TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/RD-85/14+418-1F		

4. Title and Subtitle	5. Report Date
Use of Existing Highway Right-of-Way for High Speed Rail Transportation	February 1985
	6. Performing Organization Code
7. Author(s) Richard L. Peterson, Harry Petersen, Robert Q. Brackett, and Carlos Bonilla.	8. Performing Organization Report No. Research Report 418-1F
9. Performing Organization Name and Address Texas Transportation Institute The Texas A&M University System College Station, Texas 77843	10. Work Unit No.
	11. Contract or Grant No. Study No. 2-10-84-418
12. Sponsoring Agency Name and Address Texas State Dept. of Highways and Public Transportation; Transportation Planning Division P. O. Box 5051 Austin, Texas 78763	13. Type of Report and Period Covered Final - September 1983 February 1985
	14. Sponsoring Agency Code

15. Supplementary Notes
Research performed in cooperation with DOT, FHWA.
Research Study Title: Use of Existing Highway Right-of-Way for Other Transportation Services

16. Abstract

This study investigates the feasibility of using Interstate freeway rights-of-way for High Speed Rail (HRS) passenger service in the State of Texas. The Texas Triangle project is a proposed HSR system connecting the urbanized areas of San Antonio, Fort Worth/Dallas and Houston; a total distance of some 750 miles. The primary data bases used in the study consisted of: 1) a survey of U. S. and foreign HSR systems and proposals; 2) an inventory of the Interstate freeway characteristics serving the Texas Triangle; and, 3) performance and operating characteristics of a range of HSR technologies. Given the freeway geometrics and the operating capabilities of the different HSR systems, the various technologies were superimposed upon the highway rights-of-way to determine travel speeds and times achievable by the trains. Results of the study indicate that, in general it is physically possible to construct and operate HSR service within the existing Interstate right-of-way. Travel times between the downtown areas of the involved urban areas for certain HSR technologies are less than for airline travel. To determine the financial feasibility of HSR in the Texas Triangle, ridership estimates would need to be determined. Ridership projections, however, were not included as part of this feasibility study.

More KEY Words: Transportation Planning, AMTRAK, Mode Change Facilities, Park-and-Ride, Park-and-Pool, Mass Transportation.

17. Key Words	18. Distribution Statement
High Speed Rail, Trains, Maglev, TGV, Bullet Train, Texas Triangle, Transit, Public Transportation, Highway Right-of-Way, Rail Passenger Service, Intercity Transport, Railroads (ABOVE)	No restrictions. This document is available to the public through the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified		

Form DOT F 1700.7 (8-69)

USE OF EXISTING HIGHWAY
RIGHT-OF-WAY FOR HIGH SPEED RAIL TRANSPORTATION

By:

Richard L. Peterson
Study Supervisor

Carlos R. Bonilla
Assistant Research Engineer

Harry C. Petersen
Engineering Research Associate

and

Robert Quinn Brackett
Assistant Research Specialist

Research Report 418-1F
Study Number 2-10-84-418

Sponsored by
State Department of Highways and Public Transportation
in cooperation with
The U.S. Department of Transportation
Federal Highway Administration

Texas Transportation Institute
The Texas A&M University System
College Station, Texas 77843

February 1985

ACKNOWLEDGEMENTS

The authors wish to express their sincere appreciation to the many individuals, public agencies and private companies who participated in this study effort. To extend recognition to all of the persons who contributed help and information would be impractical. However, special appreciation is extended to Don Dial, Herman Haenel and Phil Wilson of the State Department of Highways and Public Transportation for their guidance and assistance throughout the study. In addition, the individuals, companies and agencies listed in the Bibliography Section of this report contributed significantly in the accomplishment of the research objectives.

ABSTRACT

This study investigates the feasibility of using Interstate freeway rights-of-way for High Speed Rail (HRS) passenger service in the State of Texas. The Texas Triangle project is a proposed HSR system connecting the urbanized areas of San Antonio, Fort Worth/Dallas and Houston; a total distance of some 750 miles. The primary data bases used in the study consisted of: 1) a survey of U.S. and foreign HSR systems and proposals; 2) an inventory of the Interstate freeway characteristics serving the Texas Triangle; and, 3) performance and operating characteristics of a range of HSR technologies. Given the freeway geometrics and the operating capabilities of the different HSR systems, the various technologies were superimposed upon the highway rights-of-way to determine travel speeds and times achievable by the trains. Results of the study indicate that, in general, it is physically possible to construct and operate HSR service within the existing Interstate right-of-way. Travel times between the downtown areas of the involved urban areas for certain HSR technologies are less than for airline travel. To determine the financial feasibility of HSR in the Texas Triangle, ridership estimates would need to be determined. Ridership projections, however, were not included as part of this feasibility study.

Key Words: High Speed Rail, Trains, MagLev, TGV, Bullet Train, Texas Triangle, Transit, Public Transportation, Highway Right-of-Way, Rail Passenger Service, Intercity Transport, Railroads, Transportation Planning, AMTRAK, Mode Change Facilities, Park-and-Ride, Park-and-Pool, Mass Transportation.

SUMMARY

Purpose

The goal of this study was to determine the feasibility of using existing highway rights-of-way for rail passenger services between major urban areas within the State of Texas. The work undertaken was intended to satisfy the following objectives:

- To survey U.S. and foreign rail projects which utilize highway rights-of-way;
- To investigate institutional, jurisdictional, economic and legal considerations;
- To assess construction and operational considerations; and,
- To assess the feasibility and potential of utilizing existing highway rights-of-way for intercity rail passenger transportation.

The intent of the study was to determine the physical practicality of implementing high speed rail passenger service on existing highways in the "Texas Triangle" corridors (San Antonio to Houston, Houston to Dallas/Fort Worth, and Dallas/Fort Worth to San Antonio). This research does not include an investigation of market potential or a detailed analysis of the financial feasibility of implementing and operating high speed rail service.

High Speed Rail (HSR) passenger service has been proposed in numerous travel corridors throughout the United States. Over 4800 miles of HSR is suggested for 16 projects detailed in the "Survey" section of the report. This represents, in capital costs alone, some $34 billion if an average construction cost of $7 million per mile were assumed. The length of the proposed systems range from some 300 miles for the Philadelphia to Atlantic City corridor to approximately 750 miles for the proposed Texas Triangle project. The State of Florida is considering a long-range plan for HSR service consisting of some 1200 route miles. High Speed Rail proposals, if

implemented, would constitute one of the nation's larger transportation undertakings in recent years.

The Texas Triangle

The Texas Triangle is connected by a modern system on Interstate facilities composed of both rural and urban freeway segments. Some 730 miles of the Interstate highways, as shown in Table S-1, were surveyed and included in this study. Figure S-1 presents the major urban areas and transportation facilities of the Triangle.

TABLE S-1: INTERSTATE HIGHWAY FACILITIES CONNECTING THE TEXAS TRIANGLE

Interstate Highway(s)	Connecting	Mileage	Survey Limits
IH-10	Houston and San Antonio	198.4	I-45 to I-35
IH-35 & IH-35W	San Antonio and Fort Worth	266.7	I-10 to I-30
IH-30	Fort Worth and Dallas	32.3	I-35W to I-45
IH-45	Dallas and Houston	233.1	I-30 to I-10

The following six SMSA regions with their 1980 populations are contained within the Triangle:

- San Antonio SMSA (Population - 1,071,954);
- Houston SMSA (Population - 2,905,350);
- Dallas/Fort Worth SMSA (Population - 2,934,878);
- Waco SMSA (Population - 170,755);
- Killeen/Temple SMSA (Population - 214,656); and,
- Austin SMSA (Population - 536,450).

The total 1980 population of the involved SMSA's is 7.9 million which represent approximately 55% of the State's 14.2 million residents. The growing population and growing economy give Texas an increasing importance in

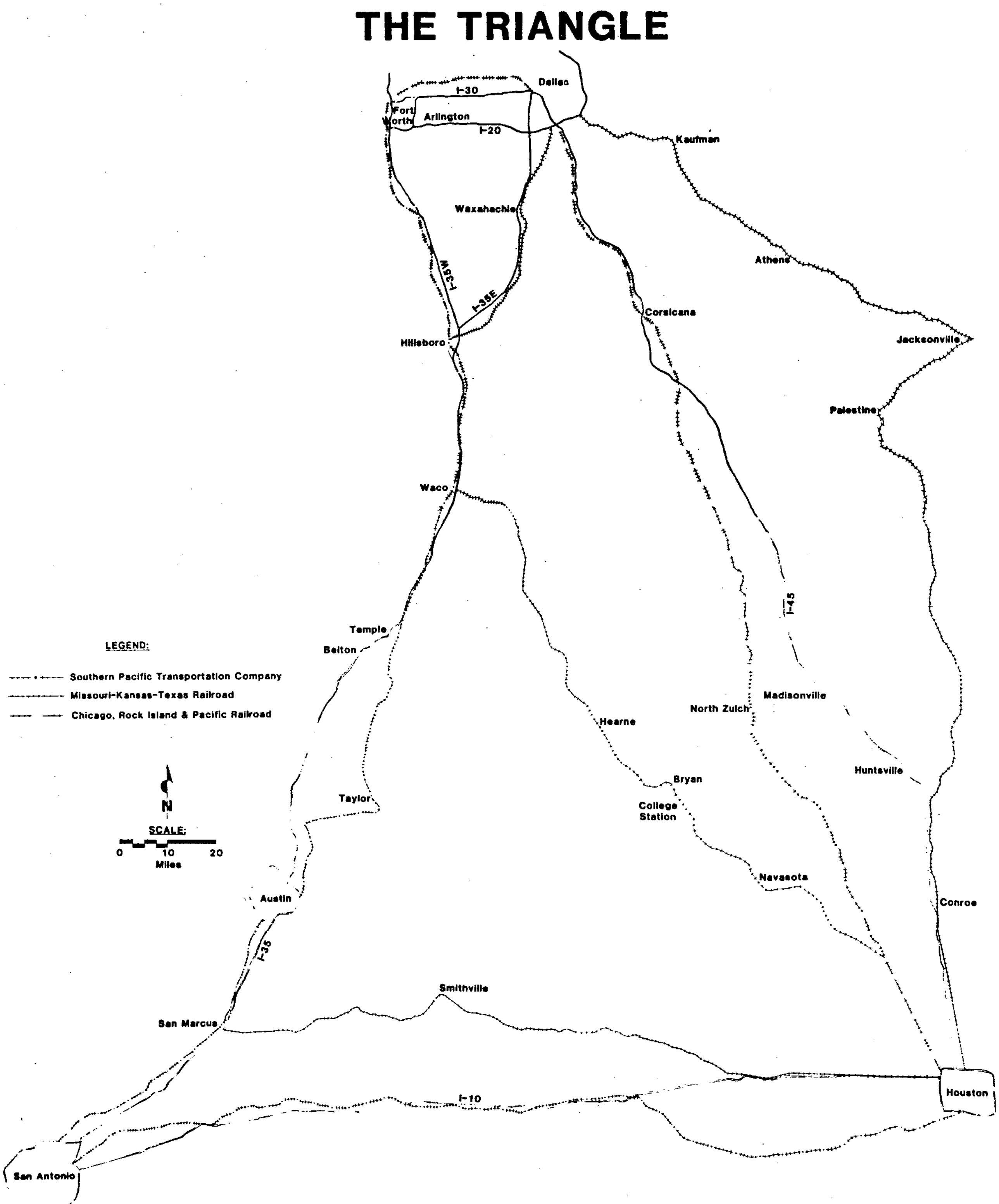


Figure S-1. The Proposed Texas Triangle Connecting Houston, San Antonio and Fort Worth/Dallas the national and world economies. The population of the Texas Triangle is expected to increase some 39% to 11 million people by 1990, and to 15 million by the year 2000 (an increase of 90%). By 2020, it is estimated that there will be 20 million people in the Triangle out of a total State population of 30 million.

A vast majority of the 730 miles of surveyed Interstate freeways connecting the urban areas of the Texas Triangle are located in rural areas similar to that shown in Figure S-2. With the exception of those freeways within or near an urbanized area, the Interstate facilities have a 4-lane cross section, or 2-lanes in each direction, divided by a grassy median of variable width. Over 80% of the Interstate mileage has a 4-lane cross section with a typical clear median space of 36 feet or more. In certain locations, the freeway cross section also includes parallel frontage roads outside of the main travel lanes.

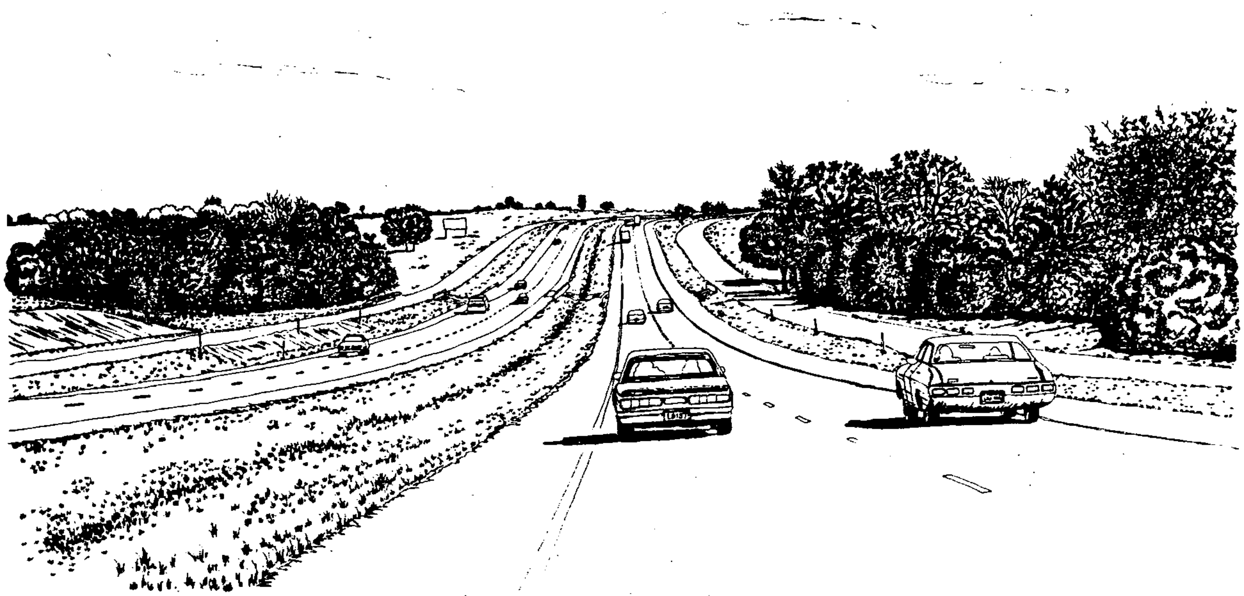


Figure S-2: Typical Rural Texas Freeway with Median and Frontage Roads.

The investigation included a physical features survey of the five involved Interstate highways. Major structures (i.e., bridges and overpasses), transmission power lines and horizontal curves greater than 0.5 degrees were recorded and referenced by mile post and county line. A summary of these physical features is presented in Table S-2. At least one of these potential obstructions can be expected, on the average, every 0.6 mile along the 730 mile route.

TABLE S-2: INTERSTATE FREEWAY CHARACTERISTIC FOR THE TEXAS TRIANGLE

Freeway	Miles	Percent of Triangle	Average Distance (Miles) Between Observed:				
			Bridges	Overpasses	Transmission Lines[1]	Horizontal Curves[2]	Features[3]
IH-10	198.4	27.2	1.6	2.5	11.0	2.7	0.7
IH-35	216.3	29.6	1.9	1.9	8.7	2.1	0.6
IH-35W	50.4	6.9	2.3	1.6	5.6	2.3	0.6
IH-30	32.3	4.4	1.4	1.0	10.8	1.0	0.4
IH-45	233.2	31.9	2.1	2.9	9.7	2.1	0.8
Totals	730.6	100.0	1.8	2.2	9.2	2.1	0.6

Note: 1. Only major power transmission lines considered.
2. Horizontal curves of 0.5 degrees or more recorded.
3. Features included all observed bridges, overpasses, transmission lines and curves.

Other Factors and Considerations

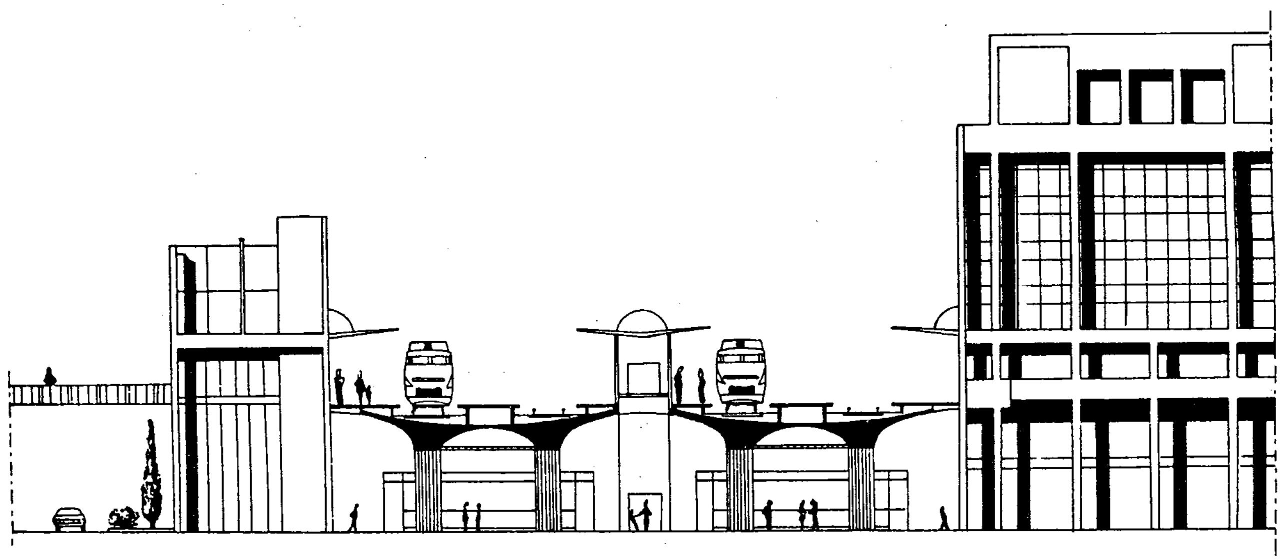
In addition to "technical" considerations of implementing a High Speed Rail (HSR) service within the Triangle, numerous other factors were investigated in order to determine the practicality of building such a system. A section of the report discusses many related issues which must be addressed.

High Speed Rail system in the State of Texas? What, if any, role would AMTRAK play in HSR service? If the HSR alignment follows both highway and railroad rights-of-way, which governmental agencies will be involved and with what responsibilities? To what extent do opportunities exist for public/private cooperation in HSR ventures for Texas?

The State Department of Highways and Public Transportation (SDHPT) is responsible for planning, designing, operating and maintaining the Texas highway system. In the case of Interstate highways, SDHPT closely coordinated their activities with the Federal Highway Administration (FHWA) and, if public transit is involved, the Urban Mass Transportation Administration (UMTA). The Texas Railroad Commission is responsible for intercity rate regulation of motor buses and freight railroads. The Commission works closely with the Interstate Commerce Commission (ICC) in its regulatory role and with the Federal Railroad Administration (FRA) regarding planning activities and track standards. If HSR service is implemented on portions of railroad rights-of-way, the Commission will obviously be involved. However, it is unclear as to what role the Commission would play in rate setting for a HSR system built upon highway right-of-way. The Texas State Legislature will need to address these and other questions if HSR service is to become a reality in the Texas Triangle.

Local governments (i.e., cities, counties, MPO's, COG's, transit authorities) must be brought into the early phases of HSR planning if such a service is to be a success. Convenient and accessible stations must be provided close to the major traffic generation points in the Central Business District's (CBD's) and other activity centers. Ridership projections should be performed in concert with local knowledge of new or planned developments in the urban areas. Mode-change facilities and transit services should be an intregal part of planning access to and from a HSR system. The HSR guideway and stations could significantly impact other planned developments in an urban area. Route alignments and station location as well as design should be determined in close coordination with the affected local entities. Elevated stations, like shown in Figure S-3, could severly impact an urban area if not incorporated in the overall development plans.

**ELEVATED DOWNTOWN STATION
POSSIBLE CROSS SECTION**

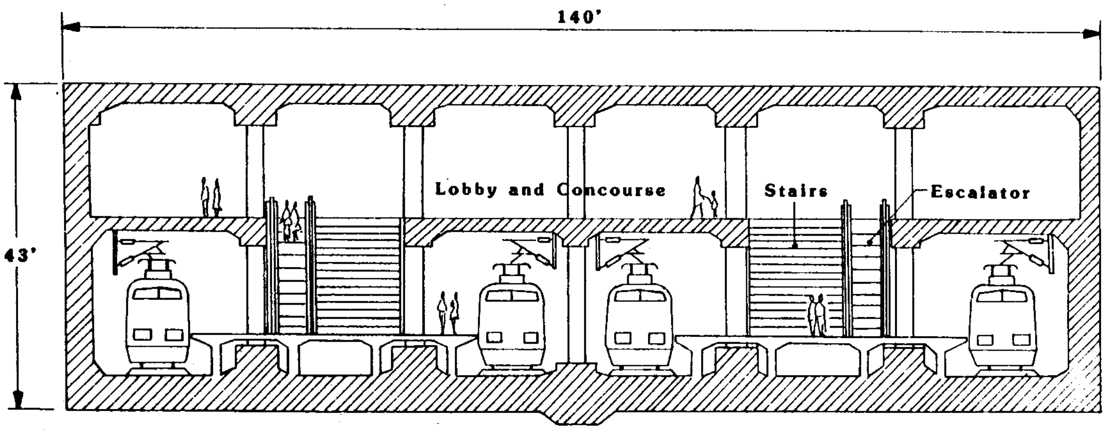


**Source:
The TGV Company,
Very High Speed Rail
Proposal for Florida,
December 1983.**

Figure S-3. Elevated HSR Station Impacting an Urban Area

Local governments and planning bodies in the State of Texas are active in trying to meet the needs of their respective areas. Texas cities are experiencing rapid growth and development which places a strain on the infrastructure including the transportation facilities. An underground HSR interface with the CBD may be more desirable than an elevated interface. Figure

S-4 shows an artist's rendering of an underground HSR station. Whoever is the lead agency or company for planning HSR in Texas, full and complete coordination with the affected local entities can not be overemphasized.



TYPICAL CROSS SECTION OF UNDERGROUND STATION

SOURCE:
Preliminary Description of Proposed Los Angeles to San Diego High Speed Rail Project, American High Speed Rail Corporation, August 1983

Figure S-4. An Alternative to the Elevated HSR Station Concept

If Interstate right-of-way is used for HSR passenger service, several federal laws and implementing regulations apply. These laws and regulations are outlined within the report section entitled "Factors and Considerations of Implementing HSR Services". The SDHPT will need to be closely involved in the planning of any HSR system which contemplates using highway right-of-way and will need to coordinate such planning with the Federal Highway Administrator, U.S. Department of Transportation. The FHWA Administrator has the discretion to consider or not to consider an application for such non-highway use of rights-of-way.

Other factors associated with HSR implementation should be addressed during the 3-C planning process. These include public support, energy requirements, regional mobility, airport congestion, tourism and development/ land use impacts. Through cooperative, comprehensive and continuing (3-C) planning, participated in by all affected parties, many if not all of the issues can be successfully addressed.

Construction and Operation

Construction and operational considerations play a key role in determining the technical feasibility of implementing a HSR system on highway rights-of-way. The various institutional, jurisdictional, legal, etc., factors, previously highlighted, provide the basis for assessing the practical feasibility of building HSR on highway property. When all of the various considerations are viewed in the total context of the overall transportation system, a general assessment of the potential for HSR systems in the State of Texas can be made.

The design of HSR systems, as with other people transport modes, is dependent upon the human element or the passengers intended to be served by the system. The comfort of passengers is determined by the acceleration/ deceleration forces applied to the human body by the transport mechanism. Two forms of acceleration are of particular concern for HSR service: 1) linear; and, 2) radial. Linear forces result primarily from a train accelerating longitudinally to operating speed or slowing to a stop. Radial forces result as a train traverses vertical and horizontal curves in the track or guideway. Radial forces are controlled by the degree of curvature in concert with superelevation and/or vehicle tilting. Linear forces resulting from acceleration and deceleration of the vehicle have, in practice, been limited by passenger comfort considerations rather than by human tolerances.

In terms of high speed ground transportation in the range of 120 MPH to 350 MPH, the maximum acceleration allowed is also limited by the propulsion system and hardware technologies.

The French and Japanese systems define High Speed in the 150 MPH to 200 MPH range whereas the new MagLev Technologies may approach 350 MPH. Operating performance (i.e., maximum acceleration rates) varies with the type of propulsion used and the technology being considered. A range of HSR technologies, from 120 MPH AMTRAK service to 350 MPH advanced systems, were identified along with their performance characteristics for potential implemenation on freeway rights-of-way within the Texas Triangle.

The performance of HSR technologies was combined with the track geometrics determined by the existing freeway facilities. A total of eight different systems were analyzed for possible implementation on highway rights-of-way in the Triangle. These eight systems along with their performance characteristics are shown in Table S-3.

The eight rail technologies were "superimposed" upon the highway geometrics to determine operating speeds achievable and required travel time on the various Interstate freeway corridors. Performance of each HSR technology in combination with travel distances and horizontal curvatures of the involved freeways were the key components of the employed simulation anaylsis. Figure S-5 illustrates a fundamental principal employed in the investigation. The maximum velocity of a train varies with the particular technology but also is dependent upon horizontal curves along the freeway alignment and predetermined station stops. The simulation assumed the role of the "control center" and supervised the operation of the train through a given corridor. As revealed in the simulation analysis, some difficulty in maintaining maximum train velocity can be expected if the HSR alignment is confined to

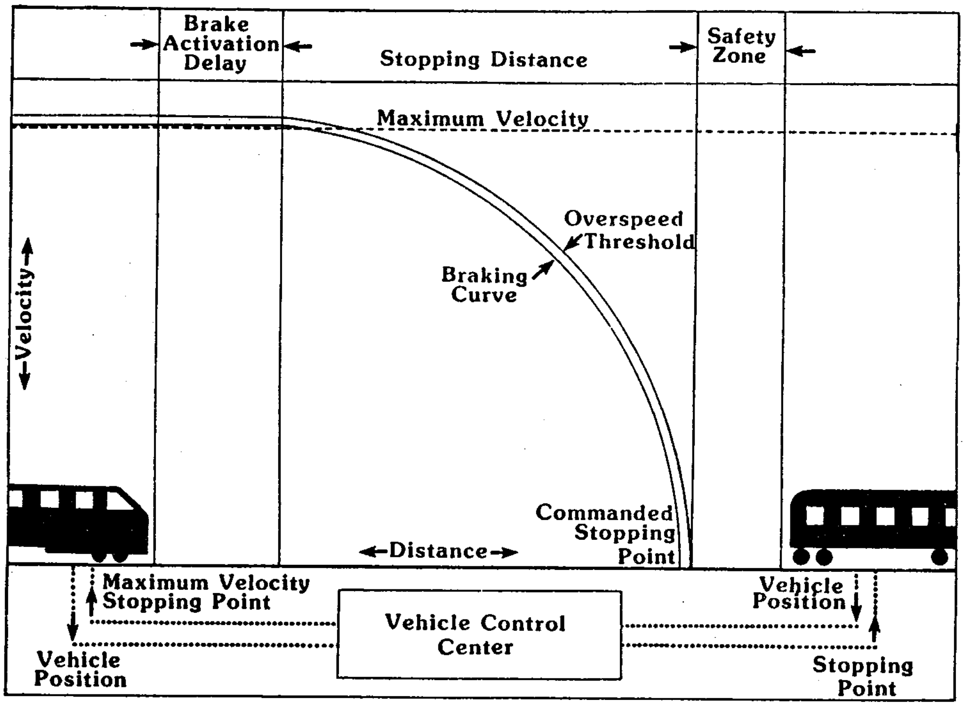
TABLE S-3: HSR SYSTEMS INVESTIGATED FOR THE TEXAS TRIANGLE

System	Maximum Speed (MPH)	Total Superelevation allowed*	Acceleration in MPH per Seconds*							Deceleration in MPH/Sec.	Remarks
			0 to 50	50 to 100	100 to 150	150 to 200	200 to 250	250 to 300	300 +		
#1	120	12 inches	1.8	0.5	0.2	NA	NA	NA	NA	-2.0	AMTRAK
#2	200	12 inches	2.5	1.6	1.1	0.5	NA	NA	NA	-2.0	HSR (i.e., TGV or Bullet)
#3	200	18 inches	2.5	1.6	1.1	0.5	NA	NA	NA	-2.0	HSR w/Tilt Mechanism
#4	200	18 inches	3.0	3.0	2.0	2.0	NA	NA	NA	-3.0	HSR (Ideal Prototype)
#5	350	18 inches	3.0	3.0	2.0	2.0	1.0	1.0	0.5	-3.0	HSR (Ideal Prototype)
#6	200	24 inches	3.0	3.0	2.0	2.0	NA	NA	NA	-3.0	HSR (Ideal Prototype)
#7	350	24 inches	3.0	3.0	2.0	2.0	1.0	1.0	0.5	-3.0	HSR (Ideal Prototype)
#8	350	36 inches	7.0	7.0	7.0	7.0	7.0	7.0	7.0	-7.5	HSR (Ultra Prototype)

*NOTE: 1. Total Superelevation includes track superelevation, unbalanced superelevation, and vehicle tilt capabilities.

2. Acceleration rates vary as a function of speed.

BRAKING PROFILE: TYPICAL CONTROL



SOURCE:
ITT, The SELTRAC System of Automatic Train Control, Ontario, Canada, May 1984.

Figure S-5. Simplified Illustration of the HSR Simulation Analysis

TABLE S-4: SIMULATED TRAVEL TIMES FOR THE TEXAS TRIANGLE BY HSR SYSTEM (MINUTES)

System:	Max Speed (mph)	Super-elevation (Inches)	Travel Corridor				Total Triangle
			IH-10	IH-35/35W	IH-30	IH-45	
#1	120	12	111	131	18	130	390
#2	200	12	78	97	14	94	283
#3	200	18	73	87	12	86	258
#4	200	18	69	68	12	82	249
#5	350	18	59	79	11	74	223
#6	200	24	67	81	11	80	239
#7	350	24	55	70	10	69	204
#8	350	36	NA	NA	NA	53	NA

existing freeway right-of-way and geometrics. Results of the investigation are included in Table S-4 for the eight HSR systems investigated.

Travel time required for the entire triangle, excluding station dwell time, ranged from 204 minutes (3.4 hours) to 390 minutes (6.5 hours) for seven simulated HSR systems. The eighth system was simulated for only IH-45 or the Dallas to Houston corridor. The total time required to travel the triangle by HSR is one-fourth to one-half of the time required by an automobile (approximately 13.7 hours).

Air travel between Dallas and Houston, including access and boarding times, requires some 140 minutes (2.3 hours) from CBD to CBD under favorable conditions. All of the HSR technologies, except the 120 MPH AMTRAK system, simulated on the IH-45 freeway right-of-way provide faster service than the airlines (15 minute station access time was assumed for HSR service). The CBD to CBD travel time by HSR operating in the 200 MPH to 350 MPH range, including station access times, requires in the range of 68 minutes (1.1 hours) to 109 minutes (1.8 hours). The Dallas to Houston trip by HSR operating within the freeway median could be approximately 1.3 to 2.1 times as fast as airline travel; a time savings of some 31 to 72 minutes.

HSR service can be implemented with adequate planning and design. Highway rights-of-way could be a viable alignment alternative provided that sufficient median and/or outside width exists for the proposed system. Some problems, however, can be expected in urban areas when attempting to place a HSR system on highway property or when interfacing the service to the core of the Central Business District (CBD). In some cases, such as in Houston, the freeway medians have been dedicated to other people movement facilities (i.e., HOV Lanes) and would not be practical alignments for a HSR system.

If 24 feet of median width exists in an urban area, an elevated two directional HSR system could be implemented. Figure S-6 illustrates one concept of constructing an elevated HSR guideway within a typical urban freeway median. Given the freeway cross section shown, the inside shoulders would be eliminated if no adjustments were made to the mainlines. It may be possible, through proper engineering, to narrow the single pier support to 6 or 8 feet in order to maintain the inside freeway shoulders. However, if a median of 58 feet were available then either an at-grade or elevated 2-way HSR system could be implemented with minimum disruption to the existing freeway configuration.

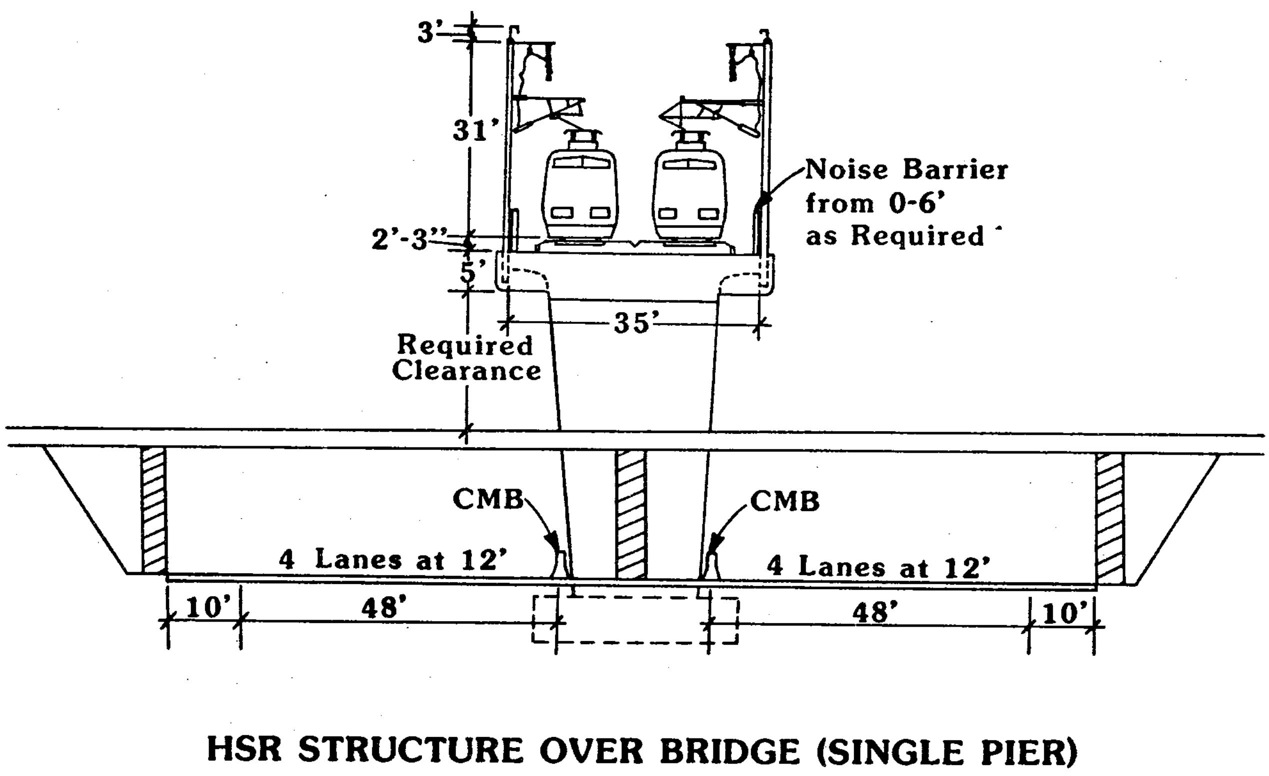
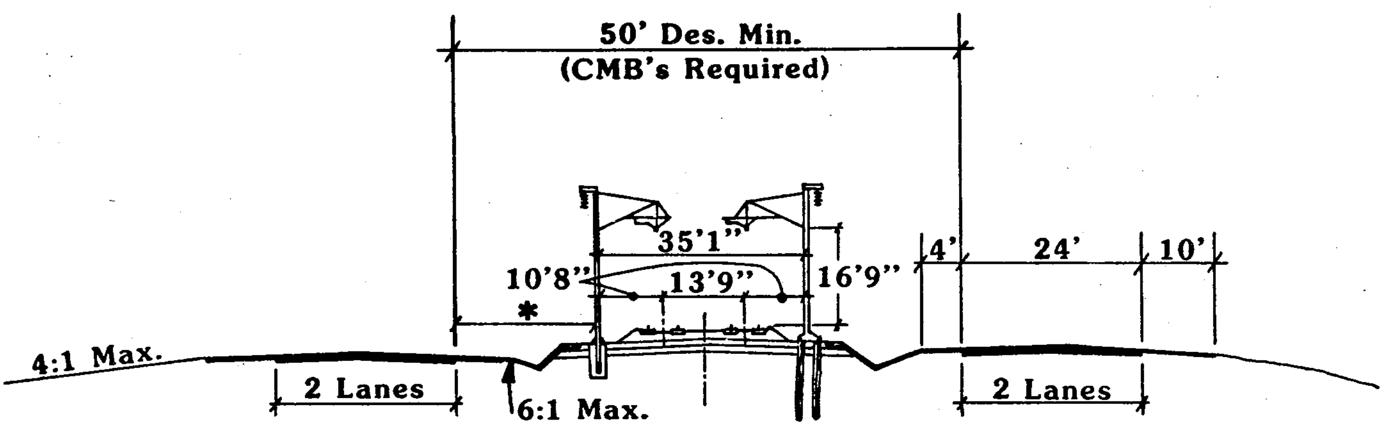


Figure S-6. Concept of an Elevated HSR System on a Single Pier Within the Median of an Urban Freeway

If a rural freeway is fairly straight and has a relatively wide median then a HSR system could be implemented at-grade between the traveled lanes as shown in Figure S-7. Medians of 96 feet or wider would provide sufficient clearance to maintain the 30 foot clear zone for a 2-way system. However, considering safety, noise and visual impacts, it may be desirable to construct Concrete Median Barriers (CMB's) to shield the High Speed trains from adjacent traffic. At-grade construction with appropriate protective devices on tangent sections of freeway is feasible if the median is some 50 feet or greater in width. An at-grade HSR system will, however, preclude any crossovers between the different directions of freeway travel; in essence, an undesirable access restriction to enforcement and emergency vehicles unless special treatment (i.e., tunnels) is provided at selective locations.

AT-GRADE HSR IN FREEWAY MEDIAN



NOTE:
1. **CMB's May Be Desirable for Safety, Noise and Visual Reasons.**
2. **Medians 96' and Wider Provide Required 30' Clearances.**

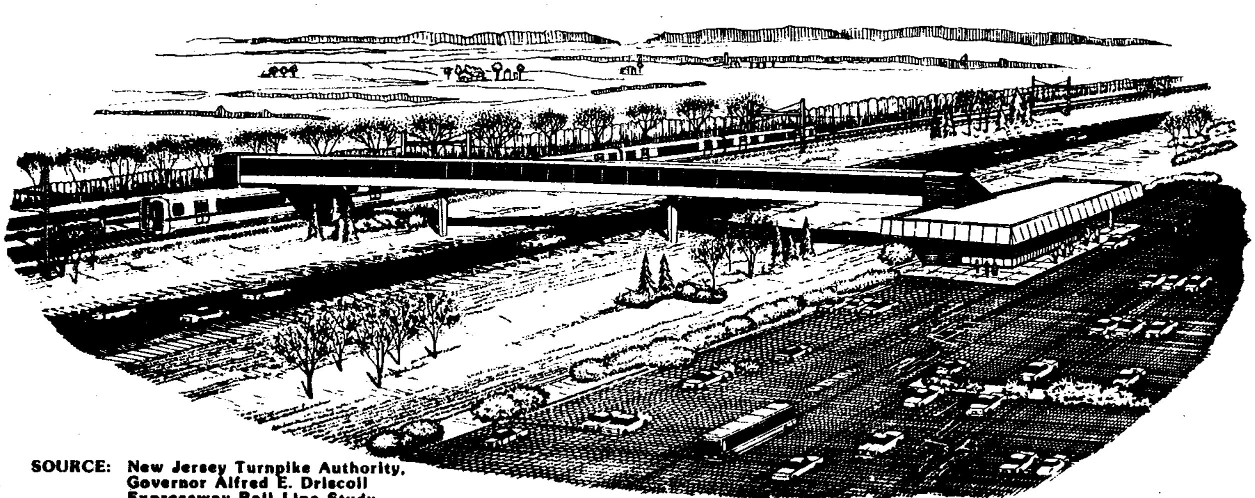
*** Provide Protection Where Clearance <30'**

Figure S-7. Concept of an At-Grade HSR System Between Freeway Mainlanes

Due to the variable design requirements associated with the different HSR systems and geometric characteristics found at certain locations along the Interstate facilities, it may be necessary or desirable to elevate portions of the guideway. Reasons to deviate from the at-grade construction could include topographic features (i.e., rivers), narrow medians, horizontal or vertical curvatures, insufficient clearances and/or overpasses.

Given sufficient right-of-way, mode-change facilities could be constructed similar to the one shown in Figure S-8. The selection of access points along the Texas Triangle will require an in-depth analysis of potential ridership demands. It will be important, from an operational prospective, to minimize the number of stops along the various routes in order to maximize the running speeds. Unfortunately, an alignment following I-45 between Dallas and Houston will pass some 40 miles to the east of Bryan/College Station. Likewise, the route between Fort Worth and San Antonio along I-35 passes some 20 miles to the east of Killeen and Fort Hood. It may be possible with properly designed and placed mode-change facilities like the one suggested in Figure S-8, to attract a high percentage of the potential ridership market from areas not immediately adjacent the HSR alignment. It should be noted, however, that ridership analysis was outside the scope of this study.

MODE CHANGE FACILITY ADJACENT FREEWAY



SOURCE: New Jersey Turnpike Authority, Governor Alfred E. Driscoll Expressway Rail Line Study, October 1975.

Figure S-8. Conceptual Illustration of a Facility on and Adjacent to Freeway Right-of-Way

IMPLEMENTATION STATEMENT

This project is oriented toward assisting the State Department of Highways and Public Transportation (SDHPT) in the planning and evaluation of other than automobile use of highway rights-of-way. The study concentrates on the Interstate freeway system between San Antonio - Fort Worth/Dallas - Houston. A survey of geometric and physical features of the involved freeways provides the primary data base for the study; results of the survey are documented herein.

High Speed Rail (HSR) passenger service has been proposed for the State and is commonly referred to as the Texas Triangle project. This study investigates the technical and practical feasibility of implementing HSR service on the Interstate highways of Texas. The results of this research should assist the Department in evaluating any requests to use highway rights-of-way for such purpose. The findings documented herein should also be helpful in planning HSR systems on other rights-of-way if such systems are determined desirable and practical.

DISCLAIMER

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (CONT'D)

LIST OF FIGURES (CONT'D)

INTRODUCTION

High Speed Rail (HSR) passenger service has been proposed for major travel corridors throughout the United States and the world. One of the proposed systems is the 750 mile "Texas Triangle" which connects Fort Worth/ Dallas - Houston - San Antonio. Prior to this study, preliminary work in analyzing the feasibility of HSR in the State of Texas was performed by the private sector. These prior investigations by private interests have concentrated on existing, and potentially available, railroad rights-of-way. This study considers the feasibility of using highway rights-of-way for implementing HSR passenger services. Five Interstate freeways, which connect the urbanized areas of the Triangle, were surveyed for the physical and geometric features which would be relevant to implementing HSR within the right-of-way cross sections. A range of HSR technologies, extending from 120 MPH to 350 MPH operation, were superimposed upon the Interstate geometry to determine if the system could be constructed and, if so, their respective operating characteristics. This final report documents the study effort and presents the findings in the following four major sections:

- Survey of High Speed Rail Projects;
- Factors and Considerations of Implementing HSR Services;
- Construction and Operations Considerations of Implementing HSR Service; and,
- Feasibility and Potential of Implementing HSR on Highway Rights-of-Way.

The "Survey of HSR Projects" section summarizes the proposed systems being investigated or discussed in the United States and abroad. The "Factors and Considerations" section identifies and discusses related issues which should be investigated in planning HSR services. These issues are explored and presented in the following categories:

- Institutional and Jurisdictional Factors;
- Social and Economic Factors; and,
- Legal and Regulatory Factors.

Several topics are presented within the "Construction and Operational Considerations" section including human factors, train technologies, track geometrics and Interstate characteristics and features within the Triangle. Also presented in this section is an overview of the simulation analysis performed on the different highway corridors using different HSR systems and designs.

The last section, "Feasibility and Potential of Implementing HSR on Highway Rights-of-Way", discusses the technical and practical aspects of constructing HSR systems on rural and urban freeways. This section also indicates that to assess the potential for HSR in Texas, a thorough analysis of ridership must be performed. Ridership projections and the related economic analyses were beyond the scope of this study.

STUDY OBJECTIVES

The primary goal of this study was to determine the feasibility of using existing highway rights-of-way for rail passenger services between major urban areas within the State of Texas. The work undertaken by the research team was intended to satisfy the following general objectives:

- To identify, survey and assess U.S. and foreign rail projects which utilize highway rights-of-way between major urbanized areas;
- To identify, investigate and summarize the institutional, jurisdictional, economic and legal constraints, considerations and/or concerns associated with the joint use of highway facilities by rail systems;
- To identify and assess construction and operational considerations of high-capacity rail systems operating within existing highway rights-of-way both in major urban areas and between cities in rural areas; and,
- To assess the general feasibility and potential of utilizing existing highway rights-of-way for intercity rail passenger transportation within the State of Texas.

It should be recognized that the intent and direction of the study was toward assessing the physical practicality of implementing high speed rail passenger service on existing highways in Texas. This research does <u>not</u> include an investigation of market potential or a detailed analysis of the financial feasibility of implementing and operating high speed rail service within the Texas Triangle.

STUDY PROCEDURE

To accomplish the study objectives, the research team undertook a work program consisting of the following principal tasks:

1. Literature search and review;
2. Identification and survey of U.S. and foreign projects providing or considering high speed rail passenger service;
3. Identification of institutional, jurisdictional, operational, design, economic and legal considerations/ constraints/concerns;
4. Secondary and primary data collection;
5. Data analysis/synthesis; and,
6. Preparation of a final report documenting the study efforts.

Primarily through the literature search, the authors were able to identify both operational and proposed high speed rail projects throughout the world. Approximately 200 letters of inquiry were sent to individuals, public agencies and private companies to obtain more information on the various projects. In addition to asking about highway right-of-way use, these inquiries requested technical information on the rail technologies being applied or anticipated for application on the project.

An inventory of physical highway characteristics was performed on the interstate freeways within the Texas Triangle. Data was collected on 730 miles of the triangle composed of portions of the following five freeways:

I-45 (Dallas to Houston);
I-10 (Houston to San Antonio);
I-35 (San Antonio to Hillsboro);
I-35W (Hillsboro to Fort Worth); and,
I-30 (Fort Worth to Dallas).

Based upon the inventory of freeway geometrics and facilities, the research team "superimposed" a range of high speed rail technologies on the travel corridors to model or simulate train operations.

Results of these investigations along with the analysis of technical and practical considerations of implementing high speed rail service on the freeway rights-of-way are presented in subsequent sections of this final report.

LITERATURE SEARCH AND REVIEW

In an attempt to assemble and assess the current state-of-the-art for investigating, planning and implementing other transportation services on highway right-of-way, an extensive literature search was undertaken by the research team. Three primary sources were utilized in the literature investigation.

1. Texas A&M University's Automated Information Retrieval Service (AIRS).
2. Personal contact with transportation professionals engaged in operating or planning high speed rail passenger services.
3. Contact and survey of agencies, associations, institutes, organizations and companies familiar with, or knowledgeable of, the use of highway rights-of-way for public transit or other forms of transportation service.

The Automated Information Retrieval Service (AIRS), available to Texas Transportation Institute Staff, provides customized searches of published literature in over 150 indexes, abstracting services, and directories. Identification of relevant work is based on the occurrence of data elements, keywords, subject codes, author names, etc. The researcher creates a profile of the particular subject area being investigated and specifies the key words or terms used by AIRS in the literature search. The principal transportation and information directory used in the AIRS search for relevant railroad/transit data was the Transportation Research Information Service (TRIS).

Over 250 reports and publications were identified by AIRS which related to the joint or shared use of highway right-of-way for high speed rail passenger service. Abstracts of these published works were obtained and reviewed for possible utilization in this study. The applicable publications have been referenced herein where appropriate and are included in the Bibliography Section at the end of this report.

Relevant transportation rail planning data were provided by numerous transportation officials, agencies, companies and individuals. Reports, studies and documents were obtained from public agencies, private companies, and professional associations or societies. Some 200 individuals or companies were contacted and invited to provide input to the study effort.

Information gathered in this literature search identified numerous proposals for high speed rail passenger service. Various operating and design characteristics of different rail technologies, both operational and in the prototype stage, were assembled for their possible application on the proposed Texas Triangle. Results of this literature review are presented and referenced in subsequent sections of this report.

SURVEY OF HIGH SPEED RAIL PROJECTS

General

Considerable attention is being focused on high speed rail (HSR) passenger service both in the United States and abroad. The definition of HSR service varies considerably and ranges from 80 miles per hour for some suggested AMTRAK routes to 300 or 350 miles per hour for some of the newer technologies such as the MagLev Systems. Numerous proposals have been advanced by advocates of the different HSR technologies to implement modern rail passenger service in populated corridors which currently have, or are projected to have, sufficient travel demand to justify the system.

This section of the report summarizes some of the proposals for HSR service in addition to describing a few of the systems currently in operation. The three systems of HSR which are frequently discussed and publicized are: (1) The Japanese "Bullet Train"; (2) The French "TGV" (Train a' Grande Vitesse); and, (3) The German and Japanese "MagLev" Systems. These and other more conventional rail technologies are discussed in a subsequent section of this report in terms of their operational and design characteristics.

The HSR proposals or systems discussed herein are:

- The Texas Triangle
- Philadelphia - Atlantic City
- Northeast Corridor
- New York City - Montreal
- Florida
- Los Angeles - Las Vegas
- Los Angeles - San Diego
- Midwest U.S. (eight corridors)
- Washington State
- Rio Grande Corridor (New Mexico)
- France
- West Germany
- Great Britain
- Japan
- Sweden
- Canada

Proposed U.S. Systems

As shown in Figure 1, several travel corridors in the United States have been suggested as candidate alignments for HSR passenger service. Some of the corridors are in the early conceptual planning phase while others are being actively pursued and rigorously investigated. Based upon the available information, short summaries of the different HSR projects are presented herein.

The Texas Triangle

Figure 2 shows the proposed Texas Triangle which connects the following three major urbanized areas of the state:

1. Houston;
2. San Antonio; and,
3. Dallas/Fort Worth.

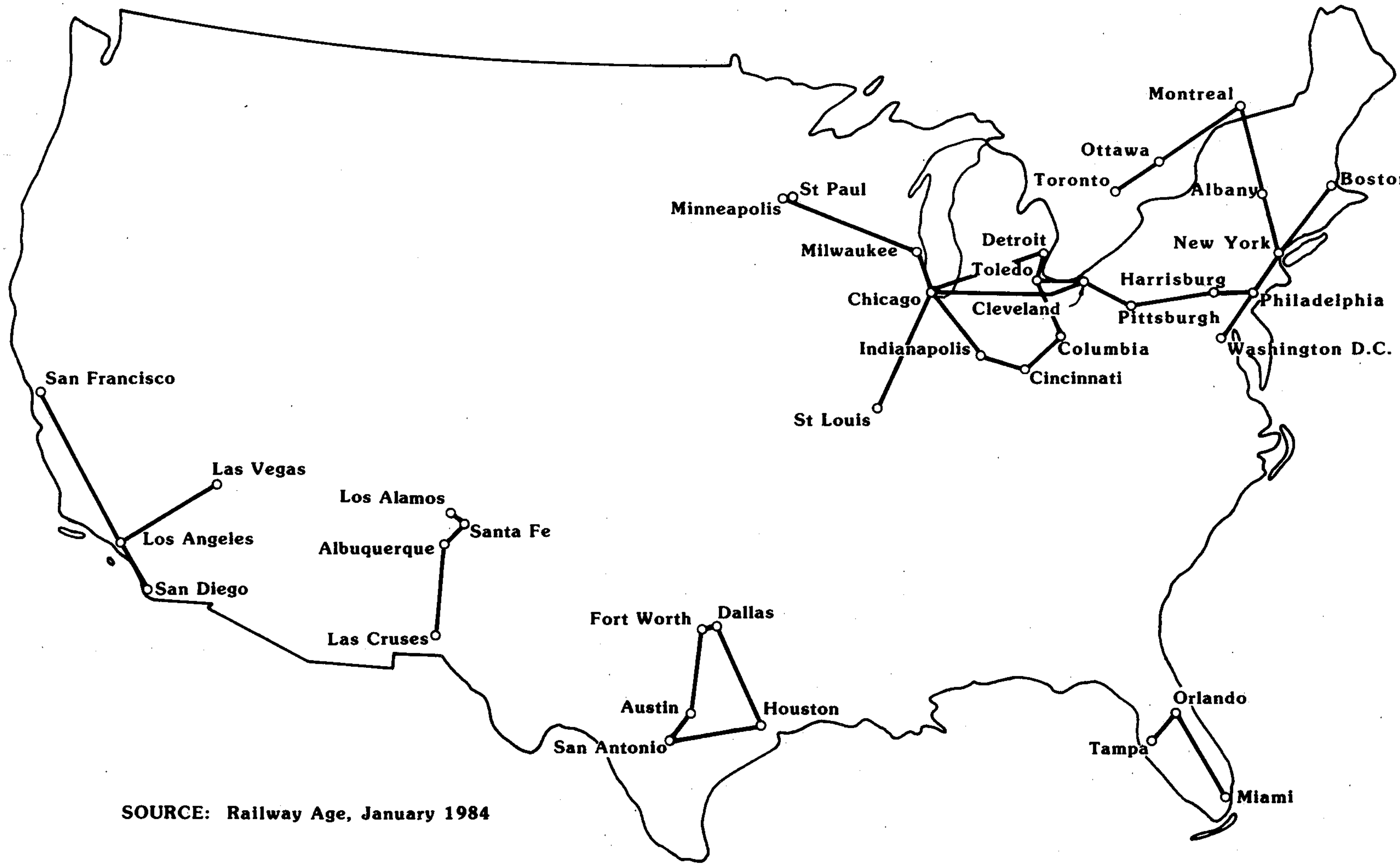
Both the Interstate Highways and the existing railroad alignments which serve the Triangle are shown in Figure 2. The major urbanized areas are currently connected by a transportation system composed of five Interstate Highways:

- I-10;
- I-35;
- I-35W;
- I-30; and,
- I-45.

In addition, a number of railroad companies have lines which currently connect the involved urban areas including: (1) Southern Pacific; (2) Missouri - Kansas - Texas; and, (3) Chicago, Rock Island and Pacific. Over 50% of the State's population is served by the transportation network within the Triangle.

The Texas Triangle, defined by Interstate highway routing, consists of over 750 roadway miles which connect the following eight major population centers:

Proposed High Speed Rail Systems



SOURCE: Railway Age, January 1984

Figure 1: Proposed HSR Systems In The United States

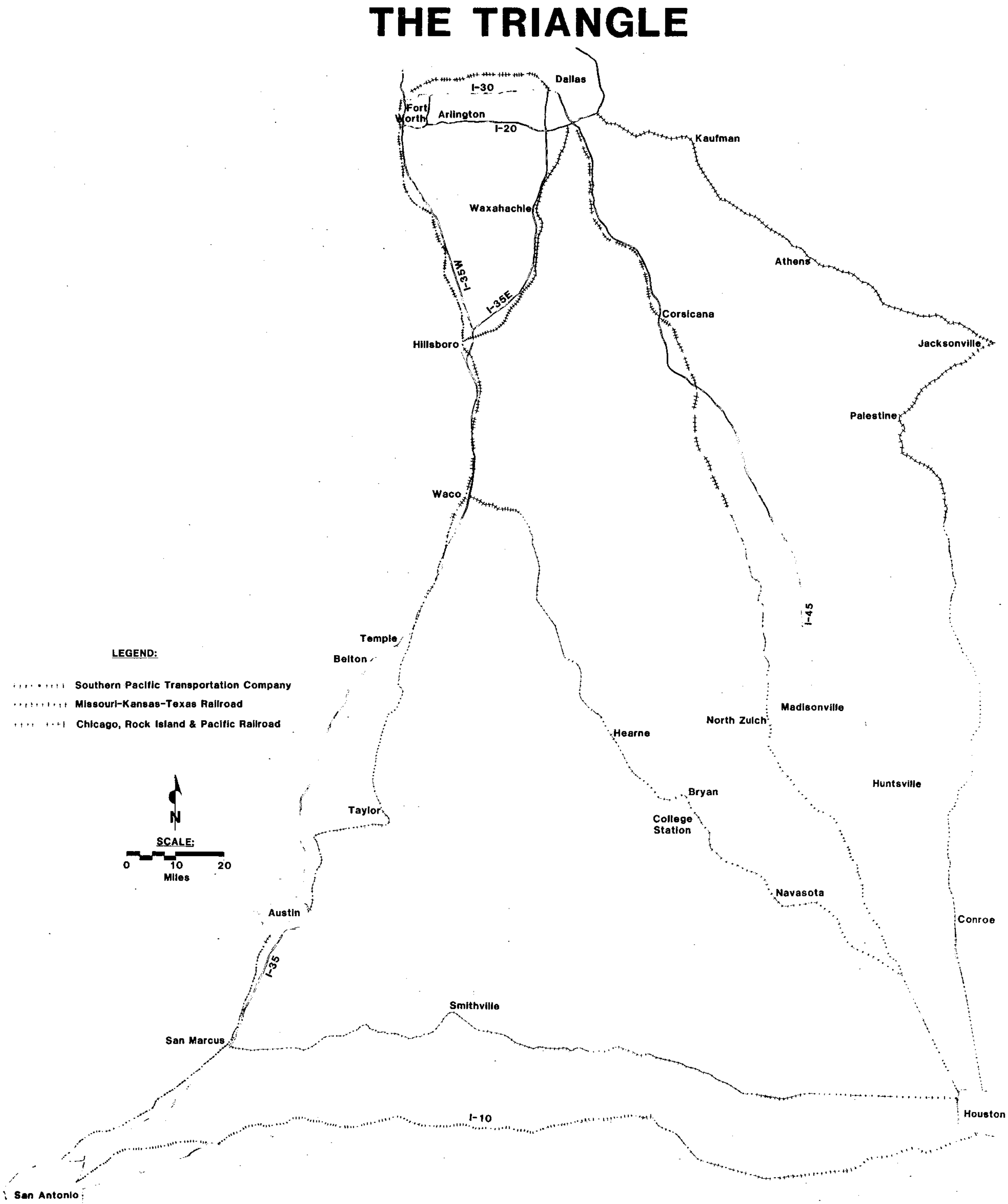


Figure 2. The Proposed Texas Triangle Connecting Houston, San Antonio And Fort Worth/Dallas

- San Antonio (Population - 785,410);
- Houston (Population - 1,594,086);
- Dallas (Population - 904,078);
- Arlington (Population - 160,123);
- Fort Worth (Population - 385,141);
- Waco (Population - 101,261);
- Killeen/Temple (Population - 88,779); and,
- Austin (Population - 345,496).

The populations shown above are for the incorporated areas based upon the 1980 U.S. Bureau of the Census count. The total population for the nine cities amounts to some 4.4 million; however, this only represents about 55% of the involved population within the six SMSA regions contained within the Triangle. The SMSA regions along with the 1980 Census data are:

- San Antonio SMSA (Population - 1,071,954);
- Houston SMSA (Population - 2,905,350);
- Dallas/Fort Worth SMSA (Population - 2,934,878);
- Waco SMSA (Population - 170,755);
- Killeen/Temple SMSA (Population - 214,656); and,
- Austin SMSA (Population - 536,450).

The 7.9 million total population of the involved SMSA's represents some 69% of all Texas SMSA regions and approximately 55% of the State's 14.2 million residents. Given the population growth rate being experienced by the urban areas of Texas, these figures can be considered very conservative.

The growing population and growing economy give Texas an increasing importance in the national and world economies. The population of the Texas Triangle is expected to increase some 39% to 11 million people by 1990, and 15 million by the year 2000 (an increase of 90%). By 2020, it is estimated that there will be 20 million people in the Texas Triangle out of a total state population of 30 million. Recent economic studies indicate that as much as 25% of the total research and development expenditures in the United States during this period will occur in the Texas Triangle region. The results of this population growth and economic activity are increased traffic congestion and energy use, which will restrict economic growth if not properly managed. Texas' intracity and intercity transportation systems are now almost entirely reliant on petroleum-dependent and energy-intensive highway and air transport in an increasingly congested system (Cooper, 1984).

The Texas Railroad Transportation Company (TRTC) was formed for the specific purpose of implementing a HSR passenger service between Houston and Dallas/Fort Worth and, eventually, throughout the Texas Triangle. TRTC signed a contract with the Trustees of the Rock Island Railroad to purchase half interest in the old joint Texas Division Rail Line between Houston and Dallas for $17.5 million dollars (approximately $73,000 per mile). This contract was extended by the Federal Bankruptcy Court in Chicago until December 31, 1984, with an additional escrow payment of $250,000. TRTC hired Parson, Brinckerhoff, Quade & Douglas to make initial market projections of ridership in the Houston-Dallas corridor. Results of this study indicate enough passenger ridership to generate sufficient revenues to make the project economically viable. These results were similar to earlier in-house estimates by TRTC of an initial year startup ridership of 5,000 to 10,000 passengers per day. Total passenger movements in the corridor are 25,000 to 40,000 passengers per day, with an approximate modal distribution of 70% of the total trips by automobile, 28% by aircraft, and 2% by bus (Cooper, 1984).

The International Engineering Company was hired by TRTC to conduct needed engineering feasibility studies, in conjunction with URS Engineers and the Interfield Engineering Company. Results of these studies should be available in 1984. The Arthur Anderson Company was hired to conduct the necessary economic and financial analyses. If all of these studies show positive results, it is TRTC's intention that the detailed engineering design will begin in 1984 with completion by mid-to-late 1985. Construction is estimated to begin in 1985 with operation to start between 1988 and 1990. The French TGV, German IC-E, Japanese Shinkansen and English HST high speed train technologies are being considered for this system, all of which operate on conventional railroad tracks. Negotiations are in varying stages with foreign manufacturers of each of these technologies (Cooper, 1984).

Operation of intercity passenger trains at speeds of up to 200 miles per hour is contemplated on separate parallel tracks with freight trains on common existing railroad rights-of-way. Initial studies of the suitability of the Houston-Dallas railroad right-of-way for high speed rail passenger service are being conducted for TRTC by engineers from the French National Railroads and the German Federal Railways. Preliminary results indicate no major technical problems with implementing such a service on this route although it will be necessary to provide for 200 grade separations with public roads and to allow for access to 100 industrial spur tracks and sidings. The total capital cost for all aspects of the Houston-Dallas project is estimated at 1.5 to 2.0 billion dollars (approximately $6.2 to $8.3 million per mile). The cost for installing high speed rail passenger lines along all three legs of the Texas Triangle is initially estimated at 4.5 to 5.0 billion dollars (some $6 to $7 million per mile). TRTC plans to finance the entire project from private sources without any direct grants of Federal or State governmental funds, with a possible exception being grade separation construction. It is expected by TRTC that debt financing through export credits, bonds and loans will provide 60 to 70 percent of the total financing required, with equity contributions providing 30 to 40 percent. It is further expected that additional business activities will be utilized to improve the economic viability of the project, including mail and express package hauling, conventional and intermodal freight services, fiberoptic telecommunications, electric power generation and transmission, commercial, industrial and residential real estate development, and conventional passenger services (Cooper, 1984).

Prior to this present SDHPT - sponsored investigation of HSR passenger service on Interstate highway right-of-way, recent work performed in analyzing and planning HSR for the Texas Triangle was performed by the private sector (the Texas Railroad Transportation Company). Although the rail technologies considered in this study are similar to those investigated by TRTC, the route alignments are different. TRTC is concentrating on the shared use of existing railroad rights-of-way. This study considers the practicality of placing HSR service on existing highway rights-of-way within the Triangle.

Philadelphia-Atlantic City

The 68-mile route between Philadelphia's 30th Street Station and Atlantic City, shown in Figure 3, has been examined as a corridor for improved rail passenger service by the State of New Jersey. Both commuter service (with intermediate stops yet to be determined) and express service have been suggested. The focus of this project is more toward rehabilitating existing track and providing for necessary track and safety improvements than constructing new facilities.

The estimated capital costs for implementing the project are $50 million ($735,000 per route mile), $20 million of which the State of New Jersey must provide in order to qualify for $30 million in Federal Northeast Corridor Improvements Project (NECIP) funds through AMTRAK (See Figure 4). Atlantic City invited casinos to suggest methods to fund the State's share of the project. The only casino to reply, Resorts International, proposes to pay $23 million for the high speed rail line and to provide a terminal at the casino. Costs for design and construction of the terminal, estimated at $10.5 million, will also be funded by Resorts International. The proposal still must be approved by New Jersey Transit, the Atlantic City Improvement Authority, and the New Jersey Casino Control Commission.

still must be approved by New Jersey Transit, the Atlantic City Improvement Authority, and the New Jersey Casino Control Commission.

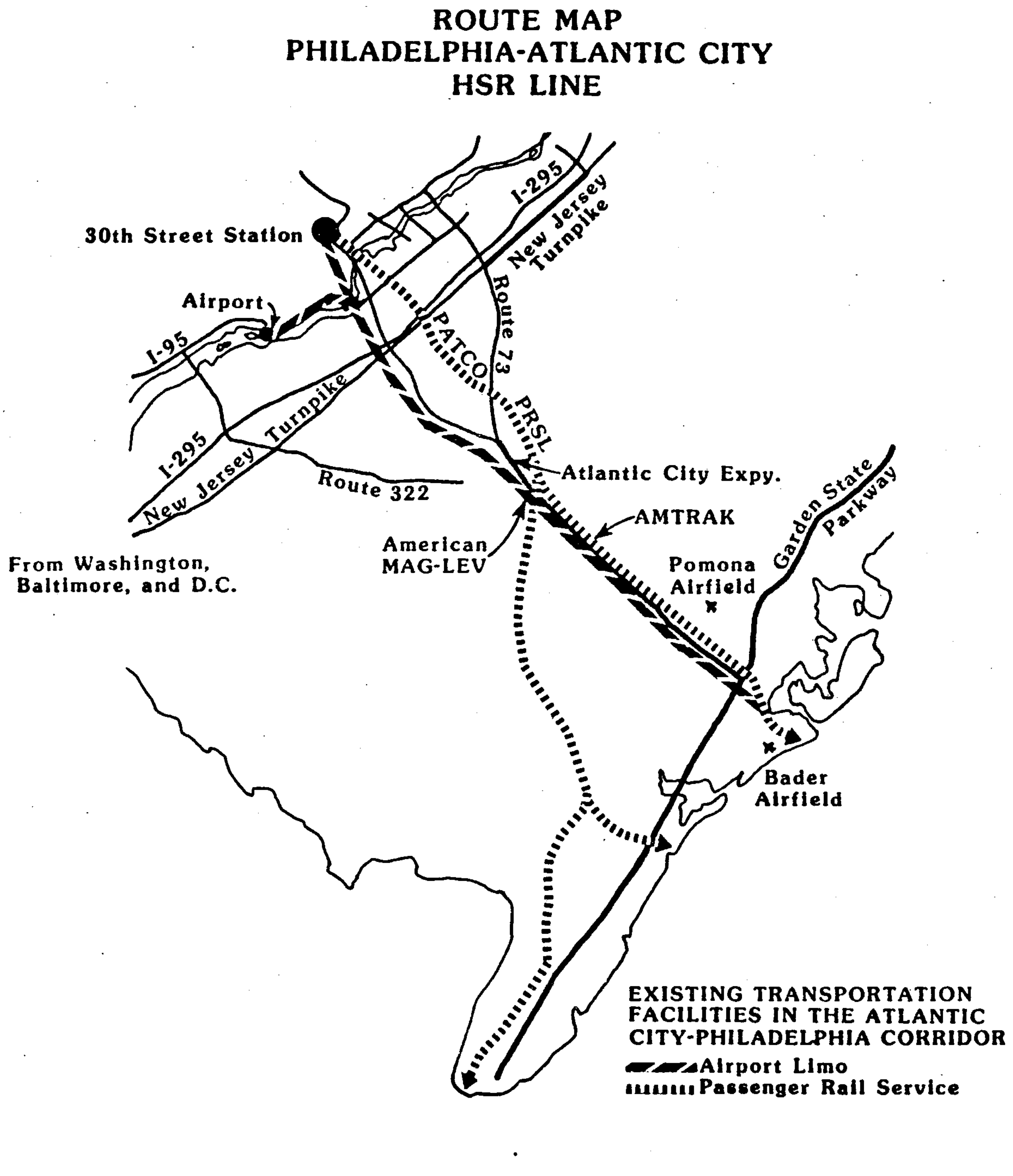
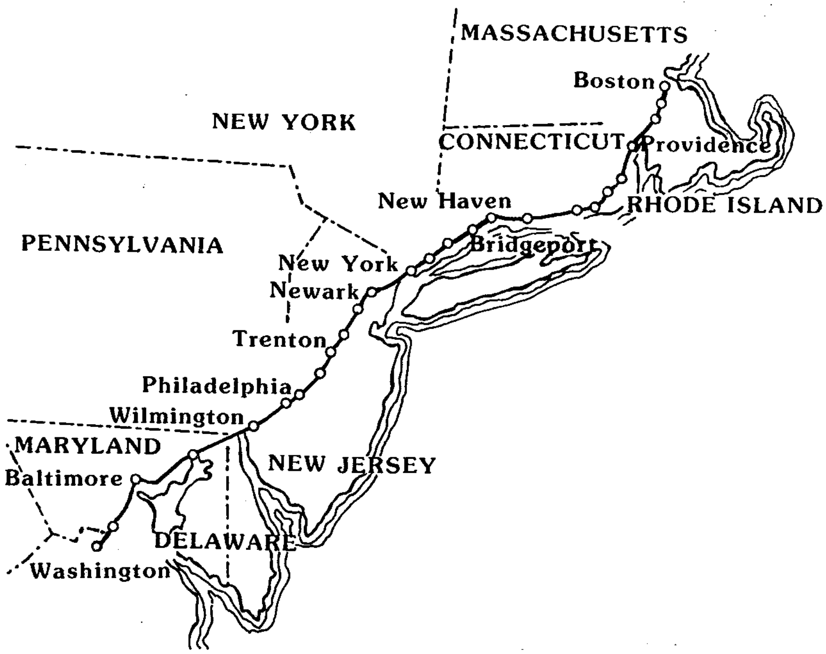


Figure 3. Proposed Alignment for the Philadelphia to Atlantic City HSR System

THE NORTHEAST CORRIDER IMPROVEMENT PROJECT



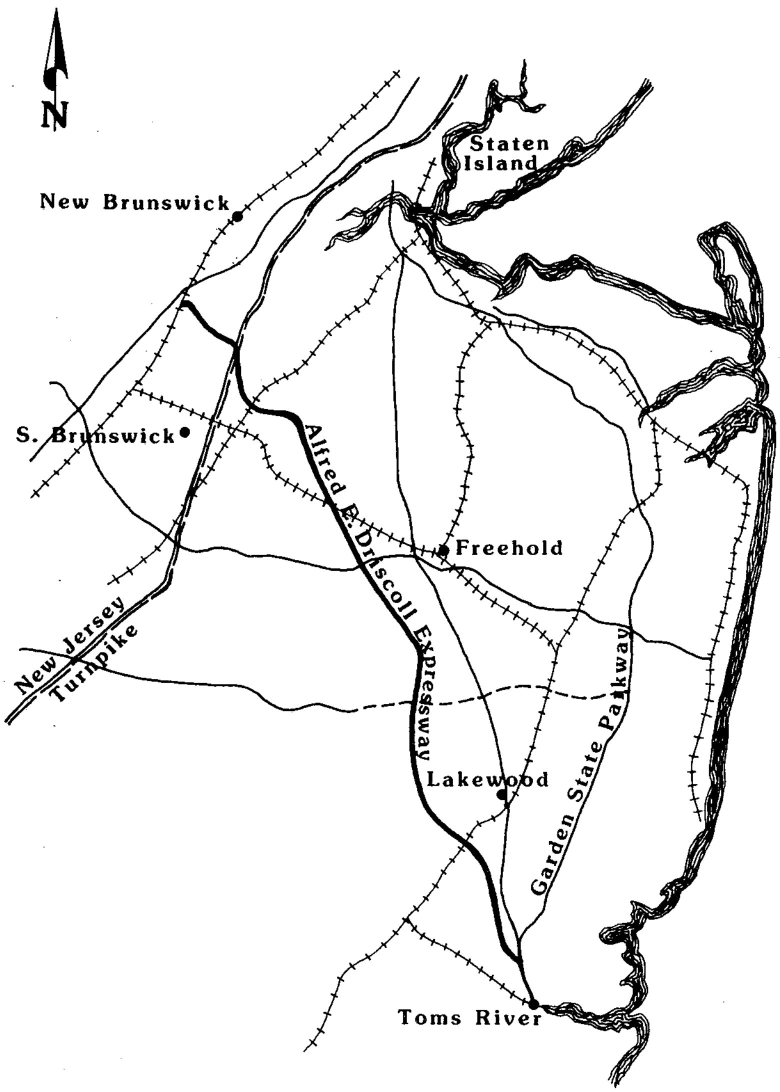
SOURCE: Executive Summary of Programmatic Environmental Impact Statement. Connecticut Department of Transportation, September 1977.

