Illinois Department of Transportation

Minnesota Department of Transportation

Wisconsin Department of Transportation

Tri-State High Speed Rail Study

Chicago - Milwaukee - Twin Cities Corridor

TMS/Benesch High Speed Rail Consultants

Transportation Management Systems, Inc.
Alfred Benesch & Company

Tri-State Study of High Speed Rail Service

Prepared For

Illinois, Minnesota and Wisconsin
Departments of Transportation

By

TMS/Benesch
Tri-State High Speed Rail Consultants

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This report is intended to assist the Illinois, Minnesota and Wisconsin Departments of Transportation in determining the future of high speed rail passenger service in the Tri-State Corridor. The findings contained herein are the sole responsibility of the Consultant Team.

TABLE OF CONTENTS

1 INTRODUCTION

The Study Area 1-1
Purpose and Objectives of the Study 1-3
Study Reports 1-4

2 RAIL TECHNOLOGY

Characteristics of the High Speed Technology 2-1
Characteristics of the Very High Speed Technology 2-2
Characteristics of the Super Speed Technology 2-3
Technologies Selected for Study Analysis 2-3
    High Speed Technology Option 2-4
    Very High Speed Technology Option 2-4
    Super Speed Technology Option 2-5
Technology Issues 2-5

3 ROUTES

Routes Selected for Analysis 3-3
Comparative Evaluation of Routes 3-6
    Comparative Evaluation of Environmental Constraints 3-6
    Comparative Engineering Evaluation 3-7
Recommended Routes 3-8
    Route #1: Existing Amtrak Route 3-8
    Route #4: South Route Modified 3-10
    Route #7: North Route Modified 3-10

4 RIDERSHIP

Zone System 4-1
Data Base 4-2
    Network Data 4-2
    Socioeconomic Data 4-2
    Origin-Destination Data 4-3
Development of Values of Time and Values of Frequency 4-4
    Attitudinal Survey 4-4
    Results of the Trade-Off Analysis 4-7

Basic Structure of the COMPASS(c) Model 4-9
Total Demand Model 4-10
The Socioeconomic Variables 4-10
Generalized Cost 4-11
Calibration of the Total Demand Model 4-11
Zone System for Calibration 4-12
Calibration Results for the Total Demand Model 4-12
Modal Split Model 4-12
Form of the Modal Split Model 4-13
Combined Mode Generalized Cost 4-15
Ratio Model versus Difference Model 4-15
Calibration Results for Public versus Private Auto 4-16
Calibration Results for Surface versus Air 4-16
Calibration Results for Rail versus Bus 4-17
Conclusions 4-18
Model Verification 4-18
Forecasting Process 4-18
Economic Scenarios 4-18
Transportation Strategies 4-20
Other Mode "Action" Cases 4-21
Forecast Results 4-22
Model Variations 4-24
Half VOT/VOF Analysis 4-24
Logsum Model 4-26
Super Speed/Low Speed Modal Split Model 4-29
Results of the Model Variations 4-30

5 SYSTEM OPERATIONS

Train Running Times and Timetables 5-1
Timetable Development Criteria 5-3
Development of Timetables 5-5
Train Running Time Results 5-7
Fleet Requirements 5-9
Train Consist Size 5-10
Freight Train Interference 5-11

6 REVENUES AND COSTS

Revenues 6-1
Operating and Maintenance Costs 6-2
Operating and Maintenance Unit Costs 6-2
Annual Operating and Maintenance Costs 6-4

Infrastructure Costs 6-5
Infrastructure Unit Costs 6-5
Infrastructure and Total Capital Cost Estimates 6-7

7 FINANCIAL AND ECONOMIC ANALYSIS

Financial Analysis 7-1
Financial Model 7-2
Discount Rate 7-2
Interest Rates for Municipal Bonds 7-2
Interest Rates for Private Loans 7-3
Measures of Financial Performance 7-3
Other Financial Assumptions 7-4
Results of the Financial Analysis 7-5
Sensitivity Analysis 7-6
Financial Analysis Conclusions 7-8
Economic Analysis 7-8
User Benefits 7-9
Community Benefits 7-12
Results of the Economic Analysis 7-14
Conclusions 7-16

8 SUMMARY

Findings 8-1
Conclusions 8-2
Recommendations 8-3

CHAPTER 1

INTRODUCTION

In recent years, the potential for the development of high speed rail corridors has become an increasingly important element of long-range transportation plans in North America for intercity and interregional travel. The continued growth in the demand for intercity travel, coupled with the increasing congestion and costs associated with traditional forms of intercity travel (air and auto), has resulted in a search for new ways to provide fast and effective travel between urban areas.

High speed rail is not expected to replace air and auto travel, but rather to complement these modes by providing a preferred alternative for trips between 150 and 400 miles in length. High speed rail transportation is generally considered the logical choice of travel mode for the "gap" between the most comfortable, convenient trip lengths for auto travel (0-150 miles) and air travel (400-2000+ miles). If the volume of trips between 150 and 400 miles in length continues to expand rapidly (possibly doubling or tripling) over the next twenty to thirty years, regional travel will replace urban/suburban travel as the fastest growing travel market and there will be an ever increasing need for a more effective interregional transportation system.

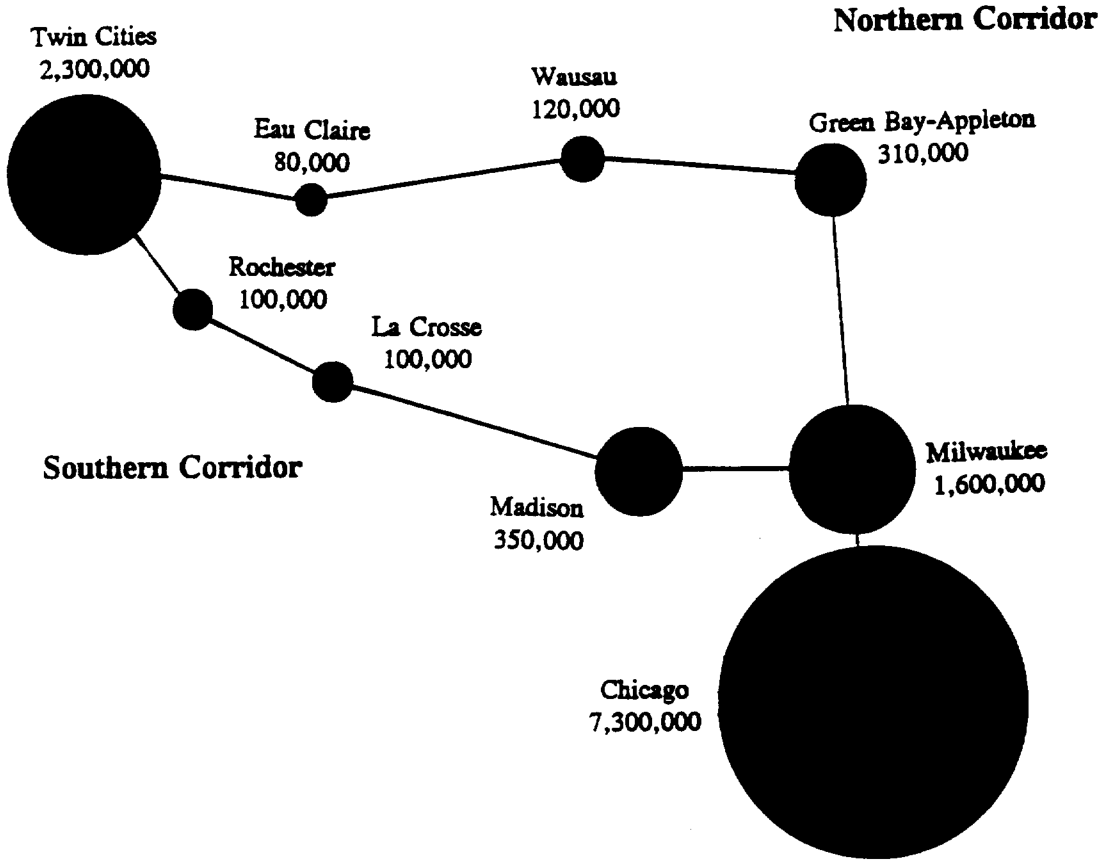
Because intercity and interregional travelers are more interested in "door-to-door" journey times than a train's maximum speed, minimum access, terminal and interchange times and maximum frequency (convenience) and reliability are the critical elements affecting their decision as to which travel mode to choose. High speed rail systems successfully meet these criteria for trips under 400 miles and, thus, appear to present an effective transportation option. Where high speed rail systems have been implemented elsewhere in the world (specifically in Europe and Japan), they are well used and highly regarded by the general populace. What needs to be understood is whether high speed rail can prove as useful in a North American context and, if so, what type of financial and institutional supports would be needed for its successful implementation.

The Tri-State Study of High Speed Rail Service has set out to answer these questions for the corridor between Chicago, Milwaukee and Minneapolis-St. Paul. The study is the direct result of the realization by the Minnesota, Wisconsin and Illinois Departments of Transportation that high speed rail could considerably improve regional accessibility in eastern Minnesota, the entire state of Wisconsin, and northern Illinois. To that end, a Tri-State "Memorandum of Understanding" was established in 1990 for evaluating the potential for high speed rail in this corridor, and the Consultant Team of Transportation Management Systems, Inc./Alfred Benesch & Company (TMS/Benesch) was retained in June 1990 to carry out a pre-feasibility study.

THE STUDY AREA

As shown in Exhibit 1.1, the study area encompassed a Southern Corridor which included Madison, La Crosse and Rochester and a Northern Corridor which included Green Bay-Appleton, Wausau and Eau Claire.

Exhibit 1.1
Population of Corridor Communities and Conurbations (1989)



Both corridors link Chicago, which has a population of nearly 8.0 million and is North America's major transportation hub, with the nearby city of Milwaukee (less than 100 miles away), which has a population of 1.6 million. These metropolitan areas clearly have a strong affinity with each other while maintaining their independence and distinctive character. Minneapolis-St. Paul, 300 miles from Milwaukee and with a population of 2.3 million, stands surrounded on three sides by the emptiness of the Great Plains to the west, Canada to the north, and Lake Superior and Lake Michigan to the north and east. As a result, its population shows a strong desire for a viable physical linkage with Chicago which serves as its "gateway" to the rest of the U.S.

Along the Southern Corridor lie the smaller cities of Madison, Wisconsin (population of 350,000), La Crosse, Wisconsin (population of 100,000) and Rochester, Minnesota (population of 100,000). While Madison, the capital of Wisconsin, has strong connections with Milwaukee, approximately 100 miles to the east, La Crosse and Rochester look to Minneapolis-St. Paul for many services and urban facilities. Madison, as a capital city, and Rochester, as the home of the Mayo Clinic, have an "attractiveness" and significance as travel destinations that cannot be accounted for by their population size. In the Northern Corridor, the key population centers are Green Bay-Appleton (population of 310,000), Wausau (population of 120,000), and Eau Claire (population of 80,000). These cities look to Milwaukee, Chicago and Minneapolis-St. Paul for specific services and urban facilities.

Overall, the Tri-State Corridor is characterized by three distinctive relationships:

- The almost intra-urban Chicago-Milwaukee relationship.
- The more typical intercity or interregional relationship of Minneapolis-St. Paul with Chicago and Milwaukee.
- The relationship of the smaller urban areas with the nearest large city (Chicago, Milwaukee or Minneapolis-St. Paul).

In the case of Madison and Rochester, however, the typical small city/large city relationship is "surpassed" by their special roles as educational, political and medical care centers.

In conclusion, the demand for intercity or interregional travel in the Tri-State Corridor is somewhat different from other proposed high speed rail corridors in North America, as the corridor has a number of unique relationships and, thus, a higher than typical level of demand for intercity and interregional travel.

Purpose and Objectives of the Study

The purpose of the Tri-State Study of High Speed Rail Service was to investigate the economic and financial potential for constructing and operating a high speed rail system in one of two corridors (a Northern or a Southern Corridor) between Chicago and Minneapolis-St. Paul. The specific objectives of the study were to:

- Assess three high speed rail technology options, High Speed (125 mph), Very High Speed (185 mph) and Super Speed (300 mph).
- Calibrate a demand forecasting model and estimate rail ridership and revenues.
- Determine the most appropriate route and operating conditions for each technology and route option.
- Analyze potential impacts on freight rail movements.
- Identify major socioeconomic, environmental and energy impacts.
- Estimate the capital costs and operating and maintenance costs that would be associated with each of the route and technology options.
- Evaluate the potential financial and economic returns associated with each of the route and technology options.
- Assess the role of private and public funding of a high speed rail system in the Tri-State Corridor.

Study Reports

This report, the Final Report for the Tri-State Study of High Speed Rail Service, describes the work carried out by TMS/Benesch in analyzing the potential for high speed rail in the Tri-State Corridor. Specifically, the study provides a pre-feasibility concept assessment of the role of high speed rail by analyzing the potential:

- Technology and route options
- Environmental constraints
- Ridership and revenue estimates
- Operating options
- Operating and maintenance costs
- Capital costs
- Financial and economic returns

This report presents a summary description of the study process, its findings, conclusions and recommendations. In carrying out the study, TMS/Benesch prepared a series of five Technical Reports which provide supporting documentation and analyses. The contents of the Technical Reports are described in Exhibit 1.2.

Exhibit 1.2
Technical Reports Prepared for the Tri-State Study[1]

Report Number	Description of Contents
1	Finalized Study Plan
	Review and assessment of available demand forecasting data (including socioeconomic data, origin-destination data and network data), engineering route data, rail technology data, and unit cost data for the infrastructure and operating and maintenance cost estimates, environmental data, and data for the economic and financial analyses
	Zone system and network selection
2	Demand data bank for origin-destination data, network data and socioeconomic data
	COMPASS(c) Model System
	Train performance data base
	Track inspection data base
	Data base for infrastructure unit costs
	Data base for operating and maintenance unit costs
3	Route engineering analysis
	Environmental constraints analysis
	Comparative engineering and environmental evaluation
4	Attitudinal Survey including the Trade-Off Analysis
	Calibration of LOCOMOTION(c) Train Performance Calculator
	Railroad and competitive modes strategies
	Calibration of the COMPASS(c) Model including database development pursuant to calibration
	Generalized cost elasticities
5	Economic scenarios including historical growth trends and base case forecasts
	Ridership forecasts and revenue projections
	Operating plan including train running times and projected timetables and fleet requirements
	Operating and maintenance cost estimates
	Infrastructure and capital cost estimates

(1) *Technical reports can be reviewed at: Illinois Department of Transportation, Bureau of Railroads, Office of Planning & Programming, 2300 South Dirksen Parkway, Springfield, Illinois 62764; Minnesota Department of Transportation, Office of Railroads & Waterways, Program Management Division, 395 John Ireland Boulevard, St. Paul, Minnesota 55155; and Wisconsin Department of Transportation, Policy Analysis & Information Section, Division of Planning & Budget, 4802 Sheboygan Avenue, P.O. Box 7913, Madison, Wisconsin 53707-7913.*

CHAPTER 2

RAIL TECHNOLOGY

Rail technology is in a state of continual evolution as the requirement for improved intercity transportation has resulted in extensive research and development programs by European, Japanese and North American manufacturers. In North America, much of the emphasis has been placed on rail freight transportation but, elsewhere, every aspect of rail passenger transportation from motive power, to passenger cars, signaling and communications systems, and track infrastructure is continually under development and refinement. Even during the course of this six-month study, two major technological advances were announced: the introduction of the Swedish Railroad's X2 tilt technology and the commencement of the construction of the first sixty miles of the Japanese superconducting magnetic levitation system between Tokyo and Osaka at a cost of 345 billion yen ($2.6 billion).

For purposes of this study, three generic technologies were considered:

- High Speed — Maximum commercial speed of 125 mph
- Very High Speed — Maximum commercial speed of 185 mph
- Super Speed — Maximum commercial speed of 300 mph

Commercial speed is defined as the timetable speed or actual speed a technology is capable of achieving on a given route under "real-world" operating conditions, including curves, bridges, gradients, station stops and other speed restrictions. Design speed, on the other hand, is the "top" speed a technology can achieve under ideal operating conditions.

For each generic technology, detailed data were obtained from operators, equipment suppliers and published sources on vehicle dimensions, performance capabilities, type of propulsion, characteristics of track and related infrastructure.

CHARACTERISTICS OF THE HIGH SPEED (125 MPH) TECHNOLOGY

High Speed passenger rail service capable of providing a commercial speed of 125 mph is widely available throughout the world and is generally the result of a progressive upgrading of existing technologies, systems and infrastructure. There are three dominant propulsion systems associated with this conventional steel-wheel-on-steel-rail technology:

- **Diesel-Electric Propulsion**

  Diesel-electric propulsion is characterized by well known, highly reliable technology. Typically, in high speed applications, one or more locomotives work in consist to provide the required power level. The diesel engine drives a three-phase alternating current generator. The electric power generated is, in turn, fed to the traction motors.

  Applications of this technology include the British Rail HST and the Australian XPT, which have maximum commercial speeds of 125 mph and 100 mph respectively.

- **Turbine-Electric Propulsion**

  Similar to diesel-electric technology, on-board gas turbines are used to drive a three-phase alternating current generator whose output is fed to the traction motors. The primary advantage of the turbine technology is the considerable increase in the power-to-weight ratio over diesel engines and hence the potential for increases in speed. However, fuel consumption and maintenance requirements are high. In the early 1970's, France became the pioneer in gas turbine traction and experimented with direct-drive turbines using hydraulic transmission.

  Applications of this technology include the prototype of the Advanced Passenger Train (APT) in Great Britain, the prototype of the Train à Grande Vitesse (TGV-001) in France, and the Turboliners used by Amtrak on the Albany-New York Corridor.

- **Electrification**

  Using overhead catenaries to transmit traction power directly to the locomotives, electrification permits a further increase in the power-to-weight ratio and hence greater potential for increased speeds. Trains in this category have commercial speeds that range from 100 mph to 125 mph depending on the specific routes over which the equipment is operated. The primary disadvantage of electrification is the high capital expenditure required for power transmission facilities.

  Commercial applications of this technology include Amtrak's 125 mph AEM7 service between Washington, D.C. and New York City; Germany's 100 mph intercity express train service; and, most recently, Sweden's electric X2 train which, with the help of active body tilting, can operate at speeds exceeding 125 mph.

CHARACTERISTICS OF THE VERY HIGH SPEED (185 MPH) TECHNOLOGY

Commercial intercity passenger service at a 185 mph commercial speed is a recent development, and is the result of a significant research and development investment by Japan and a few countries in Europe that have made a commitment to implementing their respective technologies over their national networks. The equipment for Very High Speed operations is based on steel-wheel-on-steel-rail technology, but uses electric traction with overhead power distribution. Rail operations at 185 mph generally require dedicated, grade-separated rights-of-way and are developed as fully integrated systems.

There are currently three operational systems in commercial use:

- The Japanese Shinkansen or "Bullet Train" which operates between Tokyo and Osaka, a distance of 310 miles, at a maximum commercial speed of 160 mph.

- The French TGV-Atlantique which provides service between Paris and LeMans at a commercial speed of 185 mph and attained a maximum speed of 322 mph in a test run in 1990.

- The British Electra or Class 91 on the East Coast and West Coast Main Lines with a maximum speed of 180 mph.

In addition, there is the German Intercity Experimental (ICE) Train which has attained a maximum speed of 256 mph and is scheduled to enter commercial operation between Munich and Hamburg in the summer of 1991

CHARACTERISTICS OF THE SUPER SPEED (300 MPH) TECHNOLOGY

Most technologies proposed for Super Speed passenger operations incorporate gearless traction and therefore represent a departure from traditional steel-wheel-on-steel-rail technologies. These technologies, which incorporate magnetic levitation (maglev), are propelled by linear induction. Maglev requires a totally dedicated guideway, which is usually envisioned as being elevated to physically separate it from its surroundings.

There are currently no commercial maglev systems in operation. However, both Germany and Japan have announced that they will have systems in commercial operation by 1998. German research has focused almost exclusively on attraction-type systems (the Transrapid). Japanese research efforts have encompassed both alternative means of magnetic levitation: Japan Airlines with its HSST, which is based on attraction-type levitation and Japan National Railways' development of superconducting repulsion-type systems.

TECHNOLOGIES SELECTED FOR STUDY ANALYSIS

To effectively represent the technology characteristics of the High Speed (125 mph), Very High Speed (185 mph) and Super Speed (300 mph) technologies, it was necessary to identify specific systems that could be used in the Tri-State Study to characterize the performance of that group of technologies. In the case of the High Speed and Very High Speed technologies, there are obvious candidates in terms of well proven technologies. For the Super Speed option, there is no proven technology, only prototype German and Japanese technology.

For the study analysis, the following systems were selected to represent the High Speed, Very High Speed and Super Speed technology options:

• High Speed	125 mph	British Railways HST
• Very High Speed	185 mph	French Railways TGV-Atlantique
• Super Speed	300 mph	Japanese MLU or Linear Express (superconducting)

The design specifications for the selected technology options are compared with those of Amtrak in Exhibit 2.1.

Exhibit 2.1
Technology Specifications for the 125 mph, 185 mph and 300 mph Technology Options Compared with Amtrak[1]

	Amtrak	125 mph	185 mph	300 mph
Consist[2]	1 + 8	2 + 7/8	2 + 8	2-car unit
Motive Power	25 KV 60 Hz electric	12-cylinder diesel	25 KV 50 Hz electric	Superconducting magnetic levitation
Power Car/Locomotive Weight (tons)	100	70 each	70.9 each	—
Maximum Axle Load (tons)	19	17	16.5	—
Buff Strength (tons)	268	200	200	—
Maximum Design Speed (mph)	125	125	185	300
Maximum Commercial Speed (mph)	120	125	185	300
Typical Commercial Speed (mph)	100	100	160	200
Seating Capacity (per coach)	84	48/72[3]	38/80[3]	96

(1) *North East Corridor.*
(2) *For the three steel-wheel-on-steel-rail technologies, the first number indicates the number of locomotives in the consist and the second number, the number of passenger cars.*
(3) *Number of seats in a given car depends upon whether it is a first class/second class car.*

HIGH SPEED TECHNOLOGY OPTION

For the High Speed or 125 mph technology option, the most outstanding system is undoubtedly the British HST which, since its introduction in 1975, has been the backbone of British Railway's intercity network. With a high-speed, 12-cylinder Paxman diesel engine, the HST has produced over 200,000 miles of passenger service a year at average commercial speeds of 100 mph. With low axle weights and the ability to pull 7 to 10 cars, the technology has exceeded the expectations of its producers with respect to low track maintenance costs and the market appeal of riding the train. The 125 mph technology is a low-cost option as it requires no electrification and limited grade-separated crossings. The major limitation of the technology is that, because it is operating at peak performance in terms of speed and miles operated per year, the maintenance costs and life cycle costs for the two lightweight power packs are high in relation to comparable electric traction.

VERY HIGH SPEED TECHNOLOGY OPTION

At increased speeds and certainly at 185 mph, electric traction provides the only real steel-wheel-on-steel-rail alternative for Very High Speed rail operations. The French TGV-Atlantique is undoubtedly the most effective candidate for this technology option, having set the world record of 320 mph (515.3 kph) in a test run in May 1990. The TGV system has the same lightweight characteristics as the British HST, with a maximum axle load of 16.5 tons and life cycle costs which are not substantially greater than those of 125 mph electric train systems. Given the ability of electric power packs to be upgraded for increased speed without major redesign, it is not surprising that the second generation of the TGV, the TGV-Atlantique, was able to easily provide a 185 mph commercial speed since its introduction on the Paris-LeMans route in 1989. While new

German, Italian, Japanese, Swedish and British technology is under development or currently entering service, the French TGV is the only proven system capable of maintaining a commercial speed of 185 mph.

SUPER SPEED TECHNOLOGY OPTION

With respect to the Super Speed (300 mph) or maglev technology option, both Germany and Japan have been working on the development of maglev technology for the past twenty years. At least two different forms of traction systems, superconducting and electromagnetic, are under investigation. The superconducting systems have powerful, lightweight magnets mounted on the vehicles, which produce levitation, propulsion and guidance by interacting with a metal track, usually aluminum, that is attached to an at-grade or elevated track structure. The electromagnetic systems have electromagnets along both sides of the vehicle as well as along the track. The electromagnets along the track are typically attached to the underside of the track structure and levitation, propulsion and guidance are generated from the "attractiveness" of the electromagnets on the vehicles and the track.

In terms of performance and costs, the electromagnetic systems appear to have a number of disadvantages. Because the electromagnets have an iron core, the magnets on the vehicles and on the track are very heavy. To minimize the impact of the vehicle weight on power requirements, the electromagnetic gap is kept as small as possible (3/8ths of an inch compared with 4 inches for the superconducting system). As a result, the electromagnetic system is inherently unstable when compared with superconducting levitation, and requires expensive, sophisticated control systems to monitor the gap between the vehicle and the track. In addition, the guideway support requirements of the electromagnetic system (and its construction costs) are significantly greater than those for the superconducting system. Moreover, the German electromagnetic system is purported to be capable of achieving a commercial speed of 250 mph, compared to 300 mph for the Japanese superconducting.

Given the decision of the Japanese to proceed with the Tokyo-Osaka project, which means that the superconducting maglev system will be the first in commercial service, that technology was selected as the most appropriate for the Tri-State Study.

TECHNOLOGY ISSUES

With respect to the introduction of the 125 mph and 185 mph technologies in the Tri-State Corridor, a number of issues must be considered because of the requirement for interworking with existing freight operations.

The first technology issue concerns buff strength, which is the level of head-on impact force that a rail vehicle can withstand and not buckle or crumple. The Federal Railroad Administration (FRA) regulations call for an end load strength of 400 tons for locomotives; if the train has less than six cars, this regulation does not apply. The FRA does not have a buff strength regulation for cars; instead, the American Association of Railroads (AAR) has a recommended standard of 400 tons which the railroad industry generally complies with. The FRA regulation/AAR standard of 400 tons is nearly twice the European Union International du Chemin de Fer standard of 200 metric tons used by both the French and British technologies. While the European standard is lower because of the reduced size of its freight trains, it should be noted that waivers are granted on a regular basis by the FRA. The FRA can grant a waiver if it determines that a system is safe to operate with a lower buff load. For example, the AEM7's used on Amtrak's North East Corridor have a buff load of 268 tons.

For purposes of the Tri-State Study, the assumption was made that a buff strength of 400 tons would be complied with for the 125 mph and 185 mph technologies (with no loss of performance), or a waiver would be granted for the buff strength requirement. In other words, either the European technology would be redesigned to the meet the FRA regulation, or the regulation waived to take account of recent advances in locomotive design.

The second technology issue concerns the differences in certain design criteria used in Europe, Japan and North America. It is assumed that, for the 125 mph and 185 mph technologies, design issues such as coupling height, electrical systems, braking standards, noise and diesel emissions, equipment needs (for example, hand rails and hand brakes) and heating and cooling systems can all be accommodated. In this regard, when the British HST was redesigned as the XPT for Australian conditions (which are close to those of North America in terms of operating conditions and climate), there were no major design problems despite the combination of high speed technology with a freight environment that is similar to North America's.

In the case of the maglev technology, it was assumed for study purposes that, since maglev is a new technology and not a "conventional" rail technology, a new set of regulations would be defined for the technology.

CHAPTER 3

ROUTES

The Tri-State Steering Committee established two corridors, shown in Exhibit 3.1, to be studied in order to determine the feasibility of high speed rail between Chicago, Milwaukee and Minneapolis-St. Paul: the Southern Corridor (Chicago-Milwaukee-Madison-La Crosse-Winona-Rochester-Minneapolis/St. Paul) and the Northern Corridor (Chicago-Milwaukee-Appleton- Green Bay-Wausau-Eau Claire-Minneapolis/St. Paul).

The existing Amtrak route in the Southern Corridor was selected for the High Speed technology option in order to determine the feasibility of upgrading Amtrak service to 125 mph service. The identification of route options within the two corridors for the Very High Speed (185 mph) and Super Speed (300 mph) technologies was based on the following four objectives:

- Minimizing travel time between the major cities to be served.

