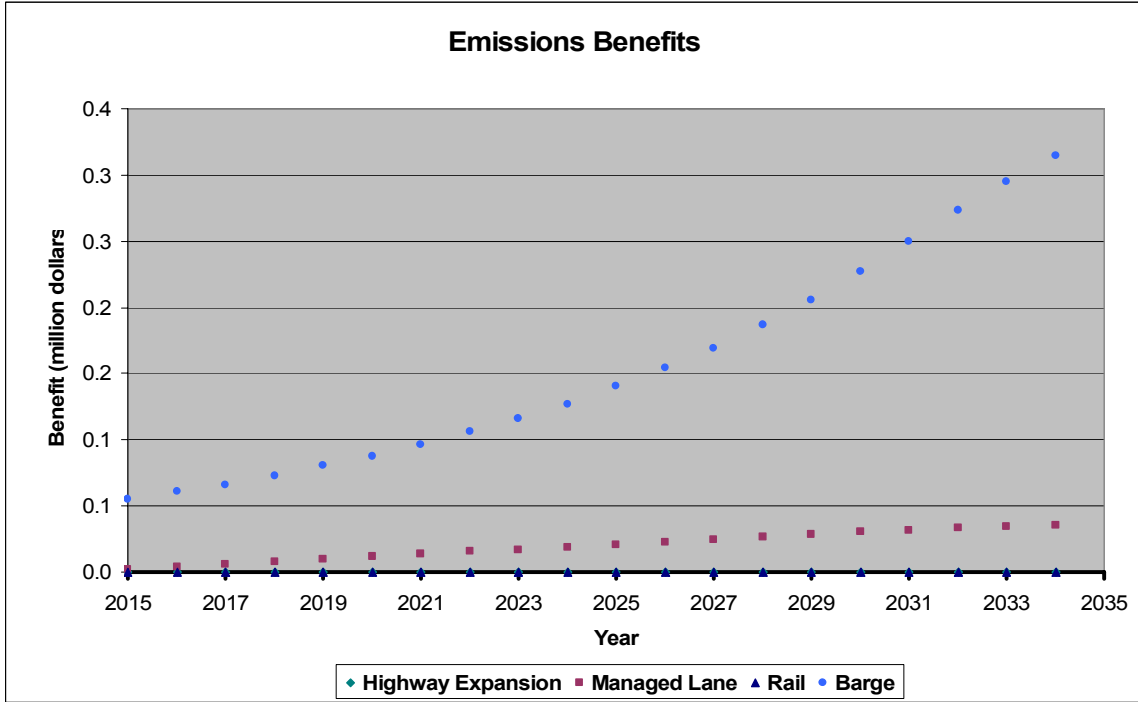
Figure 4.6 – Barge Case Study Emissions Benefits Graph

This chapter has outlined the second intermodal case study that was run in MAFT. The results were presented and discussed. Chapter 5 contains a sensitivity analysis which looks at which input values have the largest impact on the results.

5: SENSITIVITY ANALYSIS

Because of the uncertainties surrounding the assumptions, values and magnitudes in a benefit cost analysis it is useful to conduct a sensitivity analysis. Sensitivity analysis is useful to determine the values which are most influential, i.e. a change in the variable will result in a large change in the net present value. A sensitivity analysis was performed on MAFT using the TopRank software published by the Palisade Corporation.

TOPRANK SOFTWARE

TopRank is add-on software which can perform automated sensitivity analyses within Microsoft Excel spreadsheets. It determines which variables have the greatest influence on the results of a spreadsheet application. TopRank automatically scans the spreadsheet to identify influential factors and then varies them to determine how the results will change. To use TopRank, an output cell is selected and the software will assess all of cells that affect the result of the chosen output cell.

PROCEDURE

A separate sensitivity analysis was run on the case studies discussed in Chapters 3 and 4. In the first run of sensitivity analyses, the net present value of the project was used as an output cell. However, this was problematic because the results showed that the way in which the costs and benefits were discounted was the most influential factor. Since the process of discounting is the critical component of a benefit cost analysis, this information was not very helpful in determining which input values drive the results. Thus, it was determined that looking at the factors that drive each of the benefits, separately would be a better way to perform the analysis.

The process of analysis was to run a separate sensitivity analysis on each of the case studies. Within each case study a separate sensitivity analysis was run on the five benefits for each of the modes. For example, a sensitivity analysis was run using the output cell for the Travel Time benefits in the Managed Lane mode of the Rail Case Study. For each case study there were essentially ten separate sensitivity analyses.

In almost all of the sensitivity analysis that were run the timing of the project, usually the opening year of both alternatives considered in the case study as well as the benefit period and

the analysis year, were some of the most, if not the most influential factors. In an effort to avoid repetition, the following sections will not discuss them. However it should be noted that the timing of the project has a large effect on the benefits realized and that it should not be dismissed.

This chapter will look at the results of the sensitivity analysis performed by the TopRank software. The results of the rail case study will be presented first, followed by the results of the barge case study.

RAIL CASE STUDY

The rail case study compares a managed lane facility to a rail improvement. For each of the five benefit categories the managed lane component is discussed and then the rail component is discussed.

Travel Time Benefits

For the managed lane travel time benefits, the Margiotta delay equations drive the results. For a positive ten percent change in these coefficients, the travel time benefits can be altered by more than 200 percent. These coefficients are part of a model and therefore the analyst cannot change them until new research is performed, but this shows the importance that having a good delay model has on tools such as MAFT.

The line haul time for the rail mode is also the critical input for this calculation. A ten percent change in the line haul time can change the travel time benefits for the rail component by approximately 25 percent.

Vehicle Operations Benefits

The most important factor in the vehicle operations benefits for the managed lane is the length of the link. Both the length of the base case link and the proposed managed lane link are important. This reflects the fact that benefits associated with alternatives in MAFT are measured in comparison to the base case. The analysis shows that increasing the length of the base case link will result in larger operations benefits for the managed lane component but that the reverse is true for the length of the managed lane link.

The analysis for the vehicle operations benefits in the rail component of the case study showed that the length of the base case link and the managed lane link, as well as the number of trucks diverted to the rail mode are also influential. The vehicle operations benefits for the rail component are based on the fuel and maintenance costs of the rail operations as well as the reduction in these same costs that would result in the base case scenario. Therefore, the 16 percent and 27 percent changes that a ten percent change in the managed lane length of link and base case length of link produce respectively are not unreasonable. The number of trucks diverted to the rail mode will obviously be influential in this calculation as an increase in trucks will result in an increase in the operating costs of the rail component and well as a decrease in the operating costs of the base case component.