Figure 4. Interface Between NECIP and the Philadelphia to Atlantic City HSR Proposal

The American MagLev Corporation is raising funds for an engineering study to construct a privately financed MagLev system that would make the Philadelphia/Atlantic City run in 22 minutes. The most desirable option, claims the company, is construction of the system in the median or alongside I-295 and RT 42 in the Atlantic City Expressway right-of-way.

In addition, a proposal for utilizing expressway right-of-way in northern New Jersey has been proposed for a rail transit system. The alignment, shown in Figure 5, follows the Alfred E. Driscoll Expressway and connects the Northeast Corridor to Toms River.

Expressway Alignment

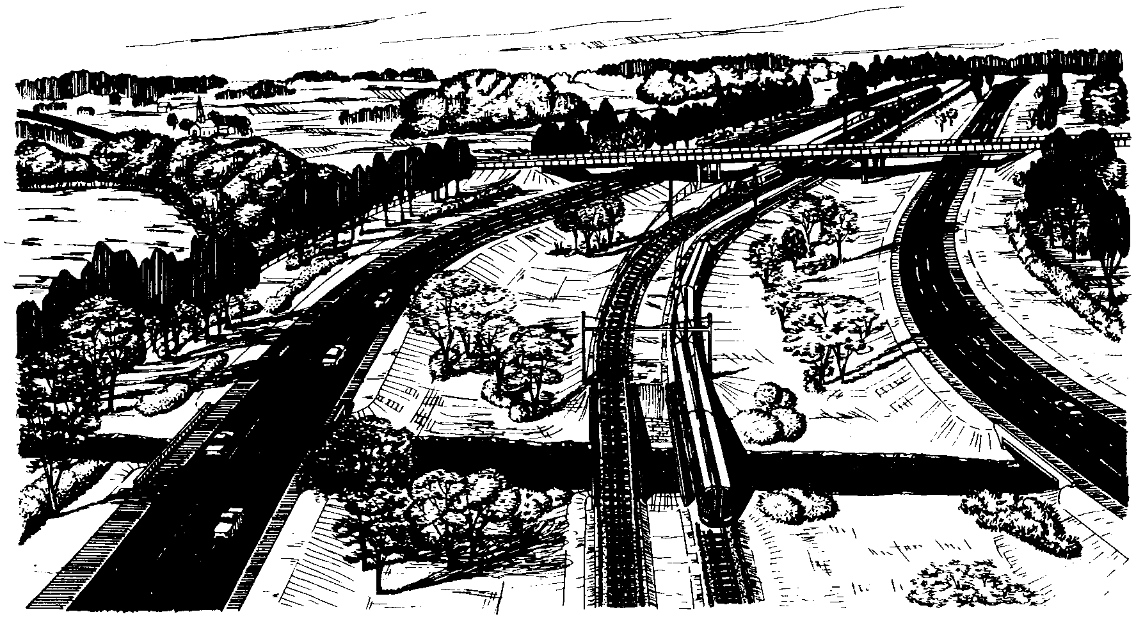


SOURCE: New Jersey Turnpike Authority, Governor Alfred E. Driscoll Expressway Rail Line Study, October 1975.

Figure 5. Proposed Alignment for Rail System In Expressway Right-of-Way

Preliminary feasibility studies indicate that a rail transit system could be constructed within portions of the Expressway's median as shown in Figure 6. Mode change facilities such as Park-and-Ride and/or Park-and-Pool Lots have been proposed adjacent to the Expressway to provide convenient

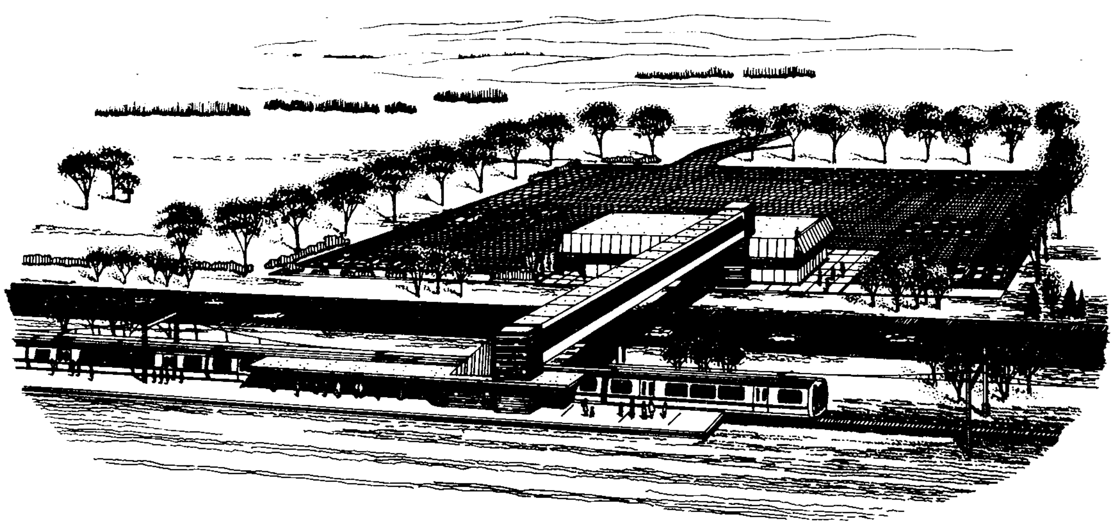
Proposed Rail Line Within The Expressway Right-Of-Way



SOURCE: New Jersey Turnpike Authority, Governor Alfred E. Driscoll Expressway Rail Line Study, October 1975.

Figure 6. Median Alignment of Rail Transit System In Northern New Jersey

Rail Park-And-Ride Station Adjacent Expressway



SOURCE: New Jersey Turnpike Authority, Governor Alfred E. Driscoll Expressway Rail Line Study, October 1975.

Figure 7. Concept of Mode-Change Facility for the New Jersey Rail Proposal

access to the rail system; an artist's concept of these facilities is presented in Figure 7.

Northeast Corridor

The Northeast Corridor Improvement Project (NECIP) was developed in the mid-1970's in order to promote rehabilitation of existing Northeast Corridor facilities for high speed rail passenger service. The Northeast Corridor rail system constitutes 455 miles of rail line between Washington D.C. and Boston, along with several feeder lines to the route as shown in Figure 8. The Washington to New York City route passes through Baltimore, Wilmington, Philadelphia, Trenton, New Brunswick, and Newark. The New York to Boston line stops in Stanford, New Haven, and Providence. The Pennsylvania feeder line links Harrisburg with Philadelphia, the New York feeder serves New York from Albany to New York City, and the Inland Route feeder connects Boston and New Haven.

The Northeast Corridor, which accounts for 55% of AMTRAK ridership, has been considered by some individuals as the most favorable route for high speed rail passenger service in the United States because of the high population density along the corridor. AMTRAK's fleet of Metroliners and Amfleet cars plus the new GM AEM-7 locomotives (modeled after the Swedish ASEA Rc4a) operate on some portions of the route at speeds up to 120 MPH. The NEC line is also used by the Conrail freight service.

The NECIP Implementation Master Plan of 1977 was found to be unattainable due to deficiencies in project scope, budget and a lack of attention to the service needs of commuter and freight operators. A redirection study was completed in 1979 to respond to these deficiencies as well as existing funding authorization (U.S. DOT, 1979). The redirected NECIP is scheduled for completion in 1984 at a cost of $2.5 billion ($5.49 million per route mile).

Source : North Corridor Improvement Project-Feeder Line Improvement Program: Inland Route, FRA, U.S. DOT, January 1980.

Figure 8. Northeast Corridor Improvement Project (NECIP) With Feeder Line Links

In 1971, a report was released by the U.S. Department of Transportation which outlined improvements for Northeast Corridor Transportation (Miller, 1971). The study not only recommended improved high speed rail service (such as that carried out by the NECIP), but also suggested investigation into Tracked Air Cushion Vehicles (TACV) and further research in tunneling and magnetic levitation technology. The report suggested prompt investigation into possible right-of-way for TACV routes, and research and development efforts emphasizing environmental impacts of such a system. The French TGV Company has also examined the route and considers it one of the best corridors for exclusive high speed rail passenger service.

New York City - Montreal

The states of New York and Vermont and the Providence of Quebec have recently agreed upon a "mutual understanding" compact to construct a high speed rail passenger line linking New York City and Montreal. In addition, the formation of a "Study Management Group", with New York chairing the committee, has been examined. The proposed 365-mile corridor will make intermediate stops in Albany, New York and Burlington, Vermont as it makes its way along the Hudson River and Lake Champlain.

A preliminary technical study for the route was sponsored by the City of Montreal. The French engineers who conducted the study initially considered using I-87 right-of-way for the route, but the northern section of the route was eventually abandoned in order to take advantage of the more gentle topography of Vermont (Lussi, 1983).

The Province of Quebec determined in a separate study that the project was feasible and highly desirable. To reduce train travel time from 8 hours and 45 minutes to 3 hours, a top speed of 185 MPH (similar to that of the

French TGV) was proposed. Cost of the project is estimated at $1.5 billion ($4.1 million per route mile).

Both New York and Vermont have received FRA grants for further studies. New York is using a $300,000 grant received in July, 1983, for planning studies (patronage, fares, running time), while a $100,000 grant received by Vermont is being used for studying economic impacts involved with constructing a TGV system.

Florida

A high speed rail line connecting Miami and Tampa by way of Orlando has been proposed by the State of Florida. The line, shown in Figure 9, is part of a 1200-mile high speed rail network that has been proposed by the Florida Department of Transportation (Rankin, 1977). The Miami-Tampa project is under the direction of the Florida HSR Commission but is intended to be financed and operated by a private firm.

The proposed 295-mile route from Miami to Tampa will have terminals at each of the cities' airports and at Disney World near Orlando. The system will require very little new right-of-way acquisition since it will be constructed within the 40 feet of outside right-of-way on the Florida turnpike, I-4, and I-95. Much of the line will run on viaducts several miles in length, as illustrated in Figure 10, to bridge interchanges and intersecting roadways. Elevation of the railway will assure an even ride and disburse noise more evenly. South of Orlando to Fort Lauderdale, the railroad bed will be constructed at-grade, as shown in Figure 11, since few interchanges exist. The sandy soil in this section will absorb and disburse the noise.

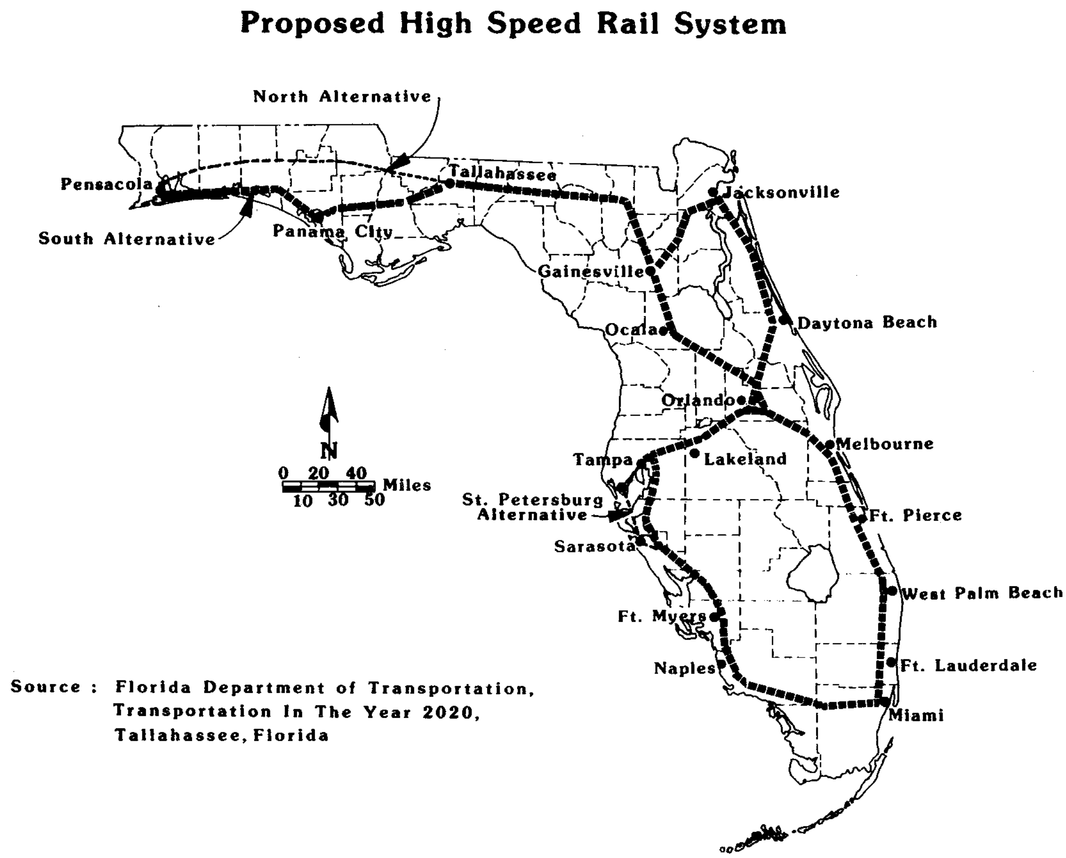


Figure 9. The Prosposed HSR Network for Florida

A preliminary assessment of high speed rail passenger service in Florida was conducted by AMTRAK and the Japanese Railway Technology Corporation or JRTC (National Railroad Passenger Corporation, 1983). AMTRAK conducted the ridership and revenue projections, while the JRTC estimated construction and operating costs. The economic feasibility of the rail line was confirmed.

Conceptual plans with a range of different rail technologies were submitted to the HSR committee by seven companies:

1. American High Speed Rail Corporation, Los Angeles; proposes the Japanese Bullet Train;

2. American MagLev, Inc. Pitman, New Jersey; proposes MagLev technology;

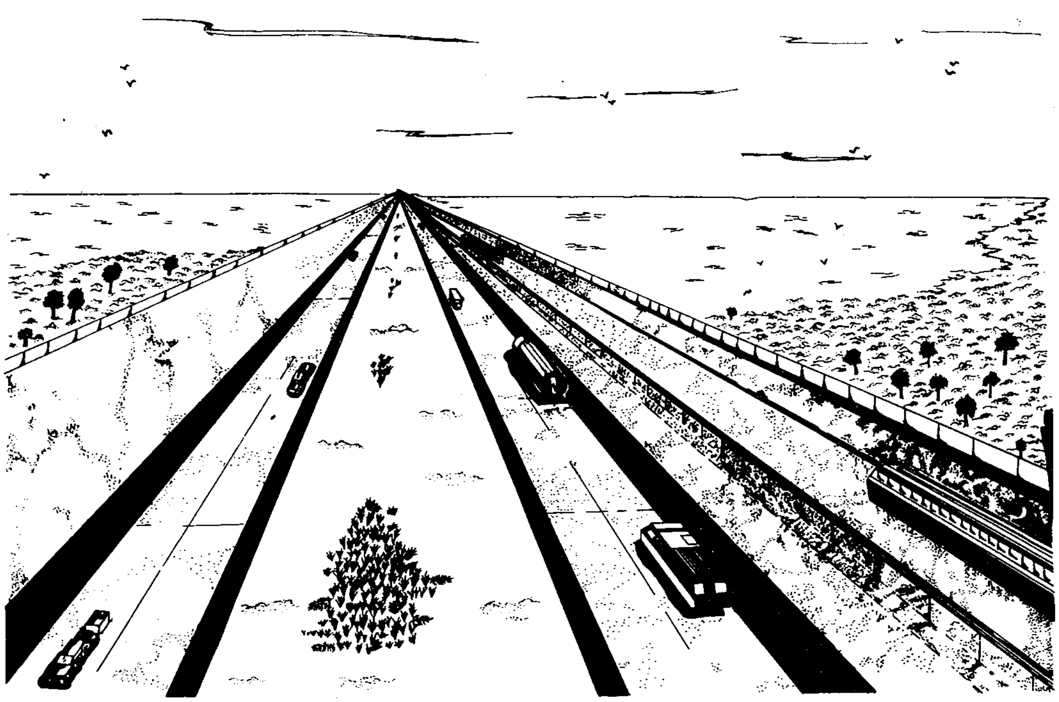
3. Bombardier, Inc., Boucherville, Quebec; proposes a turbo charged diesel upgraded to electrified;

Typical Elevated HSR Configuration

Source : Florida Department of Transportation,
Transportation In The Year 2020,
Tallahassee, Florida

Figure 10. The Florida Proposal for Elevated Construction of a HSR System Within Freeway Right-of-Way

Typical At-Grade HSR Configuration



Source : Florida Department of Transpotation,
Transportation In The Year 2020,
Tallahassee, Florida

Figure 11. The Florida Proposal for At-Grade Construction of a HSR System Within Freeway Right-of-Way

4. The Budd Company, Fort Washington, Pennsylvania; proposes MagLev;

5. Guideway International, Inc., Wadsworth, Ohio; suggests MagLev;

6. TGV Company, Washington, D.C., proposes the French TGV; and,

7. United States Research Laboratories, Inc., Lynwood, CA; proposes MagLev.

Estimated costs for the system range from $1 billion to $5 billion, or $3.4 million to $16.9 million per route mile. The state contracted with Barton-Aschman and Associates through a $500,000 FHWA grant to conduct an evaluation study on the seven conceptual proposals that have been submitted. The franchise is expected to be awarded in July 1985.

The project has run into several problems during its development. Some observers are skeptical that such a project can be completely financed within the private sector. The American High Speed Rail Corporation claims, in its proposal submitted to the state, that without state subsidies the system would incur a $7 billion debt by the year 2000 (Heany, 1984). Furthermore, if the system was subsidized by the state, it would not be self-sufficient until 2002.

Environmental groups have been hesitant to support the proposed rail line for fear that a privately operated system would not be adequately assessed with respect to environmental issues. A new proposition agreed upon by the Florida HSR Commission, the Florida Department of Environmental Regulation, and the U.S. Army Corps of Engineers has received tentative support from environmentalists. The proposed route is to be reviewed by a process modeled after the Transmission Siting Act, which outlines the procedure for placement of major power lines.

One additional conflict is with AMTRAK, which has exclusive jurisdiction over city-to-city passenger rail service in the United States. The State of Florida claims that it should not be required to have AMTRAK's consent, nor be responsible for any losses AMTRAK incurs as a result of the new rail line, especially since the new line will be constructed in highway right-of-way and not the railroad right-of-way on which AMTRAK currently operates. A bill recently submitted to Congress sought to eliminate exceptions to the exclusive jurisdiction rule. The bill was later withdrawn but the conflict between AMTRAK and private HSR rail systems still continues.

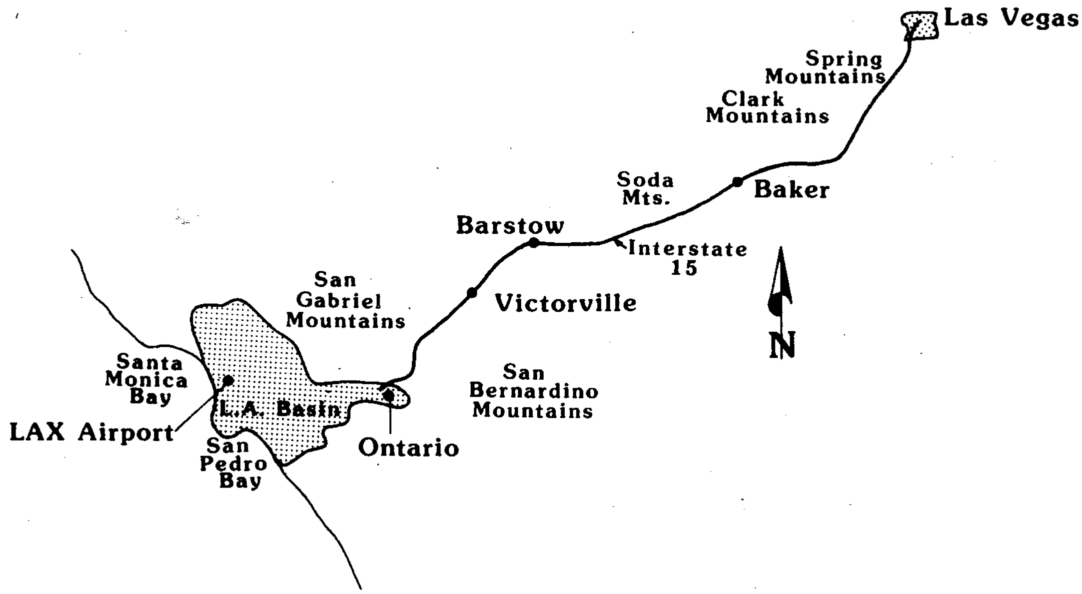
Los Angeles - Las Vegas

A 250 MPH MagLev train system is being proposed by the City of Las Vegas to link the City with Los Angeles. The suggested "base-line system" originates at the intersection of I-10 and I-15 and extends along I-15 through the Cajon Pass to Union Plaza in Las Vegas as shown in Figure 12. Sixty-four percent of the proposed route will be at grade, with the remaining 36 percent elevated. The 230-mile trip is expected to be run in 70 minutes at an average speed of 197 MPH.

A feasibility study in which different routes and high speed rail technologies were analyzed was completed in 1983 (Budd Company, 1983). One section of the report focused specifically on MagLev technology. Three MagLev systems were compared, including one from Germany and two from Japan. Projected costs for the project are $1.865 billion ($8.1 million per route mile) in 1982 construction dollars, and $33 million per year for operation and maintenance ($143 thousand per mile).

The study recommended establishing a public/private task force to direct initial implementation of the project and obtain $10 million to finance the start of the implementation process. The next steps in the process are to determine patronage and optimum ownership and financial structure (considering public and private sources of financing), and to begin conceptual system design.

BASELINE ROUTE:
LAS VEGAS/LOS ANGELES MAGLEV PROJECT



SOURCE:
Las Vegas/Southern California Super-Speed Ground Transportation System, Mike Daly, Las Vegas, Nevada, 1984.

Figure 12. The Proposed HSR Alignment Between Los Angeles and Las Vegas

The U.S. Department of Transportation awarded the City of Las Vegas a $1.25 million grant to begin the design/development stage. An environmental impact review, a MagLev technology assessment, and a socio-economic analysis are now being conducted. The system is expected to be operable by 1991.

Los Angeles - San Diego

Planning and design of the Los Angeles to San Diego high speed rail line has progressed further than any other HSR system in the United States. The American High Speed Rail Corporation (AHSRC) of Los Angeles is promoting the system and intends to provide private financing for the system as well as operate it. AHSRC is currently overseeing planning and design of the line while the State of California conducts environmental and economic studies.

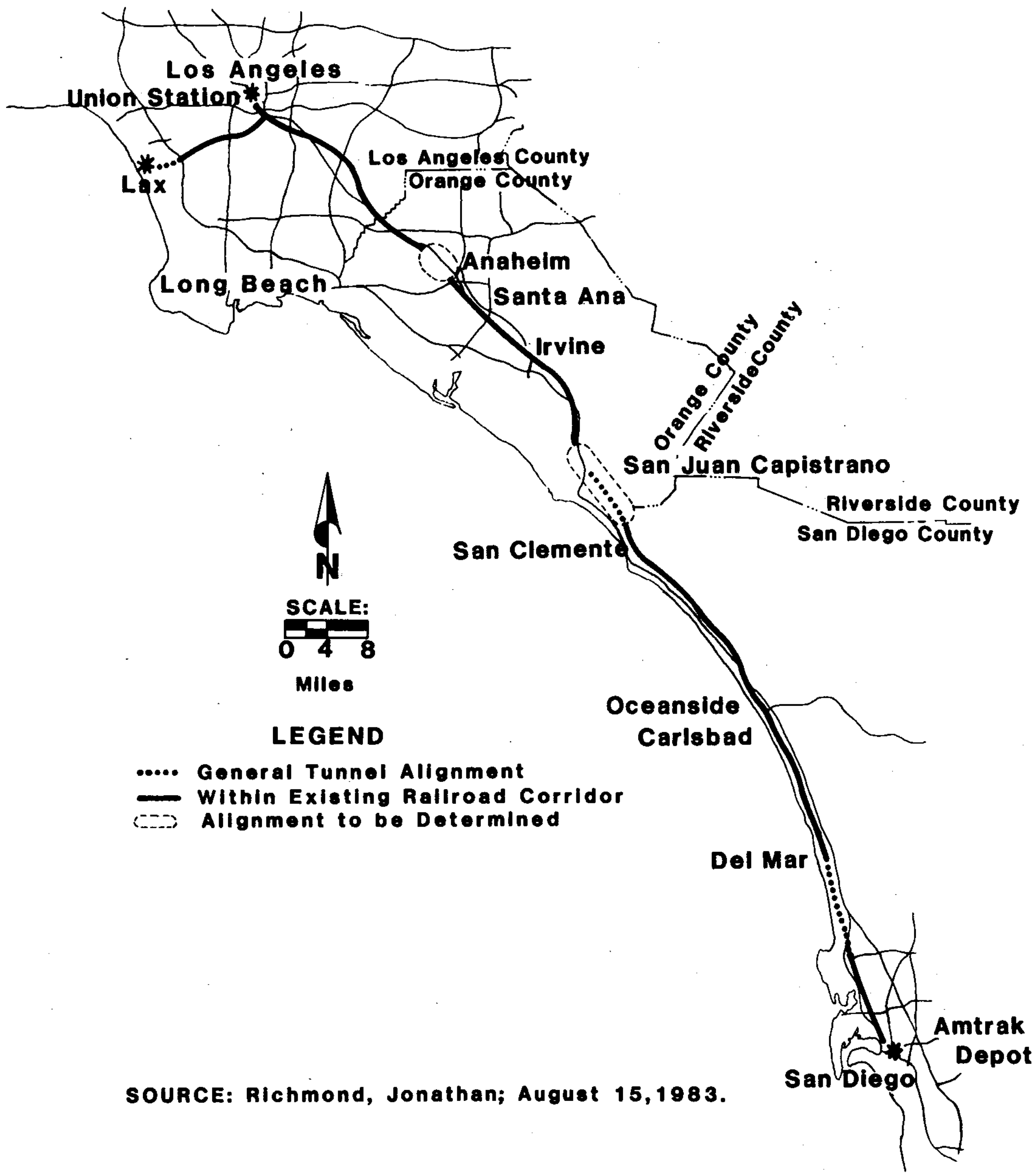
The 132-mile route, shown in Figure 13, follows the Santa Fe Railroad from Los Angeles International Airport (LAX) to Union Station in Los Angeles. From there the line follows the corridor formed by I-5 and the Santa Fe right-of-way to the Santa Fe Depot in San Diego. An intermediate stop has been proposed at the Santa Ana Transportation Center; specific stops still must be located at Anaheim and LAX. Eighty-five percent of the route will run in existing transportation corridors, 30 percent of which will run on viaducts through congested areas. The remaining 15 percent will run in tunnels.

At some locations the train will run at depressed grades that exceed the height of the catenary system. A typical depressed section is characterized by parallel earth beams and sound-reducing walls. Two hundred and eighty-eight grade crossings have been identified, including streets, highways, railways, and bodies of water.

The high speed train technology that AHSRC is promoting for the Los Angeles - San Diego system is an improved version of the electrically - powered Hikari type Shinkansen (bullet train) used in Japan. The trains will be controlled by a centralized control system and equipped with sensors for detecting earthquakes, high winds, flooding, and structural damage. The non-stop trip will be made in 59 minutes and a four-stop trip will be made in 90 minutes with trains traveling at a maximum speed of 160 MPH.

A portion of the route may be opened by late 1987. The full route is expected to be completed in 1988 at a total cost of $3.1 billion ($23.6 million per route mile). AHSRC is looking for financial backing from Japanese as well as U.S. sources.

ROUTE MAP FOR LOS ANGELES-SAN DIEGO BULLET TRAIN



SOURCE: Richmond, Jonathan; August 15,1983.

Figure 13. The 132 Mile HSR Proposal Between Los Angeles And San Diego

The proposed Los Angeles to San Diego HSR System has not been without its problems. Several cities, including San Diego, have filed a lawsuit against AHSRC because of their legislatively-authorized exemption from the state Environmental Quality Act. The City of Tustin independently commissioned a study which challenged the ridership and revenue projections reported in a feasibility study for AHSRC. Tustin's negative report criticizes AHSRC's determination of ridership estimates and claims that the project is "doomed to fail" (Richmond, 1983).

Further complications have been encountered in determining the alignment through Camp Pendleton, a large marine base located between Los Angeles and San Diego. The Marines claim that any deviation in alignment from the I-5 right-of-way will restrict military maneuvers. They also believe that an electromagnetic field produced by the train will disrupt civilian and military communications.

<u>Midwest U.S.</u>

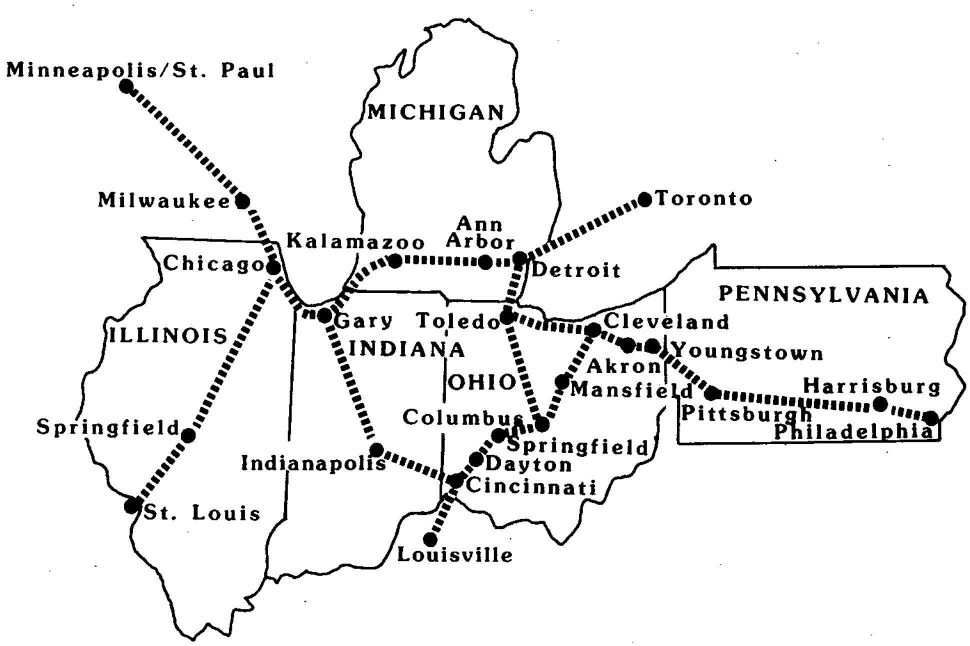
In 1979, the High Speed Rail Compact was formed in order to promote a regional approach to the planning and development of high speed passenger rail service in the Great Lakes area. The organization is made up of two delegates from each of the five states involved - Indiana, Illinois, Michigan, Ohio, and Pennsylvania - and three committees composed of state employees, that concentrate on technical, financial, and legislative issues.

The following eight corridors in the compact region have been identified as potential high speed rail corridors and are shown in Figure 14:

1. Detroit - Kalamazoo - Chicago;
2. Philadelphia - Harrisburg - Pittsburgh;
3. Cleveland - Columbus - Cincinnati;
4. Pittsburgh - Cleveland - Detroit;
5. Detroit - Columbus - Cincinnati;
6. Chicago - Indianapolis - Cincinnati;
7. Chicago - Milwaukee - Minneapolis; and,
8. Chicago - Springfield - St. Louis.

These corridors make up a 2200-mile network that would provide high speed rail service to approximately 30 million persons. The network would also offer a connection to the Northeast Corridor at Philadelphia. An extension from Detroit to Toronto and Montreal would serve an estimated 10 million Canadian residents.

POTENTIAL MIDWEST HIGH SPEED RAIL ROUTES



SOURCE:
High Speed Rail Compact,
Michigan Department of Transportation

Figure 14. The Eight HSR Corridors Proposed for the Midwest Region

Detroit - Kalamazoo - Chicago

Several studies on this route have been sponsored by the State of Michigan. The Michigan HS Intercity Rail Development Study assessed potential demand for high speed rail service in several corridors, among them the Detroit-Chicago corridor. The FRA/MSU/Transmode Study, completed in 1982, proposed upgrading the line with 125-mph diesel service in order to provide a three hour travel time. The Michigan State Transportation Commission has also appointed a three member subcommittee to examine high speed rail service in Michigan.

The proposed 280-mile route will connect Detroit and Chicago through the cities of Dearborn, Ann Arbor, Jackson, Battlecreek, Kalamazoo and Niles in Michigan and through Gary, Indiana. The $900 million ($3.2 million/route mile) estimated cost of the line is based on the cost of upgrading the current AMTRAK rails to accommodate high speed trains. The Michigan legislature recently passed a bill giving authority to the state to regulate passenger train speeds.

The state has been devoting most of its time to looking at existing railroad rights-of-way. A consortium of companies is examining the prospect of a completely new high speed rail facility and estimate the minimum cost of such a system to be $1 billion ($3.6 million per route mile).

Philadelphia - Harrisburg - Pittsburgh

The Pennsylvania High Speed Intercity Rail Passenger Commission was established with the responsibility to study development of a Philadelphia - Pittsburgh high speed rail system. One of the several studies being conducted for the Commission, an economic impact study, was released in December of 1983. The study reported that such a high speed rail system would be beneficial in improving the economy by creating thousands of jobs. The report projected a travel time of 2 hours and 15 minutes.

A $2.3 million feasibility study for high speed rail on the route is being conducted by an engineering group of Parsons Brinckerhoff/Gannett Fleming for the Commission. Initial funding for the study will come from a

$850,000 legislative appropriation and a $200,000 federal grant. A consortium, headed by STV Engineers of Pottstown, Pennsylvania, has been selected as the oversight consultant on the proposed project.

Cleveland - Columbus - Cincinnati

This 244-mile route is the major Ohio corridor as identified in the 1977 Ohio High Speed Intercity Rail Passenger Plan. In Phase I, conventional rail service over upgraded existing lines was studied. It was determined from this study that the system would require an operating subsidy at 60, 80 and possibly 110 MPH, and that only at very high speed - 150 MPH - would it be self-supporting. Phase II of the report concluded that the optimum alternative would be a state-of-the-art electrified steel-wheel-on-steel-rail system so that grade crossings would be eliminated. The capital costs of such a facility are estimated at $10 million per route mile. Phase III, completed in September 1982, defined preliminary engineering parameters needed for the system.

In November, 1982, Ohio voters overwhelmingly defeated a referendum which sought to impose a one cent per dollar sales tax to fund construction of the system. Since the sales tax defeat, the new governor and legislature have budgeted $350,000 for further studies on high speed rail and $150,000 for a governor-appointed task force.

Pittsburgh - Cleveland - Detroit
Detroit - Columbus - Cincinnati

These two routes are being examined primarily as extensions of the proposed high speed rail network in Ohio rather than separate high speed rail facilities. The Ohio High Speed Intercity Passenger Rail Plan identified three major Ohio corridors, as well as connections to Pittsburgh and Detroit that would serve as out-of-state extensions.

Chicago - Indianapolis - Cincinnati

The U.S. Department of Transportation and AMTRAK have completed studies on market potential and the magnitude of engineering and financial considerations for this corridor. The economic feasibility of construction and operation of a high speed passenger rail line on this route was justified.

Chicago - Milwaukee - Minneapolis

The Council of Upper Great Lakes Governors Study identified potential economic impacts of providing high speed rail service in the Chicago - Milwaukee - Minneapolis corridor as an extension to the Detroit - Chicago line.

The Budd Company is conducting a feasibility study for a Chicago-Milwaukee HSR line with $40,000 funded by grants from local agencies, the federal government, and private interests. The study will focus on potential routes, cost alternatives and station locations for a MagLev system between downtown Milwaukee and Chicago's O'Hare Airport. It is estimated that a MagLev train could make the 90-mile run in approximately 20 minutes at an average speed of 270 MPH.

Chicago - Springfield - St. Louis

A study conducted by Transportation and Distribution Associates, Inc. addressed capital and operational improvement requirements for high speed rail passenger service between Chicago and St. Louis. Marketing strategies were developed and evaluated for cost effectiveness by Reebie Associates. These studies indicate that improvement in service on the 450-mile route, beyond 79 MPH maximum speed would not be cost effective since a substantial capital investment would be required and the projected increase in ridership would not be sufficient to reduce operating losses. The maximum allowable speed for safety reasons is 100 mph. To reach this speed, improvements to existing facilities would cost $74 million or $164,000 per route mile. In order to run at a speed greater than 100 MPH, 230 grade separations and a new main line would be required at a total cost of $870 million or $1.9 million per route mile.

Washington State

The Washington State Legislative Transportation Committee released a Request for Proposal on the assessment of economic feasibility of a high speed rail line in Western Washington. The suggested route links Vancouver and Bellingham, Washington, with possible extensions north to Vancouver, British Columbia and south to Portland, Oregon (Smith 1984).

Rio Grande Corridor - New Mexico

In October 1983, the State of New Mexico Transportation Department released a Request for Proposal (RFP) soliciting proposals for a feasibility study on a rapid rail passenger system in the Rio Grande Corridor. The 300-mile corridor links Los Alamos, Santa Fe, Albequerque, and Las Cruces.

The RFP listed six technical options to be examined in the study. Nine proposals were received. The feasibility study will be used as a "go or no go" decision for further study of the proposed project (Sheck, 1984).

Foreign HSR Systems and Proposals

Numerous HSR Systems are in operation or being planned throughout the world. Europe, Japan, and Canada currently have operational systems and are planning system enhancements and/or expansions of HSR service. Some of the characteristics and highlights of these foreign rail passenger systems are presented in this section of the report.

France

The TGV or Train a' Grande Vitesse (very high speed) is at present the fastest passenger train in the world. The French HSR line runs 265 miles from Paris to Lyon as illustrated in Figure 15. The train is operated by the French National Railraods (SNCF) which began the HSR service in September of 1981 and expects to make enough profit to pay off investment costs of $1.5 billion ($5.6 million per route mile) by 1990.

The Paris - Lyon run is made in 2 hours with trains running at speeds of approximately 165 MPH. Grade crossings have been eliminated, and fencing prevents objects from getting onto the track. The train is electrified and the track is used exclusively for passenger service.

Plans are being made to extend service to Avignon and Marseilles in the South of France and to Geneva, Switzerland in the east. President Mitterand recently approved a new line linking Paris with Bordeaux, Brittany (to the northeast), and the Atlantic coast. Planners project an eventual TGV link between Paris and London via a channel tunnel.

France, Belgium and West Germany are teaming up to conduct feasibility studies for a high-speed train link from Paris to Cologne via Brussels. Rival technologies are being considered for the 500-mile plus route: two types of conventional rail and a magnetic-levitation system. The rail systems are France's TGV and West Germany's Intercity Experimental (IC-E).

PROPOSED EUROPEAN HIGH-SPEED TRAIN NETWORK

SOURCE: High-Speed Trains, Rollab, Sweden, 1984.

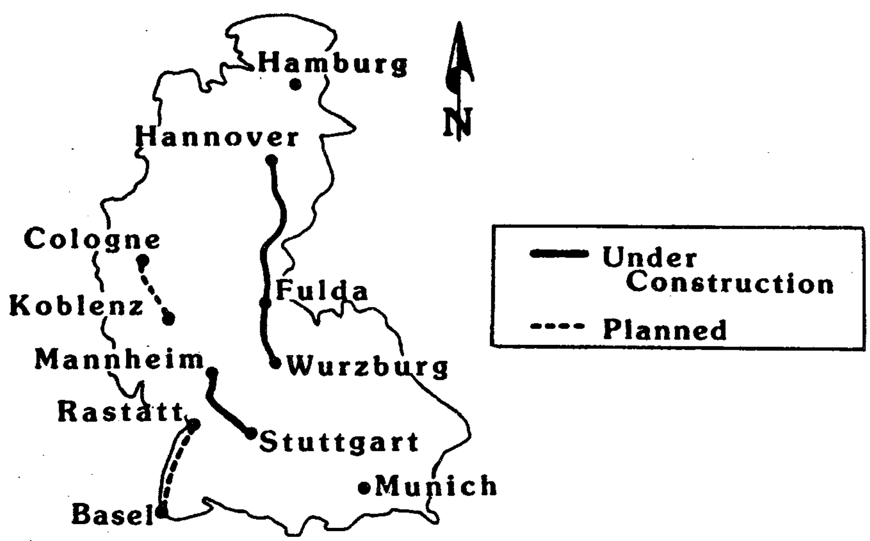
Figure 15. The Existing and Proposed HSR System of Europe

West Germany's super-fast Transrapid, a magnetic-levitation system, is challenging both of the high speed proposals.

Paris-Brussels-Cologne travel time could be cut from its present five hours to two hours and 45 minutes on a rail system averaging 156 MPH, or to less than two hours on a MagLev train averaging 250 MPH. A rail system is estimated to cost $2.1 billion ($4.2 million per mile) while a MagLev system is estimated at $3.2 billion ($6.4 million per mile).

West Germany

West Germany is now constructing 266 miles of HSR line between Hanover and Wurzburg and between Manheim and Stuttgart as shown in Figure 16. The lines are expected to be completed by 1991 at a total cost of $5.6 billion or $21 million per route mile. Electrically powered (IC-E) trains traveling at speeds of 157 MPH are to be used on the routes.



GERMANY'S 266 MILE HSR CONSTRUCTION

SOURCE:
Engineering News Record, Vol 212, No. 4, January 26, 1984.

Figure 16. The West German HSR Systems

Of the 266 miles, 13 miles will be at grade, 92.5 miles of the line will run through 77 tunnels, 22.5 miles will cross 357 bridges, and the remaining 138 miles will be on embankments and through cuts.

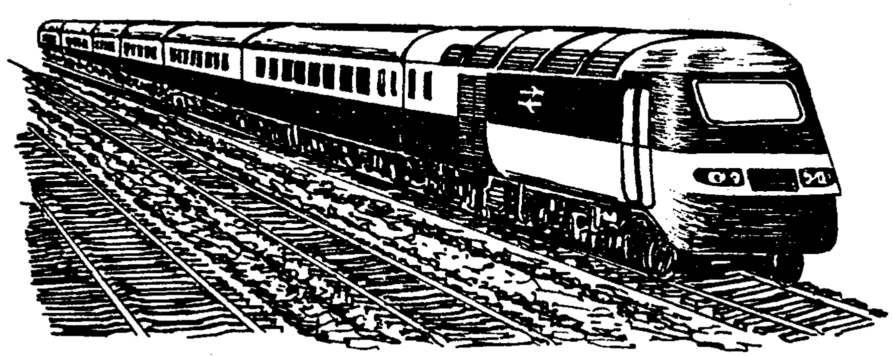
West Germany is also studying MagLev technology, and is considered to be the front runner in MagLev technology development.

Great Britain

High speed rail passenger service was first initiated in Great Britain in 1967 when the west coast rail lines from London to Birmingham, Manchester, and Liverpool were electrified. As a result, service speeds were increased to 160 km/hr (99 MPH).

The diesel High Speed Train (HST) shown in Figure 17, first introduced in 1976, is being operated on the British rail network (previously shown in Figure 15). The train which averages 145 km/hr (90 MPH), operates on sections of reworked and improved rail lines.

British High Speed Train

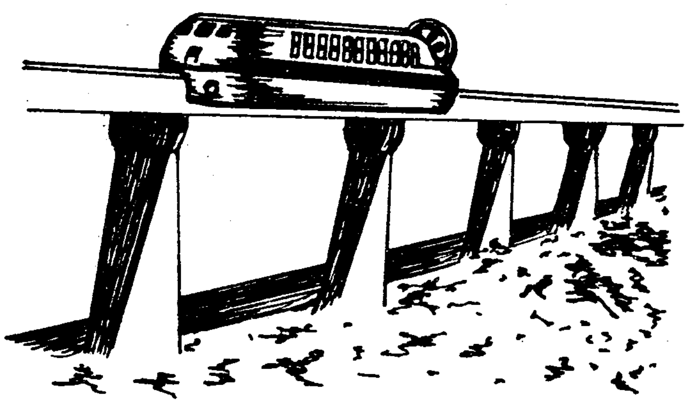


SOURCE: Boocock, D., ITE Compendium of Technical Papers, August 1983.

Figure 17. The Diesel Powered High Speed Train (HST)

The British have investigated various rail propulsion systems and guideway concepts over the past years. One alternative propulsion system, operated on a test track in England, is the turbo train shown in Figure 18.

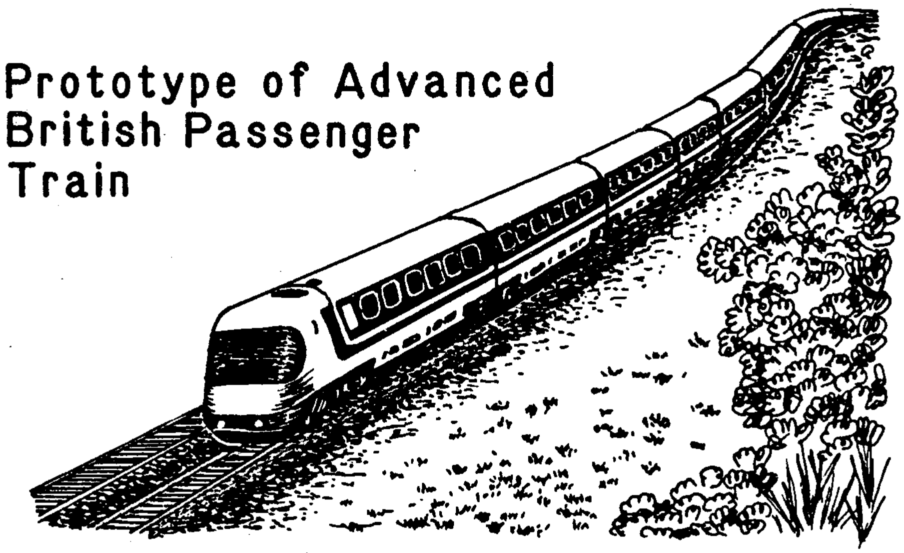
Turbo-propulsion on an 18 km test track in England



SOURCE: Rosen, John, ITE Compendium of Technical Papers, August 1983.

Figure 18. British Testing of Alternative HSR Propulsion Systems

The electrically powered Advanced Passenger Train (APT) being developed by the British Rails Derby Research Center is, shown in Figure 19. It is designed to travel at speeds up to 155 MPH with little or no alterations to existing track or signaling. The faster speeds are achieved by means of a tilt-body train that relieves the discomforting effect of centrifugal forces on passengers.



SOURCE: Boocock, D., ITE Compendium of Technical Papers, August 1983.

Figure 19. The Advanced Passenger Train (APT) with Tilt Mechanisms

The reason that high speed trains are being developed to utilize existing track is that there are no inter-city corridors within Britain which are likely to generate enough passenger traffic to justify construction of new high speed railways. A reduction in travel time is needed on the existing intercity rail corridors in order for rail to remain competitive with other forms of passengers transport and increase rail's market share.

Japan

The Japanese bullet train, or "Shinkansen", has been in operation since 1964. Operated by the Japanese National Railways, the Shinkansen runs on three major corridors extending from Tokyo as shown in Figure 20. The first is from Tokyo to Hakata, which consists of the original "Tokaido Shinkansen" from Tokyo to Shin-Osaka, and the "Sanyo Shinkansen" from Shin-Osaka to Hakata. Construction on the 320-mile Tokaido line began in 1959 and the line was opened for service five years later in 1964. The system was constructed at a cost of $890 million, or $2.8 million per route mile, and has been profitable since its second year of operation. The 344-mile Sanyo line was constructed at a cost of $3.14 billion, or $9 million per route mile, and was completed in 1975.

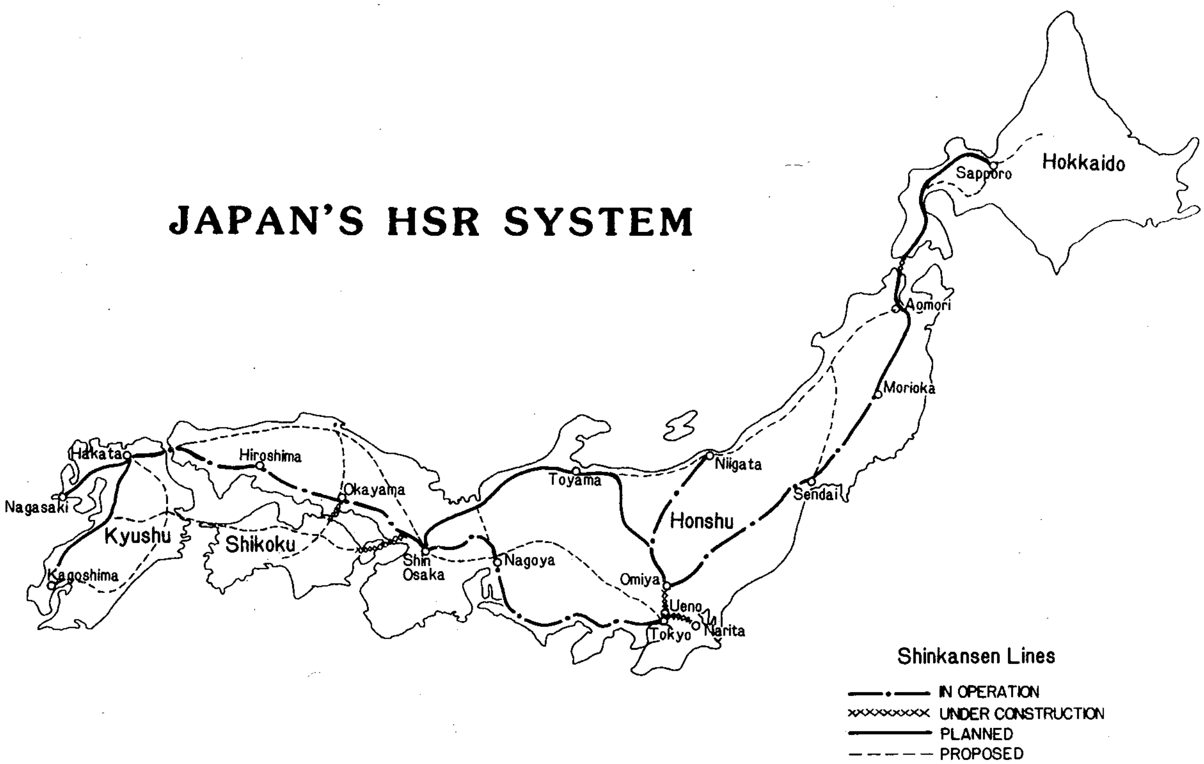


Figure 20. The Japanese Shinkansen (Bullet) HSR Route System

The 308-mile "Tokoku Shinkansen" between Tokyo and Morioka and the 167-mile "Joetsu Shinkansen" between Tokyo and Niigata are the newest lines. Both were planned in 1971 and began operating in 1982. The Tohoku line required $7 billion ($22.7 million per route mile) for construction, and the cost of the Joetsu line was roughly $5.7 billion ($34.1 million per route mile). Construction costs for both the Tohoku and Joetsu lines far exceeded original estimates due to land price, urban restraints on construction and environmental problems (Watanabe, 1983).

The electrically powered trains travel at a maximum speed of 130 MPH on separate rights-of-way where grade crossings have been eliminated. Some of the features of the Shinkansen include Automatic Train Control (ATC) which continually monitors speed in relation to distance between trains and route conditions, provisions for snow removal, and extensive tunneling which, along with bridging, is unavoidable due to the varied topography. A future speed of 150 MPH is expected to be technologically feasible without adversely affecting the environment.

Five Shinkansen lines are planned for the next stage, and 12 have been projected for a later stage. Because of budget pressures and right-of-way acquisition difficulties, construction of the first five lines will be suspended until a system of public assistance and funding sources can be devised.

Sweden

The Swedish State Railways have been investigating the implementation of high speed rail. The existing rail service operates with 80 MPH locomotives on a network characterized by frequent curves. The most promising choice for new HSR service is ASEA's X2 class tilt-body train which travels at 125 MPH on existing track. Fifty new X2 trains are to be delivered in 1988 (ASEA, 1984).

Canada

High speed rail passenger service is currently in operation between Toronto and Montreal utilizing the LRC (light rapid comfortable) train developed by the Canadian firm Bombardier.

The LRC passenger coaches have been designed to tilt inward on curves to counteract the outward pull of gravity. This enables the train to operate on existing track at speeds up to 125 MPH. The current revenue service between Toronto and Montreal, however, is limited to a 95 MPH speed because of signaling constraints.

The LRC is under serious consideration for Windsor - Toronto - Montreal - Ottawa HSR line. In addition to the LRC, 280 MPH MagLev and 160 MPH electric train technologies have been examined. Estimated costs in 1978 Canadian dollars for the HSR system are $3 billion for MagLev, $1.5 billion for electric, and $1 billion for diesel or diesel electric.

FACTORS AND CONSIDERATIONS OF IMPLEMENTING HSR SERVICES

One objective of this study was to investigate and summarize the institutional, jurisdictional, economic and legal constraints, considerations and/or concerns of implementing High Speed Rail (HSR) passenger service on highway right-of-way within the Texas Triangle. This section of the report sets forth various factors and considerations which should be taken into account when planning for HSR service. Construction and operational considerations are discussed in a subsequent section.

Institutional and Jurisdictional Factors

Amtrak

AMTRAK currently has statutory authority to provide intercity passenger rail service in the United States. Although some questions exist about whether such authority extends only to routes over which AMTRAK trains now operate or to any proposed route, implementation of HSR service cannot be accomplished without some prior agreement with AMTRAK. If AMTRAK is not the operator of the proposed HSR system, a number of institutional questions must be addressed. Will the HSR service conflict with any AMTRAK trains? How would a competing system affect AMTRAK's finances? Would the existence of profitable HSR rail service in the United States put pressure on AMTRAK to provide high-speed rail service in the corridors it serves, and what would the effect be? (U.S. Congress, 1983).

Private Railroad Companies

A second institutional consideration is what, if any, role private railroads are to play in HSR service? Most railroad track in America is owned by private railroads. Introducing high-speed rail in railroad corridors would require some sort of lease/purchase agreement with existing owners. If the HSR system requires a dedicated track, acquisition of an existing right-of-way may hinge on whether there is a practical alternative route to handle the freight now being carried on the line. Competitive reasons may also severely limit the degree to which private railroads would share their freight lines (U.S. Congress, 1983). Given these considerations, highway right-of-way may be an attractive alternative for HSR implementation.

Texas State Agencies

There are two principal Texas agencies which are concerned with the movement of people and goods:

1. The Texas Railroad Commission; and,
2. The State Department of Highways and Public Transportation.

Depending upon the right-of-way used (railroad or highway) for a HSR system, one or both of these agencies may be involved in its implementation and operation. In addition, the Texas State Legislature will no doubt enact special legislation specifically addressing HSR service in the Texas Triangle if such service is to become a reality. A 1983 bill, enacted by the Legislature, authorized the collection of $.25 on driver's license renewals for the study of rail passenger service in the Texas Triangle. If an appropriations bill is passed, these funds may be allocated to the Railroad Commission for investigating high speed rail service.

An overview of these two primary state agencies which are likely to be involved in HSR service implementation is included herein. Other State agencies are mentioned in conjunction with environmental assessments as part of the SDHPT discussion.

Railroad Commission

The regulation of railroads by the State of Texas was authorized by an 1890 amendment to the Texas Constitution. The Texas Legislature created the

Railroad Commission in 1891 with the following powers (Peterson, et. al., 1984):

1. To prescribe fares, freight rates and express rates and rules.
2. To prescribe a classification system.
3. To prescribe divisions when railroads could not agree.
4. To make different rates for different roads and for different lines under the same management or different parts of the same lines if found necessary to do justice.
5. To regulate the supply of equipment and the interchange of cars between connecting lines.
6. To require at least one train a day (Sundays excluded) for passengers; it was prohibited from relaxing this provision.
7. To see that "all laws of this State concerning railroads are enforced and obeyed."
8. To investigate interstate rates, and to seek relief from the Interstate Commerce Commission when the railroads failed to make proper adjustment.
9. To prevent extortion and discrimination.
10. To regulate free transportation of persons and property.

Since the passage of the Act, the Railroad Commission has been given additional powers with regard to railroads. In addition, intrastate regulatory authority has been given the Commission over truck lines, buses and pipelines plus the regulation of oil and gas production.

The Railroad Commission of Texas is the principal agency acting on behalf of the State in railroad matters. While direct power to influence a privately owned industry that is regulated by the Federal Government is limited, the Texas Railroad Commission has two roles:

1. It approves rates on intrastate shipments (Regulatory Role).
2. It represents the State of Texas in all matters related to railroad planning and Federal grants administered by the Federal Railroad Administration (Designated Agency Role).

Through the Designated Agency Role, the Texas Railroad Commission is the planning and grant administering arm for Federal funds to assist the railroads of Texas. As a planning function it oversees Federal Study grants to a number of Metropolitan Planning Organizations (MPO's) to address specific local rail issues (i.e., rail line relocation, rail crossing problems, and rail yard relocation) (Peterson, et. al., 1984).

The Railroad Commission promulgates rules and regulations in accordance with a 1925 General Law requiring all railway companies and all persons to maintain not less than a 22 foot clearance above the rails and not less than 8 feet - 6 inches away from the track centerline. Variances to the clearance law must be granted by the Railroad Commission.

State Department of Highways and Public Transportation

The State Department of Highways and Public Transportation (SDHPT) is responsible for planning, designing, constructing and maintaining the State's highway system. The Highway Design Division is responsible for guiding the complex development of all highway construction projects through the preliminary engineering stages on both rural and urban roadways. The Division's responsibilities begin with the initial stage of each project's conception and development, prior to actual location and design, and continue through the design stages to the completion of plans, specifications and estimates prior to release for bids for construction. More specifically, this Division develops design criteria; prepares highway design standards; issues authority to do preliminary planning; programs Federal-aid projects; coordinates the development of the Twenty-Year Project Development and Control Plan, the one-year advance letting schedule, and the monthly letting schedule; processes plans and specifications for letting; and, through Field contact representatives, coordinates archeological and environmental studies, plan development, construction specifications, engineering estimates and agreements. Also available to the Field Offices upon request are specialized consultant services in the areas of computerized project data, illumination, traffic, geometrics, pavement design and rehabilitation, social and environmental considerations, archeological and cultural resources, air, water and noise pollution studies, and highway economic and evaluation studies.

The SDHPT Bridge Division has responsibility for the selection of railroad grade crossing improvement projects. The crossings are selected from a priority list developed from hazard indices, calculated from the State inventory of railroad crossings. Since 1972, the Federal Highway Administration has funded grade crossing improvement projects through Section 203 of the Highway Trust Fund. This on-going program, in addition to others, puts SDHPT personnel in close contact with railroad officials in all of the State's operating railroad companies. The SDHPT also interacts with the railroads in areas other than grade crossing improvements. Among these situations are when (Peterson, et. al., 1984):

1. The highway crosses railroad property.
2. The railroad crosses a State highway.
3. The railroad crosses above a State highway.
4. The State highway crosses above railroad property.
5. The railroad runs a spur track across a State highway.
6. Drainage ditches run parallel between a State highway and adjacent railroad tracks.

SDHPT works closely with other State agencies, particularly when preparing environmental impact statements. Draft environmental statements are circulated to members of the State's Natural Resources Council (NRC) consisting of the:

- Governor
- Texas Air Control Board
- Texas Industrial Commission
- Texas Parks and Wildlife Department
- Texas Railroad Commission
- Texas State Soil and Water Conservation Board
- Texas Department of Water Resources

- University of Texas System
- General Land Office
- Texas A&M University System
- Texas Department of Agriculture
- Texas Department of Health Resources
- Texas Historical Commission

In addition, the SDHPT works closely with local governmental agencies and local elected officials throughout project planning and development. These local agencies include cities, counties, councils of government, metropolitan planning organizations and transit authorities.

Local Governments and Transit Agencies

Where construction of a HSR system can be shown to attract enough ridership, site-specific concerns will have to be taken into account by local governments as well as developers. For example, to make best use of their high speed, trains should not make frequent stops. Local governments may base decisions to compete for a stop on whether the system is expected to be self-sufficient, whether demands will be made on them to improve the station surroundings, and on whether local development may occur as a result of a station. For example, parking lots large enough to permit riders to Park-and-Ride may be required before the HSR operators will agree to an intermediate stop. By the same token, if the system draws many riders, local governments and private entrepreneurs may wish to develop the area around the station. In most instances in which high speed rail may be contemplated, local transit is assumed necessary to feed the intercity service, as illustrated in many European and Japanese cities. Proponents of the high speed rail system in question may locate stations to maximize ridership for both systems. If local transit systems are inadequate, the potential of HSR proposals may be reduced. Or, if demand for the high speed intercity service is strong enough, there could be pressures on the city and the Federal Government to strengthen the local transit systems (U.S. Congress, 1983).

Social and Economic Factors

Public Sentiment

Polls reveal that a majority of Americans wish to preserve rail service as a transportation option, even when subsidy is required. Some advocates of HSR in this Country regard it as a matter of National pride. Those who believe that our Country's status as the technological world leader should be preserved and promoted may well support the introduction of HSR Services. Others question whether implementation of rail, considered by many as a mature technology, is advisable (U.S. Congress, 1983).

Energy Considerations

The energy crisis in 1973 triggered many efforts to curb the Nation's use of petroleum resources and to lessen dependence on foreign oil. One alternative examined was upgrading intercity rail service to higher speeds so that travelers would turn to rail and reduce less fuel-efficient automobile travel. Although projections indicated that ridership would increase under certain circumstances, DOT's overall conclusion was that "energy impacts of rail corridor development are at best insignificant." Although AMTRAK believed the energy savings would be much higher than DOT estimated, it agreed that any energy savings were an incidental benefit of corridor service and could not serve as the sole or major justification for upgrading service. Any significant energy savings are likely to occur only if substantial displacement of automobile (or airline) use occurs which means current U.S. transportation patterns would have to change (U.S. Congress, 1983). To effect such changes, the HSR alternative would have to favorably compete in terms of service and travel times with other existing modes (i.e., automobiles, airlines).

Increased Highway Mobility

Increased mobility and improved transport system capacity are important reasons for implementing HSR, particularly in regions of the country experiencing population growth such as Texas. High ridership levels are made possible by the capacities typically offered by HSR with frequent service. The original Tokyo-Osaka line attracted 85 million riders in 1970. The total line, extending fom Tokyo to Hakata, attracted a high ridership in 1975 of 157 million passengers. In the United States the market for intercity passenger rail has been eroded by the introduction and extensive use of air and automobile technologies. If rail is to attract the ridership necessary to sustain at least operating costs, it must compete with other transport modes in the private sectors. Some argue that the loss of ridership and the potential service losses of these other modes, if HSR were to be successful, should be considered a public cost, particularly if the new rail service receives Government support. Others argue that other modes are already subsidized, and rail deserves parity in treatment. Crucial to evaluating increased mobility are answers to questions related to: What are near- and long-term transport systems' capacities and needs for a given region? What are the likely tradeoffs among transport options? Are conditions on a corridor such that people would use the rail system if implemented? (U.S. Congress, 1983).

The extent to which high-speed rail could be expected to alleviate highway congestion depends on the following factors:

- the degree to which the congestion is or will remain unsolvable by other means;
- the degree to which automobile drivers choose to ride the train to avoid the highway;

- the degree to which there is available right-of-way to install HSR service; and,
- the degree to which it may provide service to potentially offset long-term capacity needs for a region.

Studies indicate that congestion of the Interstate Highway Systems results more from commuter traffic than from intercity travel. Therefore, the issue is whether commuters making relatively short daily trips could be induced to use high speed rail for commuting, whether the corridor service is convenient for other urban area trips and whether high speed trains are the appropriate technology for such a service. Current U.S. intercity rail service typically is not designed as a commuter or transit system. Some studies show that most people will discontinue using their automobile only under severe parking restrictions. Some rail proponents suggest that the trend toward longer term ownership and use of older vehicles may begin to alter people's choices for intercity travel modes (U.S. Congress, 1983).

To evaluate the impact of HSR on long-term capacity and congestion problems, answers are required to the following questions: What is the projected population growth of the area? What regional plans exist for development of the area, and to what extent are the long-term transportation options being evaluated? What factors are likely to occur that would encourage eventual diversions to any proposed rail system? Other questions regarding tradeoffs between highway and rail include: How many drivers use the highway to make the full intercity trip? Would drivers be willing to pay more to arrive at their destination quicker (recognizing that, if so, they might prefer taking the plane)? Would the station location and transit service availability at their destination affect their decision? Is HSR an appropriate application of technology to alleviate commuter or urban freeway congestion? (U.S. Congress, 1983).

Alleviating Airport Congestion

High speed rail has been proposed for corridors where heavy demand is straining airport ground capacity. The extent to which HSR would alleviate airport congestion depends on several factors:

- the degree to which the HSR route matches origins and destinations of air travelers;
- the degree to which the congestion is unsolvable by other means; and,
- the degree to which air travelers can be induced to select the train over the airplane.

In the early 1970's, a major argument for HSR in the Northeast Corridor (NEC) was that New York City could avoid building a fourth airport, which at the time appeared inevitable. Yet today, even though the NEC still does not provide HSR service of the sort then contemplated, New York City is no longer seeking to build a fourth airport. The prognosis changed because: 1) New York's forecasted growth in air travel did not materialize; 2) larger planes and more efficient air traffic control systems allowed the existing airports to handle more traffic without building new facilities; and, 3) the problems of finding a suitable airport site proved more difficult than planners imagined (U.S. Congress, 1983).

It does not appear that HSR service would have an appreciable effect on ground congestion at all airports. The travel patterns for large "hub" airports that now have, or are soon expected to have, severe congestion (e.g., Chicago's O,Hare, Atlanta's Hartsfield, and Denver's Stapleton) are not such that HSR would be an appropriate substitute for air. These airports are served by a hub-and-spoke pattern of air routes, and much of the congestion results from passengers transferring between flights. High speed rail, which works best when there is a high volume of origin-destination traffic along a corridor, would not compete effectively in most long distance, hub-and-spoke markets. If an airport is to serve as a HSR station, frequency of service from the airport must be a major consideration (U.S. Congress, 1983).

Tourism

Regions of the country, where tourism is vital to the economy, are looking at HSR service two reasons:

1. to maintain access for tourists should other forms of transportation become constrained; and,
2. to increase tourist travel by building a high speed rail system so technologically advanced that the rail trip itself will serve as an attraction and inducement.

Whether HSR in itself can lure additional tourists to a given location is uncertain. Estimating the degree to which technology may induce demand is difficult since it is not always possible to predict with certainty the desires of tourists. Understanding how and why tourists currently come to a location, together with surveys to determine the likelihood of their using HSR or other advanced ground technologies, would contribute to the analyses. Typically, tourists prefer to travel by car because they wish to visit widely scattered sights and they frequently travel with much luggage. The auto provides flexibility not offered by most public modes of transportation (U.S. Congress, 1983).

Regional Development

High speed rail systems are being proposed on the grounds that they would stimulate economic development along the route as did the Erie Canal and the railroads of the 19th century. Historically, regional development has followed new transportation development because the transportation provided a new, more efficient means of reaching an area. Questions concerning HSR include whether it meets a need that is not already being met and whether this need is significant enough to bring about the sort of economic development contemplated by proposers. While economic development might occur, tradeoffs such as HSR competition with air, automobile, and bus for passengers must also be examined. The regional benefits of economic development around a corridor must be analyzed against the possbility that the region or Nation eventually may have to support operating losses if the rail system does not prove profitable or if ridership levels projected do not materialize (U.S. Congress, 1983).

One of the underlying fallacies, however, upon which much rail-passenger planning in the U.S. has been based, is that intercity passenger trains are basically and inherently unprofitable. One can say that many systems operate at breakeven or better. In addition to numerous operations in Japan and parts of Western Europe, most of the countries of Eastern Europe are close to breakeven, if not above; also consistently in the breakeven-or-better category are the lines and systems of India, Continental China and the Soviet Union. In total, the world's more modern railway passenger services move over 500 billion passenger-miles at breakeven or better; systems losing money are handling about 240 billion passenger-miles. Thus, over 67% of rail service in the world pays its own way. However, since Americans travel mainly in the U.S. or Western Europe where most trains lose money, the typical U.S. planner's impression is based upon the misconception that rail passenger service is unprofitable and infeasible (Rice, 1975).

Legal and Regulatory Factors

At the present time, there is no highway law or regulation which deals specifically with High Speed Rail (HSR) or the use of highway rights-of-way for HSR systems. Section 142 of title 23, United States Code, and implementing regulations (23 CFR Part 810, Subpart C), addresses publicly owned mass transit facilities. Section 142 (g) provides that the Federal Highway Administrator may authorize a State to make available, to a publicly-owned mass transit authority, existing rights-of-way for rail or other non-highway public mass transit facilities. As set forth in the implementing regulations, the Administrator has the "discretion" to consider or not to consider an application for such non-highway use of rights-of-way (Calhoun, 1984).

Section 142, Title 23, U.S.C., Public Transportation

(a)(1) To encourage the development, improvement, and use of public mass transportation systems operating motor vehicles (other than on rail) on Federal-aid highways for the transportation of passengers (here after in this section referred to as "buses"), so as to increase the traffic capacity of the Federal-aid systems for the movement of persons, the Secretary may approve as a project on any Federal-aid system the construction of exclusive or preferential high occupancy vehicle lanes, highway traffic control devices, bus passenger loading areas and facilities (including shelters), and fringe and transportation corridor parking facilities to serve high occupancy vehicle and public mass transportation passengers, and sums apportioned under section 104 (b) of this title shall be available to finance the cost of projects under this paragraph. If fees are charged for the use of any parking facility constructed under this section, the rate thereof shall not be in excess of that required for maintenance and operation of the facility and the cost of providing shuttle service to and from the facility (including compensation to any person for operating the facility and for providing such shuttle service.)

(2) In addition to the projects under paragraph (1), the Secretary may, beginning with the fiscal year ending June 30, 1975, approve as a project on the Federal-aid urban system, for payment from sums apportioned under section 104(b)(6) of this title, the purchase of buses, and, beginning with the fiscal year ending June 30, 1976, approve as a project on the Federal-aid urban system, for payment from sums apportioned under section 104(b)(6) of this title, the construction, reconstruction, and improvement of fixed rail facilities, including the purchase of rolling stock for fixed rail,

except that not more than $200,000,000 of all sums apportioned for the fiscal year ending June 30, 1975, under section 104(b)(6) shall be available for the payment of the Federal share of projects for the purchase of buses.

(b) Sums apportioned in accordance with paragraph (95) of subsection (b) of section 104 of this title shall be available to finance the Federal share of projects for exclusive or preferential high occupancy vehicle, truck, and emergency vehicle routes or lanes. Routes constructed under this subsection shall not be subject to the third sentence of section 109(b) of this title.

(c) Whenever responsible local officials of an urbanized area notify the State highway department that, in lieu of a highway project the Federal share of which is to be paid from funds apportioned under section 104(b)(6) of this title for the fiscal year ending June 30, 1974, and June 30, 1975, their needs require a nonhighway public mass transit project involving the construction of fixed rail facilities, or the purchase of passenger equipment, including rolling stock for any mode of mass transit, or both, and the State highway department determines that (the planning process has been met), such public mass transit project shall be submitted for approval to the Secretary. Approval of the plans, specifications, and estimates for such project by the Secretary shall be deemed a contractual obligation of the United States for payment out of the general funds of its proportional share of the cost of such project in an amount equal to the Federal share which would have been paid if such project were a highway project under section 120(a) of this title. Funds previously apportioned to such State under section 104(b)(6) of this title shall be reduced by an amount equal to such Federal share.

(d) The establishment of routes and schedules of such public mass transportation systems in urbanized areas shall be based upon a continuing comprehensive transportation planning process carried on in accordance with section 134 of this title.

(e)(1) For all purposes of this title, a project authorized by subsection (a)(1) of this section shall be deemed to be a highway project.

(2) Notwithstanding section 209(f)(1) of the Highway Revenue Act of 1956, the Highway Trust Fund shall be available for making expenditures to meet obligations resulting from projects authorized by subsection (a)(2) of this section and such projects shall be subject to, and governed in accordance with, all provisions of this title applicable to projects on the Federal-aid urban system, except to the extent determined inconsistent by the Secretary.

(3) The Federal share payable on account of projects authorized by subsection (a) of this section shall be that provided in section 120 of this title.

(f) No project authorized by this section shall be approved unless the Secretary of Transportation has received assurances satisfactory to him from the State that high occupancy vehicles will fully utilize the proposed project.

(g) In any case where sufficient land exists within the publicly acquired rights-of-way of any Federal-aid highway to accommodate needed rail or nonhighway public mass transit facilities and where this can be accomplished without impairing automotive safety or future highway improvements, the Administrator may authorize a State to make such lands and rights-of-way available without charge to a publicly owned mass transit authority for such purposes wherever he may deem that the public interest will be served thereby.

(h) The provision of assistance under subsection (a)(2) or subsection (c) of this section shall not be construed as bringing within the application of chapter 15 of title 5, United States Code, any nonsupervisory employee of an urban mass transportation system (or of any other agency or entity performing related functions) to whom such chapter is otherwise inapplicable.

(i) Funds available for expenditure to carry out the purposes of subsection (a)(2) and subsection (c) of this section shall be supplementary to and not in substitution for funds authorized and available for obligation pursuant to the Urban Mass Transportation Act of 1964, as amended.

(j) The provisions of section 3(e)(4) of the Urban Mass Transportation Act of 1964, as amended, shall apply in carrying out subsection (a)(2) and subsection (c) of this section.

(k) The Secretary shall not approve any project under subsection (a)(2) of this section in any fiscal year when there has been enacted an Urban Transportation Trust Fund or similar assured funding for both highway and public transportation.