  The routes were to be as direct as possible and curves limited to zero degrees and twenty minutes so that the route would be able to accommodate either the Very High Speed (185 mph) or the Super Speed (300 mph) technology.

- Minimizing the impact of the rail system on the natural topography and, conversely, the impact of topography on the rail system.

  High speed trains for optimum efficiency require a gradient of three percent or less so, in order to maximize speeds and minimize construction costs, large topographic features were to be avoided wherever possible. Because railroads have historically chosen the best vertical alignments between cities, an effort was made to stay near existing or former rail lines.

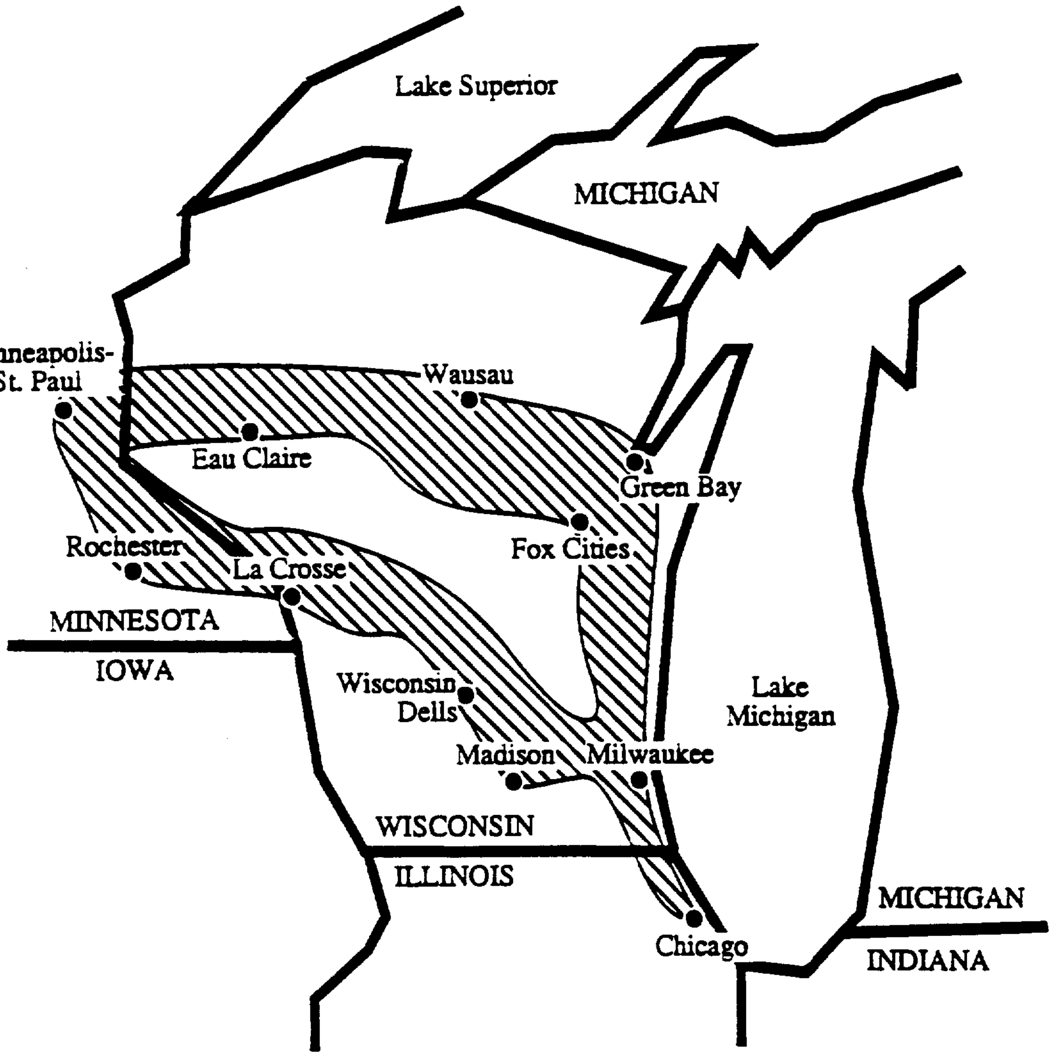
- Maximizing regional accessibility.

  To ensure the highest level of service, the rail routes were to connect to as many population centers as reasonable given the need to minimize travel times, capital costs, and operating and maintenance costs. Each route was to have a station in downtown Chicago, Milwaukee and Minneapolis-St. Paul, and additional stations at suitable locations along the route.

- Minimizing the impact of the construction and operation of high speed trains on the environment.

  Wetlands, wildlife preserves and areas of known or suspected historical and archeological resources were to be avoided wherever possible.

Exhibit 3.1
Northern and Southern Corridors
Tri-State Study of High Speed Rail Service



ROUTES SELECTED FOR ANALYSIS

Based on the objectives outlined above, three routes in the Southern Corridor and four routes in the Northern Corridor were selected for analysis:

- Southern Corridor
  - Route #1: Existing Amtrak Route
  - Route #2: South Route (Columbus/Rochester)
  - Route #4: South Route Modified (Madison/Rochester)

- Northern Corridor
  - Route #3: North Route (Ripon)
  - Route #5: North Route Modified (Fox Cities)
  - Route #6: North Route Modified (Green Bay)
  - Route #7: North Route Modified (Green Bay/Fox Cities)

Each of the seven routes was subjected to a preliminary, but rigorous analysis that was based on: field inspection of the rights-of-way; environmental constraints; distribution of population and employment; and topographic and geologic conditions. The engineering analysis also assessed the availability of electrical power, and the location of nearby transmission lines, substation and generating plants were identified.

To facilitate the engineering and environmental analysis process, each route was subdivided into route segments as shown in Exhibit 3.2. The following provides a brief description of the general alignment for each of the seven routes.

SOUTHERN CORRIDOR

Route #1: Existing Amtrak Route

Route #1 proceeds from Union Station in downtown Chicago (MP0) northerly to the outskirts of Kenosha, Wisconsin (MP40) and on to Milwaukee (MP85). From Milwaukee, the route proceeds in a northwesterly direction through Columbus (MP150), Portage (MP178), Wisconsin Dells (MP195), and Tomah (MP240) and then proceeds to La Crosse (MP282). North of La Crosse, the route proceeds west of the Mississippi River through Winona (MP308) and Red Wing, Minnesota (MP371) to Minneapolis-St. Paul (MP418).

Route #2: South Route (Columbus/Rochester)

Route #2 proceeds north from Chicago (MP0) parallel to the Amtrak Route to Kenosha, Wisconsin (MP40), Milwaukee (MP85), and Duplainville (MP100). From Duplainville, it proceeds to Pewaukee (MP103), Hartland (MP107), Oconomowoc (MP113), Watertown (MP128), Columbus (MP147), Portage (MP174) and Wisconsin Dells (MP193). Immediately west of Wisconsin Dells, the route runs north of and parallel to Interstate 90-94 to Tomah (MP237). At Tomah, the route crosses Interstate 90 to Rockland (MP259) where it crosses Interstate 90 to La Crosse (MP274). From La Crosse, the route proceeds south of and parallel to Interstate 90 to St. Charles, Minnesota (MP320) where it diverges from the highway and proceeds north to Rochester (MP341). From Rochester, the route parallels the west side of Highway 52 to Minneapolis-St. Paul (MP415).

Exhibit 3.2
Route Segments

Route	Route Segment	Milepost	Nearest City
Southern Corridor			
#1	1a	0 to 85	Chicago to Milwaukee
		85 to 102	Milwaukee to Duplainville
	1c	102 to 178	Duplainville to Portage
	1d	178 to 418	Portage to Minneapolis-St. Paul
#2	2a	0 to 85	Chicago to Milwaukee
	2b	85 to 100	Milwaukee to Duplainville
	2c	100 to 174	Duplainville to Portage
	2d	174 to 415	Portage to Minneapolis-St. Paul
#4	2a	0 to 85	Chicago to Milwaukee
	2b	85 to 100	Milwaukee to Duplainville
	4c	100 to 164	Duplainville to Madison
		164 to 194	Madison to Portage
	2d	194 to 435	Portage to Minneapolis-St. Paul
Northern Corridor			
#3	2a	0 to 85	Chicago to Milwaukee
	2b	85 to 100	Milwaukee to Duplainville
	3c	100 to 208	Duplainville to Waupaca
	3d	208 to 275	Waupaca to Spencer
	3e	275 to 432	Spencer to Minneapolis-St. Paul
#5	2a	0 to 85	Chicago to Milwaukee
	2b	85 to 100	Milwaukee to Duplainville
	5c	100 to 215	Duplainville to Fox Cities to Waupaca
	3d	215 to 282	Waupaca to Spencer
	3e	282 to 439	Spencer to Minneapolis-St. Paul
#6	2a	0 to 85	Chicago to Milwaukee
	6c	85 to 253	Milwaukee to Green Bay to Waupaca
	3d	253 to 317	Waupaca to Spencer
	3e	317 to 474	Spencer to Minneapolis-St. Paul
#7	2a	0 to 85	Chicago to Milwaukee
	7b	85 to 305	Milwaukee to Wrightstown to Spencer
	7e	305 to 462	Spencer to Minneapolis-St. Paul

Route #4: South Route Modified (Madison/Rochester)

Route #4 is on the same alignment as the South Route (Route #2) from Chicago (MP0) to Milwaukee (MP85) to MP119. The route then proceeds westerly toward Watertown (MP128). It continues to proceed west, parallel to the north side of Interstate 94, to Lake Mills (MP141) and toward Madison. Near the interchange of Interstate 90-94 and U.S. Highway 151 (MP164), it proceeds along the west side of Interstate 90-94 to Portage (MP194). The route then proceeds along the South Route (Route #2) to Minneapolis-St. Paul (MP435).

NORTHERN CORRIDOR

Route #3: North Route (Ripon)

Route #3 proceeds north from Chicago, parallel to the Amtrak Route, to Kenosha, Wisconsin (MP40). The routes departs from the Amtrak Route and proceeds parallel to and one mile east of the Amtrak Route until it meets the Amtrak Route at MP51. The route then proceeds parallel to the Amtrak Route through Milwaukee (MP85) to Duplainville (MP100). From Duplainville, the route proceeds north, parallel to and west of U.S. Highway 41, to Lomira (MP139). From Lomira, it proceeds northwesterly to the vicinity of Oakfield (MP148), to Rosendale, Ripon (MP166), Rush Lake and Weyauwega. From Weyauwega, the route proceeds westerly and parallel with U.S. Route 10 to the vicinity of Stevens Point (MP234) and Marshfield. West of Marshfield, the route proceeds north of and parallel to the Wisconsin Central tracks to Spencer (MP275) and Owen (MP295). The route proceeds parallel to Wisconsin Route 29 from Owen to Chippewa Falls (MP336). West of Chippewa Falls, the route proceeds along the existing Wisconsin Central tracks to the vicinity of Colfax, Glenwood City (MP376) and on to Somerset, White Bear Lake and Minneapolis-St. Paul (MP432).

Route #5: North Route Modified (Fox Cities)

Route #5 proceeds along the same alignment as the North Route (Route #3) from Chicago (MP0) to Lomira, Wisconsin (MP139). From Lomira, it proceeds northerly parallel to the west side of U.S. Highway 41 to the vicinity of Oskhosh (MP170) crossing the Lake Butte des Morts. It proceeds north to the Fox Cities area and then westerly, paralleling the existing alignment of the Wisconsin Central Railroad, to the vicinity immediately east of Waupaca (MP215). The route then proceeds on the same alignment as the North Route (Route #3) to Minneapolis-St. Paul (MP439).

Route #6: North Route Modified (Green Bay)

Route #6 proceeds on the same alignment as the North Route (Route #3) from Chicago (MP0) to Milwaukee (MP85). North of Milwaukee, the route proceeds through Port Washington, Sheboygan and Manitowoc to Green Bay. From Green Bay, the route proceeds westerly, paralleling the alignment of the Green Bay and Western Railroad, to Amherst Junction. From Amherst Junction, the route proceeds on the same alignment as the North Route (Route #3).

Route #7: North Route Modified (Green Bay/Fox Cities)

Route #7 proceeds on the same alignment as the North Route (Route #3) from Chicago (MP0) to Milwaukee (MP85). North of Milwaukee at Brown Deer (MP96), the route crosses Interstate 43 near Lakefield and proceeds north parallel to State Route 57. The route then proceed east of

Plymouth (MP138), St. Nazianz (MP157), Reedsville (MP167), and across the Niagara Escarpment northeast of Greenleaf (MP185). At Greenleaf, the route proceeds west, beyond Wrightstown, towards the vicinity of New London (MP218) and Mosinee (MP274). The route continues in a westerly direction from Mosinee to Spencer (MP305). At Spencer, the route proceeds on the same alignment as the North Route (Route #3) to Minneapolis-St. Paul (MP462).

COMPARATIVE EVALUATION OF ROUTES

A comparative evaluation of each of the seven routes was conducted to ascertain the extent to which each achieved the objectives established for route selection. These objectives were minimizing travel time between major cities, minimizing the impact on the natural topography, maximizing regional accessibility, and minimizing the impact on the environment.

A Comparative Evaluation of Environmental Constraints by route segment was first completed, and its results used as input to the Comparative Engineering Evaluation.

COMPARATIVE EVALUATION OF ENVIRONMENTAL CONSTRAINTS

To properly evaluate environmental constraints, a rating system was established. Based on a careful assessment of the environmental constraints and concerns, a rating from one to five was applied to each route segment identified in Exhibit 3.2. A rating of one (1) indicates that the construction of a high speed rail system would have major environmental impact(s), whereas a rating of five (5) indicates that there are minimal environmental concerns. In order to arrive at a rating for each route, the cumulative total for each route is divided by the number of route segments. The results of the Comparative Evaluation of Environmental Constraints are presented in Exhibits 3.3 and 3.4.

Exhibit 3.3
Comparative Evaluation of Environmental Constraints in the Southern Corridor

Route #1 Existing Amtrak		Route #2 Columbus/Rochester		Route #4 Madison/Rochester	
Segment	Rating	Segment	Rating	Segment	Rating
1a	4	2a	3	2a	3
		2b	3	2b	3
1c	4	2c	2	4c	4
1d	4	2d	2	2d	2
	--		--		--
	12		10		12
Average	4.0	Average	2.5	Average	3.0

Exhibit 3.4
Comparative Evaluation of Environmental Constraints in the Northern Corridor

Route #3 Ripon		Route #5 Fox Cities		Route #6 Green Bay		Route #7 Green Bay/Fox Cities	
Segment	Rating	Segment	Rating	Segment	Rating	Segment	Rating
2a	3	2a	3	2a	3	2a	3
2b	3	2b	3			7b	2
3c	3	5c	2	6c	1		
3d	3	3d	3	3d	3		
3e	3	3e	3	3e	3	3e	3
	--		--		--		--
	15		14		10		8
Average	3.0	Average	2.8	Average	2.5	Average	2.7

In the Southern Corridor, Route #1 scored the highest, indicating that this route would have the least impact on the environment. This result was expected since the route essentially follows the existing Amtrak Route, with only a few reductions of curvatures in the alignment when necessary to maintain speed. Route #4 scored higher than Route #2, principally because there are fewer wetlands in the immediate vicinity of Route #4.

In the Northern Corridor, Route #3 scored the highest, followed by Route #5 and Route #7, with Route #6 scoring the lowest.

COMPARATIVE ENGINEERING EVALUATION

Similarly, for the Comparative Engineering Evaluation of the seven routes, a subjective rating system was used to compare the extent to which each route achieves the four objectives relating to travel time, topography, regional accessibility and environmental impact. The ratings already determined for the Comparative Environmental Evaluation (Exhibits 3.3 and 3.4) were used and, for the other three objectives, a rating of one to five was applied. A rating of one (1) indicates very poor; two (2), poor; three (3), fair; four (4), good; and five (5) is excellent. The results of the Comparative Engineering Evaluation are given in Exhibit 3.5.

As shown in Exhibit 3.5, Route #4 (South Route Modified-Madison/Rochester) in the Southern Corridor and Route #7 (North Route Modified-Green Bay/Fox Cities) in the Northern Corridor, along with Route #1 (Existing Amtrak Route), achieved the highest ratings. Route #4 and Route #7 scored highest with respect to regional accessibility and travel time. With the exception of Route #1, the Existing Amtrak Route, all the routes had essentially the same ratings for minimizing impacts on natural topography and the environment.

Exhibit 3.5
Comparative Engineering Evaluation

	Southern Corridor			Northern Corridor			
	Rating for Route			Rating for Route			
Objective	#1	#2	#4	#3	#5	#6	#7
Minimizing Travel Time	3.0	5.0	4.0	5.0	5.0	3.0	4.0
Minimizing Impact on Topography	5.0	2.0	3.0	4.0	4.0	3.0	3.0
Maximizing Regional Access	3.0	3.0	5.0	1.0	2.0	3.0	5.0
Minimizing Impact on the Environment	4.0	2.5	3.0	3.0	2.8	2.5	2.7
Total	15.0	12.5	15.0	13.0	13.8	11.5	14.7

RECOMMENDED ROUTES

The three routes shown in Exhibit 3.6 are recommended for further engineering and economic evaluation:

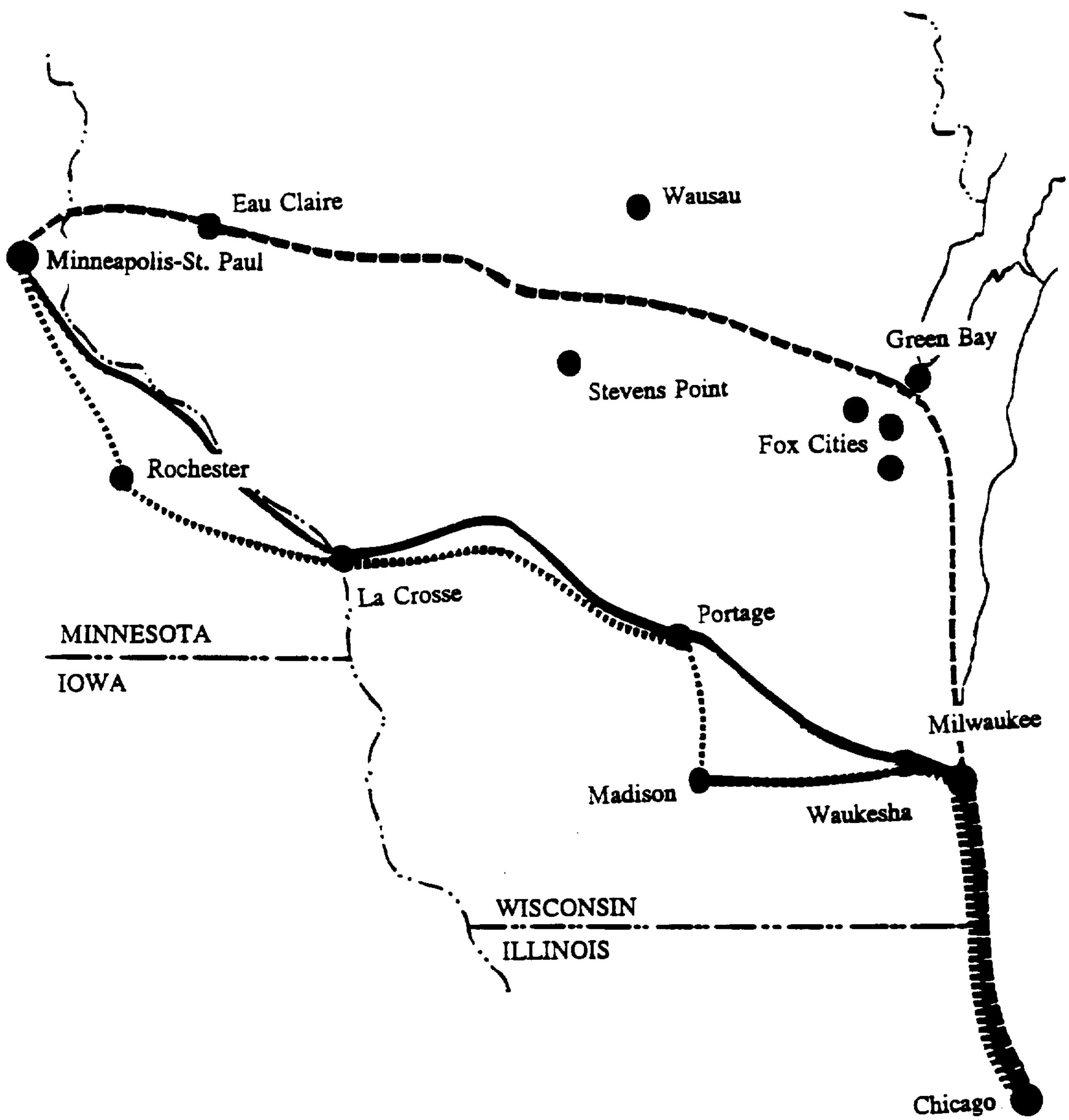
- Route #1: Existing Amtrak Route in the Southern Corridor
- Route #4: South Route Modified (Madison/Rochester) in the Southern Corridor
- Route #7: North Route Modified (Green Bay/Fox Cities) in the Northern Corridor

On the basis of the evaluation conducted for this study, it is felt that potential major problem areas and constraints relating to topography and the environment have been identified. The specific route alignments used in the study, however, are of a preliminary nature and their primary function was to provide a basis for preparing preliminary ridership forecasts, preliminary capital costs, and preliminary operating and maintenance costs. The three routes must be subjected to further study and evaluated in greater detail prior to the final selection of a route.

ROUTE #1: EXISTING AMTRAK ROUTE

Route #1, the Existing Amtrak Route, between Chicago and Minneapolis-St. Paul was specified as the base case option in order to determine the feasibility of upgrading Amtrak service to 125 mph. It has been determined that the route is suitable for High Speed (125 mph) diesel passenger trains, provided that curves are reduced to 0°-45' as opposed to 0°-20' for the 185 mph and 300 mph options. With reference to topographical considerations and environmental constraints, Route #1 received the highest rating, since it basically follows the existing Amtrak alignment. This route received a rating of 3 (fair) for travel time, because the average trip between Chicago and Minneapolis-St. Paul now takes in excess of eight hours. However, improvements to the alignment by reducing curves will substantially reduce travel time.

Exhibit 3.6
Recommended Routes



Route #1: Existing Amtrak Route
Route #4: South Route Modified (Madison/Rochester)
Route #7: North Route Modified (Green Bay/Fox Cities)

Accessibility was rated as 3 (fair) since the existing route does not connect with Madison or Rochester. The total evaluation rating for Route #1 is 15.0, and the route is recommended for further engineering and economic evaluation.

ROUTE #4: SOUTH ROUTE MODIFIED (MADISON/ROCHESTER)

Two additional routes in the Southern Corridor were analyzed: Route #2, South Route (Columbus/Rochester) and Route #4, South Route Modified (Madison/Rochester). The Comparative Engineering Evaluation indicates that Route #4, with a rating of 15.0, is superior to Route #2.

For travel time, Route #4 was rated 4 (good) and Route #2 was rated 5 (excellent) as it is twenty miles shorter. With reference to topographical considerations, Route #4 was assigned a rating of 3 (fair) and Route #2, a rating of 2 (poor). Similarly, with reference to environmental constraints, Route #4 received a higher rating than Route #2. Route #4 crosses two major rivers, the Rock and Crawfish, a minimum amount of wetlands, and generally follows existing interstate highways through relative undeveloped land on favorable topography, while Route #2 passes through rugged terrain and crosses the Beaver Dam River, Mud Lake State Wildlife Area, and associated wetlands. Route #2, which largely follows the Soo Line maintrack, also passes near existing towns and developed areas.

With reference to regional accessibility, Route #4 is accessible to the Madison metropolitan area and accordingly was rated 5 (excellent), whereas Route #2, which is not accessible to Madison, was rated 3 (fair).

In the Southern Corridor, Route #4 with its more favorable topography, lesser environmental impact, and better regional accessibility generated by its serving the Madison area is recommended for further engineering and economic evaluation.

ROUTE #7: NORTH ROUTE MODIFIED (GREEN BAY/FOX CITIES)

In the Northern Corridor, four routes were analyzed: Route #3, North Route (Ripon); Route #5, North Route Modified (Fox Cities); Route #6, North Route Modified (Green Bay); and Route #7, North Route Modified (Green Bay/Fox Cities).

With reference to travel time and regional accessibility, Route #3 is the shortest and, therefore, requires the least travel time, but it is not generally accessible to population centers in the region. Route #5, although slightly longer, is accessible to Fox Cities. Both of these routes were assigned a rating of 5 (excellent) for travel time. Because of their poor regional accessibility, Route #3 was rated 1 (very poor) and Route #5 was rated 2 (poor).

Route #6, while it is the longest route, is accessible to Sheboygan, Manitowoc and Green Bay; Route #7 is accessible to Sheboygan, Manitowoc, Green Bay, Fox Cities and Wausau. Route #6 was rated 3 (fair) for travel time and accessibility, whereas Route #7 was rated 4 (good) for travel time and 5 (excellent) for regional accessibility.

All the routes analyzed in the Northern Corridor have environmental drawbacks and received ratings of 3 (fair) or less. With reference to topographical considerations, Route #3 and Route #5 scored higher than Route #6 and Route #7. Both Route #6 and Route #7 cross the Wolf and Embarrass Rivers and encroach on the Niagara Escarpment. The Niagara Escarpment is a barrier to high speed rail, not only because of the environmental concerns associated with it but also because of the additional engineering costs that are imposed on any route that crosses it.

Due to the tremendous cost that will be required to construct a high speed rail system and the fact that there are no overriding environmental issues which clearly dictate a route choice, regional accessibility became the overriding factor in the selection of a route in the Northern Corridor for further analysis. Route #7 (Green Bay/Fox Cities) received the highest rating for regional accessibility. Route #7 also had the highest overall rating, 14.7, as compared with 13.8 for Route #5, 13.0 for Route #3 and 11.5 for Route #6.

CHAPTER 4

RIDERSHIP

A key step in determining the feasibility of high speed rail in the Tri-State Corridor was the evaluation of existing travel patterns between the communities of the Northern and Southern Corridors, how these travel patterns and ridership levels were expected to change and grow over the next twenty to thirty years, the impact that a high speed rail system might have on travel behavior, and the ridership that high speed rail could be expected to generate.

To evaluate the nature of existing travel patterns, a comprehensive data base was developed including zone-to-zone (origin-destination) travel movements by trip purpose for the whole study area, information on the modes of travel (air, rail, bus and auto) and the associated costs and times of journeys, and socioeconomic data (income, employment, population) for the different travel zones. These data were largely available from existing data sources. Where weaknesses in the data assembled were identified, specific analyses were undertaken to mitigate the effects of those weaknesses.

The travel data and information were supplemented by an Attitudinal Survey which was undertaken to provide insight into the choices individuals make between time and money and the circumstances under which travelers might be willing to pay a different fare for a different level of service. The survey information was assessed using a Trade-Off Analysis based on stated preference techniques to provide specific Values of Time and Values of Frequency for use in the forecasting process.

Once a clear understanding of the existing travel patterns was obtained, the COMPASS(c) Model was used to make forecasts of, one, future traffic and, two, the market share that could be achieved by high speed rail. The model was validated using a series of statistical and "reasonableness" checks, and forecasts were prepared on a mode, purpose, and zone-to-zone trip-making basis. The forecasts were based on a series of economic scenarios and transportation strategies and subjected to sensitivity assessments to check the robustness of the forecasts and the stability of the results achieved.

ZONE SYSTEM

The study area consists of two corridors between Chicago, Milwaukee and Minneapolis-St. Paul and, as previously shown in Exhibit 3.1, covers parts of Illinois, Wisconsin and Minnesota. Since the primary unit of analysis of the transportation forecasting system is zone-to-zone trips, the first step in the analysis was to divide the study area into a set of zones. Appropriate zone size is determined by a series of analytic and pragmatic considerations: the zones should be small enough to provide insight into the patterns of travel but large enough to ensure a sufficient volume of trips for statistical analysis and compatibility with state and local planning data.