Agency Operations Benefits

The analysis on the agency operations benefits for the managed lane component of the case study showed that the number of lanes in the base case scenario produces significant changes in the results. A ten percent change in the number of lanes will produce a 20 percent change in the agency operations benefits. This is a slightly misleading result since the analyst will not have control over the number of lanes in the base case (an existing roadway) and therefore cannot alter this input to produce better results. In addition, the number of ESALs per truck class is also influential. A positive or negative ten percent change in the number of ESALs will produce a 15 percent change in the agency operations costs for the managed lane component. The number of ESALs per truck class is one of the models embedded in MAFT and this shows that it is important for MAFT to be updated as new research becomes available.

For the rail component of the case study the agency cost savings are mainly composed of the reduction in maintenance costs due to the diverted trucks. The number of ESALs per truck class, the number of lanes in the base case scenario and the number of trucks diverted are all influential. A positive ten percent change in the number of lanes in the base case scenario will result in a 17 percent change in the agency operations benefits. A positive or negative ten percent change in the trucks diverted results in approximately a ten percent change in the agency operation benefits for the rail component.

Safety Benefits

The sensitivity analysis on the safety benefit calculation for the managed lane component showed that the influential factors are the length of the managed lane link and the number of trucks diverted to the rail mode. Given that the number of severe accidents (more costly accidents) is proportional to the number of trucks on the facility, it is not surprising that the diverted trucks input is influential in this calculation.

The sensitivity analysis for the safety benefits in the rail component of the case study shows that the most influential factors are the models predicting the severity of traffic accidents (based on truck involvement) and the average annual daily traffic. The safety information for the rail mode is based on statistics provided by the Federal Railroad Administration. However, for the highway modes, including the base case scenario, the crash rates are based on models. Again, since MAFT calculates benefits in relation to the base case, it is not unreasonable that elements which determine the safety costs in the base case can be most influential in this calculation.

Emissions Benefits

The most influential factors for the emissions benefits in the managed lane component were the posted speed on the facility, the Margiotta delay equations and the length of the managed lane link. The emissions benefits are based on the EPA Mobile 5 model, as discussed in Chapter 2. A base emissions rate is determined using specifics of the model and is then corrected for speed in MAFT. Therefore, the fact that a ten percent change in the speed on the roadway can result in either a doubling or a halving of the emissions benefits is not unreasonable. In addition, since MAFT calculates emissions in grams per mile and then converts to tons of pollutant over the length of the corridor, the significance of the corridor length is fairly large. The sensitivity analysis shows that a positive or negative ten percent change in the length of the managed lane facility can produce approximately a 75 percent increase or reduction in the emissions benefits for the managed lane component , respectively.

For the rail component of the case study, the most influential factors in the emissions benefits the Margiotta delay equations, length of the base case link and the number of trucks diverted from the base case to the rail mode are also influential. In a similar manner to the safety benefits it appears that the emissions costs in the base case scenario (dependant on the length of the link)

can drive the overall benefits associated with the rail component since the rail benefits are measured against the base case.

BARGE CASE STUDY

The barge case study compares a managed lane facility to a new barge route. For each of the five benefit categories the managed lane component is discussed and then the barge component is discussed.

Travel Time Benefits

For the managed lane component of the barge case study, the sensitivity analysis shows that the Margiotta delay equations are the most significant factor. In addition, the annual truck traffic growth and the posted speed limit in the base case and the managed lane components are also very influential. A positive ten percent change in the managed lane posted speed limit will result in a 30 percent increase in the managed lane travel time benefits.

For the barge component of this case study the most influential factors are the line haul time for the barge trip and the number of trucks diverted from the base case to the barge mode. A ten percent decrease in the line haul time resulted in an 11 percent increase in the travel time benefits for the barge component. Additionally, as would be expected, an increase in the number of trucks diverted to the barge mode will reduce the travel time benefits for the barge component.

Vehicle Operations Benefits

The analysis of managed lane vehicle operations benefits shows that the length of the managed lane link and the base case link as well as the annual truck traffic growth in the base case are the most influential factors. A ten percent change in the annual truck traffic growth in the base case results in a 16 percent change in the vehicle operations benefits for the managed lane component. Correct information concerning traffic growth on the existing facility is very important.

For the barge component, the same three factors that drove the managed lane calculations drive the barge vehicle operations benefits. In this case the annual traffic growth in the base case

has a slightly more significant role as a ten percent change results in a 20 percent change in the barge vehicle operations benefits.

Agency Operations Benefits

The sensitivity analysis on the managed lane agency operation benefits show that the length of the link and the number of lanes in the base case scenario are the most influential factors. As with the rail case study, this is slightly misleading since the number of lanes in the base case (an existing roadway) cannot be changed. So while this is a very influential factor the analyst will be unable to use it as a means of increasing the agency operations benefits. The number of ESALs per truck class is also an influential factor, however, again as with the rail case study, this is part of a model and shows only that it is important to update MAFT as new information becomes available.

For the barge component the sensitivity analysis shows that the most influential factors in the agency operations benefits calculations are the length of the link in the base case and the number of trucks diverted from the base case to the barge mode. A positive ten percent change in the number of trucks diverted will result in approximately a positive ten percent change in the overall barge agency operations benefits.

Safety Benefits

The analysis shows that for the managed lane safety benefits in this case study the most significant factors are the average annual daily traffic in the base case and the percentage of trucks in that traffic. The input values for the safety models embedded in MAFT which determine the number of fatalities in crashes involving trucks versus crashes without truck involvement are also influential.

For the barge safety benefits in this case study, the analysis shows that the tons moved by barge is the most influential factor. A ten percent change in the tonnage moved by barge will result in a 17 percent change in the safety benefits realized in the barge component of the case study. The accident rates embedded in MAFT for the barge mode are based on million tons moved by barge which explains the influential nature of this input value. In addition, the annual barge traffic growth and the number of trucks diverted from the base case to the barge mode are also significant.

Emissions Benefits

For the managed lane component of this case study the analysis shows that the most significant factors in the emissions benefit calculations are the Margiotta delay equations and the initial percentage of trucks in the base case traffic. Additional the base case average annual daily traffic and the number of trucks diverted from the base case to the managed lane facility are also influential. A ten percent reduction in the number of trucks diverted to the managed lane facility will result in a 20 percent reduction in the emissions benefits realized by the managed lane component.

For the barge component the emissions benefits are most influenced by the Margiotta delay equations, the length of the corridor in the base case scenario and the annual truck traffic growth in the base case scenario. The number of trucks diverted from the base case scenario to the barge alternative is also significant. A ten percent reduction in the number of trucks diverted results in approximately a ten percent reduction in the emissions benefits for the barge component.