The application process and the factors to be considered by the Administrator for public mass transit use of highways are set out at 23 CFR 810, Subpart C as follows (Calhoun, 1984):

<u>23 CFR 810, Subpart C, Making Highway Rights-of-Way Available for Mass Transit Projects.</u>

810.200 Purpose

The purpose of the regulations in this subpart is to implement 23 U.S.C. 142(g), which permits the Federal Highway Administrator to authorize a State to make available to a publicly-owned mass transit authority existing highway rights-of-way for rail or other nonhighway public mass transit facilities.

810.202 Applicability

(a) The provisions of this subpart are applicable to the rights-of-way of all Federal-aid highways in which Federal-aid highway funds have participated or will participate in any part of the cost of the highway.

(b) The provisions of this subpart do not preclude acquistion of rights-of-way for use involving mass transit facilities under the provisions of Subparts B and D of this part. Rights-of-way made available under this Subpart may be used in combination with rights-of-way acquired under Subparts B and D of this part.

810.204 Application by Mass Transit Authority

A publicly-owned mass transit authority desiring to utilize land existing within the publicly acquired right-of-way of any Federal-aid highway for a rail or other nonhighway public mass transit facility may submit an application therefore to the State highway agency.

810.206 Review by the State Highway Agency.

The State highway agency, after reviewing the application, may request the Federal Highway Administrator to authorize the state to make available to the publicly-owned mass transit authority the land needed for the proposed facility. A request shall be accompanied by evidence that utilization of the land for the proposed purposes will not impair future highway improvements or the safety of highway users.

810.208 Action by the Federal Highway Administrator

The Federal Highway Administrator after consultation with the Urban Mass Transportation Administrator may authorize the State to make available to the publicly-owned mass transit authority the land needed for the proposed facility, if he finds:

(a) The evidence submitted by the State highway agency under 810.206 to be satisfactory;

(b) The public interest will be served thereby; and,

(c) The proposed action in urbanized areas is based on a continuing comprehensive transportation planning process carried on in accordance with 23 U.S.C. 134 as described under 23 CFR Part 450, Subpart A.

810.210 Authorization for Use and Occupancy by Mass Transit

(a) Upon being authorized by Federal Highway Administrator, the State shall enter into a written agreement with the publicly-owned mass transit authority relating to the use and occupancy of highway right-of-way subject to the following conditions:

(1) That any significant revision in the design, construction, or use of the facility for which the land was made available shall receive prior review and approval by the State highway agency.

(2) The use of the lands made available to the publicly-owned mass transit authority shall not be transferred to another party without the prior approval of the State highway agency.

(3) That, if the publicly-owned mass transit authority fails within a reasonable or agreed time to use the land for the purpose for which it was made available, or if it abandons the land or the facility developed, such use shall terminate and any abandoned facility developed or under development by the publicly-owned mass transit authority shall be disposed of in a manner prescribed by the State.

(b) A copy of the use and modification under paragraphs (a)(1),(2), and (3) of this section shall be forwarded to the Federal Highway Administrator.

810.212 Use to be Without Charge

The use and occupancy of the lands made available by the State to the publicly-owned transit authority shall be without charge. Costs incidental to making the lands available for mass transit shall be borne by the publicly-owned mass transit authority.

Section III of title 23, U.S.C., as implemented (23 CFR Section 1.23), applies to privately-owned rail facilities using Interstate rights-of-way. Section 1.23 (c) provides that an approval decision must be based on the factor that the private use is in the "public interest". However, this is the minimum requirement. The Federal Highway Administration (FHWA) may apply other criteria in accordance with law to such determinations. The Administrator's decision to consider an application for private use of rights-of-way is also "discretionary" (Calhoun, 1984).

23 CFR Section 1.23, Rights-of-Way

(a) Interest to be acquired. The State shall acquire rights-of-way of such nature and extent as are adequate for the construction, operation and maintenance of a project.

(b) Use for highway purposes. Except as provided under paragraph (c) of this section, all real property, included air space, within the right-of-way boundaries of a project shall be accepted as complete until this requirement has been satisfied. The State highway department shall be responsible for preserving such right-of-way free of all public and private installations, facilities or encroachments, except (1) those approved under paragraph (c) of this section; (2) those which the Administrator approves as constituting a part of a highway or as necessary for its operation, use or maintenance for public highway purposes and (3) informational sites established and maintained in accordance with 1.35 of the regulations in this part.

(c) Other use or occupancy. Subject to 23 U.S.C. 111, the temporary or permanent occupancy or use of right-of-way including air space, for nonhighway purposes and the reservation of subsurface mineral rights within the boundaries of the rights-of-way of Federal-aid highways, may be approved by the Administrator, if he determines that such occupancy, use or reservation is in the public interest and will not impair the highway or interfere with the free and safe flow of traffic thereon.

Regardless of the application, public or private, Federal approval for use on Interstate rights-of-way for a HSR system would probably trigger the National Environmental Policy Act (NEPA); Sections 4321 through 4347 of title 42, U.S.C. NEPA applies to certain Federal actions and requires comprehensive consideration of environmental impacts as a condition for Federal approval (Calhoun, 1984). The subject areas addressed by the various sections of the Act are:

Section 4321.	Congressional declaration of purpose
Section 4331.	Congressional declaration of national environmental policy
Section 4332.	Cooperation of agencies; reports; availability of information; recommendations; international and national coordination of efforts
Section 4333.	Conformity of administrative procedures to national environmental policy.
Section 4334.	Other statutory obligations of agencies
Section 4335.	Efforts supplemental to existing authorizations
Section 4341.	Reports to Congress; recommendations for legislation
Section 4342.	Establishment; membership; chairman; appointments
Section 4343.	Employment of personnel, experts and consultants

Section 4344.	Duties and functions
Section 4345.	Consultation with Citizen's Advisory Committee on Environmental Quality and other representatives
Section 4346.	Tenure and compensation of members
Section 4347.	Authorization of appropriations

Sections 4342 through 4346 of the Act deal with the establishment and work of the Council on Environmental Quality in the Office of the President. The NEPA process has been implemented by the Council of Environmental Quality issuing procedures at 40 CFR parts 1500 - 1508 that apply to all Federal agencies with an approval or permitting role. These regulations specify what must be done to comply with the procedures and to achieve NEPA goals (Calhoun, 1984). The topic areas covered in the regulations issued by the Council are:

Part 1500	Purpose, policy, and mandate
Part 1501	NEPA and Agency planning
Part 1502	Environmental impact statement
Part 1503	Commenting
Part 1504	Predecision referrals to the Council of proposed Federal actions determined to be environmentally unsatisfactory
Part 1505	NEPA and Agency decisionmaking
Part 1506	Other requirements of NEPA
Part 1507	Agency compliance
Part 1508	Terminology and Index

In accordance with the Council's regulations, FHWA issued joint regulations with the Urban Mass Transportation Administration (UMTA) at 23 CFR 771. These regulations are designed to incorporate the Department of Transportation procedures (Calhoun, 1984). The various sections of 23 CFR 771 consist of:

Section 771.101	Purpose.
Section 771.103	Authority and related statutes and orders.
Section 771.105	Policy.
Section 771.107	Definitions.
Section 771.109	Applicability and responsibilities.
Section 771.111	Early coordination, public involvement, and project development.
Section 771.113	Timing of administration actions.
Section 771.115	Classes of action.
Section 771.117	Categorical exclusions.
Section 771.119	Environmental assessments.
Section 771.121	Finding of no significant impact.

Section 771.123	Draft environmental impact statements.
Section 771.125	Final environmental impact statements.
Section 771.127	Record of decision.
Section 771.129	Reevaluation.
Section 771.131	Emergency action procedures.
Section 771.133	Compliance with other requirements.
Section 771.135	Section 4(f) of the Department of Transportation Act.
Section 771.137	International actions.

The "Texas Triangle" could involve the activities of several agencies and, therefore, require their review and approval. While this is no means comprehensive, a listing of the Federal laws that the HSR project could trigger follows: HSR construction, if in wetland areas, may require a dredge and fill (section 404) permit under the Clean Water Act from the United States Army Corps of Engineers; 33 U.S.C. part 1344, implementing regulations at 33 CFR 330. If the project requires a bridge or structure to be built over or in any navigable water, a bridge permit would be required from the United States Coast Guard; 33 CFR 114-115. Under the Endangered Species Act, 16 U.S.C. Parts 1531-1543, the FHWA would have to ensure that approval of the HSR project is not likely to jeopardize the continued existence of any endangered or threatened plant or animal species, or result in the destruction or adverse modification of a habitat area determined by the Secretary of the Interior to be critical to the species continued existence. If the project affects properties included in or eligible for inclusion in the National Register of Historic Places, the National Historic Preservation Act (16 U.S.C. 470, implemented at 36 CFR 800) would apply and require approval of the Advisory Council on Historic Preservation (Calhoun, 1984).

Federal highway planning requirements would also apply to both private and public use of rights-of-way in urban areas of 50,000 population or more. A proposed action in urbanized areas must be based on a continuing comprehensive transportation planning process carried on in accordance with 23. U.S.C. 134 as described under 23 CFR 450, Subparts A and B (Calhoun, 1984).

CONSTRUCTION AND OPERATIONAL CONSIDERATIONS OF IMPLEMENTING HSR SERVICES

General

This section of the report presents both the design and operational considerations associated with HSR systems and the physical characteristics of the involved Interstate highways connecting the Texas Triangle. Included herein are the following subsections:

- Human Factors Pertaining to HSR Operation
- High Speed Train Technologies
- High Speed Rail Geometrics
- Interstate Characteristics on the Texas Triangle
- Simulation of High Speed Rail Operation

The subject of "Human Factors" plays a key role in defining the operational limits or parameters under which a HSR system may operate. The six degrees of vehicle movement are presented along with the human tolerances to acceleration forces, vibration and jerk. The passenger or human tolerance to these dynamic forces will determine the range of acceptable HSR technologies. The part dealing with "High Speed Train Technologies" presents the technical and operations factors associated with a variety of rail systems extending from conventional AMTRAK service to the relatively new MagLev systems.

The subsection entitled "High Speed Rail Geometrics" discusses horizontal curves and the necessity of incorporating spirals and tracks superelevation in the design of a HSR system. In addition, an analysis of various alignments, as a function of train speed, is presented in terms of existing Interstate rights-of-way and geometrics.

The part titled "Interstate Characteristics on the Texas Triangle" summarizes the physical features and highway geometrics found on the existing freeway facilities of the Triangle. The last subsection, "Simulation of High Speed Rail Operation", presents the results of superimposing a range of HSR technologies upon the existing freeway geometrics.

Human Factors Pertaining to HSR Operation

The general problem of isolating the passenger compartment of ground-based vehicles from external disturbances (such as roadway irregularities, wind gusts, banking in curves, etc.) is rather complex. Passenger accelerations which arise from the vertical, lateral and longitudinal accelerations of the center of mass of the vehicle and from the roll, pitch and yaw motions of the vehicle around its center of mass should be kept within tolerable passenger comfort limits while guiding the vehicle along a prescribed path. Even neglecting the torsional and bending modes of the vehicle itself, the task becomes extremely difficult as cruising speeds are increased. A vehicle in motion has six degrees of possible movement as illustrated in Figure 21 and in Table 1.

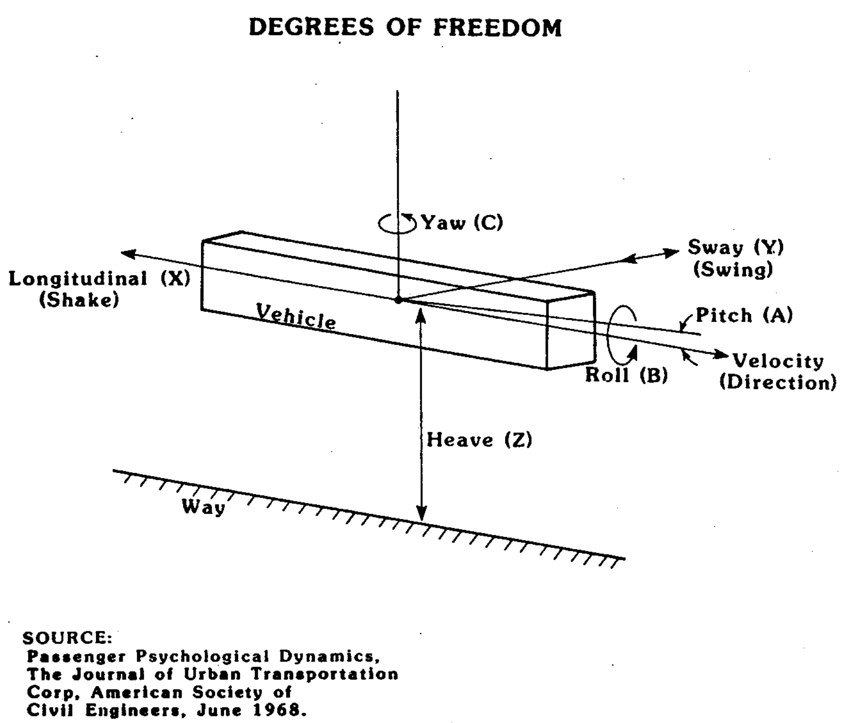


Figure 21: A Vehicle's Six Degrees of Movement

TABLE 1: LINEAR AND TORSIONAL DEGREES OF FREEDOM

(X) (Z) (Y)	Longitudinal (Shake) Vertical (Heave) Lateral (Sway)/(Swing)	LINEAR
(A) (B) (C)	Pitch Roll Yaw	TORSIONAL

Note: Refer to Figure 21 for the six degrees of movement.

The passenger is primarily concerned with only one motion, the speed (velocity) in the direction of their destination. However, in early (1932) pioneering work on linear motion tolerance, the following was noted (Passenger Psychological Dynamics, 1968):

> Human beings are not directly sensitive to velocity. They are sometimes indirectly sensitive, as when high velocity produces high wind pressure upon part of the body. Carried in a completely closed box moving without vibration a human being could not tell whether the box was standing or being moved at low or extremely high velocity. The reason is simple: Once in motion at any constant velocity and within an enclosure which moves our atmosphere with us, no force need operate on us to keep us in such motion. It is the operation of forces that we are sensitive to. The conditions are...quite different when velocity is being changed,...when acceleration occurs. To produce (acceleration) a force must act upon us....Thus if an individual is seated in a cushioned, high backed seat and is accelerated in the forward direction, the accelerating forces will be applied by the seat and distributed well over a large area of the body. The standing and walking passenger are in positions in which comparatively small accelerating forces may be expected to have large effects upon their equilibrium and comfort....(since) the passenger can be accelerated only by means of the parts of the car with which he is in contact.

Nothing is achieved without costs. The newer high speed passenger rail lines are no exceptions. Aside from the obvious costs associated with development and construction, there are more subtle considerations which must be taken into account. One of these considerations involves the cost associated with the benefit of the time savings of higher speeds. This cost can be rendered in terms of the acceleration forces to which passengers are subjected.

Acceleration is a characteristic of movement to which humans have a limited tolerance and an even smaller comfort range. It is a characteristic that has been experienced in small quantities, in automobiles, airplanes, and amusement rides, by virtually everyone in modern society.

It is generally measured in terms of the ratio of acceleration generated to the acceleration of gravity. For example, a body accelerating at 96.6 ft./sec^2 is experiencing an acceleration of 96.6/32.2 or 3G. A body accelerating upward at 3G would feel a weight of three times its normal weight (Gell, 1961).

Acceleration can be either linear or angular. Linear acceleration is the rate of change of velocity of mass, the direction of movement being kept constant. In turn, angular acceleration is the rate of change of direction of a mass, the velocity of which is kept constant. However, there are two forms of angular acceleration. One form, radial acceleration, is that in which the axis of rotation is external to the body (as in an aircraft turn). The other, commonly refered to as angular acceleration, is that in which the axis of rotation passes through the body (as when a ballet dancer is twirling around on her toe) (McCormick, 1976).

In the case of passengers on a high speed train, the two forms of acceleration of concern are linear and radial. Linear forces result primarily from a train accelerating to operating speed or slowing to a stop. Radial forces result as a train traverses vertical and horizontal curves on the track.

When the human body is caused to accelerate, that is, change velocity or direction, a physiologically reactive force is created in opposition to the change. "This reactive force is manifested by a displacement of the heart and other organs, body tissue, and blood, since these body components are not rigid." (McCormick, 1976).

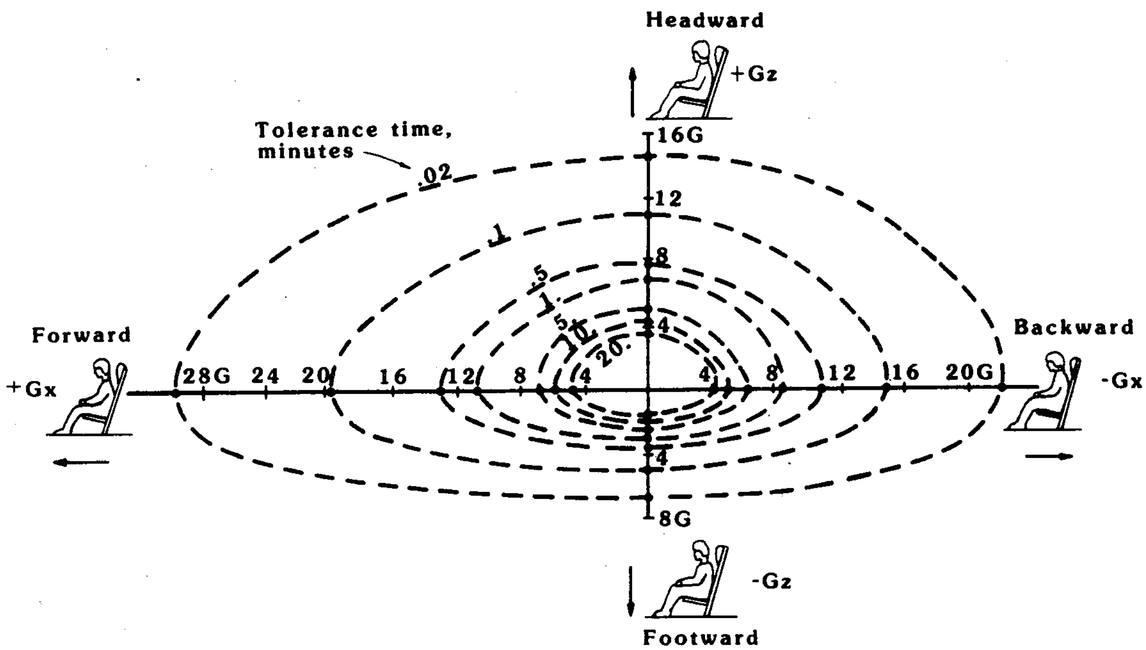
The effects of physiological reactive forces increase with the magnitude of acceleration applied and the duration of that acceleration. They range from difficulties in movement to loss of consciousness, internal damage and death. There are also variations in effects due to direction, for example, headward acceleration causes a pooling of blood in the feet and results in blackout, or loss of vision. Footward acceleration causes an infusion of blood to the head and leads to redout, or reddening of vision. Reference ranges necessary to produce various effects are presented in Table 2. A range of voluntary tolerance to acceleration and the duration of exposure is presented in Figure 22.

Comfort limits for acceleration are drastically lower than tolerance levels. These limits occur well before the onset of any major physiological change and have been assessed by means of subjective opinion. Comfort limits vary with the position of the person subjected to the acceleration (seated or standing), the task being performed (driver or passenger), and vehicle type.

TABLE 2. PHYSIOLOGICAL EFFECTS OF ACCELERATION

ACCELERATION RANGE	DIRECTION	PHYSIOLOGICAL EFFECTS
About 2 1/2 G	Headward	Difficult to raise oneself.
3 to 4 G	Headward	Impossible to raise oneself, progressive dimming of vision.
4 1/2 to 6 G	Headward	Diminution of vision, progressing to blackout after 5 seconds.
1 G	Footward	Unpleasant, but tolerable facial suffusion and congestion.
2 to 3 G	Footward	Severe facial congestion, throbbing headache, progressive blurring, graying or occasionally reddening of vision after 5 seconds.
5 G	Footward	Blackout after 5 seconds.
12 to 15 G	Forward & Backward	Can be tolerated for 100 seconds.

Duration Limits of Voluntary Acceleration Tolerance



SOURCE: McCormick, E.J., Human Factors in Engineering and Design, 1976.

Figure 22. Human Tolerance Limits to Acceleration Forces

In general, the comfort range for forward acceleration (starting) is between 0.09 to 0.26G (2.0 to 5.7 mphps); the range for backward acceleration (stopping) is approximately the same. The comfort range for lateral acceleration (horizontal curves) is slightly lower, between 0.06 to 0.22G (1.3 to 4.8 mphps). Acceptable vertical acceleration (vertical curves) is around 0.3G (6.6 mphps) (Gebhard, 1970; Quinby, 1976). A summary of comfort limits for acceleration under various conditions is presented in Table 3.

TABLE 3. ACCELERATION COMFORT LIMITS FROM VARIOUS STUDIES

Vehicle	Passenger Position	Acceleration (g)	Jerk (g/s)
Starting			
Trolley bus	Seated & standing	0.12	----
Elec. train	Seated & standing	0.11	----
Elec. train	Seated	0.15	----
Laboratory car on a track	Standing (freely)	0.09[1]	----
	Standing (strap)	0.23[2]	----
	Standing (stanchion)	0.27[2]	----
Automobile	Seated	0.26	----
Stopping			
Trolley bus	Seated & standing	0.12	----
Elec. train	Seated & standing	0.11	----
Elec. train	Seated	0.13	----
Elec. train	Seated	0.14	0.30
Elec. train	Standing	0.11	0.12
Elec. train	Seated	0.11[3]	0.09
Elec. train	Standing	0.09[3]	0.06
Automobile	Seated	0.26	----
Curves			
Steam train	Seated	0.06	0.04
Diesel train	Seated	0.10	0.03
Trolley car	Seated	0.07	----
Elec. train	Seated	0.11	----
Elec. train	Seated	0.22[3]	0.07

[1]Equilibrium maintained in 90% of all tests to the attained acceleration.

[2]Average acceleration attained before balance was lost.

[3]For 90% of all passengers.

NOTE: 1.00G equals 21.95 miles per hour per second (mphps).

Source: Gebhard, 1970

The acceleration forces experienced by passengers of high speed trains can be controlled by various means. Starting and stopping forces can be limited by the acceleration and braking characteristics of the system. Use of longer distances to get to operating speed and to begin stopping can reduce the acceleration. The comfort limits imposed can be extended to some degree by providing high backed, reclining seats with arms. However, this will not assist passengers who are standing or walking. It has been suggested that a warning system that signals starting, stopping and the impending entrance to curves, coupled with hand rails or other means of supporting standing passengers, could be used to extend the range of comfortable acceleration (Gebhard, 1970).

The acceleration forces generated by vertical curves are determined by speed and by changes in grades along the right-of-way. In the instance of rail lines following right-of-way of interstate highway systems, vertical acceleration should not be a problem. In those few cases where rapid changes in grades may exist, it would be necessary to reduce speeds to accommodate passengers.

Horizontal curves produce accelerations that are the most difficult and expensive to control. In order to maintain a constant speed, changes are required in either radius of curvature or track superelevation (banking) to reduce lateral acceleration. Using a simplified computational expression, it can be determined that a train travelling at 100 mph around a curve having a radius of 10,000 feet on a track with an 8 degree bank would produce a lateral acceleration of about 0.47G, which is twice the comfortable limit (Miller, 1959):

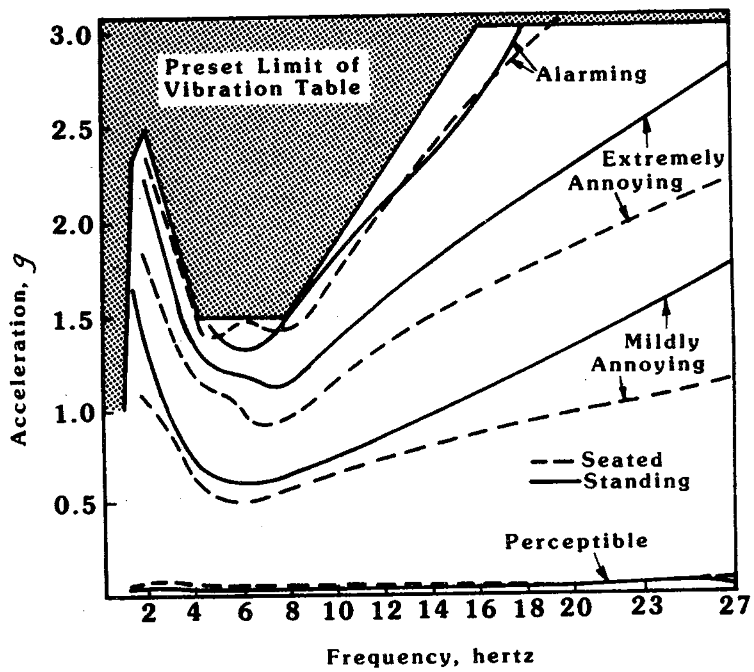
$$\text{Lateral Acceleration} = \frac{\text{(Train Speed) X (Train Speed)}}{\text{(Curves Radius) X (Tangent of Superelevation) X 32}}$$

Curves of such large radius are common on existing high speed rail facilities; however, they normally require purchases of large and expensive rights-of-way. Likewise, increases in track superelevation are costly and are limited in their magnitude. Another method of compensating for lateral acceleration in horizontal curves involves tilting car bodies. Experimental results from prototype vehicles indicate that passenger comfort can be maintained while speeds are increased 30 percent by having a car body tilt about 6.5 degrees. Tilting car bodies appear to artificially increase the superelevation of a track, but will undoubtedly increase expense as well (Middleton, 1984). Once again, the least expensive alternative would be to reduce speeds on the approaches to curves.

The use of restraints, either active or passive, for passengers would allow slight increases in acceleration comfort limits and would be particularly useful in instances of collision and derailment. Unfortunately, they would not serve those passengers who are standing or walking around.

One other facet of acceleration which must be considered is vibration or jerk, the frequency of onset and offset of acceleration. The maximum jerk rate preferred for comfort is around 0.10G per second (Gebhard, 1970; Quinby, 1976). Since high speed rail facilities will be intercity with few station stops, this should not be a problem. Vibration from wheels over track joints should be dampered by the suspension system of the rail car and should not pose a problem to passenger comfort. However, Figure 23 is included for reference.

COMFORT RANGE OF VIBRATION



SOURCE: McCormick, E.J., Human Factors in Engineering and Design, 1976.

Figure 23: Frequency Limits of Vibration or Jerk on Passengers

High Speed Train Technologies

General: Technologies Investigated

Range of Technologies

Historically, many planners have failed to appreciate the early achievements of railway technology in High Speed Rail (HSR) passenger service. A speed of 112 MPH was achieved as early as 1893 by the Empire State Express of the New York Central. The following presents an abbreviated summary of past HSR records (Rice, 1975):

1893, U.S.A., Empire State Express of the New York Central Railroad; 112 MPH steam engine pulling 3 coaches in Mohawk Valley, New York; approximately 200 tons with 500 horsepower (2.5 HP/T).

1903, Germany (Two Records), Specially built 3-phase test track and railcars; 125 MPH single electric units south of Berlin; approximately 70 tons with 1200 horsepower (17.1 HP/T).

1905, U.S.A., Broadway Limited on the Pennsylvania Railroad; 127 MPH steam engine pulling 3 cars in Ohio; approximately 300 tons with 800 horsepower (2.7 HP/T).

1933, Germany, The "Flying Hamburger" of the German Railways; 134 MPH two-car articulated train; approximately 100 tons with 1000 horsepower (10 HP/T).

1934, U.S.A., Pioneer Zephyr on the Chicago, Burlington & Quincy Railroad; 112 MPH lightweight diesel train from Chicago to Denver; weight and horsepower unknown.

1937, Italy, The ETR-200 Unit Electric Trains; 120 MPH on the Rome to Milan run; weight and horsepower unknown.

1954-55, France, French National Railways Electric Locomotive Trains; 205 MPH record using 1500 V. dc locomotives with three car train on straight track near Bordeaux; approximately 250 to 300 tons with 8000 horsepower (27 HP/T).

1963, Japan, Tokaido Line of the Japanese National Railway; 159 MPH on test runs using 2 and 4 car trains; approximately 260 tons with 3200 horsepower (12.3 HP/T).

1966, U.S.A., Jet-Propelled "RDC" Car on New York Central Railroad; 184 MPH converted rail car using a B-36 Convair Dual engine pod on long tangent between Butler, Indiana and Striker, Ohio; weight and horsepower unknown.

1967, U.S.A., Northeast Corridor EMU Test train on the Pennsylvania Railroad; 156 MPH four electric suburban cars between Trenton and New Brunswick; approximately 200 to 250 tons with 4000 horsepower (16.0 HP/T).

The conventional steel-wheel-on-steel-rail technologies investigated for this study ranged from the AMTRAK train, as shown in Figure 24, through current HSR systems such as the British HST (Boocock, 1976, 1982, 1983; British Rail, no date) and the French Train a' Grande Vitesse (TGV) trains as shown in Figure 25 (French Railway Techniques, 1978). In addition, an assumed "Ideal" train was considered which may only be theoretically possible or which may exceed operational limits in some assumptions. All but the theoretical or "Ideal" train have been constructed and successfully operated. The AMTRAK train was the lowest-performance option while the 350 MPH technology was the highest. Each of the major subdivisions of rail technology is discussed herein. The conventional diesel-powered passenger train operating on shared freight railroad tracks was not included, as this investigation assumed exclusive passenger trackage.

AMTRAK SERVICE WITH ELECTRICAL POWER

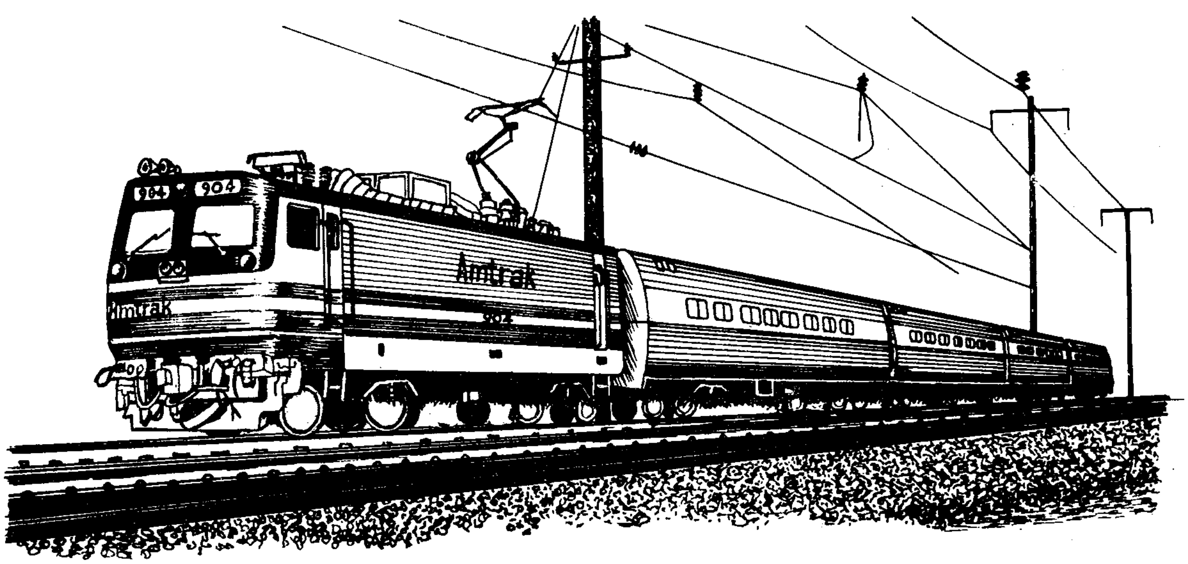


Figure 24. Conventional Steel-Wheel-On-Steel-Rail AMTRAK Train.

FRENCH TGV IN RURAL AREA

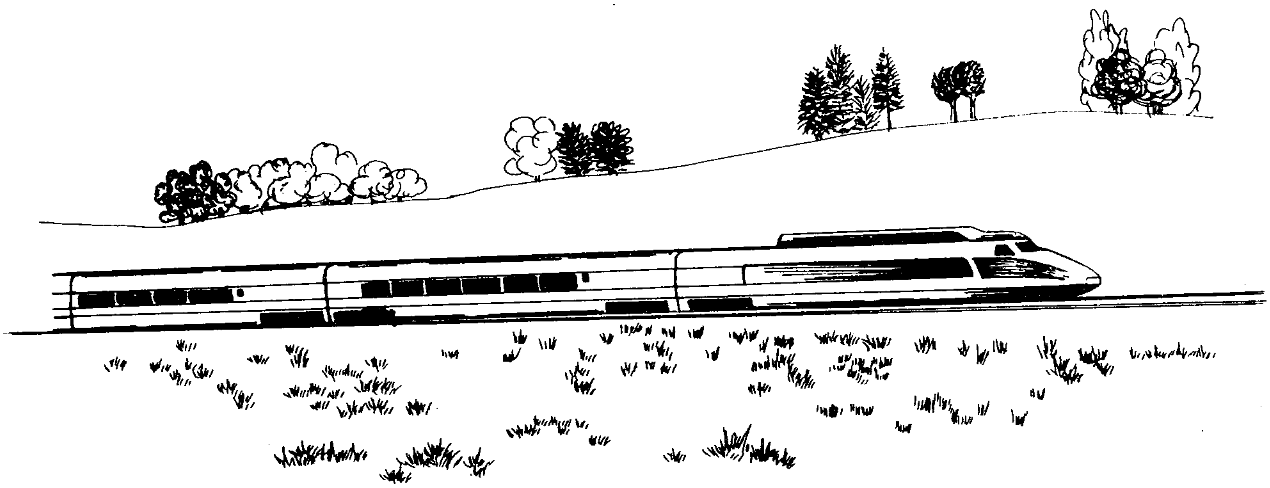


Figure 25. Advanced HSR Service Operating in France

Performance characteristics of these trains were estimated and employed in a computer simulation to investigate operations on the Highway rights-of-way of the Texas Triangle. Results indicated that the AMTRAK train, with a maximum speed of 120 MPH, would be slower than travel by air. At the other extreme, the "Ideal" train with a top speed of 350 MPH and the 200 MPH conventional High Speed train would favorably compete, in terms of travel time, with air travel. The Simulation portion and Appendix B of this report contains further discussions of the runs, assumptions, and implications of applying the various rail technologies on the Texas Triangle.

Motive Power

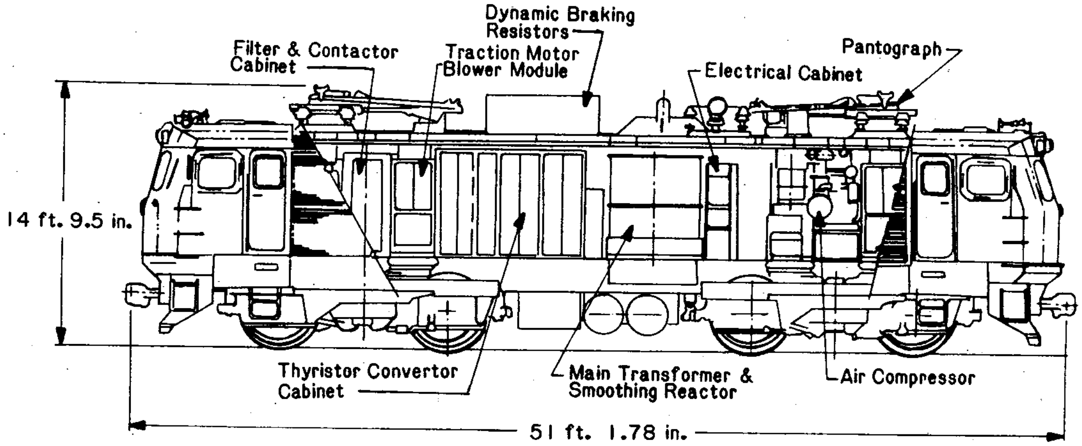
Three common types of train motive power which could be used on the Texas Triangle are Diesel-Electric, Gas Turbine-Electric, and straight Electric. For this study, only straight electric external-source power was considered. Both diesel-electric and gas-turbine power sources are bulkier due to the requirement of on-board power generation. If these power sources, similar to the locomotive shown in Figure 26, are considered desirable to reduce construction costs on more lightly-traveled lines, it can be assumed that somewhat higher horsepower would provide performance similar to that of the straight electric power used for this study.

Figure 26. Conventional On-Board Power Generating Locomotive for HSR Service

Straight electric propulsion systems for HSR usually take power from an overhead catenary system. A single electric locomotive can be used as illustrated in Figure 27 for an AMTRAK train or electricity may be distributed to powered axles throughout the length of the train as represented for the TGV system in Figure 28. Straight electric power eliminates the need for on-board generators and allows the use of larger, stationary generation plants with high efficiency, multiple energy sources, and effective pollution abatement devices. Furthermore, if the power transmission system is adequate, very high short-term applications of power can be made to the traction motors which are considerably higher than the motors' continuous ratings.

The electric traction motors can be used as brakes by electrically switching them to serve as generators, which will aid the other braking systems in slowing the trains. While regenerative possibilities exist (electricity generated by the traction motors in the braking mode being fed back into the power distribution system), in practice this would increase weight and complexity of on-board equipment to a considerable degree; it is more likely that the power generated during braking would be "wasted" through a resistor grid unless new technology is developed.

Straight electric power for the Texas Triangle will necessitate high-voltage overhead power distribution, with its attendant costs and problems. The high power requirements of the trains, coupled with the relatively long distances involved, will require transmission voltages in the area of 11,000 volts AC or higher. Sparking and bounce of the electrical pickup (made more severe by high speed) may be a serious problem. Due to the high power requirements, it is anticipated that every axle may be powered with a 500 or 600 horsepower motor. Pantographs cause aerodynamic drag, and the overhead transmission line with its supporting structure may be considered unsightly to some. The high-voltage transmission system can cause nearby electrical



The AEM-7 Locomotive General Arrangement

Source : Ephaim , Max ," The AEM-7 : A New High Speed , Light Weight Electric Passenger Locomotive ", ASME, Paper No. 82-RT-7 , New York , New York

Figure 27. Electric Locomotive Typical of High Speed AMTRAK Service.

THE FRENCH TGV CATENARY SYSTEM

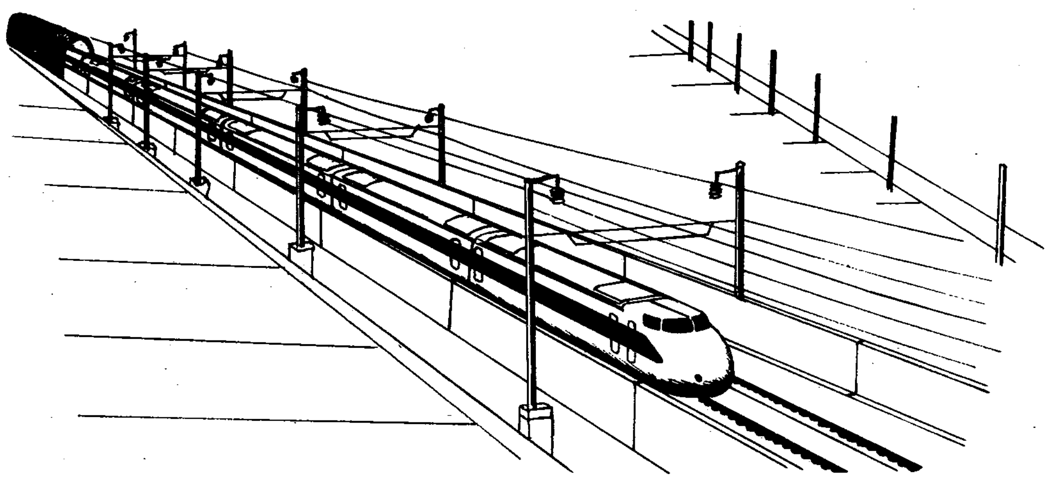


Figure 28. Electrical Power Distributed to Powered Axles Throughout a TGV Train.

interference to radio and communication systems. The power transmission system is expensive and the power losses in the distribution system can be significant. However, the overall advantages of straight electric power are expected to outweigh the disadvantages for an advanced HSR system.

Non-electric final drive propulsion systems, such as steam, direct diesel drive, or diesel-hydraulic, were not considered here; the performance of such systems for HSR service of 200 MPH and higher has not been proven reliable or cost-effective, as of this time. If future developments make a non-electric drive feasible for the Texas Triangle, differences in the performance curves might cause some changes in travel times; however, changes in trip times are not expected to be significant.

AMTRAK Trains

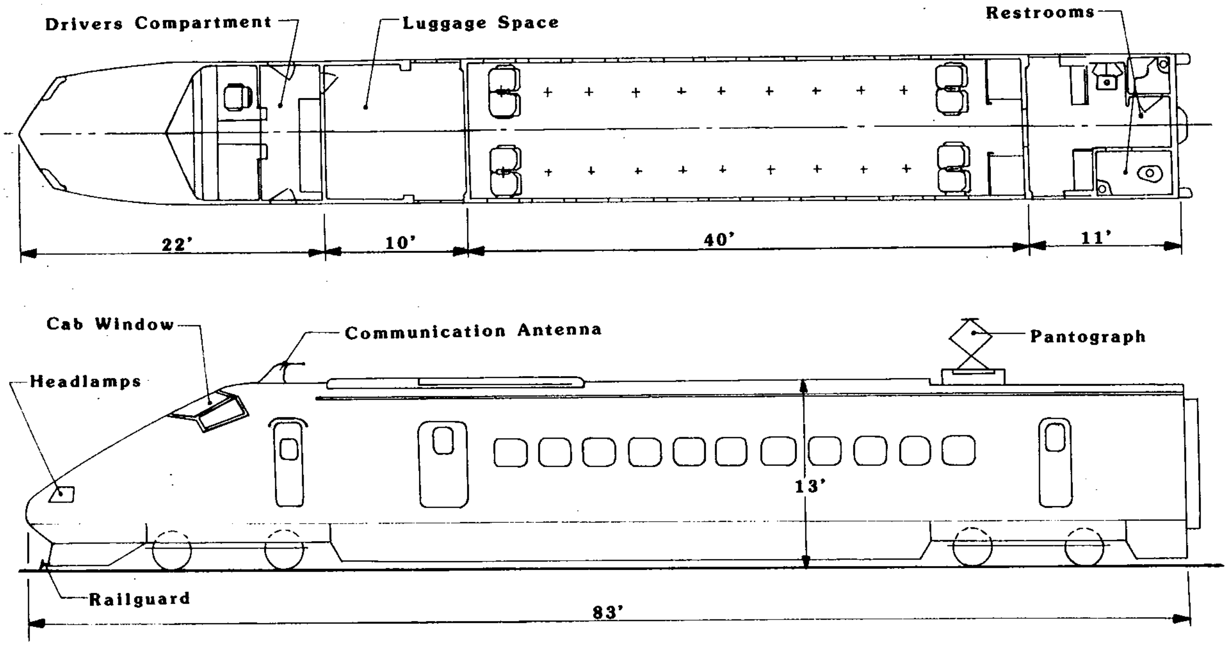
The AMTRAK train selected for comparison is composed of a 6000-hp General Electric E60 CP, six-motor, 6-axle (C-C) locomotive, with a continuous tractive effort of 34,000 pounds and a starting tractive effort of 75,000 pounds. This locomotive is 71.25 feet long (inside coupler knuckles), weighs 350,000 pounds (175 tons), has a top speed of 120 MPH, and can use 11,000 volts, 12,500 volts, or 25,000 volts. Performance characteristics were approximated in straight-line segments from an acceleration curve for the locomotive pulling a modern 7-car Amcoach train (Hay, 1982). Deceleration was assumed to be a constant minus 2 MPH per second. Each car is 85 feet long and 10.5 feet wide with electric heat. This type of car comes in Amcoach, Amcafe, Amdinette, and Amlounge configurations (Car & Locomotive Cyclopedia, 1980).

This train is actually very close to some foreign High Speed Trains. As pointed out in Railway Age (Publisher's Perspective, May 1984), the 120 MPH AMTRAK Metroliner trains operate only 5 to 10 MPH less than some of the highly-publicized Japanese Shinkansen trains. The Metroliners were originally designed for even higher speeds of 160 MPH, and have been tested at 164 MPH (High Speed Jetport Access, 1969). Thus, it is a misconception that only foreign trains are capable of high speed service.

Japanese Shinkansen "Bullet" Trains

The double-ended Japanese Shinkansen "Bullet" trains were put into service between Tokyo and Shin-Osaka in 1964 or some 20 years ago. The original line has been extended since that time. Original maximum operating speed was 210 km/hr, or 128 MPH, although new lines are being built which would be capable of 260 km/hr (159 MPH) if environmental problems can be adequately addressed. Each axle is powered by a 185 kw motor. Estimated average life of the coaches is 13 years (Nordqvist, 1980). These trains as proposed for HSR corridors in California and Florida would generally follow a standard North American engineering practice. Figures 29 and 30 present a typical profile and cross section of a proposed American adaptation of the Japanese Bullet train, respectively.

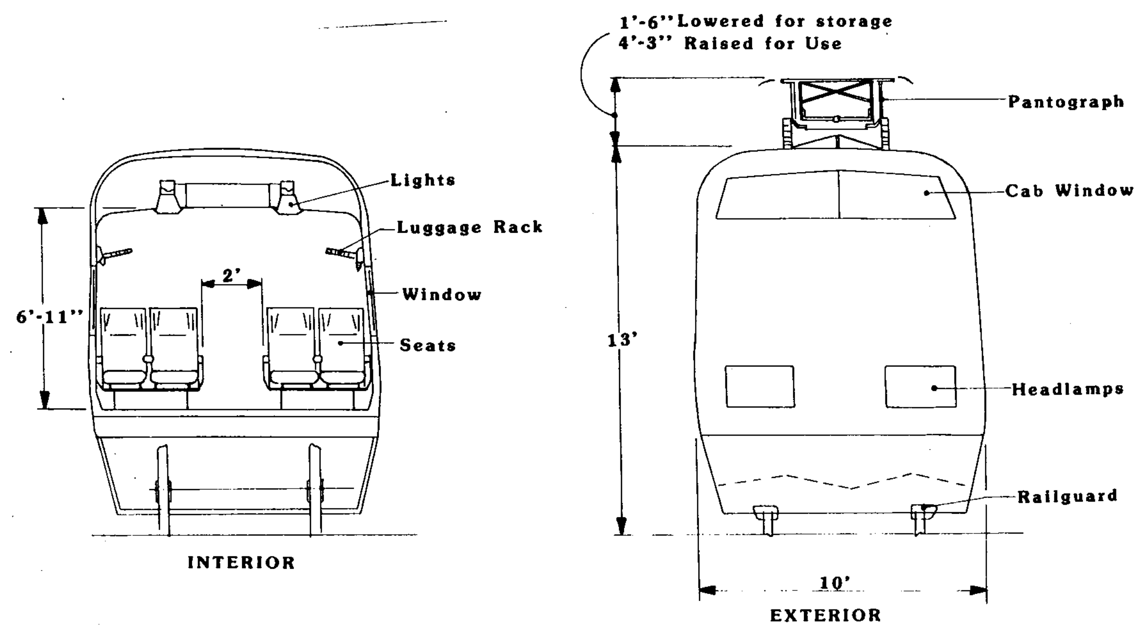
As noted previously, current Shinkansen operation is not markedly superior to AMTRAK technology. However, the Japanese track is given considerably more labor-intensive maintenance than track used by AMTRAK in the Northeast Corridor. With American maintenance standards, Shinkansen trains could be expected to perform only slightly faster than the AMTRAK train. For this reason, the Shinkansen train was not simulated as a separate rail technology. This is not to imply that the improved, higher-speed Japanese trains are not suitable for the Texas Triangle. A Japanese "Bullet" train with 200 MPH top speed might be expected to give performance characteristics similar to the High Speed trains simulated in this analysis.



TYPICAL CALIFORNIA HIGH SPEED TRAIN

SOURCE:
American High Speed
Rail Corporation, Los Angeles,
California, January 1984

Figure 29. Profile View of the Japanese Bullet Train



TYPICAL CROSS SECTION OF CALIFORNIA HIGH SPEED TRAIN

SOURCE:
American High Speed
Rail Corporation, Los Angeles,
California, January 1984

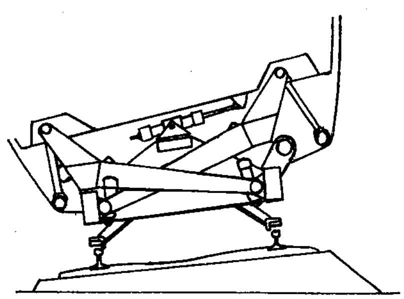
Figure 30. Cross Section and Frontal View of Japanese Bullet Train

Tilting Trains

One limiting factor in high speed train operation is "passenger comfort" when going around curves as discussed in the Human Factors section. Several European countries and Canada have been testing the concept of tilting the bodies of the trains as they round curves to allow higher operating speeds with a given track curvature. The mechanical limitations of speed on curves are much higher than the comfort limitations. Tilting of the train bodies, as illustrated in Figure 31, allows significantly higher operating speeds.

Operation of a high speed train over existing rights-of-way often involves rounding curves which are too sharp to be traversed in comfort, due to the lateral forces on passengers. Increasing track superelevation ("tilting" the tracks) will increase the speeds at which trains can comfortably round curves. Practical superelevation limits probably lie between 8 inches and 12 inches for exclusive passenger lines; the current AREA and FRA superelevation

PASSENGER COMFORT CONSIDERATIONS



Tilting Mechanism

SOURCE: Rosen, John, ITE Compendium of Technical Papers, August 1983.

Figure 31. Tilting of Train Cars to Achieve Higher Speeds on Horizontal Curves.

limits are 6 inches. Various studies have shown that passengers can comfortably take lateral forces equivalent to 3.5 to 6 inches unbalanced superelevation (Hay, 1982; Paquette, 1982; Gebhard, 1970) which corresponds to 0.06 to 0.10 g's. Present US DOT specifications for High Speed ground transportation allow a maximum of 0.08 g lateral acceleration, which is approximately 4.75 inches of unbalanced superelevation, and 0.15 g longitudinal acceleration, which is approximately 3.28 MPH per second (Ronald, et. al., 1976). Even with greater unbalanced superelevations, sharper curves limit maximum operating speeds significantly based on the estimate that the sine of the superelevation angle approximates the tangent of that angle at small angles:

$$E = 0.0007V^2D \qquad \text{Eq. 1}$$

Where: E = Superelevation in inches for standard 4' 8-1/2" gage

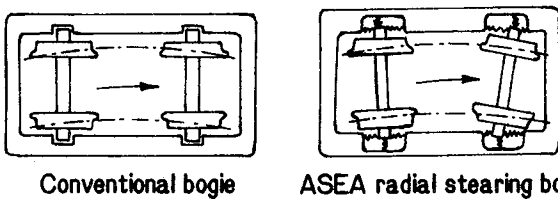
V = Train speed in MPH

D = Degrees of curvature

Several concepts have been investigated for improving train operation on horizontal curves; some of these have proven adequate for HSR systems. Modifications of the truck (bogie) are shown in Figure 32 and free running wheelsets as illustrated in Figure 33 are examples of these investigations. The Spanish Talgo train tested the concept of tilting the carbodies in 1977 at speeds up to 122 MPH (200 km/hr), using a pendulum-type of mechanism (Carillo, 1977). For the speeds contemplated today, a more positive mechanism is necessary. The Italian Pendolino train utilizes hydraulically-tilted coaches, but operating speed is only 180 km/hr or 110 MPH (Nordqvist, 1980). The Canadian LRC can tilt as much as 8.5 degrees with a maximum speed of 125 MPH (Hollingworth, 1984).

The British have developed a train which can tilt up to 9 degrees and operate at speeds of up to 250 km/hr (155 MPH). Tilting is accomplished by

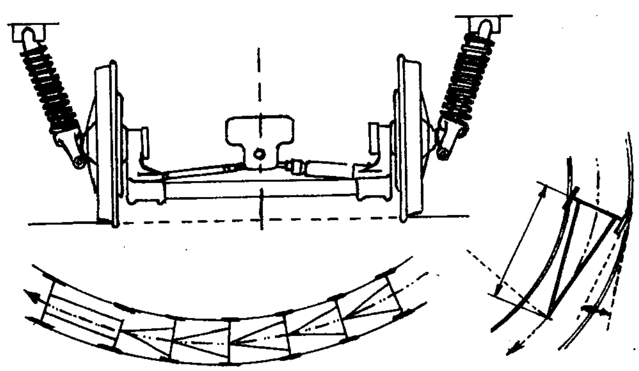
BOGIE SYSTEMS



SOURCE: Rosen, John, ITE Compendium of Technical Papers, August 1983.

Figure 32. Modification of Bogie to Improve Train Operation on Horizontal Curves

FREE RUNNING WHEELSETS



The Talgo train concept

SOURCE: Rosen, John, ITE Compendium of Technical Papers, August 1983.

Figure 33. Investigation of Wheelset Modification to Improve Train Operation on Horizontal Curves

use of spirit-level accelerometers which control hydraulic jacks as shown in Figure 34. While development and refinement are still underway, some problems with the tilting control have been encountered. If the tilting mechanism fails to return the cars upright, striking adjacent trains may result. On the other hand, even with a full reverse tilt or the maximum malfunction mode, the trains retain stability on sharp curves, although with considerable passenger discomfort. These British APT trains differ from the Japanese and the French trains in that motive power is provided by centrally-located power cars; coach axles are not powered (Boocock, 1982 & 1983).

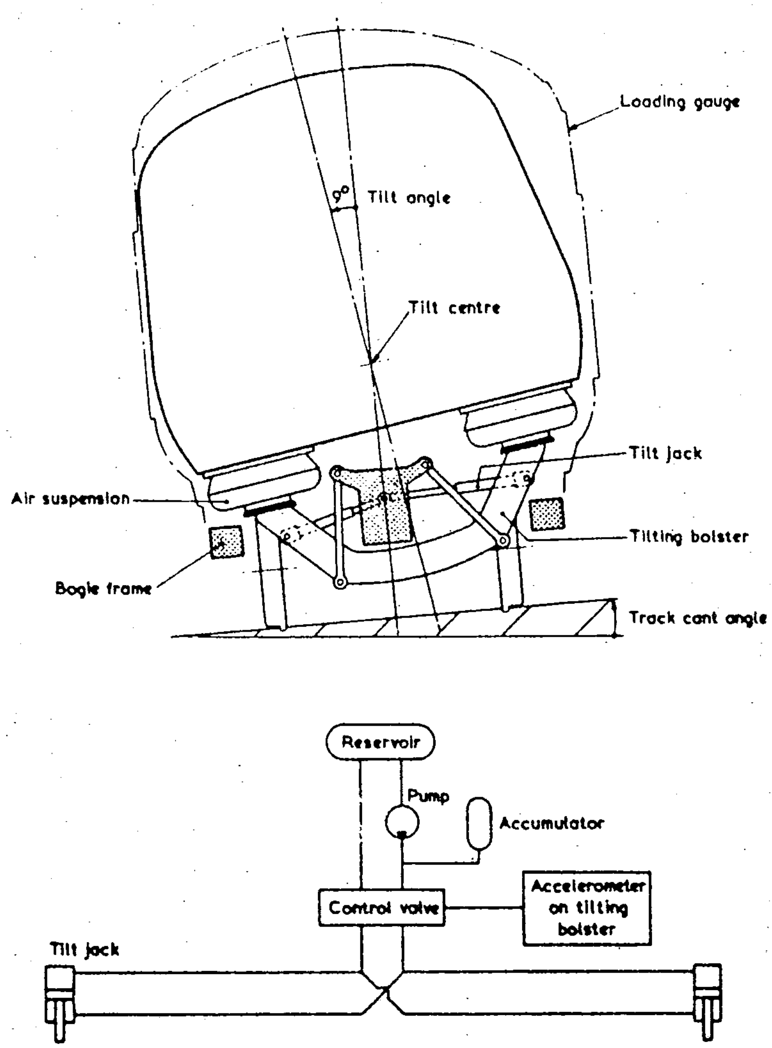


Figure 34. Arrangement of Vehicle Tilt Suspension and Simplified Control System

Sweden has been experimenting with a computer-controlled tilting mechanism which provides for train tilting of up to 6.5 degrees (Middleton, 1984). These tests are not complete as of this writing.

Due to the British problems, it was decided to limit the tilt of the prototype trains simulated for the Texas Triangle to 6 degrees. This does not imply that greater tilts may not be feasible, or that a greater amount of tilt coupled with less actual "on-the-track" superelevation might not be employed to achieve the same total (Actual + Tilt + Unbalance) superelevation as those simulated.

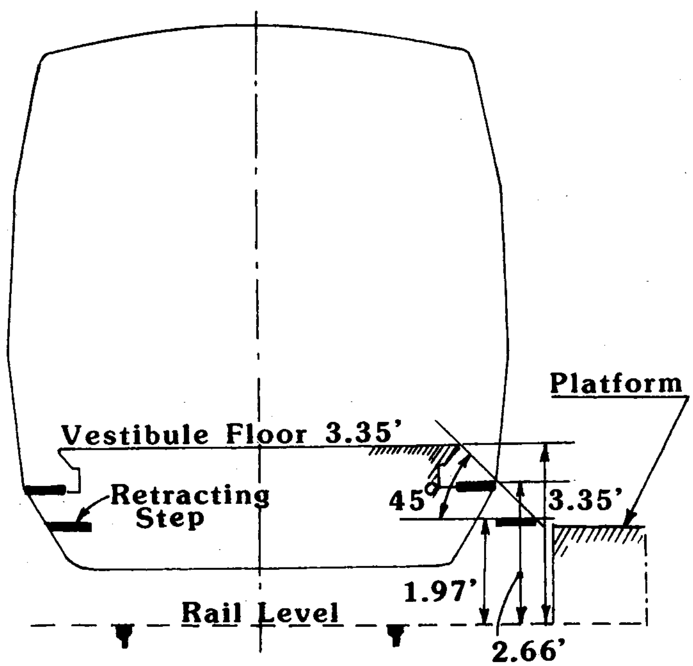
French TGV Trains

The French have been operating a high-speed passenger train called the TGV (Train a' Grande Vitesse) at speeds of up to 183 MPH (300 km/hr) between Paris and Lyon, using conventional rail technology refined to a very high degree (French Railway Techniques, 1978). The TGV has set the present maximum speed for conventional railroad trains, achieving 239 MPH (392 km/hr) on a special speed run (American Railway Engineering Association presentation, New Orleans, October 1982).

Although curves are very wide (radius of 4000 meters or 13,120 feet), the maximum grade is 3.5%. The cars do not tilt. Propulsion is straight electric, with every other truck powered on this articulated train (one truck between and supporting each two coaches). The shape has been highly streamlined through wind-tunnel tests (French Railway Techniques, 1978; Metzler, 1983). One aerodynamic feature of the car bodies is the retractable steps for passengers as shown in Figure 35.

Track is standard 4' 8-1/2" gage, with 115 pound rail clipped to prestressed concrete ties in ballast. This type of construction is similar to that used by AMTRAK on the Northeast Corridor. The TGV train has been proposed for use in Florida and also for operation between Houston and Dallas over the former Rock Island right-of-way (Cooper, 1984). While the simulations indicate that this type of train would be feasible for operation in the Texas Triangle, the simulations also suggest that performance of such trains in highway medians would be significantly improved by the addition of carbody tilting mechanisms as previously described. Preliminary examination of the structure of the TGV suggests that this could be added; however, further engineering would be required to determine if a tilting TGV would, in fact, be feasible.

ACCESS STEPS FOR THE TGV



SOURCE: French Railway Techniques,
Francorail, Paris, France, 1978.

Figure 35. Cross Section of French TGV Showing Aerodynamically Designed Retractable Passenger Steps

"Ideal" Train Concept

Another conventional train technology examined for use on the Texas Triangle was a theoretical train with enough power to fully take advantage of all mechanical capabilities up to a speed of 350 MPH. As such, it must be recognized that a train of this performance level has yet to be constructed. Some of the assumptions made may be too extreme for actual service in a somewhat uncertain physical world. For example, the assumed adhesion (coefficient of friction between the wheels and the rails) of 0.05 at 350 MPH is based upon French tests at lower speeds; such adhesion (and the resulting acceleration rate) could require dry rails, obviously impossible to guarantee. As maximum tractive effort (accelerating force) is equal to weight times adhesion if all wheels are powered, performance will be limited at high speeds due to the reduction in adhesion.

Furthermore, at these high speeds, streamlining will play a major role in the air resistance portion of total train resistance. Force for acceleration must be provided through wheel traction, unless some alternate form of motive power, such as jet propulsion or linear induction motors, are employed. As train speed increases, air resistance will increase exponentially. As this occurs, more tractive force will be used to overcome train resistance, leaving less for acceleration, until top speed on level ground is reached when all tractive force is used to balance train resistance:

$$A = F/m = (TE - Rt \pm Rg)/m = (TE - Rt)/m \quad \text{if } Rg = 0 \qquad \text{Eq. 2}$$

A = Acceleration
F = Resultant Force
TE = Tractive effort
m = Mass
Rt = Train Resistance = .Friction Factors + .Air Resistance Factors
Rg = Grade Resistance (assumed to be zero for this study)

Various studies indicate that air resistance is highly dependent upon streamlining and increases exponentially with speed. Tests of train streamlining in the 1930's resulted in the Totten Formula (Hay, 1982):

$$Ra = (0.0020\ Pc(1/100)^{0.88} + K)V^2 \qquad \text{Eq. 3}$$

Where Ra = Air resistance in pounds
L = Length of train in feet
Pc = Perimeter in feet (assumed 35)
K = Streamline design factor (0.0 if perfect)
V = Train speed in MPH

For illustration, using this formula for a train of six-85-foot cars:

$$Ra = 0.29V^2 \qquad \text{Eq. 4}$$

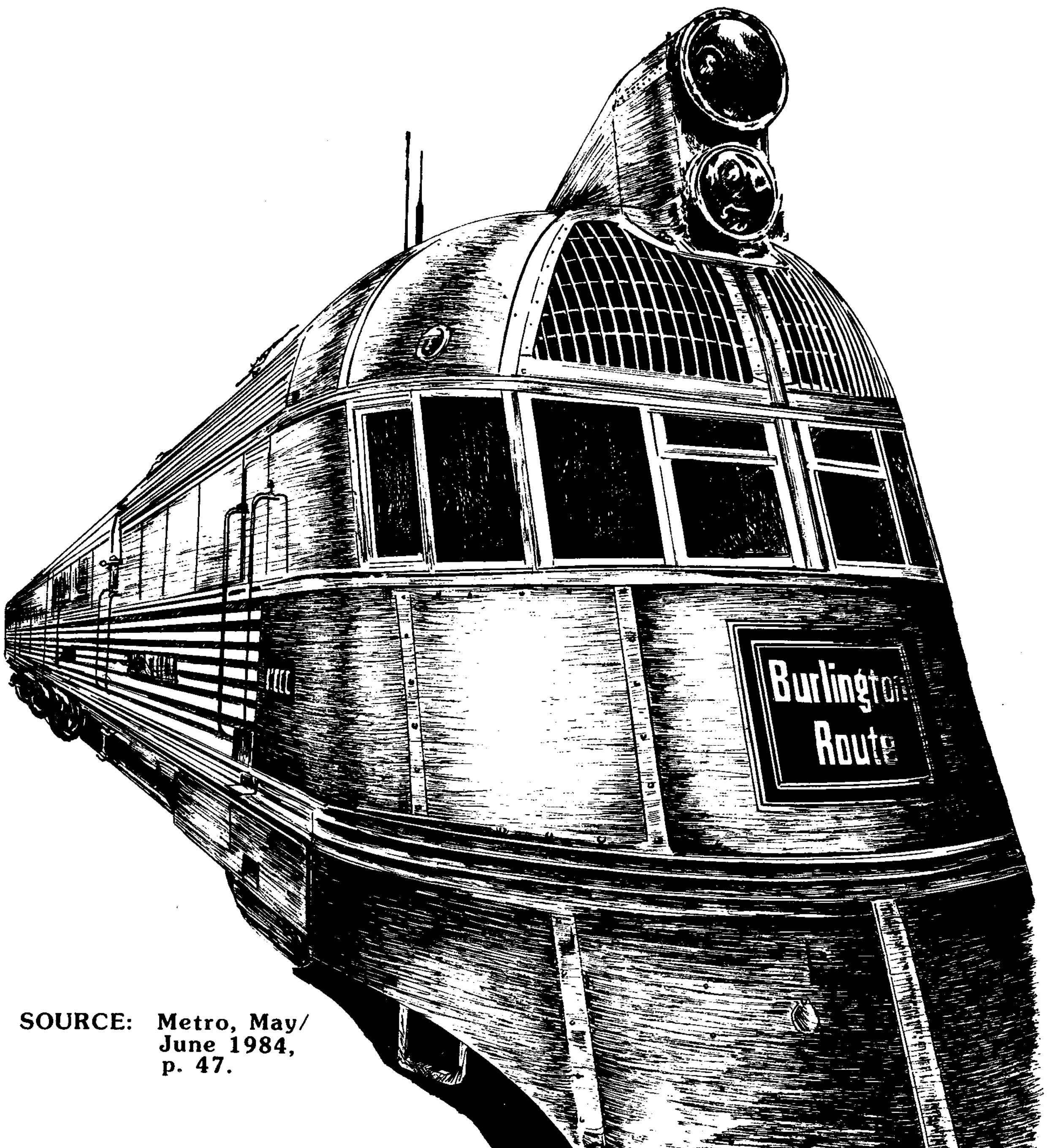
Air resistance increases with the square of the velocity or speed. This results in a resistance of 2900 pounds at 100 MPH, 11,600 pounds at 200 MPH, and 35,525 pounds at 350 MPH, using this formula.

More recent wind tunnel studies no longer depend on these simplified assumptions. They show that interference effects such as gaps between cars and protruding items produce marked changes (Rosen, 1983; French Railway Techniques, 1978).

It is interesting to note that one of the World's first High Speed, diesel-powered trains was designed and operated in the United States over 50 years ago. This lightweight train was aerodynamically streamlined and reached a top speed of 112.5 miles per hour on May 26, 1934; it was known as the Pioneer Zephyr and is shown in Figure 36 (Metro, May/June 1984).

Although grade and curve resistance will affect acceleration, their effects were not considered, as both grades and resistance should not have much overall affect on performance or schedules for the routes investigated. Deceleration would be greater, as train resistance would augment wheel traction rather than oppose it. Nevertheless, at higher speeds there may not be enough retarding force in the combination of train resistance and wheel friction to slow that train at the assumed comfort maximum of minus 3 MPH per

THE PIONEER ZEPHYR-1934



SOURCE: Metro, May/ June 1984, p. 47.

Figure 36. World's First Diesel-Powered HSR Train which was Aerodynamically Designed Using the Totten Formula (The "Ideal" Train of the 1930's)

second. Additional retarding force might be obtained from retractable spoilers, magnetic attraction to the rails (possibly using electric current from regenerative braking), or even sliding direct-rail contact magnetic brakes. Wheel brakes would not be the freight-type brake shoes which bear directly on the wheel tread, as these would generate excessive heat within the wheel rims which would probably result in wheel fracture. Instead, some combination of regenerative braking (with traction motors turned into generators), disk brakes, such as used by AMTRAK and the TGV, or turbine brakes, such as used by British Rail would be used; possibly with additional emergency systems such as direct-rail contact magnetic brakes. The heat energy generated during braking would probably be expended into the air.

No construction details of this "Ideal" train concept were developed, as it was assumed that the train would be capable of providing a comfortable, safe ride at these high speeds. The train would probably be articulated, and all axles would be, of necessity, powered. A high degree of streamlining would be required. The train could conceivably resemble the French TGV in appearance, but exceeding the current design in the number of powered axles and performance. The train might be fully-skirted to minimize air resistance. Carbody tilt would probably be a necessity to minimize the need for drastic speed reductions at each curve or the use of excessive track superelevation.

At higher speeds, the shock wave and proximity effects caused by the rapid passage of the train through the air could be severe (HSGT Systems, 1970). The "wind wash" of a 350-MPH train in a highway median overtaking a vehicle moving at 55 MPH could be enough to impact the motorist. The driver also would probably be very startled as the train passed less than 20 feet away. For these reasons, it would probably be necessary to either fence the trains within the median to separate them visually and block the wind wash, or to use grade separation of the tracks in the highway medians. Further tests and experiments would be needed to determine the severity of the problem, based on the shape of the train and the top speed. It can be expected that a 200-MPH top speed would have less wind wash than a 350-MPH train speed. Also, the colors of the train might be made more subdued to minimize the "startle" effects of being passed. Noise could also play a major role in system design.

MagLev Technology

The ability of conventional trains to travel safely at speeds above 200 MPH is often questioned. The adhesion capability and the instability of the steel wheels over steel rails is cited. Magnetically levitated trains, better known by their abbreviated name of "MagLev", seem quite capable of achieving speeds well over 200 MPH with a high degree of safety.

MagLev is an emerging technology in the prototype stage that depends on magnetically induced energy fields to support, propel and stop these trains and to power onboard electrical equipment. No physical contacts exist between a moving train and the tracks.

The Germans and the Japanese have tested prototype models and are in the process of manufacturing full scale trains to run on test tracks. The German system, designated as Transrapid, braces the train suspension around the T-shaped track as shown in Figures 37 and 38. The Japanese MagLev test vehicle and guideway are shown in Figure 39. These vehicles are unlikely to derail or have an accident with another train or vehicle. Since the train rides on a beam structure, the guideway must be elevated. The possibility of a collision with another train on the same track is unlikely because both train speed and direction are controlled by the linear motor partly built onto the track. Figures 40 and 41 show the German support structure and the cross section of a typical car, respectively.

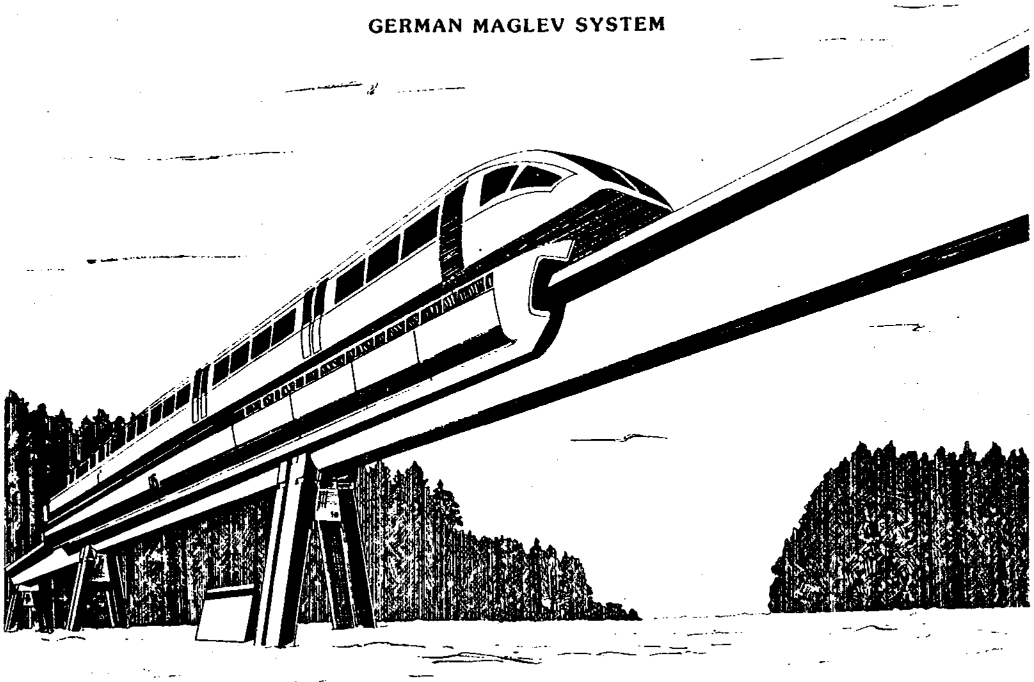
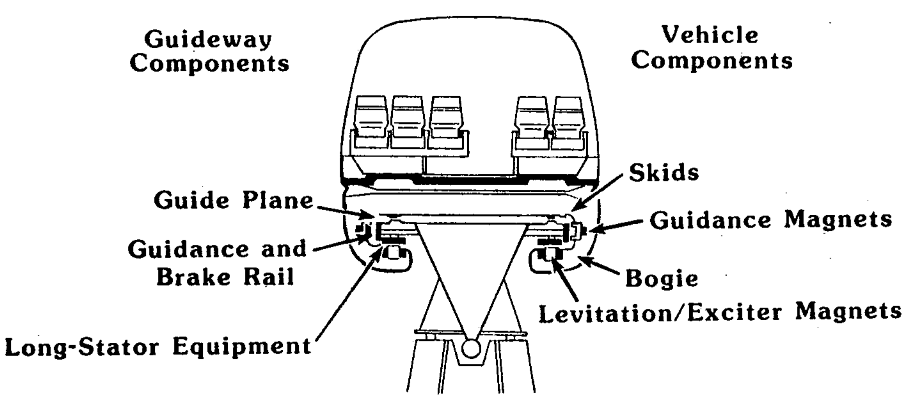


Figure 37. The German MagLev High Speed Support Structure and Train

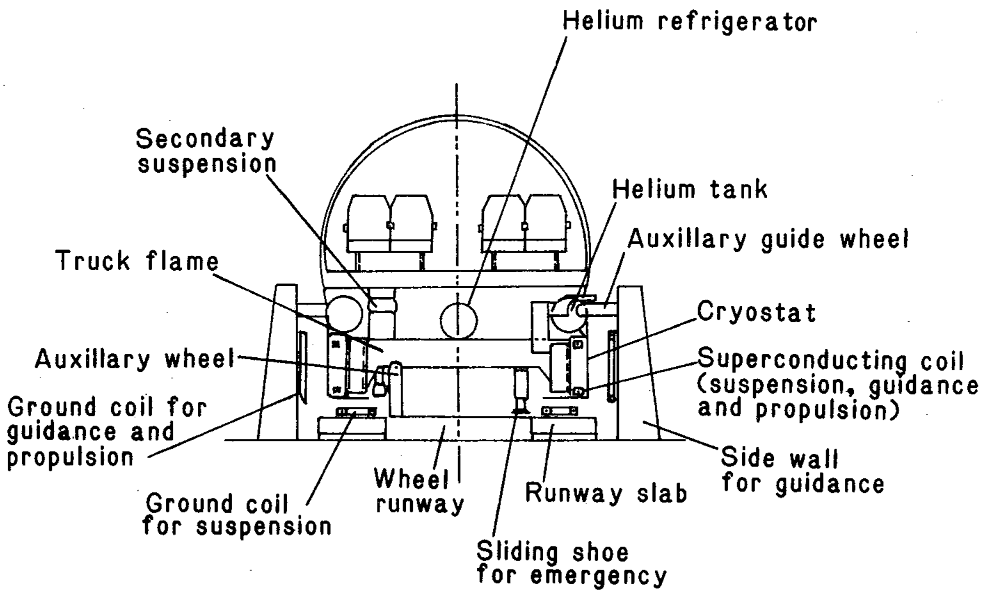


Cross section drawing identifies principal lifting, guidance and propulsion elements of the Transrapid 06 magnetic levitation system.