To meet these needs, the county was chosen as the basic zonal unit. In remote rural areas, counties were aggregated into larger zones; and, in densely populated urban areas, counties were disaggregated into zones of an appropriate size. The zone system for the Tri-State Study consists of 139 zones and, to facilitate data assembly, was designed to be compatible with the different zone systems used by state and local planning agencies. The zones were defined using the Wisconsin Department of Transportation's (WisDOT's) Travel Analysis Zones, the Twin Cities Metro Council's Urban Activity Forecast Districts for the Minneapolis-St. Paul metropolitan area and, from the Illinois Department of Transportation (IDOT), the Traffic Zones of the Illinois Rail Forecasting Model.

DATA BASE

Once the zone system was defined, data on travel networks, socioeconomic characteristics of the population, and origins-destinations were assembled in a data base.

NETWORK DATA

The network characteristics data (time and cost of trip-making) are an important input to the forecasting process and are essential for model calibration. In transportation analysis, the desirability of travel is measured in terms of both the cost and time of travel and, as such, a full itinerary of travel costs and times is needed. The network data assembled for the study included the following for all zones pairs:

- For private mode (auto):
    - Travel time including rest time
    - Travel cost (vehicle operating cost)
    - Tolls

- For public modes (air, rail and bus):
    - Access and egress times and costs
    - Terminal waiting and delay times
    - In-vehicle travel times
    - Number of interchanges and connect times
    - Fares
    - Frequency of service

The network data were obtained from a variety of sources, the most important being the urban and statewide models of IDOT, WisDOT, Southeastern Wisconsin Regional Planning Commission, Twin Cities Metro Council, and CATS (Chicago Area Transportation Study). Data on private auto operating costs were obtained from the Federal Highway Administration and the American Automobile Association. Public transportation travel time and cost data were derived from Amtrak schedules, the Official Airline Guide, and Russell's Bus Guide. Data on air terminal connections were derived from an evaluation of route options and known travel behavior.

SOCIOECONOMIC DATA

The data bank for socioeconomic variables was derived from existing publications. The data were checked for consistency and processed to fit the COMPASS(c) Model's zonal system requirements for the base and forecast years. Periodicals published by state and federal agencies provided the bulk of the data, supplemented by economic model forecasts from recently completed transportation studies or from independent research institutes. The variables required for the COMPASS[c] Model are population, employment and household income.

Data processing procedures were carried out in order to ensure that socioeconomic data from the various sources provided a consistent assessment of the performance of the economies of the three states in the base year and the forecast years. The data processing work included data updates, conversions of variables, reallocation of county data to smaller urban zones, data interpolation, and consistency checks.

ORIGIN-DESTINATION DATA

Travel data required for the study included the annual passenger volumes between zone pairs for each mode and each trip purpose. Traffic volumes at specific locations on highways or between stations/terminals for public modes were readily available from the State DOT's and relevant agencies. The passenger flow between zone pairs is usually obtained from origin-destination surveys. Such surveys for the auto mode are carried out periodically by State DOT's. Similar surveys for public modes were not readily available, although station-to-station or terminal-to-terminal data were available from Amtrak and the Federal Aviation Administration. For bus travel, the bulk of the origin-destination data were obtained from a recent Wisconsin statewide survey.

The origin-destination data were assembled in a data base and a series of data processes were applied to provide a comprehensive 1989 origin-destination matrix. The matrix included bus, rail, air and auto travel by work, commuting and "other" travel purposes. The data processing procedures used included:

- Factoring historical data to the 1989 base year
- Reconciling travel purpose data between the different data sets
- Apportioning traffic flow data to specific zone pairs
- Quantifying fare/distance relationships for air, rail and bus.
- Estimating trip volumes in rural areas and across state boundaries.

There were a number of data weaknesses resulting from the nature of the data sets and the averaging effects of the trip expansion process, which caused data "noise" and "inconsistencies." Specific data weaknesses included:

- Inadequate car data in northern Wisconsin and between smaller settlements throughout Wisconsin.

- Interface problems for car and bus data at the Wisconsin/Minnesota and Wisconsin/Illinois borders.

- Lack of data on ultimate zone origins and destinations for rail and air.

- Inadequate definition of rail and air trip purposes.

To overcome or minimize the effects of specific data weaknesses, a detailed assessment was made of the data and a number of aggregation procedures were adopted during the calibration process.

DEVELOPMENT OF VALUES OF TIME AND VALUES OF FREQUENCY

An important element in the development of the traffic forecasting and evaluation process is the assessment of an individual's perception of the importance of travel time and service frequency. To identify the travel behavior characteristics of individuals in the Tri-State Corridor, an Attitudinal Survey was undertaken in August and September 1990, the results of which were used to derive Values of Time and Values of Frequency.

Value of Time is defined as the amount of money (dollars/hour) an individual is willing to pay to save a given amount of travel time. Value of Frequency is the amount of money (dollars/hour) that an individual is willing to pay when traveling on public transportation to reduce the time between departures.

ATTITUDINAL SURVEY

To carry out the most extensive survey possible within the time scales and budget of the study, the Attitudinal Survey was structured into three distinct surveys: one for long-distance air trips, one for long-distance surface trips, and one for short-distance surface trips. Long-distance trips are defined as trips of more than 100 miles, and short-distance trips as trips of 100 miles or less. The air survey took place in the Milwaukee, Madison and Minneapolis-St. Paul airport departure lounges, the rail survey aboard Amtrak trains in the corridor, and the bus survey on Greyhound and Badger buses in the corridor. For Wisconsin and Minnesota, the auto survey was a mail-out/mail-back questionnaire sent to licensed drivers; in Illinois, it was a hand-out/mail-back survey.

The survey questionnaires were designed to derive Values of Time and Values of Frequency using stated preference techniques. The essence of the stated preference approach is to ask the traveler to make a series of trade-off choices based on different combinations of travel time, frequency and cost. The use of a series of questions is essential both to allow individuals to understand the process and provide improved responses, but also to check the consistency and rationality of the responses given.

To ensure that the individuals surveyed would be representative of the general population, a quota sample was defined that incorporated the most important factors that affect travel choice. These included the four modes by which individuals in the corridor travel (auto, air, bus and rail), the three principal reasons for travel (work, commuting and "other"), the length of the trip made (short or long), and the socioeconomic characteristics of the traveler based on a two-fold income stratification (high or low). A successful quota survey requires that at least 30, and more comfortably 40, surveys are obtained for each stratification group for the survey results to be statistically significant. The survey quota results for the Attitudinal Survey are shown in Exhibit 4.1.

Exhibit 4.1
Number of Valid Surveys by Quota Cell by Travel Mode and Purpose

	Air	Rail	Auto	Bus	Total
Business	183	63	54	18	318
Commuter	8	21	142	8	179
Other	270	207	377	145	999
Total	461	291	573	171	1496

It can be seen that the survey process produced valid survey numbers (more than 30 surveys) in the key categories of business travel for air, rail and auto, "other" travel for all modes, and commuting for auto. It should be noted that, because intercity bus, air and rail are not extensively used for commuting in the corridor, the number of valid surveys is lower for these three categories.

Once the data were obtained, they were subjected to a series of range and consistency checks to ensure the validity of the responses and the quality of the data. The data were evaluated using a Trade-Off Analysis, which identified how individuals choose between time and money in selecting travel options. Two trade-off analysis methods, the Comparison Method and the Binary Logit Method, were employed to analyze the Attitudinal Survey data and determine Values of Time (VOT's) and Values of Frequency (VOF's).

In the Comparison Method, the trade-off choices made by individuals are ranked in descending or ascending (VOT or VOF) order, along with the individual's choice between time and money and the degree of preference the individual had for that specific trade-off choice. The individual's VOT or VOF is then determined by identifying the point of inflection, or the point at which an individual changes from spending more time to save money to preferring to spend more money to save time in making a given journey. The Comparison Method provides a clear and detailed understanding of how travelers react to the series of binary choice trade-off questions. Once the individual trade-off values are determined, the results are averaged to give overall population values.

The Binary Logit Method uses a logit curve to calculate the coefficients of the time and cost variables. The individual's VOT or VOF is derived as the ratio of the time and cost coefficients. While this method is a less subjective and more automatic process than the Comparison Method, the statistical rigidity of the Binary Logit Method frequently provides less understanding of travel behavior and less ability to interpret behavior effectively. Furthermore, because this method cannot incorporate the results for individuals who quite rationally do not make a trade-off (preferring time or money options consistently over the whole range of trade-off choices), the Binary Logit Method can only be used at the most aggregate level. Therefore, for the Tri-State Study, the Binary Logit Method was used only for the "by mode/by purpose" assessment and as a check on the consistency of the Comparison Method.

In most cases where the quota samples were over 30, the results obtained from the Comparison Method (Method 1) and the Binary Logit Method (Method 2) were within a 10-20 percent range of each other, providing a high degree of confidence in the results of the Trade-Off Analysis. A comparison of the two trade-off analysis methods is given in Exhibit 4.2.

Exhibit 4.2
Comparison of VOT Results[1]

Mode/Purpose	No. of Valid Surveys Method 1	No. of Valid Surveys Method 2	VOT (1990$/Hour) Method 1	VOT (1990$/Hour) Method 2
Air/Business	183	77	64.8	66.6
Air/Other	270	97	34.0	41.9
Rail/Business	63	24	39.9	45.1
Long Trips	14 [2]	8 [2]	44.5	39.8
Short Trips	49	16 [2]	38.6	47.7
Rail/Other	207	115	28.0	32.8
Long Trips	149	101	31.0	37.4
Short Trips	58	14 [2]	20.1	30.0
Bus/Other	145	64	21.8	31.7
Long Trips	72	48	28.5	34.2
Short Trips	73	16 [2]	15.1	24.1
Auto/Business	54	36	43.0	44.2
Long Trips	35	23 [2]	46.3	47.4
Short Trips	19 [2]	13 [2]	37.1	38.5
Auto/Commuting	142	50	21.3	30.3
Long Trips	6 [2]	3 [2]	25.7	47.4
Short Trips	136	47	20.9	29.3
Auto/Other	377	200	25.8	37.4
Long Trips	221	145	32.3	37.4
Short Trips	156	55	16.9	37.1

[1] *Long trips are over 100 miles, and short trips are 100 miles or less.*
[2] *Less than 30 valid surveys.*

The results of the Trade-Off Analysis were subjected to a range of statistical and "reasonableness" tests. The first test evaluated the distribution of individuals' VOT's and VOF's across modes of travel. This test found that the distributions of the VOT's and VOF's had small standard errors and were log normal in shape, and were therefore in line with expectations about the likely range of values for the population in the Tri-State Corridor. A second test compared the results of the Attitudinal Survey with the results obtained in studies carried out elsewhere. This comparison, shown in Exhibit 4.3, showed that the overall VOT's derived for the Tri-State Corridor were higher in absolute terms than results obtained elsewhere in North America but were comparable when normalized for distance.

The Tri-State Corridor is longer than many other North American corridors, and it is believed that this factor generated higher Values of Time. As a result, the VOT's used in the Tri-State Study were segmented not only on a mode and purpose basis but also on a trip-length basis. This ensured a proper representation of travel behavior and the effective representation of time and frequency variables in developing travel forecasts.

Exhibit 4.3
Comparison of VOT Results with Other Corridor Studies[1]

	Tri-State (430 Miles)	New York[2] (310 Miles)	Ontario-Quebec[3] (180-300 Miles)	Illinois[4] (200-300 Miles)
Values of Time (1990$/Hour)				
Air				
Business	65	51	58	54
Non-Business	34	32	32	19
Rail				
Business	40	26	25	28
Non-Business	28	21	19	13
Auto				
Business	43	26	25	23
Non-Business	26	26	18	13
Bus				
Business	25	--	17	--
Non-Business	22	32	12	--
Values of Frequency (1990$/Hour)				
Air				
Business	33	24	31	11
Non-Business	22	3	21	7
Rail				
Business	18	11	15	6
Non-Business	16	8	11	4
Auto				
Business	--	17	18	7
Non-Business	--	14	12	6
Bus				
Business	16	--	13	--
Non-Business	13	10	9	--

[1] *To facilitate comparison with the Tri-State Study, values derived for the other three corridors were inflated to 1990$.*
[2] *Rensselaer Polytechnic/Cole, Sherman Inc.*
[3] *Consumer Contact Ltd./Cole, Sherman Associates, Ltd.*
[4] *British Rail.*

RESULTS OF THE TRADE-OFF ANALYSIS

A summary of the results of the VOT and VOF Trade-Off Analysis is given in Exhibit 4.4. The values were deflated to 1989 dollars for use in the COMPASS[c] Model, to conform with the base year established for the study.

Exhibit 4.4
Summary of VOT and VOF Trade-Off Results

	Air	Rail	Bus	Auto
Value of Time (1990$/Hour)				
Business	64.8	39.9	25.4[1]	43.0
Commuting	50.9[1]	27.0	13.7[1]	21.3
Other	34.0	28.0	21.8	25.8
Value of Frequency (1990$/Hour)				
Business	33.4	17.7	15.5[1]	--
Commuting	27.7[1]	16.1	10.9[1]	--
Other	22.0	16.1	13.0	--

[1] *Quota cells not originally identified for analysis.*

As shown in Exhibit 4.4, the Values of Time vary widely by mode and by purpose. Similarly, as shown in Exhibit 4.5, trip distance was also found to have a strong effect on the VOT's. The relationships between income level and VOT's and VOF's are shown in Exhibit 4.6. It should be noted that the income variable does not appear to have had as strong an effect on VOT as distance.

Exhibit 4.5
VOT and VOF Trade-Off Results by Trip Length[1]

		Rail		Bus		Auto	
	Air	Long	Short	Long	Short	Long	Short
Value of Time (1990$/Hour)							
Business	64.8	44.5 (14)[3]	38.6	NI[2]	NI	46.3	37.1 (7)
Commuting	NI	NI	27.0	NI	13.7 (7)	25.7	20.9
Other	34.0	31.0	20.1	28.5	15.1	32.3	16.9
Value of Frequency (1990$/Hour)							
Business	33.4	18.2 (13)	17.5	NI	NI	--	--
Commuting	NI	NI	16.1 (21)	NI	10.0 (7)	--	--
Other	22.0	17.8	11.7	15.1	10.9	--	--

[1] *"Long" indicates long-distance trips of more than 100 miles, and "short" indicates short trips of 100 miles or less.*
[2] *"NI" stands for "not included" and indicates quota cells deliberately excluded from the quota survey and Trade-Off Analysis as they were too small a sample group to be effectively analyzed.*
[3] *Quota cells with numbers in parentheses had less than 30 valid surveys; the number given in parentheses is the actual number of surveys.*

Exhibit 4.6
VOT and VOF Trade-Off Results by Income Group[1]

	Air		Rail		Bus		Auto	
	High	Low	High	Low	High	Low	High	Low
Value of Time (1990$/Hour)								
Business	73.7	55.6	45.7 (27)[3]	35.0	NI[2]	21.6	44.9 (22)	41.7
Commuting	NI	NI	NI	NI	26.8 (28)	20.2	NI	NI
Other	36.4	32.0	30.2	26.9	29.5	25.5	21.8 (21)	22.4
Value of Frequency (1990$/Hour)								
Business	35.4	32.6	19.9 (27)	16.9	NI	NI	--	--
Commuting	25.9	20.3	14.5	16.8	11.4 (20)	13.5	--	--

(1) *"High" stands for high household income of $60,000 or more per year, and "low" indicates low household income of less than $60,000 per year.*
(2) *"NI" stands for "not included" and indicates quota cells deliberately excluded from the quota survey and Trade-Off Analysis as they were too small a sample group to be effectively analyzed.*
(3) *Quota cells with numbers in parentheses had less than 30 valid surveys; the number given in parentheses is the actual number of surveys.*

Further analysis was undertaken to explore the significance of income levels on the Values of Time. The results show that, while income had significant effects in some cases, the effects were largely subsumed in the modal choices made by travelers. As a result, for the Tri-State Study, a decision was made to stratify Values of Time not only by mode and purpose, but by trip length as well.

BASIC STRUCTURE OF THE COMPASS(c) MODEL

The COMPASS(c) Model System is a flexible demand forecasting tool. It provides the user with the ability to evaluate alternative socioeconomic and network scenarios for comparative purposes. It also allows input variables to be modified to test sensitivity to such parameters as elasticities, Values of Time and Values of Frequency.

The COMPASS(c) forecasting system is structured on two principal models: Total Demand Model and Hierarchical Modal Split Model. These two models are calibrated separately for the three trip purposes (business, commuting and "other"). In each case, the models are calibrated for internal origin-destination data. Trips with an origin or destination (or both) outside the study area are excluded as they do not have the typical trip-making characteristics of corridor travelers. For forecasting purposes, externals trips are factored up in relation to overall socioeconomic growth and transportation improvements.

TOTAL DEMAND MODEL

The Total Demand Model, as shown in Equation 1, provides a mechanism for assessing overall growth in the travel market.

$$T_{ijp} = e^{B_{0p}}(SE_{ijp})^{B_{1p}}(GC_{ijp})^{B_{2p}} \tag{1}$$

where

T_{ijp} = Volume of trips between zones i and j for purpose p

SE_{ijp} = Socioeconomic variables for zones i and j for purpose p

GC_{ijp} = All mode generalized cost of travel for zones i and j for purpose p

B_{0p}, B_{1p}, B_{2p} = Coefficients for purpose p

As shown in Equation 1, the total number of trips between any two zones for all modes of travel, segmented by journey purpose, is a function of the socioeconomic characteristics of the zones and the degree of spatial separation between the zones. Trip purposes include business, commuting and "other" (social). Typical socioeconomic characteristics include household income, employment and population. The spatial separation between the zones is measured by generalized cost which includes the time, cost and frequency of travel. The Total Demand Model equation may be interpreted as meaning that travel between the zones will increase as socioeconomic factors rise or the generalized cost of travel between zones is reduced. As a result, the effect of both changes in socioeconomic and travel characteristics on total demand can be evaluated with the Total Demand Model.

The Socioeconomic Variables

The socioeconomic variables in the Total Demand Model show the impact of economic growth on travel demand. The COMPASS[(c)] modeling system, in line with most intercity modeling systems, uses three variables (population, employment and household income) to represent the socioeconomic characteristics of a zone. Depending on trip purpose, the socioeconomic variables are used independently or in product form. Different combinations were tested in the calibration process for the Tri-State Study but, as found elsewhere, the most reasonable and stable relationship used the following formulation:

Trip Purpose	Socioeconomic Variable
Business	Employment (x) Annual Household Income
Commuting	Population (x) Annual Household Income
Other	Population (x) Annual Household Income

Both the population and employment estimates are taken as the arithmetic average for a zone pair, while income is the average, weighted by population, of a zone pair.

Generalized Cost

The generalized cost variable is used to estimate the impact of improvements in the transportation system on overall levels of trip-making. As such, the generalized cost variable needs to incorporate all the key modal attributes (such as travel times and fares) which affect an individual's desire to make trips. Thus, the generalized cost of travel, which is typically defined in travel time rather than dollars, is a measure of all travel attributes. Costs are converted to time by applying appropriate conversion factors as shown below in Equation 2.

The generalized cost (GC) of travel between zones i and j for mode m and purpose p is calculated as follows:

$$GC_{ijmp} = TT_{ijm} + \frac{TC_{ijmp}}{VOT_{mp}} + \frac{VOF_{mp} \ x \ OH}{VOT_{mp} \ x \ F_{ijm}} \tag{2}$$

where

TT_{ijm}	=	Travel time between zones i and j for mode m (in-vehicle time + waiting time + delay time + connect time + access/egress time + interchange penalty), with waiting, delay, connect and access/egress time multiplied by two to account for the additional disutility felt by travelers for these activities
TC_{ijmp}	=	Travel cost between zones i and j for mode m and purpose p (fare + access/egress cost for public modes, operating costs for auto)
VOT_{mp}	=	Value of Time for mode m and purpose p
VOF_{mp}	=	Value of Frequency for mode m and purpose p
F_{ijm}	=	Frequency in departures per week between zones i and j for mode m
OH	=	Operating hours per week

In using generalized cost in the modeling process, it was necessary to obtain average generalized cost values weighted by modal share. For model calibration purposes, generalized costs were combined using base year modal split proportions. For forecasting, however, generalized costs were weighted by future year modal split proportions. This adjustment of weights was necessary to more properly reflect the impact of new technologies or the impact of introducing high speed rail service into corridors that previously had little or no service. It should be noted that using future year modal split proportions in the forecast process would not be appropriate for an analysis of the incremental upgrading or improvement of Amtrak service.

Calibration of the Total Demand Model

For the purpose of calibrating the Total Demand Model coefficients by linear regression techniques, Equation 1 was transformed by taking the natural logarithm of both sides, as shown in Equation 3:

$$\log(T_{ijp}) = B_{0p} + B_{1p}\log(SE_{ijp}) + B_{2p}\log(GC_{ijp}) \tag{3}$$

This provides a linear specification of the model, a prerequisite for regression analysis.

Zone System for Calibration

The calibration process was initiated at the most disaggregate zone system level (i.e., 139 zones). However, it was found that, due to data "noise and inconsistencies" caused by the nature of the data sets used in the study and the averaging effects of the trip expansion process, the results were less than ideal. The regression results, while showing good correlation between the dependent variables (total trips) and the independent variables (socioeconomic and network data), were distorted.

To improve the calibration, a detailed assessment was made of the data itself. Subsequently, the zones were aggregated to a 93-zone system in order to minimize a number of the weaknesses and inconsistencies in the data sets. With the aggregated zone system, the regression statistics improved significantly and coefficients had the correct sign and magnitude.

Calibration Results for the Total Demand Model

The results of the calibration of the Total Demand Model are shown in Exhibit 4.7. It can be seen that the models were all significant with good R^2, Mean Percent Residual, "t" and "F" values.

Exhibit 4.7
Total Demand Model Coefficients[1]

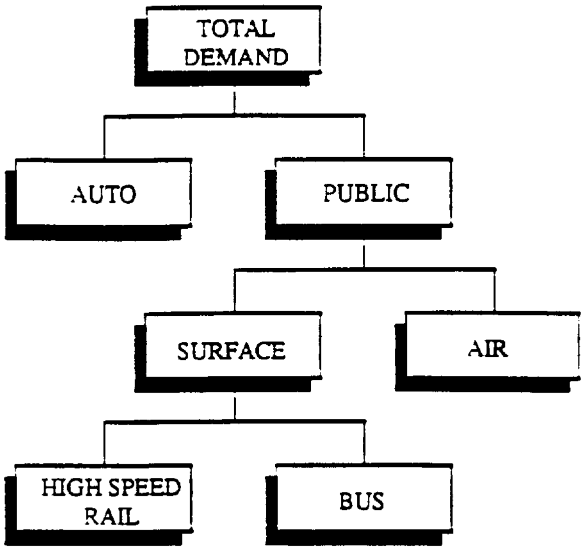
Purpose	Constant (B_{0p})	Socio-economic (B_{1p})	Network (B_{2p})	Number of Observations	R^2	M%R[2]	"F" Statistic
Business	-0.709 (-18)	1.169 (16)	-2.750 (-22)	1806	0.61	18	1410
Commuting	0.241 (12)	1.080 (13)	-2.814 (-15)	1280	0.66	17	1239
Other	-1.186 (-19)	1.136 (21)	-2.596 (-20)	2213	0.55	20	1351

(1) "t" values are shown in parentheses.
(2) M%R is Mean Percent Residual.

MODAL SPLIT MODEL

The role of the Modal Split Model is to estimate relative modal shares given the estimation of the total market share by the Total Demand Model. The relative modal shares are derived by comparing the relative levels of service offered by each of the four transportation modes. As specified in the Terms of Reference for the Tri-State Study, the COMPASS[c] Modal Split Model was based on the nested or hierarchical modal split model structure. The calibration structure takes the form shown in Exhibit 4.8. At the top level of the hierarchy, the public modes (air, bus and rail) are first combined to compete with the private auto mode. At the second level, the surface modes (bus and rail) are combined to compete with the air mode and finally, at the third level, bus competes with rail.

Exhibit 4.8
Modal Split Structure



The main feature of the Hierarchical Modal Split Model structure is the increasing commonality of travel characteristics as the structure is descended. The first split separates the choice of private auto travel, with a spontaneous frequency, low access and highly personalized travel, from the public mode options. The second level of the structure separates air, the fastest, more expensive, and perhaps more frequent and comfortable public mode, from the rail and bus surface modes. The last level separates rail, a potentially faster, reliable and more comfortable mode, from intercity bus. Under current travel conditions, the last two modes both have lower frequencies and fares than air.

Form of the Modal Split Model

As only two choices exist at each level of the hierarchical structure, a Binary Logit Model is used, as shown in Equation 4:

$$P_{ijmp} = \frac{e^{U_{ijmp}}}{e^{U_{ijmp}} + e^{U_{ijnp}}} \qquad (4)$$

where

P_{ijmp} = Percentage of trips between zones i and j by mode m for purpose p

U_{ijmp}, U_{ijnp} = Disutility functions of modes m and n between zones i and j for purpose p

Equation 4 can be rewritten as follows:

$$P_{ijmp} = \frac{1}{1 + e^{-(U_{ijmp} - U_{ijnp})}} \qquad (5)$$

If disutility is estimated as a linear function of generalized cost, then Equation 5 can be transformed as follows:

$$P_{ijmp} = \frac{1}{1 + e^{-[B_{0p} + B_{1p}(GC_{ijmp} - GC_{ijnp})]}} \qquad (6)$$

where

GC_{ijmp}, GC_{ijnp} = Generalized cost of travel by modes m and n for purpose p between zones i and j

and where the generalized cost curves versus disutility for modes m and n are assumed to have the same slope (i.e., B_1).

The model is expressing modal split as a function of the generalized cost difference between the two modes, which is commonly called a Difference Model. The model can alternatively be expressed as a Ratio Model by taking the ratio of the two generalized costs as shown in Equation 7:

$$P_{ijmp} = \frac{1}{1 + e^{-[B_{0p} + B_{1p}(\frac{GC_{ijmp}}{GC_{ijnp}})]}} \qquad (7)$$

For the purpose of applying regression analysis, Equations 6 and 7 are transformed to a linear form as shown in Equations 8 and 9.

$$Ln\left(\frac{P_{ijmp}}{P_{ijnp}}\right) = B_{0p} + B_{1p}(GC_{ijmp} - GC_{ijnp}) \quad (8)$$

$$Ln\left(\frac{P_{ijmp}}{P_{ijnp}}\right) = B_{0p} + B_{1p}\left(\frac{GC_{ijmp}}{GC_{ijnp}}\right) \quad (9)$$

Combined Mode Generalized Cost

At each modal split level, the model is evaluating two modes (binary choice) at a time. It is therefore necessary to obtain the weighted values for generalized costs. The weightings are based on trips and the process at each level is shown in Exhibit 4.9.

The percentage trips at each level were calculated from the expanded trip data. In order to reflect the relative weight of each observation point, the observations were also weighted by the number of trips. This ensures that the largest flows have the greatest impact on determining modal share and that the smallest flows have the least. To be compatible with the Total Demand Model and also to improve statistical reliability, the 93-zone system was also used for calibration of the Modal Split Model.

Exhibit 4.9
Generalized Cost Weighting Process[(1)]

Modal Split Model	Binary Choice	Component Modes	Combined Modes
Public versus Auto	Public Auto	Rail, Bus, Air Auto	All
Surface versus Air	Surface Air	Rail, Bus Air	Public
Rail versus Bus	Rail Bus	Rail Bus	Surface

(1) Weighted to trips by component mode.