SUMMARY OF RESULTS

The sensitivity analyses performed on the rail and the barge case study show that the characteristics of benefit cost analysis and the model parameters embedded in the tool which drive the results in MAFT.

For all five benefit categories, regardless of the alternative being assessed or the case study, the input values affecting the timing of the project were very significant. The characteristics of benefit cost analysis are such that the timing of a project is often very significant due to the discounting of values to an analysis year.

The model parameters embedded in MAFT in the general assumptions sections drive many of the calculations in MAFT. These values are "best estimates" and their significance in the results shows the importance of updating MAFT as more research becomes available.

While the input values are influential in certain cases, it is often values that the analyst cannot control, such as the number of lanes in the base case scenario that are most significant. While the input values are important in terms of running MAFT successfully, small changes in these values will not produce very much of a change in the overall results of the project. This is

not to say that projects with very different characteristics will return the same results, but to say that a small or moderate change in one or more input value will not have a profound effect on the results produced by the tool.

6: CONCLUSIONS

STRENGTHS OF MAFT

The sketch planning nature of MAFT is its greatest strength. Projects can be evaluated in a timely manner and order of magnitude results can be obtained to make basic comparisons between modes. In addition, the completely transparent calculations and the relatively few data inputs needed to run MAFT keep the tool from being cumbersome and difficult to use. Lastly, the ability to print, save and export the data and results make it easy for the analyst to share results.

Sketch Planning Nature

The sketch planning nature of MAFT is one of its greatest strengths. The tool is very easy to use and provides a user friendly format which leads the analyst through a five step process to obtain results.

MAFT provides immediate, order of magnitude results which will allow TxDOT analysts to make basic "first order" comparisons between modal investments. This will enable TxDOT to determine if further analysis about investing in non-traditional modes is necessary or if the costs far outweigh the benefits. The tool is spreadsheet based thus easy to use. In addition, Microsoft Excel is widely available, providing a convenient platform.

Transparent Calculations

Although the worksheets in which calculations are made are hidden from view when the tool opens, these worksheets can be made visible if the analyst so desires. Therefore the calculations are completely transparent and the analyst can view the equations used to obtain not only each output value but each value used to obtain said output value.

Quantity of Input Data

MAFT requires relatively few input values for each mode. The geometric characteristics of the project, construction and acquisition cost information, as well as the data used to calculate the impacts are required. The rail and barge modes require slightly more input data as the rolling

stock and barges must be considered as well. However, the tool is not data intensive. This is one of the main advantages of MAFT, because obtaining the input values can often be the most time consuming part of running such a model.

Printing, Saving and Exporting Capabilities

Since MAFT is based in Microsoft Excel, it has all the capabilities of a regular spreadsheet. The output summary and graphs can be printed and saved or exported to a word processing program. Therefore, results from MAFT can easily be reported. In addition, the input values and calculations for each mode can also be printed from their spreadsheet format. The analyst can then look at the data for each year within the benefit period if necessary.

This section has outlined some of the strengths of the tool. Based on the results of this research the next section outlines some recommendations for future research and what can be done to improve the tool even further.

OVERSIMPLIFICATIONS IN MAFT

Traffic Calculations

O-D Pairs

The tool assumes that all traffic has the same origin and destination, which means that the traffic patterns are more of an average. In assuming that all traffic originates at mile one of the corridor and is destined for mile x, MAFT does not consider the added congestion that occurs in and around urban areas, where large numbers of vehicles will use the corridor for short trips. The result of this is that there is an unclear picture of what the traffic pattern at any one point on the corridor looks like. Although an oversimplification, it might not be critical, given the uncertainty that surrounds even passenger vehicle models.

Rail and Barge Capacity

MAFT only has the capability to consider current users of the highway and managed lane modes. Current users on the rail and barge infrastructure are not considered. The benefits associated with the rail and barge modes are thus underestimated. The graph in Figure 6.1 shows the way in which benefits are calculated in MAFT. D is the demand for transportation at various costs, C. S is the supply of transportation options, where S is the base case and S' is the

transportation improvement. Q is the quantity of transportation purchased. Area A represents the time and cost savings to current users of the facility and area B represents the benefits to new users of the facility.

For the highway expansion and managed lane portions of MAFT both areas A and B are evaluated. However, for the rail and barge investments, only area B is considered. MAFT assumes there are no current users of these modes. The underestimation of the benefits to current users can be quite large depending on the level of current users. This is perhaps the most serious oversimplification in MAFT.

In addition, MAFT does not consider the capacity of the rail and barge modes. MAFT will continue to add trains or barges as traffic grows, but will never consider whether the infrastructure will be able to handle the added vehicles. This leads to an underestimation of travel time due to the fact that the infrastructure never gets congested. In reality, congestion would occur as more trains or barges were added and the average speed for these modes would decrease. However, in MAFT, the average speed remains the same despite the number of trains or barges being added.
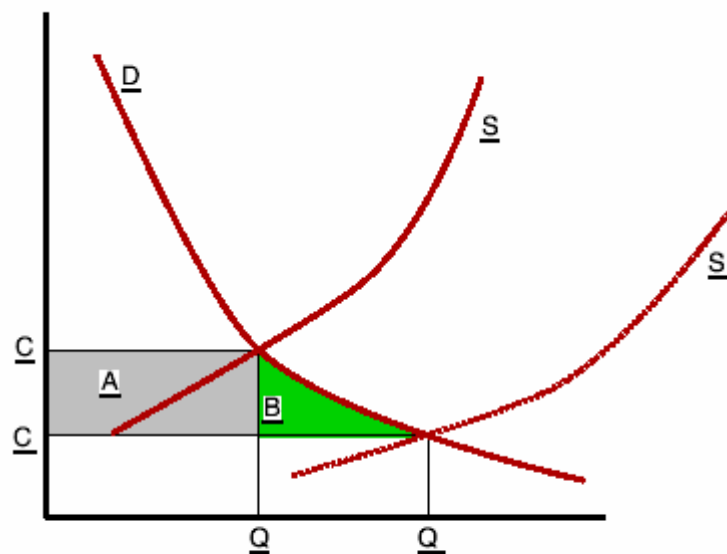
Source: Transtech Management Inc. 2000

Figure 6.1 – Equilibrating Demand Given a Change in Transportation Supply

Cost Calculations

MAFT considers all construction costs at the midpoint of construction, which is specified by the analyst. If the time value of money was considered correctly then the construction cost in each year would be discounted to the analysis year. However, this became too cumbersome to perform in MAFT. The nature of the discount rate is such that, assuming a uniform series of costs, the further into the future the costs are incurred, the lower the net present value of those costs will be. Due to this simplification there is an implicit assumption that most costs are incurred towards the midpoint of construction. This simplification means that the net present value of construction costs across all modes is most likely being either over- or under- estimated.