Source: The Budd Company,1984

Figure 38. The German MagLev Propulsion System

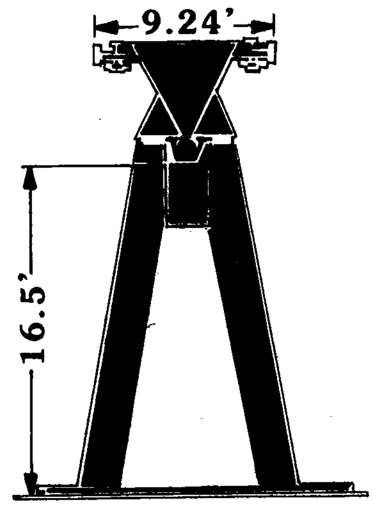
Standard Cross Section of Test Vehicle and Guideway



Source: Japanese National Railways,
1982 Edition: Facts & Figures

Figure 39. The Japanese MagLev Propulsion System

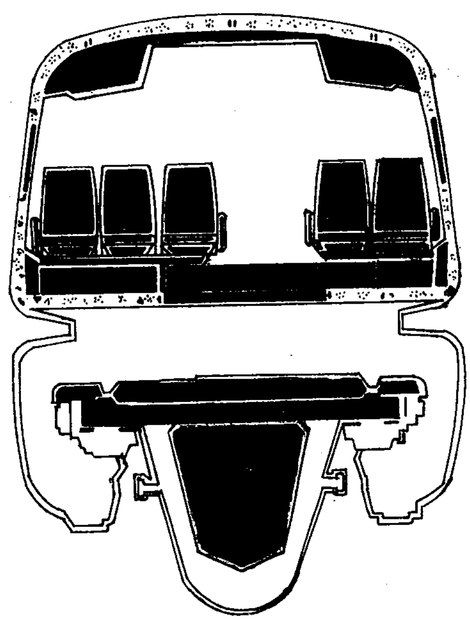
MagLev Support Structure



Source : AEG-TELEFUNKEN,Berlin,February 1984

Figure 40. The German Support Structure for MagLev Vehicles

MagLev Cross-Section



Source : AEG-TELEFUNKEN,Berlin,February 1984

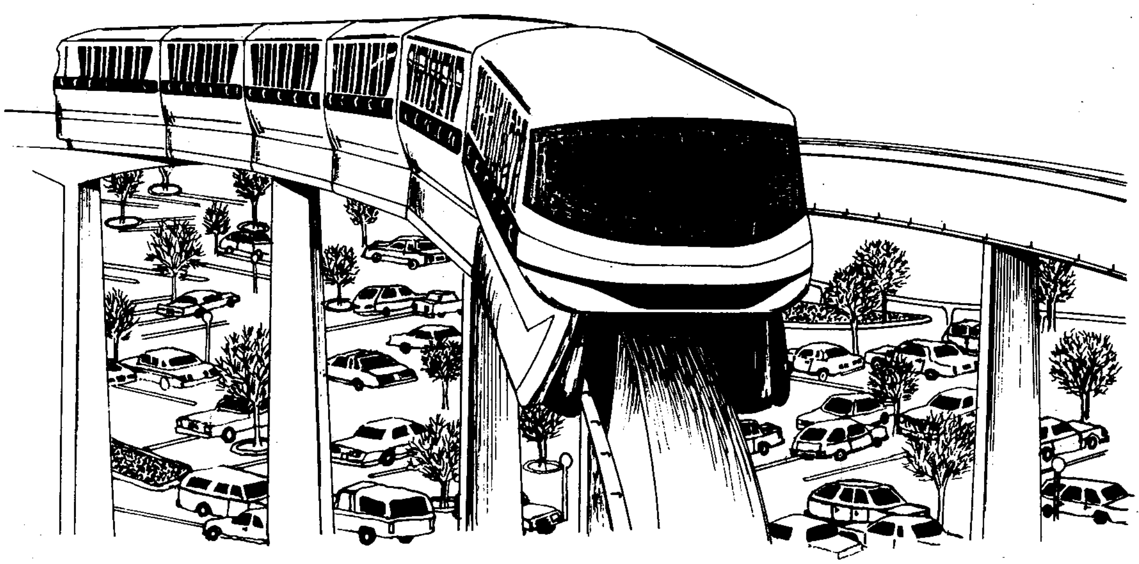
Figure 41. A Typical Cross-Section of a German MagLev Car Showing the Internal Beam Structure

What makes MagLev different from conventional rail systems and the similar looking Monorails (shown in Figure 42) is the magnetic, no-contact suspension and propulsion. In the Transrapid (German) version, each vehicle is levitated by 32 magnets mounted on the car's undercarriage below the guideway beam, while 28 magnets facing the outside edges of the track beam provide guidance (The Budd Company, 1984). Levitation and guidance power are supplied from on-board batteries which in turn are recharged by linear generators. At a standstill or slow speed, onboard batteries provide energy for the various train functions such as leviation, guidance, lighting and air conditioning. As the train gains speed, 45 MPH or over with Transrapid, a linear generator provides the power required for train functions. Beyond 75 MPH enough energy is generated to recharge the batteries. The German MagLev uses ElectroMagnetic Suspension (EMS) whereas the Japanese system employs ElectroDynamic Suspension (EDS) technology.

Propulsion in both the German and Japanese systems is provided by a synchronized linear induction motor similar to an AC motor which has been cut open and laid flat, as shown in Figure 43. It consists of continuous ferromagnetic stator elements with three phase windings mounted under both sides of the guideway beam throughout its length. The magnetic flux from the flat stator reacts with the car mounted levitation magnets; the magnets are equivalent to the rotor in an AC motor. The linear motor also serves as a standard brake. Variations in voltage, frequency and polarity of the power drawn from the power distribution substation provides the required propulsion or braking forces. To conserve energy the track is subdivided into several sections which are independently energized as a train approaches each section and switched off as the train leaves. The German MagLev floats on an air gap of 0.5 inches while the Japanese version has a 4.0 inch gap. Unlike the

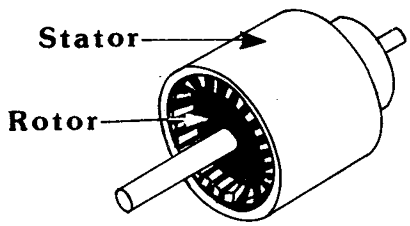
German system, the EDS technology has auxilary wheels for support at low speeds (less than 50 MPH).

**DISNEY WORLD MONORAIL
SERVING PARK-AND-RIDE LOT**

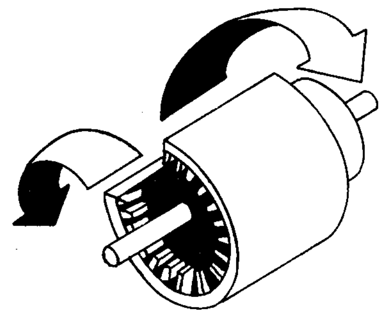


SOURCE: Passenger Transport, APTA, Vol. 41, No. 42, October 24, 1983, p. 72.

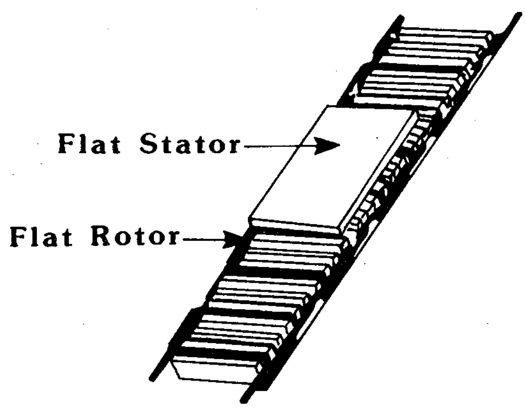
Figure 42. A Similar Appearing But Different Rail Technology from MagLev Systems



a) Conventional 3-Phase AC Motor



b) Cutting Open the AC Motor



c) Linear Induction Motor

Figure 43. Concept of the Synchronized Linear Induction Motor Used for MagLev Propulsion

Train speed and acceleration can be significantly improved over existing technology. The TGV cruises at 183 MPH (TGV Update, 1983) with initial acceleration estimated at about 1.6 mphps. In contrast the test track under construction for Transrapid in West Germany is planned to run at speeds up to 250 MPH (Repositioning for the Future, 1984). Early test by a Japanese prototype train achieved a top speed of 320 MPH with average acceleration of over 7 mphps (MagLev, 1983). Japanese EDS technology is more sophisticated than that of the Transrapid in that it uses superconducting magnets, but their marketable product seems to be running a few years behind the German system.

Both the Germans and the Japanese with their American partners have expressed interest in building a system in the United States. Various groups in Florida, Pennsylvania and the City of Las Vegas have considered the possibility of building an intercity system using this technology (High Speed Trains Gain Momentum, 1984). However, all projects are in the feasibility stage and are also considering conventional technology together with MagLev.

High Speed Rail Geometrics

Horizontal Curves

Travel time of rail passengers is a function of average train speed, and speed is a determinant of track geometrics. Train speed at equilibrium, that is when outer and inner wheels bear equally on the rails, is defined as:

$$V = \sqrt{\frac{e}{0.0007\ D}} \qquad \text{Eq. 5}$$

where: V = Train speed (mph),
e = Total or combined superelevation (inches), and
D = Degrees of horizontal curvature.

Both the degree of curvature and the superelevation affect track alignment.

The feasibility of utilizing freeway right-of-way (ROW) for high speed rail (HSR) service in the Texas Triangle (Houston to Dallas/Fort Worth to San Antonio) is dependent on track alignment. Ideally, high-speed trains would travel along freeway medians to make maximum use of ROW dedicated to transportation while keeping to a minimum construction costs and disruption to freeway traffic and adjacent land uses. However, freeways have been designed for much lower speeds than currently envisioned for the proposed HSR systems; road alignment is a constraint on track layout that determines the HSR cruise speed.

Vertical and horizontal track alignment is composed of tangents, curves, and spirals. Tangents are used whenever possible but curves and spirals are required to avoid obstacles resulting from natural and manmade topography. Vertical curves have an impact on project cost but can be discounted for preliminary analysis because freeway grades are generally smooth and below 5 percent. Horizontal alignment, however, can significantly affect grade separation, extra ROW and traffic disruption.

Service by HSR along the Texas Triangle is also limited by perceived passenger comfort. Speed restrictions at curves are largely the result of passenger comfort rather than the train's ability to negotiate curves at any given speed. Simple horizontal curves with spirals provide the smooth transition required to join tangent track alignments. For any given speed the degree of curvature and superelevation must be controlled to maintain lateral passenger acceleration and its rate of change (jerk) within the comfort limits.

Conventional trains moving along a horizontal curve subject themselves and passengers to centrifugal forces acting radially away from the center of curve. The centrifugal force, in pounds, is expressed by the equation:

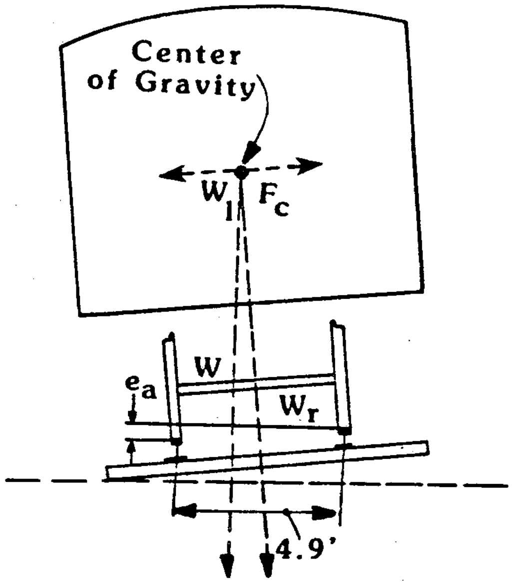
$$F_c \quad \frac{Wv}{Rg} \qquad \text{Eq. 6}$$

where: W = Weight of the car (lbs)
v = Speed of travel (ft/sec)
R = Curve radius (ft), and
g = The gravity constant (32.2 ft/sec^2)
F_c = Centrifugal force (lbs).

Figure 44 shows the forces acting on a rail car while moving along a curve.

The centrifugal force (F_c) is balanced by the lateral component, W_1 of the weight of the car brought about by the superelevation of the outside track, e_a. When this condition exists the car is said to be in equilibrium and passengers ride in comfort due to the absence of lateral forces on their bodies, much like "turn and bank" used by pilots in air travel.

Based on experience, it has been found that passengers can still feel comfortable when higher or lower speed induces an unbalanced lateral force. The Federal Railway Administration (FRA) specifies the use of a maximum of 3 inches of unbalanced superelevation, as measured by the extra superelevation that would be required to achieve equilibrium speed by raising the outer



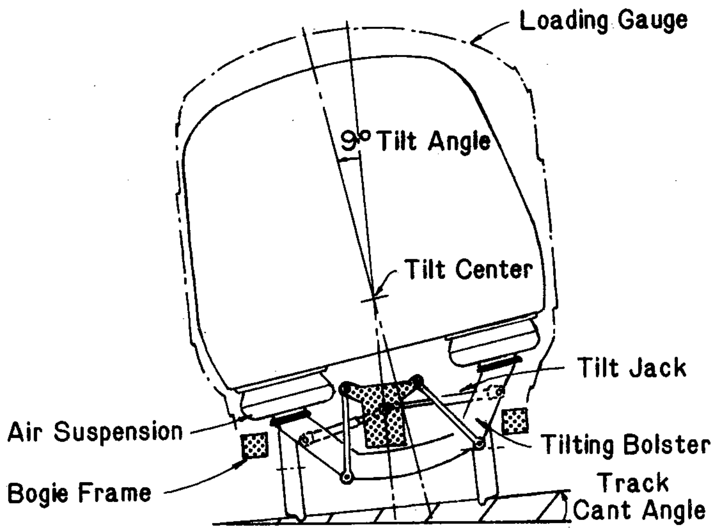
W = weight of rail
W_l = lateral component of W
W_r = normal component of W
F_c = centrifugal force
e_a = actual rail superelevation

Figure 44. Forces Acting Upon a Rail Car While Negotiating a Horizontal Curve

rail. Recent studies (Ronald, 1976) demonstrate the feasibility of using up to 4.5 inches of unbalanced superelevation in passenger trains equipped with stiffer suspension without significantly affecting comfort. The French railroads have allowed for the use of a maximum of 6.3 inches of unbalanced superelevation in their Train a' Grande Vitesse (TGV), even though in practice the new Paris-Lyon line remains below 4 inches.

Another way of achieving balanced forces on the passengers is to tilt passenger cars as done by the Swedish with their X-15 test train (Andersson, 1982). All three cars of this train have been equipped with body tilting up to a maximum angle of about 8 degrees. Tilting control responds to a sensor system including lateral accelerometers located in the first bogie of the train. The British railways also use tilting mechanisms which are active on the passenger cars only. Figure 45 depicts the way the British Advanced Passenger Train (APT) achieves tilting.

BRITISH RAILWAYS
ADVANCED PASSENGER TRAIN (APT)



APT Vehicle Tilt Suspension

SOURCE: Boocock, D., ITE Compendium of Technical Papers, August 1983.

Figure 45. Rail Car Tilting Mechanism Used By the British

To maximize speed along curves, maximum use of combined superelevation, e_c, should be made. This is composed of actual rail superelevation, train tilt, plus unbalanced superelevation. For the Texas Triangle, an advanced train that uses current but so far independent technologies could feasibly operate with 8 inches of actual superelevation, 6 inches of tilt equivalent superelevation and 4 inches of unbalanced superelevation. Maximum operating speed of such trains would be computed based on 18 inches of total superelevation.

Magnetically levitated trains (MagLev) could achieve even higher speeds (250+ mph) since they use no moving parts, but this technology is still in the prototype stage. Unlike conventional trains, these MagLev vehicles have a much wider track and are less subject to derailment even with very high actual superelevation. An actual superelevation equivalent of 20 inches is feasible, even though some passenger mobility problems may arise if trains need to stop at a curve under such conditions. Combined superelevation could total as much as 24 inches, allowing for 4 inches of unbalanced superelevation.

From Equations 1 and 5 it follows that at any given speed and superelevation a train can negotiate curves up to a certain degree of curvature. Degrees of each curve, as defined by the central angle subtended by a 100 feet arc (Meyer, et. al., 1980), can be obtained using the formula:

$$D = \frac{e_c}{0.0007\ V^2} \qquad \text{Eq. 7}$$

Where: e_c = Combined superelevation (inches), and

V = Train speed (mph), and

D = Degree of horizontal curve.

Table 4 shows computed values of degrees of curvature for speeds between 100 to 350 mph and superelevation of 4 to 24 inches.

TABLE 4: DEGREES OF CURVATURE (ARC DEFINITION)

Superelevation (Inches)	Speed (mph)					
	100	150	200	250	300	350
4.0	0.571	0.254	0.143	0.091	0.063	0.047
6.0	0.857	0.381	0.214	0.137	0.095	0.070
8.0	1.143	0.508	0.286	0.183	0.127	0.093
10.0	1.429	0.635	0.357	0.229	0.159	0.117
12.0	1.714	0.762	0.429	0.274	0.190	0.140
14.0	2.000	0.889	0.500	0.320	0.222	0.163
16.0	2.286	1.016	0.571	0.366	0.254	0.187
18.0	2.571	1.143	0.643	0.411	0.286	0.210
20.0	2.857	1.270	0.714	0.457	0.317	0.233
22.0	3.143	1.397	0.786	0.503	0.349	0.257
24.0	3.429	1.524	0.857	0.549	0.381	0.280

Note that superelevation is expressed in inches and implies combined superelevation, be it actual, tilt or unbalanced. Values range between 3.4 degrees for a train running at 100 mph with 24 inches of superelevation to 0.047 degrees (2 minutes-49 seconds) for a train speed of 350 mph with 4 inches of superelevation. For quick comparison, radius of a curve in feet can be approximately obtained from degrees of curvature by use of the equation:

$$R = \frac{5729.58}{D} \qquad \text{Eq. 7}$$

It may be observed that the above curves are all under one degree for speeds at or above 200 mph. Several freeway curves exceed one degree along the Texas Triangle's Interstate routing.

Spirals

Spirals are easement or transition curves joining tangents and simple curves. Spirals are necessary on railroads to gradually turn from the infinite radius of a tangent to the radius of a simple curve. Spirals also provide transitions in superelevation that together with gradual radius changes, permit balancing of the lateral force induced on passengers as a train travels through a curve.

The spiral commonly used throughout the United States is the cubic parabola, also known as linear spiral, where the offsets from the tangent to the spiral vary in proportion to the cube of the distance along the curve. Other countries such as Japan and Germany use the Cosine and Sine spirals, respectively, for high speed passenger railroads. All achieve the transitioning objective even though minor tradeoffs exist.

Figure 46 shows the use of spirals before and after a simple curve to join two tangents. Clockwise, the first spiral begins as the tangent to spiral point, TS, and ends at the spiral to curve point, SC. A detailed explanation of such spiral is beyond our scope but is explained in reference texts (Hay, 1982). For an HSR, spiral length is primarily a function of passenger comfort regarding vertical and lateral acceleration. At high speed and with current train technology, lateral acceleration is significantly greater that vertical acceleration (Ronald, 1976). Normally, the length of spiral in feet can be computed by:

$$L_s = 1.08\ e_u\ V \qquad \text{Eq. 9}$$

where: e_u = Unbalanced superelevation (inches); and

V = Train Velocity (MPH).

If actual superelevation remains significant while unbalanced superelevation is reduced, the length of spiral may be controlled by:

$$L_s = 0.24\ e_a\ V \qquad \text{Eq. 10}$$

where: e_a is actual superelevation (inches).

For non-tilting trains, minimum spiral length is the larger of the two relationships.

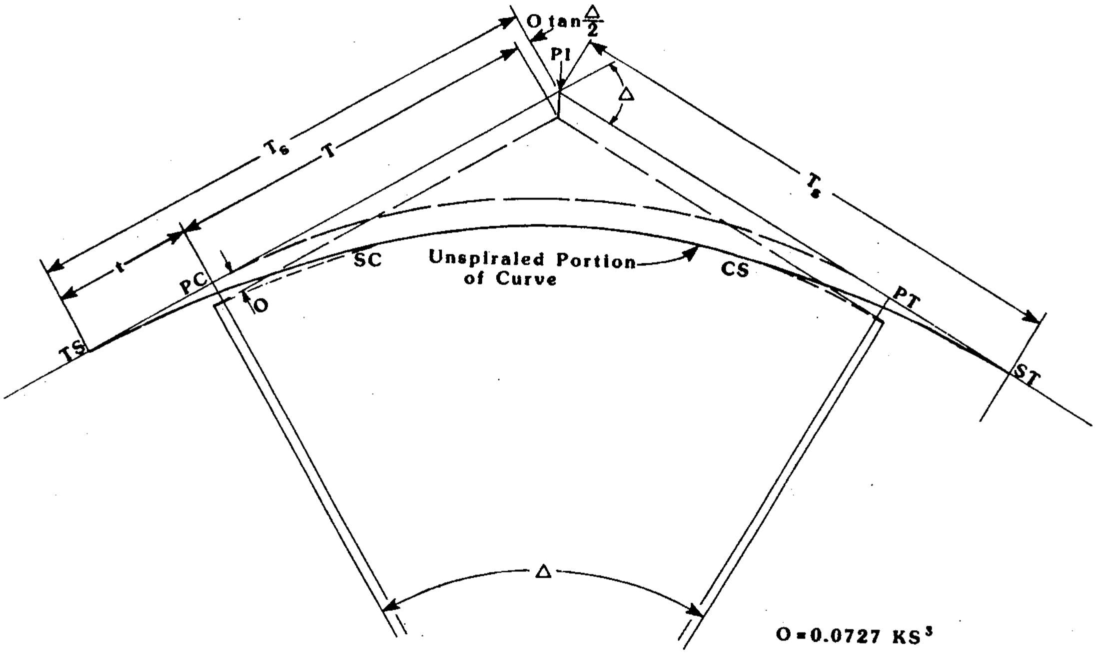


Figure 46. Use of Spirals Before and After a Simple Curve

With tilting trains, it is recommended to use the concept of determining minimum spiral length based on the distance travelled by a car in 3.33 seconds (Ronald, 1976). This is in consideration for the roll induced by the tilt and uncertainty regarding this technology. The equation to be used is:

$$L_S = 4.89\ V \qquad \text{Eq. 11}$$

This equation can be used for trains equipped with tilt, providing up to 9 inches of equivalent superelevation.

It is also recommended that when linear spirals are used for high speed trains, a quadratic fairing (extra transition) should be added to each spiral end to reduce jerk and horizontal forces on the rails (Ronald, 1976). Commonly, fairings are 39 feet long. Total spiral length then becomes 78 feet longer (i.e., if the computed spiral length is 500 feet, total length becomes 578 feet).

The spiral length is about evenly divided between a segment substituting for the tangent and a segment substituting for the curve. The segment substituting for the tangent introduces an offset, O, that makes the spiral and curve combination to offtrack when compared to the alignment followed by the simple curve. The offset expressed in feet is:

$$O = 0.0727\ K\ S^3 \qquad \text{Eq. 12}$$

where: K = Rate of change (degrees per station), and
S = Length of spiral (stations in 100 ft increments).

Referring back to Figure 46, the spiral point of beginning, TS, is located before the point of curvature, PC, of the simple curve. The spiral point of termination, ST, is located beyond the point of tangency, PT, of the simple curve. Thus, the spiral length and the spiral offset combined make the spiralled curve to be longer and to follow a significantly different path than a simple curve on the Interstate highways.

In order to travel at faster speeds, curves flatter than described by the freeway medians are selected, but track alignment encroaches on the mainlanes at such curves. When two highway reverse curves are located close to each other, the significance of the alignment problem is even more serious. The distance of the spiralled curve tangents, can be long enough so that the end of spiral of the first curve may be beyond the beginning of the second spiralled curve. A track following such alignment would require two more spiralled curves further down the tracks to return back to the highway median, provided that the highway remains on tangent alignment long enough. These features will be explained in the section following, based on specific examples of track alignment at a selected location of an existing freeway.

Using Freeway Right-of-Way

Based on above considerations of track geometrics, freeways connecting the Texas Triangle need to be examined to analyze the ability of the HSR to operate within existing freeway rights-of-way. A first look is taken at the site specific level, to graphically depict the alignment of such tracks designed for various speed limits.

To avoid limitations on train technology affecting possible track alignment, trains with maximum combined superelevation (actual, tilt and unbalance) of 18 inches are assumed to be operating with conventional technology; that is, trains running on steel-wheels-over-steel-rails. Lower levels of superelevation than required to negotiate safely a given curve are always possible by reducing speed. Higher levels of superelevation may be possible with new technology such as MagLev but less likely with conventional technology. However, it should be cautioned that even the use of 18 inches of combined superelevation is advanced technology which is not currently in service but would be feasible with existing hardware.

Train speeds considered in this analysis vary between 100 mph to 227 mph. These correspond to maximum cruising speeds under normal operating conditions for systems ranging between current AMTRAK trains to an improved TGV.

Figures 47 and 48 show the effect of speed on the ability of any HSR to operate within the freeway ROW through a roadway segment of I-45 by Corsicana, Texas (some 55 miles south of Dallas). Based on available design drawings, it is assumed that a minimum of 44 feet of clear ROW exits along the freeway medians. This is considered wide enough to allow two one-way HSR tracks to be laid along that median.

Figure 47 shows the centerline alignment for the inner tracks only, that is, the one that requires the shortest radius or highest degree of curvature.

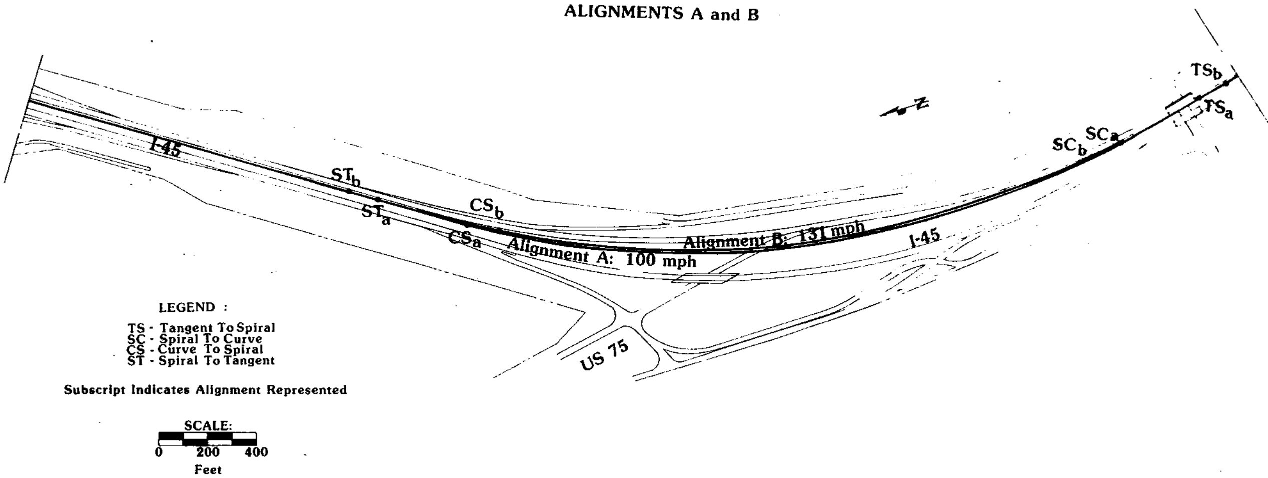


Figure 47. HSR Alignment for 100 MPH and 131 MPH Within I-45 Median Near Corsicana, Texas

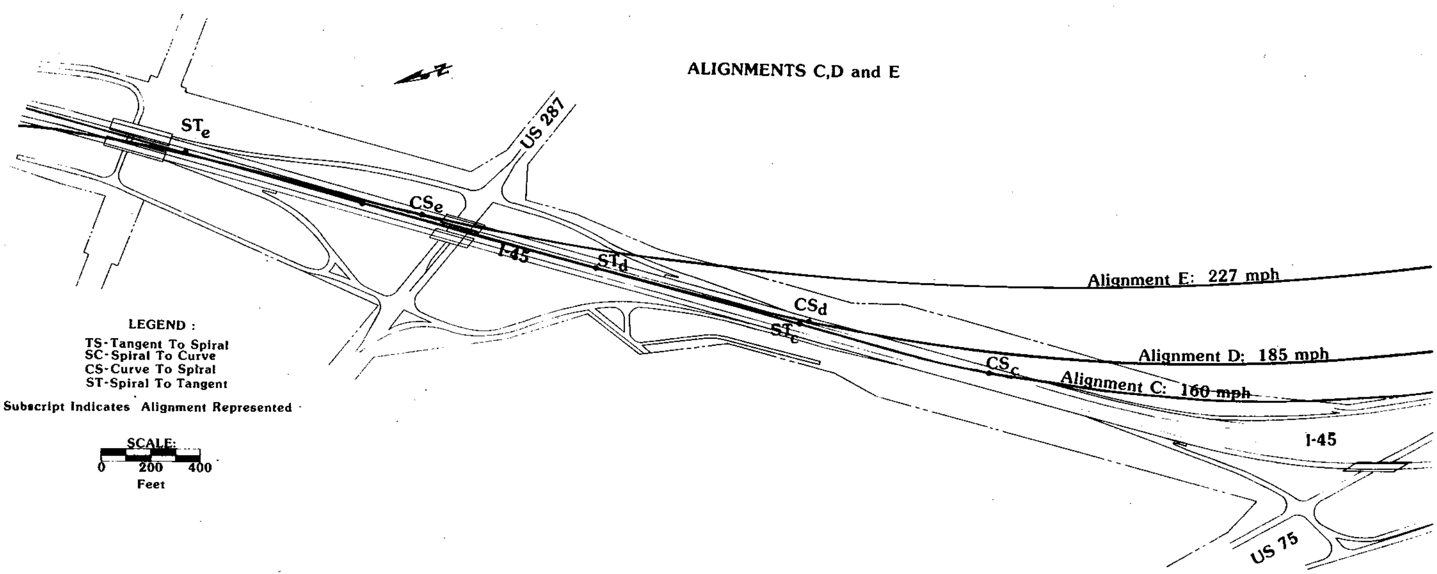


Figure 48. HSR Alignments for 160 MPH - 227 MPH Outside of Median Near Corsicana, Texas

The highway curve at this location, the interchange between I-45 and US 75, is actually a broken-back curve composed of two 1.75 degree curves tied by a short tangent. A simple curve of 1.5 degrees describes more appropriately the median, where the HSR would ideally go through. Alignment A represents a train travelling at 100 mph which requires approximately 10.5 inches of combined superelevation. Alignment B represents a train travelling at 131 mph that uses the maximum allowable 18 inches of combined superelevation. Both trains can manage to remain withing the freeway median following a 1.5 degree curve with spiral offsets of 1.6 and 4.5 feet respectively. Since the median at this highway curve is very wide, there would be enough latitude for the placement of high barrier walls, if needed or desirable to protect the train and highway traffic when the train is operating at-grade.

Figure 48 shows Alignments C, D, and E, representing trains running at 160, 185, and 227 mph respectively. All require maximum combined superelevation of 18 inches and must operate on broader curves (less degrees of curvature) than possible through the median. Thus all alignments need to straddle the northbound freeway lanes. Alignment C, tracing a 1 degree curve, proceeds mostly withing the existing ROW and may present very little problem in property acquisition. However, construction costs and problems escalate rapidly. Elevated track structure must straddle the northbound freeway lanes for more than 800 feet. This requires the construction of 7 or more bents spanning those highway lanes, at each end of the spiralled curve. Bents are undesirable because they are slow to build, require special traffic control when going over existing lanes, and multiply construction costs. Still, this makes no consideration for possible utility conflicts that may exist within the outer separation or the straddling of frontage roads which may be required.

Alignments D and E, following 0.75 and 0.5 degree curves, depart from the ROW more extensively. Property rights would need to be acquired and project construction may be delayed. Property acquisition by a government agency typically takes from 1 to 2 years. Lack of information on land uses beyond the ROW preclude further speculations. Under some circumstances it may be more economical to go beyond the freeway ROW to save on costs or to increase speed.

Table 5 contains some of the railway curve characteristics that introduce constraints on their utilization. These are: combined superelevation, e_c; tangent length of spiralled curve, T_s; spiral length, L_s; and spiral offset, O.

TABLE 5: CURVE CHARACTERISTICS BY SPEED AND DEGREE OF CURVATURE

Δ = 47 Degrees

Alignment	Speed (mph)		Curvature (degrees) 1.5	1.0	.75	0.5
A	100	e_c T_s L_s O	10.5 1852 378 1.6			
B	131	e_c T_s L_s O	18 1983 641 4.5			
C	160	e_c T_s L_s O		18 2884 782 4.5		
D	185	e_c T_s L_s O			18 3772 905 4.5	
E	227	e_c T_s L_s O				18 5540 1110 4.5

e_c = total superelevation ($e_a + e_u + e_t$), in inches
T_s = tangent length from PS to PI, in feet
L_s = spiral length, in feet
O = sprial offset, in feet
Δ = deflection angle between tangents, in degrees

The combined superelevation for Alignment A is only 10.5 inches; this can be achieved with full track superelevation, 8 inches, plus 3.5 inches of unbalanced superelevation. Spiral length can be determined through the use of Equation 9. Since unbalanced superelevation is less than the maximum allowable and cars do not need to tilt to reach the required superelevation, spiral length is only 378 feet. From Equation 12, the computed offset is only 1.6 feet.

Alignment B is very close to Alignment A but operates at the higher speed of 131 mph. From Table 5, it can be observed that combined superelevation is the full 18 inches. The resulting spiral length is 641 feet using the tilting train criteria and Equation 11. Spiral length is 70 percent greater than for Alignment A. From Equation 12, the offset is 4.5 feet or 2.8 times greater than for Alignment A. Both spiral length and the offset may create problems in trying to follow the freeway median. Even though both seem to track close to each other, the ability of Alignment B to trace typical freeway medians is somewhat reduced by the greater need to offset the track. Alignment B, however, increases speed by 31 percent.

Figure 49 shows Alignments D and E through the previous highway curves (intersection of I-45 with US 75) and the path through the reverse curve located just north of US 287. The second highway curve north of US 287 has only 1 degree of curvature, however, it happens to be only 1.15 miles away. Alignment D presents no real geometric problems even though it goes out of the ROW. Alignment E presents a peculiar problem that exists due to the proximity between reversed highway curves.

Two simple highway curves running in opposite directions, frequently called an "S" curve, need to be joined by a tangent section to reverse the superelevation. Spiralled curves, however, need two spirals between two such curves to achieve the superelevation reversal that occurs in the tangent joining unspiralled highway curves. Referring back to Figure 47, when such spirals extend a considerable distance beyond the normal PC, the end of spiral, ST, may be located beyond where the next spiral begins at the TS.

Two main options are available to resolve the conflict of adjacent reverse curves. The first and simplest is to reduce speed, thus shortening spiral length but increasing travel time. A second option is to allow the train to go away from the right-of-way through the second curve and to return

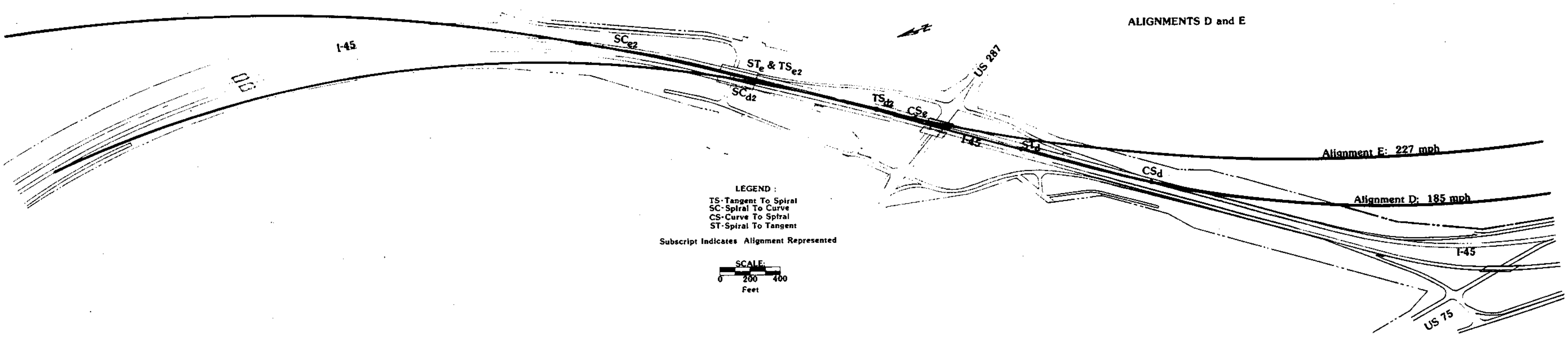


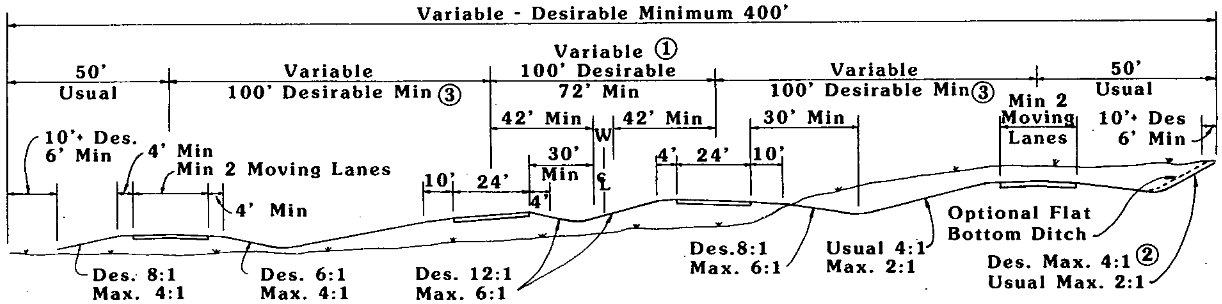
Figure 49. HSR Alignment through a Reverse I-45 Curve Near Corsicana, Texas

at some point farther down the line. The first approach results in reducing speed to 131 mph; the second requires additional ROW and some means to get back to the median. Speeds beyond 227 mph increase the deviation from the freeway right-of-way and the uncertainty of the feasibility of such approach.

From Figure 49, it may be observed that a northbound train travelling at 227 mph cannot negotiate the first curve turning clockwise while banking to the right in time to get back to the horizontal, transitioning to a counterclockwise curve while still remaining within the ROW. To accomplish this, Alignment E departs from the ROW in such a way that it cannot reenter to get back to tangent after the second highway curve without employing another reversed railway curve. Alignment E would need to track inside the highway curve, similar to Alignment D, to be able to get back to the highway median. No attempt is made here to find the proper alignment back to the freeway median, once past the second curve, since little is know about adjacent land uses and this is beyond the scope of the study.

It becomes evident that median curvatures control the speed of any alignment that intends to maximize use of the highway median and to reduce shallow angle crossings over freeway mainlanes. The cross section of the typical Texas rural freeway, as shown in Figure 50, allows for the minimum highway median width of 40 feet and is generally 44 or 46 feet wide. In such a space it is possible to accommodate a train similar to the TGV, as shown in Figures 51 and 52. Such a train requires a cross-section of approximately 35 feet plus safety clearances to accommodate two-way conventional tracks and auxiliary equipment for an HSR.

TYPICAL TEXAS RURAL FREEWAY SECTION
WITH FRONTAGE ROADS



NOTES:

① For Min. 30' Clearance to Obstruction in Median, Width ℄ to ℄ of 84' + W is Required. (W is Width of Obstruction)

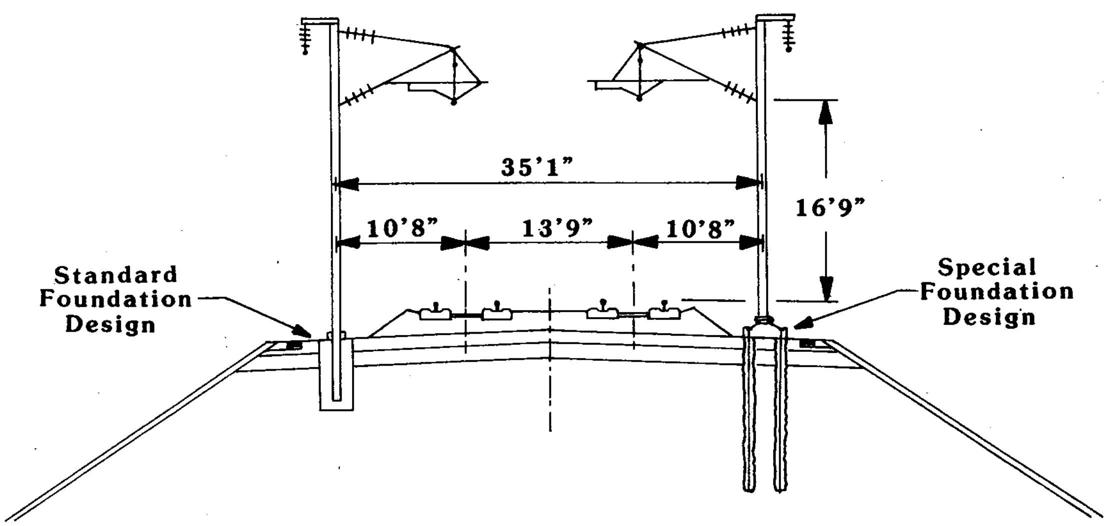
② Backslope in Cuts May be Exceeded in Rock.

③ Additional Width Required in Interchange Areas.

SOURCE: SDHPT Operations and Procedures Manual, p. 4-81.

Figure 50. Cross Section of Typical Texas Rural Freeway

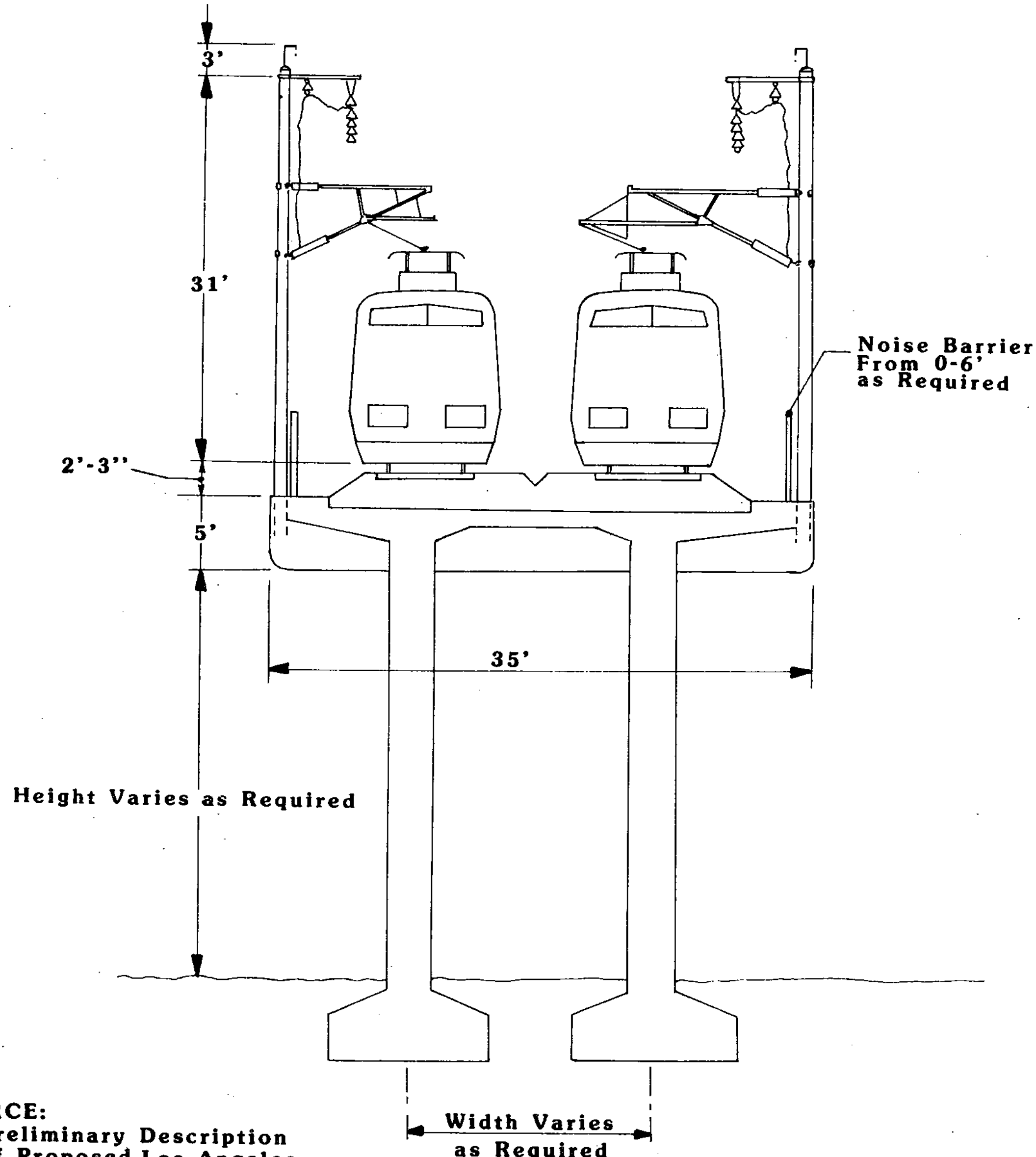
OVERHEAD WIRE DESIGN
(CATENARY SYSTEM)



Source:
The TGV Company,
Very High Speed Rail
Proposal for Florida,
December 1983.

Figure 51. Typical HSR Cross Section Constructed At-Grade

TYPICAL CROSS SECTION OF TWIN COLUMN VIADUCT



SOURCE:
Preliminary Description of Proposed Los Angeles to San Diego High Speed Rail Project, American High Speed Rail Corporation, August 1983

Figure 52. Typical HSR Cross-Section With Elevated Structure

MagLev technology may take slightly less width while on tangent track. However, to attain higher speeds than probable with conventional technology (beyond 250 mph), higher unbalanced superelevation may be required. In turn, higher unbalanced superelevation will require larger spiral offsets that may place the tracks on or above existing freeway lanes. The existing highway lanes would need to be moved laterally or the railway tracks vertically separated. Indeed, higher speeds should require greater use of grade separation to maintain gentler vertical grades.

The ROW availability indicates the desirability of remaining within the median as much as possible. Yet, these factors need to be weighed against time benefits accrued by higher speeds possible with a less confined alignment. A study of alternatives should incorporate a detailed corridor evaluation to account for several of the major factors that affect capital as well as operating costs. The effectiveness of higher trains speeds could then be assessed through benefits/cost (B/C) ratios.

Interstate Characteristics on the Texas Triangle

General

The Texas Triangle, extending from Fort Worth/Dallas to Houston to San Antonio, is currently served by a system of five Interstate highway facilities consisting of: 1) I-45; 2) I-10; 3) I-35; 4) I-35W; and, 5) I-30. Over 50% of the State's population is served by the transportation network connecting the Triangle's major urbanized areas.

In addition to the Interstate freeway system, there is railroad network serving the Triangle. Three railroad companies which have lines currently in existence and connect the involved urban areas include:

1. Southern Pacific
2. Missouri-Kansas-Texas
3. Chicago, Rock Island and Pacific

This section of the report defines the physical features and geometric characteristics of the existing Interstate facilities under consideration. Both primary and secondary data are combined to provide an overall description of the highway corridors. The roadway and right-of-way features directly related to the physical feasibility of implementing a High Speed Rail (HSR) system on existing highway property are presented herein.

Physical Survey of Triangle

The research team surveyed the five Interstate Highways within the Texas Triangle to collect data on the physical characteristics of the involved roadways. Information recorded in the field included the following:

- Bridge Structures;
- Overpasses;
- Vertical Clearances;
- Major Transmission Lines;
- Mile Post Numbers; and,
- General Observations.

The above items were referenced by mileage or distance from the county lines to facilitate cross-referencing the data with the SDHPT's RI2T-LOG (described subsequently). In addition, the research team estimated horizontal curve data from aerial photographs and county maps. Detailed results of these efforts are shown in Appendix A.

Roadway Inventory File

The State Department of Highways and Public Transportation maintains a roadway inventory file known as the RI2T-LOG. In addition to traffic data, this file contains information on the physical characteristics of the Texas highway system including:

- Number of Lanes;
- Roadbed Width;
- Surface Width;
- Right-of-Way Width; and,
- Section Lengths.

Generally speaking, the file is maintained by SDHPT for each of the State's counties, in that control sections and lengths for the most part begin and end at the county lines. Key roadway geometrics, derived from the RI2T-LOG, for the five Interstate Highways composing the Triangle are tabulated in Appendix A.

Summary

Table 6 presents a summary of physical features of the facilities. The data presented in the table are derived from both the "Physical Survey" and the SDHPT "Roadway Inventory File". The average surface width, road bed width and right-of-way width are weighted based upon section length defined within the RI2T-LOG file. A total of 396 bridge structures were observed on the Triangle of which 82 were single structures (one bridge for both directions of travel) and 314 were separate or double structures. In general, one or more bridge structures, can be expected every 1.8 miles along the

Interstate route; however, this average varies from county to county based upon local terrain and topography.

TABLE 6. SURVEY OF THE TEXAS TRIANGLE ROUTE

FREEWAY	MILEAGE ON SYSTEM	BRIDGE STRUCTURES		OVERPASS (NUMBER)	TRANS-MISSION LINES	HORIZONTAL CURVES		Highway AVERAGES		
		SINGLE (NUMBER)	DOUBLE (NUMBER)			NO.	AVG DEGREE	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
IH 10	198.39	23	103	79	18	74	0.96	54	84	319-368
IH 30	32.34	6	17	33	3	32	1.13	72	98	291-340
IH 35	216.30	21	92	114	25	104	0.87	53	79	264-313
IH 35 W	50.42	9	13	31	9	22	0.57	51	81	304-353
IH 45	233.14	23	89	80	24	113	0.86	51	80	320-369
TOTALS	730.59	82	314	337	79	345	0.89	56	83	303-352

Some 337 overpass structures were observed crossing the mainlanes of the involved highways which represents, on the average, one every 2.2 miles. Vertical clearances for the overpasses ranged from 13'-7" to 22'-3" as shown in Figure 53. Eight percent of the posted clearances were 14'-6" or less. The most common height restriction posted was 16'-5". Some 67% of all observed overpasses had a clearance ranging between 15'-5" and 17'-5". Approximately 26% of the overpasses were below 15'-6" in height as measured from the traveled lanes.

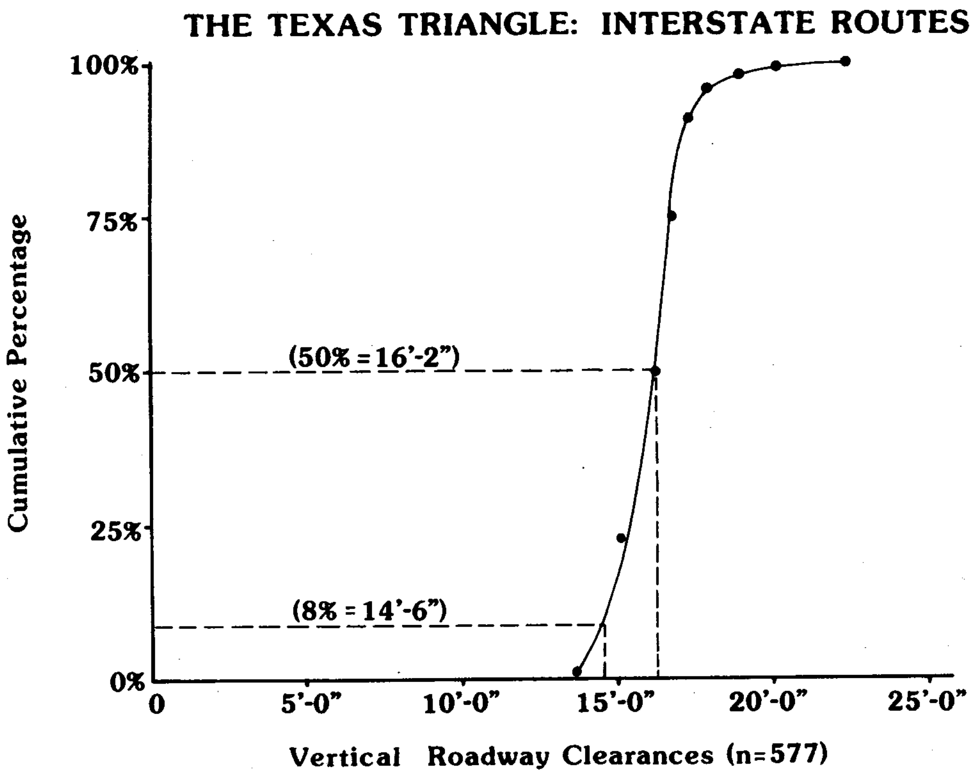


Figure 53. Clearance of Overpass Structures Crossing the Triangle Route

Only major transmission lines were recorded in the field survey. Secondary, distribution lines were assumed to be easily relocated or adjusted in the event that a High Speed Rail system were to be constructed. A total of 79 major transmission lines were observed crossing the Interstate rights-of-way or, on the average of, one every 9.2 miles. The particular lines which would require relocation/adjustment would need to be determined based upon rail technology, alignment and preliminary engineering.

A total of 345 horizontal curves, with a degree of curvature of 0.5 or greater, were recorded on the Triangle route. Some 36% of these curves were .75 degrees or more as shown in Figure 54. Given the number of curves and the total mileage, one can expect a horizontal alignment change of 0.5 degrees or greater every 2.1 miles; however, this average varies widely depending upon the particular freeway segment and surrounding terrain.

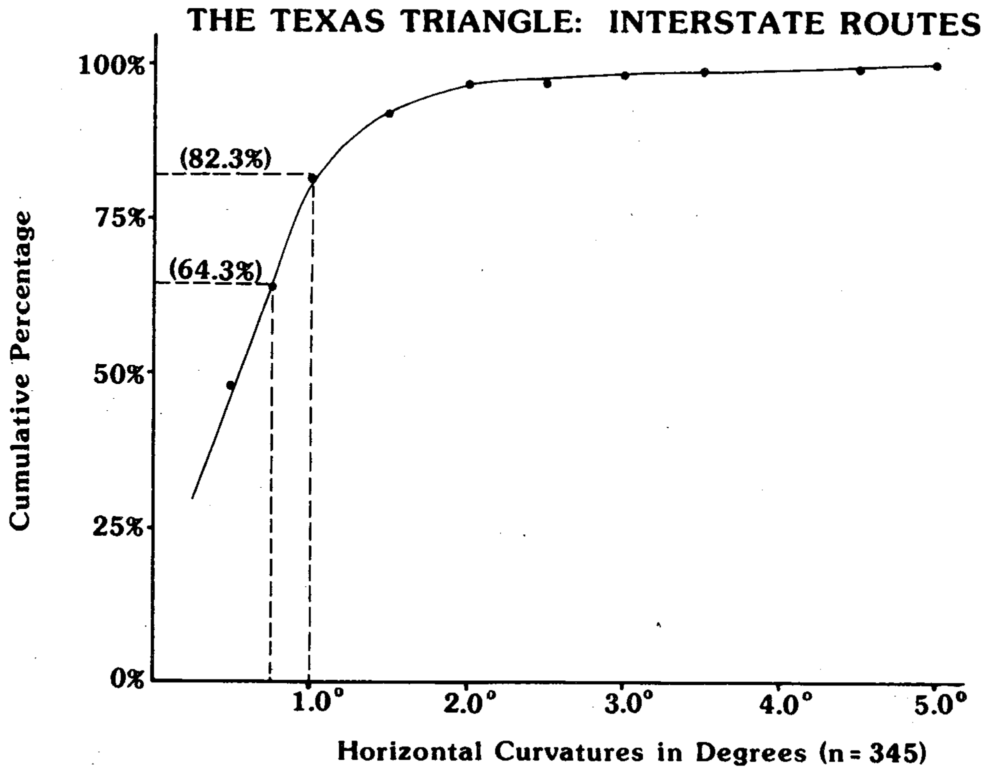


Figure 54. Roadway Curvatures Recorded for the Texas Triangle Freeways

The weighted average right-of-way width for the entire Triangle is 303' to 352'. This width, derived from the RI2T-LOG, varied from a low range of 101' to 150' to a high range of 551' to 600'. The most commonly specified right-of-way width in the SDHPT inventory file is 251' to 300'.

The five Interstate highways pass through a total of 30 Texas counties. Summary information for each of the highways, by county, is shown in the following tables:

Table 7: I-10, San Antonio to Houston
Table 8: I-30, Fort Worth to Dallas
Table 9: I-35, San Antonio to Hillsboro
Table 10: I-35W, Hillsboro to Fort Worth
Table 11: I-45, Houston to Dallas

As previously stated, more detailed information on the physical characteristics of the Texas Triangle is contained in Appendix A of this report.

TABLE 7. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 10

SDHPT DISTRICT	COUNTY	MILEAGE IN COUNTY	BRIDGE STRUCTURES		OVERPASS (NUMBER)	TRANS-MISSION LINES	HORIZONTAL CURVES		COUNTY AVERAGES		
			SINGLE (NUMBER)	DOUBLE (NUMBER)			NO.	AVG DEGREE	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
15	BEXAR	23.92	7	12	13	0	1	0.50	56	84	291-340
15	GUADALUPE	36.62	0	23	10	7	9	0.92	48	80	304-353
14	CALDWELL	4.57	0	3	0	0	0	.	48	80	424-473
13	GONZALES	22.04	0	13	6	1	2	0.50	48	80	378-427
13	FAYETTE	22.76	0	13	7	1	8	0.50	48	80	407-456
13	COLORADO	31.88	0	11	13	4	14	0.77	48	83	304-353
13	AUSTIN	16.02	0	7	5	2	6	0.88	48	76	294-343
12	WALLER	11.12	0	16	5	0	5	0.95	48	80	362-411
12	FORT BEND	3.40	0	3	1	1	2	2.00	48	82	302-351
12	HARRIS	26.06	16	2	19	2	27	1.20	79	103	260-309
	TOTALS	198.39	23	103	79	18	74	0.96	53	83	319-368

TABLE 8. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 30

SDHPT DISTRICT	COUNTY	MILEAGE IN COUNTY	BRIDGE STRUCTURES		OVERPASS (NUMBER)	TRANS-MISSION LINES	HORIZONTAL CURVES		COUNTY AVERAGES		
			SINGLE (NUMBER)	DOUBLE (NUMBER)			NO.	AVG DEGREE	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
2	TARRANT	16.69	3	6	25	3	9	0.75	64	88	273-322
18	DALLAS	15.66	3	11	8	0	23	1.28	74	102	297-346
	TOTALS	32.34	6	17	33	3	32	1.13	72	101	291-340

TABLE 9. SURVEY OF THE TEXAS TRIANGLE ROUTE FOR INTERSTATE HIGHWAY 35

SDHPT DISTRICT	COUNTY	MILEAGE IN COUNTY	BRIDGE STRUCTURES		OVERPASS (NUMBER)	TRANS-MISSION LINES	HORIZONTAL CURVES		COUNTY AVERAGES		
			SINGLE (NUMBER)	DOUBLE (NUMBER)			NO.	AVG DEGREE	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
15	BEXAR	20.29	7	9	18	0	26	0.81	68	74	238-287
15	GUADALUPE	3.19	0	0	1	1	1	0.50	48	78	251-300
15	COMAL	20.29	0	10	7	2	8	0.75	49	72	251-300
14	HAYS	24.26	0	10	9	3	9	0.61	48	78	300-349
14	TRAVIS	28.22	4	12	16	2	17	1.10	61	86	248-297
14	WILLIAMSON	27.35	0	12	14	5	7	0.68	48	76	327-376
9	BELL	35.48	10	5	22	6	14	0.95	52	84	213-262
9	FALLS	1.96	0	1	1	0	1	1.50	48	80	251-300
9	MCLENNAN	39.71	0	25	19	4	16	0.91	54	85	252-301
9	HILL	15.55	0	8	7	2	5	0.85	48	78	283-332
	TOTALS	216.30	21	92	114	25	104	0.87	53	79	264-313

TABLE 10. SURVEY OF THE TEXAS TRIANGLE ROUTE FOR INTERSTATE HIGHWAY 35 W

SDHPT DISTRICT	COUNTY	MILEAGE IN COUNTY	BRIDGE STRUCTURES		OVERPASS (NUMBER)	TRANS-MISSION LINES	HORIZONTAL CURVES		COUNTY AVERAGES		
			SINGLE (NUMBER)	DOUBLE (NUMBER)			NO.	AVG DEGREE	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
9	HILL	13.96	0	2	6	2	3	0.50	48	80	304-353
2	JOHNSON	23.07	2	11	9	4	10	0.63	48	80	299-348
2	TARRANT	13.39	7	0	16	3	9	0.53	63	86	316-365
	TOTALS	50.42	9	13	31	9	22	0.57	53	84	304-353

TABLE 11. SURVEY OF THE TEXAS TRIANGLE ROUTE FOR INTERSTATE HIGHWAY 45

SDHPT DISTRICT	COUNTY	MILEAGE IN COUNTY	BRIDGE STRUCTURES		OVERPASS (NUMBER)	TRANS-MISSION LINES	HORIZONTAL CURVES		COUNTY AVERAGES		
			SINGLE (NUMBER)	DOUBLE (NUMBER)			NO.	AVG DEGREE	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
12	HARRIS	24.62	17	5	7	2	36	1.06	73	99	266-315
12	MONTGOMERY	27.76	2	9	12	6	15	0.65	48	80	289-338
17	WALKER	32.70	0	8	8	2	8	0.63	48	80	395-444
17	MADISON	18.23	0	4	4	0	7	0.71	48	80	325-374
17	LEON	28.43	0	9	6	2	9	0.72	48	78	301-350
17	FREESTONE	31.93	0	11	9	3	12	0.75	48	80	362-411
18	NAVARRO	30.69	2	15	15	3	11	1.05	48	71	257-306
18	ELLIS	23.33	0	13	11	3	6	1.04	48	68	259-308
18	DALLAS	15.45	2	15	8	3	9	0.64	66	103	364-413
	TOTALS	233.14	23	89	80	24	113	0.86	52	81	320-369

Simulation of High Speed Rail Operation

General

Ideally, a high speed passenger train would travel on a straight line between two cities. Since such an ideal route is not possible due to economic, environmental and other considerations, more feasible alignments must be considered. One possible alignment would follow freeway medians along principal travel corridors. A typical view of an Interstate highway serving the Texas Triangle is shown in Figure 55.

Figure 55. Typical Freeway Median of the I-45 Corridor Between Dallas and Houston

Figure 56 shows the spatial relationship between Houston, Dallas, Fort Worth and San Antonio. The loop connecting these four cities, plus downtown connecting links, is approximately 750 miles long and makes use of I-45, I-30, I-35W and I-10 freeways. The latter, connecting San Antonio with Houston, traverses fairly flat terrain while the other four corridors are characterized as gently rolling. Typically a 40 foot-plus median separates outbound from inbound mainlanes.

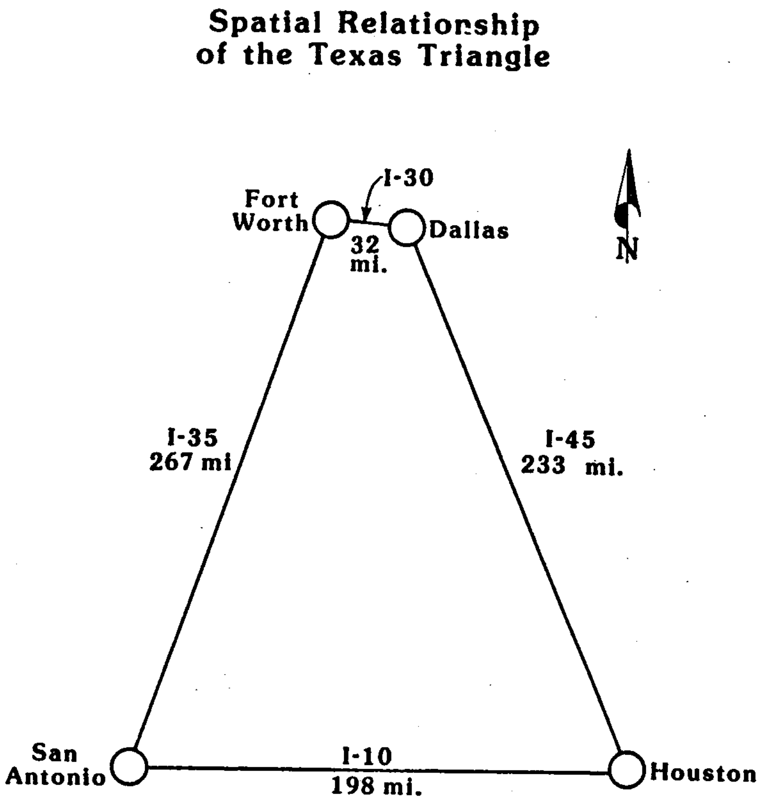


Figure 56. Roadway Mileages and Interstate Freeways Composing the Texas Triangle Routing

Simulation Analysis

A microcomputer was used to analyze each city pair with track alignment on the freeway medians and varying train technology. Average speed between city pairs is a function of maximum cruise speed, maximum combined superelevation, acceleration/deceleration rates, length of tangent track and degree of highway curves encountered. The first three variables are directly attributed to train technology. The other two, length of tangent track and degree of highway curves, are track variables. Appendix B explains the simulation procedure in greater detail.

Maximum cruise speed and acceleration/deceleration rates were estimated for existing technology and assumed for advanced or prototype systems. Superelevation was assumed based on existing train capabilities, and was combined to include actual (rail) superelevation, unbalanced superelevation with limits set by comfort, and tilting of trains. The degrees of highway curves and location along the corridor were graphically estimated from the County Highway Maps published by the Texas State Department of Highways and Public Transportation. Unless otherwise noted, the track curves were assumed to have the same curvature as the freeway centerlines.

The result of each simulation is a distance versus speed profile, as shown in Figures 57 and 58, that depicts how the train accelerates, cruises and decelerates to travel along a selected freeway corridor. A summary of the run is provided at the end of the printout to show the miles travelled, the travel time in minutes and the average speed in miles per hour. For preliminary comparisons of alternatives, a critical element to consider is travel time, as this factor will be significant in determining projected ridership.

VELOCITY PROFILE

MILE	TIME	ACCEL	MPH	0.0 — 100 — 200 — 300		
0.00	0.0	2.5	0.0	A	3.00	0.0
0.25	0.4	2.5	67.1	A	3.00	92.6
0.50	0.6	1.6	85.9	A	2.00	113.4
0.75	0.8	1.6	101.3	A	1.50	130.9
1.00	0.9	1.1	110.6	A		
1.25	1.1	1.1	119.2	A		
1.50	1.2	1.1	127.3	A	0.75	185.2
1.75	1.3	1.1	134.8	A	0.50	226.8
2.00	1.4	1.1	142.0	A	0.50	226.8
2.25	1.5	1.1	148.8	A		
2.50	1.6	-2.0	136.2	D	0.50	226.8
2.75	1.7	-2.0	122.2	D	0.50	226.8
3.00	1.9	0.0	113.4	C	2.00	113.4
3.25	2.0	1.1	121.8	A		
3.50	2.1	1.1	129.7	A		
3.75	2.2	1.1	137.1	A		
4.00	2.3	1.1	144.1	A		
4.25	2.4	1.1	150.9	A		
4.50	2.5	0.5	153.8	A		
4.75	2.6	0.5	156.7	A		
5.00	2.7	0.5	159.6	A		
5.25	2.8	0.5	162.3	A	0.50	226.8
5.50	2.9	0.5	165.1	A		
5.75	3.0	0.5	167.8	A		
6.00	3.1	0.5	170.5	A		
6.25	3.2	0.0	160.4	C	0.50	226.8
6.50	3.3	0.0	160.4	C	1.00	160.4
6.75	3.4	0.0	160.4	C	1.00	160.4
7.00	3.5	0.5	163.1	A		
7.25	3.6	0.5	165.9	A		
7.50	3.6	0.5	168.6	A		
7.75	3.7	0.5	171.2	A		
8.00	3.8	0.5	173.8	A		
8.25	3.9	0.5	176.4	A		
8.50	4.0	0.5	178.9	A		
8.75	4.1	0.5	181.4	A		
9.00	4.2	0.5	183.9	A		
9.25	4.2	0.5	186.3	A		
9.50	4.3	-2.0	176.4	D	0.50	226.8
9.75	4.4	-2.0	165.9	D		
10.00	4.5	-2.0	154.6	D		
10.25	4.6	-2.0	142.5	D		
10.50	4.7	0.0	130.9	C	0.50	226.8
10.75	4.8	0.0	130.9	C	1.50	130.9
11.00	4.9	1.1	138.3	A		
11.25	5.0	1.1	145.3	A		
11.50	5.1	1.1	151.9	A		
11.75	5.2	0.5	154.9	A		
12.00	5.3	0.5	157.7	A	1.00	160.4
12.25	5.4	0.5	160.6	A		
12.50	5.5	0.5	163.3	A	0.75	185.2
12.75	5.6	0.5	166.1	A		
13.00	5.7	0.5	168.8	A	0.50	226.8
13.25	5.8	0.5	171.4	A	0.50	226.8
13.50	5.9	0.5	174.0	A		
13.75	6.0	0.5	176.6	A		

Figure 57. Distance versus Speed Profile for a 240 MPH Train - Start of Simulation

```
246.00  79.7  0.5 175.7  |           |        A  |           |
246.25  79.8  0.5 178.2  |           |        A  |           |
246.50  79.9  0.5 180.7  |           |        A  |           |
246.75  79.9  0.5 183.2  |           |        A  |           |
247.00  80.0  0.5 185.6  |           |         A |           |
247.25  80.1  0.5 188.0  |           |         A |           |
247.50  80.2  0.5 190.4  |           |         A |           |
247.75  80.3  0.5 192.8  |           |          A|           |        0.50 226.8
248.00  80.3  0.5 195.1  |           |          A|           |        0.50 226.8
248.25  80.4  0.5 197.4  |           |          A|           |
248.50  80.5  0.5 199.6  |           |          A|           |        0.50 226.8
248.75  80.6  0.5 201.9  |           |           A           |        0.50 226.8
249.00  80.6  0.2 202.8  |           |           A           |
249.25  80.7  0.2 203.7  |           |           A           |
249.50  80.8 -2.0 194.6  |           |          D|           |
249.75  80.9 -2.0 185.1  |           |         D |           |
250.00  80.9 -2.0 175.1  |           |        D  |           |
250.25  81.0 -2.0 164.6  |           |      D    |           |
250.50  81.1 -2.0 153.2  |           |     D     |           |
250.75  81.2 -2.0 141.0  |           |   D       |           |        0.50 226.8
251.00  81.3 -2.0 127.6  |           |  D        |           |
251.25  81.5 -2.0 112.6  |           |D          |           |
251.50  81.6 -2.0  95.3  |          D|           |           |
251.75  81.8 -2.0  74.0  |       D   |           |           |        1.50 130.9
252.00  82.0 -2.0  43.3  |    D      |           |           |        3.00  92.6
252.25  82.4 -2.0   0.0  D           |           |           |
252.50 TRAIN IS STOPPED
```

SUMMARY

RUN OF 252.5 MILES TOOK 82.401 MINUTES.
AVERAGE SPEED = 183.857 MPH.

MAXIMUM SPEED ACHIEVED WAS 240 MILES PER HOUR.

MAXIMUM ALLOWED SPEED WAS 240 MILES PER HOUR.

THE NAME OF THE FILE USED FOR THIS RUN WAS OHOU/DAL

Superelevation = 18 Inches

Acceleration values (MPH per second):

```
  0  >  50:  2.5                   50+ > 100:  1.6
100+ > 150:  1.1                  150+ > 200:  .5
200+ > 250:  .2                   250+ > 300:  0
300+ >     :  0
```

Deceleration = -2 MPH per second

Figure 58. Distance versus Speed Profile for a 240 MPH Train - End of Simulation

Time Savings

Table 12 shows travel time for two advanced HSR technologies that could be used to serve the Texas Triangle. This is not off-the-shelf rail technology but the type that is considered to be feasible. The first assumes a maximum cruise speed of 200 MPH and uses the TGV type of technology adapted with tilt mechanisms on all cars. The second uses advanced trains with a maximum cruise speed of 350 MPH (i.e., MagLev technology). Both systems could operate with 18 inches or 24 inches of combined superelevation; that is, actual rail, tilt equivalent plus unbalanced superelevation.