Ratio Model versus Difference Model

Both Difference and Ratio Models were calibrated for the Tri-State Study. Historically, the Difference Model has been used in urban modelling to compare two alternatives. This is partly because the Difference Model is compatible with a utility maximizing derivation of the Distribution and Modal Split Models and partly because it is the individual's more normal response to travel choices over shorter distances. For example, for a 100-minute journey by mode 1 costing $50 or a 150-minute journey by mode 2 costing $20, the individual will assess the choice between modes as a 50-minute increase in travel time at a savings of $30. For intercity trips, it can be argued that the ratio of utilities better reflects travel decisions for long trips. Therefore, for the same trip, the individual would perceive the choice as a 50 percent increase in time for a 60 percent savings in cost. Since both options are reasonable interpretations of decision making and since the trade-off questionnaire was deliberately designed to be "neutral" with respect to the way individuals interpret choices, the Tri-State calibration included both difference and ratio formulations.

Calibration Results for Public versus Private Auto

Exhibit 4.10 shows the results of the two calibrations (Ratio Model and Difference Model) for the three trip purposes at the first level in the modal split hierarchy.

Exhibit 4.10
Public versus Auto Modal Split Model Coefficients[1]

Purpose	Model	B_{0p}	B_{1p}	R^2	Auto Bias (%)
Business	Ratio	1.747 (12)	-1.941 (-17)	0.58	5
	Difference	-0.120 (-14)	-0.010 (-14)	0.79	3
Commuting	Ratio	0.922 (8)	-1.203 (-12)	0.36	7
	Difference	-0.161 (-13)	-0.007 (-18)	0.60	4
Other	Ratio	-0.378 (-14)	-0.866 (-16)	0.35	12
	Difference	-0.279 (-17)	-0.002 (-23)	0.63	7

(1) *"t" values are shown in parentheses.*

Exhibit 4.10 shows clearly that the Difference Model is statistically preferable to the Ratio Model. For all three Difference Models, the R^2 values are significant, and the "t" values of the slope (B_1) are very high because of the large sample size. The "Auto Bias" column represents the percentage of total trips that would use the auto mode when the generalized costs of the public and auto modes are equal. The bias towards auto indicates that there are some variables missing from the utilities function, in particular non-quantifiable variables such as convenience and privacy. The biases are greater for commuting and "other" trip purposes because the importance of the freedom associated with auto travel is greater for non-work-related trips.

Calibration Results for Surface versus Air

Exhibit 4.11 shows the results of the two calibrations (Ratio Model and Difference Model) for the three trip purposes at the second level of the modal split hierarchy.

Exhibit 4.11
Surface versus Air Modal Split Model Coefficients[1]

Purpose	Model	B_{0p}	B_{1p}	R^2	Air Bias (%)
Business	Ratio	2.795 (20)	-3.894 (-17)	0.67	25
	Difference	-0.840 (-15)	-0.006 (-14)	0.62	20
Commuting[2]	Ratio	4.122 (—)	-4.241 (—)	--	3
	Difference	-0.000 (—)	-0.005 (—)	--	0
Other	Ratio	4.122 (11)	-4.241 (-10)	0.66	3
	Difference	-0.000 (-16)	-0.005 (-13)	0.70	0

[1] "t" values are shown in parentheses.
[2] Same as "other" purpose coefficients.

Exhibit 4.11 shows that both models gave similar results. For both, the R^2 and "t" values are good. The percentages of surface trips in both models are very similar, which provides confidence in the model. There is a bias towards air travel, probably because air travel is normally perceived to be a faster and superior mode of transportation. There was not sufficient information available to define a commuter purpose split for the air mode. Previous studies, such as the 1989 VIA Rail Study for the Ontario-Quebec Corridor, have shown that these coefficients are very similar to those of the "other" trip purpose. Also, because this is not a large modal split group, "other" purpose coefficients were used for the commuter trip purpose.

Calibration Results for Rail versus Bus

Exhibit 4.12 shows the results of the two calibrations (Ratio Model and Difference Model) for the three trip purposes at the third level of the modal split hierarchy.

Exhibit 4.12
Rail versus Bus Modal Split Model Coefficients[1]

Purpose	Model	B_{0p}	B_{1p}	R^2	Rail Bias (%)
Business	Ratio	7.858 (7)	-6.019 (-3)	0.66	36
	Difference	2.110 (5)	-0.009 (-7)	0.82	39
Commuting	Ratio	7.739 (4)	-7.066 (-4)	0.36	16
	Difference	0.631 (5)	-0.008 (-5)	0.41	15
Other	Ratio	5.583 (4)	-5.137 (-6)	0.62	11
	Difference	0.382 (7)	-0.007 (-4)	0.64	9

[1] "t" values are shown in parentheses.

The "t" values are not as good as those for the other two modal split levels but the results are all significant. Furthermore, the biases are logical, with few people using the bus mode for business trips, more people using the bus for commuting, and even more people using the bus for "other" purposes. There is a very strong perception, especially among business travelers, that bus is an inferior mode. The high values of B_1 indicate that travelers are very sensitive to changes in generalized cost.

CONCLUSIONS

In general, the calibration process was successful in deriving significant equations for total demand and modal choice. The only exception was surface versus air commuting, as the information needed to derive a commuting purpose split was not available. Therefore, the "other" purpose coefficients were adopted for forecasting purposes.

The calibration of the modal split equations revealed that the Difference Model rather than the Ratio Model provided the best equations, with better modal split predictability and improved statistical performance in most cases.

MODEL VERIFICATION

In the calibration process, socioeconomic and generalized cost elasticities were derived for the Total Demand Model, and generalized cost elasticities were derived for the Modal Split Model. To verify the results for the Tri-State calibration, the models were compared to the results for the Ontario-Quebec Corridor (Windsor-Toronto-Montreal-Quebec City), the New York Corridor (Buffalo-Albany-New York City), and the Illinois Corridor (Chicago-Springfield-St. Louis).

In general, it was found that the Tri-State model calibration had parameters which were in line with results (typically within ± 20 percent) found elsewhere in the Midwest. The Total Demand Model is almost interchangeable with the models calibrated elsewhere. In the case of the Modal Split Model, while the results are within the range of values derived elsewhere, they are different particularly for public versus auto and air versus surface. In overall terms, the Tri-State Model proved to be more comparable with the recent Ontario-Quebec and New York calibrations than with the earlier Illinois model.

FORECASTING PROCESS

In developing ridership forecasts for the different technology and route options, two principal inputs are required: economic scenarios which describe the likely rates of economic growth over the forecasting period, and transportation strategies which describe the service attributes of the high speed rail options and the competitive modes.

ECONOMIC SCENARIOS

Economic scenarios were developed to cover the economic life of the project, from the base year 1989 to the year 2024. Because the economic scenarios are intended to show the potential range of economic growth, three economic scenarios were defined: an upper (optimistic) case, a central (trend) case, and a lower (pessimistic) case. For each economic scenario, population, employment and household income estimates are required for input to the Total Demand Model. The methodology employed to develop each economic scenario included:

- A review of historical trends and variations in economic performance on a statewide basis, as shown in Exhibit 4.13.
- The use of official state and federal (U.S. Bureau of Economic Analysis) forecasts to establish the central case option.
- An analysis of the range of forecasts made by state agencies, research institutes, and regional economic studies to establish the upper and lower case scenarios.

Exhibit 4.13
Historical Annual Growth Rates (1979-1988)

	Population	Per Capita Income	Employment
Minnesota	0.72	1.41	1.86
Wisconsin	0.44	0.82	1.32
Illinois	0.18	1.01	0.92

Overall, a conservative approach was taken to identifying rates of economic growth and a wide range of possible variations in the growth rates was incorporated in the upper and lower case economic scenarios. The economic scenarios developed for the Tri-State Study are shown in Exhibit 4.14.

Exhibit 4.14
Economic Scenarios Average Annual Growth Rates (1990-2024)

State	Scenario	Population Percent Average Annual Growth	Per Capita Income Percent Average Annual Growth	Employment Percent Average Annual Growth
Wisconsin	Trend	0.40	0.88	0.95
	Upper	0.50	1.00	1.19
	Lower	0.27	0.76	0.64
Minnesota	Trend	0.56	1.24	0.94
	Upper	0.65	1.41	1.17
	Lower	0.47	0.89	0.47
Illinois	Trend	0.45	1.11	0.93
	Upper	0.52	1.23	1.00
	Lower	0.18	1.01	0.45
U.S.[1]	--	0.56	0.91	0.53

[1] *U.S. figure is for 1988 rather than 1990.*

It can be seen that the variations in the average annual growth rates were typically +15 to +25 percent for the upper case scenario and -20 to -50 percent for the lower case scenario, both of which represent substantial variations from the central case (trend) scenario. Given the range of historical variations in economic growth, while it is considered possible that the upper and lower limits might be exceeded in any one year, they are unlikely to be exceeded in any consecutive five- or ten-year period.

TRANSPORTATION STRATEGIES

Transportation strategies were developed to reflect, firstly, the competitive position of the air, auto and bus modes at the time of the introduction of high speed rail and then, secondly, the effect of different high speed rail technologies. The transportation strategies developed for the Tri-State Study are shown in Exhibit 4.15.

To assess the competitive position of the other modes (air, auto and bus), a "no action" case was defined. It included all proposed improvements to the competitive modes (improvements to airports, highways, transit systems, etc.) but excluded any improvements to rail. The "no action" case is the basis against which the proposed high speed rail options were judged in terms of attracting ridership, generating revenues and increasing economic benefits.

To evaluate the potential of the different high speed rail options, a set of "action" cases was defined, each of which reflected the performance of a single high speed rail technology (125 mph, 185 mph or 300 mph). For the two higher speed options (185 mph and 300 mph), an "action" case was defined for both the Northern Corridor and the Southern Corridor. The Amtrak upgrade option in the Southern Corridor was the only one developed for the 125 mph technology.

In defining the high speed rail "action" cases, a number of assumptions were made regarding the level of service that might be offered. For example, decisions must be made about the level of frequency and fares associated with the three rail technology options. The rail frequencies used in this analysis (12, 18 and 24 trains per day respectively for the 125 mph, 185 mph and 300 mph options) were based on the "rule of thumb" established by Dr. A.E. Metcalf ("Rules of Thumb for High Speed Rail Planning," Paper prepared for Union International du Chemin de Fer, 1985) that frequencies should be based on the minimum level of service that would be reasonably required to pay the capital costs for a 300- to 400-mile-long corridor. With respect to fares, previous research by A.E. Metcalf, F.S. Koppelman ("Analysis of the Market Demand for High Speed Rail in the Quebec/Ontario Corridor," in association with KPMG Peat Marwick, 1990), and the Chicago Federal Reserve Bank ("High Speed Rail in the Midwest: An Economic Analysis," 1984) suggests that fares for high speed rail are optimized at between 65 to 75 percent of air fares. The proposed frequencies and fares for the three technologies are shown in Exhibit 4.15.

Exhibit 4.15
Transportation Strategies

"No Action" Case

Auto	Planned Highway Investment Current Energy Prices
Air	Planned Improvements Current Fares and Frequencies
Bus	Current Fares and Frequencies
Rail	Amtrak Service with Planned Improvements

"Action" Case for Rail

Planned Technology Options (125 mph, 185 mph and 300 mph)

	125 mph	185 mph	300 mph
Frequency (No. of Trains per Day)	12	18	24
Fare as Percent of Air Fare	65%	65%	65%
Fare for Chicago-Milwaukee	$30.96	$30.96	$30.96
Fare for Chicago-Twin Cities	$155.85	$155.85	$155.85

"Action" Case for Other Modes

Auto	Increases in Energy Prices of 20% and 50% Increases in Congestion of 20% and 50%
Air	Reduction in Fares of 20% Increases in Energy Prices of 20% and 50% Increases in Congestion of 20% and 50%
Bus	Reductions in Fares of 10% and 30% Increases in Frequencies of 10% and 30%

OTHER MODE "ACTION" CASES

In addition to the high speed rail "action" cases, "action" cases were defined to evaluate the impact on project finances of a range of sensitivity factors for the other modes. As shown in Exhibit 4.15, they included a competitive response by the air and bus industries to implementation of a high speed rail service, options to assess possible increases in air and auto congestion, and increases in energy costs. The effect of increased congestion was evaluated by increasing as appropriate air wait and delay times, auto in-vehicle times, and air and auto access times. The impact of increased energy costs were evaluated by increasing fares and auto operating costs to the extent that fuel is related to these costs; air fares are 25 percent fuel-related and auto operating costs are 20 percent and 80 percent fuel-related for business and non-business travel respectively.

FORECAST RESULTS

Forecasts for the five different high speed rail technology and corridor options were generated for the same 93-zone system used for calibration. The five forecast options were as follows:

- Southern Corridor — HST (125 mph), upgraded Amtrak on revised alignment
  TGV (185 mph) on Route #4
  Maglev (300 mph) on Route #4

- Northern Corridor — TGV (185 mph) on Route #7
  Maglev (300 mph) on Route #7

In all cases, implementation of the high speed rail service was assumed to occur in the year 2000. The results of these forecasts are summarized in Exhibit 4.16.

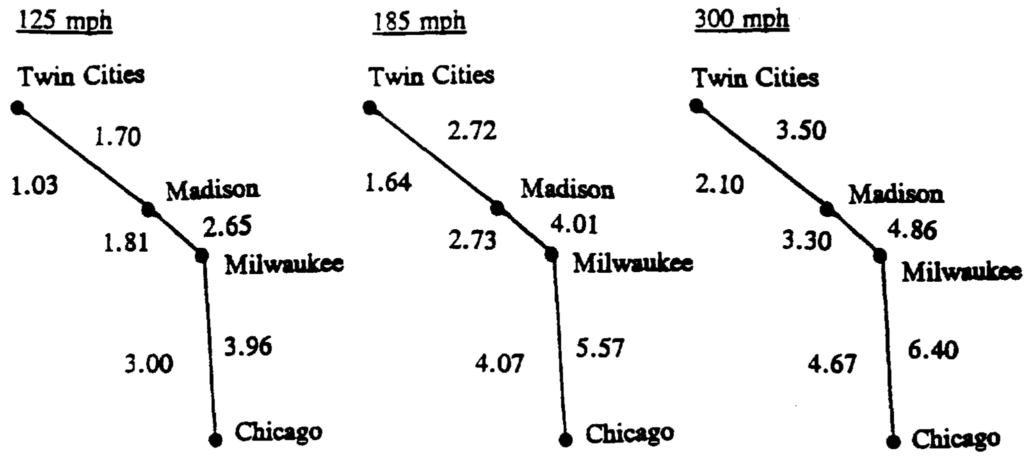
Exhibit 4.16
Rail Ridership for the Years 2000 and 2024

		Southern Corridor		Northern Corridor	
		2000	2024	2000	2024
125 mph	Total Annual	5,759,000	8,085,000	---	---
	Daily Trips	15,800	22,200	---	---
	Market Share	10.3%	10.1%	---	---
185 mph	Total Annual	7,466,000	10,614,000	7,066,000	10,149,000
	Daily Trips	20,500	29,100	19,400	27,800
	Market Share	12.9%	12.8%	12.7%	12.6%
300 mph	Total Annual	8,532,000	12,177,000	8,104,000	11,694,000
	Daily Trips	23,400	33,400	22,200	32,000
	Market Share	14.5%	14.4%	14.3%	14.2%

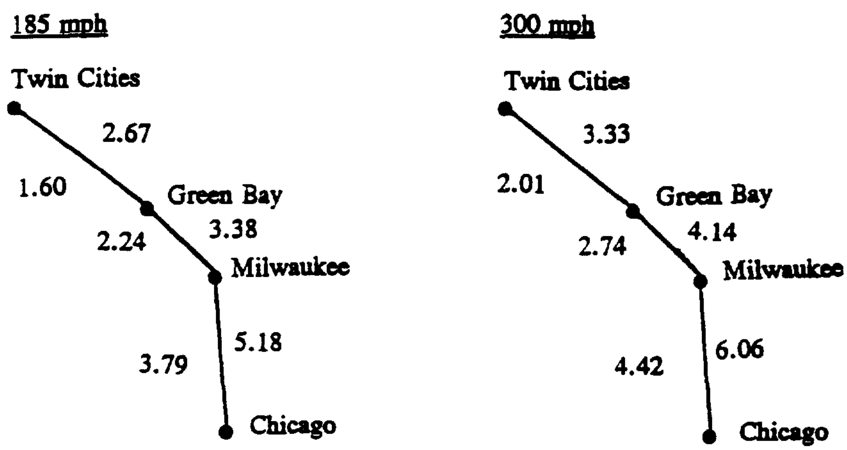
It can be seen from the forecast results that maglev (300 mph) produces more trips than TGV (185 mph), which in turn produces more trips than HST (125 mph). The Southern Corridor produces more trips than the Northern Corridor. The difference in ridership between the year 2000 and the year 2024 is a result of natural growth on the base year rail trips, induced rail trips, and trips diverted to rail from air, auto and bus. The overall ridership levels rise between 40 and 45 percent by the year 2024 in both the Southern and Northern Corridors. Overall, the effect of speed improvements from the 125 mph to the 185 mph to 300 mph is to increase demand by approximately 30 percent and 15 percent respectively. The link loadings (or the seating capacity required for each route segment) corresponding to these demand numbers are shown in Exhibit 4.17.

Exhibit 4.17
Link Loadings by Route Segment for the Years 2000 and 2024[(1)(2)]

Southern Corridor



Northern Corridor



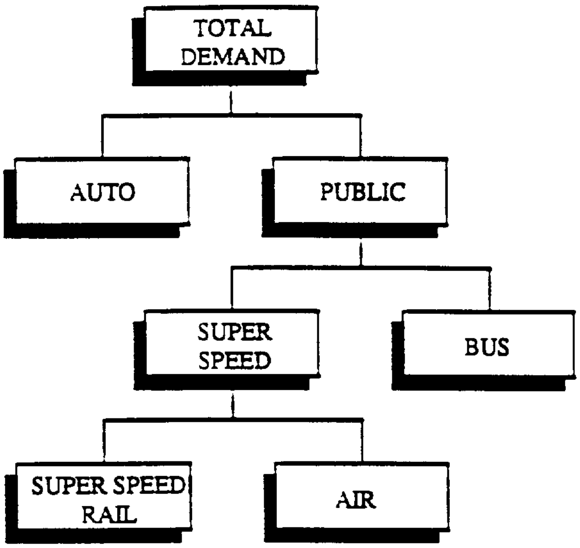
(1) *Millions of trips annually, with the year 2000 forecasts on the left side of the axis and the year 2024 forecasts on the right side.*
(2) *By definition, link loadings by route segment exclude intrazonal trips.*

MODEL VARIATIONS

At the request of the Tri-State Steering Committee, three additional model calibrations were carried out. The first was a calibration using half Values of Time and half Values of Frequency. This analysis was designed to examine the effect of lower Values of Time and Values of Frequency on ridership forecasts. The second was a logsum utility calibration, as the logsum model is frequently regarded as a superior structure because it incorporates the effect of modal bias in the travel impedance function.

A third model variation, using the modal split structure illustrated in Exhibit 4.18, was also performed. This super speed/low speed modal split structure was developed specifically to examine the impact of the Very High Speed (185 mph) and Super Speed (300 mph) rail technologies, both of which are capable of producing timetables comparable to the air mode.

Exhibit 4.18
Super Speed/Low Speed Modal Split Structure(1)



(1) *Super Speed is defined as those technology options capable of producing timetables comparable with air travel. For the Tri-State Study, both the TGV (185 mph) and maglev (300 mph) technologies were considered Super Speed.*

HALF VOT/VOF ANALYSIS

A Trade-Off Analysis using stated preference techniques was carried out to determine the VOT and VOF values to be used in the COMPASS(c) Model. The values established in the Trade-Off Analysis were higher than those associated with the typical 200- to 300-mile corridor studied elsewhere in the U.S. and, as such, the Tri-State Steering Committee requested a sensitivity analysis of lower time and frequency values. Half VOT and VOF values were used to produce new base year Generalized Costs, which in turn were used to calibrate new total demand and modal split models. The results of this calibration are shown in Exhibit 4.19.

Exhibit 4.19
Half VOT/VOF Model Calibration[1]

Modal Split Equations: Rail versus Bus

Purpose	Equation	R^2	Rail Bias (%)
Business	$Ln(P_{rail}/P_{bus}) = \underset{(3)}{2.280} - \underset{(-4)}{0.008} \times (GC_{rail} - GC_{bus})$	0.40	41
Commuting	$Ln(P_{rail}/P_{bus}) = \underset{(4)}{0.695} - \underset{(-6)}{0.008} \times (GC_{rail} - GC_{bus})$	0.48	17
Other	$Ln(P_{rail}/P_{bus}) = \underset{(4)}{0.424} - \underset{(-2)}{0.007} \times (GC_{rail} - GC_{bus})$	0.52	10

Modal Split Equations: Surface versus Air

Purpose	Equation	R^2	Air Bias (%)
Business	$Ln(P_{surf}/P_{air}) = \underset{(-8)}{-0.931} - \underset{(-10)}{0.007} \times (GC_{surf} - GC_{air})$	0.47	21
Commuting	$Ln(P_{surf}/P_{air}) = \underset{(-10)}{-0.406} - \underset{(-12)}{0.005} \times (GC_{surf} - GC_{air})$	0.55	10
Other	$Ln(P_{surf}/P_{air}) = \underset{(-11)}{-0.393} - \underset{(-13)}{0.005} \times (GC_{surf} - GC_{air})$	0.50	10

Modal Split Equations: Public versus Auto

Purpose	Equation	R^2	Public Bias (%)
Business	$Ln(P_{publ}/P_{auto}) = \underset{(10)}{0.800} - \underset{(-9)}{0.011} \times (GC_{publ} - GC_{auto})$	0.60	19
Commuting	$Ln(P_{publ}/P_{auto}) = \underset{(6)}{1.824} - \underset{(-7)}{0.008} \times (GC_{publ} - GC_{auto})$	0.53	36
Other	$Ln(P_{publ}/P_{auto}) = \underset{(13)}{0.956} - \underset{(-14)}{0.005} \times (GC_{publ} - GC_{auto})$	0.48	22

Total Demand Equations

Purpose	Equation	R^2
Business	$Ln(trips) = \underset{(12)}{1.340} + \underset{(13)}{1.314} \times Ln(SE) - \underset{(-16)}{2.380} \times Ln(GC)$	0.43
Commuting	$Ln(trips) = \underset{(-10)}{-0.128} + \underset{(9)}{1.285} \times Ln(SE) - \underset{(-10)}{2.435} \times Ln(GC)$	0.50
Other	$Ln(trips) = \underset{(-9)}{-0.964} + \underset{(14)}{1.433} \times Ln(SE) - \underset{(-12)}{2.255} \times Ln(GC)$	0.39

[1] *"t" values are shown in parentheses.*

The half VOT/VOF model calibration was not as good statistically as the COMPASS[(c)] calibration which used the full Values of Time and Values of Frequency. As anticipated, the "t" and R^2 values were lower and the level of explanation was less satisfactory. This is because the half VOT's do not represent individuals' behavior as well as the full VOT's and VOF's.

The key characteristics of the half VOT/VOF model is that it increased the overall volume of trip-making, as shown in Exhibit 4.20. The lower VOT/VOF values resulted in higher modal generalized costs (since generalized cost is calculated in minutes). Changing the VOT/VOF values had the effect of changing the forecasting scale by expanding the generalized cost curve. The new generalized costs skewed the distribution of forecasts by increasing the number of shorter trips at the expense of longer trips. The shorter trips more than compensated for the loss of longer trips, increasing overall trip levels by just over 10 percent. However, the increased trip-making was not reflected in the revenues generated, and the overall result was a 10 percent decrease in revenue for the 125 mph technology option and a 2 to 5 percent decrease in revenues for the 185 mph and 300 mph options.

Exhibit 4.20
Comparison of COMPASS[(c)] and Half VOT/VOF Model Results[(1)]

		Half VOT/VOF Model		COMPASS[(c)] Model	
Technology	Year	Annual Trips	Annual Revenue	Annual Trips	Annual Revenue
125 mph	2000	6,469,000	$207,416,000	5,759,000	$226,642,000
	2024	8,895,000	$302,330,000	8,085,000	$339,459,000
185 mph	2000	8,635,000	$323,223,000	7,466,000	$336,128,000
	2024	12,029,000	$478,809,000	10,614,000	$508,725,000
300 mph	2000	10,012,000	$410,385,000	8,532,000	$409,262,000
	2024	14,182,000	$612,119,000	12,177,000	$621,585,000

(1) Revenues given in 1989 dollars.

LOGSUM MODEL

Also, at the request of the Tri-State Steering Committee, an analysis was carried out on the effect of using a logsum utility formulation in the forecasting process. The theory behind the logsum model is that the utility of travel should incorporate modal biases which are typically generated by modal split equations. The conventional wisdom is that the constant term generated by a modal split equation in fact represents additional information on travel behavior, which is not included in a simple generalized cost equation (as is used in COMPASS[(c)]) because it only uses the coefficients of the modal split equation. It is then argued that, since modal bias is an integral part of the utility of travel, it should be incorporated in the utility function by adding it to the generalized cost function. The way in which the constant terms is incorporated in the logsum equation is as follows.

Modal Split Equations

$$Ln(\frac{P_{rail}}{P_{bus}}) = U_{rail} - U_{bus} \tag{10}$$

$$Ln(\frac{P_{surf}}{P_{bus}}) = \theta_s U_{surf} - U_{air} \tag{11}$$

$$Ln(\frac{P_{surf}}{P_{air}}) = \theta_p U_{pub} - U_{auto} \tag{12}$$

where:

$U_{rail} = r_0 + r_1 GC_{rail}$

$U_{bus} = b_1 GC_{bus}$

$U_{air} = a_0 + a_1 GC_{air}$

$U_{auto} = c_0 + c_1 GC_{auto}$

$U_{surf} = Ln(e^{U_{rail}} + e^{U_{bus}})$

$U_{pub} = Ln(e^{U_{air}} + e^{\theta_s U_{surf}})$

Total Demand Equation

$$Ln(trips) = t_0 + t_1 Ln(SE) + t_2 U_{tot} \tag{13}$$

where:

$U_{tot} = Ln(e^{\theta_p U_{pub}} + e^{U_{auto}})$

a_0, a_1, b_1, c_0, c_1
$r_0, r_1, \theta_s, \theta_r$
t_0, t_1, t_3 = Calibrated coefficients

The results of the logsum model calibration are shown in Exhibit 4.21.