Benefit Calculations

Safety

The calculation of safety benefits is complex especially when two different modes are being compared.   Safety records for the rail and barge modes have traditionally been better than for highway modes. Hazardous materials are often moved by these modes because they present less risk. However, MAFT considers the rail and barge facilities as part of a larger system, which includes the already existing highway facility. Therefore, results for the safety benefits section may be over- or under-estimated based on the interaction between modes.

For the rail and barge modes the accident statistics are based on actual data obtained from the Federal Railroad Administration[25] and the US DOT[26] respectively. However for the highway mode, MAFT uses models developed by Zhou and Sisiopiku. These models differentiate between property damage only accidents and casualty accidents but do not further evaluate if the casualty accidents are injury accidents or fatality accidents.   Therefore it was necessary to use models developed by Chang and Mannering to estimate what percentages of the casualty accidents were injuries and fatalities. The highway accident statistics will be less accurate since they are based on models whereas the rail and barge safety information is based on published accident rates. The use of models to calculate the accident rates will certainly lead to either an under- or overestimation of the number of accidents occurring in the highway mode.

Emissions

MAFT uses the EPA Mobile 5 model to estimate the emissions from vehicles. At the time MAFT was developed Mobile 6 was in its initial phases and there were still a large number of unknowns associated with the model. In addition, the emission calculations for trucks in Mobile 6 are more complete and involve a larger number of truck classes. The uncertainties and complexity surrounding Mobile 6 lead to Mobile 5 being embedded in MAFT. As a result, the emissions values for passenger vehicles and for trucks could be more accurate. However, given the sketch planning nature of MAFT the use of Mobile 5 is probably not a fatal flaw.

MAFT cannot assess particulate matter (PM-10) emissions for the barge mode because of a lack of PM-10 emissions data for pusher tugs. This does lead to an underestimation of the impact that the barge mode has on air quality.

This chapter has outlined the oversimplifications within MAFT and explained the effect that they may have on the results of a project.

RECOMMENDATIONS

During the period of this research project MAFT has been tested on four different case studies. However, the tool needs to be tested on a real scenario. The application of the tool on real projects can only help to identify issues that need to be resolved. In addition, a lack of research related to freight movement has led to a number of limitations. As this research becomes more prominent and data becomes available, the tool can be improved and more accurate appraisals of modal investments can occur.

The oversimplifications addressed in Chapter 5 should be looked at and addressed where possible. It is important not to make the tool too cumbersome and eliminate the benefits associated with its sketch planning nature. However certain limitations can be addressed without changing the format and purpose of MAFT. It seems especially important to address the limitations of the barge and rail modes, such as the capacity restraints and the current traffic, since there is little information in the public domain to compare results to. The more accurate the results for these two modes can be the easier it will be for analysts to realistically present these modes as alternatives to traditional highway spending.

REFERENCES

American Association of Port Authorities. 2004. US/Canada Container Port Traffic 1980-2004.
WEBSITE: http://www.aapa-ports.org/pdf/CONTAINER_TRAFFIC_CANADA_US.xls

Barnes, G. and P. Langworthy. 2003. "The Per-Mile Costs of Operating Automobiles and Trucks." University of Minnesota, Humphrey Institute of Public Affairs. Research Report MN/RC 2003-19, 2003

Brzezinksi, D.; P. Enns; and C. Hart. 1999. "Facility-Specific Speed Correction Factors." US Environmental Protection Agency Report Number M6.SPD.002

Bureau of Transportation Statistics. 2002. "National Transportation Statistics 2002." Bureau of Transporation Statistics Report BTS03-05.

Bureau of Transportation Statistics, 2005. "National Transportation Statistics, 2004." Table 1-52: Freight Activity in the United States

Bureau of Transportation Statistics, 2005. "U.S. International Trade and Freight Transportation Trends." Value of International Merchandise Trade, 1990-2001.   Report BTS03-02

Bureau of Transportation Statistics. 2005. "National Transportation Statistics, 2005." Table 1-48: U.S. - Canadian Border, Land Freight Gateways

Bureau of Transportation Statistics. 2005. "National Transportation Statistics, 2005." Table 1-49: U.S. - Mexican Border, Land Freight Gateways

Chang, L. Y. and F. Mannering. 1999. "Analysis of Injury Severity and Vehicle Occupancy in Truck and Non-Truck Involved Accidents." Accidents Analysis & Prevention 31, 579-592.

Department of Energy, "Transportation Energy Data Book". *2003.*
WEBSITE: http://www-cta.ornl.gov/data/Index.html

Environmental Protection Agency. 1997. "Emission Factor for Locomotive: Technical Highlights." US EPA, Air and Radiation, Report EPA420-F-97-051

Environemental Protection Agency. 1997. "Emission Standards Reference Guide for Heavy-Duty and Non-Road Engines." US EPA. Air and Radiation, Report EPA420-F-97-014

Federal Highway Administration, Office of Freight Management and Operations, *Regulation: From Economic Deregulation to Safety Regulation.*
WEBSITE: http://ops.fhwa.dot.gov/freight/theme_papers/final_thm8_v4.htm

Federal Railroad Administration. 2003. Safety Statistics
WEBSITE: http://safetydata.fra.dot.gov/officeofsafety/stats.asp

Luskin, D.; A. Garcia-Diaz; D. Lee; Z. Zhang; and M. Walton. 2000. "Highway Allocation Cost Study." University of Texas at Austin, Center for Transportation Research. Research Report 0-1810.

Margiotta, R.; H. Cohen; G. Elkins; A. Rathi; and M. Venigalla. 1994. "Generic Vehicle Speed Model Based on Traffic Simulation: Development and Application." Presentation at the 74th Annual Meeting of the Transportation Research Board.

National Research Council TRB. 2000. "Special Report 209 Highway Capacity Manual." Washington, D.C.

Schrank, D. and T. Lomax. 2005. "2005 Urban Mobility Report" Texas Transportation Institute, Texas A&M University

Small, K. and C. Kazimi. 1995. "On the Costs of Air Pollution from Motor Vehicles." Journal of Transport Economic and Policy, 7-32.

US DOT Maritime Administration. 2003. U.S. Waterborne Statistics Website: http://www.marad.dot.gov/Marad_Statistics/

Zhou, M. and V.P. Sisiopiku. 1997. "Relationship between Volume –to-Capacity Ratios and Accident Rates." Transportation Research Record 1581, 47-52.

APPENDIX A: RAIL INDUSTRY DATA

University of Texas at Austin Data Request
Association of American Railroads
4/21/2005

These freight railroad statistics were requested by Michael Walton of the University of Texas at Austin in a letter to Craig Rockey of the Association of American Railroads, dated March 9. All statistics, unless stated otherwise, are 2003 averages for Class I freight railroads in the United States. Class II and Class III railway averages may differ significantly from those of Class I railroads.