TABLE 12: SIMULATED CORRIDOR TRAVEL TIMES FOR ADVANCED TECHNOLOGIES (MINUTES)

Speed (mph)	Houston to Dallas		Dallas to Fort Worth		Fort Worth to San Antonio		San Antonio to Houston		Total Triangle	
	Superelevation		Superelevation		Superelevation		Superelevation		Superelevation	
	18"	24"	18"	24"	18"	24"	18"	24"	18"	24"
350	74.1	68.7	10.7	10.1	78.6	69.6	58.8	55.4	222.2	203.8
200	82.4	79.6	11.6	11.4	85.6	80.7	69.4	67.3	249.0	239.0

Acceleration is assumed as 3 mphps up to 100 mph, 2 mphps up to 200 mph, 1 mphps up to 300 mph and 0.5 mphps up to 350 mph. Deceleration is assumed as 3 mphps from highest speed to stopped condition.

Assumptions regarding railway alignment were:

- Vertical curves have no effect on speed since they can be overcome by traction and/or the kinetic energy of the train travelling at high speed.
- Horizontal curves are approximated in intervals of 30 minutes, 45 minutes, 1 degree, 1.5 degree and increasing at 30 minutes intervals from there on. Curves flatter than 30 minutes are considered to be tangent.
- The effect of spiral offset and length are disregarded in estimating performance even though it is acknowledged that they may introduce some conflicts with roadway alignment.

From Table 12 a few comparisons are in order. A train with a maximum cruise speed of 200 MPH can traverse the Texas Triangle in 249 minutes (4.1 hours) excluding station dwell time, while operating with 18 inches of combined superelevation (actual, tilt, plus unbalanced). A train with a maximum cruise speed of 350 MPH and as much superelevation can make the same trip in 222 minutes (3.7 hours) excluding dwell time. Thus a 75% increase in maximum cruise speed allows for an 11% decrease in travel time or a savings of 27 minutes. A similar comparison with maximum superelevation of 24 inches shows that a 75% increase in maximum cruise speed would decrease travel time by 15% or a savings of 35 minutes. These simulations indicate that an increase in speed is not necessarily followed by a comparable decrease in travel time.

It is doubtful if an advanced TGV type train would operate with more than 18 inches of combined superelevation. A MagLev train is more likely to operate with 24 inches of combined superelevation. Based on this premise, total trip travel time would be 249 minutes (4.1 hours) for the advanced TGV and 204 minutes (3.4 hours) for the theoretical (ideal) train or MagLev. A 75% increase in maximum speed will bring an 18% reduction in travel time or a time savings of 45 minutes; this time difference is fairly significant in terms of being attractive to potential riders.

Time differences may be greater in some corridors where trains can operate at cruising speed for a longer portion of the trip. In the Houston to San Antonio corridor, the MagLev train makes the run in 55 minutes and the advanced TGV-type technology takes 69 minutes. Travel time is 20% less for the MagLev than for the TGV train. This improvement can be attributed to the long tangent sections between the two cities such as shown in Figure 59.

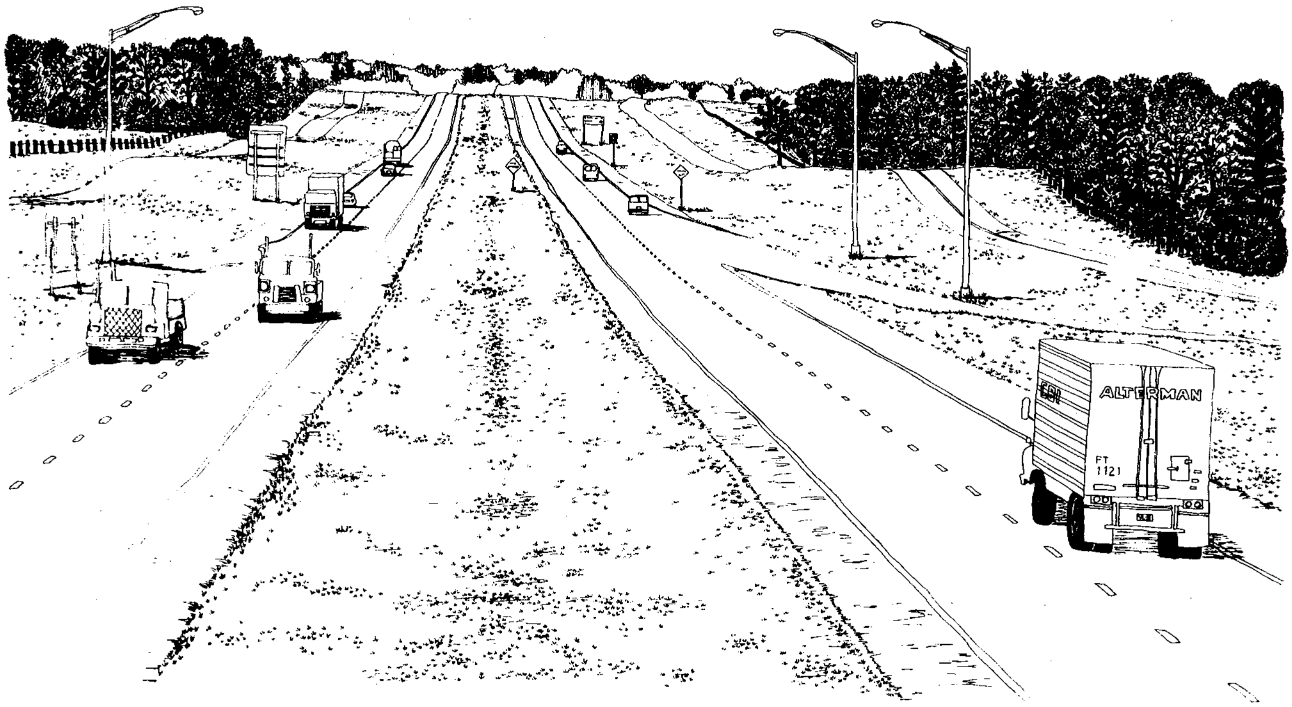


Figure 59. Freeway Alignment with Relatively Long Tangent Sections of Roadway

Analysis of speed profile curves suggests that while a 200 MPH train is capable of reaching and sustaining cruise speed a significant portion of the time, a train travelling at 350 MPH is not. The faster train is accelerating or decelerating most of the time in order to traverse curves at the maximum speed allowed by track curvature and combined superelevation.

A 350 MPH train with 24 inches of superelevation would make very limited use of its full ability to operate at cruising speed along the medians. In the simulation, full cruise speed is only reached in the Houston to Dallas and the San Antonio to Houston corridors and then only for 2% and 9% of the distance, respectively. This is in spite of the fast acceleration and deceleration capabilities assumed for the simulated technology. Conversely, a 200 MPH train operating with 18 inches of superelevation travels at full speed 68% of the distance in the Houston to Dallas corridor and 74% of the distance in the San Antonio to Houston corridor. The 200 MPH train goes at full speed along 68% of the length of all corridors connecting the Texas Triangle.

Closer to existing technology would be AMTRAK type trains cruising at 120 MPH and conventional TGV type trains cruising at 200 mph. Both can operate with maximum combined superelevation of 12 inches that is, 8 inches of actual plus 4 inches of unbalanced superelevation. Table 13 displays simulated travel times for these two train technologies while travelling the Texas Triangle. The footnote shows that acceleration is considerably slower than assumed for the previously discussed advanced HSR technologies. For comparative purposes, Table 13 also includes travel time for a conventional auto.

TABLE 13: SIMULATED CORRIDOR TRAVEL TIMES FOR CONVENTIONAL RAIL TECHNOLOGIES (MINUTES)

Mode	Speed (mph)	Houston to Dallas	Dallas to Fort Worth	Fort Worth to San Antonio	San Antonio Houston	Total Triangle
TGV	200	94.0	13.5	96.7	78.5	282.7
AMTRAK	120	130.5	17.5	130.9	110.7	389.6
AUTO	55	276.0	34.0	278.0	233.0	821.0

Acceleration for the Amtrak train is approximately 1.8 mphps from 0 to 50 mph, 0.5 mphps from 50 to 100 mph and 0.2 mphps thereafter. Acceleration for the TGV is estimated at 2.5 mphps from 0 to 50 mph, 1.6 mphps from 50 to 100 mph, 1.1 mphps from 100 to 150 mph and 0.5 mphps from 150 to 200 mph.

Based on simulation, it would take the AMTRAK train 390 minutes (excluding station dwell time) or 6.5 hours to go around the entire corridor. A TGV-type train would travel for 283 minutes or about 4.7 hours. Thus, a 67%

increase in maximum speed would decrease travel time by 27%; this is a considerable improvement in travel time that should be very attractive to travelers. Assuming an average speed of 55 MPH, a private auto would take 821 minutes or close to 13.7 hours to travel the same corridor.

The TGV type train could compete with airlines on the basis of travel time between CBD's, when access time to and from the airport/airplane is considered. For instance, the scheduled flight time between the Houston International and the Dallas/Fort Worth airports is about 49 minutes. It is estimated that under good conditions it takes 30 minutes to get from the CBD to the airport, 30 minutes to get from the airport to the CBD, plus 20 minutes to board and 10 minutes to clear the airplane; this is roughly 90 minutes, minimum. Total travel time between the Dallas and Houston CBD's using the airlines is 139 minutes. A similar estimate using the TGV type train including 7.5 minutes of access/egrees time at each end, would take 109 minutes. Use of the TGV-type train reflects a time savings of 30 minutes or a 22% decrease in travel time over the best existing mode.

Several other comparisons are possible. Appendix B presents the numerical results of the above and other simulations of travel time for various HSR technologies considered in this study. For example, one of the simulations changed very tight curves for wider curves in the Corsicana area along I-45, to investigate potential corridor time savings. Two minutes were saved when 0.5 degree curves were used instead of the sharper existing ones; this time savings may be insignificant compared to the effects on cost and construction difficulties.

Economic Implications

The most significant implication of the simulation runs is the suggestion that a maximum speed of 350 MPH confined to Interstate Highway medians may not be a viable HSR technology. Time savings between a 350 MPH train with 24 inches of combined superelevation and a conventional TGV-type train operating with 12 inches on combined superelevation is less than 27 minutes on any route; this happens in the Fort Worth to San Antonio corridor. Maximum time savings would be only 27 minutes, while the increase in construction, vehicle, and operating costs would be considerable. Even considering 6000 passengers per day, with the value of their time at $7.00 per hour, the 27-minute time savings from Fort Worth to San Antonio would result in:

6000 pass/day x 27 min/60 x $7/hr x 250 workdays/year

= $4,725,000 time savings per year

This would cover the interest on $47,250,000 with cost of capital at 10%, if all additional energy costs are ignored. This translates into only 3 to 5 miles of elevated guideway. As the Corsicana test demonstrated, much greater mileage of curve smoothing through elevated guideways would be required to result in significant time savings per run. Thus it seems that 350 MPH trains running within Interstate medians of the Texas Triangle may not be economically desirable. However, further analysis and engineering will be required to make this determination with certainty.

Many options are open for investigation at this level including the use of new separate right-of-way or railroad right-of-way. Yet, it is proposed that an HSR intended to make use of Texas Triangle freeways should remain within their medians as much as possible. Simulations indicate that cruise speeds within highway medians much higher than allowed by highway curves may be wasteful. Engineering considerations indicate that a HSR technology similar to that provided by the TGV with cruise speeds around 200 MPH may be a feasible alternative.

FEASIBILITY AND POTENTIAL OF IMPLEMENTING HSR ON HIGHWAY RIGHTS-OF-WAY

General

The primary reason for conducting this research was to determine the feasibility of using existing highway rights-of-way for High Speed Rail (HSR) passenger services in the State of Texas. The surveys of HSR projects throughout the United States and in foreign countries provide insight on various rail technologies, proposals and uses of available rights-of-way. In addition, the surveys provide, for certain HSR systems, an estimate of capital investments required for implementing HSR services.

The "Construction and Operational Considerations" play a key role in determining the technical feasibility of implementing a HSR system on highway rights-of-way. On the other hand, the various institutional, jurisdictional, legal, etc., factors provide the basis for assessing the practical feasibility of building HSR on highway property.

When all of the various considerations are viewed in the total context of the overall transportation system, a general assessment of the potential for HSR systems in the State of Texas can be made. This section of the report summarizes the findings of this research in the following subsections:

- Technical Feasibility;
- Practical Feasibility; and,
- Potential for HSR Services.

Technical Feasibility

The Human Element

The design of HSR systems, as with other people transport modes, is dependent upon the human element or the passengers intended to be served by the system. As was presented in the "Construction and Operational Considerations" section, the comfort of passengers is determined by the acceleration/deceleration forces applied to the human body by the transport mechanism. A vehicle such as a train car has six degrees of possible movement: (1) longitudinal; (2) sway; (3) heave; (4) pitch; (5) roll; and, (6) yaw. Two forms of acceleration are of particular concern for HSR service: (1) linear; and, (2) radial. Linear forces result primarily from a train accelerating longitudinally to operating speed or slowing to a stop. Radial forces result as a train traverses vertical and horizontal curves in the track or guideway. The length of time or duration that such forces are applied to the human is also an important consideration. Radial forces are controlled by the degree of curvature in concert with superelevation and/or vehicle tilting, similar to "turn and bank" in aircraft operation. Linear forces resulting from acceleration and deceleration of the vehicle have, in practice, been limited by passenger comfort considerations rather than by human tolerances. In terms of high speed ground transportation in the range of 120 MPH to 350 MPH, the maximum acceleration allowed is also limited by the propulsion system and hardware technologies. Given the performance characteristics of current and prototype HSR systems, the maximum linear forces achievable are well within the limits of passenger or human comfort.

HSR Technologies and Geometrics

To adequately assess construction and operational factors associated with implementing High Speed Rail passenger services on highway rights-of-way, a range of technologies was investigated. The definition of "High Speed" varies with operating or planning agency as well as with the type of technology under consideration. On existing AMTRAK routes in the United States, High Speed is defined as 79 MPH or greater. The operating French and Japanese systems define High Speed in the 150 MPH to 200 MPH range whereas the new MagLev Technologies may approach 350 MPH. Operating performance (i.e., maximum acceleration rates) varies with the type of propulsion used and the technology considered. A range of HSR technologies, from 120 MPH to 350 MPH maximum cruise speed, were identified along with their performance characteristics for potential implementation on freeway rights-of-way within the Texas Triangle.

Some of the identified HSR technologies incorporate tilting mechanisms to allow higher speeds through horizontal curves. These tilting mechanisms, when used in combination with track superelevation, allow greater operating flexibility and higher average speeds over a given route. For the purposes of this investigation, all of the technologies were considered to be electrically powered from a high-voltage overhead power distribution system. With the exception of the AMTRAK locomotive, the HSR trains were assumed to have multiple powered axles throughout the length of the train in order to develop the required propulsion for the higher speeds. No attempt was made to analyze the total power requirements or the total consumed energy for the different technologies operating in the Triangle. The energy requirements for a given HSR system could play a deciding factor in selecting one technology over another.

When combining the HSR technologies with the track geometrics, a total of eight different systems were analyzed for possible implementation on highway rights-of-way in the Texas Triangle. These eight systems along with their approximate performance characteristics are shown in Table 14.

The different HSR technologies are further explained in the "Construction and Operational Considerations" section of this report and in Appendix B. The total superelevation allowed for any given system is the combination of actual track elevation, car body tilt, plus unbalanced superelevation imposed upon the passenger.

TABLE 14: HSR SYSTEMS INVESTIGATED FOR THE TEXAS TRIANGLE

System	Maximum Speed (MPH)	Total Superelevation allowed	Acceleration in MPH per Second*							Deceleration in MPH/Sec.	Remarks
			0 to 50	50 to 100	100 to 150	150 to 200	200 to 250	250 to 300	300 +		
#1	120	12 inches	1.8	0.5	0.2	NA	NA	NA	NA	-2.0	AMTRAK
#2	200	12 inches	2.5	1.6	1.1	0.5	NA	NA	NA	-2.0	HSR (i.e., TGV or Bullet)
#3	200	18 inches	2.5	1.6	1.1	0.5	NA	NA	NA	-2.0	HSR w/Tilt Mechanism
#4	200	18 inches	3.0	3.0	2.0	2.0	NA	NA	NA	-3.0	HSR (Ideal Prototype)
#5	350	18 inches	3.0	3.0	2.0	2.0	1.0	1.0	0.5	-3.0	HSR (Ideal Prototype)
#6	200	24 inches	3.0	3.0	2.0	2.0	NA	NA	NA	-3.0	HSR (Ideal Prototype)
#7	350	24 inches	3.0	3.0	2.0	2.0	1.0	1.0	0.5	-3.0	HSR (Ideal Prototype)
#8	350	36 inches	7.0	7.0	7.0	7.0	7.0	7.0	7.0	-7.5	HSR (Ultra Prototype)

*Note: Acceleration rates vary as a function of Speed.

Interstate (Freeway) Characteristics

In order to analyze the technical feasibility of implementing HSR service on existing highway rights-of-way, the physical and geometric features of the involved Interstate Freeways must be determined. The Texas Triangle is connected by a modern system of Interstate facilities composed of both rural and urban segments. Both primary (field inventory) and secondary (SDHPT's Roadway Inventory File) data were used in developing a profile of highway features and characteristics. Some 730 miles of the involved Interstate highways were investigated as show in Table 15.

TABLE 15: INTERSTATE HIGHWAY FACILITIES CONNECTING THE TEXAS TRIANGLE

Interstate Highway(s)	Connecting	Mileage	Survey Limits
IH-10	Houston and San Antonio	198.4	I-45 to I-35
IH-35 and IH-35W	San Antonio and Fort Worth	266.7	I-10 to I-30
IH-30	Fort Worth and Dallas	32.3	I-35W to I-45
IH-45	Dallas and Houston	233.1	I-30 to I-10

The physical features survey did <u>not</u> include the required rail connections to the central business districts (CBD's) of the major urbanized areas. Since the involved major cities within the Texas Triangle are experiencing rapid population growth and dynamic development/land use changes, the identification of CBD connecting alignments for a HSR system will need to be performed in close cooperation with the local community and responsible planning organizations.

The physical survey of the 4 travel corridors included an inventory of bridge structures and horizontal curves as illustrated in Figure 60. In addition, the survey recorded overpass structures and vertical clearances as

Figure 60. Typical Rural Interstate Section with Bridge Structure and Horizontal Curve

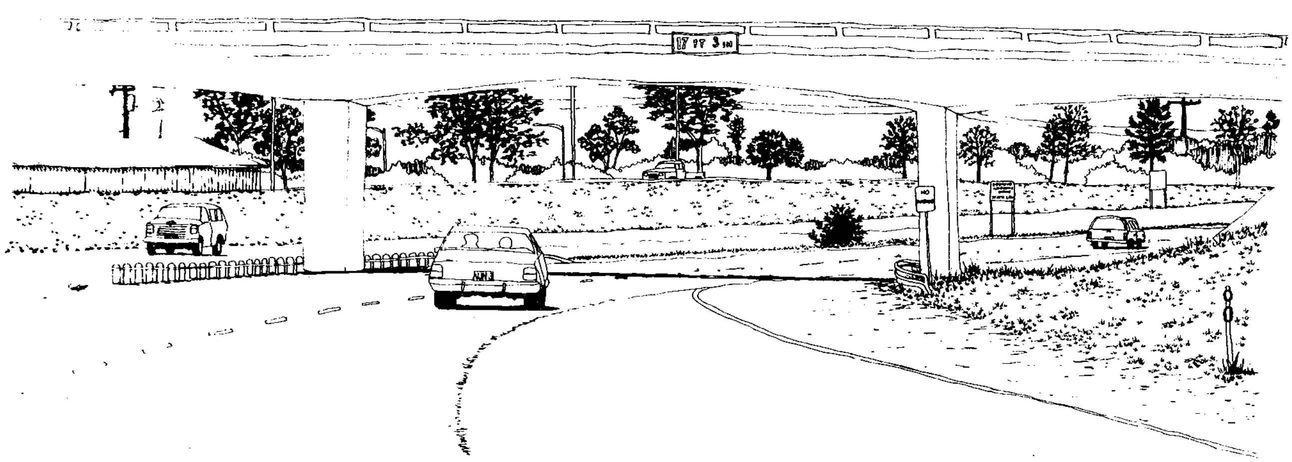
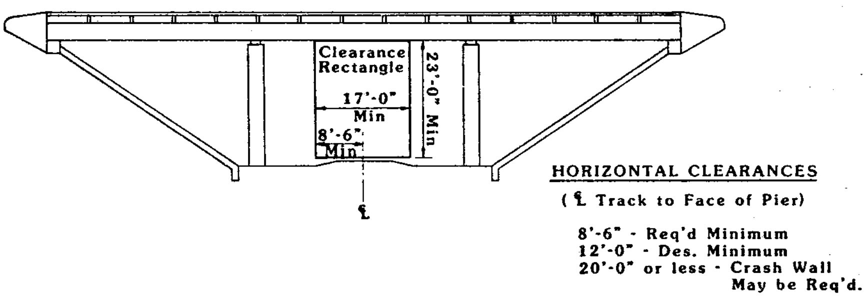


Figure 61. Typical Urban Interstate Section with Overpass and Posted Clearance

posted in the field similar to that shown in Figure 61. Summary results of these and other observations are presented in the "Construction and Operational Consideration" section with more detailed information being included in Appendix A of this report.

Some of the Interstate bridge structures (illustrated in Figure 60) are necessitated by natural features such as rivers or creeks. Others are required for crossing other roads and/or railroad tracks such as what is shown in Figure 62. If a HSR system is implemented on Interstate right-of-way, these physical features will need to be taken into account when designing the guideway and determining route alignment.

TYPICAL TEXAS HIGHWAY RAILROAD OVERPASS

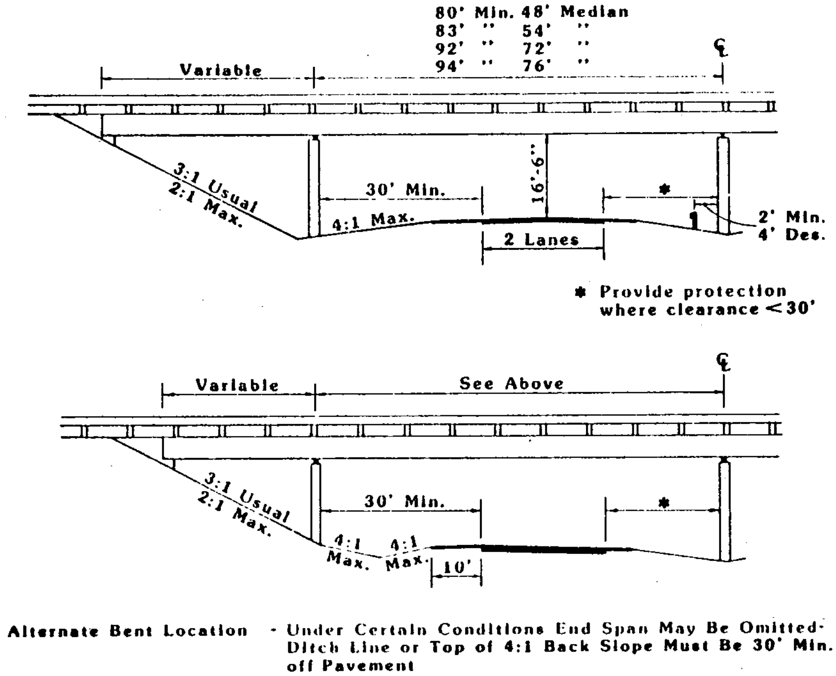


SOURCE: SDHPT Operations and Procedures Manual, p. 4-89.

Figure 62. Bridge Structure Crossing Over a Typical Railroad Track

Roadway alignment, vertical clearances and available rights-of-way will all play a significant role in determining the required track alignment for a given HSR system. Typical freeway cross sections are shown in Figures 63 and 64. Figure 63 illustrates one-half of a 4-lane freeway without frontage roads while Figure 64 shows one with frontage roads.

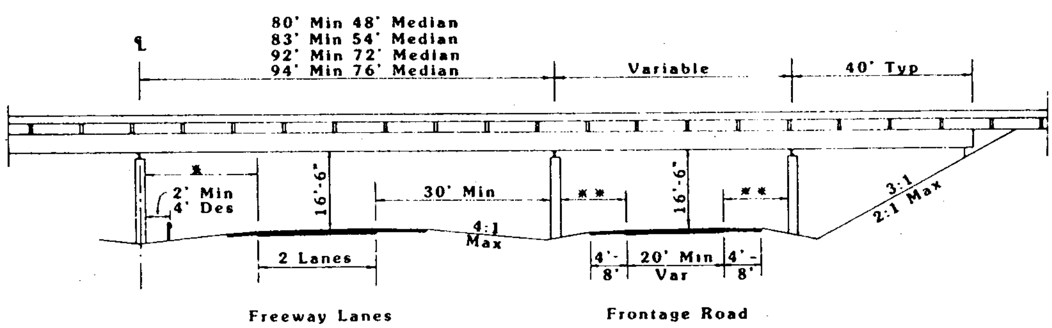
TYPICAL TEXAS FREEWAY UNDERPASSES
WITHOUT FRONTAGE ROADS



SOURCE: SDHPT Operations and Procedures Manual, p. 4-87.

Figure 63. Typical 4-Lane Freeway Cross Section Without Frontage Roads

TYPICAL TEXAS FREEWAY UNDERPASSES
WITH FRONTAGE ROADS



* Provide protection where clearance < 30'

** For design speed of 50 mph or greater with 1500 ADT - 30' clear zone
For lower design speeds 6' minimum, 10' to 15' preferred

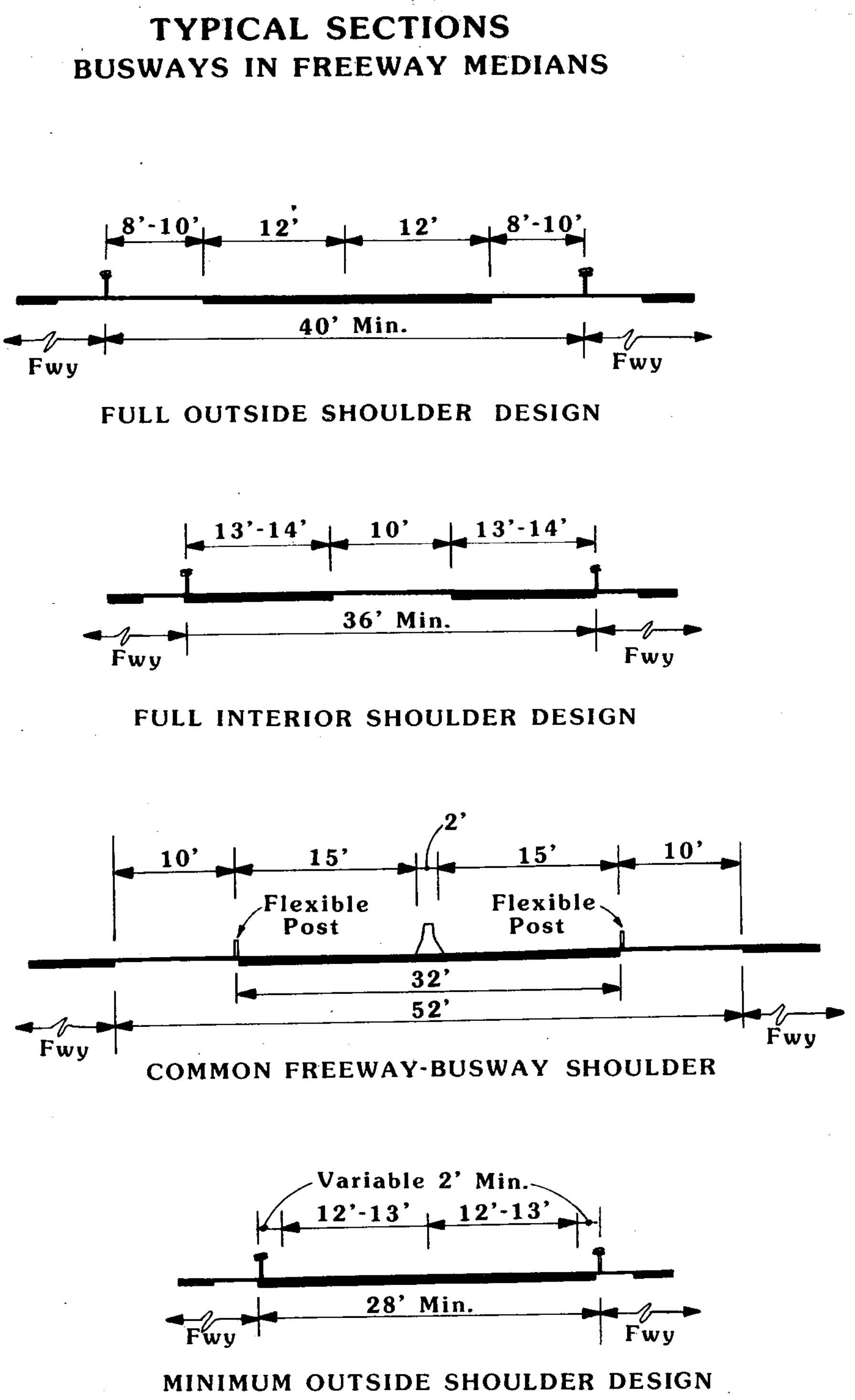
NOTE: Minimum and desirable clearances for frontage road also apply to headwalls.

SOURCE: SDHPT Operations and Procedures Manual, p. 4 - 88.

Figure 64. Typical 4-Lane Freeway Cross Section with Frontage Roads

As previously mentioned, the urban areas of Texas are constantly changing in response to the dynamic growth and development now being experienced throughout the State and, more specifically, within the Texas Triangle. Rapid population growth translates into ever increasing demands upon the transportation facilities. In an attempt to increase the people movement capacity of existing facilities, the SDHPT has embarked upon a program of implementing exclusive lanes for High Occupancy Vehicles (i.e., buses, carpools, vanpools) within existing highway rights-of-way. HOV lanes are currently under construction in Houston and being planned in Dallas. Other urban areas of Texas are also considering the implementation of such HOV facilities (i.e., San Antonio, Austin, Fort Worth). On occasion, sufficient freeway median width exists in the urban areas to implement HOV lanes (sometimes referred to as Busways, Transitways or Authorized Vehicle Lanes - AVL's) as shown in Figure 65. At other times it is necessary to either widen the freeway to the outside and/or narrow the freeway mainlanes to provide sufficient width for the HOV facility.

Figures 66 and 67 show typical urban freeway cross sections common to 6 and 8-lane highways of Texas. Figure 66 illustrates a freeway having outside frontage roads while Figure 67 shows a typical 8-lane cross section at an overpass structure. Both typical cross sections provide a median of at least 24 feet in width. However, in some cases the normal freeway median has been or will be altered by HOV treatments; this is the case on the North Freeway (I-45) and on the Katy Freeway (I-10) in Houston. Alternative alignments for a HSR system, to the outside of the freeway mainlanes or external to the right-of-way, may need to be identified in such cases if the system is to be implemented.



Source:
SDHPT Operations
and Procedures
Manual, p. 4-112

Figure 65. Alternative Methods to Utilize Freeway Rights-of-Way for High Occupancy Vehicle (HOV) Facilities

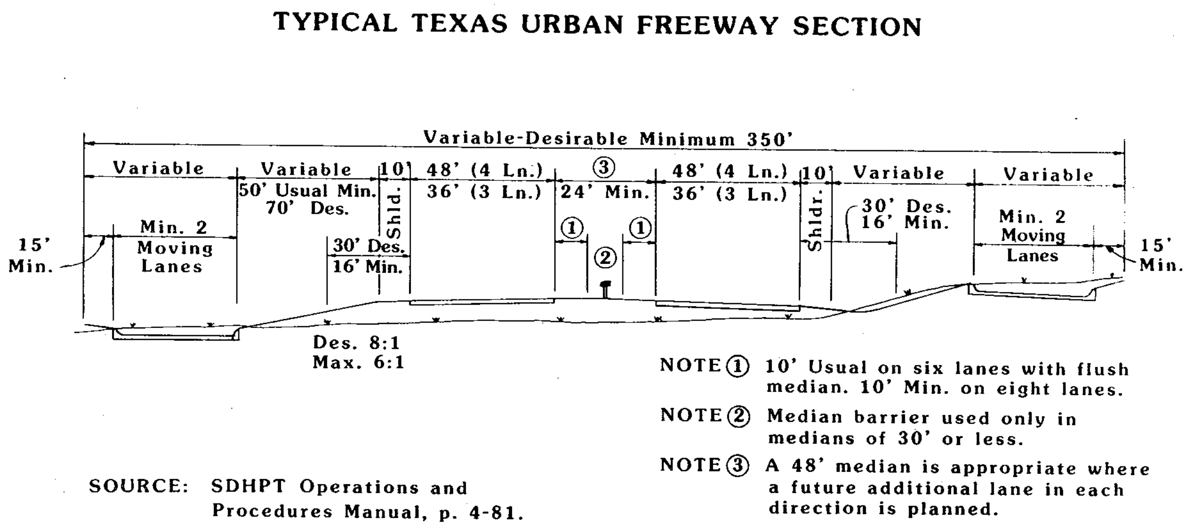


Figure 66. Typical Cross Section of an Urban Freeway with Frontage Roads

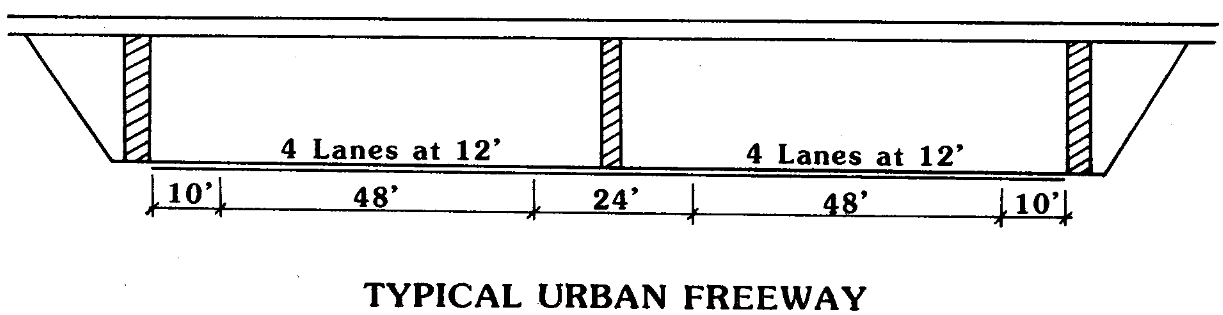
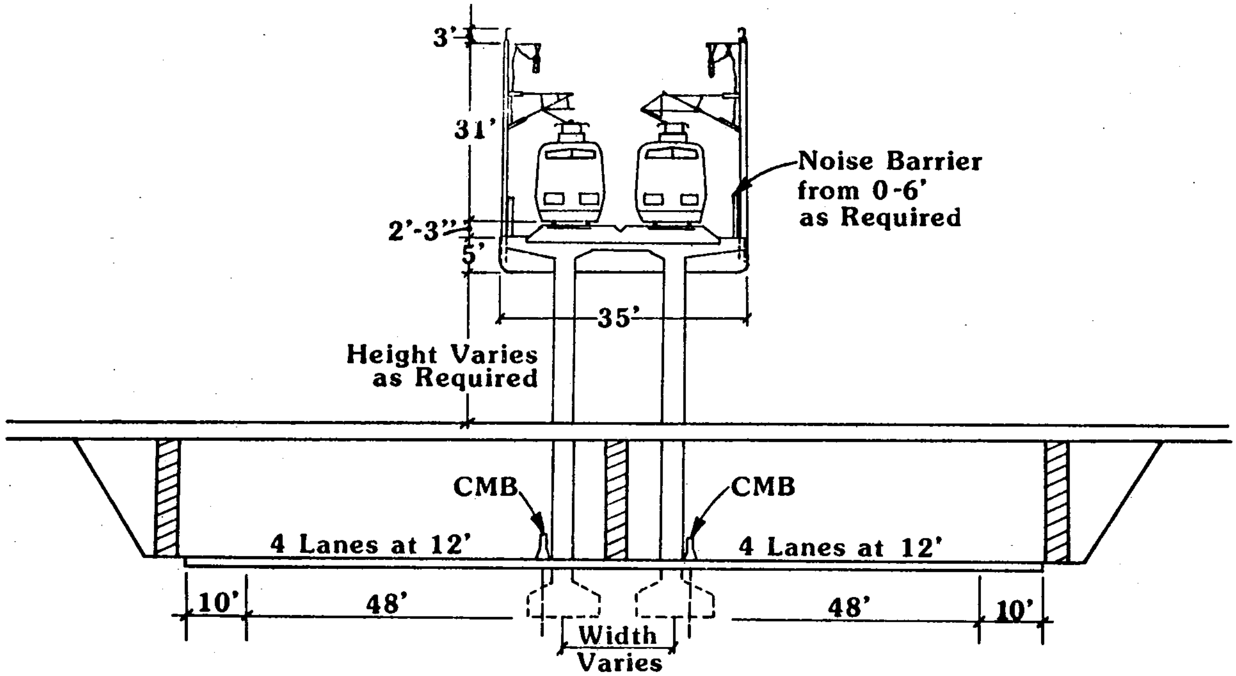
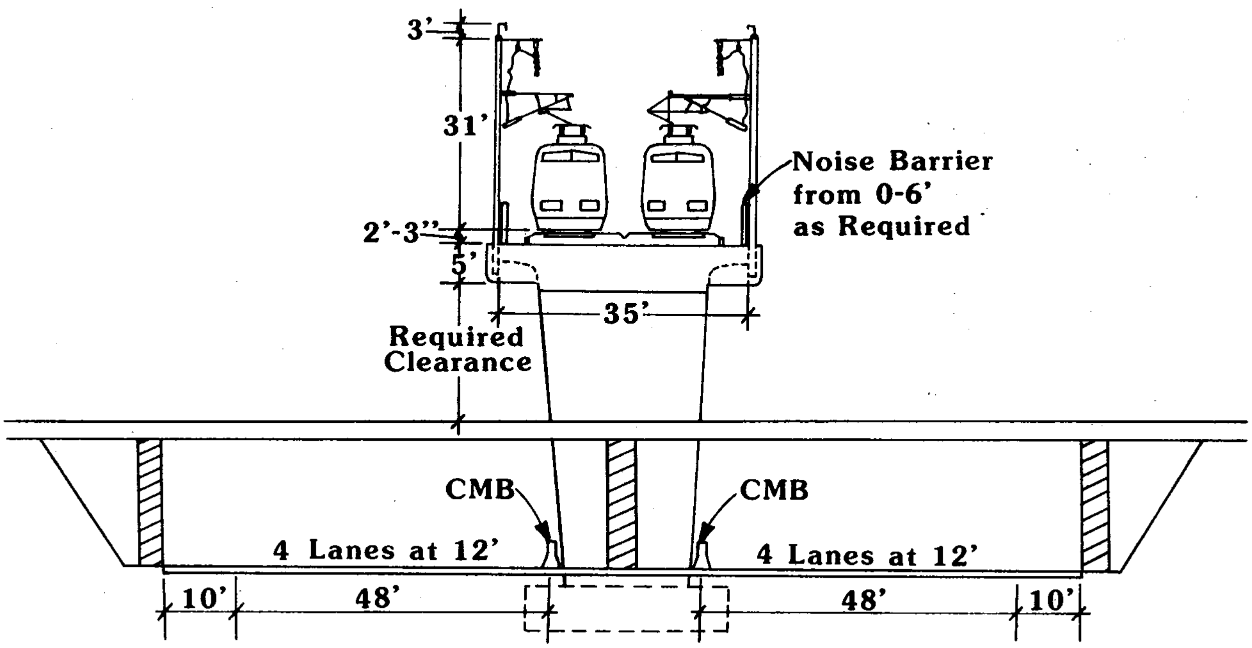


Figure 67. Cross Section of an 8-Lane Urban Freeway at an Overpass Structure



HSR STRUCTURE OVER BRIDGE (TWIN COLUMN)

Figure 68. Concept of an Elevated HSR System Within the Median of an Urban Freeway



HSR STRUCTURE OVER BRIDGE (SINGLE PIER)

Figure 69. Concept of an Elevated HSR System on a Single Pier Within the Median of an Urban Freeway

Providing that some 24 feet or more of median width exists in an urban area, an elevated 2-way HSR system could be implemented. Figures 68 and 69 illustrate two concepts of constructing an elevated HSR guideway within an available freeway median. It should be noted that, given the freeway cross section shown, the inside shoulders would be eliminated if no adjustments were made to the mainlanes. It may be possible, through proper engineering, to narrow the single pier (shown in Figure 69) to 6 or 8 feet in order to maintain the inside freeway shoulders. However, if a median of 58 feet were available, an at-grade or elevated HSR system could be implemented for a 2-way operation with minimum disruption to the existing freeway configuration.

The vast majority of the 730 miles of Interstate Freeways connecting the urban areas of the Texas Triangle are located in rural areas similar to what is shown in Figure 70. With the exception of those freeways within or near an urbanized area, the Interstate facilities have a 4-lane cross section, or 2-lanes in each direction, divided by a grassy median of variable width. In certain locations, the freeway cross section also includes parallel frontage roads outside of the main travel lanes.

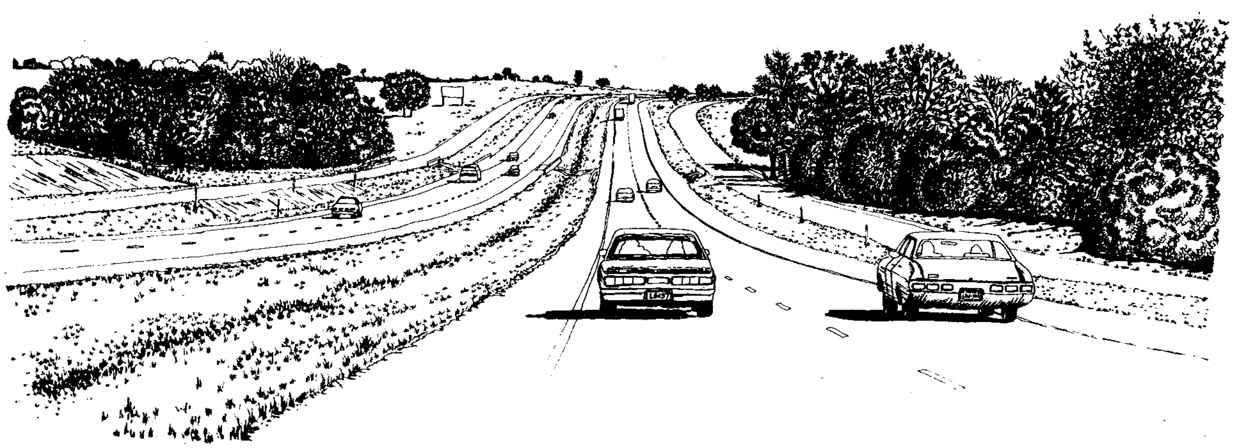


Figure 70. Typical Rural Texas Freeway with Median and Frontage Roads

If a rural freeway is fairly straight and has a relatively wide median then a HSR system could be implemented at-grade between the traveled lanes as shown in Figure 71. Medians of 96 feet or wider would provide sufficient clearance to maintain the 30-foot clear zone for 2-way operation. However, considering safety, noise and visual impacts, it may be desirable to construct Concrete Median Barriers (CMB's) to shield the High Speed trains from adjacent traffic. At-grade construction with appropriate protective devices on tangent sections of freeway is feasible for two directional HSR if the median is some 50 feet or greater in width. This will, however, preclude any cross-overs between the different directions of freeway travel; in essence, it will result in an undesirable access restriction to enforcement and emergency vehicles. This restriction could be eliminated if underpasses (i.e., tunnels) were provided at selective locations and/or emergency vehicles.

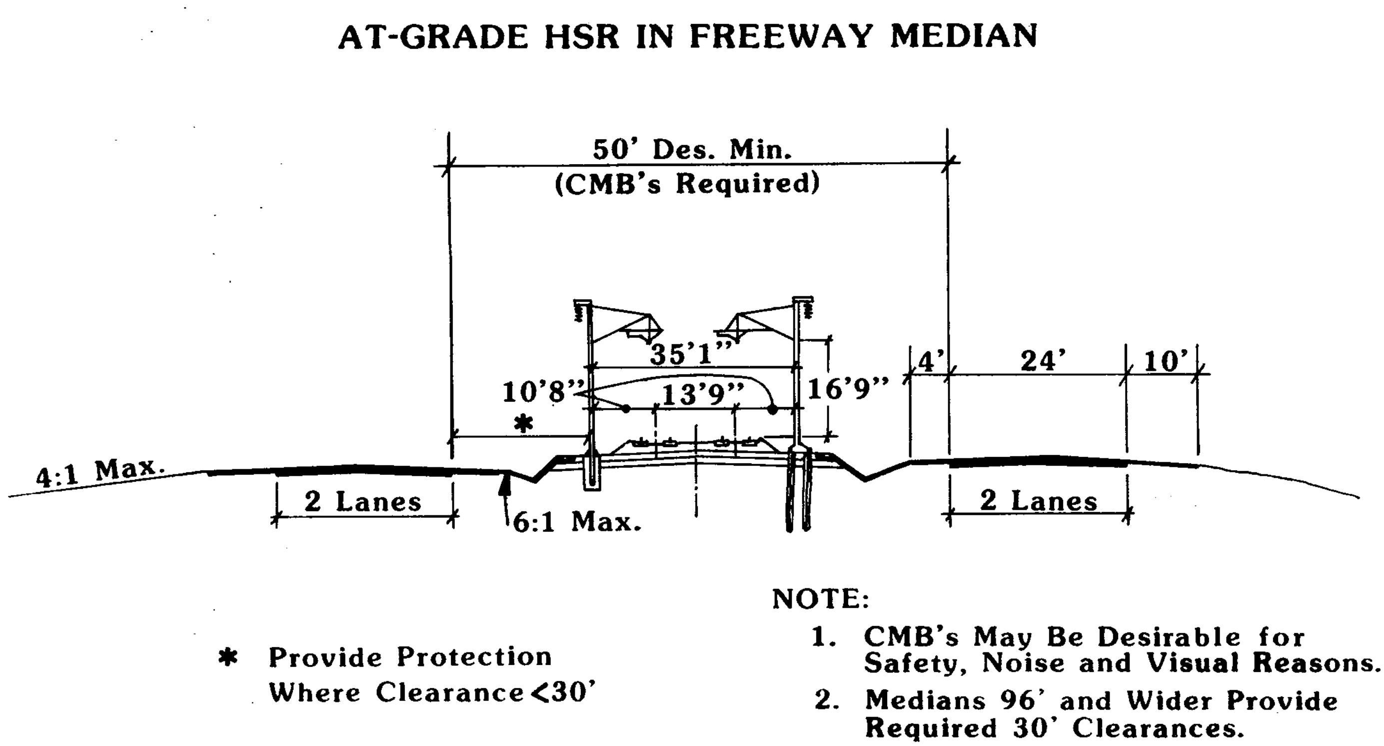
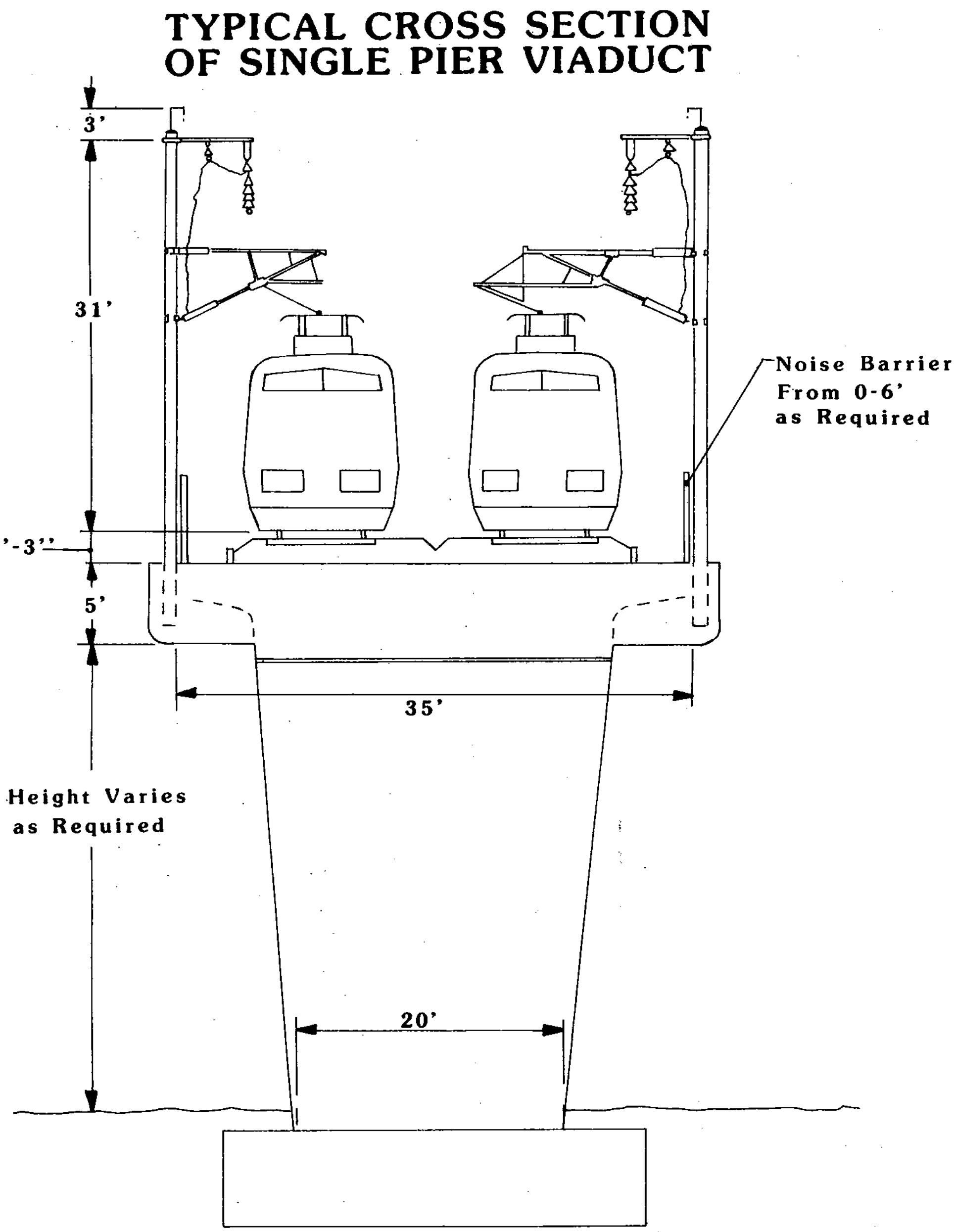


Figure 71. Concept of an At-Grade HSR System Between Freeway Mainlanes

Due to the variable design requirements associated with the different HSR systems and geometric characteristics found at certain locations along the Interstate facilities, it may be necessary or desirable to elevate portions of the guideway. Reasons to deviate from the at-grade construction could include topographic features (i.e., rivers), narrow medians, horizontal or vertical curvatures, insufficient clearances and/or overpasses. If, for some reason or reasons, it is determined desirable to elevate the HSR guideway, a structure similar to that shown in Figures 72 and 73 might be considered. Typical span lengths are in the range of 100 feet between piers. However, if the freeway curvature and/or desired HSR alignment require crossing the freeway mainlanes, it may be necessary to construct "bents" which span the freeway lanes. Alternate supporting structures, used in Japan with the Bullet train, are shown in Figure 74. These support structures are presented only for illustrating different concepts for elevating a HSR alignment; other types of structures can be designed based upon the requirements of a given location and the particular train technology.

Several of the proposed HSR systems under investigation in the United States have advanced to the detailed planning stages. Route alignments, rail technology and guideway type have been suggested for portions of the HSR corridors. Reasons for elevating the guideway may also include soil conditions or noise abatement considerations. To determine the desirability of either at-grade or elevated HSR construction, preliminary engineering studies must be conducted; such work is now underway for many of the proposed systems such as the one in Florida represented in Figure 75.



SOURCE:
Preliminary Description of Proposed Los Angeles to San Diego High Speed Rail Project, American High Speed Rail Corporation, August 1983

Figure 72. Possible Structure for Elevated HSR Alignment

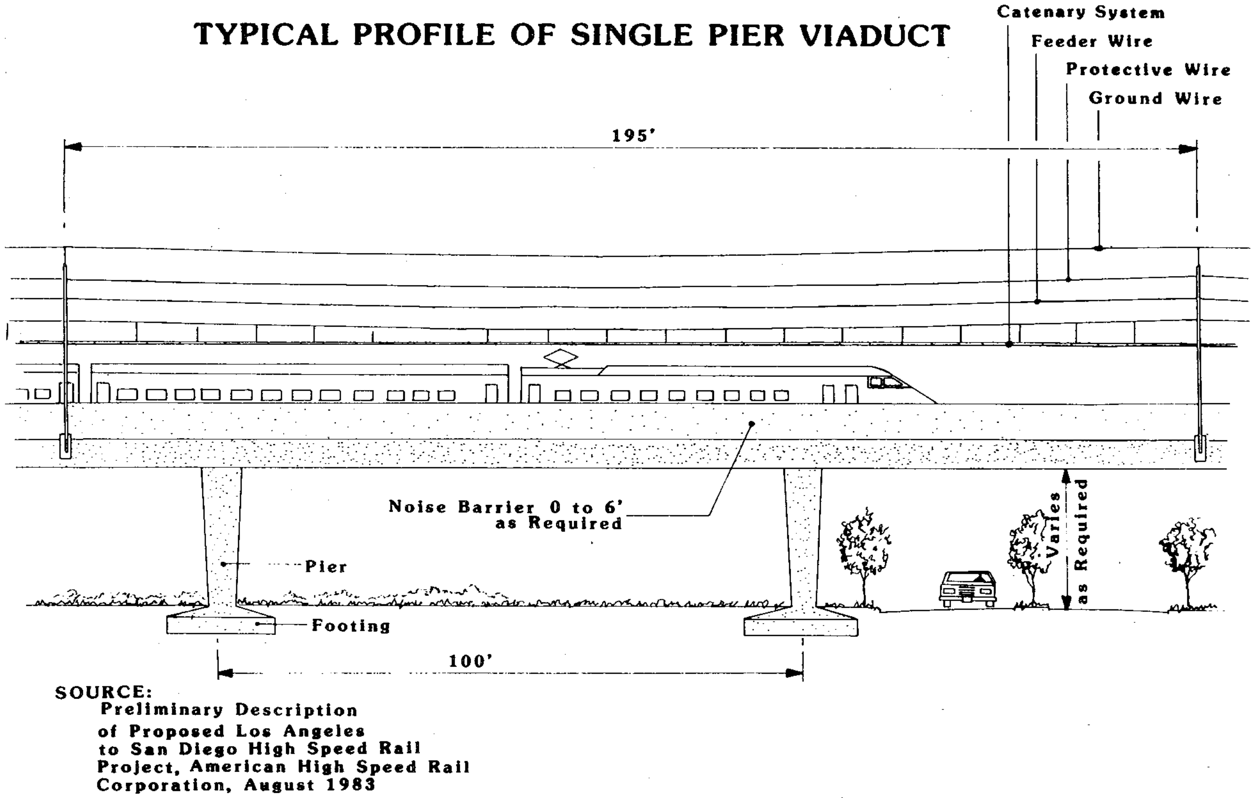
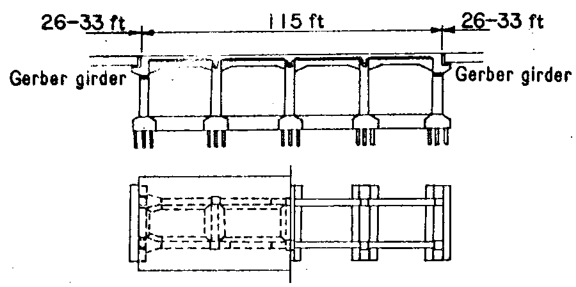
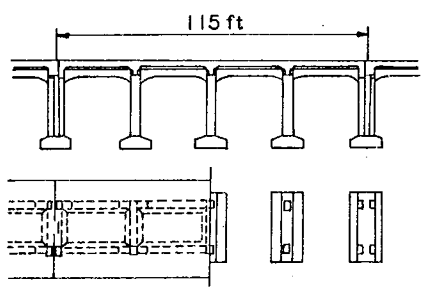


Figure 73. Profile of an Elevated HSR Alignment



Gerber Type Viaduct



Split – back Type Viaduct

Source: Japanese Railway Engineering Vol. 22 No. 4, 1982

Figure 74. Alternate Concepts of HSR Structures

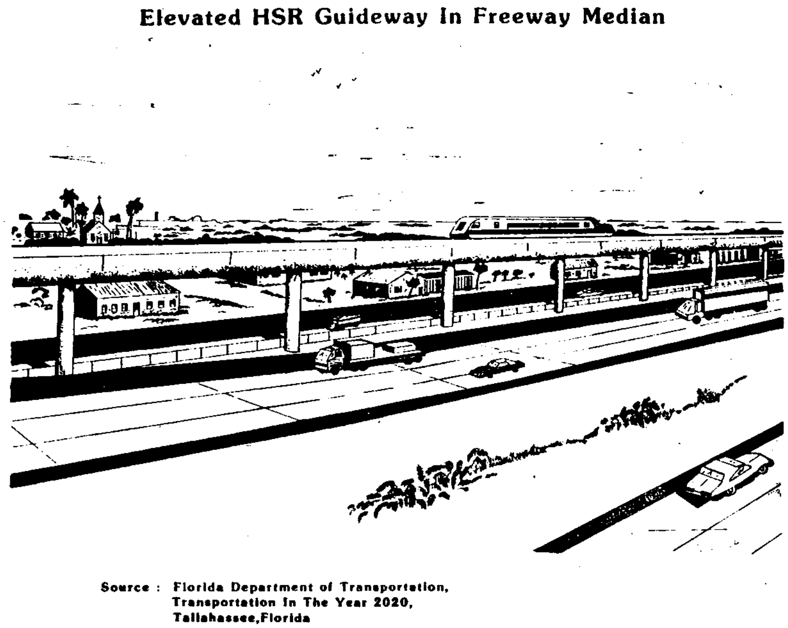
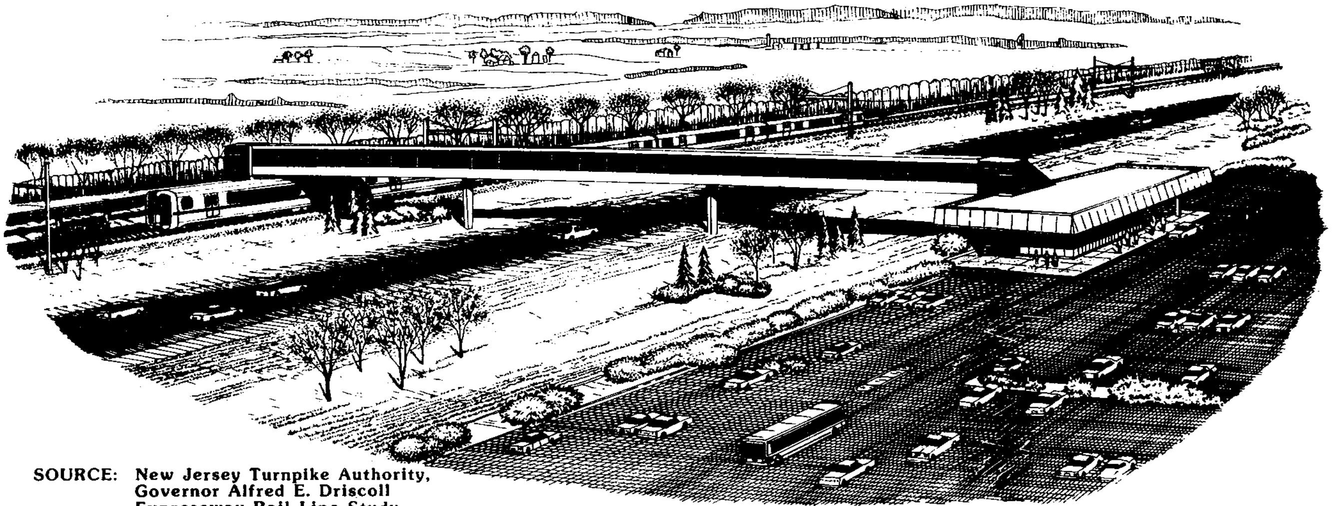


Figure 75. The Desirability of Elevating a HSR Guideway Based Upon Preliminary Engineering Studies

Given sufficient right-of-way and median width, mode-change facilities could be constructed similar to those shown in Figures 76 and 77. The selection of access points along the Texas Triangle will require an indepth analysis of potential ridership demands. It will be important, from an operational prospective, to minimize the number of stops along the various routes in order to maximize the running speeds. Unfortunately, an alignment following I-45 between Dallas and Houston will pass some 40 miles to the east of Bryan/College Station. Likewise, the route between Fort Worth and San Antonio along I-35 passes some 20 miles to the east of Killeen and Fort Hood. It may be possible with properly designed and placed mode-change facilities, like the ones suggested in Figures 76 and 77, to attract a high percentage of the potential ridership market from areas not immediately adjacent the HSR alignment. It should be noted, however, that ridership analysis is outside the scope of this study.

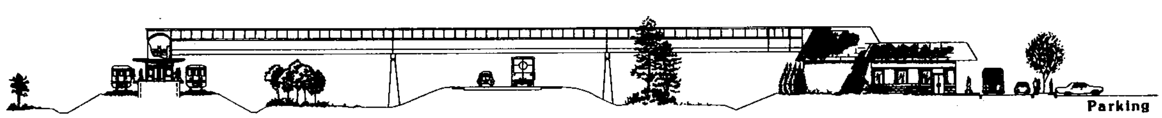
MODE CHANGE FACILITY ADJACENT FREEWAY



SOURCE: New Jersey Turnpike Authority, Governor Alfred E. Driscoll Expressway Rail Line Study, October 1975.

Figure 76. Conceptual Illustration of a Mode-Change Facility on and Adjacent to Freeway Right-of-Way

SECTION OF TYPICAL PLATFORM & STATION BUILDING



SOURCE New Jersey Turnpike Authority, Governor Alfred E. Driscoll Expressway Rail Line Study, October 1975.

Figure 77. Possible Connecting Structure Between a HSR System and a Mode-Change Facility

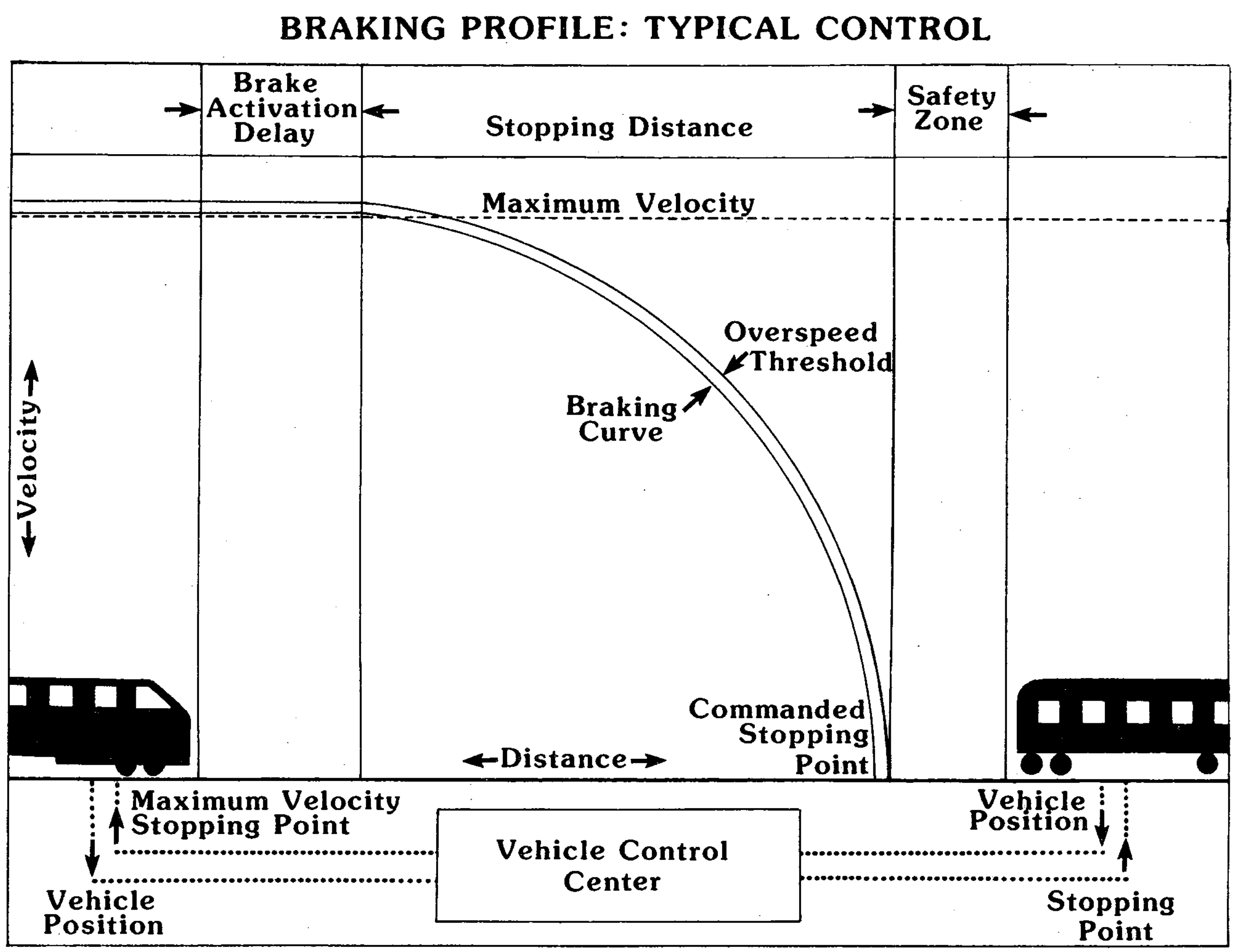
Results of HSR Simulation

The eight rail technologies, previously discussed, were superimposed upon the highway geometrics to determine operating speeds achievable and required travel time on the various Interstate Freeway Corridors. Performance characteristics of each HSR technology in combination with travel distances and horizontal curvatures of the involved freeways were the key components of the simulation analysis. Details of the simulation routine are presented elsewhere in this report. However, Figure 78 illustrates one of the fundamental principals employed in the investigation. The maximum velocity of a train varies with the particular technology but also is dependent upon horizontal curves along the freeway alignment. The simulation assumed the role of the "control center" and supervised the operation of the train through a given corridor. Results of the investigation are included in Table 16 for the eight HSR systems investigated for the Texas Triangle.

TABLE 16: TRAVEL TIME COMPARISONS FOR THE TEXAS TRIANGLE BY HSR SYSTEM (MINUTES)

System:	Max Speed (mph)	Super-elevation (Inches)	Travel Corridor				Total Triangle
			IH-10	IH-35/35W	IH-30	IH-45	
#1	120	12	111	131	18	130	390
#2	200	12	78	97	14	94	283
#3	200	18	73	87	12	86	258
#4	200	18	69	68	12	82	249
#5	350	18	59	79	11	74	223
#6	200	24	67	81	11	80	239
#7	350	24	55	70	10	69	204
#8	350	36	NA	NA	NA	53	NA

Note: Refer to Table 14 for definitions of HSR systems.



SOURCE:
ITT, The SELTRAC System of Automatic Train Control, Ontario, Canada, May 1984.

Figure 78. Illustration of Deceleration Profile Used in HSR Simulation Analysis

Travel time required for the entire triangle, excluding station dwell time, ranged from 204 minutes (3.4 hours) to 390 minutes (6.5 hours) for the 7 simulated HSR systems which were analyzed on all four Interstate corridors. The eighth system was simulated for only IH-45 or the Dallas to Houston corridor. The total time required to travel the triangle by HSR is one-fourth to one-half of the time required by an automobile (approximately 13.7 hours).

Air travel between Dallas and Houston, including access and boarding times, requires some 140 minutes (2.3 hours) from CBD to CBD under favorable conditions. All of the HSR technologies, except the 120 MPH AMTRAK system, simulated on the IH-45 freeway right-of-way provide faster service than the airlines. The CBD to CBD travel time by HSR operating in the 200 MPH to 350 MPH range, including station access times, requires in the range of 68 minutes (1.1 hours) to 109 minutes (1.8 hours). The Dallas to Houston trip by HSR would be approximately 1.3 to 2.1 times as fast as airline travel.

The "Construction and Operational Considerations" section along with Appendix B of this report provide more detail analysis of the HSR simulations. It is technically feasible to construct a HSR system on the Interstate rights-of-way which would favorably compete in terms of travel times with the private automobile and the airline industry.

Practical Feasibility

General

In addition to the "technical" considerations of implementing a High Speed Rail service within the Texas Triangle, numerous other factors must be addressed in order to determine the practicality of building such a system. The section of this report entitled "Factors and Considerations of Implementing HSR Services" presents a discussion on many related issues which must be addressed in the decision-making process. This portion of the report attempts to address some of the fundamental issues which must be considered in assessing the practical feasibility of HSR passenger services in the State of Texas.

Institutional, Jurisdictional and Social Issues

Of primary importance is resolving: Who should design and operate a new High Speed Rail system in the State of Texas? What, if any, role would AMTRAK play in HSR service? If the HSR alignment follows both highway and railroad rights-of-way, which governmental agencies will be involved and with what responsibilities? To what extent do opportunities exist for public/private cooperation in HSR ventures for Texas?

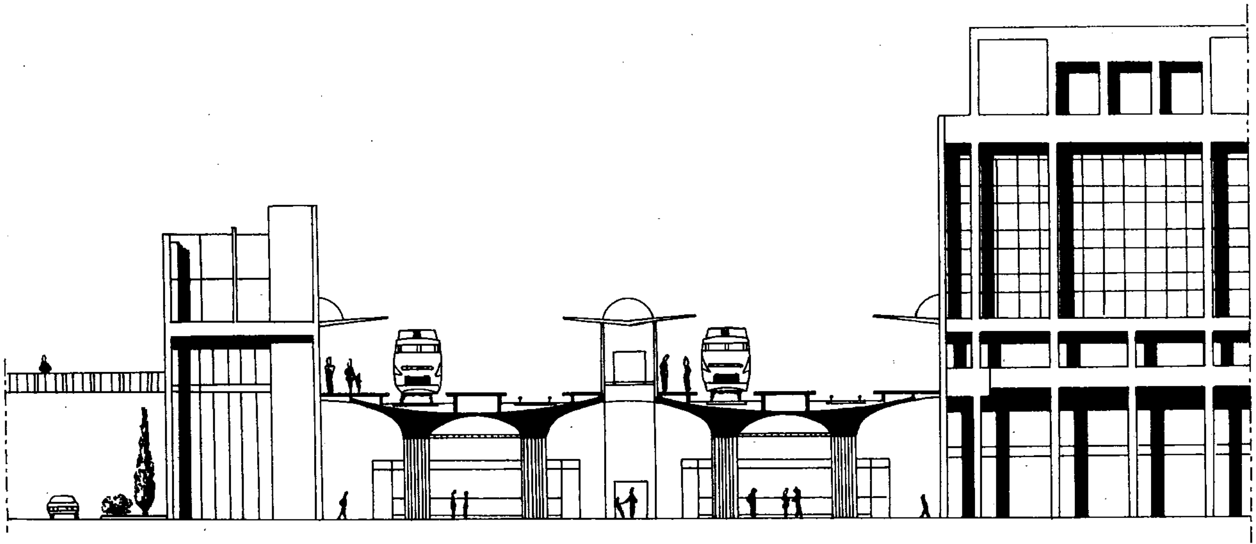
The State Department of Highways and Public Transportation (SDHPT) is responsible for planning, designing, operating and maintaining the Texas highway system. In the case of Interstate highways, SDHPT closely coordinates their activities with the Federal Highway Administration and, if public transit is involved, the Urban Mass Transportation Administration. A HSR system built totally or partially upon State highway right-of-way will necessitate SDHPT's close involvement throughout all phases of planning, implementation and operation.

The Texas Railroad Commission is responsible for intercity rate regulation of motor buses and freight railroads. The commission works closely with the Interstate Commerce Commission (ICC) in its regulatory role and with the Federal Railroad Administration (FRA) regarding planning activities and track standards. If HSR service is implemented on railroad rights-of-way, the Commission will obviously be involved. However, it is not clear as to what role the Commission would play in rate setting for a HSR system built upon highway right-of-way.

The Texas State Legislature will need to address these and other questions if HSR service is to become a reality in the Texas Triangle. Other State Agencies will also be involved in planning a HSR system through the environmental review process.