Exhibit 4.21
Logsum Model Calibration[1]

Modal Split Equations: Rail versus Bus

Purpose	Equation	R^2
Business	$Ln(P_{rail}/P_{bus}) = 3.011 - 0.005 \times GC_{rail} + 0.003 \times GC_{bus}$	0.22
	(1) (-2) (2)	
Commuting	$Ln(P_{rail}/P_{bus}) = 2.321 - 0.009 \times GC_{rail} + 0.006 \times GC_{bus}$	0.14
	(3) (-4) (2)	
Other	$Ln(P_{rail}/P_{bus}) = 1.697 - 0.003 \times GC_{rail} + 0.002 \times GC_{bus}$	0.24
	(4) (-3) (2)	

Modal Split Equations: Surface versus Air

Purpose	Equation	R^2
Business	$Ln(P_{surf}/P_{air}) = -10.100 + 0.963 \times U_{surf} + 0.018 \times GC_{air}$	0.13
	(-4) (3) (3)	
Commuting	$Ln(P_{surf}/P_{air}) = -11.067 + 0.904 \times U_{surf} + 0.023 \times GC_{air}$	0.14
	(-5) (4) (7)	
Other	$Ln(P_{surf}/P_{air}) = -6.114 + 1.211 \times U_{surf} + 0.015 \times GC_{air}$	0.12
	(-2) (2) (3)	

Modal Split Equations: Public versus Auto

Purpose	Equation	R^2
Business	$Ln(P_{pub}/P_{auto}) = -7.288 + 0.866 \times U_{pub} + 0.014 \times GC_{auto}$	0.12
	(-2) (3) (6)	
Commuting	$Ln(P_{pub}/P_{auto}) = -8.297 + 0.910 \times U_{pub} + 0.028 \times GC_{auto}$	0.15
	(-4) (3) (4)	
Other	$Ln(P_{pub}/P_{auto}) = -7.413 + 0.861 \times U_{pub} + 0.013 \times GC_{auto}$	0.10
	(-1) (2) (7)	

Total Demand Equations

Purpose	Equation	R^2
Business	$Ln(trips) = -18.235 + 1.108 \times Ln(SE) + 0.706 \times U_{tot}$	0.20
	(-3) (2) (4)	
Commuting	$Ln(trips) = -19.694 + 1.203 \times Ln(SE) + 0.873 \times U_{tot}$	0.18
	(-5) (4) (4)	
Other	$Ln(trips) = -17.002 + 1.076 \times Ln(SE) + 0.954 \times U_{tot}$	0.23
	(-8) (6) (5)	

[1] *"t" values are shown in parentheses.*

The "t" and R^2 values for the logsum calibration were not as high as in the COMPASS[c] Model and, in fact, were even lower than the half VOT/VOF calibration. The reason for this may lie in the way the model treated different trip lengths in the corridor. The logsum model has a tendency to overpredict longer trips and underpredict shorter trips. Previous work carried out for the 1989 VIA Study of the Ontario-Quebec Corridor used a logsum model and also encountered this problem; the model had to be reformulated incorporating distance indicator variables which effectively adjusted the model to eliminate the problem. The reason for the lack of explanation is probably in the assumption made by the logsum model that the regression constant term (which is included in the utility function of the logsum model as a "modal bias") is not really a modal bias but simply data noise. If this is in fact the case, then incorporating the "modal bias" is equivalent to adding a random term to the generalized cost equation, the effect of which would be to produce an inferior result.

In terms of the forecasts produced by the logsum model, the forecasts were 40 to 50 percent higher than those produced by COMPASS(c). Since the logsum model skewed the modal distribution in favor of longer trips and since its results were even higher than the half VOT/VOF model, the increase in trip-making for longer trips (between Chicago and Minneapolis-St. Paul for example) appears completely unreasonable. The logsum model needs serious modification before it can be used to effectively forecast intercity trip-making.

SUPER SPEED/LOW SPEED MODAL SPLIT MODEL

The super speed/low speed modal split structure assumes that the very high speed and super speed technology options are closer to air than to bus. As was shown in Exhibit 4.17, the super speed/low speed modal split model first compares the high speed modes (very high speed or super speed rail plus air) to low speed (bus) and secondly compares rail with air. The super speed/low speed model can be used when rail timetables are comparable to air (as they are for the 185 mph and 300 mph options). In effect, the rail mode is in direct competition with the air mode and the bus mode is reserved for those travelers with the lowest Values of Time.

The super speed/low speed modal split model was derived by reevaluating the original modal split coefficients used in the base model. The biases and elasticities of the rail mode were adjusted to more realistically reflect a situation in which the rail and air modes are seen by the traveler as being equally desirable. Desirability was defined as incorporating all the quantifiable and non-quantifiable factors that distinguish air from rail in the current situation. In effect, the model handles the mode choice between air and rail as if it were a route choice.

In terms of the impact on ridership forecasts, the super speed/low speed modal split model increased the forecasts for the super speed technologies by some 20 percent. The distribution of trips remained similar to that in the COMPASS(c) base model. This suggests that, if the super speed/low speed modal split model is accepted as a realistic interpretation of the behavioral response of individuals, then a 15 to 20 percent increase in revenues might occur that is not taken into account in the base model.

The coefficients that differ from those used in the base COMPASS(c) calibration are shown in Exhibit 4.22.

Exhibit 4.22
Super Speed/Low Speed Modal Split Model: Estimated Coefficients

Super Speed versus Low Speed

Purpose	Equation	High Speed Bias(%)
Business	$\ln(P_{high}/P_{low}) = 2.950 - 0.009 \times (GC_{high} - GC_{low})$	45
Commuting	$\ln(P_{high}/P_{low}) = 0.631 - 0.008 \times (GC_{high} - GC_{low})$	15
Other	$\ln(P_{high}/P_{low}) = 0.382 - 0.007 \times (GC_{high} - GC_{low})$	9

Rail versus Air

Purpose	Equation	Rail Bias (%)
Business	$\ln(P_{rail}/P_{air}) = 0.000 - 0.006 \times (GC_{rail} - GC_{air})$	0
Commuting	$\ln(P_{rail}/P_{air}) = 0.000 - 0.005 \times (GC_{rail} - GC_{air})$	0
Other	$\ln(P_{rail}/P_{air}) = 0.420 - 0.005 \times (GC_{rail} - GC_{air})$	10

RESULTS OF THE MODEL VARIATIONS

Three model variations were examined, testing the sensitivity of the COMPASS(c) Model to alternative functions and structures. The results of the alternative calibrations are shown in Exhibit 4.23.

Exhibit 4.23
Comparison of Forecasts for the Southern Corridor

Technology	Year	COMPASS Model	High Speed/Low Speed Modal Split Model	Half VOT/ Half VOF Model	Logsum Model
125 mph	2000	5,759,000	--	6,469,000	8,090,000
	2024	8,085,000	--	8,895,000	12,991,000
185 mph	2000	7,466,000	9,043,000	8,635,000	10,156,000
	2024	10,614,000	12,925,000	12,029,000	16,365,000
300 mph	2000	8,532,000	10,343,000	10,012,000	11,686,000
	2024	12,177,000	14,831,000	14,182,000	18,846,000

The following observations are made about the three model variations:

- The super speed/low speed modal split model, which uses a structure that allows high speed rail to compete directly with air travel, produced 20% more corridor trips. This is a useful structure for more accurately forecasting demand for the very high speed and super speed options which have characteristics more in common with air travel than "conventional" rail travel.

- The half VOT/VOF model resulted in an increase in total trips, due to the higher elasticity of shorter trips. The model did not perform as well as the COMPASS(c) base model. This reinforces the conclusion that the Attitudinal Survey did effectively measure Values of Time in the Tri-State Corridor, and that those values are a realistic interpretation of travel behavior.

- The logsum model resulted in a higher level of trip-making with a skewed distribution favoring longer trips. The model did not perform well, probably due to the role of the "modal bias" in the model which distorts travel behavior.

CHAPTER 5

SYSTEM OPERATIONS

The analysis of train operations and the development of an operational plan was concerned with three assessments:

- Establishing train running times and timetables.
- Identifying rolling stock requirements and, in particular, the number and size of train sets needed to operate the timetables.
- Evaluating the likely levels of freight train interference.

Since rolling stock requirements are determined by the timetables, this assessment followed the development of train running times and timetables.

TRAIN RUNNING TIMES AND TIMETABLES

To estimate train running times, the LOCOMOTION(c) Train Performance Calculator was used. LOCOMOTION(c) estimates the speed of a train given various types of track geometry, curves, gradients and station stopping patterns. It then calculates the train running time for each route segment and sums the times to produce a timetable. LOCOMOTION(c) assumes that a train will accelerate to the maximum possible speed and will only slow down for stations or speed restrictions due to curves, crossings, tunnels or other civil engineering works.

The input data for LOCOMOTION(c) consists of milepost-by-milepost data (as fine as 1/10th of a mile) defining gradient and curve conditions along the track. For the Tri-State Study, these data were derived from the condensed profile for existing rail alignments and from field inspection data for new routes. To assess the speed of the three technology options, specific lateral acceleration/deceleration and horizontal curve speed constraint graphs, as shown in Exhibits 5.1 and 5.2, were derived directly from data received from manufacturers.

Exhibit 5.1
Acceleration/Deceleration Curves for 125 mph, 185 mph and 300 mph Technologies

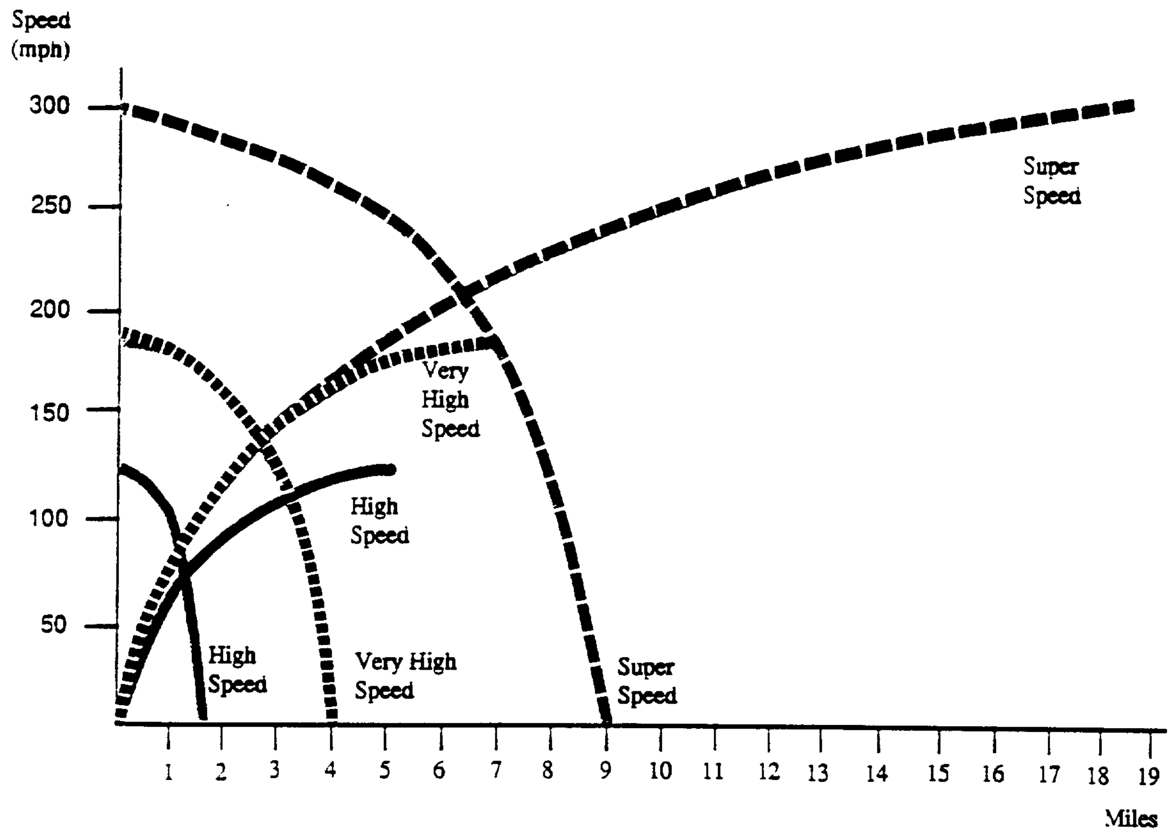
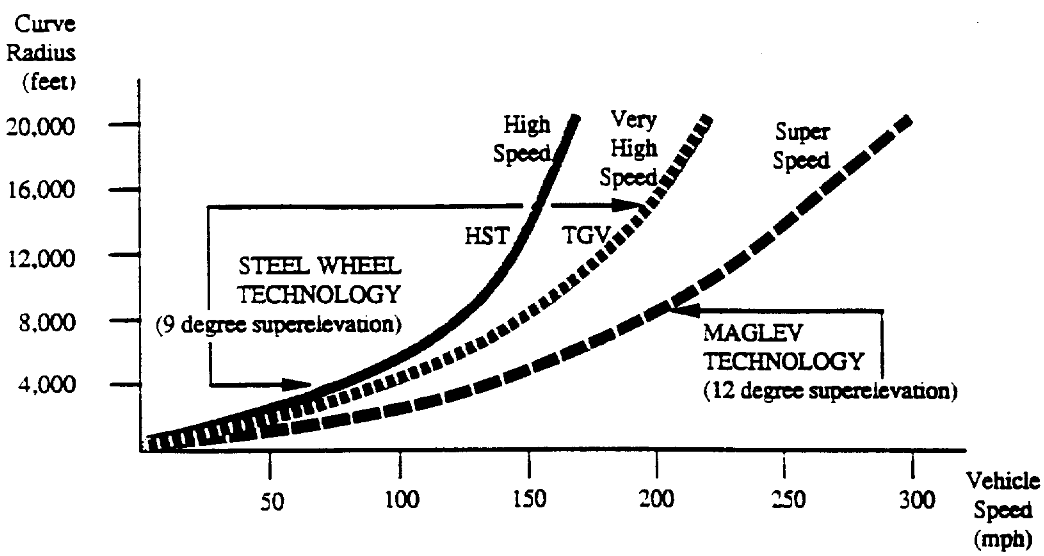


Exhibit 5.2
Curving Speed Constraint for 125 mph, 185 mph and 300 mph Technologies



The performance of the LOCOMOTION(c) model was tested, and the model was calibrated using data that reflect the track geometry, station stopping patterns and operating characteristics of existing diesel technology. Exhibit 5.3 shows a comparison of the current Amtrak timetable with the results from LOCOMOTION(c). The existing Amtrak schedule was assembled by taking the minimum station-to-station times and considering both westbound and eastbound travel. These minimum times reflect the most optimistic Amtrak times with the least interference. This was necessary since LOCOMOTION(c) cannot account for the slack time that is built into the Amtrak schedule. It should be noted that the calibration times are usually lower than the actual timetable times, since an allowance for train interference and operating safety cannot be entered into the train performance analysis. Overall, it was found that LOCOMOTION(c) simulated the current Amtrak Timetable well and could be used to provide an assessment of timetable improvements that might be obtained with faster technologies and civil engineering improvements.

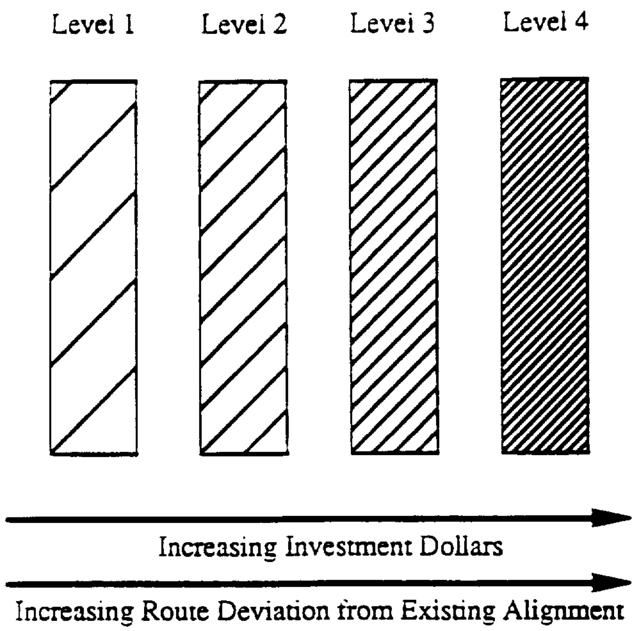
Exhibit 5.3
Comparison of Amtrak Timetable with LOCOMOTION(c) Results

		Amtrak Existing Schedule		LOCOMOTION Existing Schedule	
Station City	Milepost	Station-to-Station Minutes	Cumulative Hours	Station-to-Station Minutes	Cumulative Hours
Chicago, IL	0		Dp 0:00		Dp 0:00
		21		26	
Glenview, Il	17		Dp 0:24		Dp 0:29
		60		63	
Milwaukee, WI	85		Dp 1:27		Dp 1:35
		77		62	
Columbus, WI	150		Dp 2:47		Dp 2:40
		26		29	
Portage, WI	178		Dp 3:16		Dp 3:12
		19		18	
Wisconsin Dells, WI	195		Dp 3:38		Dp 3:33
		41		38	
Tomah, WI	240		Dp 4:22		Dp 4:14
		43		38	
La Crosse, WI	281		Dp 5:08		Dp 4:55
		35		32	
Winona, WI	308		Dp 5:46		Dp 5:30
		64		69	
Red Wing, MN	371		Dp 6:53		Dp 6:42
		67		66	
Minneapolis-St. Paul, MN	418		Ar 8:03		Ar 7:58

TIMETABLE DEVELOPMENT CRITERIA

To evaluate the potential timetables for each technology, a series of investment scenarios were developed. The investment scenarios were based on different levels of improvement and, thus, different levels of costs for each option. Exhibit 5.4 illustrates the four levels of potential improvement that might be developed for each technology option.

Exhibit 5.4
LOCOMOTION(c) Rail Investment Scenario



Level 1 - Upgrades on Existing Amtrak Alignment
Level 2 - Level 1 Plus Minor Deviations to Alignment (Up to 30% of Route)
Level 3 - Level 2 Plus Major Deviations to Alignment (Up to 95% of Route)
Level 4 - Totally New Alignment

Level 1 represents upgrades to existing track, within the existing alignment, to achieve a commercial speed of 125 mph on tangent (straight) track and 68 to 125 mph on curves. In urban areas, the speed on curves may sometimes be much lower as the right-of-way "twists" its way into the city center. A level 1 investment includes improvements to ballast, ties, rail, and structures such as bridges and culverts that are needed to obtain the maximum speed possible and the fastest time.

Level 2 involves realignment improvements except in urban areas, on both tangent and curved track, to allow the maximum feasible speed. It includes considerable work in widening curves to allow full-speed operations, and could include the purchase of new right-of-way and the rebuilding of the subgrade, ballast, ties and rails. Typically, existing track can be realigned to allow 125 mph on curves, but the civil engineering and cost restrictions to allow higher speeds are too severe.

With a level 3 investment, major route improvements are made to overcome any significant speed, environmental, or market demand constraints associated with the existing track and to thereby provide significant improvements to the timetable. This is the type of investment typically required for 185 mph trains. Because existing rights-of-way will still be used in the urban areas, 185 mph trains will face considerable reductions in speed in these areas.

Level 4 calls for a new right-of-way for the entire corridor. Level 4 optimizes engineering, environmental and market demand factors and allows the fastest speeds. Such an approach is suitable for the 300 mph option which cannot share an existing right-of-way anyway and would face significant delays without an entirely new route.

For the Very High Speed and Super Speed options (185 mph and 300 mph), investment levels 1 and 2 are largely irrelevant as a new right-of-way for most of the corridor is needed in each case. For the 185 mph option, some interworking with existing trains is possible in the urban areas and, as such, a level 3 investment was proposed for this technology. As already noted, the 300 mph technology must have a new right-of-way. Exhibit 5.5 shows the range of investment scenarios tested, as well as those selected as most appropriate, for each technology option.

Exhibit 5.5
LOCOMOTION[c] Rail Scenario Test Strategy

Investment Levels

Technology Options (mph)	1	2	3	4
100				
125	●	◇●	●	
185			◇●	
300				◇●

● Tested Investment Scenario
◇ Selected Investment Scenario

DEVELOPMENT OF TIMETABLES

As a first step in developing timetables for the three technologies, the 125 mph option was tested in relation to investment levels 1 and 2. To fully assess timetable improvements for the 125 mph option, it was run also as a 100 mph option. Exhibit 5.6 shows the train running times that can be achieved for 100 mph and 125 mph speeds on the existing alignment (level 1) and a revised alignment (level 2).

Exhibit 5.6
Chicago to Minneapolis-St. Paul Amtrak Service with 100 mph and 125 mph Train Running Times

Track Option	Speed	Timetable (No. of Hours)
Existing Alignment[1]	79 mph	8 hours
Existing Alignment	100 mph	6 hours and 38 minutes
Revised Alignment	100 mph	6 hours and 14 minutes
Existing Alignment	125 mph	6 hours and 6 minutes
Revised Alignment	125 mph	5 hours and 26 minutes

[1] *Current Amtrak Service.*

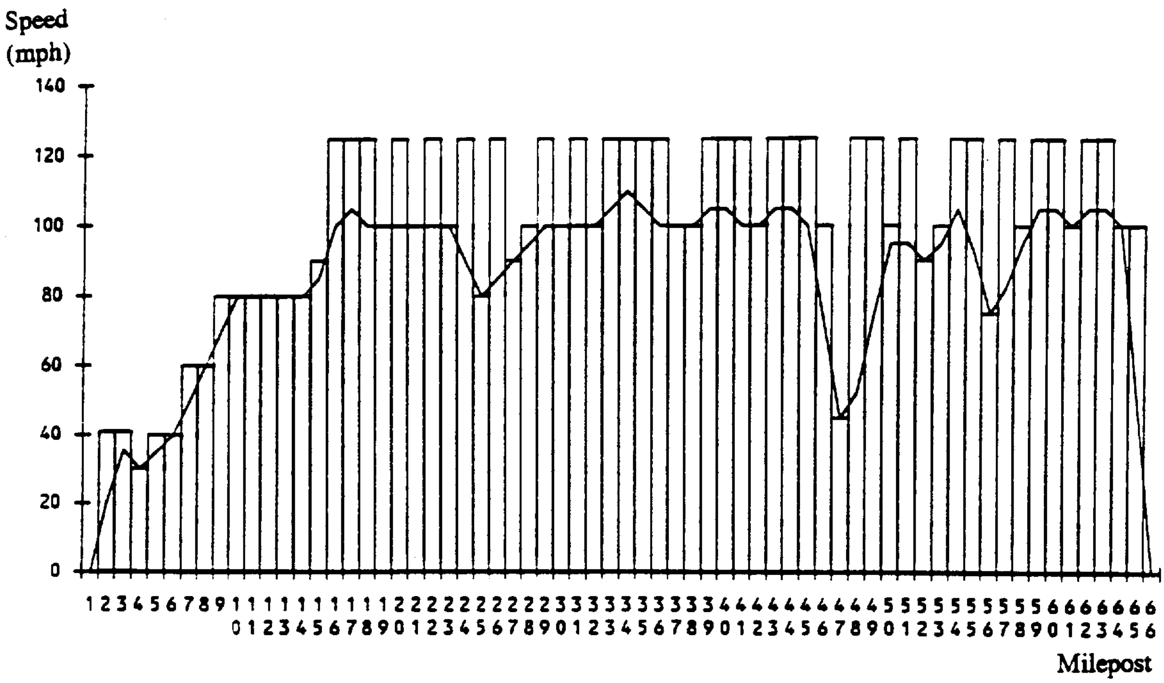
It can be seen that increasing speeds from the existing Amtrak timetable to 100 mph and 125 mph on the existing alignment would result in a savings of almost 1½ hours for the 100 mph option and 2 hours for the 125 mph option (from 8 hours to 6 hours and 38 minutes and 6 hours and 6 minutes respectively).

Further improvements to the alignment would allow overall speeds for the 100 mph option to increase and the timetable to improve by an additional twenty-four minutes (from 6 hours and 38 minutes to 6 hours and 14 minutes). For the 125 mph option, further improvements to the alignment would reduce the timetable by an additional half-hour (from 6 hours and 6 minutes to 5 hours and 26 minutes).

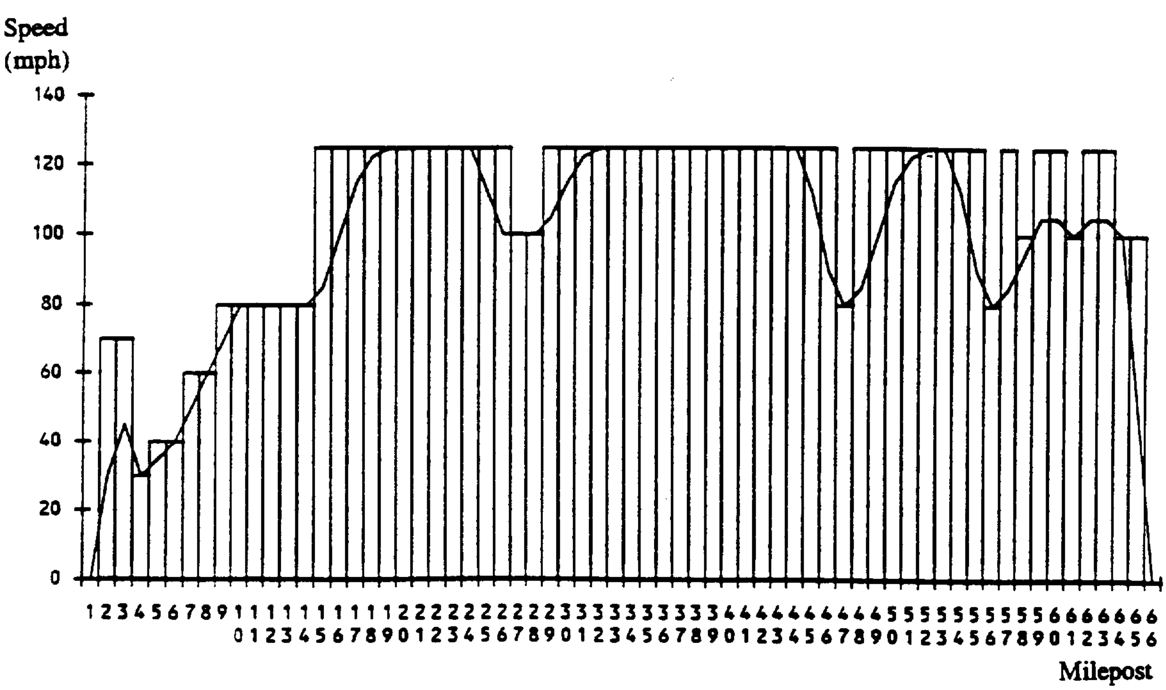
Improvements to train running times were evaluated using LOCOMOTION(c) speed profile graphs, examples of which are shown in Exhibits 5.7. Where speed restrictions were found from inspection of the graphs, an engineering evaluation was made of the potential for improvement and its likely cost. Improvements were ranked according to level of cost against the improvement in the timetable and the most significant improvements were included in the investment scenarios.

Exhibit 5.7
Sample LOCOMOTION(c) Speed Profile Graphs

Milwaukee to Columbus - Existing Alignment - 125 mph



Milwaukee to Columbus - Revised Alignment - 125 mph



TRAIN RUNNING TIME RESULTS

For each route and technology option, train running times were developed for each of the investment scenarios shown in Exhibit 5.8. In the Southern Corridor, Route #1 was developed from the existing Amtrak route for the 125 mph technology, while a new or largely new alignment, Route #4, was selected for the 185 mph and 300 mph technologies; in the Northern Corridor, a new or largely new alignment, Route #7, was selected for the 185 mph and 300 mph technologies.

Exhibit 5.8
Rail Investment Scenarios

<u>Southern Corridor</u>

Investment Levels

Technology Options (mph)	1	2	3	4
100	●	●		
125	●	●	●	
185			●	●
300				●

Level 1 Existing Amtrak Alignment
Level 2 Revised Amtrak Alignment
Level 3 Route #4
Level 4 Route #7

<u>Northern Corridor</u>

Investment Levels

Technology Options (mph)	1	2	3	4
100				
125				
185				●
300				●

Level 4 Route #7

The train running times for each technology and route option are shown in Exhibit 5.9. It should be noted that the train running times for the 125 mph and 185 mph technologies assumed a 2-minute stopping time at each station plus slack time for late running. It was assumed that the 300 mph option would not require slack time as it would be operating on its own right-of-way in a carefully monitored and controlled environment.

As shown in Exhibit 5.9, it can be seen that the 125 mph technology takes 4 hours and 20 minutes, including stopping and slack time, at a commercial speed of 100 mph for the journey between Chicago and Minneapolis-St. Paul. This is a reasonable commercial speed, typical of British Rail operations. The 185 mph technology takes some 3 hours and 15 minutes for the trip between Chicago and Minneapolis-St. Paul, with a commercial speed of 133 mph. This is a relatively low commercial speed compared with the 150 mph achieved by TGV in France, but is largely due to the speed restrictions between Chicago and Milwaukee. The first 85 miles to Milwaukee is completed in 50 minutes, with a commercial speed of 103 mph; between Milwaukee and Minneapolis-St. Paul, the commercial speed is 143 mph. The 300 mph technology option takes 2 hours and 15 minutes for the journey between Chicago and Minneapolis-St. Paul, with a commercial speed of 192 mph. Again, the journey time between Chicago and Milwaukee is relatively slow, with a commercial speed of only 137 mph and a journey time of 38 minutes.