- Average speed – 20.0 freight train-miles per freight train-hour

- Average number of freight cars per train – 68.9 freight cars, which includes empty cars.

- Maximum number of rail cars per train – There is no maximum. Maximum cars can depend on the commodity, type of service, terrain, locomotive horsepower, dispersion and length of sidings and turnouts, capacity of shipper/receiver facilities, and other factors. (Some coal unit trains have 120 cars, a few have 150 to 180 cars.)

- Average number of trailer and container units per car – Ranges from 2.4 to 4.4 based on preliminary 2004 data from three railroads.

- Average age of locomotives – At year-end 2003: about one third of locomotives are 24 years old or older, and about 15 percent are 3 years old or younger. (See attached age distribution for 2003.) The attached age distribution is based on build dates, and disregards the year of rebuilding.

- Switching time – Not available

- Load/unload time – Not available

- Rail car weight – The average weight of an empty freight car, described as the freight car's tare weight, is 33.5 tons with individual car types ranging from 24 to 57 tons. Not only does this vary by car type, but the appurtenances, materials, and components used on individual cars can also affect the tare weight. (The average weight of the *freight inside* of a freight car is 62 tons, and that average can vary significantly depending upon the density of the commodity carried.)

- Empty return rate – Empty car-miles are about 39 percent of the sum of loaded and empty car-miles, but vary widely between car types and specific types of service. Work train and no-payment car-miles are excluded from this calculation.

- Track costs, construction cost per mile – This varies depending upon bridges, land acquisition costs, and whether track is being added to existing line. In the railroad

construction projects that the AAR has observed, costs ranged from $1.2 million to $3.0 million per mile. Rapidly rising real estate values, and the need to undertake rail industry construction work in increasingly urbanized and congested areas, will substantially increase construction costs. The public-private Alameda Corridor project in Los Angeles (which included land acquisition and many bridges) cost $40 million per track mile.

- Track costs, maintenance cost per mile – Total way & structure operating expense per maintained mile of track is $34,500. This includes labor, material, purchased services, and general expenses for ties, rail, ballast, signals & communications, buildings, snow removal, depreciation, and other items. In addition to maintenance outlays that are expensed, railroads capitalize extensive amounts of track work – in 2003, Class I railroads spent $4.6 billion on capital projects for roadway & structures, which the AAR cannot segregate between spending on existing assets and spending on increases in capacity.

- Locomotive purchase cost – The reported cost of new locomotives averaged $1.5 million in 2003 and 2004. DC-Traction locomotives typically cost less than this average, while AC-Traction locomotives typically cost more. The range for locomotive prices is typically $1.3 to $2.0 million. Prices can vary depending on features and quantities purchased.

- Locomotive maintenance expense per mile – Total locomotive maintenance of equipment operating expense per locomotive unit mile is $2.02. Included are labor, material, purchased services, and general expenses for repair, equipment damaged, depreciation, rents, and other items. Similar to track maintenance, a major overhaul of a locomotive (known as rebuilding) would be capitalized and is therefore excluded from the $2.02. The AAR cannot segregate capital spending on locomotive rebuilds from expenditures on new locomotives. (Locomotive maintenance expenses should not be confused with transportation expenses. The most significant portions of transportation expenses are locomotive fuel and wages for engine crews.)

- Rail car purchase cost – Class I railroads paid an average price of $49,000 per freight car in 2003. The price can vary dramatically by car type, features, and capacity. Because of huge increases in steel prices during 2004, average prices are now much higher – reportedly in the $70,000 range.
- Rail car maintenance cost per mile – Total freight car equipment operating expense per car-mile is $0.26. This includes labor, material, purchased services, and general expenses for repair, equipment damaged, depreciation, rents, and other items. Car-miles in this equation are for railroad-owned freight cars only. Rebuilding a freight car, or changing a freight car's car type by making alterations to the freight car, would probably be capitalized – which is not included in the $0.26 per mile.

- Life of freight car – 40 to 50 years. Changes in demand for certain types of freight cars can be caused by changes in traffic, new innovations by builders, changes in freight car utilization, and other situations. Currently, high prices for scrap steel could cause a freight car owner to retire an older, seldom-used car earlier than originally planned.

- Life of track – not available. Definition of "track" could refer to the whole roadway, just the rail, or combinations of components of the roadway such as rail, ties, ballast, signals & communications, bridges, tunnels, and/or other items. Wear is best measured in gross ton-miles instead of time. Factors that can influence the life of roadway are the speed of trains, track curvature, track gradient, climate (especially for ties), quality of steel used for rail, continuous weld rail opposed to jointed rail, and the weight of the rail in relation to the weight of trains using the track.

- Life of locomotive – One third of the locomotives in service in 2003 for Class I railroads were at least 24 years old. Details on rebuilding are not available.

Locomotives

0-3 Yrs
14.8%

24+ Yrs
33.2%

4-8 Yrs
22.5%

19-23 Yrs
8.0%

14-18 Yrs
8.6%

9-13 Yrs
13.0%

Freight Cars

31-50 Yrs
23.1%

0-10 Yrs
24.6%

11-20 Yrs
10.2%

21-30 Yrs
42.0%

Age Distribution of Diesel Locomotive Fleet - December 31, 2003

Date Built	Units in Age Bracket	Percent Of Total
Jan. 1, 2003 - Dec. 31, 2003	587	2.8
Jan. 1, 2002 - Dec. 31, 2002	725	3.5
Jan. 1, 2001 - Dec. 31, 2001	891	4.3
Jan. 1, 2000 - Dec. 31, 2000	863	4.2
Jan. 1, 1995 - Dec. 31, 1999	4,673	22.5
Jan. 1, 1990 - Dec. 31, 1994	2,700	13.0
Jan. 1, 1985 - Dec. 31, 1989	1,791	8.6
Jan. 1, 1980 - Dec. 31, 1984	1,655	8.0
Before 1980	6,889	33.2
Total	20,774	100.0 %

Age Distribution of Railroad-Owned Freight Cars - January 2, 2004

Car Age (years)	Cars in Age Bracket	Percent Of Total
0-10	155,114	24.6 %
11-20	64,490	10.2
21-30	264,867	42.0
31-40	138,334	22.0
41-50	7,320	1.2
Total	630,125	100.0 %

The average age for U.S. railroad-owned freight cars is 21.9 years.

Note: The data used to determine the age distribution of the freight car fleets are not available from the same data sources used for ownership figures shown elsewhere in this publication. Therefore, the figures shown above for the total fleet size do not precisely match those shown on other pages.