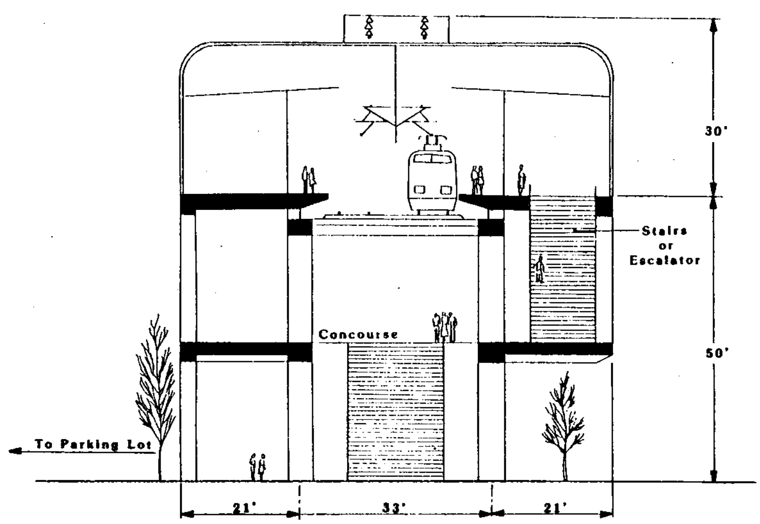
Local governments (i.e., cities, counties, MPO's, COG's, transit authorities) must be brought into the early phases of HSR planning if such a service is to be a success. Conventional and accessable stations must be provided close to the major traffic generation points in the Central Business District's (CBD's) and other activity centers. Ridership projections should be performed in concert with local knowledge of new or planned developments in the urban areas. Mode-change facilities (i.e., Park-and-Ride Lots, Park-and-Pool Lots) and services (i.e., Taxi, Shuttle Bus, Urban Rail Transit) should be an intregal part of planning access to and from a HSR system. The HSR guideway and stations could significantly impact other planned developments in any urban area. Route alignments and station location as well as design should be determined in close coordination with the affected local entities. Clearly, elevated stations like those shown in Figures 79 and 80, if constructed in a CBD, could severely impact an urban area if not incorporated in the overall development plans.

ELEVATED DOWNTOWN STATION
POSSIBLE CROSS SECTION



Source:
The TGV Company,
Very High Speed Rail
Proposal for Florida,
December 1983.

Figure 79. Elevated HSR Station Impacting an Urban Area

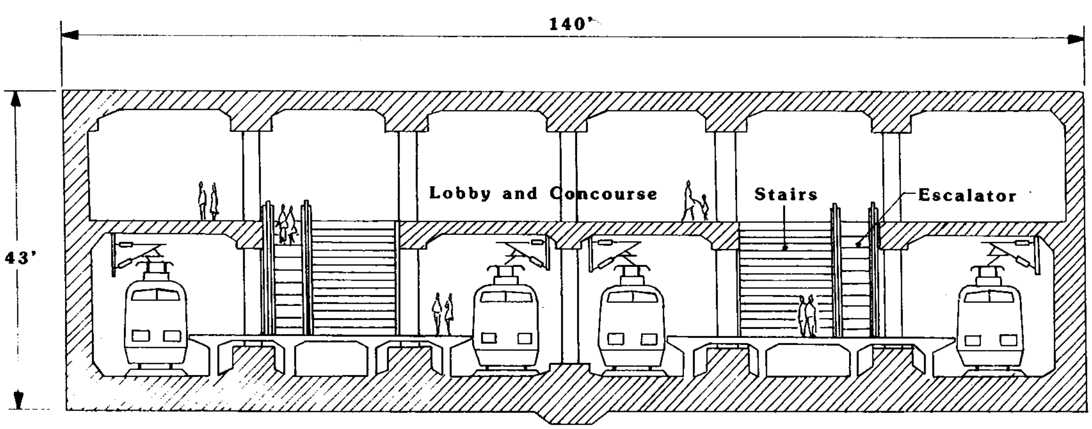


TYPICAL CROSS SECTION OF ELEVATED STATION

SOURCE:
Preliminary Description of Proposed Los Angeles to San Diego High Speed Rail Project, American High Speed Rail Corporation, August 1983

Figure 80. Concept of an Elevated HSR Station in a Downtown Area

Local governments and planning bodies in the State of Texas are very active in trying to meet the needs of their urban areas. Texas cities are experiencing rapid growth and development which places a strain on the infrastructure including the transportation facilities. In terms of local objectives and other planned projects, an underground HSR interface with the CBD may be more desirable than an elevated interface. Figure 81 shows an artist's rendering of an underground HSR station. Given these considerations, whoever is the lead agency or company for planning HSR in Texas, full and complete coordination with the affected local entities can not be overemphasized.



TYPICAL CROSS SECTION OF UNDERGROUND STATION

SOURCE:
Preliminary Description of Proposed Los Angeles to San Diego High Speed Rail Project, American High Speed Rail Corporation, August 1983

Figure 81. An Alternative to the Elevated HSR Station Concept

Several other factors associated with HSR implementation should be addressed during the 3-C planning process. These include public support, energy requirements, regional mobility, airport congestion, tourism and development/land use impacts. Through cooperative and comprehensive planning participated in by all affected parties, many if not all of the issues outlined herein can be successfully addressed.

Legal and Regulatory Issues

If Interstate right-of-way is used for HSR passenger service, several federal laws and implementing regulations apply. These laws and regulations are outlined in the report section entitled "Factors and Considerations of Impelementing HSR Services". The SDHPT will need to be closely involved in the planning of any HSR system which contemplates using highway right-of-way and will need to coordinate such planning with the Federal Highway Administrator, U.S. Department of Transportation. The FHWA Administrator has the discretion to consider or not to consider an application for such nonhighway use of rights-of-way.

Potential for HSR Services

General

High Speed Rail passenger service has been proposed in numerous travel corridors throughout the United States. Over 4800 miles of HSR is suggested for 16 projects detailed in the "Survey" section of this report. This represents, in capital costs alone some $34 billion if an average cost per mile of $7 million were assumed. The length of the proposed systems average some 300 miles for the Philadelphia to Atlantic City corridor to approximately 750 miles for the Texas Triangle. The State of Florida is considering a long range plan for HSR service consisting of some 1200 route miles. Clearly, High Speed Rail proposals, if implemented, would consititute one of the nation's larger transportation undertakings in recent years.

Technically Feasible

HSR service can be implemented with adequate planning and design. Highway rights-of-way could be a viable alignment alternative provided that sufficient median or outside width exists for the proposed system. Some problems, however, can be expected in urban areas when attempting to place a HSR system on highway property or when interfacing the service to the core of the Central Business District (CBD). In some cases, such as in Houston, the freeway medians have been dedicated to other people movement facilities (i.e., HOV Lanes) and would not be practical alignments for a HSR system.

Interfacing the HSR system with major activity centers in the downtown areas of urban areas must be closely coordinated with the local entities. Although more costly than the elevated guideway, HSR could be connected to downtown terminal with underground tunnels. Figures 82, 83 and 84 illustrate three methods for providing underground tunnels when necessary. The exact configuration and dimensions of the tunnels will be determined by the HSR technology used. For example, if a MagLev system were to be implemented similar to the one shown in Figure 85, the guideway and tunnel dimensions would need to accommodate the system's requirements.

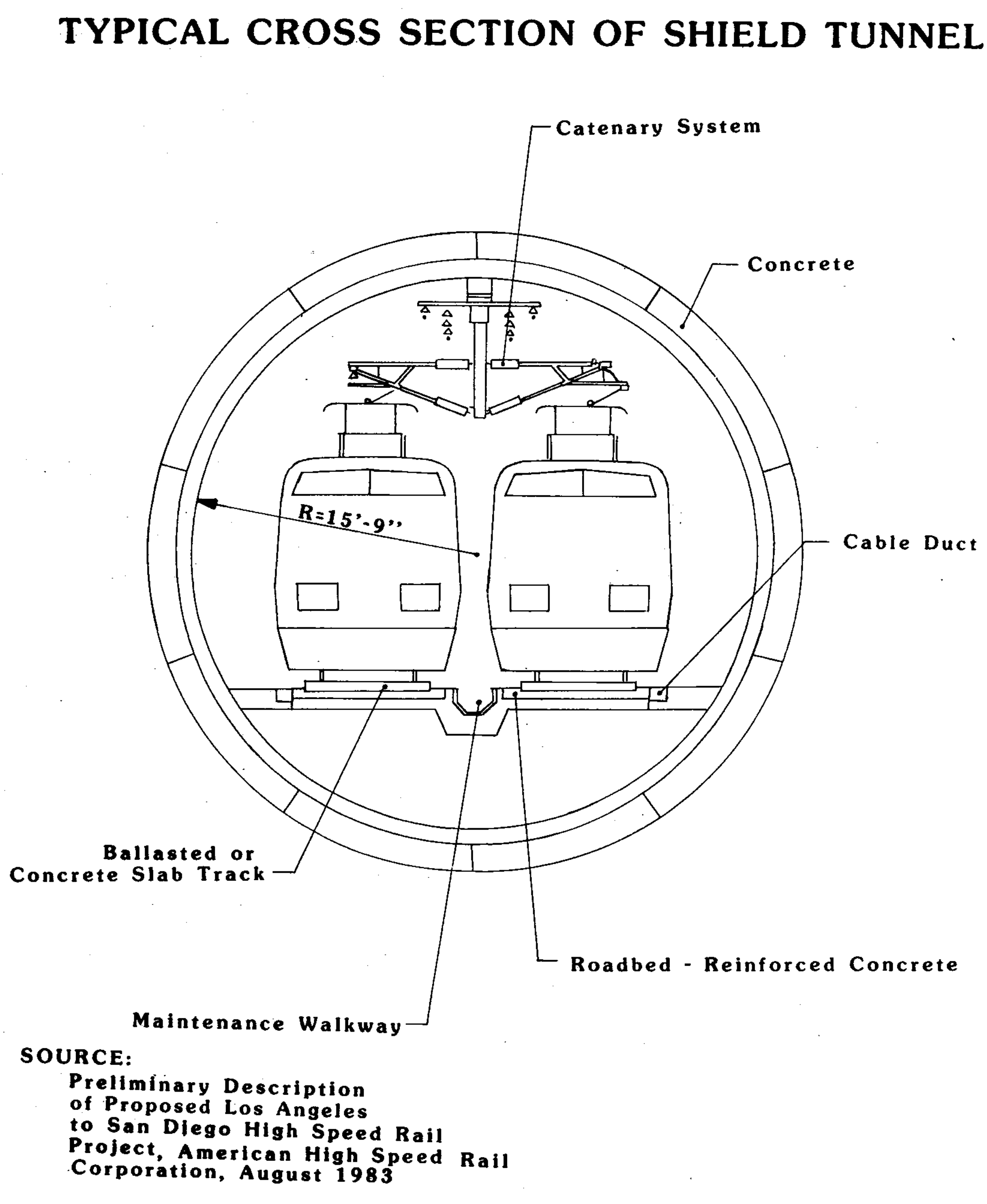
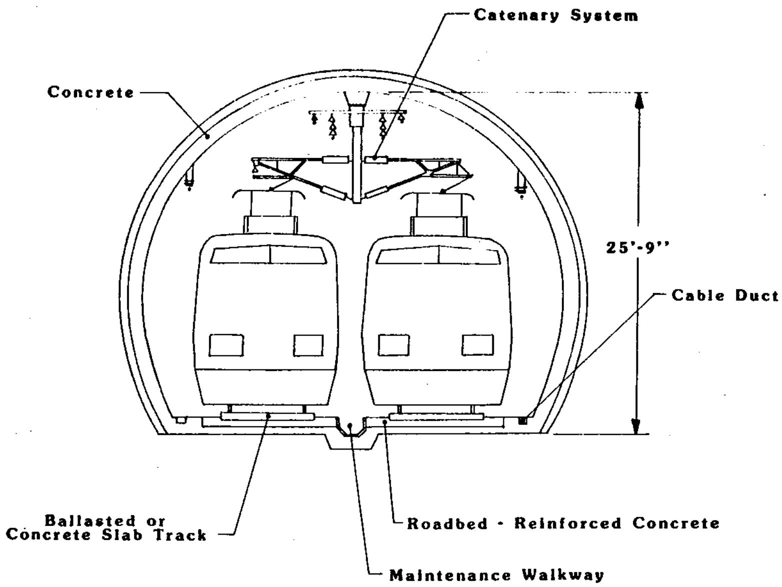


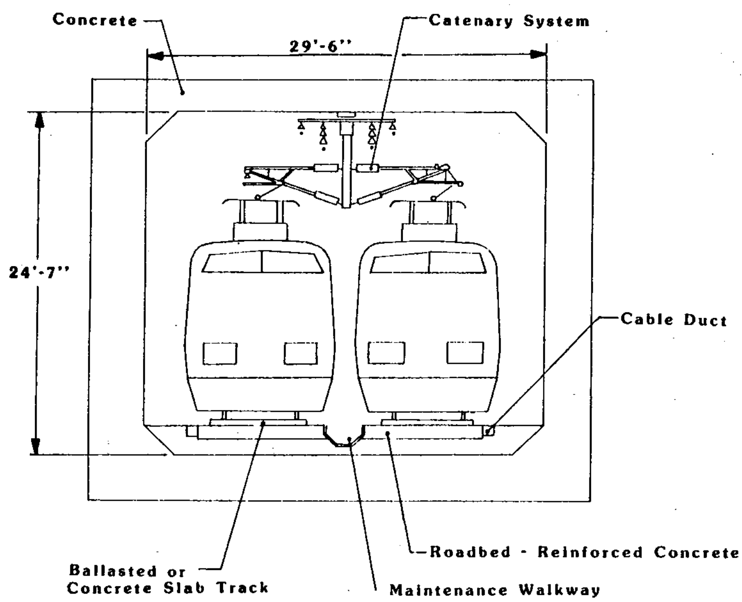
Figure 82. Alternative Method of Interfacing HSR to Downtown Terminals



TYPICAL CROSS SECTION OF DIRECT BORE TUNNEL

SOURCE:
Preliminary Description of Proposed Los Angeles to San Diego High Speed Rail Project, American High Speed Rail Corporation, August 1983

Figure 83. Alternative Method of Accommodating HSR In Central Business Districts

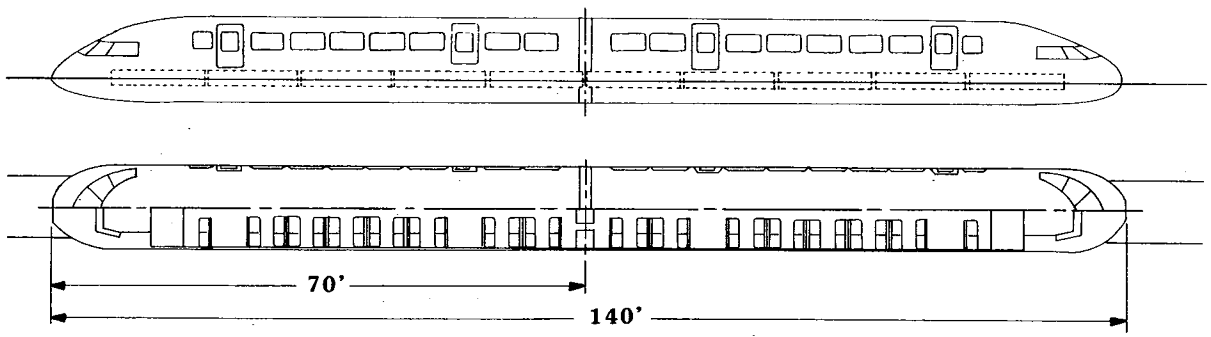


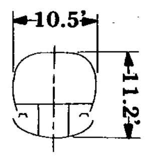
TYPICAL CROSS SECTION OF CUT & COVER TUNNEL

SOURCE:
Preliminary Description of Proposed Los Angeles to San Diego High Speed Rail Project, American High Speed Rail Corporation, August 1983

Figure 84. Cut-and-Cover Alternative for HSR In Downtown Area

PROTOTYPE MAG-LEV VEHICLE CONCEPT





- Length .... 70 ft/vehicle
- Gross weight .... 21 ton/vehicle
- Cruising speed .... 186 mph
- No.of seats 60/vehicle
- No.of modules 10/vehicle

Source : American Mag-Lev,Pitman,New Jersey,February 1984

Figure 85. HSR Technology will Determine Size and Dimensions of Underground Tunnels

Practical Potential for HSR

Unfortunately, the scope of this research did not include market analysis or the projection of possible ridership for High Speed Rail passenger service. It has been estimated by others that, in the first year of operation, some 5,000 to 10,000 passengers per day might be expected on the Dallas to Houston route. This estimate is approximately 20 to 25 percent of the total passenger movements withing the travel corridor (Cooper, 1984). The practical feasibility of constructing one or more of the HSR alignments will ultimately depend upon ridership and related revenues. The type of service provided and pricing strategies employed will play a key role in the market share that a HSR system can attract.

If further studies of ridership and financing indicate that a HSR system for the Texas Triangle is practical, then all involved parties and local governmental agencies should develop a workable planning framework for coordinating the preliminary and detail studies required. In addition, State Legislation should be enacted to clarify the roles and responsibilities of the Texas Railroad Commission and the State Department of Highway and Public Transportation as they pertain to HSR service.

BIBLOGRAPHY

Abate, Frank D., National Railroad Passenger Corporation. Letter to Richard Peterson, March 7, 1984.

Aeg-Telefunken, Berlin. Sales brochures, undated.

Ambler, Chester III, Atlantic City Urban Area Transportation Study. Letter to Richard Peterson, January 20, 1984.

American High Speed Rail Corporation. Preliminary Description of Proposed Los Angeles to San Diego High Speed Rail Project. August 1983.

American MagLev, Pitman, New Jersey. Philadelphia/Atlantic City inter-city brochure, undated.

AMTRAK Timetable, 1972.

"Amtrak Hits 120 MPH." Railway Track and Structures, Vol. 79, No. 9, September, 1983. p. 13.

Andersson, Evert. "The Development of High Speed Vehicles in Sweden." Presented at I. Mech. E, Derby Branch, October, 1982.

ASEA. "Electrical Multiple Unit Set Calss-X2." Sweden. Undated.

Association of American Railroads. Government and Private Expendiures for Highway, Waterway, Railroad and Air Rights-of-Way. Washington, D.C. September 1976.

Barry, Dennis O., State of Nevada, Department of Transportation. Letter to Richard Peterson, January 30, 1984.

Bombardier Inc. This is the LRC. Boucherville, Quebec, Canada. Undated.

Boocock, D. High Speed British Trains. Paper presented at ITE Meeting, London, 1983.

Boocock, D., and King, B.L. The Development of the Prototype Advanced Passenger Train. Institute of Mechanical Engineers. England, 1982.

Boocock, D., and Newman, M. The Advanced Passenger Train. Institute of Mechanical Engineers. England, 1976.

British Rail. Intercity APT Brochure, undated.

British Rail. Operational Aspects of High Speed, undated.

Brown, Susan, California Department of Transportation. Letter to Richard Peterson, December 19, 1983.

The Budd Company. "Budd Presents MagLev". Brochure. 1984.

The Budd Company. Las Vegas to Los Angeles High Speed/Super Speed Ground Transportation Feasibility Study. January 27, 1983.

Buffington, Jesse L., Railroad Property Acquisition, Use, Taxation and Abandonment. Texas Rail System Evaluation, Texas Transportation Institute. January, 1977.

"Bullet Train for California". Urban Transportation Abroad, Vol. 6, No. 1, Spring, 1983. p.1.

Burlington Timetable, 1963.

Calhoun, Frank L. Federal Highway Administration. Letter to Richard Peterson, January 19, 1984.

"California Bullet Train is Challenged in Suit." Engineering News-Record, Vol. 212, No. 6, February 9, 1984. p. 35.

"California Bullet Train Line Found Economically Feasible." Engineering News-Record, Vol. 210, No. 13, March 31, 1983. p. 14.

"California Bullet Train Starts on Review Journey." Engineering News-Record, August 25, 1983. pp 25-26.

Canadian MagLev Group. Electrodynamic Suspension and Linear Synchronous Motor Propulsion for High Speed Guided Ground Transportation. Canadian Institute of Guided Ground Transport, Kingston, Ontario. September, 1977.

Car and Locomotive Cyclopedia. Simmons-Boardman, Omaha, Nebraska, 1980.

Carillo Lumpie, D.J.C., "Experimental Talgo Features Pendular Body-Tilting", Railway Gazette International, February, 1977. p. 58.

Casey, Robert. "High Speed Rail Association: Legislative Report." November 18, 1983.

"Casino Stakes State on High-Speed Rail Line." Engineering News-Record, Vol. 212, No. 1, January 10, 1984. p. 34.

Cataldi, G. R., Association of American Railroads. Letter to Richard Peterson, January 31, 1984.

CF & I Steel Corporation, Pueblo, Colorado. Sales Brochures, undated.

"Cherry Blossum to Stop Bullet Train." Urban Innovation Abroad, Vol. 7, No. 12, December, 1983. p. 5.

Christiansen, Dennis L., et. al. An Evaluation of the Need for Intercity Rail Passenger Service in Texas. Texas Rail System Evaluation, Texas Transportation Institute. January, 1977.

CL Rail Trucks, Inc., Washington, D.C. Sales Fliers, 1982.

Coates, Geoffrey R., American MagLev. Letter to Richard Peterson, January 13, 1984.

Connecticut Department of Transportation, Bureau of Planning and Research. Report of the On Board Survey of Amtrak Service on the New Haven-Springfield Line. August, 1975.

Cooper, Hal B. H., Private Sector High Speed Rail Service in Texas. Presented at the 63rd Annual Meeting of the Transportation Research Board, January 17, 1984.

Cooper, Hal B. H., Summary for a Project Description: High Speed Railroad Passenger Service in the Houston-Dallas Intercity Corridro. Texas Railroad Transportation Company. March 14, 1983.

Corddry Carpenter Dietz & Zack Engineers. Governor Alfred E. Driscoll Expressway: Rail Line Study. Prepared for the New Jersey Turnpike Authority. October, 1975.

Crawford, James A., New Jersey Department of Transportation. Letter to Richard Peterson, January 26, 1984.

Criterion Inc. Analysis of the Fiscal Impacts of a High Speed Rail Station on the City of Oceanside. Prepared for the American High Speed Rail Corporation. November, 1983.

Daley, D. M., and E. T. Leonard. Rail Transit Safety: 1981 Annual Report. U.S. Department of Transportation. October, 1982.

Dallaire, Gene. "What Future for America's Railroads?" Civil Engineering - ASCE, Vol. 52, No. 11, November, 1982. pp. 54-59.

De Leuw, Cather & Company, et al. Northeast Corridor Improvement Project Task 119: Feeder Line Improvement Program-Inland Route. U.S. Department of Transportation. January, 1980.

Dick, Merwin, "The New Track Challenge." Railway Track and Structures, Vol. 80, No. 4, April, 1984. p. 54.

Dick, Timber, Messerschmitt-Bolkow-Blohm GmbH, Boulder, Colorado. Letter to Richard Peterson, November 16, 1983.

Dickhart, William W., The Budd Company Technical Center, Fort Washington, Pennsylvania. Letter to Richard Peterson, March 2, 1984.

Dorton, R. A., and H. N. Grouni. "Review of Guideway Design Criteria in Existing Transit System Codes." ACI Journal, April, 1978.

Edge, Helen H., Railway Progress Institute. Letter to Richard Peterson, January 23, 1984.

Ellis, C. H., State of New Jersey Department of Transportation. Letter to Richard Peterson, December 15, 1983.

Federal Railroad Administration. Northeast Corridor Improvement Project: Executive Summary of Programmatic Environmental Impact Statement. U.S. Department of Transportation. September, 1977.

Feiniod, Stanley G., New Jersey Transit. Letter to Richard Peterson, February 13, 1984.

"Firm Agrees to Run High-Speed Amtrak Trains." Passenger Transport, January 28, 1983. p. 9.

Fitzpatrick, C. and R. W. Lake. High Speed Passenger Locomotives and Track Structures. Canadian Institute of Guided Ground Transport, Kingston, Ontario. March 28, 1980.

Flick, David. "Fort Worth Moves Toward Buying Rock Island Right-of-Way." The Dallas Morning News, July 27, 1983.

"Florida Gets Rail Commission." Engineering News-Record, Vol. 212, No. 23, June 7, 1984. p. 18.

"Florida Won't Share Rail Line." Engineering News-Record, September 29, 1983 p. 55.

"Flying to Las Vegas on the Ground." Metropolitan, Vol. 78, No. 6, November/ December, 1982. pp. 6-8.

Foster, Adrian, et al. Michigan High Speed Intercity Rail Passenger Development Study: Market Analysis. Prepared for the Michigan Department of Transportation by Transmark, Inc. August, 1981.

"France Builds 160-mph Rail Line." Engineering News-Record Field and Office Manual. McGraw-Hill Inc., undated. pp. 50-51.

"France Moves to Enter American Train Market." Engineering News-Record, June 2, 1983. p. 18.

French Railway Techniques. Dunod. Paris, 1978.

Friesen, W. "Advanced Train Control Technology." Engineering Digest, Vol. 29, No. 9, October, 1983. pp. 36-42.

Gebhard, J. W. Acceleration and Comfort in Public Ground Transportation. Applied Physics Laboratory, John Hopkins University, Silver Spring, MD. February 1970.

Giest, Rick. "Report of the Chairman" High Speed Rail Passenger Compact Meeting, Indianapolis, Indiana, November 16-19 1983.

Gell, C. F., "Table of Equivalents for Acceleration Terminology," Aerospace Medicine, Vol. 32, No. 12, 1961. p. 1109.

GermanRail, New York, New York. Promotional brochures, undated.

Gildenston, Robert F., Lord Corporation, Eric, Pennsylvania. Letter to Richard Peterson, March 28, 1984.

Grovdahl, David, East Central Florida Regional Planning Council. Letter to Richard Peterson, February 2, 1984.

Hall, J. W. Field Study of Rail-Highway Crossing Crash Sites. University of New Mexico, October, 1982.

Hay, W. W. Railroad Engineering. 2nd Ed., John Wiley & Sons, New York. 1982.

Hayward, Charles W., National Railroad Passenger Corporation. Letter to Richard Peterson, January 16, 1984.

Heaney, Jim. "Proposal Calms Fears Over Bullet Train." The Orlando Sentinel, January 10, 1984.

Heaney, Jim. "Rail Panel Applauds Proposals." The Orlando Sentinel, January 31, 1984. p. B-1.

Hercik, J. Scott, Michigan Department of Transportation. Letter to Richard Peterson, February 7, 1984.

"High, Higher, Super Speed." Engineering News-Record, Vol. 212, No. 4, January 26, 1984. p. 64.

"High Speed Commuter Rail Study in Canada." Modern Railroads, April, 1981. p. 22.

High Speed Ground Transportation Systems Engineering Study and Supporting Studies for High Speed Ground Transportation Systems Reports, TRW Systems Group, #PB-192506 and #06818-6041-R0-00, 1970.

High Speed Jetport Access. TRW Systems Group, #FRA RT-70-38, 1969.

"High Speed Rail Advances." Engineering News-Record, July 28, 1983. pp. 13-14.

"High Speed Rail Compact Approved." Engineering News-Record, June 28, 1984. p. 5.

High Speed Rail Compact Technical Committee. High Speed Rail Compact Background Report. November, 1983.

"High Speed Rail Questioned." Engineering News-Record, Vol. 212, No. 3, January 19, 1984. p. 20.

"High Speed Rail Survey Stokes Plan Dispute." Engineering News-Record, Vol. 212, No. 21., May 24, 1984. pp. 18-20.

"High Speed Rail Tests Builders." Engineering News-Record, Vol. 212, No. 4, January 26, 1984. pp. 28-29.

"High Speed Train Plans are Submitted to Florida." Engineering News-Record, Vol. 212, No. 2, January 12, 1984. pp. 36-37.

"High Speed Trains Gain Momentum." Engineering News-Record. Vol. 212, No. 8, February 23, 1984. p. 10.

Highway User Costs Associated with Regional Rail System Construction. Prepared by the Texas Transportation Institute for the Metropolitan Transit Authority of Harris County. April 28, 1983.

Hollingsworth, B. Illustrated Encyclopedia of North American Locomotives, Crown Publishers, New York, N.Y., 1984.

Hollingsworth, Brian, and Arthur F. Cook. The Illustrated Encyclopedia of the World's Modern Locomotives. Salamander Books Ltd. 1983.

Homburger, Wolfgang S. Transportation and Traffic Engineering Handbook, 2nd Ed. Institute of Transportation Engineers, Prentice-Hall, Englewood Cliffs, New Jersey, 1982.

Howell, R. P., et. al. Northeast Corridor High Speed Rail Passenger Service Improvement Project. Task 3: Track and Structure Standards Development. Prepared for the U. S. Department of Transportation. Septemeber, 1975.

Horvitz, Paul. "Resorts Would Own, Operate Rail Terminal." The Philadelphia Inquirer, Thursday, December 29, 1983. p. 1-B

Huss, H. W., IBCOL Technical Services, Haar, West Germany. Letter to Richard Peterson, April 29, 1984.

Hudak, Alex W., General Electric Letter to Richard Peterson, January 4, 1984.

Institute of Transportation Engineers. Compendirim of Technical Papers. 53rd Annual Meeting, London, England, August 14-18, 1983.

ITT Industires of Canada Ltd., Don Mills, Ontario. Brochures, undated.

James Walker Mfg. Co., Glenwood, Illinois. Sales brochures, undated.

Japanese National Railways. "MagLev: Transportation for Tomorrow." Brochure, undated.

Japanese National Railways. Promotional brochures, undated.

Johnson, Robert. "Newfangled French Trains Hope To Make It in Texas by Moving Fast." Wall Street Journal, May 18, 1983.

Joint Development and Multiple Use of Transportation Rights-of-Way. Highway Research Board, Special Report 104, 1968.

Jones, Joseph. High-Speed Trains in France: Paris Sud Est. Prepared for the Transportation Development Centre and VIA Rail Canada, Inc. by the Canadian Institute of Guided Ground Transport. October 1981.

Katz, Gregory. "Bullet Trains for USA: The Right Track?" USA Today, January 28, 1983. p. 1B.

Kohn, Melvin J., Parsons, Brinckerhoff, Quade and Douglas, Inc. Letter to Richard Peterson, January 30, 1984.

Konsortium Magnetbahn Transrapid, Emsland, West Germany. TRANSRAPID brochures, undated

Kuempel, George. "State Oks Funds to Buy D-FW Tracks." The Dallas Morning News, March 31, 1983.

"L.A. to L.V. Line Studied." Passenger Transport, June 27, 1983. p.6.

"Las Vegas Moves Slowly on MagLev Consultants." Engineering News-Record, Vol. 212, No. 15, April 12, 1984. p. 16.

"Las Vegas Takes Flyer With MagLev." Urban Transportation Abroad, Vol. 6, No. 3, Fall, 1983. p. 3.

Lawson, K. L., et. al. Northeast Corridor High Speed Rail Passenger Service Improvement Project. Task 9: Technical and Economic Analysis of Vehicle/ Right-of-Way Systems. Volume II. Prepared for the Federal Railroad Administration. August, 1975.

Lazarek, William A., State of Connecticut Department of Transportation. Letter to Richard Peterson, February 9, 1984.

Legislative Transportation Committee, State of Washington. "Request for Proposal: Economic Feasibility of a High Speed Transportation System in Western Washington." Draft Report, March 2, 1984.

"The LRC - Tomorrow's Train Ready Today." Metropolitan, Vol. 76, No. 5, September/October, 1980. p. 141.

Lussi, John K. State of New York Department of Transportation. Letter to Richard Peterson, December 19, 1983.

Lyles, Richard W., Michigan State University. Letter to Richard Peterson, January 31, 1984.

MagLev: Transportation For the Future. Technical brochure by the Japanese National Railways, March 1983.

"Magnet-Driven Trains Save Energy." Engineering News-Record, Vol. 211, No. 22, December 1, 1983. p. 54.

"Magnetic Levitation Line Feasibility Studies Slated." Engineering News-Record, Vol. 212, No. 4, January 26, 1984 p. 20.

Malone, Frank. "The Great Train Race." Railway Age, January, 1984. pp. 46-56.

McCormick, E. J. Human Factors in Engineering and Design. McGraw-Hill Book Company, 1976.

Merchant, Robert L., State of Vermont. Letter to Richard Peterson, January 11, 1984.

Metzler, J.M.M. French Experience in Very High Speed: The TGV. Paper presented at London ITE Meeting, 1983.

Meyer, Carl F., and David W. Gibson. Route Surveying and Design. Harper and Row Publishers, Inc., New York, NY, 1980. p. 18.

Middleton, W. D., "Sweden Tries High-Speed Tilting Trains." Railway Age, January 1984, p. 56.

Miller, F. College Physics. Harcourt, Brace & World, Inc., 1959.

Miller, Myron, et al. Recommendations for Northeast Corridor Transportation. U.S. Department of Transportation. September, 1971.

Miller, R.H. "What Makes A Totally Good Railroad Crossing?" Better Roads, Vol. 53, No. 1, January, 1983, p. 17.

Nakamura, S. et al. "Experimental Results of the Single-Sided Linear Induction Motor." IEEE Transactions on Magnetics, Vol. MAG-15, No. 6, November, 1979. pp. 1434-1436.

"National Conference Held on High Speed Rail." Rail News Update, No. 2383, October 19, 1983. p. 2.

National Railroad Passenger Corporation and Japanese Railway Technology Corporation. High Speed Rail Passenger Service in Florida: A Preliminary Assessment. December 1983.

National Railroad Passenger Corporation. Rail Corridor Development: An Update. September, 1982.

Nelson, Gilbert N., TDC Electronics Inc., New York, New York. Letter to Richard Peterson, February 8, 1984.

Nesslinger, R. A., Parsons, Brinckerhoff, Quade and Douglas, Inc. Letter to Richard Peterson, January 30, 1984.

New Jersey Department of Transportation. An Operating Plan for Atlantic City/Philadelphia Rail Passenger Service. June 1, 1983.

New Mexico Transportation Deparment. Request for Proposal: Rio Grande Corridor Rapid Rail Passenger Feasibility Study: Phase I. October, 1983.

"New Report Qualifies Bullet Train Feasibility." Engineering News-Record, June 16, 1983. pp. 17-18.

New York State Deparment of Transportation, Rail Planning and Marketing Bureau. New York State Rail Preservation Program: Annual Report. September, 1982.

Nordqvist, S., J. Rosen, and B. Tidhult. High Speed Trains. Swedish Board of Technical Development, Sweden, 1980.

Norris, Paul R., Oregon Department of Transportation. Letter to Richard Peterson, January 31, 1984.

Overman, G.J., Electro-Motive Division General Motors Corporation, LaGrange, Illinois. Letter to Richard Peterson, January 11, 1984.

Paquette, R. J., N. J. Ashford, and P. H. Wright. Transportation Engineering, Planning and Design. 2nd ed. John Wiley & Sons, New York, 1982.

Passenger Psychological Dynamics, The Journal of Urban Transportation Corp., American Society of Civil Engineers, June 1968.

Paternoster, Laurie. "High-Speed Train Plans Outlined." The Houston Post, May 13, 1983. p. 8B.

Paul, Bill. "The Blue Chip Rail Derby." Metropolitan, Vol. 79, No.4, July/August 1983. p. 39.

Peterson, Richard L., C. J. Porterfield and H. C. Petersen, Feasibility of Utilizing Existing Railroad Rights-of-Way for Transit Corridors in Urban Areas, State Department of Highways and Public Transportation, TTI Report 1074-1F, May 1984.

Proceedings of the Symposuim on High Speed Ground Transportation System Technology. Munich, October 25-26, 1983.

Prouty, L. Flectcher. "High Speed Rail Passenger Service: Technology and Application." TR News, No. 108, September-October 1983. pp. 2-5.

"Publisher's Perspective." Railway Age, Vol. 185, No. 5, May 1984. p. 94.

Quinby, H. D. "Mass Transportation Characteristics." Transportation and Traffic Engineering Handbook, Prentice-Hall Inc. 1976.

Rail Passenger Transportation in Texas: A Preliminary Feasibility Study. Prepared for the Texas Mass Transportation Commission by the Texas Transportation Institute. September, 1974.

Rankin, James M., and Forest C. Deal. Transportation in the Year 2020. Prepared by the Florida Department of Transportation, 1977.

"Repositioning For the Future". Metropolitan, May-June 1984.

Rice, Richard A., "Comparative Evaluation of Train Concepts." Improved Passsenger Rail Service, Conference Report No. 7, Carnegie-Mellon University, December 1975.

Richmond, Jonathon. Slicing the Cake - The Case for a Los Angeles/San Diego Bullet Train. Prepared for the City of Tustin, California. August 15, 1983.

Ronald, C. C., et. al. Northeast Corridor High Speed Rail Passenger Service Improvement Program: Task 19 - Suport Services: Dynamics and Computer Program Development. U.S. Department of Transportation. July, 1976.

Rosen, John. "High Speed Trains." ITE Compendium of Papers, London, 1983.

San Diego Association of Goverments. "American High Speed Rail Proposal (Update)." Agenda Report No. R-77, September 30, 1983.

San Diego Association of Governments. "Bullet Train Update." Agenda Report No. R-80, October 28, 1983.

San Diego Association of Governments. "Bullet Train Update." Agenda Report No. R-92, November 18, 1983.

Scheck, Ronald C., State of New Mexico Transportation Department. Letter to Richard Peterson, March 14, 1984.

Scheffel, H., African Transport Services. Technical write-up and pamphlet on "Metrobilitz," May, 1984.

Schwarzwalder, James J., New Jersey Transit-Bus Operations Inc., Letter to Richard Peterson, January 24, 1984.

Sheridan, John P., New Jersey Commissioner of Transportation. Letter to the Philadelphia Enquirer, January 22, 1984.

Shirley, Earl, California Department of Transportation. Letter to Richard Peterson, January 31, 1984.

SNCF. "The TGV Paris-Sud-Est." Promotional brochure, undated.

Solomon, Kathleen M., et. al. Passenger Psychological Dynamics. Sources of Information on Urban Transportation-Report Number 3. June, 1968.

Stanley, Robert G., American Public Transit Association. Letter to Richard Peterson, February 18, 1983.

Stout, Robert B. Economic Regulation of Railroads. Texas Rail System Evaluation. Transportation Institute. October, 1977.

Stout, Robert B. and Dennis L. Christiansen. The Technology of Rail Passenger Service. Prepared for the State of Texas by the Texas Transportation Institute. June, 1976.

Suddes, Thomas. "Bullet Train Plan is on Track in Florida." Cleveland Plain Dealer, November 20, 1983. p. A-25.

Swedish State Railways. "High Speed Trains in Sweden." Undated.

Szilagyi, Pete. "Bullet Rail Line Picking Up Speed." Austin American-Statesman, June 5, 1983. p. A1.

Taylor, William C., and Richard W. Lyles. Economic Benefits of High Speed Rail Service in the Upper Great Lakes Region. Prepared for the Council of Upper Great Lakes Governors by the Department of Civil Engineering, Michigan State University. December, 1983.

Taylor, William C., and Richard W. Lyles. Feasibility of Private Sector High Speed Rail Service in the Detroit/Chicago Corridor. Prepared for the Federal Railway Administration by the Department of Civil Engineering, Michigan State University. December 1983.

Tennyson, E. L. "Potential and Cost of Commuter or Regional Rail Service." Transportation Research Record 908, Transportation Research Board. 1983.

The TGV Company. Very High Speed Rail Proposal for Florida. Washington, D.C. 1983.

"TGV for Texas?" Modern Railroads, July, 1983. p. 56.

"TGV Update." Urban Transportation Abroad. Vol. 6, No. 4, Winter 1983. p.3.

"TGV Visits Penn." Transportation. University of Pennsylvania, April-May 1983.

"Today in Railroading." Railway Track and Structures, June, 1983. p. 9.

"Today in Railroading." Railway Track and Structures, Vol. 79. No. 8, August, 1983. p. 9.

"Today in Railroading." Railway Track and Structures, Vol. 80, No. 3, March, 1984. p. 9.

"Transportation: A Banner Year Lies Ahead for Most Sectors." Engineering News-Record, Vol. 212, No. 2, January 12, 1984. pp. 72-76.

Transportation and Distribution Associates, Inc. Requirements for Increasing Passenger Train Speeds and Frequencies in the Chicago - St. Louis Corridor. 1981.

Travis, Merrill L., Illinois Department of Transportation. Letter to Richard Peterson, March 13, 1984.

"Tustin Study Deems Bullet Train Financially Unfeasible." News Release, Cavender Communications, Santa Ana, California. October 25, 1983.

"Two More High Speed Rail Developments." Metropolitan, Vol. 80, No. 1, January/February, 1984.

U.S. Congress, Office of Technology Assessment. U.S. Passenger Rail Technologies. December, 1983.

U.S. Department of Transportation. High Speed Ground Transportation Alternatives Study. January, 1973.

U.S. Department of Transportation. Northeast Corridor Improvement Project: Redirection Study. January, 1979.

U.S. Department of Transportation. Rail Passenger Corridors: Analysis of Potential Improvements. February, 1980.

U.S. Department of Transportation. Rail Passenger Corridors: Analysis of Potential Improvements-Supplemental Report on Four Corridors. April, 1980.

U.S. Department of Transportation. Rail Passenger Corridors: Evaluation Method and Ranking. July 1980.

U.S. Department of Transportation. Rail Passenger Corridors: Final Evaluation. April, 1981.

"U.S. High-Speed Rail Plans Still Alive and Kicking." Metropolitan, Vol. 78, No. 2, March/April, 1982. p. 47.

Walston, Timothy C., et. al. Operational Potential of Suspended Vehicle Systems (SVS). Prepared by TRW Transportation and Environmental Operations for the Federal Railroad Administration. April 1974.

Weber, Oliver. "The Signalling for the Very High Speed Line." French Railway Techniques, Dunod Publishing, Paris. 1978.

WED Transportation Systems Inc., Lake Buena Vista, Florida. "Wedway Peoplemover." Undated.

APPENDIX A

Physical Inventory of Triangle

Roadway Inventory File

APPENDIX A

This Appendix presents a tabular listing of highway geometrics, facilities and characteristics for the five Interstate roadways comprising the Texas Triangle. Tables A1 through A34 summarize the primary data collected by the research team. Tables A35 through A68 present the secondary data derived from SDHPT's roadway inventory file (RI2T-LOG). All of the tables describe a freeway segment within a given county. To facilitate referencing the data, an index to both the primary and secondary data sources is provided.

Physical Inventory of Triangle (Primary Data)

Table No.	Interstate	County
A 1	I-10	Bexar
A 2	I-10	Guadalupe
A 3	I-10	Caldwell
A 4	I-10	Gonzales
A 5	I-10	Fayette
A 6	I-10	Colorado
A 7	I-10	Austin
A 8	I-10	Waller
A 9	I-10	Fort Bend
A10	I-10	Harris
A11	I-45	Harris
A12	I-45	Mongomery
A13	I-45	Walker
A14	I-45	Madison
A15	I-45	Leon
A16	I-45	Freestone
A17	I-45	Navarro
A18	I-45	Ellis
A19	I-45	Dallas
A20	I-35	Bexar
A21	I-35	Guadalupe
A22	I-35	Comal
A23	I-35	Hays
A24	I-35	Travis
A25	I-35	Williamson
A26	I-35	Bell
A27	I-35	Falls
A28	I-35	McLennan
A29	I-35	Hill
A30	I-35W	Hill
A31	I-35W	Johnson
A32	I-35W	Tarrant
A33	I-30	Tarrant
A34	I-30	Dallas

Roadway Inventory File (Secondary Data)

Table No.	Interstate	County
A35	I-10	Bexar
A36	I-10	Guadalupe
A37	I-10	Caldwell
A38	I-10	Gonzales
A39	I-10	Fayette
A40	I-10	Colorado
A41	I-10	Austin
A42	I-10	Waller
A43	I-10	Fort Bend
A44	I-10	Harris
A45	I-45	Harris
A46	I-45	Montgomery
A47	I-45	Walker
A48	I-45	Madison
A49	I-45	Leon
A50	I-45	Freestone
A51	I-45	Navarro
A52	I-45	Ellis
A53	I-45	Dallas
A54	I-35	Bexar
A55	I-35	Guadalupe
A56	I-35	Comal
A57	I-35	Hays
A58	I-35	Travis
A59	I-35	Williamson
A60	I-35	Bell
A61	I-35	Falls
A62	I-35	McLennan
A63	I-35	Hill
A64	I-35W	Hill
A65	I-35W	Johnson
A66	I-35W	Tarrant
A67	I-30	Tarrant
A68	I-30	Dallas

TABLE A-1. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 10
SDHPT DISTRICT 15 *** BEXAR COUNTY
EASTBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	BRIDGE STRUCTURE NO	BRIDGE STRUCTURE TYPE	BRIDGE STRUCTURE LENGTH	OVERPASS NO	OVERPASS TYPE	CLEARANCE EB	CLEARANCE WB	CLEARANCE AVG	HORIZONTAL CURVE (DEGREE)	TRANS-MISSION LINES	OBSERVERS COMMENTS
	0.00	0.00	.		.	.		.	.	.	0.50	.	I10/I35 AT I10 WESTBOUND
	2.70	2.70	.		.	.		.	.	.	.	.	I10 AT US90/I35
	3.42	3.42	1	ELV	0.60	.		.	.	.	.	.	
	4.04	4.04	1	ELV	0.40	.		.	.	.	.	.	
	4.35	4.35	1	UP	.	.		.	.	.	.	.	
	4.55	4.55	.		.	1	OP	15.67	17.08	16.37	.	.	I37
	4.96	4.96	1	UP	.	.		.	.	.	.	.	
	5.27	5.27	1	UP	.	.		.	.	.	.	.	
	5.74	5.74	.		.	1	OP	14.42	14.25	14.33	.	.	
	5.99	5.99	.		.	1	OP	14.25	14.67	14.46	.	.	
	6.30	6.30	.		.	1	OP	14.92	15.50	15.21	.	.	
	6.82	6.82	.		.	1	OP	13.58	15.42	14.50	.	.	
	7.39	7.39	2	UP	.	.		.	.	.	.	.	
	7.85	7.85	2	UP	.	.		.	.	.	.	.	
	8.36	8.36	2	UP	.	.		.	.	.	.	.	
	8.88	8.88	2	UP	.	.		.	.	.	.	.	
	9.91	9.91	1	UP	.	.		.	.	.	.	.	
	10.27	10.27	1	UP	.	.		.	.	.	.	.	
	10.63	10.63	.		.	.		.	.	.	.	.	MEDIAN PAVED ALSO GUARD RAIL
	10.84	10.84	.		.	4	OP	16.25	16.25	16.25	.	.	LOOP 410 STRUCTURE
	11.45	11.45	2	CB	.	.		.	.	.	.	.	
	12.28	12.28	2	CB	.	.		.	.	.	.	.	
	12.79	12.79	.		.	1	OP	15.08	15.92	15.50	.	.	
	14.80	14.80	2	CB	.	.		.	.	.	.	.	
	15.16	15.16	.		.	.		.	.	.	.	3	LARGE STRUCTURES
	15.57	15.57	2	UP	.	.		.	.	.	.	.	
	17.43	17.43	2	UP	.	.		.	.	.	.	.	LOOP 1604
	18.56	18.56	2	CB	.	.		.	.	.	.	.	
	18.87	18.87	.		.	1	OP	16.08	16.17	16.12	.	.	
	19.54	19.54	2	CB	.	.		.	.	.	.	.	
	20.83	20.83	.		.	.		.	.	.	.	.	REST AREA BOTH SIDES
	21.50	21.50	.		.	1	OP	16.00	16.08	16.04	.	.	
	22.53	22.53	2	CB	.	.		.	.	.	.	.	WOMAN HOLLERING CREEK
593	22.68	22.68	.		.	.		.	.	.	.	.	MPT 593
	23.30	23.30	.		.	1	OP	17.00	16.58	16.79	.	.	
	23.92	23.92	.		.	.		.	.	.	.	.	BEXAR/GUADALUPE COUNTY LINE

BRIDGE STRUCTURES : UP = VEHICULAR UNDERPASS
CB = CREEK/RIVER BED
RR = RAIL ROAD
UPRR = VEHICULAR UNDERPASS WITH RAILROAD
UPCB = VEHICULAR UNDERPASS AND CREEK/RIVER BED
ELV = ELEVATED STRUCTURE

OVERPASSES : OP = VEHICULAR OVERPASS
RR = RAIL ROAD OVERPASS
PED = PEDESTRIAN OVERPASS

SOURCE : TEXAS TRANSPORTATION INSTITUTE SURVEY

TABLE A-2. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 10
SDHPT DISTRICT 15 *** GUADALUPE COUNTY
EASTBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	BRIDGE STRUCTURE NO	BRIDGE STRUCTURE TYPE	BRIDGE STRUCTURE LENGTH	OVERPASS NO	OVERPASS TYPE	OVERPASS CLEARANCE EB	OVERPASS CLEARANCE WB	OVERPASS CLEARANCE AVG	HORIZONTAL CURVE (DEGREE)	TRANSMISSION LINES	OBSERVERS COMMENTS
	0.00	23.92	.		.	.		.	.	.	.	.	GUADALUPE/BEXAR COUNTY LINE
	1.03	24.95	2	CB	.	.		.	.	.	.	.	
	2.21	26.13	.		.	1	OP	16.67	16.50	16.58	.	.	
	4.07	27.99	.		.	1	OP	16.08	16.08	16.08	.	.	
	5.51	29.43	2	CB	.	.		.	.	.	.	.	
	5.82	29.74	.		.	1	OP	15.58	16.00	15.79	.	.	
	6.99	30.91	.		.	.		.	.	.	0.50	.	
	7.47	31.38	.		.	1	OP	16.08	16.00	16.04	.	.	
	7.78	31.69	.		.	.		.	.	.	.	1	LARGE STRUCTURE
	8.39	32.31	2	UP	.	.		.	.	.	.	.	
	9.22	33.14	.		.	.		.	.	.	.	1	LARGE STRUCTURE
	10.35	34.27	2	UP	.	.		.	.	.	.	.	
604	10.76	34.68	.		.	.		.	.	.	.	.	MPT 604
	10.79	34.71	.		.	.		.	.	.	1.00	.	
	11.18	35.09	2	CB	.	.		.	.	.	.	.	
	11.74	35.66	.		.	.		.	.	.	1.00	.	
	12.00	35.92	2	UPCB	0.20	.		.	.	.	.	.	
	12.36	36.28	2	CB	.	.		.	.	.	.	.	LITTLE MILL CREEK
	12.46	36.38	.		.	1	OP	16.67	16.50	16.58	.	.	
	12.72	36.64	.		.	.		.	.	.	.	1	
	13.49	37.41	.		.	.		.	.	.	.	1	
	14.06	37.98	2	UP	.	.		.	.	.	.	.	
	14.37	38.29	2	UPRR	.	.		.	.	.	.	.	
	14.57	38.49	2	UP	.	.		.	.	.	.	.	
	14.68	38.59	2	CB	.	.		.	.	.	.	.	
	16.07	39.98	2	UP	.	.		.	.	.	.	.	
	16.50	40.42	.		.	.		.	.	.	1.50	.	
	16.53	40.45	.		.	.		.	.	.	.	1	
	16.94	40.86	2	UP	.	.		.	.	.	.	.	
	17.66	41.58	2	CB	.	.		.	.	.	.	.	GERONOMO CREEK
	18.49	42.41	2	UPRR	0.10	.		.	.	.	.	.	US 90
	19.35	43.27	.		.	.		.	.	.	0.75	.	
	20.91	44.83	2	CB	.	.		.	.	.	.	.	MILL CREEK
	21.94	45.86	.		.	.		.	.	.	.	.	WEIGH STATION NORTH SIDE
	22.81	46.73	.		.	.		.	.	.	.	.	WEIGH STATION SOUTH SIDE
	23.15	47.07	.		.	.		.	.	.	0.75	.	
	23.43	47.35	2	CB	.	.		.	.	.	.	.	LONG BRANCH
	24.15	48.07	2	UP	.	.		.	.	.	.	.	FM 2435
	25.39	49.31	.		.	1	OP	16.42	17.50	16.96	.	.	
	26.01	49.93	.		.	.		.	.	.	1.00	.	
	26.47	50.39	2	CB	.	.		.	.	.	.	.	WASH CREEK
	26.88	50.80	.		.	1	OP	16.58	16.08	16.33	.	.	
	28.07	51.98	.		.	.		.	.	.	.	.	REST AREA BOTH SIDES
	29.10	53.01	.		.	1	OP	16.00	16.33	16.16	.	.	
623	29.72	53.63	.		.	.		.	.	.	.	.	MPT 623
	29.82	53.74	2	CB	.	.		.	.	.	.	.	ALLEN CREEK
	30.23	54.15	.		.	.		.	.	.	.	1	
	30.95	54.87	2	CB	.	.		.	.	.	.	.	
	32.55	56.46	.		.	1	OP	16.08	17.92	17.00	.	.	
	33.53	57.44	2	CB	.	.		.	.	.	.	.	WEBB CREEK
	33.62	57.54	.		.	.		.	.	.	0.75	.	
	34.25	58.16	.		.	.		.	.	.	.	1	
	34.87	58.78	.		.	1	OP	17.58	15.75	16.66	.	.	SH 80
	36.10	60.02	2	CB	0.20	.		.	.	.	.	.	
	36.47	60.39	.		.	.		.	.	.	1.00	.	
	36.62	60.53	.		.	.		.	.	.	.	.	GUADALUPE/CALDWELL COUNTY LINE

BRIDGE STRUCTURES : UP = VEHICULAR UNDERPASS

OVERPASSES : OP = VEHICULAR OVERPASS

TABLE A-3. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 10
SDHPT DISTRICT 14 *** CALDWELL COUNTY
EASTBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	BRIDGE STRUCTURE NO	TYPE	LENGTH	OVERPASS NO	TYPE	CLEARANCE EB	WB	AVG	HORIZONTAL CURVE (DEGREE)	TRANS-MISSION LINES	OBSERVERS COMMENTS
	0.00	60.53	2	CB	0.15	.		.	.	.	.	.	CALDWELL/GUADALUPE COUNTY LINE
	1.84	62.38	2	CB	0.20	.		.	.	.	.	.	PLUM CREEK
	2.36	62.89	2	UP	.	.		.	.	.	.	.	US 90
634	4.06	64.59	.		.	.		.	.	.	.	.	MPT 634
	4.57	65.11	.		.	.		.	.	.	.	.	CALDWELL/GONZALES COUNTY LINE

BRIDGE STRUCTURES : UP = VEHICULAR UNDERPASS
CB = CREEK/RIVER BED
RR = RAIL ROAD
UPRR = VEHICULAR UNDERPASS WITH RAILROAD
UPCB = VEHICULAR UNDERPASS AND CREEK/RIVER BED
ELV = ELEVATED STRUCTURE

OVERPASSES : OP = VEHICULAR OVERPASS
RR = RAIL ROAD OVERPASS
PED = PEDESTRIAN OVERPASS

SOURCE : TEXAS TRANSPORTATION INSTITUTE SURVEY

TABLE A-4. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 10
SDHPT DISTRICT 13 *** GONZALES COUNTY
EASTBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	BRIDGE STRUCTURE NO	TYPE	LENGTH	OVERPASS NO	TYPE	CLEARANCE EB	WB	AVG	HORIZONTAL CURVE (DEGREE)	TRANS-MISSION LINES	OBSERVERS COMMENTS
	0.00	65.11	.		.	.		.	.	.	.	.	GONZALES/CALDWELL COUNTY LINE
	0.03	65.14	.		.	.		.	.	.	0.50	.	
	0.62	65.72	2	UP	.	.		.	.	.	.	.	
	1.44	66.55	2	CB	.	.		.	.	.	.	.	
	3.09	68.20	2	UP	.	.		.	.	.	.	.	FM 794
	3.19	68.30	.		.	.		.	.	.	.	2	
	4.27	69.38	2	RR	.	.		.	.	.	.	.	
	5.05	70.15	.		.	1	OP	16.58	16.42	16.50	.	.	
	8.45	73.55	2	UP	.	.		.	.	.	.	.	
644	9.48	74.58	.		.	.		.	.	.	.	.	MPT 644
	10.09	75.20	.		.	1	OP	16.50	16.75	16.63	.	.	
	10.51	75.61	2	CB	.	.		.	.	.	.	.	
	10.61	75.71	2	CB	.	.		.	.	.	.	.	
	11.45	76.56	.		.	.		.	.	.	0.50	.	
	11.64	76.74	.		.	1	OP	16.50	16.67	16.58	.	.	
	13.39	78.50	.		.	1	OP	16.25	16.17	16.21	.	.	
649	14.42	79.53	.		.	.		.	.	.	.	.	MPT 649
	15.35	80.45	.		.	1	OP	16.58	16.58	16.58	.	.	SH 97
	16.89	82.00	2	CB	.	.		.	.	.	.	.	
	17.10	82.20	.		.	.		.	.	.	.	1	
	17.56	82.67	2	UPRR	.	.		.	.	.	.	.	
	18.54	83.65	2	UP	.	.		.	.	.	.	.	US 90
	19.78	84.88	2	CB	0.20	.		.	.	.	.	.	
	19.88	84.98	2	CB	.	.		.	.	.	.	.	
	21.11	86.22	.		.	1	OP	16.50	16.33	16.41	.	.	
656	21.42	86.53	.		.	.		.	.	.	.	.	MPT 656
	21.53	86.63	2	CB	.	.		.	.	.	.	.	
	22.04	87.15	.		.	.		.	.	.	.	.	GONZALES/FAYETTE COUNTY LINE

BRIDGE STRUCTURES : UP = VEHICULAR UNDERPASS
CB = CREEK/RIVER BED
RR = RAIL ROAD
UPRR = VEHICULAR UNDERPASS WITH RAILROAD
UPCB = VEHICULAR UNDERPASS AND CREEK/RIVER BED
ELV = ELEVATED STRUCTURE

OVERPASSES : OP = VEHICULAR OVERPASS
RR = RAIL ROAD OVERPASS
PED = PEDESTRIAN OVERPASS

SOURCE : TEXAS TRANSPORTATION INSTITUTE SURVEY

TABLE A-5. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 10
SDHPT DISTRICT 13 *** FAYETTE COUNTY
EASTBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	BRIDGE STRUCTURE NO	BRIDGE STRUCTURE TYPE	BRIDGE STRUCTURE LENGTH	OVERPASS NO	OVERPASS TYPE	CLEARANCE EB	CLEARANCE WB	CLEARANCE AVG	HORIZONTAL CURVE (DEGREE)	TRANS-MISSION LINES	OBSERVERS COMMENTS
	0.00	87.15	.		.	.		.	.	.	.	.	FAYETTE/GONZALES COUNTY LINE
657	0.41	87.56	2	CB	.	.		.	.	.	.	.	MPT 657
	0.67	87.82	2	CB	.	.		.	.	.	.	.	
	1.24	88.38	.		.	.		.	.	.	.	.	PICNIC AREA BOTH SIDES
	2.37	89.52	.		.	1	OP	16.33	16.42	16.37	.	.	
	4.12	91.27	.		.	1	OP	16.17	17.25	16.71	.	.	
	5.05	92.19	.		.	1	RR	16.58	16.50	16.54	.	.	
	5.25	92.40	.		.	1	OP	16.58	16.42	16.50	.	.	SH 95
	5.66	92.81	2	UP	.	.		.	.	.	.	.	
663	6.39	93.53	.		.	.		.	.	.	.	.	MPT 663
	6.52	93.67	.		.	.		.	.	.	0.50	.	
	6.75	93.89	.		.	.		.	.	.	.	1	
	7.47	94.62	.		.	.		.	.	.	0.50	.	
	8.24	95.39	.		.	1	OP	18.25	16.08	17.16	.	.	
	11.64	98.79	2	UP	.	.		.	.	.	.	.	
669	12.36	99.51	.		.	.		.	.	.	.	.	MPT 669
	13.18	100.33	.		.	.		.	.	.	0.50	.	
	13.80	100.95	.		.	1	OP	16.33	16.17	16.25	.	.	
	15.08	102.23	.		.	.		.	.	.	0.50	.	
	15.30	102.44	2	CB	.	.		.	.	.	.	.	
	15.55	102.70	2	CB	.	.		.	.	.	.	.	
	16.12	103.27	.		.	1	OP	16.42	16.50	16.46	.	.	
	16.38	103.52	2	CB	.	.		.	.	.	.	.	
	16.98	104.13	.		.	.		.	.	.	0.50	.	
	17.72	104.86	2	UP	.	.		.	.	.	.	.	US 77
	17.94	105.09	.		.	.		.	.	.	0.50	.	
675	18.33	105.48	.		.	.		.	.	.	.	.	MPT 675
	19.36	106.51	2	CB	.	.		.	.	.	.	.	
	19.57	106.72	2	CB	.	.		.	.	.	.	.	
	20.79	107.94	.		.	.		.	.	.	0.50	.	
	21.01	108.16	2	UP	.	.		.	.	.	.	.	
	21.68	108.83	2	CB	.	.		.	.	.	.	.	
	21.74	108.89	.		.	.		.	.	.	0.50	.	
	21.84	108.98	2	RR	.	.		.	.	.	.	.	
	22.76	109.91	.		.	.		.	.	.	.	.	FAYETTE/COLORADO COUNTY LINE

BRIDGE STRUCTURES : UP = VEHICULAR UNDERPASS
CB = CREEK/RIVER BED
RR = RAIL ROAD
UPRR = VEHICULAR UNDERPASS WITH RAILROAD
UPCB = VEHICULAR UNDERPASS AND CREEK/RIVER BED
ELV = ELEVATED STRUCTURE

OVERPASSES : OP = VEHICULAR OVERPASS
RR = RAIL ROAD OVERPASS
PED = PEDESTRIAN OVERPASS

SOURCE : TEXAS TRANSPORTATION INSTITUTE SURVEY

TABLE A-6, SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 10
SDHPT DISTRICT 13 *** COLORADO COUNTY
EASTBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	BRIDGE STRUCTURE NO	BRIDGE STRUCTURE TYPE	BRIDGE STRUCTURE LENGTH	OVERPASS NO	OVERPASS TYPE	CLEARANCE EB	CLEARANCE WB	CLEARANCE AVG	HORIZONTAL CURVE (DEGREE)	TRANSMISSION LINES	OBSERVERS COMMENTS
	0.00	109.91											COLORADO/FAYETTE COUNTY LINE
	0.67	110.58				1	OP	16.42	16.92	16.67			
	0.88	110.79									1.00		
	1.83	111.74									1.00		
	2.16	112.07	2	UP									
	2.63	112.54				1	OP	16.25	16.25	16.25			FM 155 WEIMER
	2.78	112.69									1.00		
683	3.55	113.46											MPT 683
	4.38	114.29				1	OP	16.42	16.42	16.42			
	6.95	116.86				1	OP	16.58	16.42	16.50			
	7.26	117.17										1	
687	7.57	117.48											MPT 687
	8.39	118.31				1	OP	16.75	16.17	16.46			
	8.49	118.40									0.50		
	10.35	120.26				1	OP	15.67	15.75	15.71			
	10.39	120.30									0.50		
	12.82	122.73											REST AREA BOTH SIDES
	12.93	122.84										1	
693	13.54	123.46											MPT 693
	13.75	123.66				1	OP	16.25	16.08	16.16			FM 2434
	14.83	124.74				1	OP	16.25	16.25	16.25			
695	15.50	125.41				1	OP	16.42	16.42	16.42			MPT 695
	15.91	125.82	2	CB									
	16.07	125.98	2	CB									
	16.63	126.55	2	CB									
	16.79	126.70										1	
	16.89	126.80	2	UP									
	17.05	126.96	2	CB									
	17.56	127.47	2	CB	0.30								COLORADO RIVER
	17.97	127.88	2	CB									
	18.00	127.91									0.50		
	18.13	128.04	2	UP									
	18.54	128.45	2	RR									
	18.95	128.86									1.00		
	19.31	129.22	2	UP									COLUMBUS
	19.90	129.81									1.00		
	20.14	130.05										1	
	20.65	130.56				1	OP	16.42	16.42	16.42			FM 102
	20.85	130.76									1.00		
	21.80	131.71									1.00		
702	22.51	132.42											MPT 702
	22.75	132.66									0.75		
	23.71	133.62									0.50		
	24.77	134.68				1	OP	17.00	16.58	16.79			FM 949
	25.61	135.52									0.50		
	26.26	136.18				1	OP	16.42	16.25	16.33			
	26.56	136.47									0.50		
708	28.48	138.39											MPT 708
	29.97	139.88				1	OP	15.58	16.58	16.08			
711	31.47	141.38											MPT 711
	31.88	141.79											COLORADO/AUSTIN COUNTY LINE

BRIDGE STRUCTURES :
- UP = VEHICULAR UNDERPASS
- CB = CREEK/RIVER BED
- RR = RAIL ROAD
- UPRR = VEHICULAR UNDERPASS WITH RAILROAD
- UPCB = VEHICULAR UNDERPASS AND CREEK/RIVER BED
- ELV = ELEVATED STRUCTURE

OVERPASSES :
- OP = VEHICULAR OVERPASS
- RR = RAIL ROAD OVERPASS
- PED = PEDESTRIAN OVERPASS

TABLE A-7. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 10
SDHPT DISTRICT 13 *** AUSTIN COUNTY
EASTBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	BRIDGE STRUCTURE NO	BRIDGE STRUCTURE TYPE	BRIDGE STRUCTURE LENGTH	OVERPASS NO	OVERPASS TYPE	OVERPASS CLEARANCE EB	OVERPASS CLEARANCE WB	OVERPASS CLEARANCE AVG	HORIZONTAL CURVE (DEGREE)	TRANS-MISSION LINES	OBSERVERS COMMENTS
	0.00	141.79	.		.	.		.	.	.	.	.	AUSTIN/COLORADO COUNTY LINE
	0.15	141.94	2	CB	.	.		.	.	.	.	.	
713	1.49	143.28	.		.	.		.	.	.	.	.	MPT 713
	1.70	143.49	.		.	1	OP	16.75	16.50	16.63	.	.	
	2.42	144.21	2	CB	.	.		.	.	.	.	.	
	3.24	145.03	.		.	.		.	.	.	0.75	.	
	4.69	146.48	.		.	1	OP	16.25	16.42	16.33	.	.	
717	5.51	147.30	.		.	.		.	.	.	.	.	MPT 717
	5.61	147.40	2	CB	.	.		.	.	.	.	.	
	6.90	148.69	2	UPRR	.	.		.	.	.	.	.	
	7.78	149.57	.		.	1	OP	16.67	16.33	16.50	.	.	
	8.24	150.03	.		.	.		.	.	.	.	1	
720	8.50	150.29	.		.	.		.	.	.	.	.	MPT 720
	8.91	150.70	2	UP	.	.		.	.	.	.	.	
	8.94	150.73	.		.	.		.	.	.	1.00	.	
	9.06	150.85	2	UP	.	.		.	.	.	.	.	
	10.20	151.99	2	UP	.	.		.	.	.	.	.	
	11.02	152.81	.		.	.		.	.	.	.	1	
723	11.48	153.27	.		.	.		.	.	.	.	.	MPT 723
	11.69	153.48	.		.	1	OP	16.42	16.33	16.37	.	.	
	11.80	153.59	.		.	.		.	.	.	1.00	.	
	12.75	154.54	.		.	.		.	.	.	1.50	.	
	13.70	155.49	.		.	1	OP	16.08	.	16.08	0.50	.	
	14.65	156.44	.		.	.		.	.	.	0.50	.	
727	15.45	157.24	.		.	.		.	.	.	.	.	MPT 727
	16.02	157.81	.		.	.		.	.	.	.	.	AUSTIN/WALLER COUNTY LINE

BRIDGE STRUCTURES : UP = VEHICULAR UNDERPASS
CB = CREEK/RIVER BED
RR = RAIL ROAD
UPRR = VEHICULAR UNDERPASS WITH RAILROAD
UPCB = VEHICULAR UNDERPASS AND CREEK/RIVER BED
ELV = ELEVATED STRUCTURE

OVERPASSES : OP = VEHICULAR OVERPASS
RR = RAIL ROAD OVERPASS
PED = PEDESTRIAN OVERPASS

SOURCE : TEXAS TRANSPORTATION INSTITUTE SURVEY

TABLE A-8. SURVEY OF THE TEXAS TRIANGLE ROUTE FOR INTERSTATE HIGHWAY 10
SDHPT DISTRICT 12 *** WALLER COUNTY
EASTBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	BRIDGE STRUCTURE NO	BRIDGE STRUCTURE TYPE	BRIDGE STRUCTURE LENGTH	OVERPASS NO	OVERPASS TYPE	OVERPASS CLEARANCE EB	OVERPASS CLEARANCE WB	OVERPASS CLEARANCE AVG	HORIZONTAL CURVE (DEGREE)	TRANSMISSION LINES	OBSERVERS COMMENTS
	0.00	157.81	.		.	.		.	.	.	.	.	WALLER/AUSTIN COUNTY LINE
	0.21	158.01	2	CB	0.20	.		.	.	.	.	.	BRAZOS RIVER
	0.31	158.11	2	CB	.	.		.	.	.	.	.	
	0.41	158.22	2	CB	.	.		.	.	.	.	.	
	0.57	158.37	2	CB	.	.		.	.	.	.	.	
	0.72	158.53	2	CB	.	.		.	.	.	.	.	
	1.08	158.89	2	CB	.	.		.	.	.	.	.	
	1.34	159.14	2	CB	.	.		.	.	.	.	.	
	1.48	159.29	.		.	.		.	.	.	1.00	.	
	1.54	159.35	2	CB	.	.		.	.	.	.	.	
	1.85	159.66	2	CB	.	.		.	.	.	.	.	
	1.85	159.66	2	CB	.	.		.	.	.	.	.	
	2.06	159.87	2	UP	.	.		.	.	.	.	.	
	3.19	161.00	2	CB	.	.		.	.	.	.	.	
	3.30	161.10	.		.	1	OP	.	16.17	16.17	.	.	
	3.40	161.20	.		.	.		.	.	.	.	.	REST AREA IN MEDIAN
	3.50	161.31	2	CB	.	.		.	.	.	.	.	
	4.33	162.13	.		.	1	OP	.	16.42	16.42	.	.	
	4.34	162.15	.		.	.		.	.	.	1.00	.	
	5.29	163.10	.		.	.		.	.	.	1.50	.	
	5.36	163.16	2	UP	.	.		.	.	.	.	.	FM 359
	6.28	164.09	2	CB	.	.		.	.	.	.	.	
	7.19	165.00	.		.	.		.	.	.	0.75	.	
	7.21	165.02	.		.	1	OP	16.25	16.33	16.29	.	.	
	8.14	165.95	.		.	.		.	.	.	0.50	.	
	8.39	166.20	.		.	1	OP	.	16.33	16.33	.	.	
	8.86	166.66	2	CB	.	.		.	.	.	.	.	
737	9.48	167.28	.		.	.		.	.	.	.	.	MPT 737
	9.58	167.38	.		.	1	OP	.	16.50	16.50	.	.	
	11.12	168.93	.		.	.		.	.	.	.	.	WALLER/FORT BEND COUNTY LINE

BRIDGE STRUCTURES : UP = VEHICULAR UNDERPASS
CB = CREEK/RIVER BED
RR = RAIL ROAD
UPRR = VEHICULAR UNDERPASS WITH RAILROAD
UPCB = VEHICULAR UNDERPASS AND CREEK/RIVER BED
ELV = ELEVATED STRUCTURE

OVERPASSES : OP = VEHICULAR OVERPASS
RR = RAIL ROAD OVERPASS
PED = PEDESTRIAN OVERPASS

SOURCE : TEXAS TRANSPORTATION INSTITUTE SURVEY

TABLE A-9. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 10
SDHPT DISTRICT 12 *** FORT BEND COUNTY
EASTBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	BRIDGE STRUCTURE NO	BRIDGE STRUCTURE TYPE	BRIDGE STRUCTURE LENGTH	OVERPASS NO	OVERPASS TYPE	CLEARANCE EB	CLEARANCE WB	CLEARANCE AVG	HORIZONTAL CURVE (DEGREE)	TRANSMISSION LINES	OBSERVERS COMMENTS
	0.00	168.93	.		.	.		.	.	.	.	.	FORT BEND/WALLER COUNTY LINE
	0.93	169.86	.		.	.		.	.	.	.	1	
	1.03	169.96	2	CB	.	.		.	.	.	.	.	
740	1.34	170.27	.		.	.		.	.	.	.	.	MPT 740
	1.44	170.37	2	UP	.	.		.	.	.	.	.	
	1.75	170.68	2	CB	.	.		.	.	.	.	.	
	2.16	171.09	.		.	1	OP	16.33	16.33	16.33	.	.	
	2.96	171.89	.		.	.		.	.	.	2.00	.	
	3.20	172.13	.		.	.		.	.	.	2.00	.	
	3.40	172.33	.		.	.		.	.	.	.	.	FORT BEND/HARRIS COUNTY LINE

BRIDGE STRUCTURES : UP = VEHICULAR UNDERPASS
CB = CREEK/RIVER BED
RR = RAIL ROAD
UPRR = VEHICULAR UNDERPASS WITH RAILROAD
UPCB = VEHICULAR UNDERPASS AND CREEK/RIVER BED
ELV = ELEVATED STRUCTURE

OVERPASSES : OP = VEHICULAR OVERPASS
RR = RAIL ROAD OVERPASS
PED = PEDESTRIAN OVERPASS

SOURCE : TEXAS TRANSPORTATION INSTITUTE SURVEY

TABLE A-10. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 10
SDHPT DISTRICT 12 *** HARRIS COUNTY
EASTBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	BRIDGE STRUCTURE NO	TYPE	LENGTH	OVERPASS NO	TYPE	CLEARANCE EB	WB	AVG	HORIZONTAL CURVE (DEGREE)	TRANS-MISSION LINES	OBSERVERS COMMENTS
	0.00	172.33	2	UP	.	.		.	.	.	.	.	HARRIS/FORT BEND COUNTY LINE - START GUARD RAIL
	0.28	172.61	.		.	.		.	.	.	3.50	.	
	0.51	172.84	.		.	.		.	.	.	3.50	.	
743	0.82	173.15	.		.	.		.	.	.	.	.	MPT 743
	1.44	173.77	.		.	1	OP	19.00	21.00	20.00	.	.	
	1.47	173.80	.		.	.		.	.	.	0.50	.	
	1.94	174.27	.		.	.		.	.	.	0.50	.	
	2.42	174.75	.		.	.		.	.	.	0.50	.	
	2.88	175.21	.		.	1	OP	17.00	18.75	17.88	.	.	
	3.09	175.42	.		.	.		.	.	.	.	1	
	3.19	175.52	2	CB	.	.		.	.	.	.	.	
746	3.81	176.14	.		.	.		.	.	.	.	.	MPT 746
	3.84	176.17	.		.	.		.	.	.	0.50	.	
	4.79	177.12	.		.	.		.	.	.	0.50	.	
	4.89	177.22	.		.	1	OP	16.50	18.25	17.38	.	.	
	5.27	177.60	.		.	.		.	.	.	0.50	.	
	5.51	177.84	.		.	.		.	.	.	0.50	.	
	5.74	178.07	.		.	.		.	.	.	0.50	.	
	5.98	178.31	.		.	.		.	.	.	0.50	.	
	6.75	179.08	.		.	1	OP	16.58	18.33	17.45	.	.	
	6.93	179.26	.		.	.		.	.	.	0.50	.	
	7.17	179.50	.		.	.		.	.	.	0.50	.	
	7.41	179.74	.		.	.		.	.	.	0.50	.	
	7.65	179.98	.		.	.		.	.	.	0.50	.	
	8.60	180.93	.		.	.		.	.	.	.	1	
751	8.81	181.14	.		.	.		.	.	.	.	.	MPT 751
	9.37	181.70	1	UP	.	.		.	.	.	.	.	SH 6
	10.92	183.25	1	UP	.	.		.	.	.	.	.	
	11.64	183.97	1	UP	.	.		.	.	.	.	.	
	12.67	185.00	1	UP	.	.		.	.	.	.	.	GUARD RAIL ENDS - BEGIN CMB
	13.60	185.92	1	UP	.	.		.	.	.	.	.	
	14.21	186.54	1	UP	.	.		.	.	.	.	.	
	15.45	187.78	1	UP	.	.		.	.	.	.	.	
758	15.76	188.09	.		.	.		.	.	.	.	.	MPT 758
	16.12	188.45	1	UP	.	.		.	.	.	.	.	
	16.74	189.07	1	UP	.	.		.	.	.	.	.	
	17.20	189.53	1	UP	.	.		.	.	.	.	.	
	18.13	190.46	1	UP	.	.		.	.	.	.	.	
	18.95	191.28	1	UP	.	.		.	.	.	.	.	
	19.47	191.80	1	UP	.	.		.	.	.	.	.	
	19.98	192.31	1	UP	.	.		.	.	.	.	.	
	20.60	192.93	.		.	1	OP	.	16.58	16.58	.	.	
	20.72	193.05	.		.	.		.	.	.	1.50	.	
	20.81	193.13	.		.	3	OP	.	14.25	14.25	.	.	I-610 STRUCTURES
	20.96	193.29	.		.	.		.	.	.	1.50	.	
	21.20	193.53	.		.	.		.	.	.	1.50	.	
	21.44	193.77	.		.	.		.	.	.	2.00	.	
	21.58	193.91	.		.	1	OP	.	15.75	15.75	.	.	
764	21.73	194.06	.		.	.		.	.	.	.	.	MPT 764
	21.91	194.24	.		.	.		.	.	.	0.50	.	
	22.35	194.68	.		.	1	OP	.	15.50	15.50	.	.	
	22.62	194.95	.		.	.		.	.	.	0.50	.	
	22.66	194.99	.		.	1	OP	.	15.83	15.83	.	.	
	22.76	195.09	.		.	1	OP	.	15.83	15.83	.	.	
	22.86	195.19	.		.	.		.	.	.	0.50	.	
	22.97	195.30	.		.	1	OP	.	15.58	15.58	.	.	
	23.23	195.56	.		.	1	OP	.	15.58	15.58	.	.	
	23.43	195.76	.		.	1	OP	.	15.67	15.67	.	.	
	23.48	195.81	.		.	1	OP	.	.	.	.	.	