In the Northern Corridor, the 185 mph technology takes 3 hours and 20 minutes at a commercial speed of 138 mph. While the Northern Corridor is 28 miles longer than the Southern Corridor, the train running time is only 5 minutes longer because the mileage is completed at top speed. The Chicago to Milwaukee segment is the same as the Southern Corridor and the same speed restrictions apply. For the 300 mph technology, the timetable is 2 hours and 20 minutes and, like the 185 mph technology, it takes only 5 minutes longer than on the Southern Corridor, attaining a commercial speed of 196 mph.

Exhibit 5.9
Timetable for 125 mph, 185 mph and 300 mph Technologies

		Southern Corridor			Northern Corridor	
Station	Milepost	125 mph Schedule Time (hours)	185 mph Schedule Time (hours)	300 mph Schedule Time (hours)	185 mph Schedule Time (hours)	300 mph Schedule Time (hours)
Chicago	0	0:00	0:00	0:00	0:00	0:00
Chicago Suburb	18	0:26	0:24	0:15	0:24	0:15
Milwaukee	85	1:00	0:50	0:38	0:50	0:38
Madison	165	1:45	1:30	1:08	--	--
Wrightstown	190	--	--	--	1:33	1:11
Twin Cities Suburb	423	4:06	2:58	2:06	--	--
	452	--	--	--	3:02	2:11
Twin Cities	433	4:15	3:07	2:15	--	--
	461	--	--	--	3:11	2:20
Total Corridor Time		4:20	3:15	2:15	3:20	2:20

Fleet Requirements

Given the definition of train running times, the second concern of the operating plan was the fleet requirement. Using the final set of train times, an analysis was made of the departure and arrival times of trains so that the overall rolling stock required to service the timetables could be determined.

An important factor impacting fleet size is the time required for train cleaning and preparation. British Rail claims the ability to turnaround its HST trains in as little as fifteen minutes, while SNCF practice with the TGV is to take up to an hour. Discussions with SNCF have suggested that a shorter turnaround time would be possible, particularly if a more thorough cleaning could take place in non-peak hours or at night. A thirty-minute turnaround time was therefore assumed for the Tri-State Study.

Additional planning assumptions included: train frequencies of 12, 18 and 24 trains per day respectively for the 125 mph, 185 mph and 300 mph options, and a weekly operating schedule based on five full weekdays and half-days on Saturdays and Sundays (or 312 days per year).

Finally, although it may be physically possible to service a timetable with a given set of times, consideration was given to the life cycle cost maximum mileage for each type of technology. The 125 mph technology is capable of up to 250,000 miles per year and the 185 mph technology, 290,000 miles per year. For the 300 mph technology, 350,000 miles per year was assumed. On this basis, the fleet size was evaluated at 13 train sets for the 125 mph option, 18 train sets for the 185 mph option on both the Northern and Southern Corridors, and 19 train sets for the 300 mph option on both the Northern and Southern Corridors.

TRAIN CONSIST SIZE

The third operating issue evaluated was train consist requirements for each corridor and each technology option. Using the estimated link loadings (or seating capacity required for each route segment), an assessment was made of passenger seating requirements. Exhibit 5.10 provides estimates of seating requirements for each technology for the years 2000 and 2024 for the Milwaukee-Madison segment of the Southern Corridor and the Milwaukee-Wrightstown segment of the Northern Corridor. These segments were selected as providing the average loading for each corridor. For example, on the Southern Corridor, the Madison-Minneapolis/St. Paul segment has a lower loading while the Milwaukee-Chicago segment has a higher loading. It was assumed that on the other segments traffic would be balanced by using appropriate pricing structures. It can be seen that, for each technology option, the train loadings range between 220 and 353 passengers for the Southern Corridor and between 200 and 276 passengers for the Northern Corridor.

Exhibit 5.10
Passenger Seating Requirements for the Years 2000 and 2024

Technology Option	Year 2000	Year 2024
Southern Corridor, Milwaukee to Madison		
125 mph	1,811,000 passengers 241 people/train	2,651,000 passengers 353 people/train
185 mph	2,734,000 passengers 243 people/train	4,017,000 passengers 358 people/train
300 mph	3,297,000 passengers 220 people/train	4,859,000 passengers 324 people/train
Northern Corridor, Milwaukee to Wrightstown		
185 mph	2,243,000 passengers 200 people/train	3,377,000 passengers 301 people/train
300 mph	2,741,000 passengers 183 people/train	4,139,000 passengers 276 people/train

The train seating capacities for a 1-8-1 consist, which was selected as the base case for the Tri-State Study, are shown in Exhibit 5.11. The TGV (185 mph) provides 444 seats per train, the HST (125 mph) 504 seats per train, and maglev (300 mph) 576 seats per train. At a 64 percent loading, which is a very good load factor for high speed train operations in a deregulated market, the typical passenger load for a 1-8-1 consist for the TGV and HST and a 2 x 3 for the maglev would be approximately 320, 280 and 370 passengers per train respectively, or an average of 325 passengers per train.

Exhibit 5.11
High Speed Train Seating Capacity for 1-8-1 Consist (Number of Seats by Type of Train)

Class of Car	Number of Cars per Train Set	Number of Seats HST	TGV	Maglev
First Class	2	96	78	n.a.
Second Class	6	408	366	n.a.
Total	8	504	444	576
Loading(1)	--	323	284	369

(1) Loading is based on 64 percent occupancy.

This suggests that the passenger levels forecast for both the Northern and Southern Corridors would prove ideal for a 1-8-1 consist. Assuming typical high speed train loading patterns (64 percent ± 55 percent), peak daily, peak weekly and seasonal traffic could readily be accommodated by this type of consist.

For study purposes, the train consist for the 125 mph and 185 mph technologies was 1-8-1 for both the Northern and Southern Corridors. For maglev, the train consist was three two-car sets for the Northern Corridor and four two-car sets for the Southern Corridor.

FREIGHT TRAIN INTERFERENCE

With respect to the operation of high speed rail systems, the potential level of freight train interference will be different in each case. The 125 mph technology option will use an existing freight railroad right-of-way and could therefore conflict directly with freight train operations. The 185 option will use a new right-of-way outside the urban areas, but must use a common right-of-way to access the downtowns of the major cities (Chicago, Milwaukee and Minneapolis-St. Paul). The 300 mph option would have its own elevated guideway, and it was assumed it could access cities without directly interfering with freight operations.

In order to measure the potential for freight interference, an evaluation was made of the capacity of the relevant rights-of-way. Exhibit 5.12 shows that, on the Minneapolis-St. Paul to Milwaukee segment of the route, there are currently 24 trains per day and, on the Milwaukee to Chicago segment, 51 trains per day. For the 125 mph option, with the proposed high speed rail service, the numbers would increase to 46 and 63 respectively on the two segments.

This level of use would exceed the current capacity of the two segments which is approximately 36 and 60 trains per day respectively. However, because the implementation of a high speed rail system would include the provision of double track and the upgrading of the signaling and communications system throughout the corridor, a capacity of 80+ trains per day would be provided. This suggests that more than adequate capacity would be available to accommodate the 125 mph in conjunction with current freight operations. Moreover, it should be noted that it would be possible to virtually separate passenger and freight operations, with passenger service operating during the day and freight operations at night.

However, because freight railroads are highly sensitive to sharing their track with passenger operations even when adequate track capacity is available, it is not always easy to obtain the cooperation of the freight railroads. To provide extra capacity in areas where the freight railroads might prove particularly sensitive to sharing track with passenger operations, to ensure that the freight railroads can handle their operations in a manner appropriate to their customers' needs, and to accommodate some expansion in freight traffic, an allowance for some 60 additional miles of track was added to the capital costs for the 125 mph and 185 mph options. This additional track would provide adequate capacity in urban areas and near industrial sidings to ensure that specific "bottlenecks" could be overcome. Finally, to ensure that freight locomotives can easily cross the track near major industrial sites, a rail-over-rail grade separation was provided for the 125 mph option at the entrance to the major cities. Similar track and grade separation costs were incorporated for the 185 mph technology option.

In conclusion, if the principle of train interworking can be established with the operating freight railroads, there would be adequate capacity to meet the needs of both freight and high speed passenger trains.

Exhibit 5.12
Train Interference Analysis

	Minneapolis-St. Paul to Milwaukee	Milwaukee to Chicago
Current Traffic (Trains per Day)		
Freight	22	24
Amtrak	2	12
Metra	–	15
Total	24	51
Proposed High Speed Rail Traffic (Trains per Day)		
125 mph Technology Option (HST)	24	24
Existing Freight/Other	22	39
Total	46	63
Track Capacity (Trains per Day)		
Current Capacity	36	60
Capacity with 125 mph (HST) Upgrade(1)	80 +	80 +

(1) *Double track, CTC.*

CHAPTER 6

REVENUES AND COSTS

The revenues and costs associated with providing high speed rail in the Tri-State Corridor were calculated for each technology and route option. The revenues and costs for each option are the key inputs to the financial analysis and the assessment of the project's viability.

REVENUES

The revenues generated by a high speed rail operation would in practice include not just the fares paid by passengers but also the revenues from land development, car parking, car rental facilities, express package services, station concessions, and other specialized services such as high speed container freight operations. For the purpose of this analysis, however, only fare box revenues were included. While revenues derived from the fare box are the most significant source of income, they are very much a conservative estimate of the potential income that a high speed rail service can generate. It should be noted that including only fares in the revenues understates potential total revenues by 20 to 60 percent, depending on the way in which the project is financed and the degree of property development and other revenue-producing activities associated with the project.

The fare box revenues for each high speed rail option were calculated by applying the appropriate fare to the rail ridership forecasts for all origin-destination zone pairs. Specifically, the revenue was estimated as follows:

$$R_{mnpy} = LL_{mnpy} \times F_{mnp}$$

where

R_{mnpy} = Revenue generated from link m-n for purpose p in year y

LL_{mnpy} = Total link loading on link m-n for purpose p in year y

F_{mnp} = Fare to cross link m-n for purpose p in base year dollars

Exhibit 6.1 shows the total revenue generated from the five forecast high speed rail route/technology options for the central case economic scenario.

Exhibit 6.1
Total Revenue Projections (1989$)

	Southern Corridor			Northern Corridor	
Year	Forecast Option 1 (125 mph)	Forecast Option 2 (185 mph)	Forecast Option 3 (300 mph)	Forecast Option 4 (185 mph)	Forecast Option 5 (300 mph)
2000	$227 million	$336 million	$409 million	$311 million	$380 million
2024	$341 million	$511 million	$624 million	$477 million	$584 million

It can be seen that the Southern Corridor generates approximately 8 percent more revenue for each of the high speed rail technology options, and that revenues grow in real terms by approximately 50 percent over the life of the project. In overall terms, the 300 mph option generates just under twice the income of the 125 mph option, while the 185 option is 50 percent greater than the 125 mph technology option.

OPERATING AND MAINTENANCE COSTS

Given an understanding of the infrastructure, timetables, and rolling stock requirements for each technology, annual operating and maintenance costs were prepared for each route and technology option. Key cost items include the maintenance of track (or guideway), signals and communications, rolling stock, electrical equipment, and the operations of trains including crew, energy costs, the care of passengers at stations and terminals and, finally, the management and administrative costs associated with the marketing, financial control, operating and engineering management of the railroad. The annual operating and maintenance costs for the Southern Corridor and Northern Corridor were derived by applying unit costs to the relevant operating statistics (number of train set miles, route miles, track miles and passengers) for each of the technology options.

OPERATING AND MAINTENANCE UNIT COSTS

For each technology option, the operating and maintenance unit costs were estimated from an analysis of costs prepared for a range of U.S., Canadian, and European studies. These studies included the 1983 VIA Rail operating studies of SNCF, Transmark and JNR technologies and the 1989 VIA report for the Windsor-Quebec City Corridor; the Florida, Texas and Los Angeles-Las Vegas studies of TGV, I.C.E., and maglev; the Federal Reserve Bank of Chicago's study of high speed rail in the Midwest; the Detroit-Chicago 125 mph and 150 mph high speed rail study by Bechtel; Transmark's Edmonton-Calgary study; Peat Marwick's operating cost study for Ohio; as well as direct input from British Rail, JNR, Transrapid, TGV, and Powell/Danby on the superconducting maglev technology. The results of this analysis are shown in Exhibit 6.2.

Exhibit 6.2
Operating and Maintenance Unit Costs (1989$)

Cost Item	Unit	125 mph Unit Cost	185 mph Unit Cost	300 mph Unit Cost
1. Track/Guideway	Per track mile	26,880	33,600	20,160
2. Signals and Communications	Per track mile	10,750	10,750	10,750
3. Electrification	Per track mile	—	6,300	27,720
4. Rolling Stock	Per train set per mile	9.41	4.03	1.74
5. Train Crew	Per train set per mile	1.86	1.67	1.60
6. Control Staff	Per route mile	5,100	5,100	5,100
7. Station Staff	Per passenger	1.26	1.05	0.84
8. Energy	Per train set per mile	4.03	3.76	6.05
9. Administration	Fixed cost estimate	4,200,000	6,300,000	6,700,000

In general, the operating and maintenance unit costs developed for the Tri-State Study are somewhat lower than those suggested by some of the earlier studies, such as the 1983 VIA study. The 1983 VIA estimates were based on European and Japanese operating cost estimates modified to Canadian conditions. At that time, North American as well as French, British and Japanese railroad practice reflected a highly labor-intensive, "unionized" operation. In more recent years, there have been substantial productivity improvements in European and Japanese railroads and, as a result, operating costs have fallen. For example, British Rail in the mid-1980's went through a series of strike actions to increase "effective" driver operating hours from four to five-and-a-half hours per day.

Although the latest studies in Texas, Florida and Los Angeles-Las Vegas have suggested significantly reduced high speed train operating costs, these studies based their operating costs on the three years of operating practice of the TGV reported by N. Brand and M. Lucas in the paper "Operating and Maintenance Costs of the TGV High Speed Rail System." The weakness in the use of this data is that the operating and maintenance costs of any new system are always relatively low in the first few years but increase over the life cycle of the equipment. To overcome this limitation, the life cycle costs reported for the TGV and HST have been adjusted to reflect more realistic life cycle operating costs.

For the 300 mph technology, expert advice was sought from Powell/Danby on the issues of maintenance, life cycle costs, and annual mileage for maglev.

ANNUAL OPERATING AND MAINTENANCE COSTS

The annual operating and maintenance costs for each corridor and each technology option are given in Exhibit 6.3. The largest cost items are track, signals and communications, rolling stock, and energy.

Exhibit 6.3
Annual Operating and Maintenance Costs (1989$)

Southern Corridor

Cost Item	125 mph Costs	185 mph Costs	300 mph Costs
1. Track/Guideway	$ 23,278,080	$ 29,097,600	$ 17,458,560
2. Signals and Communications	9,309,500	9,309,500	9,309,500
3. Electrification	0	5,455,800	24,005,520
4. Rolling Stock	30,510,081	19,599,728	11,283,218
5. Train Crew	6,030,685	8,121,972	10,375,373
6. Control Staff	2,208,300	2,208,300	2,208,300
7. Station Staff	2,281,860	2,870,700	2,769,480
8. Energy	13,066,485	18,286,595	39,231,878
9. Administration	4,200,000	6,300,000	6700,000
Total Annual O & M Costs	$ 90,884,991	$101,250,194	$123,341,829

Northern Corridor

Cost Item	185 mph Costs	300 mph Costs
1. Track/Guideway	$ 31,046,400	$ 18,627,840
2. Signals and Communications	9,933,000	9,933,000
3. Electrification	5,821,200	25,613,280
4. Rolling Stock	20,912,412	12,038,907
5. Train Crew	8,665,937	11,070,259
6. Control Staff	2,356,200	2,356,200
7. Station Staff	2,355,150	2,302,440
8. Energy	19,511,332	41,859,418
9. Administration	6,300,000	6,700,000
Total Annual O & M Costs	$106,901,631	$130,501,344

For the Southern Corridor, total operating and maintenance costs rise from $90.88 million per year for the 125 mph, to $101.25 million per year for the 185 mph, to $123.34 million per year for the 300 mph technology option. For the Northern Corridor, total operating and maintenance costs increase from $106.9 million per year for the 185 mph option, to $130.5 million per year for the

300 mph option. As might be anticipated, the marginal costs of operating and maintenance do not rise significantly with increased speed (only by 36 percent from the 12 trains per day, 125 mph operation to the 24 trains per day, 300 mph operation). This is because most of the operating and maintenance costs are essentially fixed costs.

INFRASTRUCTURE COSTS

The infrastructure cost analysis was carried out by applying unit costs derived from a range of North American studies to the physical quantities associated with the routes selected in the engineering analysis. From the range of possible investment scenarios for each technology option, consideration was given to the potential for upgrading the route, the development of a new route, and the selection of the most appropriate technology. The selected technology/route options included:

- High Speed (125 mph) — Upgrade of Route #1, Existing Amtrak Route
- Very High Speed (185 mph) — New right-of-way for Route #4 in the Southern Corridor and Route #7 in the Northern Corridor
- Super Speed (300 mph) — New right-of-way for Route #4 in the Southern Corridor and Route #7 in the Northern Corridor

INFRASTRUCTURE UNIT COSTS

As with the operating and maintenance unit costs, the infrastructure unit costs were derived from an analysis of engineering unit costs associated with a range of North American projects and studies, with input from Powell/Danby on the unit costs for the 300 mph technology option. All unit costs include 15 percent for contingency and 3 percent for construction management. The results of this analysis are shown in Exhibit 6.4.

Exhibit 6.4
Infrastructure Unit Costs for 125 mph and 185 mph Technologies (1989$)

Cost Item	Unit	Unit Cost
1. Land		
Rural	Per mile	82,000
Urban	Per mile	245,000
2. Grading[(1)]	Per specific estimate	Per specific estimate
3. Track[(2)]		
Rail with Concrete Ties	Per mile	570,000
Freight Track	Per mile	800,000
Rail Replacement (Welded Rail Relay)	Per mile	261,000
High-Speed Crossover	Each	285,000
High-Speed Turnout	Each	122,000
Low-Speed Turnouts	Each	39,000
Tie Renewal[(3)]	Each	35
4. Signals and Communications - New Route[(4)]	Per mile	505,000
6. Electrification	Per mile	600,000
7. Fencing	Per route mile	168,000
8. Grade Crossing Protection		
At-Grade Short Arm	Each	170,000
At-Grade Complete Gate	Each	211,000
Highway over Rail		
Four-Lane Urban Expressway	Each	6,520,000
Four-Lane Rural Expressway	Each	1,630,000
Two-Lane Highway	Each	1,222,000
Rail over Rail	Each	4,075,000
Rail over Highway	Each	1,222,000
Road Diversions	Each	277,000
Pedestrian/Animal Crossings	Each	122,000
Farm Crossings	Per route mile	45,000
9. Stations		
New	Each	1,630,000
Refurbished	Each	244,000
10. Maintenance Facilities	Each	3,260,000
11. Demolition		
Residential	Each	100,000
Commercial	Each	150,000
12. Rolling Stock		
1-6-1 Consist for 125 mph	Each	11,116,000
1-6-1 Consist for 185 mph	Each	14,079,000
1-8-1 Consist for 125 mph	Each	13,040,000
1-8-1 Consist for 185 mph	Each	16,300,000

[(1)] *Determined by an analysis of topography on a milepost-by-milepost basis.*
[(2)] *Includes all labor, equipment, rail ties, other track material, and ballast required to complete one operating track.*
[(3)] *Includes the replacement of deteriorated ties to permit 125 mph speeds.*
[(4)] *Includes all labor, equipment and material to construct a 21st century system for the 125 mph and 185 mph options.*

With respect to the 125 mph and 185 mph technologies, because these are proven systems which have been implemented, the unit cost estimates were easily determined and are likely to prove a highly reliable guide to infrastructure costs for these technologies.

This was not the case with the 300 mph maglev technology and the unit costs for this technology are likely to prove less reliable, particularly with respect to the vehicles and electronic systems. The guideway costs which represent a substantial part of the 300 mph total infrastructure costs can be easily determined once the weight of the vehicle is known, as considerable experience exists in building concrete structures. For the Tri-State Study, the U.S./Japanese superconducting maglev technology was selected as the representative technology for the 300 mph option, rather than the electromagnetic system that was used in many of the earlier studies such as Florida and California. However, at the request of the Tri-State Steering Committee, the costs of both systems were calculated as shown in Exhibit 6.5. Since there is a substantial difference in vehicle weight between the two maglev systems, the guideway cost estimates for the electromagnetic system are nearly 40 percent higher than those for the superconducting.

Exhibit 6.5
Comparison of Unit Costs for Maglev Infrastructure (1989$)[1]

	Superconducting	Electromagnetic
Average Cost per Mile	11,112,000	16,009,000
Grading Cost per Mile	668,000	668,000
Guideway Cost per Mile	6,250,000	8,580,000
Guideway Equipment per Mile	1,392,000	3,040,000
Power Supply per Mile	1,320,000	1,816,000
Maintenance Facility	10,600,000	10,600,000

[1] *Unit costs for superconducting maglev were provided by Powell/Danby; unit costs for electromagnetic maglev were based on Transrapid estimates.*

INFRASTRUCTURE AND TOTAL CAPITAL COST ESTIMATES

The construction quantities for each route were calculated on the basis of milepost data developed for each route alignment. For example, curvature reductions and earthwork quantities for the 125 mph upgrade option were computed between mileposts and then quantified as a route total. For each route/technology option, the land acquisition and building demolition, earthworks, track work, crossings, fencing, signals and communications, station modifications and maintenance facility needs were estimated.

The infrastructure costs were then obtained by applying the unit costs to the physical quantities estimated for each route/technology option. The infrastructure cost estimates are shown in Exhibits 6.6 to 6.8. It should be noted that a project management fee of 4 percent and an engineering design fee of 6 percent were applied to provide a total construction cost estimate.

Exhibit 6.6
Estimated Construction Cost for 125 mph Technology Upgraded Amtrak on Route #1 in Southern Corridor (1989$)

Cost Item		Cost
1.	Curvature Reduction[1]	$62,957,000
2.	Crossings[2]	40,494,000
3.	Signals and Communications	211,090,000
4.	Fencing	70,224,000
5.	New Welded Rail Relay	106,227,000
6.	New Cross Ties	10,640,000
7.	Restore Double Track	78,603,000
8.	High-Speed Crossovers	6,270,000
9.	Low-Speed Turnouts	4,875,000
10.	Install New Freight Side Tracks	48,000,000
11.	Farm Crossings	18,810,000
12.	Stations[3]	16,196,000
13.	Maintenance Facilities	6,520,000
Total Infrastructure Cost		$680,906,000
Project Management Fee (4%)		27,236,000
Engineering Design Fee (6%)		40,854,000
Total Construction Cost		$748,996,000

[1] *Includes land acquisition costs.*
[2] *Assumes closure of lightly traveled roadways, installation of gates at crossings for two-lane highways, and construction of overpasses/underpasses at crossings for four-lane highways.*
[3] *Includes upgrading of the twelve existing Amtrak stations.*

Exhibit 6.7
Estimated Construction Costs for 185 mph Technology (1989$)
Route #4 in the Southern Corridor and Route #7 in the Northern Corridor

Cost Item	Costs for Route #4	Costs for Route #7
1. Land - Rural	$33,784,000	$35,916,000
2. Land - Urban	35,200,000	38,400,000
3. Grading (New Construction)	578,549,000	587,053,000
4. Highway and Stream Crossings	703,530,000	465,525,000
5. Signals and Communications	219,170,000	233,310,000
6. Fencing	72,912,000	77,616,000
7. Electrification	260,400,000	277,200,000
8. Construct Track	494,760,000	525,825,000
9. High-Speed Turnouts	2,684,000	2,684,000
10. Refurbish Stations	244,000	244,000
11. New Stations(1)	6,520,000	6,520,000
12. Maintenance Facilities	6,520,000	6,520,000
13. Residential Buildings Demolished	27,000,000	56,300,000
14. Commercial Buildings Demolished	3,750,000	---
Total Infrastructure Costs	$2,445,023,000	$2,313,113,000
Project Management Fee (4%)	97,800,000	92,524,000
Engineering Design Fee (6%)	146,700,000	138,786,000
Total Construction Costs	$2,689,523,000	$2,544,423,000

(1) *Includes six new stations.*

Exhibit 6.8
Estimated Construction Costs for 300 mph Technology (1989$)
Route #4 in the Southern Corridor and Route #7 in the Northern Corridor

Cost Item	Costs for Route #4	Costs for Route #7
1. Land - Rural	$31,652,000	$33,784,000
2. Land - Urban	76,800,000	80,000,000
3. Grading (New Construction)	290,000,000	290,000,000
4. Guideway	2,681,250,000	2,881,250,000
5. Guideway on High Bridge	62,500,000	12,500,000
6. Guideway Equipment	604,128,000	643,104,000
7. High-Speed Turnouts	9,288,000	9,288,000
8. Low-Speed Turnouts	6,114,000	6,114,000
9. Fencing	8,400,000	8,400,000
10. New Stations[1]	8,150,000	8,150,000
11. Power Supply System	572,880,000	609,840,000
12. Maintenance Facilities	2,450,000	2,450,000
13. Residential Buildings Demolished	27,000,000	35,600,000
14. Commercial Buildings Demolished	3,750,000	12,450,000
Total Infrastructure Costs	$4,384,362,000	$4,632,930,000
Project Management Fee (4%)	175,374,000	185,318,000
Engineering Design Fee (6%)	263,062,000	277,976,000
Total Construction Costs	$4,822,798,000	$5,096,224,000

[1] *Includes six new stations.*

To obtain a total capital cost estimate, rolling stock costs (derived by applying train set unit costs to the fleet requirements calculated in the operating analysis) were added to the infrastructure costs. The total capital costs for the route/technology options are shown in Exhibit 6.9.

Exhibit 6.9
Total Capital Costs for the Route/Technology Options (1989$)

Technology Option	Southern Corridor	Northern Corridor
125 mph	$0.94 billion	---
185 mph	$3.02 billion	$2.87 billion
300 mph	$5.45 billion	$5.72 billion

Interestingly, for the 185 mph option, the longer Northern Corridor is less costly than the Southern Corridor; this is largely due to the high cost of the Mississippi River crossings at La Crosse and in St. Paul. Because the 300 mph technology option is effectively built on a "bridge" (guideway) for its entire length, its costs are lower in the Southern Corridor than in the longer Northern Corridor despite the costs of crossing the Mississippi River.

In overall terms, the total capital costs of the 185 mph technology option are approximately three times those of the 125 mph option, while the 300 mph option is five times more expensive than the 125 mph option.

A comparison of the capital costs for the Southern Corridor with those of other high speed rail studies is shown in Exhibit 6.10. It can be seen that the estimated capital costs per mile are very similar.

Exhibit 6.10
Comparison of Capital Costs per Mile (Millions of 1989$)(1)

	125 mph	185 mph	300 mph
Tri-State	2.2	7.2	13.0
Ontario-Quebec(2)	3.1	7.7	12.1
Texas(3)	5.2(4)	6.8	15.5
Rules of Thumb(3)	3.3	7.4	14.7

(1) *To facilitate comparison with the Tri-State Study, costs for the other studies were adjusted to 1989 dollars.*
(2) *High Speed Rail in the Quebec/Ontario Corridor, Ontario/Quebec Rapid Train Task Force, 1990.*
(3) *Texas Triangle High Speed Rail Study, Texas Turnpike Authority, February 1989.*
(4) *Capital costs based on full-grade separation of all track and roadways.*
(5) *Rules of Thumb for High Speed Rail Planning by Dr. A.E. Metcalf for the Union International du Chemin de Fer, 1985; revised and updated for the Ontario/Quebec Rapid Train Task Force, 1990.*

CHAPTER 7

FINANCIAL AND ECONOMIC ANALYSIS

The financial and economic analysis was performed to provide insight into the potential viability of the three high speed rail technologies under a series of economic, transportation and financing scenarios. Because a high speed rail service could be implemented with public, private, or a combination of public and private financing, two markedly contrasting financing methods were used in this analysis. The methods were used to derive "favorable" and "worst" case estimates for the financial and economic results.