Sources: Locomotives - R-1 Annual Reports; Freight Cars - AAR/UMLER database

Figure A.1 – Age of Locomotives and Freight Cars

APPENDIX B: BARGE INDUSTRY DATA

- Average speed – The average speed for barges is 8 miles per hour not including terminal times (switiching and loading).

- Average number of barges per pusher tug – 2, this number applies only to the Gulf Intercoastal Waterway (GIWW) in Texas.

- Maximum number of barges per pusher tug – 4, this number applies only to the Gulf Intercoastal Waterway (GIWW) in Texas.

- Average number of containers per barge – Most jumbo barges are capable of holding 72 TEU (twenty foot equivalent units) which is equivalent to 36 40-foot containers per barge.

- Average age of pusher tugs – Using data from the Army Corps of Engineers for vessels operating on the GIWW in Texas, an average age of 30 years was obtained. This corresponds to a model year of 1975.

- Switching time – not available

- Load/unload time – not available

- Barge weight – The tare weight for a jumbo hopper barge is 250 tons.

- Empty return rate – Empty movements along the GIWW account for approximately 45 percent of the traffic.

- Construction cost per mile – not available. This will vary widely depending on the type of facility being constructed.

- Maintenance cost per mile – The largest component of infrastructure maintenance will be dredging the channel. Using Data from the Army Corps of Engineers Dredging Program, the cost of dredging per cubic yard of material removed was obtained. Goverment and Private Contractor bids were averaged to obtain a figure of $2.56 per cubic yard removed.

- Pusher tug purchase cost – Many firms noted a rule-of-thumb of $1,000 per horsepower as a replacement cost for pusher tugs. The linear model derived to represent replacement cost is as follows:

  Replacement Cost = 135,479.69 + 1,178.48*horsepower

- Pusher tug maintenance expense per mile – Data for maintenance costs was given as a daily cost associated with maintenance and repair. Please use the following formula to determine the daily cost and then multiply by the number of days the pusher tug will be operating each year.

  Daily Maintenance Cost = 0.0563 + 267.83*horsepower

- Barge purchase cost – Using information from the Army Corps of Engineers we have determined the purchase cost of a barge based on capacity as well as taken an overall average. The average barge replacement cost was $311,100 irrespective of size or capacity. When nominalized for capacity the average cost was $182.50 per ton of capacity.

- Barge maintenance cost per mile – Using information from the Army Corps of Engineers we have determined the maintenance costs of a barge based on capacity as well as taken an overall average. The daily maintenance and repair cost was $10.77 irrespective of size or capacity. When nominalized for capacity the average cost was $0.0066 per ton of capacity. Again, please note that this is a daily figure which must be converted into a yearly cost before being inputted into MAFT.

- Life of barge – not available. Again, we assume that a life of 50 years is not unreasonable as barges would have to be rehabilitated.

- Life of infrastructure – not available. Assuming a 50 year life for the infrastructure before major rehabilitation is necessary is not unreasonable. This will extend the life of the infrastructure past the benefit period for any project being analyzed.

- Life of pusher tug – We assumed that the life of a pusher tug was 50 years. Any pusher tugs older than that were assumed to have been through a major rehabilitation which would effectively give them a "new" model year.

APPENDIX C: RAIL CASE STUDY INPUT DATA

General Project Information
- Analysis Year – 2000
- Discount Rate – 7 %
- Days Considered – All Days
- Primary District – Statewide
- Benefit Period – 30 years
- Type of Trip – Intercity

Mode Selection
- Managed Lane
- Rail

Alternative Information – Non-Monetary
Category Weights
- Noise and Aesthetics – 20
- Community Issues – 20
- Accessibility and Reliability – 20
- The Environment – 20
- Regional Economic Development – 20

Questions

Table C. 1 – Rail Case Study Noise and Aesthetics Information

	Managed Lane		Rail	
	Yes/No	if yes, how great is the benefit or burden?	Yes/No	if yes, how great is the benefit or burden?
Noise and Aesthetics				
Does the alternative require the implementation of noise reduction measures?	no		no	
Will the alternative reduce the actual noise level in the area?	no		no	
Will the alternative create visual intrusions that will negatively affect community aesthetics?	yes	average burden	yes	low burden
Will lighting and signing associated with the project negatively affect community aesthetics?	no		no	

Table C. 2 – Rail Case Study Community Issues Information

	Managed Lane		Rail	
	Yes/No	if yes, how great is the benefit or burden?	Yes/No	if yes, how great is the benefit or burden?
Community Issues				
Will the alternative divide a community?	no		no	
Will the alternative impact minority groups adversely?	yes	average burden	yes	average burden
Will the alternative impose on existing pedestrian or bicycle facilities?	yes	low burden	no	

Table C. 3 – Rail Case Study Accessibility and Reliability Information

	Managed Lane		Rail	
	Yes/No	if yes, how great is the benefit or burden?	Yes/No	if yes, how great is the benefit or burden?
Accessibility and Reliability				
Does the alternative improve access to a community?	no		no	
Does the alternative provide a new access route to a community?	yes	low benefit	yes	very low benefit
Does the alternative increase the reliability of freight transportation?	no		no	
Does the alternative improve access to a freight generator?	yes	low benefit	yes	high benefit
Does the alternative provide a new access route to a freight generator?	yes	very high benefit	yes	very low benefit

Table C. 4 – Rail Case Study Environment Information

	Managed Lane		Rail	
	Yes/No	if yes, how great is the benefit or burden?	Yes/No	if yes, how great is the benefit or burden?
The Environment				
Will the alternative improve air quality in a non-attainment area?	yes	average benefit	yes	low benefit
Will the alternative improve air quality in a maintenance area?	yes	average benefit	yes	low benefit
Will the alternative adversely affect existing watershed or wetland areas?	no		no	
Will the alternative adversely affect habitat or endangered species?	yes	average burden	yes	average burden
Will the alternative adversely affect native prairie lands?	yes	average burden	yes	average burden

Table C. 5 – Rail Case Study Economic Development Information

	Managed Lane		Rail	
	Yes/No	if yes, how great is the benefit or burden?	Yes/No	if yes, how great is the benefit or burden?
Regional Economic Development				
Will the alternative result in the creation of new employment opportunities?	yes	average benefit	yes	high benefit
Will disruptions during construction of the alternative negatively affect local businesses?	yes	very low burden	yes	very low burden

Alternative Information – Monetary

Base Case – Geometric Characteristics
- Length of Link – 650 miles
- Number of Lanes – 4 lanes
- Lane Width – 12 feet
- Shoulder Width – 10 feet
- Interchange Density – 0.7 interchanges per mile
- Type of Terrain – level
- Area Location – rural
- Posted Speed Limit – 60 mph