TABLE A-10. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 10
SDHPT DISTRICT 12 *** HARRIS COUNTY
EASTBOUND DIRECTION (cont'd)

MILE POST	COUNTY MILE	CUM MILE	BRIDGE STRUCTURE NO	BRIDGE STRUCTURE TYPE	BRIDGE STRUCTURE LENGTH	OVERPASS NO	OVERPASS TYPE	CLEARANCE EB	CLEARANCE WB	CLEARANCE AVG	HORIZONTAL CURVE (DEGREE)	TRANS-MISSION LINES	OBSERVERS COMMENTS
	23.69	196.02	.		.	1	OP	.	.	.	.	.	
766	23.79	196.12	.		.	.		.	.	.	.	.	MPT 766
	24.05	196.38	.		.	.		.	.	.	1.50	.	
	24.26	196.59	1	UP	.	.		.	.	.	.	.	
	24.29	196.62	.		.	.		.	.	.	2.00	.	
	24.93	197.25	1	CB	.	.		.	.	.	.	.	
	25.23	197.56	.		.	1	OP	.	14.17	14.17	.	.	
	25.24	197.57	.		.	.		.	.	.	3.50	.	
	25.72	198.05	.		.	.		.	.	.	2.00	.	
	25.75	198.08	.		.	1	OP	.	14.92	14.92	.	.	
	25.95	198.28	.		.	.		.	.	.	2.00	.	
	26.06	198.39	.		.	.		.	.	.	.	.	I10 AT I45 HOUSTON (CMB)

BRIDGE STRUCTURES : UP = VEHICULAR UNDERPASS
CB = CREEK/RIVER BED
RR = RAIL ROAD
UPRR = VEHICULAR UNDERPASS WITH RAILROAD
UPCB = VEHICULAR UNDERPASS AND CREEK/RIVER BED
ELV = ELEVATED STRUCTURE

OVERPASSES : OP = VEHICULAR OVERPASS
RR = RAIL ROAD OVERPASS
PED = PEDESTRIAN OVERPASS

SOURCE : TEXAS TRANSPORTATION INSTITUTE SURVEY

TABLE A-11. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 45
SDHPT DISTRICT 12 *** HARRIS COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	BRIDGE STRUCTURE NO	TYPE	LENGTH	OVERPASS NO	TYPE	CLEARANCE NB	SB	AVG	HORIZONTAL CURVE (DEGREE)	TRANS-MISSION LINES	OBSERVERS COMMENTS
	0.00	0.00	.		.	.		.	.	.	5.00	.	I45 AT I10 HOUSTON
	0.23	0.23	.		.	.		.	.	.	3.00	.	
	0.47	0.47	.		.	.		.	.	.	2.00	.	
	0.70	0.70	.		.	.		.	.	.	1.50	.	
	1.34	1.34	.		.	1	OP	22.25	15.25	18.75	.	.	
	1.40	1.40	.		.	.		.	.	.	0.75	.	
	1.63	1.63	.		.	.		.	.	.	0.50	.	
	1.65	1.65	.		.	1	OP	.	14.92	14.92	.	.	
	1.85	1.85	.		.	1	OP	14.00	14.00	14.00	.	.	
	1.86	1.86	.		.	.		.	.	.	0.50	.	
	2.27	2.27	1	UP	.	.		.	.	.	.	.	
	2.33	2.33	.		.	.		.	.	.	0.50	.	
	2.56	2.56	.		.	.		.	.	.	0.50	.	
	2.63	2.63	1	UP	.	.		.	.	.	.	.	
	2.80	2.80	.		.	.		.	.	.	2.00	.	
	2.88	2.88	1	UP	.	.		.	.	.	.	.	
	3.40	3.40	1	UP	.	.		.	.	.	.	.	I-610 STRUCTURE
	3.81	3.81	1	UP	.	.		.	.	.	.	.	
	4.43	4.43	1	UP	.	.		.	.	.	.	.	
	4.84	4.84	1	UP	.	.		.	.	.	.	.	
	4.89	4.89	.		.	.		.	.	.	0.50	.	
	5.77	5.77	1	UP	.	.		.	.	.	.	.	
	5.82	5.82	.		.	.		.	.	.	0.50	.	
	6.06	6.06	.		.	.		.	.	.	1.00	.	
	6.29	6.29	.		.	.		.	.	.	1.00	.	
	6.90	6.90	1	UP	.	.		.	.	.	.	.	
	7.72	7.72	2	UP	.	.		.	.	.	.	.	
	8.14	8.14	1	UP	.	.		.	.	.	.	.	SOUTHBOUND ONLY
	8.85	8.85	.		.	.		.	.	.	0.50	.	
	9.06	9.06	2	UP	.	.		.	.	.	.	.	
	9.68	9.68	2	UP	.	.		.	.	.	.	.	
	9.79	9.79	.		.	.		.	.	.	0.50	.	
	10.02	10.02	.		.	.		.	.	.	1.50	.	
	10.81	10.81	2	UP	.	.		.	.	.	.	.	
	11.18	11.18	.		.	.		.	.	.	1.00	.	
	11.65	11.65	.		.	.		.	.	.	0.75	.	
	12.00	12.00	1	UP	.	.		.	.	.	.	.	
	12.12	12.12	.		.	.		.	.	.	0.50	.	
	12.35	12.35	.		.	.		.	.	.	0.50	.	
	12.46	12.46	.		.	1	OP	17.67	19.42	18.54	.	.	
61	12.87	12.87	1	UP	.	.		.	.	.	.	.	MPT 61
	13.24	13.24	1	UP	.	.		.	.	.	.	.	
	13.80	13.80	1	CB	.	.		.	.	.	.	.	
	14.42	14.42	1	UP	.	.		.	.	.	.	.	
	15.14	15.14	.		.	.		.	.	.	0.50	.	
	15.50	15.50	.		.	1	OP	16.83	17.25	17.04	.	.	
	15.84	15.84	.		.	.		.	.	.	0.50	.	
	16.58	16.58	.		.	1	OP	16.75	16.83	16.79	.	.	
	16.78	16.78	.		.	.		.	.	.	1.00	.	
	17.24	17.24	.		.	.		.	.	.	1.00	.	
	17.47	17.47	.		.	.		.	.	.	1.00	.	
	17.71	17.71	.		.	.		.	.	.	1.00	.	
	17.94	17.94	.		.	.		.	.	.	0.50	.	
	18.17	18.17	.		.	.		.	.	.	0.50	.	
	18.23	18.23	1	UP	.	.		.	.	.	.	.	
	18.33	18.33	.		.	.		.	.	.	.	1	MEDIAN PAVED ALSO GUARD RAIL
	19.26	19.26	2	CB	.	.		.	.	.	.	.	
	20.27	20.27	.		.	.		.	.	.	1.50	.	
	20.39	20.39	.		.	1	OP	.	16.33	16.33	.	.	

TABLE A-11. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 45
SDHPT DISTRICT 12 *** HARRIS COUNTY
NORTHBOUND DIRECTION (cont'd)

MILE POST	COUNTY MILE	CUM MILE	BRIDGE STRUCTURE NO	BRIDGE STRUCTURE TYPE	BRIDGE STRUCTURE LENGTH	OVERPASS NO	OVERPASS TYPE	OVERPASS CLEARANCE NB	OVERPASS CLEARANCE SB	OVERPASS CLEARANCE AVG	HORIZONTAL CURVE (DEGREE)	TRANS-MISSION LINES	OBSERVERS COMMENTS
	21.44	21.44	.		.	.		.	.	.	0.50	.	
	21.67	21.67	.		.	.		.	.	.	0.50	.	
	21.73	21.73	.		.	.		.	.	.	.	.	END PAVED MEDIAN AND GUARD RAIL
	21.94	21.94	1	UP	.	.		.	.	.	.	.	
	22.60	22.60	.		.	.		.	.	.	1.00	.	
	22.97	22.97	.		.	.		.	.	.	.	.	MEDIAN PAVED ALSO GUARD RAIL
	23.07	23.07	.		.	.		.	.	.	1.50	.	
	23.17	23.17	.		.	.		.	.	.	.	1	
	23.30	23.30	.		.	.		.	.	.	1.00	.	
	23.53	23.53	.		.	.		.	.	.	1.50	.	
	24.62	24.62	.		.	.		.	.	.	.	.	HARRIS/MONTGOMERY COUNTY LINE

BRIDGE STRUCTURES : UP = VEHICULAR UNDERPASS
CB = CREEK/RIVER BED
RR = RAIL ROAD
UPRR = VEHICULAR UNDERPASS WITH RAILROAD
UPCB = VEHICULAR UNDERPASS AND CREEK/RIVER BED
ELV = ELEVATED STRUCTURE

OVERPASSES : OP = VEHICULAR OVERPASS
RR = RAIL ROAD OVERPASS
PED = PEDESTRIAN OVERPASS

SOURCE : TEXAS TRANSPORTATION INSTITUTE SURVEY

TABLE A-12. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 45
SDHPT DISTRICT 12 *** MONTGOMERY COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	BRIDGE STRUCTURE NO	BRIDGE STRUCTURE TYPE	BRIDGE STRUCTURE LENGTH	OVERPASS NO	OVERPASS TYPE	OVERPASS CLEARANCE NB	OVERPASS CLEARANCE SB	OVERPASS CLEARANCE AVG	HORIZONTAL CURVE (DEGREE)	TRANS-MISSION LINES	OBSERVERS COMMENTS
	0.00	24.62	.		.	.		.	.	.	.	.	MONTGOMERY/HARRIS COUNTY LINE
	0.26	24.87	1	CB	.	.		.	.	.	.	.	
	1.08	25.70	2	UP	.	.		.	.	.	.	.	
	1.71	26.33	.		.	.		.	.	.	1.50	.	
75	2.11	26.73	.		.	.		.	.	.	.	.	MPT 75
	3.19	27.81	.		.	1	OP	14.42	14.25	14.33	.	.	
	3.34	27.96	.		.	.		.	.	.	0.50	.	
	4.27	28.89	.		.	.		.	.	.	0.50	.	
	4.69	29.30	2	UP	.	.		.	.	.	.	.	
	6.37	30.99	.		.	.		.	.	.	0.50	.	
	6.60	31.22	.		.	.		.	.	.	0.50	.	
	6.64	31.26	.		.	.		.	.	.	.	1	
	6.69	31.31	.		.	1	OP	14.33	14.17	14.25	.	.	
80	7.06	31.67	.		.	.		.	.	.	.	.	MPT 80
	7.07	31.69	.		.	.		.	.	.	0.75	.	
	8.60	33.22	.		.	1	OP	14.67	14.33	14.50	.	.	
	8.70	33.32	1	CB	.	.		.	.	.	.	.	
	8.93	33.55	.		.	.		.	.	.	1.00	.	
82	9.06	33.68	.		.	.		.	.	.	.	.	MPT 82
	9.16	33.78	.		.	.		.	.	.	1.00	.	
	9.32	33.94	2	CB	.	.		.	.	.	.	.	SAN JACINTO RIVER
	9.63	34.25	.		.	.		.	.	.	0.50	.	
	9.73	34.35	2	CB	.	.		.	.	.	.	.	
	10.71	35.33	2	UP	.	.		.	.	.	.	.	
	11.69	36.31	2	UP	.	.		.	.	.	.	.	
	12.21	36.82	.		.	.		.	.	.	.	1	
	12.31	36.93	.		.	.		.	.	.	.	1	
	12.62	37.23	.		.	1	OP	16.92	16.67	16.79	.	.	
	13.59	38.21	.		.	.		.	.	.	0.50	.	
	13.65	38.26	.		.	.		.	.	.	.	1	
	13.75	38.37	2	UP	.	.		.	.	.	.	.	
	14.27	38.88	2	UP	.	.		.	.	.	.	.	SH 105
	14.99	39.60	.		.	1	OP	.	16.58	16.58	.	.	
	15.60	40.22	.		.	1	OP	16.75	17.50	17.13	.	.	
89	16.07	40.68	.		.	.		.	.	.	.	.	MPT 98
	16.84	41.46	.		.	1	OP	17.83	16.50	17.16	.	.	
	17.09	41.71	.		.	.		.	.	.	0.50	.	
	17.92	42.54	2	CB	.	.		.	.	.	.	1	
	17.97	42.59	.		.	.		.	.	.	.	.	END OF TREES IN MEDIAN
	18.95	43.57	.		.	.		.	.	.	0.50	.	
	19.57	44.19	.		.	1	OP	16.83	17.25	17.04	.	.	
	20.55	45.17	.		.	.		.	.	.	.	.	MEDIAN WIDENS WITH TREES
	21.51	46.13	.		.	.		.	.	.	0.50	.	
	21.68	46.30	.		.	1	OP	18.33	16.75	17.54	.	.	
	21.75	46.37	.		.	.		.	.	.	0.50	.	
95	22.04	46.66	.		.	.		.	.	.	.	.	MPT 95
	22.35	46.97	.		.	.		.	.	.	.	1	
	22.71	47.33	.		.	1	OP	.	16.67	16.67	.	.	
	24.54	49.16	.		.	.		.	.	.	0.50	.	
	24.76	49.38	.		.	1	OP	20.00	16.92	18.46	.	.	
	25.60	50.21	.		.	1	OP	.	17.08	17.08	.	.	
100	27.04	51.65	.		.	.		.	.	.	.	.	MPT 100
	27.76	52.38	.		.	.		.	.	.	.	.	MONTGOMERY/WALKER COUNTY LINE

BRIDGE STRUCTURES : UP = VEHICULAR UNDERPASS
CB = CREEK/RIVER BED
RR = RAIL ROAD
UPRR = VEHICULAR UNDERPASS WITH RAILROAD

OVERPASSES : OP = VEHICULAR OVERPASS
RR = RAIL ROAD OVERPASS
PED = PEDESTRIAN OVERPASS

TABLE A-13. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 45
SDHPT DISTRICT 17 *** WALKER COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	BRIDGE STRUCTURE NO	BRIDGE STRUCTURE TYPE	BRIDGE STRUCTURE LENGTH	OVERPASS NO	OVERPASS TYPE	OVERPASS CLEARANCE NB	OVERPASS CLEARANCE SB	OVERPASS CLEARANCE AVG	HORIZONTAL CURVE (DEGREE)	TRANS-MISSION LINES	OBSERVERS COMMENTS
	0.00	52.38	.		.	.		.	.	.	.	.	WALKER/MONTGOMERY COUNTY LINE
	0.46	52.84	2	CB	.	.		.	.	.	.	.	
	1.80	54.18	.		.	1	OP	.	15.67	15.67	.	.	
	2.63	55.00	.		.	1	OP	.	15.58	15.58	.	.	
	4.38	56.75	.		.	.		.	.	.	.	.	PICNIC AREA BOTH SIDES
	5.40	57.78	.		.	.		.	.	.	0.50	.	
	6.34	58.72	.		.	.		.	.	.	0.75	.	
108	7.21	59.59	.		.	.		.	.	.	.	.	MPT 108
	8.20	60.58	.		.	.		.	.	.	0.75	.	
	9.12	61.49	2	UP	.	.		.	.	.	.	.	
	11.00	63.38	.		.	.		.	.	.	0.50	.	
	11.69	64.07	.		.	1	OP	.	17.25	17.25	.	.	
113	12.21	64.58	.		.	1	OP	.	18.58	18.58	.	.	MPT 113
	14.06	66.44	.		.	1	OP	.	14.75	14.75	.	.	FM 1374
	14.88	67.26	.		.	1	OP	.	17.25	17.25	.	.	
	15.91	68.29	.		.	1	OP	.	16.75	16.75	.	.	
	16.74	69.11	.		.	.		.	.	.	.	1	
	17.66	70.04	2	CB	.	.		.	.	.	.	.	
	18.45	70.83	.		.	.		.	.	.	0.50	.	
	21.25	73.63	.		.	.		.	.	.	0.50	.	
	22.20	74.57	2	CB	.	.		.	.	.	.	.	
	23.23	75.60	.		.	.		.	.	.	.	.	REST AREA EAST SIDE
	23.69	76.07	2	CB	.	.		.	.	.	.	.	
	23.74	76.12	.		.	.		.	.	.	.	1	
	24.04	76.42	.		.	.		.	.	.	0.50	.	
	24.77	77.15	.		.	.		.	.	.	.	.	REST AREA WEST SIDE
126	25.18	77.56	.		.	.		.	.	.	.	.	MPT 126 (TREES IN MEDIAN)
	27.77	80.15	.		.	.		.	.	.	1.00	.	
	29.66	82.04	2	CB	.	.		.	.	.	.	.	
	29.92	82.30	2	CB	.	.		.	.	.	.	.	
131	30.13	82.50	2	CB	.	.		.	.	.	.	.	MPT 131
	31.57	83.95	.		.	1	OP	.	16.58	16.58	.	.	
	32.70	85.08	.		.	.		.	.	.	.	.	WALKER/MADISON COUNTY LINE

BRIDGE STRUCTURES : UP = VEHICULAR UNDERPASS
CB = CREEK/RIVER BED
RR = RAIL ROAD
UPRR = VEHICULAR UNDERPASS WITH RAILROAD
UPCB = VEHICULAR UNDERPASS AND CREEK/RIVER BED
ELV = ELEVATED STRUCTURE

OVERPASSES : OP = VEHICULAR OVERPASS
RR = RAIL ROAD OVERPASS
PED = PEDESTRIAN OVERPASS

SOURCE : TEXAS TRANSPORTATION INSTITUTE SURVEY

TABLE A-14. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 45
SDHPT DISTRICT 17 *** MADISON COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	BRIDGE STRUCTURE NO	BRIDGE STRUCTURE TYPE	BRIDGE STRUCTURE LENGTH	OVERPASS NO	OVERPASS TYPE	OVERPASS CLEARANCE NB	OVERPASS CLEARANCE SB	OVERPASS CLEARANCE AVG	HORIZONTAL CURVE (DEGREE)	TRANSMISSION LINES	OBSERVERS COMMENTS
	0.00	85.08	2	CB	.	.		.	.	.	.	.	MADISON/WALKER COUNTY LINE
134	0.41	85.49	2	CB	.	.		.	.	.	.	.	MPT 134
	0.66	85.74	.		.	.		.	.	.	1.00	.	
	1.13	86.21	.		.	.		.	.	.	1.00	.	
	1.60	86.68	.		.	.		.	.	.	1.00	.	
	3.09	88.17	.		.	1	OP	.	16.75	16.75	.	.	SPUR 67
	6.39	91.46	2	CB	.	.		.	.	.	.	.	
	8.12	93.20	.		.	.		.	.	.	0.50	.	
	8.29	93.37	.		.	1	OP	18.83	17.75	18.29	.	.	SH 21
	11.85	96.93	.		.	.		.	.	.	0.50	.	
	12.36	97.44	2	UP	.	.		.	.	.	.	.	US 75
	12.78	97.86	.		.	.		.	.	.	0.50	.	
	13.71	98.79	.		.	.		.	.	.	0.50	.	
149	14.93	100.01	.		.	.		.	.	.	.	.	MPT 149
	15.09	100.17	.		.	1	OP	16.50	16.42	16.46	.	.	
	16.69	101.76	.		.	1	OP	17.08	16.58	16.83	.	.	
152	17.92	103.00	.		.	.		.	.	.	.	.	MPT 152
	18.23	103.31	.		.	.		.	.	.	.	.	MADISON/LEON COUNTY LINE (TEXAS OSR)

BRIDGE STRUCTURES : UP = VEHICULAR UNDERPASS
CB = CREEK/RIVER BED
RR = RAIL ROAD
UPRR = VEHICULAR UNDERPASS WITH RAILROAD
UPCB = VEHICULAR UNDERPASS AND CREEK/RIVER BED
ELV = ELEVATED STRUCTURE

OVERPASSES : OP = VEHICULAR OVERPASS
RR = RAIL ROAD OVERPASS
PED = PEDESTRIAN OVERPASS

SOURCE : TEXAS TRANSPORTATION INSTITUTE SURVEY

TABLE A-15. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 45
SDHPT DISTRICT 17 *** LEON COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	BRIDGE STRUCTURE NO	BRIDGE STRUCTURE TYPE	BRIDGE STRUCTURE LENGTH	OVERPASS NO	OVERPASS TYPE	OVERPASS CLEARANCE NB	OVERPASS CLEARANCE SB	OVERPASS CLEARANCE AVG	HORIZONTAL CURVE (DEGREE)	TRANSMISSION LINES	OBSERVERS COMMENTS
	0.00	103.31	.		.	1	OP	15.83	16.33	16.08	.	.	LEON/MADISON COUNTY LINE (TEXAS OSR)
	1.07	104.38	.		.	.		.	.	.	1.00	.	
	1.49	104.80	2	CB	.	.		.	.	.	.	.	
	2.37	105.68	.		.	1	OP	16.75	16.08	16.41	.	.	
	2.63	105.94	2	CB	.	.		.	.	.	.	.	
	3.30	106.60	.		.	.		.	.	.	.	.	PICNIC AREA EAST SIDE
156	3.66	106.97	.		.	.		.	.	.	.	.	MPT 156
	4.17	107.48	.		.	1	OP	16.75	17.08	16.91	.	.	FM 977
	4.79	108.10	.		.	.		.	.	.	.	.	LEONA CITY LIMITS
	4.80	108.11	.		.	.		.	.	.	0.75	.	
	6.64	109.95	2	CB	.	.		.	.	.	.	.	
	6.67	109.98	.		.	.		.	.	.	0.50	.	
	6.90	110.21	2	CB	.	.		.	.	.	.	.	
	7.31	110.62	.		.	.		.	.	.	.	.	PICNIC AREA WEST SIDE
	10.30	113.61	2	CB	.	.		.	.	.	.	.	
163	10.66	113.97	.		.	.		.	.	.	.	.	MPT 163
	11.74	115.05	.		.	1	OP	16.17	17.17	16.67	.	.	CENTERVILLE CITY LIMITS
	12.26	115.57	.		.	.		.	.	.	1.00	.	
	15.05	118.36	.		.	.		.	.	.	0.50	.	
	15.55	118.86	2	CB	.	.		.	.	.	.	.	
	17.85	121.16	.		.	.		.	.	.	0.75	.	
	18.39	121.69	.		.	.		.	.	.	.	1	
	18.75	122.05	.		.	1	OP	16.33	16.42	16.37	.	.	
	20.65	123.96	.		.	.		.	.	.	0.50	.	
175	22.56	125.87	.		.	.		.	.	.	.	.	MPT 175
	22.87	126.17	2	UP	.	.		.	.	.	.	.	
	23.84	127.15	.		.	.		.	.	.	.	1	
177	24.57	127.87	.		.	.		.	.	.	.	.	MPT 177
	25.31	128.62	.		.	.		.	.	.	0.75	.	
	25.75	129.06	.		.	1	RR	16.50	16.50	16.50	.	.	
	26.26	129.57	2	UP	.	.		.	.	.	.	.	US 79
	27.17	130.48	.		.	.		.	.	.	0.75	.	
180	27.55	130.86	.		.	.		.	.	.	.	.	MPT 180
	27.60	130.91	2	UP	.	.		.	.	.	.	.	
	28.43	131.74	.		.	.		.	.	.	.	.	LEON/FREESTONE COUNTY LINE

BRIDGE STRUCTURES : UP = VEHICULAR UNDERPASS
CB = CREEK/RIVER BED
RR = RAIL ROAD
UPRR = VEHICULAR UNDERPASS WITH RAILROAD
UPCB = VEHICULAR UNDERPASS AND CREEK/RIVER BED
ELV = ELEVATED STRUCTURE

OVERPASSES : OP = VEHICULAR OVERPASS
RR = RAIL ROAD OVERPASS
PED = PEDESTRIAN OVERPASS

SOURCE : TEXAS TRANSPORTATION INSTITUTE SURVEY

TABLE A-16. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 45
SDHPT DISTRICT 17 *** FREESTONE COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	BRIDGE STRUCTURE NO	BRIDGE STRUCTURE TYPE	BRIDGE STRUCTURE LENGTH	OVERPASS NO	OVERPASS TYPE	OVERPASS CLEARANCE NB	OVERPASS CLEARANCE SB	OVERPASS CLEARANCE AVG	HORIZONTAL CURVE (DEGREE)	TRANS-MISSION LINES	OBSERVERS COMMENTS
	0.00	131.74	.		.	.		.	.	.	.	.	FREESTONE/LEON COUNTY LINE
	0.21	131.94	2	CB	.	.		.	.	.	.	.	
	1.39	133.13	.		.	1	OP	16.92	16.33	16.62	.	.	
	1.65	133.38	.		.	.		.	.	.	.	.	MEDIAN RETURNS TO TYPICAL
	4.02	135.75	.		.	.		.	.	.	.	1	
	4.33	136.07	.		.	.		.	.	.	0.50	.	
	5.56	137.30	.		.	.		.	.	.	.	.	PICNIC AREA ON WEST SIDE
	7.13	138.87	.		.	.		.	.	.	0.75	.	
	7.83	139.56	.		.	.		.	.	.	.	.	MEDIAN WIDENS
	8.09	139.82	.		.	1	OP	16.67	17.17	16.92	.	.	
	8.96	140.70	.		.	1	OP	17.08	19.33	18.20	.	.	
	9.92	141.66	.		.	.		.	.	.	0.50	.	
	10.97	142.71	2	CB	.	.		.	.	.	.	.	
	11.54	143.27	.		.	1	OP	17.25	17.33	17.29	.	.	
	11.79	143.53	.		.	.		.	.	.	0.50	.	
	12.36	144.10	2	CB	.	.		.	.	.	.	.	
	12.57	144.30	2	CB	.	.		.	.	.	.	.	
	12.72	144.46	.		.	.		.	.	.	0.50	.	
	15.52	147.26	.		.	.		.	.	.	0.50	.	
	16.22	147.96	.		.	1	OP	17.00	16.83	16.91	.	.	
	16.45	148.19	.		.	.		.	.	.	0.50	.	
	17.10	148.83	.		.	1	OP	16.42	16.58	16.50	.	.	
	18.02	149.76	.		.	1	OP	17.67	16.33	17.00	.	.	
	18.31	150.05	.		.	.		.	.	.	0.75	.	
	18.64	150.38	.		.	.		.	.	.	.	1	
	19.88	151.62	2	CB	.	.		.	.	.	.	.	
	20.18	151.92	.		.	.		.	.	.	1.00	.	
	21.99	153.73	2	UP	.	.		.	.	.	.	.	
	22.04	153.78	.		.	.		.	.	.	1.00	.	
	23.69	155.43	.		.	.		.	.	.	.	.	MEDIAN RETURNS TO TYPICAL
	24.51	156.25	2	CB	0.15	.		.	.	.	.	.	
	25.39	157.13	.		.	1	OP	17.00	18.17	17.58	.	.	
	25.77	157.51	.		.	.		.	.	.	0.50	.	
	26.37	158.10	.		.	.		.	.	.	.	.	MEDIAN WIDENS WITH TREES
	26.70	158.44	.		.	.		.	.	.	2.00	.	
	27.04	158.77	.		.	.		.	.	.	.	1	LARGE STRUCTURE
	27.40	159.13	.		.	1	OP	16.17	16.58	16.37	.	.	
209	28.02	159.75	.		.	.		.	.	.	.	.	MPT 209
	28.63	160.37	2	CB	.	.		.	.	.	.	.	
	28.94	160.68	2	CB	.	.		.	.	.	.	.	
211	30.02	161.76	.		.	.		.	.	.	.	.	MPT 211
	30.59	162.33	2	UP	.	.		.	.	.	.	.	
	30.80	162.53	2	UP	.	.		.	.	.	.	.	
	31.93	163.67	.		.	.		.	.	.	.	.	FREESTONE/NAVARRO COUNTY LINE

BRIDGE STRUCTURES : UP = VEHICULAR UNDERPASS
CB = CREEK/RIVER BED
RR = RAIL ROAD
UPRR = VEHICULAR UNDERPASS WITH RAILROAD
UPCB = VEHICULAR UNDERPASS AND CREEK/RIVER BED
ELV = ELEVATED STRUCTURE

OVERPASSES : OP = VEHICULAR OVERPASS
RR = RAIL ROAD OVERPASS
PED = PEDESTRIAN OVERPASS

SOURCE : TEXAS TRANSPORTATION INSTITUTE SURVEY

TABLE A-17. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 45
SDHPT DISTRICT 18 *** NAVARRO COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	BRIDGE STRUCTURE NO	BRIDGE STRUCTURE TYPE	BRIDGE STRUCTURE LENGTH	OVERPASS NO	OVERPASS TYPE	OVERPASS CLEARANCE NB	OVERPASS CLEARANCE SB	OVERPASS CLEARANCE AVG	HORIZONTAL CURVE (DEGREE)	TRANS-MISSION LINES	OBSERVERS COMMENTS
	0.00	163.67											NAVARRO/FREESTONE COUNTY LINE
	0.41	164.08				1	OP	15.67	15.75	15.71			FM 246
216	3.04	166.71											MPT 216
	3.16	166.83									1.50		
	3.35	167.01				1	OP	15.83	15.83	15.83			
	3.50	167.17											REST AREA EAST SIDE
	3.91	167.58	2	CB									
	4.22	167.89											REST AREA WEST SIDE
	5.02	168.69									1.50		
	5.25	168.92	2	CB									
	5.36	169.02	2	CB									
	5.92	169.59				1	OP	16.17	16.25	16.21			
	6.44	170.10				1	OP		16.42	16.42			MEXIA EXIT (OVER SOUTHBOUND LANES ONLY)
	6.89	170.56									1.00		
	7.11	170.77	2	CB	0.20								
	7.72	171.39	2	CB	0.20								RICHLAND CREEK
	7.82	171.49									1.00		
	8.60	172.27				1	OP	14.50	14.67	14.58			
	9.68	173.35									0.75		
	10.15	173.81										1	
224	10.81	174.48											MPT 224
	11.84	175.51				1	OP	16.33	15.92	16.12			
	12.48	176.15									0.75		
228	14.83	178.50											MPT 228
	15.50	179.17	2	UP									
	15.66	179.32										1	
	15.91	179.58	1	UP									US 75 FOR NORTHBOUND TRAFFIC ONLY
	16.63	180.30	2	UP									
	16.89	180.56	2	UPRR									US 287
	17.51	181.18	2	CB									
231	17.82	181.49											MPT 231
	18.07	181.74									1.00		
	18.18	181.85	2	UPRR									
	18.39	182.05	2	UP									SH 31 (CORSICANA)
	18.64	182.31	2	CB									
	18.95	182.62				1	OP	15.92	16.00	15.96			
	19.62	183.29				1	OP	16.17	16.58	16.37			
234	20.86	184.52											MPT 234
	21.01	184.68				1	OP	16.00	16.25	16.13			
	21.68	185.35										1	
	21.94	185.61	2	CB									
	22.35	186.02	1	CB									SOUTHBOUND ONLY
	22.51	186.17				1	OP	16.00	16.25	16.13			
	22.87	186.53	2	UP	0.20								
	23.28	186.94	2	CB	0.20								CHAMBERS CREEK
	23.66	187.33									1.00		
237	23.90	187.56											MPT 237
	24.51	188.18				1	OP	17.83	17.42	17.62			
	25.75	189.42				1	OP	14.58	15.33	14.95			
	26.46	190.13									0.50		
	26.99	190.65				1	OP	17.42	15.08	16.25			FM 1126
241	27.91	191.58											MPT 241
	28.32	191.99									1.00		
	29.05	192.71				1	OP	15.25	14.33	14.79			
243	29.92	193.59											MPT 243
	30.02	193.69				1	OP	15.67	14.58	15.12			
	30.19	193.86									1.50		
	30.69	194.36											NAVARRO/ELLIS COUNTY LINE

TABLE A-18. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 45
SDHPT DISTRICT 18 *** ELLIS COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	BRIDGE STRUCTURE NO	BRIDGE STRUCTURE TYPE	BRIDGE STRUCTURE LENGTH	OVERPASS NO	OVERPASS TYPE	OVERPASS CLEARANCE NB	OVERPASS CLEARANCE SB	OVERPASS CLEARANCE AVG	HORIZONTAL CURVE (DEGREE)	TRANS-MISSION LINES	OBSERVERS COMMENTS
	0.00	194.36	.		.	.		.	.	.	.	.	ELLIS/NAVARRO COUNTY LINE
	0.43	194.79	.		.	.		.	.	.	1.00	.	
	0.46	194.82	.		.	1	OP	14.83	15.50	15.16	.	.	FM 1182
246	2.21	196.58	.		.	.		.	.	.	.	.	MPT 246
	2.29	196.65	.		.	.		.	.	.	1.50	.	
	2.63	196.99	2	UP	.	.		.	.	.	.	.	FM 1183
	3.22	197.58	.		.	.		.	.	.	1.50	.	
	4.16	198.52	.		.	.		.	.	.	1.00	.	
	6.08	200.44	2	UP	.	.		.	.	.	.	.	
250	6.18	200.54	.		.	.		.	.	.	.	.	MPT 250
	6.95	201.31	.		.	.		.	.	.	0.75	.	
	7.26	201.62	.		.	1	OP	14.83	15.00	14.91	.	.	
	7.88	202.24	.		.	.		.	.	.	0.50	.	
	8.03	202.39	2	UP	.	.		.	.	.	.	.	ENNIS
	9.06	203.42	.		.	1	OP	16.00	16.08	16.04	.	.	
	9.99	204.35	.		.	1	OP	15.42	14.67	15.04	.	.	
	10.40	204.76	.		.	.		.	.	.	.	1	
	11.28	205.64	.		.	1	OP	15.33	14.25	14.79	.	.	FM 879
256	12.21	206.57	.		.	.		.	.	.	.	.	MPT 256
	13.44	207.80	.		.	.		.	.	.	.	1	
	13.49	207.85	2	CB	.	.		.	.	.	.	.	
	13.80	208.16	2	CB	.	.		.	.	.	.	.	
	14.32	208.68	.		.	1	OP	14.75	14.42	14.58	.	.	
	15.45	209.81	.		.	1	OP	14.75	14.67	14.71	.	.	FM 813
260	16.22	210.58	.		.	.		.	.	.	.	.	MPT 260
	16.43	210.79	.		.	1	OP	14.58	14.33	14.45	.	.	
	16.48	210.84	.		.	.		.	.	.	.	1	
	17.15	211.51	2	CB	.	.		.	.	.	.	.	
	17.20	211.56	2	CB	.	.		.	.	.	.	.	
	17.41	211.77	2	CB	.	.		.	.	.	.	.	
	17.51	211.87	2	CB	.	.		.	.	.	.	.	
	17.97	212.33	2	CB	0.15	.		.	.	.	.	.	
	19.11	213.47	.		.	1	OP	14.75	14.75	14.75	.	.	
	19.93	214.29	.		.	1	OP	14.25	14.75	14.50	.	.	
	20.55	214.91	2	CB	.	.		.	.	.	.	.	
	21.06	215.42	.		.	1	OP	14.58	14.83	14.70	.	.	
266	22.20	216.56	.		.	.		.	.	.	.	.	MPT 266
	22.40	216.76	2	UP	.	.		.	.	.	.	.	
	22.61	216.97	2	UP	.	.		.	.	.	.	.	
	23.12	217.48	.		.	.		.	.	.	.	.	MPT 267
	23.33	217.69	.		.	.		.	.	.	.	.	ELLIS/DALLAS COUNTY LINE

BRIDGE STRUCTURES : UP = VEHICULAR UNDERPASS
CB = CREEK/RIVER BED
RR = RAIL ROAD
UPRR = VEHICULAR UNDERPASS WITH RAILROAD
UPCB = VEHICULAR UNDERPASS AND CREEK/RIVER BED
ELV = ELEVATED STRUCTURE

OVERPASSES : OP = VEHICULAR OVERPASS
RR = RAIL ROAD OVERPASS
PED = PEDESTRIAN OVERPASS

SOURCE : TEXAS TRANSPORTATION INSTITUTE SURVEY

TABLE A-19. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 45
SDHPT DISTRICT 18 *** DALLAS COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	BRIDGE NO	STRUCTURE TYPE	LENGTH	OVERPASS NO	OVERPASS TYPE	CLEARANCE NB	CLEARANCE SB	CLEARANCE AVG	HORIZONTAL CURVE (DEGREE)	TRANSMISSION LINES	OBSERVERS COMMENTS
	0.00	217.69	.		.	.		.	.	.	.	.	DALLAS/ELLIS COUNTY LINE
	0.57	218.26	2	UP	.	.		.	.	.	.	.	
	0.82	218.51	2	CB	.	.		.	.	.	.	.	
	0.88	218.57	.		.	.		.	.	.	.	1	
	0.93	218.62	2	CB	.	.		.	.	.	.	.	
	1.08	218.77	2	UP	.	.		.	.	.	.	.	
	2.32	220.01	.		.	1	OP	14.75	14.83	14.79	.	.	
270	2.78	220.47	.		.	.		.	.	.	.	.	MPT 270
	3.35	221.04	2	UP	.	.		.	.	.	.	.	
271	3.76	221.45	2	CB	.	.		.	.	.	.	.	MPT 271
	4.74	222.43	.		.	1	OP	14.58	15.00	14.79	.	.	
	5.66	223.36	.		.	1	OP	14.75	15.75	15.25	.	.	
	6.44	224.13	.		.	1	OP	14.75	14.92	14.83	.	.	
	7.62	225.31	2	UP	.	.		.	.	.	.	.	
	8.29	225.98	1	UPRR	.	.		.	.	.	.	.	
	8.32	226.01	.		.	.		.	.	.	2.00	.	
	8.34	226.03	.		.	.		.	.	.	.	1	
	8.65	226.34	.		.	1	OP	16.83	16.75	16.79	.	.	
	8.86	226.55	.		.	1	OP	.	16.42	16.42	.	.	
	9.06	226.75	.		.	1	OP	.	16.42	16.42	.	.	I20 (3 LEVEL STRUCTURE)
	9.25	226.94	.		.	.		.	.	.	0.50	.	
	9.48	227.17	.		.	.		.	.	.	0.50	.	
	10.15	227.84	2	CB	.	.		.	.	.	.	.	
	10.51	228.20	2	CB	0.20	.		.	.	.	.	.	
	10.76	228.45	2	UP	.	.		.	.	.	.	.	
	10.92	228.61	2	CB	.	.		.	.	.	.	.	
	11.12	228.81	2	CB	.	.		.	.	.	0.50	.	
	11.35	229.04	.		.	.		.	.	.	0.50	.	
	11.43	229.12	2	CB	.	.		.	.	.	.	.	
279	11.79	229.48	.		.	.		.	.	.	.	.	MPT 279
	12.15	229.84	.		.	1	OP	16.50	17.83	17.16	.	.	
	13.08	230.77	2	UP	.	.		.	.	.	.	.	
	13.18	230.87	2	UP	.	.		.	.	.	.	.	
	13.21	230.90	.		.	.		.	.	.	0.50	.	
	13.45	231.14	.		.	.		.	.	.	0.50	.	
	13.80	231.49	.		.	.		.	.	.	.	.	RETURN TO GRADE
	13.91	231.60	.		.	.		.	.	.	0.50	.	
	14.14	231.83	.		.	.		.	.	.	0.50	.	
	14.21	231.90	.		.	.		.	.	.	.	1	
	15.45	233.14	1	CB	2.00	.		.	.	.	.	.	END I45 AT TRINITY RIVER (ELEVATED)

BRIDGE STRUCTURES : UP = VEHICULAR UNDERPASS
CB = CREEK/RIVER BED
RR = RAIL ROAD
UPRR = VEHICULAR UNDERPASS WITH RAILROAD
UPCB = VEHICULAR UNDERPASS AND CREEK/RIVER BED
ELV = ELEVATED STRUCTURE

OVERPASSES : OP = VEHICULAR OVERPASS
RR = RAIL ROAD OVERPASS
PED = PEDESTRIAN OVERPASS

SOURCE : TEXAS TRANSPORTATION INSTITUTE SURVEY

TABLE A-20. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 35
SDHPT DISTRICT 15 *** BEXAR COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	BRIDGE STRUCTURE NO	BRIDGE STRUCTURE TYPE	BRIDGE STRUCTURE LENGTH	OVERPASS NO	OVERPASS TYPE	OVERPASS CLEARANCE NB	OVERPASS CLEARANCE SB	OVERPASS CLEARANCE AVG	HORIZONTAL CURVE (DEGREE)	TRANS-MISSION LINES	OBSERVERS COMMENTS
	0.00	0.00	.		.	.		.	.	.	1.00	.	START I-35 NORTHBOUND
	0.31	0.31	.		.	1	OP	14.42	.	14.42	.	.	CMB
	0.53	0.53	.		.	.		.	.	.	0.75	.	
	0.62	0.62	1	ELV	.	.		.	.	.	.	.	ELEVATED 4 LANES NO MEDIAN
	0.79	0.79	.		.	.		.	.	.	0.75	.	
	0.93	0.93	1	UP	.	.		.	.	.	.	.	
	1.06	1.06	.		.	.		.	.	.	2.00	.	
	1.32	1.32	.		.	.		.	.	.	2.00	.	
	1.39	1.39	.		.	2	RR	14.08	14.25	14.16	.	.	
	1.60	1.60	1	ELV	0.25	.		.	.	.	.	.	ELEVATED
	1.96	1.96	1	ELV	0.90	.		.	.	.	.	.	ELEVATED
	2.99	2.99	.		.	1	OP	15.50	.	15.50	.	.	
	3.09	3.09	.		.	1	OP	14.75	.	14.75	.	.	
	3.18	3.18	.		.	.		.	.	.	0.50	.	
	3.19	3.19	.		.	1	OP	14.83	.	14.83	.	.	
	3.35	3.35	.		.	1	OP	14.83	.	14.83	.	.	
	3.40	3.40	.		.	1	OP	14.83	.	14.83	.	.	
	3.44	3.44	.		.	.		.	.	.	0.50	.	
	3.71	3.71	.		.	1	OP	15.25	.	15.25	.	.	
	3.81	3.81	1	ELV	0.70	.		.	.	.	.	.	ELEVATED
	4.12	4.12	.		.	1	OP	.	.	.	.	.	I-37
	4.22	4.22	.		.	1	OP	.	.	.	.	.	I-37
	4.53	4.53	.		.	.		.	.	.	.	.	REGAIN MEDIAN
	4.63	4.63	.		.	1	OP	15.17	.	15.17	.	.	
	5.20	5.20	.		.	1	OP	15.00	16.08	15.54	.	.	
	5.56	5.56	2	UP	.	.		.	.	.	.	.	
	5.77	5.77	.		.	1	RR	15.17	.	15.17	.	.	
	5.82	5.82	.		.	1	OP	16.75	.	16.75	.	.	
	6.09	6.09	.		.	.		.	.	.	0.50	.	
	6.33	6.33	2	CB	.	.		.	.	.	.	.	
	6.35	6.35	.		.	.		.	.	.	0.50	.	
	6.59	6.59	2	UP	.	.		.	.	.	.	.	
	7.15	7.15	.		.	.		.	.	.	1.00	.	
161	7.21	7.21	.		.	.		.	.	.	.	.	MPT 161
	7.41	7.41	.		.	.		.	.	.	1.00	.	
	7.62	7.62	2	CB	.	.		.	.	.	.	.	
	7.68	7.68	.		.	.		.	.	.	1.00	.	
	8.34	8.34	.		.	1	OP	14.75	15.75	15.25	.	.	LOOP 410
	8.45	8.45	2	CB	.	.		.	.	.	.	.	
	9.53	9.53	.		.	.		.	.	.	0.50	.	
	9.58	9.58	.		.	1	OP	16.33	.	16.33	.	.	LOOP 410 SB ONLY
	9.80	9.80	.		.	.		.	.	.	0.50	.	
	10.06	10.06	.		.	.		.	.	.	0.75	.	
	10.33	10.33	.		.	.		.	.	.	0.75	.	
	10.40	10.40	2	CB	.	.		.	.	.	.	.	
	10.59	10.59	.		.	.		.	.	.	0.75	.	
	11.28	11.28	2	CB	.	.		.	.	.	.	.	
	12.18	12.18	.		.	.		.	.	.	0.75	.	
	12.26	12.26	2	CB	.	.		.	.	.	.	.	
	12.44	12.44	.		.	.		.	.	.	0.75	.	
	12.71	12.71	.		.	.		.	.	.	0.75	.	
	12.97	12.97	.		.	.		.	.	.	0.75	.	
	13.03	13.03	1	CB	0.20	.		.	.	.	.	.	
	13.24	13.24	.		.	.		.	.	.	0.50	.	
	13.50	13.50	.		.	.		.	.	.	0.50	.	
	13.77	13.77	.		.	.		.	.	.	0.50	.	
	15.09	15.09	.		.	.		.	.	.	1.00	.	
	17.21	17.21	.		.	.		.	.	.	0.75	.	
	17.66	17.66	2	UP	.	.		.	.	.	.	.	

TABLE A-20. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 35
SDHPT DISTRICT 15 *** BEXAR COUNTY
NORTHBOUND DIRECTION (cont'd)

MILE POST	COUNTY MILE	CUM MILE	BRIDGE STRUCTURE NO	BRIDGE STRUCTURE TYPE	BRIDGE STRUCTURE LENGTH	OVERPASS NO	OVERPASS TYPE	CLEARANCE NB	CLEARANCE SB	CLEARANCE AVG	HORIZONTAL CURVE (DEGREE)	TRANS-MISSION LINES	OBSERVERS COMMENTS
	19.05	19.05	.		.	1	OP	16.08	16.33	16.20	.	.	
	20.14	20.14	1	UP	.	.		.	.	.	.	.	
	20.29	20.29	.		.	.		.	.	.	.	.	BEXAR/GUADALUPE COUNTY LINE

BRIDGE STRUCTURES : UP = VEHICULAR UNDERPASS
CB = CREEK/RIVER BED
RR = RAIL ROAD
UPRR = VEHICULAR UNDERPASS WITH RAILROAD
UPCB = VEHICULAR UNDERPASS AND CREEK/RIVER BED
ELV = ELEVATED STRUCTURE

OVERPASSES : OP = VEHICULAR OVERPASS
RR = RAIL ROAD OVERPASS
PED = PEDESTRIAN OVERPASS

SOURCE : TEXAS TRANSPORTATION INSTITUTE SURVEY

TABLE A-21. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 35
SDHPT DISTRICT 15 *** GUADALUPE COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	BRIDGE STRUCTURE NO	BRIDGE STRUCTURE TYPE	BRIDGE STRUCTURE LENGTH	OVERPASS NO	OVERPASS TYPE	OVERPASS CLEARANCE NB	OVERPASS CLEARANCE SB	OVERPASS CLEARANCE AVG	HORIZONTAL CURVE (DEGREE)	TRANS-MISSION LINES	OBSERVERS COMMENTS
	0.00	20.29	.		.	.		.	.	.	.	.	GUADALUPE/BEXAR COUNTY LINE
175	1.03	21.32	.		.	.		.	.	.	.	.	MPT 175
	1.85	22.14	.		.	1	OP	16.83	17.17	17.00	.	.	
	2.21	22.50	.		.	.		.	.	.	0.50	.	
	2.68	22.97	.		.	.		.	.	.	.	1	LARGE STRUCTURE
	3.19	23.48	.		.	.		.	.	.	.	.	GUADALUPE/COMAL COUNTY LINE

BRIDGE STRUCTURES : UP = VEHICULAR UNDERPASS
CB = CREEK/RIVER BED
RR = RAIL ROAD
UPRR = VEHICULAR UNDERPASS WITH RAILROAD
UPCB = VEHICULAR UNDERPASS AND CREEK/RIVER BED
ELV = ELEVATED STRUCTURE

OVERPASSES : OP = VEHICULAR OVERPASS
RR = RAIL ROAD OVERPASS
PED = PEDESTRIAN OVERPASS

SOURCE : TEXAS TRANSPORTATION INSTITUTE SURVEY

TABLE A-22. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 35
SDHPT DISTRICT 15 *** COMAL COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	BRIDGE STRUCTURE NO	BRIDGE STRUCTURE TYPE	BRIDGE STRUCTURE LENGTH	OVERPASS NO	OVERPASS TYPE	OVERPASS CLEARANCE NB	OVERPASS CLEARANCE SB	OVERPASS CLEARANCE AVG	HORIZONTAL CURVE (DEGREE)	TRANSMISSION LINES	OBSERVERS COMMENTS
	0.00	23.48	.		.	.		.	.	.	.	.	COMAL/GUADALUPE COUNTY LINE
	0.08	23.56	.		.	.		.	.	.	0.50	.	
	0.31	23.79	.		.	1	OP	16.67	16.42	16.54	.	.	
178	0.72	24.20	.		.	.		.	.	.	.	.	MPT 178
	1.54	25.02	.		.	1	OP	16.75	16.42	16.58	.	.	
	2.20	25.68	.		.	.		.	.	.	1.00	.	
	2.57	26.05	.		.	.		.	.	.	.	.	REST AREAS (BOTH SIDES)
180	2.73	26.21	.		.	.		.	.	.	.	.	MPT 180
	3.26	26.74	.		.	.		.	.	.	0.75	.	
	3.45	26.93	2	UP	.	.		.	.	.	.	.	
	3.81	27.29	.		.	.		.	.	.	.	1	LARGE STRUCTURE
	5.15	28.63	2	UP	.	.		.	.	.	.	.	
	5.38	28.86	.		.	.		.	.	.	1.00	.	
	6.44	29.92	.		.	.		.	.	.	0.75	.	
	6.49	29.97	.		.	1	OP	15.83	16.42	16.12	.	.	
184	6.69	30.17	.		.	.		.	.	.	.	.	MPT 184
	7.50	30.98	.		.	.		.	.	.	0.75	.	
	7.62	31.10	.		.	1	OP	15.92	.	15.92	.	.	
	8.55	32.03	2	UP	.	.		.	.	.	.	.	
	9.58	33.06	2	UP	.	.		.	.	.	.	.	
	9.61	33.09	.		.	.		.	.	.	0.75	.	
	10.61	34.09	2	UP	.	.		.	.	.	.	.	
	10.71	34.19	2	UPCB	0.20	.		.	.	.	.	.	
	11.74	35.22	2	UP	.	.		.	.	.	.	.	
	12.72	36.20	2	UP	.	.		.	.	.	.	.	
	12.79	36.27	.		.	.		.	.	.	0.50	.	
191	13.70	37.18	.		.	.		.	.	.	.	.	MPT 191
	14.01	37.49	2	UP	.	.		.	.	.	.	.	
	14.83	38.31	2	CB	.	.		.	.	.	.	.	
	15.76	39.24	.		.	1	OP	16.17	17.75	16.96	.	.	
	18.28	41.76	.		.	1	OP	17.33	16.08	16.70	.	.	
	18.69	42.17	.		.	.		.	.	.	.	1	LARGE STRUCTURE
	19.57	43.05	.		.	1	OP	15.25	17.58	16.41	.	.	
	20.29	43.77	.		.	.		.	.	.	.	.	COMAL/HAYS COUNTY LINE

BRIDGE STRUCTURES : UP = VEHICULAR UNDERPASS
CB = CREEK/RIVER BED
RR = RAIL ROAD
UPRR = VEHICULAR UNDERPASS WITH RAILROAD
UPCB = VEHICULAR UNDERPASS AND CREEK/RIVER BED
ELV = ELEVATED STRUCTURE

OVERPASSES : OP = VEHICULAR OVERPASS
RR = RAIL ROAD OVERPASS
PED = PEDESTRIAN OVERPASS

SOURCE : TEXAS TRANSPORTATION INSTITUTE SURVEY

TABLE A-23. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 35
SDHPT DISTRICT 14 *** HAYS COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	BRIDGE STRUCTURE NO	BRIDGE STRUCTURE TYPE	BRIDGE STRUCTURE LENGTH	OVERPASS NO	OVERPASS TYPE	OVERPASS CLEARANCE NB	OVERPASS CLEARANCE SB	OVERPASS CLEARANCE AVG	HORIZONTAL CURVE (DEGREE)	TRANS-MISSION LINES	OBSERVERS COMMENTS
	0.00	43.77	.		.	.		.	.	.	.	.	HAYS/COMAL COUNTY LINE
198	0.41	44.19	.		.	.		.	.	.	.	.	MPT 198
	0.97	44.74	.		.	.		.	.	.	0.50	.	
	1.54	45.32	.		.	1	OP	16.75	16.92	16.83	.	.	
	2.03	45.80	.		.	.		.	.	.	0.50	.	
200	2.37	46.15	.		.	.		.	.	.	.	.	MPT 200
	2.57	46.35	.		.	1	OP	16.92	17.00	16.96	.	.	
	3.09	46.87	.		.	.		.	.	.	.	1	
	3.71	47.49	.		.	1	OP	16.33	16.83	16.58	.	.	
	4.15	47.92	.		.	.		.	.	.	0.50	.	
	5.36	49.14	.		.	1	OP	17.00	17.00	17.00	.	.	
	6.49	50.27	2	UP	.	.		.	.	.	.	.	
	6.85	50.63	2	UP	.	.		.	.	.	.	.	
	7.11	50.89	2	UPCB	.	.		.	.	.	.	.	
	7.88	51.66	2	UP	.	.		.	.	.	.	.	
	8.09	51.87	2	UP	.	.		.	.	.	.	.	
	8.39	52.16	.		.	.		.	.	.	0.50	.	
	8.75	52.53	2	UP	.	.		.	.	.	.	.	
	9.44	53.21	.		.	.		.	.	.	0.50	.	
	10.30	54.08	.		.	.		.	.	.	.	1	
	10.35	54.13	2	CB	0.15	.		.	.	.	.	.	
209	11.33	55.11	.		.	.		.	.	.	.	.	MPT 209
	11.56	55.33	.		.	.		.	.	.	0.50	.	
	12.98	56.76	.		.	1	OP	16.83	17.33	17.08	.	.	
	13.39	57.17	.		.	.		.	.	.	.	.	REST AREA WEST SIDE
	13.60	57.38	.		.	.		.	.	.	.	.	WEIGH STATION EAST SIDE
	13.68	57.45	.		.	.		.	.	.	0.50	.	
	14.11	57.89	.		.	.		.	.	.	.	.	REST AREA EAST SIDE
212	14.32	58.10	.		.	.		.	.	.	.	.	MPT 212
	15.86	59.64	.		.	1	OP	16.00	16.58	16.29	.	.	
	16.94	60.72	2	CB	.	.		.	.	.	.	.	
215	17.30	61.08	.		.	.		.	.	.	.	.	MPT 215
	17.72	61.50	.		.	1	OP	16.00	17.00	16.50	.	.	
	18.02	61.80	2	UP	.	.		.	.	.	.	.	
	19.57	63.35	.		.	1	OP	16.17	16.50	16.33	.	.	
	22.15	65.92	.		.	.		.	.	.	0.50	1	
	22.76	66.54	.		.	1	OP	16.08	16.00	16.04	.	.	
	23.21	66.98	.		.	.		.	.	.	1.50	.	
	23.48	67.26	2	UP	.	.		.	.	.	.	.	
	24.26	68.04	.		.	.		.	.	.	.	.	HAYS/TRAVIS COUNTY LINE

BRIDGE STRUCTURES : UP = VEHICULAR UNDERPASS
CB = CREEK/RIVER BED
RR = RAIL ROAD
UPRR = VEHICULAR UNDERPASS WITH RAILROAD
UPCB = VEHICULAR UNDERPASS AND CREEK/RIVER BED
ELV = ELEVATED STRUCTURE

OVERPASSES : OP = VEHICULAR OVERPASS
RR = RAIL ROAD OVERPASS
PED = PEDESTRIAN OVERPASS

SOURCE : TEXAS TRANSPORTATION INSTITUTE SURVEY

TABLE A-24. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 35
SDHPT DISTRICT 14 *** TRAVIS COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	BRIDGE STRUCTURE NO	BRIDGE STRUCTURE TYPE	BRIDGE STRUCTURE LENGTH	OVERPASS NO	OVERPASS TYPE	CLEARANCE NB	CLEARANCE SB	CLEARANCE AVG	HORIZONTAL CURVE (DEGREE)	TRANS-MISSION LINES	OBSERVERS COMMENTS
	0.00	68.04											TRAVIS/HAYS COUNTY LINE
223	1.03	69.06				1	OP	16.83	16.42	16.62			MPT 223
	1.06	69.10									1.00		
	2.57	70.60	2	CB									
	2.78	70.81				1	OP	14.92	14.75	14.83			
225	2.99	71.02											MPT 225
	3.18	71.22									0.50		
	3.71	71.74				1	OP	14.75	14.58	14.66			
	3.91	71.94	2	UP									
	4.94	72.97	2	UP									
	5.56	73.60									2.50		
	6.62	74.66									1.50		
	6.80	74.83				1	OP	13.92		13.92			
	7.00	75.03											MPT 229
	7.47	75.50				1	OP	16.58	16.50	16.54			NEW STRUCTURE
	7.72	75.75	2	UP									
	8.21	76.25									0.50		
	8.86	76.89	2	UP									SH 71
	9.48	77.51				1	OP	15.25	15.25	15.25			
	10.30	78.33				1	OP	15.83	16.00	15.91			IN CITY LIMITS
	10.81	78.84	2	UP									
	10.86	78.90									1.00		
	11.33	79.36				1	OP	14.25	14.25	14.25			
	11.43	79.46	1	CB	0.20								TOWN LAKE
	11.91	79.95									1.00		
	12.18	80.22									1.00		
	12.36	80.39	2	ELV	0.50								ELEVATED
	12.93	80.96				1	OP						
	13.49	81.52				1	OP	16.67	16.00	16.33			
	13.70	81.73	1	ELV	1.60								ELEVATED
	15.91	83.94				1	OP	17.08	17.50	17.29			
	16.42	84.46									0.75		
	16.69	84.72	1	UP	0.20								US 290
	17.47	85.51									1.50		
	17.51	85.54				1	OP	17.50	17.00	17.25			
	17.74	85.78									1.50		
	18.00	86.04									1.50		
	18.02	86.05	1	UP									
	18.27	86.31									1.50		
	19.57	87.60	2	UP									
243	20.91	88.94											MPT 243
	21.01	89.04				1	OP	16.25	16.33	16.29			
	21.78	89.81	2	CB									WALNUT CREEK
	21.94	89.97										1	
	21.97	90.01									1.00		
	22.24	90.28									1.00		
	22.56	90.59				1	OP	16.42	16.25	16.33			
	23.12	91.15										1	
	23.28	91.31				1	OP	16.75	16.67	16.71			
	24.36	92.39	2	UP									
	25.42	93.46									0.50		
	25.44	93.47	2	UP									
	26.57	94.60	2	UP									
	27.53	95.57									0.50		
	28.22	96.25				1	OP	15.92	16.00	15.96			TRAVIS/WILLIAMSON COUNTY LINE

BRIDGE STRUCTURES : UP = VEHICULAR UNDERPASS
CB = CREEK/RIVER BED
RR = RAIL ROAD
UPRR = VEHICULAR UNDERPASS WITH RAILROAD
UPCB = VEHICULAR UNDERPASS AND CREEK/RIVER BED
ELV = ELEVATED STRUCTURE

OVERPASSES : OP = VEHICULAR OVERPASS
RR = RAIL ROAD OVERPASS
PED = PEDESTRIAN OVERPASS

SOURCE : TEXAS TRANSPORTATION INSTITUTE SURVEY

TABLE A-25. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 35
SDHPT DISTRICT 14 *** WILLIAMSON COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	BRIDGE STRUCTURE NO	BRIDGE STRUCTURE TYPE	BRIDGE STRUCTURE LENGTH	OVERPASS NO	OVERPASS TYPE	CLEARANCE NB	CLEARANCE SB	CLEARANCE AVG	HORIZONTAL CURVE (DEGREE)	TRANS-MISSION LINES	OBSERVERS COMMENTS
	0.00	96.25	.		.	.		.	.	.	.	.	WILLIAMSON/TRAVIS COUNTY LINE
	0.67	96.92	.		.	1	OP	15.67	.	15.67	.	.	
252	1.60	97.85	2	UPRR	.	.		.	.	.	.	.	MPT 252
	1.96	98.21	2	CB	.	.		.	.	.	.	.	
	2.16	98.41	.		.	1	OP	15.08	15.17	15.12	.	.	
	2.37	98.62	2	UP	.	.		.	.	.	.	.	
	2.68	98.93	2	UP	.	.		.	.	.	.	.	
	3.55	99.80	.		.	.		.	.	.	.	1	
	3.56	99.81	.		.	.		.	.	.	0.50	.	
254	3.60	99.85	.		.	.		.	.	.	.	.	MPT 254
	3.91	100.16	.		.	1	OP	15.75	14.50	15.13	.	.	
	4.62	100.87	.		.	.		.	.	.	1.00	.	
	4.94	101.19	.		.	.		.	.	.	.	.	REST AREA EAST SIDE
	5.25	101.50	2	CB	.	.		.	.	.	.	.	
256	5.51	101.76	.		.	1	OP	16.17	16.08	16.12	.	.	MPT 256
	5.87	102.12	.		.	.		.	.	.	.	.	REST AREA WEST SIDE
	6.74	102.99	.		.	.		.	.	.	0.75	.	
	6.85	103.10	.		.	1	OP	16.08	16.08	16.08	.	.	
	6.90	103.15	.		.	.		.	.	.	.	1	
	7.80	104.05	.		.	.		.	.	.	0.50	.	
	8.96	105.21	2	UPRR	.	.		.	.	.	.	.	
	9.68	105.93	.		.	.		.	.	.	.	1	
	9.94	106.19	.		.	1	OP	16.42	16.67	16.54	.	.	
	10.20	106.45	2	CB	.	.		.	.	.	.	.	SOUTH SAN GABRIEL RIVER
262	10.58	106.83	.		.	.		.	.	.	.	.	MPT 262
	10.71	106.96	.		.	1	OP	16.50	17.08	16.79	.	.	
	10.97	107.22	.		.	.		.	.	.	0.50	.	
	11.12	107.37	.		.	.		.	.	.	.	1	
	11.69	107.94	2	CB	0.15	.		.	.	.	.	.	NORTH SAN GABRIEL RIVER
	12.15	108.40	.		.	1	OP	16.75	16.83	16.79	.	.	
	13.65	109.90	.		.	.		.	.	.	.	1	
	14.01	110.26	.		.	1	OP	16.92	16.00	16.46	.	.	
	15.30	111.55	2	CB	.	.		.	.	.	.	.	
	16.02	112.27	.		.	1	OP	16.50	16.33	16.41	.	.	SH 195
	16.27	112.52	2	CB	.	.		.	.	.	.	.	
267	16.48	112.73	.		.	.		.	.	.	.	.	MPT 267
	17.61	113.86	2	UP	.	.		.	.	.	.	.	
	18.49	114.74	.		.	1	OP	16.33	16.58	16.45	.	.	
271	20.45	116.70	.		.	.		.	.	.	.	.	MPT 271
	21.22	117.47	.		.	1	OP	16.33	16.33	16.33	.	.	
	23.59	119.84	.		.	1	OP	16.17	16.33	16.25	.	.	
	24.74	120.99	.		.	.		.	.	.	0.75	.	
	24.98	121.23	2	UP	.	.		.	.	.	.	.	
276	25.44	121.69	.		.	.		.	.	.	.	.	MPT 276
	25.80	122.05	.		.	.		.	.	.	0.75	.	
	26.47	122.72	.		.	1	OP	16.17	16.25	16.21	.	.	
	27.35	123.60	.		.	.		.	.	.	.	.	WILLIAMSON/BELL COUNTY LINE

BRIDGE STRUCTURES : UP = VEHICULAR UNDERPASS
CB = CREEK/RIVER BED
RR = RAIL ROAD
UPRR = VEHICULAR UNDERPASS WITH RAILROAD
UPCB = VEHICULAR UNDERPASS AND CREEK/RIVER BED
ELV = ELEVATED STRUCTURE

OVERPASSES : OP = VEHICULAR OVERPASS
RR = RAIL ROAD OVERPASS
PED = PEDESTRIAN OVERPASS

SOURCE : TEXAS TRANSPORTATION INSTITUTE SURVEY

TABLE A-26. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 35
SDHPT DISTRICT 9 *** BELL COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	BRIDGE STRUCTURE NO	TYPE	LENGTH	OVERPASS NO	TYPE	CLEARANCE NB	SB	AVG	HORIZONTAL CURVE (DEGREE)	TRANS-MISSION LINES	OBSERVERS COMMENTS
	0.00	123.60	.		.	.		.	.	.	.	.	BELL/WILLIAMSON COUNTY LINE
278	0.10	123.70	.		.	.		.	.	.	.	.	MPT 278
	0.57	124.17	.		.	.		.	.	.	0.75	.	
	2.37	125.97	.		.	1	OP	16.00	16.08	16.04	.	.	
	2.69	126.29	.		.	.		.	.	.	0.50	.	
	3.50	127.10	.		.	.		.	.	.	.	.	REST AREA EAST SIDE
	3.74	127.34	.		.	.		.	.	.	0.75	.	
282	4.12	127.72	.		.	.		.	.	.	.	.	MPT 282
	4.33	127.93	.		.	.		.	.	.	.	.	REST AREA WEST SIDE
	4.94	128.54	.		.	1	OP	16.08	16.00	16.04	.	.	FM 2843
	6.08	129.68	.		.	1	OP	17.08	16.25	16.66	.	.	
	6.59	130.19	.		.	.		.	.	.	.	.	START GUARD RAIL IN MEDIAN
	6.69	130.29	1	CB	.	.		.	.	.	.	.	
	6.92	130.52	.		.	.		.	.	.	0.50	.	
	7.00	130.60	.		.	1	OP	15.08	14.67	14.87	.	.	
	7.72	131.32	2	UP	.	.		.	.	.	.	.	
	7.83	131.43	.		.	.		.	.	.	.	.	END GUARD RAIL IN MEDIAN
	8.29	131.89	.		.	1	OP	16.83	16.17	16.50	.	.	
	9.17	132.77	.		.	.		.	.	.	.	1	LARGE STRUCTURE
	9.68	133.28	.		.	1	OP	15.92	16.17	16.04	.	.	
288	10.09	133.69	.		.	.		.	.	.	.	.	MPT 288
	10.10	133.70	.		.	.		.	.	.	0.50	.	
	11.16	134.76	.		.	.		.	.	.	0.50	.	
	11.43	135.03	.		.	1	OP	16.00	16.17	16.08	.	.	
	11.64	135.24	2	CB	.	.		.	.	.	.	.	LAMPASSAS RIVER
	12.22	135.82	.		.	.		.	.	.	1.00	.	
	12.77	136.37	.		.	1	OP	16.83	16.17	16.50	.	.	
	13.28	136.88	.		.	.		.	.	.	0.50	.	
	13.96	137.56	.		.	1	OP	16.17	17.58	16.87	.	.	BELTON CITY LIMITS
	14.33	137.93	.		.	.		.	.	.	0.75	.	
	14.93	138.53	1	UP	.	.		.	.	.	.	.	START CMB
	15.09	138.69	.		.	1	OP	19.17	.	19.17	.	.	
	15.76	139.36	1	UP	.	.		.	.	.	.	.	
	15.96	139.56	1	UP	.	.		.	.	.	.	.	
	16.07	139.67	.		.	.		.	.	.	.	1	
	16.45	140.05	.		.	.		.	.	.	1.50	.	
	16.48	140.08	.		.	1	OP	16.58	16.50	16.54	.	.	
	16.58	140.18	1	CB	.	.		.	.	.	.	.	
	16.99	140.59	.		.	.		.	.	.	.	1	
295	17.05	140.65	.		.	.		.	.	.	.	.	MPT 295
	17.46	141.06	.		.	.		.	.	.	.	1	TEMPLE
	17.82	141.42	1	CB	.	.		.	.	.	.	.	
	19.16	142.76	1	UP	.	.		.	.	.	.	.	
	19.21	142.81	.		.	.		.	.	.	.	1	
	19.63	143.23	.		.	.		.	.	.	2.00	.	
	20.39	143.99	.		.	.		.	.	.	.	.	CMB ENDS REPLACED WITH GUARD RAIL
	20.81	144.41	.		.	2	OP	16.42	16.42	16.42	.	.	
299	21.01	144.61	.		.	.		.	.	.	.	.	MPT 299
	21.32	144.92	1	ELV	0.70	.		.	.	.	.	.	
	21.75	145.35	.		.	.		.	.	.	1.50	.	
	22.14	145.74	1	UP	.	.		.	.	.	.	.	
	22.71	146.31	.		.	2	OP	16.08	15.00	15.54	.	.	
	22.81	146.41	.		.	.		.	.	.	2.00	.	
	22.87	146.47	.		.	.		.	.	.	.	.	CMB RESUMES
	23.54	147.14	.		.	1	OP	16.08	16.08	16.08	.	.	
	24.10	147.70	1	UPRR	0.20	.		.	.	.	.	.	
	24.67	148.27	.		.	1	RR	16.25	.	16.25	.	.	
	24.82	148.42	.		.	1	OP	16.25	.	16.25	.	.	
	25.13	148.73	.		.	1	OP	17.92	15.67	16.79	.	.	