The use of tax-exempt municipal bonds for major infrastructure projects represents the most favorable financing circumstances. While this type of financing is open to the private sector (as well as the public sector), this financing method could well require the jurisdictional backing of the three States involved. It was, therefore, designated the public financing method. Alternatively, all or part of a high speed rail project could be financed by commercial bank loan(s) at a commercial interest rate. While this type of financing is open to both the public and private sectors, this analysis assumed an interest rate that might be required for private sector financing of a major infrastructure project. This second approach has been designated the private financing method. The "favorable" case public financing method and the "worst" case private financing method were intended to represent the likely extremes for any high speed rail financing package.

Regardless of the nature of the source of financing, economic benefits will flow from a high speed rail investment to both current users and non-users of the system. It should be noted that the economic benefits identified in this analysis are specific to high speed rail and do not take into account the economic benefits that would be generated by alternative transportation investments. Other alternative transportation investments (airports, highways, etc.) would also produce economic benefits that could be larger or smaller than those identified in this analysis for a high speed rail investment.

FINANCIAL ANALYSIS

A financial analysis was carried out for the five high speed rail options evaluated for the Tri-State High Speed Rail Study (125 mph, 185 mph and 300 mph in the Southern Corridor and 185 mph and 300 mph in the Northern Corridor). The purpose of the financial analysis was to determine the financial returns associated with each of the five options and provide a basis for the comparing the options. The financial analysis included:

- Development of a financial model for the five options, incorporating revenues, capital costs, and operating and maintenance costs (in 1989$) and assuming implementation in the year 2000.

- Generation of cash flow projections for revenues, capital costs, and operating and maintenance costs for the 25-year life of the project (from the year 2000 to 2024).

- Analysis of net cash flows using two financing methods to ensure that the two extremes of public and private financing were effectively represented by the financial analysis:

    - 7½ percent interest-bearing, non-taxable (municipal) bonds as typically associated with state highway investment to represent the "favorable" financing method.

    - Private bank at a 16 percent interest rate to represent the "worst case" financing method.

- Evaluation, using an appropriate discount rate, of both the Internal Rate of Return (IRR) and the Net Present Value (NPV) associated with each of the five options.

FINANCIAL MODEL

The Financial Model is based on an analysis of Discounted Cash Flow (DCF). The DCF is an extended stream of cash flows and can be written as:

$$PV = \sum \frac{C_t}{(1+r)^t}$$

where

PV = Present value

C_t = Cash flow

r = Opportunity cost of capital

t = Time period

In calculating the Discounted Cash Flow, two specific financial rates, the discount rate and the interest rate, have to be determined independently.

Discount Rate

The discount rate is the financial return forgone by investing in a project (such as high speed rail) rather than in securities. A 5.0 percent real rate (excluding inflation) is normally used for government transportation projects. For the Tri-State study, a nominal rate of 9.0 percent (based on 5.0 percent real plus 4.0 percent inflation) was used as the discount rate for both the private (loan) and public (municipal bond) financing methods. It should be noted that the 9.0 percent rate also approximates the rate of return in the long-term securities market.

Interest Rates for Municipal Bonds

Since interest on municipal bonds is tax-exempt, their after-tax yield is the same as their pre-tax yield. In determining the interest rate to be used for bonds, two "rules-of-thumb" were compared. Firstly, there is the bond dealers' rule-of-thumb which assumes that it pays investors to buy municipal bonds at 66 percent of the pre-tax yield of taxable bonds (given a corporate tax rate of

34 percent). This would be equivalent to a 6.5 percent annual interest rate for the issuer of the municipal bonds. Secondly, the financial analysts' rule-of-thumb is that the interest rate should be three-quarters of the prime rate. Assuming the 10 percent prime rate that was in effect in November 1990, the interest rate for the issuer of municipal bonds would be 7½ percent. Following this assessment, it was decided to adopt the more stringent (and more conservative) interest rate of 7½ percent for the Tri-State Study.

Interest Rates for Private Loans

For private bank loans, an interest rate of 11.0 percent (prime plus one percent) was deemed possible, given that a project such as high speed rail would be undertaken by large corporations with strong financial backing. However, taking into consideration the size of the project and to ensure a conservative approach, a "severe" 16.0 percent interest rate (prime plus 6.0 percent) was used for this analysis.

In reality, government support or backing for the project could greatly reduce the rate of interest, as would the participation of a major construction company or rolling stock manufacturer making a major equity or project loan contribution.

MEASURES OF FINANCIAL PERFORMANCE

From the Discounted Cash Flow formula, the Net Present Value (NPV) and the Internal Rate of Return (IRR) can be calculated. The Net Present Value is defined as the value that measures the combined worth of all the cash flows (positive and negative) associated with a project at a given point in time. For the Tri-State Study, the NPV includes revenues, operating and maintenance costs, and capital costs.

Net Present Value, stated in terms of cash flow, is:

$$NPV = C_0 + PV$$

where

C_0 = Initial cash outflow (capital)

PV = Present value of cost and revenue streams that result from the operation of the project (discounted to the first year of the project)

A positive NPV shows that an investment is worth more than it costs; a negative NPV shows that an investment costs more than it generates in income.

The Internal Rate of Return is defined as the rate of interest which makes the Net Present Value equal to zero. As such, the Internal Rate of Return achieved should be judged against the required discount rate which, for the purposes of the Tri-State Study, was set at 9 percent. An IRR value over 9 percent means that the project would be financially viable, while an IRR below 9 percent means that a project would not achieve the desired financial return.

OTHER FINANCIAL ASSUMPTIONS

For the purposes of this analysis, tax issues have been ignored and simplifying procedures have been adopted in calculating cash flows. Cash flows have simply been estimated as the difference between estimated ridership revenues and estimated operating costs. Equally, no pro forma income statement projections have been developed.

To carry out the financial analysis, it was necessary to identify financial requirements during the construction period. For analysis purposes, it has been assumed that the 185 mph and 300 mph options would take five years to construct, whereas the 125 mph option could be implemented in three years. For both the 185 mph and 300 mph options, the bulk of the expenditure would be focused in year three to year five, as the first two years would be largely concerned with land acquisition, design, and environmental issues. Because this work would be less complex for the 125 mph technology, a three-year construction program was considered sufficient. It has been assumed for all three options that rolling stock would be purchased the year before operations begin, so that commissioning, testing and staff training could occur in a timely manner. The assumptions made for the financial analysis regarding project implementation are shown in Exhibit 7.1.

Exhibit 7.1
Financial Analysis Assumptions

	125 mph	185 mph		300 mph[1]	
Timing Data	Southern Corridor	Southern Corridor	Northern Corridor	Southern Corridor	Northern Corridor
Construction Duration	3 years	5 years	5 years	5 years	5 years
First Year of Construction	1997	1995	1995	1995	1995
First Year of Operation[2]	2000	2000	2000	2000	2000
Last Year of Operation	2024	2024	2024	2024	2024
Construction Phasing (Percent per Year)	20/45/35	5/10/25/30/30	5/10/25/30/30	5/10/25/30/30	5/10/25/30/30
Rolling Stock (No. of Train Sets and Size of Consist)	13 1-8-1	18 1-8-1	18 1-8-1	19 3 x 2	19 3 x 2
Capital Costs (Millions of 1989$)					
Infrastructure	749.0	2689.5	2544.4	4822.8	5096.2
Rolling Stock	190.7	330.0	330.0	627.0	627.0
Total	939.7	3019.5	2874.4	5449.8	5723.2

(1) *Because the 300 mph option is an unproven technology, there could be unforeseen problems that would extend the construction period and reduce the financial performance of this technology option.*

(2) *It should be noted that the 125 mph technology option could be implemented earlier than the year 2000. It has been assumed to begin operations in the year 2000 to ensure a proper comparison between the three technology options.*

With respect to the likely changes in cash flows over the life of the project, a number of assumptions have been made about revenues and costs. Rates of increase in both revenues and operating and maintenance costs tend to be highly correlated with inflation rates and, for the financial analysis, have been assumed to follow inflation trends. Although infrastructure costs tend to be lower than inflation due to productivity gains and other improvements that reduce the impact of inflation, for the Tri-State Study, they were assumed to escalate at the same rate as revenues and operating and maintenance costs. In developing the cash flow analysis, it was assumed that:

- Revenues would rise in line with inflation at 4.0 percent per year.
- Operating and maintenance costs would rise in line with inflation at 4.0 percent per year.
- Infrastructure costs would escalate at a rate of 4.0 percent, which is in line with the performance of the construction industry in the last ten years and expectations for the next ten years.

The financial analysis was based on the ridership and revenue forecasts developed for the base case transportation strategy and central case economic scenario. The base case transportation strategy assumed replacement of the existing Amtrak service and implementation of a new high speed rail service, the implementation of planned highway and airport plans, but no competitive response by the air or bus industry. The central case economic scenario assumed the continuation of existing economic trends throughout the Tri-State Corridor in terms of income, population and employment, including the assumption that energy costs would remain stable.

Finally, it should be noted that the financial analysis did not include any savings to state government(s) associated with current expenditures for operating rail passenger service in the Tri-State Corridor.

RESULTS OF THE FINANCIAL ANALYSIS

The financial analysis was undertaken using the central case economic scenario, a 25-year Discounted Cash Flow analysis, and the two financing methods established for the study. The 125 mph on the upgraded Amtrak route ranked highest in terms of financial "attractiveness," the 185 mph option second, and the 300 mph option lowest. Even with the "severe" 16 percent interest rate used for the private financing method, the NPV for the 125 mph option was positive at $91.0 million and the IRR was 9.3 percent. This was the only investment option where the private financing method showed a positive NPV and an IRR greater than the 9 percent discount rate.

With the public (municipal bond) financing method of issuing non-taxable bonds at 7½ percent yield, the 125 mph and 185 mph technology options showed positive IRR's and NPV's because of the lower cost of capital. The return on the 300 mph option remained unfavorable with a negative NPV although, in the Southern Corridor, the return was becoming marginal.

The financial results of the central case economic scenario are summarized in Exhibit 7.2.

Exhibit 7.2
Results of Financial Analysis (Discount Rate 9% Nominal)[1]

		Southern Corridor			Northern Corridor	
		125 mph	185 mph	300 mph	185 mph	300 mph
Public Financing	IRR	19.7	11.8	8.3	11.1	7.0
	NPV	2388.0	1714.9	-666.4	1215.8	-1963.7
Private Financing	IRR	9.3	1.8	-2.3	1.1	-4.0
	NPV	91.0	-5815.9	-14294.3	-5972.6	-16282.3

[1] *NPV is in millions of dollars and IRR is percent return.*

The financial analysis shows a very strong case for high speed rail investment in the Tri-State Corridor. The low-cost 125 mph option ($1 billion) performed exceptionally well under both financing methods, and the level of return achieved suggests that this type of high speed rail would rank high on any priority list of transportation proposals. The higher capital costs of the 185 mph ($3.1 billion) and the 300 mph ($5.6 billion) reduced the financial return on these two options but, with the public financing method, the level of return would be acceptable for the 185 mph and marginal for the 300 mph technology option. While these results are only preliminary, a case could be made for each technology option, particularly if a public agency believed that the higher speed technologies would fulfill other public objectives more effectively than the 125 mph option. Furthermore, the financial results were encouraging, given the conservative nature of the input assumptions. If the specifics of the financing package were improved, the NPV's and IRR's might well prove acceptable for all three technologies. Factors to be considered include the level of equity participation, interest rates, financial grace periods, associated real estate development, and potential government contributions (in terms of loan guarantees, purchase of rights-of-way, etc.), all of which could greatly improve the overall financial results.

SENSITIVITY ANALYSIS

To test the strength of the findings of the financial analysis, a series of sensitivity tests were conducted for the Southern Corridor on the impact of economic change, increased energy prices, increased traffic congestion, potential competitive responses by the air and bus industries, and a variation in the Values of Time used to gauge travel choices (i.e., half VOT's). Exhibit 7.3 shows the results of the different sensitivity assessments for the three technology options. The sensitivity tests were made using the public financing method (7½ percent municipal bond) and, unless otherwise stated, the central case economic scenario.

Exhibit 7.3
Sensitivity Analysis for Southern Corridor[(1)]

	125 mph		185 mph		300 mph	
	NPV	IRR	NPV	IRR	NPV	IRR
Base Case	2388.0	19.7	1714.9	11.8	-666.4	8.3
Lower Economic Growth	1928.2	18.5	1004.2	10.7	-1561.2	7.4
Higher Economic Growth	3402.2	22.7	3191.6	13.6	1124.8	10.0
Increased Energy Costs (+50 percent)	2623.1	20.6	2131.0	12.4	-122.6	8.9
Increased Congestion (+50 percent)	4904.7	28.3	6552.4	17.8	5478.4	13.6
Increased Air Competition (Fares -20 percent)	2076.9	18.5	1222.8	11.0	-1777.1	7.6
Increased Bus Competition (Frequency +30 percent, Fares -30 percent)	2146.5	18.8	—	—	—	—
Half VOT's	1681.0	17.5	1272.0	11.1	-762.9	8.2

[(1)] *NPV is in millions of dollars and IRR is percent return.*

The effect of increased or reduced economic growth was consistently small for all three technologies, with the 185 mph and 300 mph options experiencing greater increases and decreases in NPV with changes in economic circumstances. The percentage changes in the NPV's were +40 percent and -20 percent for the 125 mph option; +85 percent and -40 percent for the 185 mph option; and +270 percent and -130 percent for the 300 mph option. The IRR results were much less affected by changes in economic growth, changing only by a couple of percentage points in each case. This analysis suggests that the 300 mph technology would be favored by improved economic circumstances, and that improved economic conditions could in fact make the project financially viable. The 125 mph and 185 mph options would be less affected by lower economic growth in that they would remain viable options. Overall, changes in economic growth would not seriously affect the viability of a high speed rail investment.

The impact of increased energy costs was to raise the NPV's and IRR's for all three options. The NPV's rose by 10 percent for the 125 mph, 24 percent for the 185 mph, and 80 percent for the 300 mph option, while the IRR's rose by one or two points in each instance. This suggests that the case for the 300 mph technology would be improved with higher energy costs, to the extent that it would be almost viable with only a small negative NPV.

In evaluating the effect of congestion, it was found that increased air and highway congestion dramatically enhanced the case for high speed rail investment. It increased the NPV's by a factor of 2.0 to \$4.9 billion for the 125 mph option and by a factor of 3.5 to \$6.6 billion for the 185 mph option, and even made the 300 mph option, with a positive NPV of \$5.5 billion, very attractive when compared with the 125 mph option. In this sensitivity analysis, the 185 mph option has the highest NPV. The sensitivity tests show that financially high speed rail offers a very attractive means for reducing congestion and maintaining regional mobility.

An assessment was made of the potential competitive response of the air and bus industries to the introduction of high speed rail. For air, it was found that a 20 percent reduction in real air fares would have little impact on the IRR's and NPV's for the three technologies, reducing the IRR's by approximately one percent. With respect to bus competition, it was found that substantial increases in service (+30 percent) and cuts in fares (-30 percent) would have very little impact on the 125 mph technology, which is the option that would be most vulnerable to bus competition.

The impact of a variation in travel behavior associated with using half VOT's in the demand model was a reduction in revenues, which was reflected in the NPV's for all three technology options and the IRR for the 125 mph option. The NPV decreased by 30 percent for the 125 mph option, 25 percent for the 185 mph option, and 15 percent for the 300 mph option. The IRR for the 125 mph option declined from 19.7 percent to 17.5 percent, with the IRR's remaining fairly constant for the other two options.

Overall, the sensitivity analysis suggested that the impact of changes in the economy, energy prices, air and bus competition, and halving the Values of Time would have marginal effects on the financial case for proceeding with an investment in high speed rail. The most significant factor was the effect of congestion, which dramatically strengthens the already strong case for high speed rail investment.

FINANCIAL ANALYSIS CONCLUSIONS

The financial analysis shows that there is a strong case for high speed rail in the Tri-State Corridor with very strong financial results for all three technologies. The financial returns suggest that the ordering of the technology options is 125 mph, 185 mph and 300 mph, and that the routes in the Southern Corridor are preferred over the routes in the Northern Corridor. With respect to public versus private financing, it is clear that the returns would be much higher with the public (municipal bond) financing method and that both the 185 mph and 300 mph options would have negative results if financed with the private (loan) financing method. As most high speed rail projects proposed by the private sector (such as those in Florida and Texas) use much more sophisticated and complex financing methods, it is likely that the financing package for the private financing method would "internalize" some of the property and economic benefits (by raising fares and accruing rents) and thereby achieve much higher IRR's and NPV's. In strict financial terms, there is little doubt that the Tri-State Corridor offers a significant opportunity for high speed rail investment.

ECONOMIC ANALYSIS

The economic analysis for the Tri-State Study was carried out using the RENTS(c) Model and consisted of two evaluations:

- An assessment of user benefits (or Consumer Surplus) which measured potential improvements in travel times and costs to rail, air, bus and auto travelers in the Tri-State Corridor.

- An assessment of community benefits which measured potential improvements in economic welfare (income, employment, tax base, property values) that would accrue to the inhabitants of the Tri-State Corridor.

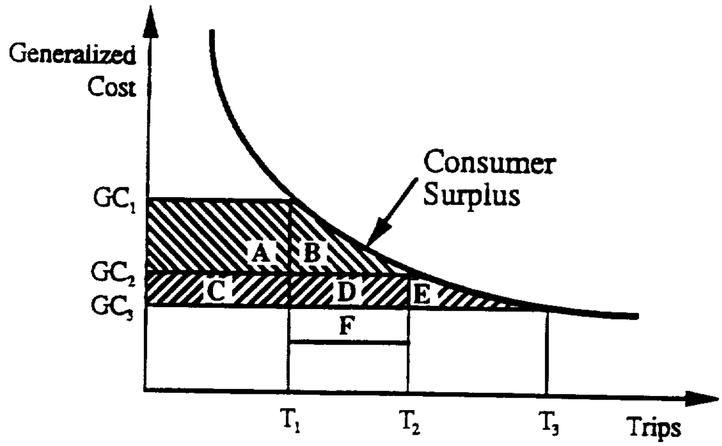
USER BENEFITS

User benefits were measured using the Consumer Surplus concept. In this concept, the effect of a transportation improvement (such as the implementation of a high speed rail system) is seen as providing user benefits, in terms of time and cost savings to both existing users of that mode (rail) as well as new users induced (persons who previously did not make a trip) or diverted (users who previously used a different mode) by the new level of (rail) service.

In the Consumer Surplus analysis, the improvement in service was measured as an improvement in generalized cost. For high speed rail, the improvement in generalized cost includes both time and fare savings: improvements in time and frequency for existing rail users, better times and lower fares for current air travelers, and improved time for bus and auto users. In some cases, individuals may pay higher fares (for example, existing rail users), but the improvement in time is such that it more than compensates for the increased fare given the Values of Time and Values of Frequency that individuals in the Tri-State Corridor use to make travel decisions. It should be noted that, for consistency purposes and because they represent the appropriate "behavioral" values, the same Values of Time and Values of Frequency were used in the economic analysis as in the demand forecasting process.

To calculate the size of the Gross Consumer Surplus, an evaluation was made that compared the generalized cost of travel without the high speed rail option to the generalized cost of travel with the high speed rail option. As shown in Exhibit 7.4, Area "A" represents the improvement in the generalized cost of travel for existing users, and Area "B" represents the improvement in the generalized cost of travel for induced or diverted users.

Exhibit 7.4
Consumer Surplus Curve



The Gross Consumer Surplus can be measured by the following equation, which assumes that Area "B" is a triangle and the arc of the demand curve is a straight line.

$$GCS = [(GC_1 - GC_2)T_1] + [(GC_1 - GC_2)(T_2 - T_1)(0.5)]$$

where

GCS = Gross Consumer Surplus

Area "A" = $(GC_1 - GC_2)T_1$

Area "B" = $(GC_1 - GC_2)(T_2 - T_1)(0.5)$

It should be noted that the Gross Consumer Surplus measured in this analysis considered only rail travelers. User benefits would also accrue to air, bus and auto travelers who benefit from reduced congestion and reduced delays at airports and terminals, and on the highways. To evaluate these benefits would require a detailed appraisal of each mode, which is beyond the scope of the current study. It should be noted, however, that the benefits to users of the other modes would probably be relatively small. Nonetheless, by the year 2010, the effects of reduced congestion on airport capacity and suburban highway congestion (resulting from the implementation of a high speed rail service) would be significant and could add 10 to 30 percent to the user benefit values. This would be a particularly significant effect for the 185 mph and 300 mph options that divert significant air traffic and, to a lesser extent, highway traffic.

If the Gross Consumer Surplus is measured in constant 1989 dollars for the project life (year 2000 to 2024), the Present Value of the economic benefits can be determined by discounting at an appropriate value. For this analysis, the Present Values were determined by discounting at a real rate of 5.0 percent, which is equivalent to the 9.0 percent nominal rate used in the financial analysis. The results of the Present Values of the Gross Consumer Surplus are shown in Exhibit 7.5.

Exhibit 7.5
Results of Economic Analysis

	Southern Corridor			Northern Corridor	
	125 mph	185 mph	300 mph	185 mph	300 mph
Gross Consumer Surplus PV[1]	1737.4	3091.3	4071.8	2532.3	3406.6
Additional Revenue PV[1]	3520.2	5387.2	6630.9	4987.0	6160.3
Total Capital and Operating Cost PV[1]	(2252.8)	(4627.2)	(7512.0)	(4552.0)	(7904.9)
Project Net Present Value	3004.8	3851.3	3190.7	2967.3	1662.0
Capital Constrained Consumer Surplus[2]	3.09	1.20	0.55	0.97	0.27

[1] *Discount Rate 5% Real, Millions of 1989$.*
[2] *Ratio of benefit to total capital cost.*

It can be seen that the highest level of Present Value of the Gross Consumer Surplus benefit was achieved in the Southern Corridor. As shown in Exhibit 7.5, economic benefits in the Southern Corridor were approximately 15 to 20 percent higher than in the Northern Corridor. For the three technology options, the results of the user benefit analysis were the reverse of the financial analysis, in that the 300 mph technology has the highest level of benefit and the 185 mph option the second highest level. The Gross Consumer Surplus benefits for the 300 mph option are 30 percent greater than the 185 mph option, and 130 percent greater than the 125 mph option. The 185 mph option provides Consumer Surplus benefits that are 80 percent greater than those of the 125 mph option.

The evaluation of the Gross Consumer Surplus is useful in identifying the benefits to society if the high speed rail project is privately funded at no cost to the public sector. Funds for the project would be derived from outside the Tri-State Corridor, and the financial returns for the project are receipted back to the source of the capital.

However, if the project is undertaken with public funds, then a Net Present Value estimate is required including both the costs as well as the benefits to the Tri-State Corridor. A Net Present Value is calculated including the capital and operating and maintenance costs and the Total Consumer Surplus of the project, including all transfer payments. In line with the financial analysis, savings to the state governments on expenditures associated with the cessation of Amtrak operations were not included in the surplus benefits calculation.

The Total Consumer Surplus for the Tri-State project therefore includes the additional consumer surplus "internalized" by the railroad company in terms of higher fares which is in effect a transfer payment. In theory, the Total Consumer Surplus can be measured in the same way as the Gross Consumer Surplus by comparing GC_1, the "no action" generalized cost with GC_3, the generalized cost associated with implementing the high speed rail option but with existing Amtrak fares.

The consumer surplus internalized by the railroad company however only equals Areas "C" and "D" (as shown on Exhibit 7.4) since Area "E" is lost when the rail fare rises to GC_2.

Unfortunately, the direct measurement of Total Consumer Surplus in this manner will tend to overstate the level of benefit, as the Amtrak level of fare is not sufficient to cover the costs of any of the three technology options. While marginal revenue (fare) would equal marginal cost under "perfect competition" conditions, this is not the case for projects involving substantial infrastructure investments. Rather, the marginal cost of increased rail capacity rises, particularly for the higher speed options.

To overcome this problem, it was decided to adopt an approach in which the internalized consumer surplus was measured by a direct comparison of the additional revenue generated by the high speed rail system with the total capital and operating costs of providing the system. In this way, the internalized consumer surplus that must go towards the increased costs of providing the system is effectively considered. The additional revenue of the railroad is equal to Areas "C" + "D" + "F". Area "F" is the part of the revenue paid by new rail users, which they would have expended if fares had remained at the Amtrak level and not been raised by the railroad company. The additional revenue is shown in Exhibit 7.5.

It can be seen that the highest additional revenue is achieved by the 300 mph option, followed by the 185 mph and 125 mph options respectively.

The Project Net Present Value can then be calculated by adding the Gross Consumer Surplus to the additional revenue and then subtracting the total costs for building and operating the system. This requires that capital and operating costs be expressed in present values in 1989 dollars. The results of this analysis are shown in Exhibit 7.5. It can be seen that the Net Present Values for the Southern Corridor are substantially higher than for the Northern Corridor. With respect to the technology options, the NPV is highest for the 185 mph option, or approximately 20 percent higher than the NPV for the 300 mph option and 25 percent higher than the 125 mph option.

A third potential financing situation would be a public sector financed project but under severe capital limitations. In this environment, the evaluation might well be made in terms of Net Consumer Surplus earned per dollar invested. This suggests a different ordering of the results, namely, 125 mph, 185 mph and 300 mph. It can be seen that the Northern Corridor provides less net consumer surplus benefit per dollar invested than the Southern Corridor.

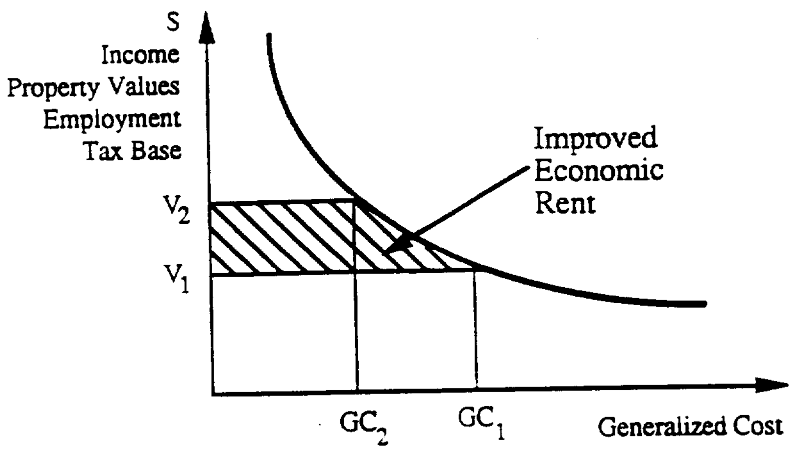
COMMUNITY BENEFITS

Non-travelers would also benefit from the implementation of high speed rail. These benefits can be measured in terms of the potential increase in the number of permanent jobs, incomes and property values. The analysis of community benefits was based on the potential increase in economic activities (Economic Rent) that would occur in those areas that experience improved accessibility to the major cities.

The concept of Economic Rent is derived from basic Ricardian economic theory as a means of explaining the increased value of economic resources such as land in certain locations. Accessibility is a key spatial variable that affects the likely uses of land and therefore its value.

Changes in accessibility will, in turn, change the Economic Rent that the land can command and, therefore, its value and the character of the economic activities that take place on the land. As a result, for important economic welfare criteria (such as income, property values, employment and the tax base), an evaluation can be made of the likely change in Economic Rent that would be associated with an improvement in accessibility. Accessibility is measured in terms of generalized cost. The Economic Rent concept is illustrated in Exhibit 7.6.