Base Case – Benefits
- Average Annual Daily Traffic – 12,000 vehicles
- Annual Vehicle Traffic Growth – 2.5 %
- Annual Truck Traffic Growth – 3 %
- Initial Truck Percentage – 25 %
- Type of Road Surface – Flexible (asphalt)
- Type of Highway – Interstate
- 30th Highest Annual Hourly Volume – 7 % of AADT

Managed Lane – Geometric Characteristics
- Facility Description – Truck Toll Road
- Length of Link – 600 miles
- Number of Additional Lanes – 2 lanes
- Lane Width – 12 feet
- Shoulder Width – 10 feet
- Interchange Density – 0.05 interchanges per mile
- Type of Terrain – level
- Area Location – rural
- Posted Speed Limit – 70 mph

Managed Lane – Land Acquisition Costs
- Width of ROW – 60 feet
- Cost of ROW – $0.32 per square foot
- Year Price – 2005

Managed Lane – Construction/O&M Costs
- Road Opening Year – 2030
- Construction Midpoint – 2017
- Life of Roadway – 30 years
- Construction Cost – $1,308,488.62 per lane-mile
- Year Price – 2005
- Annual Maintenance Cost – $16,274.07
- Year Price – 2005

Managed Lane – Benefits
- Trucks Diverted – 2,700
- Annual Truck Traffic Growth – 3.2 %
- Type of Road Surface – flexible (asphalt)
- Type of Highway – Interstate
- 30th Highest Annual Hourly Volume – 7 % of AADT

Rail – Geometric Characteristics
- Length of Link – 620 miles
- Ave. Number of Rail Cars per Train – 68.9 rail cars
- Max. Number of Rail Cars per Train – 150 rail cars
- Number of Trailers per Rail Car – 3 trailers

Rail – Land Acquisition Costs
- Width of ROW – 100 feet
- Cost of ROW – $0.00
- Year Price – 2005

Rail – Equipment Acquisition Costs
- Locomotive Model Year – 1986
- Cost of Locomotive – $2 million
- Year Price – 2005
- Life of Locomotive –50 years
- Cost of Rail Car – $51,333.33
- Year Price – 2005
- Life of Rail Car – 50 years
- Rail Cars Acquired – 900

Rail – Construction Costs
- Opening Year – 2025
- Construction Midpoint – 2020
- Life of Track – 50 years
- Construction Cost – $2,000,000 per track mile
- Year Price – 2005

Rail – O & M Costs
- Track Maintenance Cost – $36,142.86 per mile
- Year Price – 2005
- Rail Car Maintenance Cost – $0.26 per rail car-mile
- Year Price – 2005
- Locomotive Maintenance Cost – $2.02 per locomotive-mile
- Year Price – 2005

Rail – Benefits
- Trucks Diverted – 1,350
- Annual Rail Traffic Growth – 2.8 %
- Line Haul Time – 25 hours
- Switching Time – 0 hours
- Load/Unload Time – 0 hours
- Rail Car Weight – 33.5 tons
- Percent Empty Returns – 39 %

APPENDIX D: BARGE CASE STUDY INPUT DATA

General Project Information
- Analysis Year – 2005
- Consumer Price Index – 3.25 %
- Discount Rate – 7 %
- Days Considered – Week Days
- Primary District – Houston
- Benefit Period – 20 years
- Type of Trip – Local

Mode Selection
- Managed Lane
- Barge

Alternative Information – Non-Monetary
Category Weights
- Noise and Aesthetics – 10
- Community Issues – 10
- Accessibility and Reliability – 30
- The Environment – 30
- Regional Economic Development – 10

Questions

Table D. 1 – Barge Case Study Noise and Aesthetics Information

	Managed Lane		Rail	
	Yes/ No	if yes, how great is the benefit or burden?	Yes/ No	if yes, how great is the benefit or burden?
Noise and Aesthetics				
Does the alternative require the implementation of noise reduction measures?	no		no	
Will the alternative reduce the actual noise level in the area?	no		no	
Will the alternative create visual intrusions that will negatively affect community aesthetics?	yes	low burden	no	
Will lighting and signing associated with the project negatively affect community aesthetics?	no		no	

Table D. 2 – Barge Case Study Community Issues Information

	Managed Lane		Rail	
	Yes/ No	if yes, how great is the benefit or burden?	Yes/ No	if yes, how great is the benefit or burden?
Community Issues				
Will the alternative divide a community?	no		no	
Will the alternative impact minority groups adversely?	no		no	
Will the alternative impose on existing pedestrian or bicycle facilities?	no		no	

Table D. 3 – Barge Case Study Accessibility and Reliability Information

	Managed Lane		Rail	
	Yes/ No	if yes, how great is the benefit or burden?	Yes/ No	if yes, how great is the benefit or burden?
Accessibility and Reliability				
Does the alternative improve access to a community?	no		no	
Does the alternative provide a new access route to a community?	no		no	
Does the alternative increase the reliability of freight transportation?	yes	very high benefit	yes	high benefit
Does the alternative improve access to a freight generator?	yes	high benefit	yes	high benefit
Does the alternative provide a new access route to a freight generator?	yes	high benefit	yes	high benefit

Table D. 4 – Barge Case Study Environment Information

	Managed Lane		Rail	
	Yes/ No	if yes, how great is the benefit or burden?	Yes/ No	if yes, how great is the benefit or burden?
The Environment				
Will the alternative improve air quality in a non-attainment area?	no		no	
Will the alternative improve air quality in a maintenance area?	no		no	
Will the alternative adversely affect existing watershed or wetland areas?	no		no	
Will the alternative adversely affect habitat or endangered species?	no		no	
Will the alternative adversely affect native prairie lands?	no		no	

Table D. 5 – Barge Case Study Economic Development Information

	Managed Lane		Rail	
	Yes/ No	if yes, how great is the benefit or burden?	Yes/ No	if yes, how great is the benefit or burden?
Regional Economic Development				
Will the alternative result in the creation of new employment opportunities?	no		no	
Will disruptions during construction of the alternative negatively affect local businesses?	yes	very low burden	yes	very low burden

Alternative Information – Monetary

Base Case – Geometric Characteristics
- Length of Link – 20 miles
- Number of Lanes – 2 lanes
- Lane Width – 12 feet
- Shoulder Width – 10 feet
- Interchange Density – 0.7 interchanges per mile
- Type of Terrain – level
- Area Location – urban
- Posted Speed Limit – 50 mph

Base Case – Benefits
- Average Annual Daily Traffic – 1,000 vehicles
- Annual Vehicle Traffic Growth – 0 %
- Annual Truck Traffic Growth – 1 %
- Initial Truck Percentage – 100 %
- Type of Road Surface – Flexible (asphalt)
- Type of Highway – Farm to Market
- 30th Highest Annual Hourly Volume – 7 % of AADT