Exhibit 7.6
Economic Rent Curve



For the Tri-State Study, an Economic Rent analysis was completed using the observed relationship between the economic indicators of the zones and their accessibility to the major cities. A three-tier Economic Rent structure which reflected the hierarchy of cities in the corridor in terms of their economic activity and population was built into the analysis. Chicago and Minneapolis-St. Paul were defined as "first-tier" cities, Milwaukee as a "second-tier" city, and Madison and Green Bay as "third-tier" cities. Each major city is unique in the net benefits it would receive from the different route and technology options. By analyzing a range of zone data collection for the demand model, mathematical relationships were established between generalized cost (GC), employment, income, and property values for each corridor and major city. The general form of the model is:

$$SE_1 = \beta_0 GC_i^{\beta_1}$$

where

SE_i = Socioeconomic indicators (employment, income, property value) of county i

GC_i = Generalized cost of rail travel from county i to major city

β_0 and β_1 = Parameters to be estimated

This equation can be transformed as follows:

$$\ln GC = \beta_0 + \beta_1 \ln Emp + \beta_2 \ln Inc + \beta_3 \ln PropVal$$

where

GC	=	Generalized cost
Emp	=	Employment
Inc	=	Household income
PropVal	=	Property value
β_0, β_1, β_2, β_3	=	Parameters to be estimated

For each city tier, an Economic Rent curve was defined and calibrated. The Economic Rent equation implies a shift in "rents" to the area affected by the implementation of high speed rail, as well as a rise in "Rents" in the "hinterland" of the major cities. The results of the Economic Rent calibration are shown in Exhibit 7.7.

Exhibit 7.7
Economic Rent Coefficients[1]

	Employment	Income	Property Value	R^2
1st Tier	-0.057 (-2.75)	-0.548 (-2.17)	-0.178 (-2.80)	0.78
2nd Tier	-0.044 (-1.48)	-1.100 (-3.09)	-0.160 (-1.75)	0.71
3rd Tier	-0.042 (-1.19)	-0.808 (-2.07)	-0.132 (-1.29)	0.42

[1] *"t" values are given in parentheses.*

RESULTS OF THE ECONOMIC ANALYSIS

Three variables (employment, household income and property values) were found to be significant. For each city tier analysis, the Economic Rent model was significant with correct signs on coefficients and good "t" and R^2 values. This was particularly true for the first- and second-tier cities. The coefficients of the model suggest reasonably consistent results, with employment and property value coefficients of the same order of magnitude and decreasing in value from the first- to the third-tier cities. The income coefficients range between 0.5 and 1.1, suggesting that the size of the coefficient rises for smaller cities. Since elasticities will vary with the size of "hinterland" identified for the city and since socioeconomic data were available only on a county basis, it is possible that this level of aggregation distorted the "hinterland" identified for the third-tier cities and the calibration for income.

In terms of the "present value" of the economic benefits that would be generated by any high speed rail investment in either the Southern or the Northern Corridor, a calculation was made of the person-years of employment, the percent increase in regional household income, and the percent increase in total regional property values that would be generated over the life of the project for the Tri-State Corridor as a whole. Exhibit 7.8 shows the results of this analysis for each route and technology option.

It can be seen that the Southern Corridor produces a higher level of community benefit than the Northern Corridor. The benefits derived for the Southern Corridor were approximately 20 percent higher than those for the Northern Corridor. The results for the Northern Corridor are lower because of the substantial loss of benefits by cities such as Madison in the Southern Corridor if the high speed rail system were built in the Northern Corridor. These cities would face an absolute loss of accessibility and Economic Rent if the 185 mph or 300 mph option was implemented in the Northern Corridor.

In terms of the technologies, it can be seen that the 300 mph option provides only marginally higher community benefits than either the 185 mph or 125 mph option. The reason for this is the relatively small reduction in "door-to-door" travel associated with the 300 mph option over the other two technologies.

Exhibit 7.8
Total Community Benefits (for 25-Year Project Life)

	Southern Corridor			Northern Corridor	
	125 mph	185 mph	300 mph	185 mph	300 mph
Employment					
Number of Person Years	16525	17850	18650	13975	15525
Household Income					
Percent Increase	1.3	1.3	1.3	1.0	1.0
Dollar Value[1]	3.4	3.2	3.5	2.9	3.0
Property Value					
Percent Increase	1.9	2.2	2.4	1.7	2.0
Dollar Value[1]	5.4	6.1	6.7	4.8	5.5

[1] *Billions of 1989 dollars.*

In overall terms, the investment in high speed rail would create 14,000 to 19,000 person-years of employment over the life of the project (excluding jobs associated with the construction and operation of the high speed rail system), increase corridor household incomes by an average of 1.3 percent which is equivalent to an absolute increase of $2.5 to 3.5 billion, and increase property values by 1.7 to 2.4 percent or $4.8 to $6.7 billion. In total, the implementation of a high speed rail project could be expected to generate an additional $8 to $10 billion of economic benefits in the Tri-State Corridor.

CONCLUSIONS

The financial and economic analyses show that a strong case can be made for a high speed rail system in the Tri-State Corridor. As demonstrated by the financial analysis, the critical issues are the cost of money and the potential for revenue enhancement. The current evaluation suggests that the 125 mph option would yield the highest financial return. However, a case could be made for all the route/technology options if a competitively low interest cost and modest revenue enhancements were part of the financial package.

With respect to the economic analysis, all three options generated significant economic benefits in terms of Consumer Surplus and community benefits (employment, household income and property values). In all cases, the Southern Corridor provided greater benefits than the Northern Corridor. With respect to Consumer Surplus, the Gross Consumer Surplus (which is relevant to a privately funded project) suggested an ordering of technologies as 300 mph, 185 mph and 125 mph, while the Net Consumer Surplus (which is relevant to a publicly funded project), suggested an ordering of 185 mph, 300 mph and 125 mph. Overall, the highest level of community benefits were derived for the 300 mph option, followed by the 185 mph option and then the 125 mph option. However, the difference in the benefits generated by the three options was marginal and not as substantial as might have been expected; for example, the 125 mph option generated 85 percent of the 300 mph option's level of community benefit.

While the financial and economic analysis completed to date is preliminary in nature and included a number of assumptions, the economic and financial prospects for high speed rail in the Tri-State Corridor appear very positive and are sufficiently strong to justify the undertaking of a more detailed and comprehensive analysis.

CHAPTER 8

SUMMARY

FINDINGS

The Tri-State Study of High Speed Rail Service has shown that the Chicago-Milwaukee-Twin Cities Corridor appears very promising in terms of ridership, revenues, and financial and economic benefits that could be achieved. The market is a combination of the short-distance, almost intra-urban Chicago-Milwaukee market and the long-distance Chicago/Milwaukee-Twin Cities market. Together, the two markets offer a potential for high speed rail which is matched in passenger volumes by the North East Corridor and the Los Angeles-San Diego Corridor.

The evaluation of the corridors and technologies studied suggest that:

- In environmental, economic and financial terms, the Southern Corridor is preferred to the Northern Corridor.
  - It should be noted that the Northern Corridor, despite being substantially longer, is only marginally more costly and marginally less financially and economically attractive than the Southern Corridor.
  - It should also be noted that many of the benefits of the Northern Corridor could be obtained for the northern communities by providing rail connections from Green Bay to Milwaukee and from Eau Claire to Minneapolis-St. Paul if a route in the Southern Corridor is implemented.
- In financial terms, the preferred ordering of the technology options is 125 mph, 185 mph and 300 mph.
  - In terms of the ability of the public or private sector to finance any option, the availability of non-taxable bonds (for all or part of the required investment) is critical.
  - It should be recognized that the revenue analysis for this study is a conservative one, and revenues could be increased significantly by property value capture, optimized fares, express parcel and container operations, and other related revenue-enriching activities that are frequently associated with high speed rail.
  - Under the current revenue assumptions, only the 125 mph technology option could be financed by a bank loan with a 16 percent interest rate. It should be noted that a 16 percent interest rate is highly conservative, and most high speed rail implementation proposals achieve a lower cost of money.
  - Under the current revenue assumptions, if a private sector group takes responsibility for the project, it will need to obtain lower-cost capital and revenue enrichments to ensure financial success with either the 185 mph or 300 mph option.

- The preferred ordering of the technology options in terms of economic benefits derived depends on the sources and availability of capital.

  - For a public sector project, the net economic benefit derived from the consumer surplus analysis must be compared with the capital and operating and maintenance costs incurred, and that gives a preferred ordering of 185 mph, 300 mph and 125 mph.

  - For a private sector project with capital from outside the Tri-State region, the preferred ordering of the technologies is 300 mph, 185 mph and 125 mph, as the gross economic benefit is directly correlated with the speed of the train.

  - The preferred ordering of the technologies in terms of economic return per dollar invested, which would apply where a public sector investor was constrained in terms of capital availability, is the 125 mph option followed by the 185 mph option and then the 300 mph option.

- In terms of community benefits, a high speed rail project might be expected to provide between $8 and $10 billion of support to the communities along the right-of-way, and the level of return is very similar for each technology.

- From an environmental perspective, the use of existing rights-of-way (as with the 125 mph option) is clearly preferred over the development of new rights-of-way as would be needed for the 185 mph and 300 mph options.

  - In many ways, the 185 option is subject to more difficult environmental constraints than the 300 mph option. The latter operates on a grade-separated guideway and therefore can easily avoid many problems related to community "severance" and disruption.

  - Visual intrusion will be a concern with both the 185 mph and 300 mph options in environmentally sensitive areas. Careful planning and alignment selection will be critical in any feasibility planning study.

CONCLUSIONS

The major conclusions of the Tri-State Study are:

- The Southern Corridor is preferred to the Northern Corridor.

- The 125 mph option offers the best financial return, the least environmental costs, and the highest economic benefits per dollar invested, which would be relevant to a public sector capital-constrained investment program. While the net economic benefits are not quite as high with this option as with the 185 mph and 300 mph options, the level of benefit is substantial. The economic benefits achieved by the 125 mph option are 80 percent of those achieved by the 185 mph and 94 percent of those achieved by the 300 mph technology.

- The 185 mph technology has a good financial return and the highest net economic benefits, but suffers from the highest environmental costs because of the "severance" problems associated with its new right-of-way.

- The 300 mph technology provides good economic benefits, but has only a marginal financial performance due to its substantial capital costs. It has substantial but lower environmental costs than the 185 mph technology as its new right-of-way causes less "severance" problems. What is most surprising is that the 300 mph option performs as well as it does given its huge capital costs. However, the key issue with this technology is that, today, maglev is still at the prototype stage which would raise further the risks associated with its implementation, both to the investment community and to any proposed operator.

RECOMMENDATIONS

The Tri-State Study has been undertaken using existing travel data, existing operating and capital unit costs, and a generic approach to technology, operating concepts, infrastructure, financing and environmental concerns. A more detailed and comprehensive feasibility study of the Southern Corridor is now required to identify a preferred approach to high speed rail in the Tri-State Corridor. The Consultant Team recommends that the following be included in this feasibility study:

- Collection of a specific and comprehensive origin-destination data set. This will overcome a number of the data interface problems associated with existing data sources.

- The development of a base year weighted demand model for evaluating any proposed incremental alternatives. It should be noted that in this study the 125 mph option has been treated as a "new" technology rather than an upgraded Amtrak option.

- Development of a new ridership forecasting model, which would include an assessment of the impact of the base year and forecast year weights, as well as the effects of different model structures only some of which were assessed in this study.

- A full-scale technology appraisal which would include the newly introduced Swedish Railroad "tilt" technology option that was not evaluated in this study, and a realistic assessment of the availability and likely commercialization time scales of the 300 mph maglev technology.

    - It seems probable that the "tilt" technology could produce financial returns equal to that of the 125 mph technology option, with nearly the same economic benefits as the 185 mph option and with only marginally more environmental problems than the 125 mph option. This would suggest that a "tilt" technology option might well become a preferred alternative of any future feasibility study.

    - The 300 mph maglev technology evaluated for this study is only at the prototype stage. While German and Japanese research continues, it is clear that this technology is still evolutionary in character and cannot be regarded in the same way as conventional steel-wheel-on-steel-rail technologies. The difference between an operational and a prototype system is not just the risk associated with potential increases in capital and operating and maintenance costs, but also the risk associated with the system ever becoming operational. These concerns need to be resolved before maglev can be considered a practical alternative to a steel-wheel-on-steel-rail investment.

If the results of this analysis are positive, the next steps would include:

- A detailed engineering and environmental analysis that would evaluate routes, crossings, infrastructure needs, and environmental concerns and issues in greater detail.

- A comprehensive financial and economic analysis including a full financial assessment. The financial assessment should be based on a comprehensive analysis of the likely form of the financing package.

- An implementation plan and program for proceeding beyond the feasibility study work.

EXECUTIVE SUMMARY

BACKGROUND

The purpose of the Tri-State Study of High Speed Rail Service was to evaluate the potential for high speed rail along two corridors: a Southern Corridor (Chicago-Milwaukee-Madison-La Crosse-Winona-Rochester-Minneapolis-St. Paul) and a Northern Corridor (Chicago-Milwaukee-Appleton-Green Bay-Wausau-Eau Claire-Minneapolis-St. Paul).

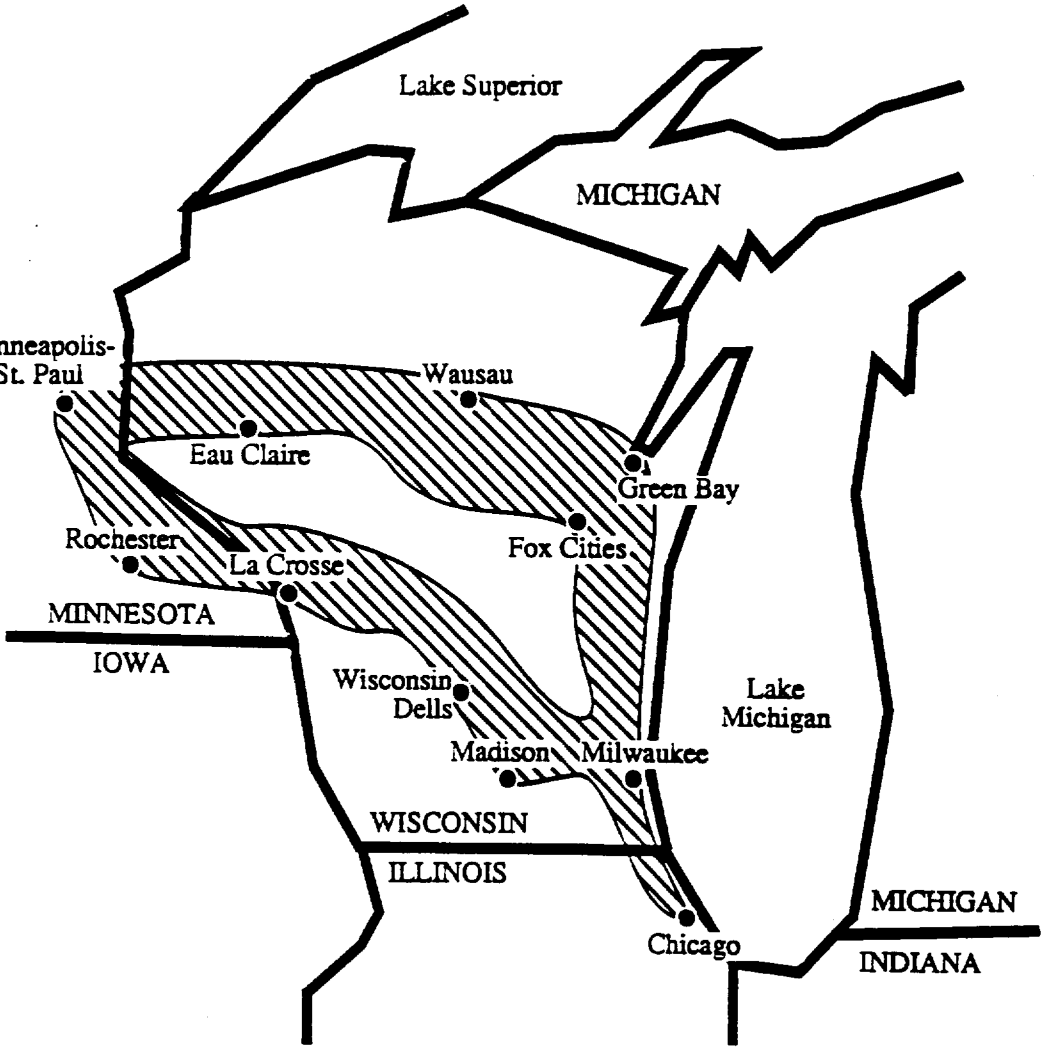
In the Southern Corridor, the evaluation included a 125 mph "Amtrak upgrade" High Speed option, a 185 mph "TGV/ICE" Very High Speed option, and a 300 mph Super Speed "maglev" option. In the Northern Corridor, which currently has no rail service, only the 185 mph and 300 mph technologies were assessed.

The study process included the development of an appropriate origin-destination data base using existing State highway, FAA airport, Amtrak rail, and intercity bus timetable data; forecasting ridership and revenue for the life of the project (that is, from the year 2000, the first year of high speed train operation, to the year 2024); estimating capital costs and operating and maintenance costs on a unit cost basis; a preliminary evaluation of major socioeconomic, environmental and energy impacts; and an assessment of key implementation issues such as potential private financing opportunities and rail freight interference problems.

STUDY ROUTES AND COSTS

The evaluation of the High Speed technology option was based on the continued use of the existing Amtrak route in the Southern Corridor; there was no High Speed option evaluated for the Northern Corridor. Following a detailed analysis of a wide range of alternative routes, a route in the Southern Corridor and a route in the Northern Corridor were selected as the basis for evaluating the Very High Speed (185 mph) and Super Speed (300 mph) technologies. The selection of these routes was based on minimizing travel time, minimizing gradients, curves and other physical impediments, maximizing regional accessibility, and minimizing environmental impacts.

The capital costs for each route/technology option were assessed using a unit cost data bank generated by the Consultant Team from previous high speed rail feasibility studies and local information on rail infrastructure costs. Using milepost-by-milepost data generated by the track inspection carried out for the study, the physical requirements of each route were assessed, converted to physical construction quantities (miles of track, cubic tons of earthwork, etc.) and then costed using the unit cost data bank. The infrastructure costs were combined with the rolling stock costs to derive capital costs.


Lake Superior
MICHIGAN
Minneapolis-
St. Paul
Wausau
Eau Claire
Green Bay
Rochester
La Crosse
Fox Cities
MINNESOTA
IOWA
Wisconsin
Dells
Lake
Michigan
Madison
Milwaukee
WISCONSIN
ILLINOIS
MICHIGAN
INDIANA
Chicago

Total Capital Costs for the Route/Technology Options (1989$)

Technology Option	Southern Corridor	Northern Corridor
125 mph	$0.94 billion	—
185 mph	$3.02 billion	$2.87 billion
300 mph	$5.45 billion	$5.72 billion

OPERATING TIMETABLES AND COSTS

For each route/technology option, operating times for trains were calculated using the LOCOMOTION(c) Train Performance Calculator. LOCOMOTION(c) uses train performance data (acceleration, deceleration and horizontal curve speed capabilities of each technology, physical track condition data on a milepost-by-milepost basis, curve radii, station locations, and track speed limitations) to estimate overall train running times.

Train Running Times for the Route/Technology Options

Technology Option	Southern Corridor	Northern Corridor
125 mph	4 hours 20 minutes	---
185 mph	3 hours 15 minutes	3 hours 20 minutes
300 mph	2 hours 15 minutes	2 hours 20 minutes

Rail operating and maintenance costs were estimated from an understanding of the train timetables, the life cycle and maintenance costs of rolling stock, and the proposed levels of service. The operating costs were estimated using the Consultant Team's data bank of operating unit costs that is based on data obtained from operational railroads in England, France and Japan, previous high speed rail studies in the United States and Canada, and an analysis of recent trends in labor and maintenance costs. The operating costs included track, signaling, rolling stock and other equipment maintenance costs, train control, station and administrative staff costs, together with the energy costs for operating the trains.

Annual Operating Costs for the Route/Technology Options (1989$)

Technology Option	Southern Corridor	Northern Corridor
125 mph	$ 90.9 million	---
185 mph	$101.3 million	$106.9 million
300 mph	$123.3 million	$130.5 million

RIDERSHIP AND REVENUE

The ridership estimates for each route/technology option were developed using the COMPASS(c) demand forecasting system, which provided a specific behavioral analysis of travel characteristics in the Chicago-Milwaukee-Minneapolis-St. Paul Corridor. The COMPASS(c) models for total, induced and diverted demand were calibrated using the behavioral values of time, the origin-destination data base that was assembled from existing data sources, and network information for each mode (rail, auto, bus and air). The models were calibrated for each mode of travel and found to provide a very good statistical fit and overall performance.

The ridership forecasts were based on the central case economic scenario which assumed that current trends will continue, and a "no action" transportation strategy which included planned improvements to highways, airports and bus services but no improvements for rail. The revenue estimates were not "optimized," but were based on a reasonable level of fare given the quality of service associated with each technology option and assumed no competitive response from the air and bus modes.

Forecasts of Rail Ridership (Millions of Trips) and Revenue (Millions of $1989) for the Years 2000 and 2024

		Southern Corridor		Northern Corridor	
		2000	2024	2000	2024
125 mph	Ridership	5.8	8.1	--	--
	Revenue	$226.6	$341.1	--	--
185 mph	Ridership	7.5	10.6	7.1	10.1
	Revenue	$336.1	$510.9	$311.0	$477.1
300 mph	Ridership	8.5	12.2	8.1	11.7
	Revenue	$409.3	$624.2	$379.8	$584.4

FINANCIAL RETURNS

The financial returns for each route/technology option were established for two situations: public (municipal bond) financing and private (loan) financing, which were intended to represent the likely extremes for any high speed rail financing package. The evaluation process for public financing assumed 7½ percent interest-bearing non-taxable bonds, while for private (loan) financing it assumed a severe 16 percent cost of capital. For both assessments, a discount rate of 9 percent (5 percent real, 4 percent inflation), 4 percent inflation in revenues, operating costs, and capital costs, and a twenty-five-year operation period were assumed.

The results for each route/technology option were assessed using Net Present Value and Internal Rate of Return measures.

Results of Financial Analysis (Discount Rate 9% Nominal)(1)

		Southern Corridor			Northern Corridor	
Financing		125 mph	185 mph	300 mph	185 mph	300 mph
Public	IRR	19.7	11.8	8.3	11.1	7.0
	NPV	2388.0	1714.9	-666.4	1215.8	-1963.7
Private	IRR	9.3	1.8	-2.3	1.1	-4.0
	NPV	91.0	-5815.9	-14294.3	-5972.6	-16282.3

(1) NPV is in millions of dollars and IRR is percent return.

The level of return achieved is very high and suggests that there is a strong case in financial terms for the development of a high speed rail system in the Southern Corridor rather than the Northern Corridor. The highest financial return is obtained by the 125 mph option, the lowest by the 300 mph option which is marginal even with public (municipal bond) financing.

The economic impacts of high speed rail were measured using the RENTS[(c)] model. Two sets of benefits were measured: benefits to current and future intercity travelers, referred to as consumer surplus, and benefits to communities along the route.

Results of Economic Analysis (Discount Rate 5% Real)[(1)]

	Southern Corridor			Northern Corridor	
	125 mph	185 mph	300 mph	185 mph	300 mph
Gross Consumer Surplus PV	1737.4	3091.3	4071.8	2532.3	3406.6
Net Consumer Surplus NPV	3004.8	3851.3	3190.7	2967.3	1662.0

[(1)] *Consumer surplus is in millions of 1989$.*

The consumer surplus analysis, which measures the improvement in travel times and costs for rail, air, auto and bus travelers, shows that the greatest benefit is achieved in the Southern Corridor. The Southern Corridor has economic benefits that are consistently higher than the Northern Corridor by approximately 20 percent. In terms of the technology options, the gross consumer surplus (which is appropriate for a private sector project and is directly correlated with train speed) gives a preferred order of 300 mph, 185 mph and 125 mph. For the net consumer surplus (which is appropriate for a public sector project for which the capital costs have to be considered), the preferred order changes to 185 mph, 300 mph and 125 mph.

With respect to community benefits, a high speed rail project would provide $8 to $10 billion of benefits to the corridor. While the level of benefits provided by each technology is substantial, the 300 mph technology benefits are marginally higher than those for the 185 mph and 125 mph options.

SENSITIVITY ANALYSIS

To test the strength of the findings of the financial analysis, a series of sensitivity tests were conducted for the Southern Corridor on the impact of economic change, energy prices, traffic congestion, and the potential competitive response of the air and bus industries. The sensitivity tests for the 125 mph, 185 mph and 300 mph technology options were made using the 7½ percent (municipal) bonding finance option and, unless otherwise stated, the central case economic scenario.

Sensitivity Analysis for Southern Corridor[1]

	125 mph		185 mph		300 mph	
	NPV	IRR	NPV	IRR	NPV	IRR
Base Case	2388.0	19.7	1714.9	11.8	-666.4	8.3
Lower Economic Growth	1928.2	18.5	1004.2	10.7	-1561.2	7.4
Higher Economic Growth	3402.2	22.7	3191.6	13.6	1124.8	10.0
Increased Energy Costs (+50 percent)	2623.1	20.6	2131.0	12.4	-122.6	8.9
Increased Congestion (+50 percent)	4904.7	28.3	6552.4	17.8	5478.4	13.6
Increased Air Competition (Fares -20 percent)	2076.9	18.5	1222.8	11.0	-1777.1	7.6
Increased Bus Competition (Frequency +30 percent, Fares -30 percent)	2146.5	18.8	—	—	—	—
Half VOT's	1681.0	17.5	1272.0	11.1	-762.9	8.2

[1] *NPV is in millions of dollars and IRR is percent return.*

Overall, the sensitivity analysis suggests that the impact of changes in the economy, energy prices, congestion, and air and bus competition would have little effect on the financial case for proceeding with an investment in high speed rail. The most significant factor was the effect of congestion, which dramatically strengthens the already strong case for high speed rail investment.

Conclusions and Recommendations

This Tri-State Study of High Speed Rail Service has shown that the Chicago-Milwaukee-Twin Cities Corridor appears very promising in terms of ridership, revenues, and financial and economic benefits that high speed rail could generate. The market is a combination of the short-distance, almost intra-urban Chicago-Milwaukee market and the long-distance Chicago/Milwaukee-Twin Cities market. Together, the two markets offer a significant potential for high speed rail.

The evaluation of the corridors and technologies studied suggest that:

- In environmental, economic and financial terms, the Southern Corridor is preferred to the Northern Corridor.

- In purely financial terms, the preferred ordering of the technology options is 125 mph, 185 mph and 300 mph.

- The preferred ordering of the technology options in economic terms depends on the source and availability of capital and is as follows:

  - For a private investment, 300 mph, 185 mph, 125 mph.
  - For a public investment, 185 mph, 300 mph, 125 mph.
  - For a public capital-constrained investment, 125 mph, 185 mph and 300 mph.

- From an environmental perspective, the use of existing rights-of-way (as in the 125 mph Amtrak upgrade) is clearly preferred over the development of new rights-of-way (as needed for the 185 mph and 300 mph technology options).

The Tri-State Study has been undertaken using existing travel data, existing operating and capital unit costs, and a generic approach to technology, operating concepts, infrastructure, financing and environmental concerns. A more detailed and comprehensive feasibility study of the Southern Corridor is now required to identify a preferred approach to high speed rail. The Consultant Team recommends that the following be included in this feasibility study:

- Collection of a specific and comprehensive origin-destination data set.

- A full-scale technology appraisal which would include an evaluation of the newly introduced Swedish Railroad "tilt" technology option that was not included in this study and a review of the time scales and practicality of implementing a maglev system. (It seems possible that the "tilt" technology could produce better financial returns than the 125 mph option, with nearly the same economic benefits as the 185 mph technology option and with only marginally more environmental problems than the 125 mph option.)

- A detailed engineering and environmental analysis that would evaluate routes, crossings, infrastructure needs, and environmental concerns and issues in greater depth.

- A comprehensive financial and economic analysis including a full financing assessment.

- An implementation plan and program for proceeding beyond the feasibility study work.