Managed Lane – Geometric Characteristics
- Length of Link – 15 miles
- Number of Additional Lanes – 2 lanes
- Lane Width – 12 feet
- Shoulder Width – 10 feet
- Interchange Density – 0 interchanges per mile
- Type of Terrain – level
- Area Location – urban
- Posted Speed Limit – 65 mph

Managed Lane – Land Acquisition
- Width of ROW – 60 feet
- Cost of ROW – $0.32 per square foot
- Year Price – 2005

Managed Lane – Construction/O&M Costs
- Road Opening Year – 2015
- Construction Midpoint – 2012
- Life of Roadway – 30 years
- Construction Cost – $1,308,488.62 per lane-mile
- Year Price – 2005
- Annual Maintenance Cost – $16,274.07
- Year Price – 2005

Managed Lane – Benefits
- Trucks Diverted – 950
- Annual Truck Traffic Growth – 1 %
- Type of Road Surface – flexible (asphalt)
- Type of Highway – Farm to Market
- 30th Highest Annual Hourly Volume – 7 % of AADT

Barge – Geometric Characteristics
- Length of Link – 7 miles
- Ave. Number of Barges per Pusher Tug – 2 barges
- Max. Number of Barges per Pusher Tug – 4 barges
- Number of Trailers per barge – 36 trailers

Barge – Land Acquisition Costs
- Width of ROW – 100 feet
- Cost of ROW – $0.00
- Year Price – 2005

Barge – Equipment Acquisition Costs
- Pusher Tug Model Year – 1975
- Cost of Pusher Tug – $1,533,385.09
- Year Price – 2005
- Life of Pusher Tug –50 years
- Cost of Barge – $276,009.32
- Year Price – 2005
- Life of Barge – 50 years
- Barges Acquired – 25

Barge – Construction Costs
- Opening Year – 2015
- Construction Midpoint – 2012
- Life of Track – 50 years
- Construction Cost – $0
- Year Price – 2005

Barge – O & M Costs
- Infrastructure Maintenance Cost – $1,308.49 per mile
- Year Price – 2005
- Barge Maintenance Cost – $0.55 per barge car-mile
- Year Price – 2005
- Pusher Tug Maintenance Cost – $1.84 per locomotive-mile
- Year Price – 2005

Barge – Benefits
- Trucks Diverted – 900
- Annual Barge Traffic Growth – 1 %
- Line Haul Time – 1.15 hours
- Switching Time – 0 hours
- Load/Unload Time – 0 hours
- Barge Weight – 250 tons
- Percent Empty Returns – 45 %

---

[1] Schrank, D. and T. Lomax. 2005. "2005 Urban Mobility Report" Texas Transportation Institute, Texas A&M University

[2] Bureau of Transportation Statistics, 2005. "National Transportation Statistics, 2004." Table 1-52: Freight Activity in the United States

[3] Ibid.

[4] Bureau of Transportation Statistics, 2005. "U.S. International Trade and Freight Transportation Trends." Value of International Merchandise Trade, 1990-2001. Report BTS03-02

[5] American Association of Port Authorities. 2004. US/Canada Container Port Traffic 1980-2004.
WEBSITE: http://www.aapa-ports.org/pdf/CONTAINER_TRAFFIC_CANADA_US.xls

[6] Bureau of Transportation Statistics. 2005. "National Transportation Statistics, 2005." Table 1-48: U.S. - Canadian Border, Land Freight Gateways

[7] Bureau of Transportation Statistics. 2005. "National Transportation Statistics, 2005." Table 1-49: U.S. - Mexican Border, Land Freight Gateways

[8] Federal Highway Administration, Office of Freight Management and Operations, *Regulation: From Economic Deregulation to Safety Regulation*. WEBSITE: http://ops.fhwa.dot.gov/freight/theme_papers/final_thm8_v4.htm

[9] Ibid
[10] Ibid
[11] National Research Council TRB. 2000. "Special Report 209 Highway Capacity Manual." Washington, D.C.

[12] Margiotta, R.; H. Cohen; G. Elkins; A. Rathi; and M. Venigalla. 1994. "Generic Vehicle Speed Model Based on Traffic Simulation: Development and Application." Presentation at the 74th Annual Meeting of the Transportation Research Board.

[13] Department of Energy, "Transportation Energy Data Book". *2003*.
WEBSITE: http://www-cta.ornl.gov/data/Index.html

[14] Barnes, G. and P. Langworthy. 2003. "The Per-Mile Costs of Operating Automobiles and Trucks." University of Minnesota, Humphrey Institute of Public Affairs. Research Report MN/RC 2003-19, 2003

[15] Luskin, D.; A. Garcia-Diaz; D. Lee; Z. Zhang; and M. Walton. 2000. "Highway Allocation Cost Study." University of Texas at Austin, Center for Transportation Research. Research Report 0-1810.

[16] Zhou, M. and V.P. Sisiopiku. 1997. "Relationship between Volume –to-Capacity Ratios and Accident Rates." Transportation Research Record 1581, 47-52.

[17] Chang, L. Y. and F. Mannering. 1999. "Analysis of Injury Severity and Vehicle Occupancy in Truck and Non-Truck Involved Accidents." Accidents Analysis & Prevention 31, 579-592.

[18] Federal Railroad Administration. 2003. Safety Statistics Website: http://safetydata.fra.dot.gov/officeofsafety/stats.asp

[19] Bureau of Transportation Statistics. 2002. "National Transportation Statistics 2002." Bureau of Transporation Statistics Report BTS03-05.

[20] Ibid

[21] Brzezinksi, D.; P. Enns; and C. Hart. 1999. "Facility-Specific Speed Correction Factors." US Environmental Protection Agency Report Number M6.SPD.002

[22] Environmental Protection Agency. 1997. "Emission Factor for Locomotive: Technical Highlights." US EPA, Air and Radiation, Report EPA420-F-97-051

[23] Environemental Protection Agency. 1997. "Emission Standards Reference Guide for Heavy-Duty and Non-Road Engines." US EPA. Air and Radiation, Report EPA420-F-97-014

[24] Small, K. and C. Kazimi. 1995. "On the Costs of Air Pollution from Motor Vehicles." Journal of Transport Economic and Policy, 7-32.

[25] Federal Railroad Administration 2003. Safety Statistics Website: http://safetydata.fra.dot.gov/officeofsafety/stats.asp

[26] US DOT Maritime Administration. 2003. U.S. Waterborne Statistics Website: http://www.marad.dot.gov/Marad_Statistics/