TABLE A-26. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 35
SDHPT DISTRICT 9 *** BELL COUNTY
NORTHBOUND DIRECTION (cont'd)

MILE POST	COUNTY MILE	CUM MILE	BRIDGE STRUCTURE NO	BRIDGE STRUCTURE TYPE	BRIDGE STRUCTURE LENGTH	OVERPASS NO	OVERPASS TYPE	OVERPASS CLEARANCE NB	OVERPASS CLEARANCE SB	OVERPASS CLEARANCE AVG	HORIZONTAL CURVE (DEGREE)	TRANSMISSION LINES	OBSERVERS COMMENTS
	25.34	148.94	.		.	.		.	.	.	.	.	END CMB
	25.34	148.94	.		.	.		.	.	.	.	.	CONSTRUCTION FOR 1.05 MILES
	26.52	150.12	2	CB	.	.		.	.	.	.	.	
305	26.99	150.59	.		.	.		.	.	.	.	.	MPT 305
	27.19	150.79	2	UP	.	.		.	.	.	.	.	
	27.81	151.41	.		.	.		.	.	.	.	1	
	28.89	152.49	.		.	1	OP	15.75	15.67	15.71	.	.	
	29.16	152.76	.		.	.		.	.	.	0.50	.	
	30.95	154.55	.		.	1	OP	14.92	14.83	14.87	.	.	
	32.34	155.94	2	CB	.	.		.	.	.	.	.	
	33.27	156.87	.		.	1	OP	15.42	16.08	15.75	.	.	BIG ELM ROAD
312	33.78	157.38	.		.	.		.	.	.	.	.	MPT 312
	35.48	159.08	.		.	.		.	.	.	.	.	BELL/FALLS COUNTY LINE

BRIDGE STRUCTURES : UP = VEHICULAR UNDERPASS
CB = CREEK/RIVER BED
RR = RAIL ROAD
UPRR = VEHICULAR UNDERPASS WITH RAILROAD
UPCB = VEHICULAR UNDERPASS AND CREEK/RIVER BED
ELV = ELEVATED STRUCTURE

OVERPASSES : OP = VEHICULAR OVERPASS
RR = RAIL ROAD OVERPASS
PED = PEDESTRIAN OVERPASS

SOURCE : TEXAS TRANSPORTATION INSTITUTE SURVEY

TABLE A-27. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 35
SDHPT DISTRICT 9 *** FALLS COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	BRIDGE STRUCTURE NO	TYPE	LENGTH	OVERPASS NO	TYPE	CLEARANCE NB	SB	AVG	HORIZONTAL CURVE (DEGREE)	TRANSMISSION LINES	OBSERVERS COMMENTS
	0.00	159.08	.		.	.		.	.	.	.	.	FALLS/BELL COUNTY LINE
	0.03	159.11	.		.	.		.	.	.	1.50	.	
	0.05	159.13	2	CB	.	.		.	.	.	.	.	
314	0.51	159.59	.		.	.		.	.	.	.	.	MPT 314
	1.18	160.26	.		.	1	OP	15.50	15.42	15.46	.	.	
	1.96	161.04	.		.	.		.	.	.	.	.	FALLS/MCLENNAN COUNTY LINE

BRIDGE STRUCTURES :
- UP = VEHICULAR UNDERPASS
- CB = CREEK/RIVER BED
- RR = RAIL ROAD
- UPRR = VEHICULAR UNDERPASS WITH RAILROAD
- UPCB = VEHICULAR UNDERPASS AND CREEK/RIVER BED
- ELV = ELEVATED STRUCTURE

OVERPASSES :
- OP = VEHICULAR OVERPASS
- RR = RAIL ROAD OVERPASS
- PED = PEDESTRIAN OVERPASS

SOURCE : TEXAS TRANSPORTATION INSTITUTE SURVEY

TABLE A-28. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 35
SDHPT DISTRICT 9 *** MCLENNAN COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	BRIDGE STRUCTURE NO	BRIDGE STRUCTURE TYPE	BRIDGE STRUCTURE LENGTH	OVERPASS NO	OVERPASS TYPE	OVERPASS CLEARANCE NB	OVERPASS CLEARANCE SB	OVERPASS CLEARANCE AVG	HORIZONTAL CURVE (DEGREE)	TRANS-MISSION LINES	OBSERVERS COMMENTS
	0.00	161.04	.		.	.		.	.	.	.	.	MCLENNAN/FALLS COUNTY LINE
	0.21	161.25	.		.	1	OP	15.00	15.00	15.00	.	.	
316	0.46	161.50	.		.	.		.	.	.	.	.	MPT 316
	1.25	162.29	.		.	.		.	.	.	1.50	.	
	1.44	162.48	.		.	.		.	.	.	.	1	
	2.16	163.20	2	UPRR	.	.		.	.	.	.	.	
	2.31	163.35	.		.	.		.	.	.	0.50	.	
	2.68	163.72	.		.	.		.	.	.	.	.	REST AREA EAST SIDE
	3.09	164.13	.		.	.		.	.	.	.	.	REST AREA WEST SIDE
	3.40	164.44	2	CB	.	.		.	.	.	.	.	
319	3.50	164.54	.		.	.		.	.	.	.	.	MPT 319
	3.60	164.64	2	UP	.	.		.	.	.	.	.	
	5.49	166.53	.		.	.		.	.	.	0.50	.	
	5.87	166.91	2	CB	.	.		.	.	.	.	.	
	5.92	166.96	.		.	.		.	.	.	.	.	LORENA CITY LIMITS
	6.55	167.59	.		.	.		.	.	.	0.50	.	
	6.59	167.63	.		.	1	OP	14.75	14.75	14.75	.	.	
	7.57	168.61	.		.	1	OP	14.92	14.75	14.83	.	.	
324	8.45	169.49	.		.	.		.	.	.	.	.	MPT 324
	9.37	170.41	2	UP	.	.		.	.	.	.	.	
	9.68	170.72	.		.	1	OP	14.33	15.92	15.12	.	.	
326	10.40	171.44	.		.	.		.	.	.	.	.	MPT 326
327	11.43	172.47	.		.	.		.	.	.	.	.	MPT 327
	12.26	173.30	.		.	.		.	.	.	.	.	MEDIAN NARROWS
	12.46	173.50	.		.	1	OP	15.92	14.67	15.29	.	.	
	12.77	173.81	.		.	.		.	.	.	.	.	MEDIAN WIDENS
	14.63	175.67	.		.	.		.	.	.	.	1	
	15.14	176.18	.		.	1	OP	15.58	16.42	16.00	.	.	LOOP 340
	16.33	177.37	2	UP	.	.		.	.	.	.	.	WACO CITY LIMITS
	17.14	178.18	.		.	.		.	.	.	0.50	.	
	17.30	178.34	2	UP	.	.		.	.	.	.	.	
	17.61	178.65	.		.	1	OP	16.17	.	16.17	.	.	
	17.66	178.70	.		.	1	OP	16.17	.	16.17	.	.	
	17.72	178.76	.		.	1	OP	16.17	.	16.17	.	.	
	18.20	179.24	.		.	.		.	.	.	1.00	.	
	18.33	179.37	2	UP	.	.		.	.	.	.	.	
	18.39	179.43	2	UP	.	.		.	.	.	.	.	
	18.85	179.89	.		.	1	OP	17.33	16.50	16.91	.	.	
	19.21	180.25	.		.	1	PED	17.17	16.00	16.58	.	.	
	19.25	180.29	.		.	.		.	.	.	1.50	.	
	19.42	180.46	2	UP	.	.		.	.	.	.	.	
	19.78	180.82	2	UP	.	.		.	.	.	.	.	
	19.93	180.97	2	CB	.	.		.	.	.	.	.	BRAZOS RIVER
	20.24	181.28	2	UP	.	.		.	.	.	.	.	
	20.31	181.35	.		.	.		.	.	.	1.50	.	
	20.50	181.54	.		.	.		.	.	.	.	1	
	20.55	181.59	2	UPRR	.	.		.	.	.	.	.	
	20.86	181.90	.		.	1	OP	16.83	16.58	16.70	.	.	
	21.32	182.36	2	UP	0.25	.		.	.	.	.	.	
	21.37	182.41	.		.	.		.	.	.	1.00	.	
	21.94	182.98	2	UP	.	.		.	.	.	.	.	
	22.43	183.47	.		.	.		.	.	.	1.00	.	
	22.76	183.80	2	UP	.	.		.	.	.	.	.	
	23.38	184.42	2	UP	.	.		.	.	.	.	.	LOOP 340
	23.59	184.63	2	UPRR	.	.		.	.	.	.	.	
	23.64	184.68	.		.	.		.	.	.	.	.	WACO CITY LIMITS
	24.10	185.14	2	UP	.	.		.	.	.	.	.	
340	24.36	185.40	.		.	.		.	.	.	.	.	MPT 340
	24.55	185.59	.		.	.		.	.	.	1.00	.	

TABLE A-28. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 35
SDHPT DISTRICT 9 *** MCLENNAN COUNTY
NORTHBOUND DIRECTION (cont'd)

MILE POST	COUNTY MILE	CUM MILE	BRIDGE STRUCTURE NO	BRIDGE STRUCTURE TYPE	BRIDGE STRUCTURE LENGTH	OVERPASS NO	OVERPASS TYPE	OVERPASS CLEARANCE NB	OVERPASS CLEARANCE SB	OVERPASS CLEARANCE AVG	HORIZONTAL CURVE (DEGREE)	TRANS-MISSION LINES	OBSERVERS COMMENTS
	25.08	186.12	2	UP	.	.		.	.	.	.	.	
	25.61	186.65	.		.	.		.	.	.	2.00	.	
	25.90	186.94	2	UP	.	.		.	.	.	.	.	TSTI
342	26.32	187.36	.		.	.		.	.	.	.	.	MPT 342
	26.78	187.82	2	UP	.	.		.	.	.	.	.	
	28.17	189.21	2	UP	.	.		.	.	.	.	.	
	28.79	189.83	.		.	.		.	.	.	0.50	.	
	29.30	190.34	.		.	1	OP	14.08	15.17	14.62	.	.	
	29.77	190.81	.		.	.		.	.	.	.	.	PICNIC AREA BOTH SIDES
	30.18	191.22	.		.			.	.	.	.	1	LARGE STRUCTURE
346	30.33	191.37	.		.	.		.	.	.	.	.	MPT 346
	31.21	192.25	.		.	1	OP	14.58	15.08	14.83	.	.	
	32.14	193.18	.		.	1	OP	14.58	14.75	14.66	.	.	FM 3149
	33.02	194.06	.		.	.		.	.	.	0.50	.	
	33.84	194.88	.		.	1	OP	14.75	15.25	15.00	.	.	
351	35.33	196.37	.		.	.		.	.	.	.	.	MPT 351
	36.15	197.19	.		.	1	OP	16.08	14.75	15.41	.	.	FM 1858
	37.26	198.30	.		.	.		.	.	.	0.50	.	
	37.29	198.33	2	UP	.	.		.	.	.	.	.	WEST CITY LIMITS
	38.37	199.41	.		.	1	OP	16.50	13.75	15.13	.	.	
355	39.29	200.33	.		.	.		.	.	.	.	.	MPT 355
	39.38	200.42	.		.	.		.	.	.	0.50	.	
	39.71	200.75	.		.	1	OP	16.08	14.50	15.29	.	.	MCLENNAN/HILL COUNTY LINE

BRIDGE STRUCTURES : UP = VEHICULAR UNDERPASS
CB = CREEK/RIVER BED
RR = RAIL ROAD
UPRR = VEHICULAR UNDERPASS WITH RAILROAD
UPCB = VEHICULAR UNDERPASS AND CREEK/RIVER BED
ELV = ELEVATED STRUCTURE

OVERPASSES : OP = VEHICULAR OVERPASS
RR = RAIL ROAD OVERPASS
PED = PEDESTRIAN OVERPASS

SOURCE : TEXAS TRANSPORTATION INSTITUTE SURVEY

TABLE A-29. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 35
SDHPT DISTRICT 9 *** HILL COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	BRIDGE STRUCTURE NO	BRIDGE STRUCTURE TYPE	BRIDGE STRUCTURE LENGTH	OVERPASS NO	OVERPASS TYPE	OVERPASS CLEARANCE NB	OVERPASS CLEARANCE SB	OVERPASS CLEARANCE AVG	HORIZONTAL CURVE (DEGREE)	TRANS-MISSION LINES	OBSERVERS COMMENTS
	0.00	200.75	.		.	.		.	.	.	.	.	HILL/MCLENNAN COUNTY LINE
356	0.62	201.37	.		.	.		.	.	.	.	.	MPT 356
	1.13	201.88	.		.	1	OP	14.67	14.83	14.75	.	.	
	1.78	202.53	.		.	.		.	.	.	0.75	.	
358	2.57	203.32	.		.	.		.	.	.	.	.	MPT 358
	3.30	204.05	2	UP	.	.		.	.	.	.	.	
	4.43	205.18	2	UP	.	.		.	.	.	.	.	
	5.92	206.67	2	CB	.	.		.	.	.	.	.	
362	6.59	207.34	.		.	.		.	.	.	.	.	MPT 362
	7.31	208.06	2	UP	.	.		.	.	.	.	.	
	8.14	208.89	.		.	.		.	.	.	1.50	.	
	8.60	209.35	2	UP	.	.		.	.	.	.	.	FM 310 & MPT 364
	9.27	210.02	.		.	1	OP	15.92	.	15.92	.	.	SOUTHBOUND ONLY (TO HILLSBORO)
	9.78	210.53	.		.	1	OP	16.17	16.75	16.46	.	1	
366	10.56	211.31	2	RR	.	.		.	.	.	.	.	MPT 366
	11.31	212.06	.		.	.		.	.	.	1.00	.	
	11.84	212.59	.		.	1	OP	15.42	15.50	15.46	.	.	FM 3267
	12.57	213.32	.		.	1	OP	15.58	15.92	15.75	.	.	MPT 368
	13.08	213.83	2	UP	.	.		.	.	.	.	.	
	14.11	214.86	.		.	1	RR	16.25	16.25	16.25	.	.	
	14.49	215.24	.		.	.		.	.	.	0.50	.	
	14.68	215.43	.		.	1	OP	16.42	16.50	16.46	.	.	
	14.99	215.74	2	UP	.	.		.	.	.	.	.	
	15.30	216.05	.		.	.		.	.	.	.	1	
371	15.55	216.30	.		.	.		.	.	.	0.50	.	MPT 371 & END OF I-35

BRIDGE STRUCTURES : UP = VEHICULAR UNDERPASS
CB = CREEK/RIVER BED
RR = RAIL ROAD
UPRR = VEHICULAR UNDERPASS WITH RAILROAD
UPCB = VEHICULAR UNDERPASS AND CREEK/RIVER BED
ELV = ELEVATED STRUCTURE

OVERPASSES : OP = VEHICULAR OVERPASS
RR = RAIL ROAD OVERPASS
PED = PEDESTRIAN OVERPASS

SOURCE : TEXAS TRANSPORTATION INSTITUTE SURVEY

TABLE A-30. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 35 W
SDHPT DISTRICT 9 *** HILL COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	BRIDGE STRUCTURE NO	BRIDGE STRUCTURE TYPE	BRIDGE STRUCTURE LENGTH	OVERPASS NO	OVERPASS TYPE	OVERPASS CLEARANCE NB	OVERPASS CLEARANCE SB	OVERPASS CLEARANCE AVG	HORIZONTAL CURVE (DEGREE)	TRANS-MISSION LINES	OBSERVERS COMMENTS
	0.00	0.00	.		.	1	OP	16.08	.	16.08	.	.	NORTHBOUND ONLY (I35 E) - START OF I35W
	0.46	0.46	.		.	1	OP	16.58	16.42	16.50	.	.	
1	0.67	0.67	.		.	.		.	.	.	.	.	MPT 1
	3.04	3.04	.		.	1	OP	16.08	16.17	16.12	.	.	
	5.77	5.77	.		.	.		.	.	.	.	1	
	6.20	6.20	.		.	.		.	.	.	0.50	.	
	6.95	6.95	.		.	1	OP	16.75	16.33	16.54	.	.	
	7.06	7.06	.		.	.		.	.	.	.	.	REST AREA EAST SIDE
	8.09	8.09	.		.	1	OP	16.08	16.92	16.50	.	.	FM 66
	8.19	8.19	.		.	.		.	.	.	.	.	REST AREA WEST SIDE
	8.27	8.27	.		.	.		.	.	.	0.50	.	
9	8.60	8.60	.		.	.		.	.	.	.	.	MPT 9
	9.48	9.48	.		.	1	OP	16.42	16.83	16.62	.	.	
	12.46	12.46	2	UP	.	.		.	.	.	.	.	FM 67
	13.03	13.03	.		.	.		.	.	.	.	1	
	13.34	13.34	2	CB	.	.		.	.	.	.	.	
	13.44	13.44	.		.	.		.	.	.	0.50	.	
14	13.60	13.60	.		.	.		.	.	.	.	.	MPT 14
	13.96	13.96	.		.	.		.	.	.	.	.	HILL/JOHNSON COUNTY LINE

BRIDGE STRUCTURES : UP = VEHICULAR UNDERPASS
CB = CREEK/RIVER BED
RR = RAIL ROAD
UPRR = VEHICULAR UNDERPASS WITH RAILROAD
UPCB = VEHICULAR UNDERPASS AND CREEK/RIVER BED
ELV = ELEVATED STRUCTURE

OVERPASSES : OP = VEHICULAR OVERPASS
RR = RAIL ROAD OVERPASS
PED = PEDESTRIAN OVERPASS

SOURCE : TEXAS TRANSPORTATION INSTITUTE SURVEY

TABLE A-31. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 35 W
SDHPT DISTRICT 2 *** JOHNSON COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	BRIDGE STRUCTURE NO	BRIDGE STRUCTURE TYPE	BRIDGE STRUCTURE LENGTH	OVERPASS NO	OVERPASS TYPE	CLEARANCE NB	CLEARANCE SB	CLEARANCE AVG	HORIZONTAL CURVE (DEGREE)	TRANS-MISSION LINES	OBSERVERS COMMENTS
	0.00	13.96	.		.	.		.	.	.	.	.	JOHNSON/HILL COUNTY LINE
	0.21	14.16	2	UP	.	.		.	.	.	.	.	
15	0.67	14.63	.		.	.		.	.	.	.	.	MPT 15
	1.55	15.51	.		.	.		.	.	.	0.50	.	
	1.60	15.55	2	UP	.	.		.	.	.	.	.	CO RD 201
	2.63	16.58	.		.	1	OP	16.42	16.67	16.54	.	.	
	2.99	16.94	2	CB	0.10	.		.	.	.	.	.	
	3.50	17.46	.		.	1	OP	16.25	16.17	16.21	.	.	
18	3.66	17.61	.		.	.		.	.	.	.	.	MPT 18
	5.36	19.31	.		.	1	OP	16.58	16.50	16.54	.	.	
21	6.64	20.60	.		.	.		.	.	.	.	.	MPT 21
	7.42	21.37	.		.	1	OP	15.92	16.83	16.37	.	.	
	7.93	21.89	2	CB	.	.		.	.	.	.	.	
	8.79	22.75	.		.	.		.	.	.	0.75	.	
	9.27	23.23	.		.	1	OP	17.75	16.33	17.04	.	.	
	9.68	23.64	2	CB	.	.		.	.	.	.	.	
	10.30	24.26	2	UP	.	.		.	.	.	.	.	ALVARADO
	10.86	24.82	.		.	.		.	.	.	0.75	.	
	11.07	25.03	2	UPRR	.	.		.	.	.	.	.	
	11.89	25.85	.		.	.		.	.	.	0.75	.	
	12.10	26.06	2	UP	.	.		.	.	.	.	.	
	12.46	26.42	1	UP	.	.		.	.	.	.	.	US 67/US 81 BUSINESS (NORTHBOUND ONLY)
	13.29	27.24	.		.	1	OP	15.92	15.75	15.83	.	.	
	13.70	27.66	.		.	.		.	.	.	.	1	
	13.96	27.92	.		.	.		.	.	.	0.75	.	
29	14.63	28.58	.		.	.		.	.	.	.	.	MPT 29
	15.55	29.51	.		.	.		.	.	.	.	1	
	16.22	30.18	.		.	1	OP	16.67	17.00	16.83	.	.	FM 917
	16.58	30.54	.		.	.		.	.	.	.	1	
	17.05	31.00	.		.	.		.	.	.	.	.	REST AREA EAST SIDE
	17.06	31.02	.		.	.		.	.	.	0.50	.	
	17.92	31.88	.		.	1	OP	16.67	16.75	16.71	.	.	
	18.09	32.05	.		.	.		.	.	.	0.50	.	
	18.54	32.50	2	CB	.	.		.	.	.	.	.	
	18.85	32.81	.		.	.		.	.	.	.	.	REST AREA WEST SIDE
	20.08	34.04	.		.	1	OP	17.50	17.00	17.25	.	.	
	20.16	34.12	.		.	.		.	.	.	0.50	.	
	21.20	35.16	.		.	.		.	.	.	0.50	.	
	22.14	36.10	2	CB	.	.		.	.	.	.	.	
	22.30	36.26	.		.	.		.	.	.	.	1	
	22.35	36.31	2	UP	.	.		.	.	.	.	.	
	22.49	36.45	.		.	.		.	.	.	0.75	.	
	22.76	36.72	.		.	.		.	.	.	.	.	START CMB WITH PAVED MEDIAN
	23.07	37.03	1	UP	.	.		.	.	.	.	.	JOHNSON/TARRANT COUNTY LINE

BRIDGE STRUCTURES : UP = VEHICULAR UNDERPASS
CB = CREEK/RIVER BED
RR = RAIL ROAD
UPRR = VEHICULAR UNDERPASS WITH RAILROAD
UPCB = VEHICULAR UNDERPASS AND CREEK/RIVER BED
ELV = ELEVATED STRUCTURE

OVERPASSES : OP = VEHICULAR OVERPASS
RR = RAIL ROAD OVERPASS
PED = PEDESTRIAN OVERPASS

SOURCE : TEXAS TRANSPORTATION INSTITUTE SURVEY

A-41

TABLE A-32. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 35 W
SDHPT DISTRICT 2 *** TARRANT COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	BRIDGE STRUCTURE NO	BRIDGE STRUCTURE TYPE	BRIDGE STRUCTURE LENGTH	OVERPASS NO	OVERPASS TYPE	OVERPASS CLEARANCE NB	OVERPASS CLEARANCE SB	OVERPASS CLEARANCE AVG	HORIZONTAL CURVE (DEGREE)	TRANS-MISSION LINES	OBSERVERS COMMENTS
	0.00	37.03	.		.	.		.	.	.	.	.	TARRANT/JOHNSON COUNTY LINE
	0.71	37.74	.		.	.		.	.	.	0.50	.	
	0.72	37.75	.		.	1	OP	16.83	16.92	16.87	.	.	
	1.23	38.26	.		.	.		.	.	.	0.50	.	
	1.34	38.37	.		.	1	OP	18.33	16.25	17.29	.	.	
39	1.54	38.57	.		.	.		.	.	.	.	.	MPT 39
	1.75	38.78	.		.	1	OP	17.17	16.17	16.67	.	.	
	2.47	39.50	1	UP	.	.		.	.	.	.	.	
	2.52	39.55	.		.	.		.	.	.	.	1	LARGE STRUCTURE
	2.57	39.60	.		.	.		.	.	.	.	1	HUGALAY HOSPITAL
	3.04	40.07	.		.	.		.	.	.	0.50	.	
	3.19	40.22	.		.	1	OP	16.33	16.92	16.62	.	.	
41	3.50	40.53	.		.	.		.	.	.	.	.	MPT 41
	3.81	40.84	.		.	.		.	.	.	0.75	.	
	4.22	41.25	1	UP	.	.		.	.	.	.	.	
	5.15	42.18	1	UP	.	.		.	.	.	.	.	
	5.66	42.69	1	UP	.	.		.	.	.	.	.	
	6.39	43.41	.		.	.		.	.	.	.	1	
	6.90	43.93	1	UP	.	.		.	.	.	.	.	
	7.42	44.44	.		.	1	OP	16.08	16.42	16.25	.	.	
	7.69	44.72	.		.	.		.	.	.	0.50	.	
	7.88	44.91	.		.	1	OP	13.75	13.75	13.75	.	.	I-20/LOOP 820
	8.21	45.24	.		.	.		.	.	.	0.50	.	
	8.47	45.50	.		.	.		.	.	.	0.50	.	
	9.06	46.09	.		.	1	OP	15.00	15.00	15.00	.	.	
	9.24	46.27	.		.	.		.	.	.	0.50	.	
47	9.48	46.50	.		.	.		.	.	.	.	.	MPT 47
	9.89	46.92	.		.	1	OP	16.83	17.17	17.00	.	.	
	10.35	47.38	.		.	1	RR	14.25	14.25	14.25	.	.	
	10.51	47.53	.		.	1	OP	15.00	15.75	15.38	.	.	
	11.02	48.05	.		.	1	OP	15.50	16.25	15.88	.	.	
	11.12	48.15	.		.	1	PED	14.17	14.17	14.17	.	.	PEDESTRIAN OVERPASS
	11.84	48.87	1	UP	.	.		.	.	.	.	.	
	11.95	48.98	.		.	1	OP	17.00	.	17.00	.	.	
	12.36	49.39	1	UP	.	.		.	.	.	.	.	
	12.72	49.75	.		.	1	OP	14.67	.	14.67	.	.	
	12.93	49.96	.		.	1	PED	14.25	.	14.25	.	.	PEDESTRIAN OVERPASS
	12.98	50.01	.		.	1	OP	13.83	.	13.83	.	.	
	13.38	50.41	.		.	.		.	.	.	0.50	.	
	13.39	50.42	.		.	.		.	.	.	.	.	END OF I35W AT I30 IN FORT WORTH

BRIDGE STRUCTURES : UP = VEHICULAR UNDERPASS
CB = CREEK/RIVER BED
RR = RAIL ROAD
UPRR = VEHICULAR UNDERPASS WITH RAILROAD
UPCB = VEHICULAR UNDERPASS AND CREEK/RIVER BED
ELV = ELEVATED STRUCTURE

OVERPASSES : OP = VEHICULAR OVERPASS
RR = RAIL ROAD OVERPASS
PED = PEDESTRIAN OVERPASS

SOURCE : TEXAS TRANSPORTATION INSTITUTE SURVEY

TABLE A-33. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 30
SDHPT DISTRICT 2 *** TARRANT COUNTY
EASTBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	BRIDGE STRUCTURE NO	TYPE	LENGTH	OVERPASS NO	TYPE	CLEARANCE EB	WB	AVG	HORIZONTAL CURVE (DEGREE)	TRANS-MISSION LINES	OBSERVERS COMMENTS
	0.00	0.00	.		.	.		.	.	.	.	.	START I30 AT I35W IN FORT WORTH
	0.21	0.21	.		.	1	OP	14.92	.	14.92	.	.	
	0.46	0.46	.		.	1	OP	17.42	14.25	15.83	.	.	
	0.57	0.57	1	UP	.	.		.	.	.	.	.	
	0.62	0.62	.		.	1	OP	16.75	.	16.75	.	.	
	0.82	0.82	1	UP	0.10	.		.	.	.	.	.	
	1.00	1.00	.		.	.		.	.	.	0.50	.	
	1.34	1.34	1	UP	.	.		.	.	.	.	.	
	1.44	1.44	.		.	.		.	.	.	.	1	
	1.65	1.65	.		.	1	OP	16.58	14.83	15.70	.	.	
17	1.85	1.85	.		.	.		.	.	.	.	.	MPT 17
	2.00	2.00	.		.	.		.	.	.	0.75	.	
	2.25	2.25	.		.	.		.	.	.	0.75	.	
	2.50	2.50	.		.	.		.	.	.	0.75	.	
	3.25	3.25	.		.	.		.	.	.	2.00	.	
	3.40	3.40	.		.	1	OP	17.33	15.33	16.33	.	.	
19	3.86	3.86	.		.	.		.	.	.	.	.	MPT 19 (TOLL PLAZA)
	4.69	4.69	2	UP	.	.		.	.	.	.	.	
	4.75	4.75	.		.	.		.	.	.	0.50	.	
	5.00	5.00	.		.	.		.	.	.	0.50	.	
	5.25	5.25	.		.	.		.	.	.	0.50	.	
	5.77	5.77	.		.	.		.	.	.	.	1	
	5.97	5.97	.		.	1	OP	15.58	15.92	15.75	.	.	
	6.18	6.18	2	UP	.	.		.	.	.	.	.	LOOP 820
	7.16	7.16	.		.	1	OP	15.33	14.83	15.08	.	.	
	7.52	7.52	.		.	1	OP	14.92	14.75	14.83	.	.	
23	7.83	7.83	.		.	.		.	.	.	.	.	MPT 23
	7.98	7.98	.		.	1	OP	15.42	16.08	15.75	.	.	
	8.55	8.55	2	CB	.	.		.	.	.	.	.	
	8.91	8.91	.		.	1	OP	18.00	16.75	17.38	.	.	UNDER CONSTRUCTION
	9.42	9.42	.		.	1	OP	15.92	14.67	15.29	.	.	
	9.75	9.75	.		.	.		.	.	.	0.50	.	
	9.78	9.78	.		.	.		.	.	.	.	1	
	9.89	9.89	2	UP	0.10	.		.	.	.	.	.	ARLINGTON
	10.71	10.71	2	UP	0.10	.		.	.	.	.	.	
	10.97	10.97	.		.	1	OP	14.25	15.67	14.96	.	.	
	11.48	11.48	.		.	1	OP	15.25	14.67	14.96	.	.	DAVIS DRIVE
27	11.79	11.79	.		.	.		.	.	.	.	.	MPT 27
	11.95	11.95	.		.	1	OP	16.50	14.75	15.63	.	.	
	12.62	12.62	.		.	1	OP	14.67	14.67	14.67	.	.	
	12.98	12.98	.		.	2	OP	14.50	14.67	14.58	.	.	
	14.21	14.21	.		.	1	OP	15.00	15.00	15.00	.	.	
	14.52	14.52	2	CB	.	.		.	.	.	.	.	
	14.93	14.93	.		.	3	OP	14.67	14.67	14.67	.	.	
	15.24	15.24	.		.	1	OP	14.67	14.67	14.67	.	.	
	15.96	15.96	.		.	1	OP	15.83	15.75	15.79	.	.	
	16.38	16.38	.		.	1	OP	14.75	14.83	14.79	.	.	
	16.48	16.48	.		.	1	OP	13.83	.	13.83	.	.	
	16.69	16.69	.		.	.		.	.	.	.	.	TARRANT/DALLAS COUNTY LINE

BRIDGE STRUCTURES : UP = VEHICULAR UNDERPASS
CB = CREEK/RIVER BED
RR = RAIL ROAD
UPRR = VEHICULAR UNDERPASS WITH RAILROAD
UPCB = VEHICULAR UNDERPASS AND CREEK/RIVER BED
ELV = ELEVATED STRUCTURE

OVERPASSES : OP = VEHICULAR OVERPASS
RR = RAIL ROAD OVERPASS
PED = PEDESTRIAN OVERPASS

SOURCE : TEXAS TRANSPORTATION INSTITUTE SURVEY

TABLE A-34. SURVEY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 30
SDHPT DISTRICT 18 *** DALLAS COUNTY
EASTBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	BRIDGE STRUCTURE NO	BRIDGE STRUCTURE TYPE	BRIDGE STRUCTURE LENGTH	OVERPASS NO	OVERPASS TYPE	CLEARANCE EB	CLEARANCE WB	CLEARANCE AVG	HORIZONTAL CURVE (DEGREE)	TRANS-MISSION LINES	OBSERVERS COMMENTS
	0.00	16.69	.		.	.		.	.	.	.	.	DALLAS/TARRANT COUNTY LINE
	0.26	16.94	.		.	1	OP	14.42	14.33	14.37	.	.	
	0.72	17.41	.		.	1	OP	18.42	15.33	16.87	.	.	
	1.18	17.87	2	UP	.	.		.	.	.	.	.	
	1.56	18.25	.		.	.		.	.	.	0.50	.	
	1.81	18.50	.		.	.		.	.	.	0.50	.	
	2.21	18.90	2	UP	.	.		.	.	.	.	.	
	2.31	19.00	.		.	.		.	.	.	0.50	.	
	2.56	19.25	.		.	.		.	.	.	0.50	.	
	2.68	19.36	.		.	1	OP	14.92	14.25	14.58	.	.	
	3.31	20.00	.		.	.		.	.	.	0.75	.	
	3.56	20.25	.		.	.		.	.	.	0.75	.	
	4.06	20.75	.		.	.		.	.	.	1.00	.	
	4.27	20.96	2	UP	.	.		.	.	.	.	.	
	4.47	21.16	2	CB	.	.		.	.	.	.	.	
	4.81	21.50	.		.	.		.	.	.	0.50	.	
	5.06	21.75	.		.	.		.	.	.	0.50	.	
	5.78	22.46	2	CB	.	.		.	.	.	.	.	
	5.81	22.50	.		.	.		.	.	.	0.50	.	
	6.22	22.91	2	CB	0.15	.		.	.	.	.	.	
38	6.27	22.96	.		.	.		.	.	.	.	.	MPT 38
	6.56	23.25	.		.	.		.	.	.	0.50	.	
	6.87	23.56	2	CB	0.13	.		.	.	.	.	.	
	7.22	23.91	.		.	1	OP	14.50	14.75	14.63	.	.	
	7.62	24.31	2	CB	.	.		.	.	.	.	.	
	7.78	24.46	2	CB	.	.		.	.	.	.	.	
	7.81	24.50	.		.	.		.	.	.	0.75	.	
	8.06	24.75	.		.	.		.	.	.	0.75	.	
40	8.18	24.86	.		.	.		.	.	.	.	.	MPT 40
	8.31	25.00	.		.	.		.	.	.	0.75	.	
	8.56	25.25	.		.	.		.	.	.	0.75	.	
	8.88	25.56	2	CB	.	.		.	.	.	.	.	
	9.30	25.99	2	CB	.	.		.	.	.	.	.	
	10.06	26.75	.		.	.		.	.	.	1.50	.	
	10.28	26.97	.		.	1	OP	17.33	.	17.33	.	.	
	10.32	27.01	.		.	1	OP	.	.	.	.	.	
	10.70	27.39	.		.	1	OP	14.75	14.33	14.54	.	.	
	10.81	27.50	.		.	.		.	.	.	1.50	.	
	11.06	27.75	.		.	.		.	.	.	1.50	.	
	11.17	27.85	.		.	1	OP	15.00	18.75	16.88	.	.	
	11.31	28.00	.		.	.		.	.	.	1.50	.	
	11.63	28.31	1	CB	.	.		.	.	.	.	.	NO MEDIAN
44	12.23	28.91	.		.	.		.	.	.	.	.	MPT 44
	12.37	29.06	1	CB	.	.		.	.	.	.	.	
	12.42	29.11	1	CB	0.70	.		.	.	.	.	.	BRIDGE ENDS AT I35E
	12.81	29.50	.		.	.		.	.	.	3.50	.	
	13.31	30.00	.		.	.		.	.	.	4.50	.	
	13.56	30.25	.		.	.		.	.	.	3.00	.	
	13.81	30.50	.		.	.		.	.	.	3.00	.	
	15.66	32.34	.		.	.		.	.	.	.	.	I30 AT I45

BRIDGE STRUCTURES : UP = VEHICULAR UNDERPASS
CB = CREEK/RIVER BED
RR = RAIL ROAD
UPRR = VEHICULAR UNDERPASS WITH RAILROAD
UPCB = VEHICULAR UNDERPASS AND CREEK/RIVER BED
ELV = ELEVATED STRUCTURE

OVERPASSES : OP = VEHICULAR OVERPASS
RR = RAIL ROAD OVERPASS
PED = PEDESTRIAN OVERPASS

SOURCE : TEXAS TRANSPORTATION INSTITUTE SURVEY

TABLE A-35. SUMMARY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 10
SDHPT DISTRICT 15 *** BEXAR COUNTY
EASTBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	ROADWAY GEOMETRICS			
			LANES	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
	0.00	0.00	6	72	92	251-300
	2.70	2.70	6	72	92	251-300
	3.42	3.42	6	72	100	251-300
	4.04	4.04	6	72	100	251-300
	4.35	4.35	6	72	100	251-300
	4.55	4.55	6	72	100	251-300
	4.96	4.96	8	72	100	251-300
	5.27	5.27	8	72	100	251-300
	5.74	5.74	8	72	100	251-300
	5.99	5.99	8	72	100	251-300
	6.30	6.30	8	72	100	251-300
	6.82	6.82	8	72	100	251-300
	7.39	7.39	8	72	92	251-300
	7.85	7.85	4	72	92	401-450
	8.36	8.36	4	72	92	401-450
	8.88	8.88	4	72	92	401-450
	9.91	9.91	4	48	76	401-450
	10.27	10.27	4	48	76	301-350
	10.63	10.63	4	48	76	301-350
	10.84	10.84	4	48	76	301-350
	11.45	11.45	4	48	76	301-350
	12.28	12.28	4	48	76	301-350
	12.79	12.79	4	48	76	301-350
	14.80	14.80	4	48	76	301-350
	15.16	15.16	4	48	76	301-350
	15.57	15.57	4	48	76	301-350
	17.43	17.43	4	48	76	301-350
	18.56	18.56	4	48	76	301-350
	18.87	18.87	4	48	76	301-350
	19.54	19.54	4	48	76	301-350
	20.83	20.83	4	48	76	301-350
	21.50	21.50	4	48	76	301-350
	22.53	22.53	4	48	76	301-350
593	22.68	22.68	4	48	76	301-350
	23.30	23.30	4	48	76	301-350
	23.92	23.92	4	48	76	301-350

SOURCE : SDHPT RI2-TLOG

TABLEA-36. SUMMARY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 10
SDHPT DISTRICT 15 *** GUADALUPE COUNTY
EASTBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	ROADWAY GEOMETRICS			
			LANES	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
	0.00	23.92	4	48	80	301-350
	1.03	24.95	4	48	80	301-350
	2.21	26.13	4	48	80	301-350
	4.07	27.99	4	48	80	301-350
	5.51	29.43	4	48	80	301-350
	5.82	29.74	4	48	80	301-350
	6.99	30.91	4	48	80	301-350
	7.47	31.38	4	48	80	301-350
	7.78	31.69	4	48	80	301-350
	8.39	32.31	4	48	80	301-350
	9.22	33.14	4	48	80	301-350
	10.35	34.27	4	48	80	301-350
604	10.76	34.68	4	48	80	301-350
	10.79	34.71	4	48	80	301-350
	11.18	35.09	4	48	80	301-350
	11.74	35.66	4	48	80	301-350
	12.00	35.92	4	48	80	301-350
	12.36	36.28	4	48	80	301-350
	12.46	36.38	4	48	80	301-350
	12.72	36.64	4	48	80	301-350
	13.49	37.41	4	48	80	301-350
	14.06	37.98	4	48	80	301-350
	14.37	38.29	4	48	80	301-350
	14.57	38.49	4	48	80	301-350
	14.68	38.59	4	48	80	301-350
	16.07	39.98	4	48	80	301-350
	16.50	40.42	4	48	80	301-350
	16.53	40.45	4	48	80	301-350
	16.94	40.86	4	48	80	301-350
	17.66	41.58	4	48	80	301-350
	18.49	42.41	4	48	80	301-350
	19.35	43.27	4	48	80	301-350
	20.91	44.83	4	48	80	301-350
	21.94	45.86	4	48	80	301-350
	22.81	46.73	4	48	80	301-350
	23.15	47.07	4	48	80	301-350
	23.43	47.35	4	48	80	301-350
	24.15	48.07	4	48	80	301-350
	25.39	49.31	4	48	80	301-350
	26.01	49.93	4	48	80	301-350
	26.47	50.39	4	48	80	301-350
	26.88	50.80	4	48	80	301-350
	28.07	51.98	4	48	80	301-350
	29.10	53.01	4	48	80	301-350
623	29.72	53.63	4	48	80	301-350
	29.82	53.74	4	48	80	301-350
	30.23	54.15	4	48	80	301-350
	30.95	54.87	4	48	80	301-350
	32.55	56.46	4	48	80	301-350
	33.53	57.44	4	48	80	301-350
	33.62	57.54	4	48	80	301-350
	34.25	58.16	4	48	80	301-350
	34.87	58.78	4	48	80	301-350
	36.10	60.02	4	48	80	451-500
	36.47	60.39	4	48	80	451-500
	36.62	60.53	4	48	80	451-500

SOURCE : SDHPT RI2-TLOG

TABLE A-37. SUMMARY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 10
SDHPT DISTRICT 14 *** CALDWELL COUNTY
EASTBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	ROADWAY GEOMETRICS			
			LANES	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
	0.00	60.53	4	48	80	451-500
	1.84	62.38	4	48	80	451-500
	2.36	62.89	4	48	80	451-500
634	4.06	64.59	4	48	80	351-400
	4.57	65.11	4	48	80	351-400

SOURCE : SDHPT RI2-TLOG

TABLE A-38. SUMMARY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 10
SDHPT DISTRICT 13 *** GONZALES COUNTY
EASTBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	ROADWAY GEOMETRICS			
			LANES	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
	0.00	65.11	4	48	80	401-450
	0.03	65.14	4	48	80	401-450
	0.62	65.72	4	48	80	351-400
	1.44	66.55	4	48	80	351-400
	3.09	68.20	4	48	80	351-400
	3.19	68.30	4	48	80	351-400
	4.27	69.38	4	48	80	351-400
	5.05	70.15	4	48	80	351-400
	8.45	73.55	4	48	80	451-500
644	9.48	74.58	4	48	80	451-500
	10.09	75.20	4	48	80	451-500
	10.51	75.61	4	48	80	451-500
	10.61	75.71	4	48	80	451-500
	11.45	76.56	4	48	80	451-500
	11.64	76.74	4	48	80	451-500
	13.39	78.50	4	48	80	451-500
649	14.42	79.53	4	48	80	451-500
	15.35	80.45	4	48	80	351-400
	16.89	82.00	4	48	80	351-400
	17.10	82.20	4	48	80	351-400
	17.56	82.67	4	48	80	351-400
	18.54	83.65	4	48	80	351-400
	19.78	84.88	4	48	80	351-400
	19.88	84.98	4	48	80	351-400
	21.11	86.22	4	48	80	351-400
656	21.42	86.53	4	48	80	351-400
	21.53	86.63	4	48	80	351-400
	22.04	87.15	4	48	80	351-400

SOURCE : SDHPT RI2-TLOG

TABLE A-39. SUMMARY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 10
SDHPT DISTRICT 13 *** FAYETTE COUNTY
EASTBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	ROADWAY GEOMETRICS			
			LANES	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
	0.00	87.15	4	48	80	401-450
657	0.41	87.56	4	48	80	401-450
	0.67	87.82	4	48	80	401-450
	1.24	88.38	4	48	80	401-450
	2.37	89.52	4	48	80	401-450
	4.12	91.27	4	48	80	401-450
	5.05	92.19	4	48	80	401-450
	5.25	92.40	4	48	80	401-450
	5.66	92.81	4	48	80	401-450
663	6.39	93.53	4	48	80	401-450
	6.52	93.67	4	48	80	401-450
	6.75	93.89	4	48	80	401-450
	7.47	94.62	4	48	80	401-450
	8.24	95.39	4	48	80	451-500
	11.64	98.79	4	48	80	451-500
669	12.36	99.51	4	48	80	351-400
	13.18	100.33	4	48	80	401-450
	13.80	100.95	4	48	80	401-450
	15.08	102.23	4	48	80	401-450
	15.30	102.44	4	48	80	451-500
	15.55	102.70	4	48	80	451-500
	16.12	103.27	4	48	80	451-500
	16.38	103.52	4	48	80	351-400
	16.98	104.13	4	48	80	451-500
	17.72	104.86	4	48	80	451-500
	17.94	105.09	4	48	80	451-500
675	18.33	105.48	4	48	80	451-500
	19.36	106.51	4	48	80	451-500
	19.57	106.72	4	48	80	501-550
	20.79	107.94	4	48	80	301-350
	21.01	108.16	4	48	80	301-350
	21.68	108.83	4	48	80	301-350
	21.74	108.89	4	48	80	301-350
	21.84	108.98	4	48	80	301-350
	22.76	109.91	4	48		

SOURCE : SDHPT RI2-TLOG

TABLE A-40. SUMMARY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 10
SDHPT DISTRICT 13 *** COLORADO COUNTY
EASTBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	ROADWAY GEOMETRICS			
			LANES	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
	0.00	109.91	4	48	80	301-350
	0.67	110.58	4	48	80	301-350
	0.88	110.79	4	48	80	301-350
	1.83	111.74	4	48	80	301-350
	2.16	112.07	4	48	80	301-350
	2.63	112.54	4	48	80	301-350
	2.78	112.69	4	48	80	301-350
683	3.55	113.46	4	48	80	301-350
	4.38	114.29	4	48	80	301-350
	6.95	116.86	4	48	80	301-350
	7.26	117.17	4	48	80	301-350
687	7.57	117.48	4	48	80	301-350
	8.39	118.31	4	48	80	301-350
	8.49	118.40	4	48	80	301-350
	10.35	120.26	4	48	76	301-350
	10.39	120.30	4	48	76	301-350
	12.82	122.73	4	48	76	301-350
	12.93	122.84	4	48	76	301-350
693	13.54	123.46	4	48	76	251-300
	13.75	123.66	4	48	76	251-300
	14.83	124.74	4	48	76	251-300
695	15.50	125.41	4	48	76	251-300
	15.91	125.82	4	48	76	351-400
	16.07	125.98	4	48	76	351-400
	16.63	126.55	4	48	76	351-400
	16.79	126.70	4	48	76	351-400
	16.89	126.80	4	48	76	351-400
	17.05	126.96	4	48	76	351-400
	17.56	127.47	4	48	76	351-400
	17.97	127.88	4	48	76	351-400
	18.00	127.91	4	48	76	351-400
	18.13	128.04	4	48	76	351-400
	18.54	128.45	4	48	76	351-400
	18.95	128.86	4	48	76	351-400
	19.31	129.22	4	48	76	351-400
	19.90	129.81	4	48	86	301-350
	20.14	130.05	4	48	86	301-350
	20.65	130.56	4	48	86	301-350
	20.85	130.76	4	48	86	301-350
	21.80	131.71	4	48	86	301-350
702	22.51	132.42	4	48	86	301-350
	22.75	132.66	4	48	86	301-350
	23.71	133.62	4	48	86	301-350
	24.77	134.68	4	48	86	301-350
	25.61	135.52	4	48	86	301-350
	26.26	136.18	4	48	86	301-350
	26.56	136.47	4	48	86	301-350
708	28.48	138.39	4	48	86	301-350
	29.97	139.88	4	48	86	301-350
711	31.47	141.38	4	48	86	301-350
	31.88	141.79	4	48	86	301-350

SOURCE : SDHPT RI2-TLOG

TABLE A-41. SUMMARY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 10
SDHPT DISTRICT 13 *** AUSTIN COUNTY
EASTBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	ROADWAY GEOMETRICS			
			LANES	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
	0.00	141.79	4	48	76	301-350
	0.15	141.94	4	48	76	301-350
713	1.49	143.28	4	48	76	301-350
	1.70	143.49	4	48	76	301-350
	2.42	144.21	4	48	76	301-350
	3.24	145.03	4	48	76	301-350
	4.69	146.48	4	48	76	301-350
717	5.51	147.30	4	48	76	301-350
	5.61	147.40	4	48	76	301-350
	6.90	148.69	4	48	76	251-300
	7.78	149.57	4	48	76	251-300
	8.24	150.03	4	48	76	251-300
720	8.50	150.29	4	48	76	251-300
	8.91	150.70	4	48	76	251-300
	8.94	150.73	4	48	76	251-300
	9.06	150.85	4	48	76	251-300
	10.20	151.99	4	48	76	251-300
	11.02	152.81	4	48	76	251-300
723	11.48	153.27	4	48	76	251-300
	11.69	153.48	4	48	76	251-300
	11.80	153.59	4	48	76	251-300
	12.75	154.54	4	48	76	301-350
	13.70	155.49	4	48	76	301-350
	14.65	156.44	4	48	76	301-350
727	15.45	157.24	4	48	76	301-350
	16.02	157.81	4	48	76	301-350

SOURCE : SDHPT RI2-TLOG

TABLE A-42. SUMMARY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 10
SDHPT DISTRICT 12 *** WALLER COUNTY
EASTBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	ROADWAY GEOMETRICS			
			LANES	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
	0.00	157.81	4	48	80	451-500
	0.21	158.01	4	48	80	451-500
	0.31	158.11	4	48	80	451-500
	0.41	158.22	4	48	80	451-500
	0.57	158.37	4	48	80	451-500
	0.72	158.53	4	48	80	451-500
	1.08	158.89	4	48	80	451-500
	1.34	159.14	4	48	80	451-500
	1.48	159.29	4	48	80	451-500
	1.54	159.35	4	48	80	451-500
	1.85	159.66	4	48	80	451-500
	1.85	159.66	4	48	80	451-500
	2.06	159.87	4	48	80	451-500
	3.19	161.00	4	48	80	451-500
	3.30	161.10	4	48	80	451-500
	3.40	161.20	4	48	80	451-500
	3.50	161.31	4	48	80	451-500
	4.33	162.13	4	48	80	301-350
	4.34	162.15	4	48	80	301-350
	5.29	163.10	4	48	80	301-350
	5.36	163.16	4	48	80	301-350
	6.28	164.09	4	48	80	301-350
	7.19	165.00	4	48	80	301-350
	7.21	165.02	4	48	80	301-350
	8.14	165.95	4	48	80	301-350
	8.39	166.20	4	48	80	301-350
	8.86	166.66	4	48	80	301-350
737	9.48	167.28	4	48	80	301-350
	9.58	167.38	4	48	80	301-350
	11.12	168.93	4	48	80	301-350

SOURCE : SDHPT RI2-TLOG

TABLE A-43. SUMMARY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 10
SDHPT DISTRICT 12 *** FORT BEND COUNTY
EASTBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	ROADWAY GEOMETRICS			
			LANES	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
	0.00	168.93	4	48	80	301-350
	0.93	169.86	4	48	80	301-350
	1.03	169.96	4	48	80	301-350
	1.34	170.27	4	48	80	301-350
740	1.44	170.37	4	48	80	301-350
	1.75	170.68	4	48	84	351-400
	2.16	171.09	4	48	84	301-350
	2.96	171.89	4	48	84	301-350
	3.20	172.13	4	48	84	301-350
	3.40	172.33	4	48	84	301-350

SOURCE : SDHPT RI2-TLOG

TABLE A-44. SUMMARY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 10
SDHPT DISTRICT 12 *** HARRIS COUNTY
EASTBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	ROADWAY GEOMETRICS			
			LANES	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
	0.00	172.33	4	48	76	301-350
	0.28	172.61	4	48	76	301-350
	0.51	172.84	4	48	76	251-300
743	0.82	173.15	4	48	76	251-300
	1.44	173.77	6	72	92	251-300
	1.47	173.80	6	72	92	251-300
	1.94	174.27	6	72	92	251-300
	2.42	174.75	6	72	92	251-300
	2.88	175.21	6	72	92	251-300
	3.09	175.42	6	72	92	251-300
	3.19	175.52	6	72	92	251-300
746	3.81	176.14	6	72	92	251-300
	3.84	176.17	6	72	92	251-300
	4.79	177.12	6	72	92	251-300
	4.89	177.22	6	72	92	251-300
	5.27	177.60	6	72	92	251-300
	5.51	177.84	6	72	92	251-300
	5.74	178.07	6	72	92	251-300
	5.98	178.31	6	72	92	251-300
	6.75	179.08	6	72	92	251-300
	6.93	179.26	6	72	92	251-300
	7.17	179.50	6	72	92	251-300
	7.41	179.74	6	72	92	251-300
	7.65	179.98	6	72	92	251-300
	8.60	180.93	6	72	92	251-300
751	8.81	181.14	6	72	92	251-300
	9.37	181.70	6	72	92	301-350
	10.92	183.25	6	72	92	301-350
	11.64	183.97	6	72	92	301-350
	12.67	185.00	6	72	92	251-300
	13.60	185.92	6	72	92	251-300
	14.21	186.54	6	72	92	251-300
	15.45	187.78	6	72	92	251-300
758	15.76	188.09	6	72	92	251-300
	16.12	188.45	6	72	92	251-300
	16.74	189.07	6	74	94	251-300
	17.20	189.53	6	74	94	251-300
	18.13	190.46	6	72	92	351-400
	18.95	191.28	6	72	92	251-300
	19.47	191.80	6	72	92	251-300
	19.98	192.31	6	72	92	251-300
	20.60	192.93	6	72	92	301-350
	20.72	193.05	6	72	112	301-350
	20.81	193.13	6	72	112	301-350
	20.96	193.29	10	120	160	301-350
	21.20	193.53	10	120	160	301-350
	21.44	193.77	10	120	160	201-250
	21.58	193.91	10	120	160	201-250
764	21.73	194.06	10	120	160	201-250
	21.91	194.24	10	120	160	201-250
	22.35	194.68	10	120	160	301-350
	22.62	194.95	10	120	160	301-350
	22.66	194.99	10	120	160	301-350
	22.76	195.09	10	120	160	301-350
	22.86	195.19	10	120	160	301-350
	22.97	195.30	10	120	160	301-350
	23.23	195.56	10	120	160	301-350
	23.43	195.76	10	120	160	301-350
	23.48	195.81	10	120	160	301-350
	23.69	196.02	10	120	160	301-350
766	23.79	196.12	10	120	160	301-350
	24.05	196.38	10	120	160	301-350
	24.26	196.59	10	120	160	301-350
	24.29	196.62	10	120	160	301-350
	24.93	197.25	10	120	160	301-350
	25.23	197.56	10	120	160	301-350

TABLE A-44. SUMMARY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 10
SDHPT DISTRICT 12 *** HARRIS COUNTY
EASTBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	ROADWAY GEOMETRICS			
			LANES	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
	25.24	197.57	10	120	160	301-350
	25.72	198.05	8	96	136	301-350
	25.75	198.08	8	96	136	301-350
	25.95	198.28	8	96	136	301-350
	26.06	198.39	8	96	136	301-350

SOURCE : SDHPT RI2-TLOG

TABLE A-45. SUMMARY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 45
SDHPT DISTRICT 12 *** HARRIS COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	ROADWAY GEOMETRICS			
			LANES	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
	0.00	0.00	8	96	136	551-600
	0.23	0.23	8	96	136	551-600
	0.47	0.47	8	96	136	551-600
	0.70	0.70	8	96	136	551-600
	1.34	1.34	8	96	116	301-350
	1.40	1.40	8	96	116	301-350
	1.63	1.63	8	96	116	301-350
	1.65	1.65	8	96	116	301-350
	1.85	1.85	8	96	116	301-350
	1.86	1.86	8	96	116	301-350
	2.27	2.27	8	96	116	301-350
	2.33	2.33	8	96	116	301-350
	2.56	2.56	8	96	116	301-350
	2.63	2.63	8	96	116	301-350
	2.80	2.80	8	96	116	301-350
	2.88	2.88	6	72	92	301-350
	3.40	3.40	8	96	116	251-300
	3.81	3.81	8	96	116	251-300
	4.43	4.43	6	72	92	251-300
	4.84	4.84	6	72	92	251-300
	4.89	4.89	6	72	92	251-300
	5.77	5.77	6	72	92	251-300
	5.82	5.82	6	72	92	251-300
	6.06	6.06	6	72	92	251-300
	6.29	6.29	6	72	92	251-300
	6.90	6.90	6	72	92	251-300
	7.72	7.72	6	72	104	251-300
	8.14	8.14	6	72	104	251-300
	8.85	8.85	6	72	112	251-300
	9.06	9.06	6	72	112	251-300
	9.68	9.68	6	72	112	251-300
	9.79	9.79	6	72	112	251-300
	10.02	10.02	6	72	112	251-300
	10.81	10.81	6	72	112	251-300
	11.18	11.18	6	72	112	251-300
	11.65	11.65	6	72	112	251-300
	12.00	12.00	6	72	92	251-300
	12.12	12.12	6	72	92	251-300
	12.35	12.35	6	72	92	251-300
	12.46	12.46	6	72	112	251-300
61	12.87	12.87	6	72	92	251-300
	13.24	13.24	6	72	92	251-300
	13.80	13.80	6	72	108	251-300
	14.42	14.42	6	72	102	251-300
	15.14	15.14	6	72	102	251-300
	15.50	15.50	6	72	102	251-300
	15.84	15.84	6	72	102	251-300
	16.58	16.58	6	72	102	251-300
	16.78	16.78	6	72	102	251-300
	17.24	17.24	6	72	102	251-300
	17.47	17.47	6	72	92	251-300
	17.71	17.71	6	72	92	251-300
	17.94	17.94	6	72	92	251-300
	18.17	18.17	4	48	68	251-300
	18.23	18.23	4	48	68	251-300
	18.33	18.33	4	48	68	251-300
	19.26	19.26	4	48	88	251-300
	20.27	20.27	4	48	88	251-300
	20.39	20.39	4	48	88	251-300
	21.44	21.44	4	48	88	251-300
	21.67	21.67	4	48	88	251-300
	21.73	21.73	4	48	88	251-300
	21.94	21.94	4	48	68	251-300
	22.60	22.60	4	48	68	251-300
	22.97	22.97	4	48	68	251-300
	23.07	23.07	4	48	68	251-300

TABLE A-45. SUMMARY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 45
SDHPT DISTRICT 12 *** HARRIS COUNTY
NORTHBOUND DIRECTION (cont'd)

MILE POST	COUNTY MILE	CUM MILE	ROADWAY GEOMETRICS			
			LANES	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
	23.17	23.17	4	48	68	251-300
	23.30	23.30	4	48	68	251-300
	23.53	23.53	4	48	68	251-300
	24.62	24.62	4	48	88	251-300

SOURCE : SDHPT RI2-TLOG

TABLE A-46. SUMMARY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 45
SDHPT DISTRICT 12 *** MONTGOMERY COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	ROADWAY GEOMETRICS LANES	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
	0.00	24.62	4	48	76	301-350
	0.26	24.87	4	48	76	301-350
	1.08	25.70	4	48	80	301-350
	1.71	26.33	4	48	80	301-350
75	2.11	26.73	4	48	80	301-350
	3.19	27.81	4	48	80	301-350
	3.34	27.96	4	48	80	301-350
	4.27	28.89	4	48	80	301-350
	4.69	29.30	4	48	80	301-350
	6.37	30.99	4	48	80	301-350
	6.60	31.22	4	48	80	301-350
	6.64	31.26	4	48	80	301-350
	6.69	31.31	4	48	80	301-350
80	7.06	31.67	4	48	80	301-350
	7.07	31.69	4	48	80	301-350
	8.60	33.22	4	48	80	301-350
	8.70	33.32	4	48	80	301-350
	8.93	33.55	4	48	80	301-350
82	9.06	33.68	4	48	80	301-350
	9.16	33.78	4	48	80	301-350
	9.32	33.94	4	48	80	301-350
	9.63	34.25	4	48	80	301-350
	9.73	34.35	4	48	80	301-350
	10.71	35.33	4	48	80	301-350
	11.69	36.31	4	48	80	251-300
	12.21	36.82	4	48	80	251-300
	12.31	36.93	4	48	80	251-300
	12.62	37.23	4	48	80	251-300
	13.59	38.21	4	48	80	251-300
	13.65	38.26	4	48	80	251-300
	13.75	38.37	4	48	80	251-300
	14.27	38.88	4	48	80	251-300
	14.99	39.60	4	48	80	251-300
	15.60	40.22	4	48	80	251-300
89	16.07	40.68	4	48	80	251-300
	16.84	41.46	4	48	80	251-300
	17.09	41.71	4	48	80	251-300
	17.92	42.54	4	48	80	251-300
	17.97	42.59	4	48	80	251-300
	18.95	43.57	4	48	80	301-350
	19.57	44.19	4	48	80	301-350
	20.55	45.17	4	48	80	301-350
	21.51	46.13	4	48	80	301-350
	21.68	46.30	4	48	80	301-350
	21.75	46.37	4	48	80	301-350
95	22.04	46.66	4	48	80	301-350
	22.35	46.97	4	48	80	301-350
	22.71	47.33	4	48	80	301-350
	24.54	49.16	4	48	80	301-350
	24.76	49.38	4	48	80	301-350
	25.60	50.21	4	48	80	301-350
100	27.04	51.65	4	48	80	301-350
	27.76	52.38	4	48	80	301-350

SOURCE : SDHPT RI2-TLOG

TABLE A-47. SUMMARY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 45
SDHPT DISTRICT 17 *** WALKER COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	ROADWAY GEOMETRICS			
			LANES	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
	0.00	52.38	4	48	80	351-400
	0.46	52.84	4	48	80	351-400
	1.80	54.18	4	48	80	451-500
	2.63	55.00	4	48	80	451-500
	4.38	56.75	4	48	80	351-400
	5.40	57.78	4	48	80	451-500
	6.34	58.72	4	48	80	401-450
108	7.21	59.59	4	48	80	401-450
	8.20	60.58	4	48	80	401-450
	9.12	61.49	4	48	80	401-450
	11.00	63.38	4	48	80	401-450
	11.69	64.07	4	48	80	351-400
113	12.21	64.58	4	48	80	351-400
	14.06	66.44	4	48	80	351-400
	14.88	67.26	4	48	80	301-350
	15.91	68.29	4	48	80	301-350
	16.74	69.11	4	48	80	301-350
	17.66	70.04	4	48	80	301-350
	18.45	70.83	4	48	80	401-450
	21.25	73.63	4	48	80	401-450
	22.20	74.57	4	48	80	401-450
	23.23	75.60	4	48	80	401-450
	23.69	76.07	4	48	80	401-450
	23.74	76.12	4	48	80	401-450
	24.04	76.42	4	48	80	401-450
	24.77	77.15	4	48	80	401-450
126	25.18	77.56	4	48	80	401-450
	27.77	80.15	4	48	80	401-450
	29.66	82.04	4	48	80	401-450
	29.92	82.30	4	48	80	401-450
131	30.13	82.50	4	48	80	401-450
	31.57	83.95	4	48	80	351-400
	32.70	85.08	4	48	80	351-400

SOURCE : SDHPT RI2-TLOG

TABLE A-48. SUMMARY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 45
SDHPT DISTRICT 17 *** MADISON COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	ROADWAY GEOMETRICS			
			LANES	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
	0.00	85.08	4	48	80	401-450
134	0.41	85.49	4	48	80	401-450
	0.66	85.74	4	48	80	401-450
	1.13	86.21	4	48	80	401-450
	1.60	86.68	4	48	80	401-450
	3.09	88.17	4	48	80	351-400
	6.39	91.46	4	48	80	351-400
	8.12	93.20	4	48	80	301-350
	8.29	93.37	4	48	80	301-350
	11.85	96.93	4	48	80	301-350
	12.36	97.44	4	48	80	301-350
	12.78	97.86	4	48	80	301-350
	13.71	98.79	4	48	80	301-350
149	14.93	100.01	4	48	80	301-350
	15.09	100.17	4	48	80	301-350
	16.69	101.76	4	48	80	301-350
152	17.92	103.00	4	48	80	301-350
	18.23	103.31	4	48	80	301-350

SOURCE : SDHPT RI2-TLOG

TABLE A-49. SUMMARY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 45
SDHPT DISTRICT 17 *** LEON COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	ROADWAY GEOMETRICS			
			LANES	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
	0.00	103.31	4	48	80	301-350
	1.07	104.38	4	48	80	301-350
	1.49	104.80	4	48	80	301-350
	2.37	105.68	4	48	80	301-350
	2.63	105.94	4	48	80	301-350
	3.30	106.60	4	48	80	301-350
156	3.66	106.97	4	48	80	301-350
	4.17	107.48	4	48	80	301-350
	4.79	108.10	4	48	80	301-350
	4.80	108.11	4	48	80	301-350
	6.64	109.95	4	48	80	301-350
	6.67	109.98	4	48	80	301-350
	6.90	110.21	4	48	80	301-350
	7.31	110.62	4	48	80	301-350
	10.30	113.61	4	48	80	301-350
163	10.66	113.97	4	48	80	301-350
	11.74	115.05	4	48	76	301-350
	12.26	115.57	4	48	76	301-350
	15.05	118.36	4	48	76	301-350
	15.55	118.86	4	48	76	301-350
	17.85	121.16	4	48	76	301-350
	18.39	121.69	4	48	76	301-350
	18.75	122.05	4	48	76	301-350
	20.65	123.96	4	48	76	301-350
175	22.56	125.87	4	48	76	301-350
	22.87	126.17	4	48	76	301-350
	23.84	127.15	4	48	76	301-350
177	24.57	127.87	4	48	76	301-350
	25.31	128.62	4	48	76	301-350
	25.75	129.06	4	48	76	301-350
	26.26	129.57	4	48	76	301-350
	27.17	130.48	4	48	76	301-350
180	27.55	130.86	4	48	76	301-350
	27.60	130.91	4	48	76	301-350
	28.43	131.74	4	48	76	301-350

SOURCE : SDHPT RI2-TLOG

TABLE A-50. SUMMARY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 45
SDHPT DISTRICT 17 *** FREESTONE COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	ROADWAY GEOMETRICS			
			LANES	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
	0.00	131.74	4	48	80	351-400
	0.21	131.94	4	48	80	351-400
	1.39	133.13	4	48	80	351-400
	1.65	133.38	4	48	80	351-400
	4.02	135.75	4	48	80	351-400
	4.33	136.07	4	48	80	351-400
	5.56	137.30	4	48	80	351-400
	7.13	138.87	4	48	80	351-400
	7.83	139.56	4	48	80	351-400
	8.09	139.82	4	48	80	351-400
	8.96	140.70	4	48	80	351-400
	9.92	141.66	4	48	80	351-400
	10.97	142.71	4	48	80	351-400
	11.54	143.27	4	48	80	351-400
	11.79	143.53	4	48	80	351-400
	12.36	144.10	4	48	80	351-400
	12.57	144.30	4	48	80	351-400
	12.72	144.46	4	48	80	351-400
	15.52	147.26	4	48	80	351-400
	16.22	147.96	4	48	80	351-400
	16.45	148.19	4	48	80	351-400
	17.10	148.83	4	48	80	351-400
	18.02	149.76	4	48	80	401-450
	18.31	150.05	4	48	80	401-450
	18.64	150.38	4	48	80	401-450
	19.88	151.62	4	48	80	401-450
	20.18	151.92	4	48	80	401-450
	21.99	153.73	4	48	80	401-450
	22.04	153.78	4	48	80	401-450
	23.69	155.43	4	48	80	401-450
	24.51	156.25	4	48	80	401-450
	25.39	157.13	4	48	80	401-450
	25.77	157.51	4	48	80	401-450
	26.37	158.10	4	48	80	401-450
	26.70	158.44	4	48	80	401-450
	27.04	158.77	4	48	80	401-450
	27.40	159.13	4	48	80	401-450
209	28.02	159.75	4	48	80	401-450
	28.63	160.37	4	48	80	351-400
	28.94	160.68	4	48	80	351-400
211	30.02	161.76	4	48	80	351-400
	30.59	162.33	4	48	80	351-400
	30.80	162.53	4	48	80	351-400
	31.93	163.67	4	48	80	351-400

SOURCE : SDHPT RI2-TLOG

TABLE A-5.1. SUMMARY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 45
SDHPT DISTRICT 18 *** NAVARRO COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	ROADWAY GEOMETRICS			
			LANES	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
	0.00	163.67	4	48	76	301-350
	0.41	164.08	4	48	76	301-350
216	3.04	166.71	4	48	76	301-350
	3.16	166.83	4	48	76	301-350
	3.35	167.01	4	48	76	301-350
	3.50	167.17	4	48	76	301-350
	3.91	167.58	4	48	76	301-350
	4.22	167.89	4	48	76	301-350
	5.02	168.69	4	48	76	301-350
	5.25	168.92	4	48	76	301-350
	5.36	169.02	4	48	76	301-350
	5.92	169.59	4	48	76	301-350
	6.44	170.10	4	48	76	301-350
	6.89	170.56	4	48	76	251-300
	7.11	170.77	4	48	76	251-300
	7.72	171.39	4	48	76	251-300
	7.82	171.49	4	48	76	251-300
	8.60	172.27	4	48	68	251-300
	9.68	173.35	4	48	68	251-300
	10.15	173.81	4	48	68	251-300
224	10.81	174.48	4	48	68	251-300
	11.84	175.51	4	48	68	251-300
	12.48	176.15	4	48	68	251-300
228	14.83	178.50	4	48	68	251-300
	15.50	179.17	4	48	80	251-300
	15.66	179.32	4	48	80	251-300
	15.91	179.58	4	48	80	251-300
	16.63	180.30	4	48	80	251-300
	16.89	180.56	4	48	80	251-300
	17.51	181.18	4	48	80	251-300
231	17.82	181.49	4	48	80	251-300
	18.07	181.74	4	48	80	251-300
	18.18	181.85	4	48	80	251-300
	18.39	182.05	4	48	80	251-300
	18.64	182.31	4	48	80	251-300
	18.95	182.62	4	48	80	251-300
	19.62	183.29	4	48	80	251-300
234	20.86	184.52	4	48	80	251-300
	21.01	184.68	4	48	80	251-300
	21.68	185.35	4	48	80	251-300
	21.94	185.61	4	48	80	251-300
	22.35	186.02	4	48	80	251-300
	22.51	186.17	4	48	80	251-300
	22.87	186.53	4	48	68	251-300
	23.28	186.94	4	54	54	251-300
	23.66	187.33	4	48	68	251-300
237	23.90	187.56	4	48	68	251-300
	24.51	188.18	4	48	68	251-300
	25.75	189.42	4	48	68	251-300
	26.46	190.13	4	48	68	251-300
	26.99	190.65	4	48	68	251-300
241	27.91	191.58	4	48	68	251-300
	28.32	191.99	4	48	68	251-300
	29.05	192.71	4	48	68	251-300
243	29.92	193.59	4	48	68	251-300
	30.02	193.69	4	48	68	251-300
	30.19	193.86	4	48	68	251-300
	30.69	194.36	4	48	68	251-300

SOURCE : SDHPT RI2-TLOG

TABLE A-52. SUMMARY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 45
SDHPT DISTRICT 18 *** ELLIS COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	ROADWAY GEOMETRICS			
			LANES	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
	0.00	194.36	4	48	68	301-350
	0.43	194.79	4	48	68	301-350
	0.46	194.82	4	48	68	301-350
246	2.21	196.58	4	48	68	301-350
	2.29	196.65	4	48	68	301-350
	2.63	196.99	4	48	68	301-350
	3.22	197.58	4	48	68	301-350
	4.16	198.52	4	48	68	301-350
	6.08	200.44	4	48	68	251-300
250	6.18	200.54	4	48	68	251-300
	6.95	201.31	4	48	68	251-300
	7.26	201.62	4	48	68	251-300
	7.88	202.24	4	48	68	251-300
	8.03	202.39	4	48	68	251-300
	9.06	203.42	4	48	68	251-300
	9.99	204.35	4	48	68	251-300
	10.40	204.76	4	48	68	251-300
	11.28	205.64	4	48	68	251-300
256	12.21	206.57	4	48	68	251-300
	13.44	207.80	4	48	68	251-300
	13.49	207.85	4	48	68	251-300
	13.80	208.16	4	48	68	251-300
	14.32	208.68	4	48	68	251-300
	15.45	209.81	4	48	68	251-300
260	16.22	210.58	4	48	68	251-300
	16.43	210.79	4	48	68	251-300
	16.48	210.84	4	48	68	251-300
	17.15	211.51	4	48	68	251-300
	17.20	211.56	4	48	68	251-300
	17.41	211.77	4	48	68	251-300
	17.51	211.87	4	48	68	251-300
	17.97	212.33	4	48	68	251-300
	19.11	213.47	4	48	68	251-300
	19.93	214.29	4	48	68	251-300
	20.55	214.91	4	48	68	251-300
	21.06	215.42	4	48	68	251-300
266	22.20	216.56	4	48	68	251-300
	22.40	216.76	4	48	68	251-300
	22.61	216.97	4	48	68	251-300
	23.12	217.48	4	48	68	251-300
	23.33	217.69	4	48	68	251-300

SOURCE : SDHPT RI2-TLOG

TABLE A-53. SUMMARY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 45
SDHPT DISTRICT 18 *** DALLAS COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	ROADWAY GEOMETRICS LANES	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
	0.00	217.69	4	48	68	301-350
	0.57	218.26	4	48	68	301-350
	0.82	218.51	4	48	68	301-350
	0.88	218.57	4	48	68	301-350
	0.93	218.62	4	48	68	301-350
	1.08	218.77	4	48	68	301-350
	2.32	220.01	4	48	76	251-300
270	2.78	220.47	4	48	76	251-300
	3.35	221.04	4	48	76	251-300
271	3.76	221.45	4	48	76	251-300
	4.74	222.43	4	48	76	251-300
	5.66	223.36	4	48	76	251-300
	6.44	224.13	4	48	76	251-300
	7.62	225.31	6	72	116	251-300
	8.29	225.98	6	72	116	501-550
	8.32	226.01	6	72	116	501-550
	8.34	226.03	6	72	116	501-550
	8.65	226.34	6	72	112	501-550
	8.86	226.55	6	72	112	501-550
	9.06	226.75	6	72	112	501-550
	9.25	226.94	6	72	112	501-550
	9.48	227.17	6	72	112	501-550
	10.15	227.84	6	72	112	501-550
	10.51	228.20	6	72	112	501-550
	10.76	228.45	6	72	112	501-550
	10.92	228.61	6	72	112	501-550
	11.12	228.81	6	72	112	501-550
	11.35	229.04	6	72	112	501-550
	11.43	229.12	6	72	112	501-550
279	11.79	229.48	6	72	112	501-550
	12.15	229.84	6	72	112	501-550
	13.08	230.77	6	72	112	251-300
	13.18	230.87	6	72	112	251-300
	13.21	230.90	6	72	112	251-300
	13.45	231.14	6	72	112	251-300
	13.80	231.49	6	72	112	251-300
	13.91	231.60	6	72	112	251-300
	14.14	231.83	6	72	112	251-300
	14.21	231.90	6	72	112	251-300
	15.45	233.14	6	72	112	251-300

SOURCE : SDHPT RI2-TLOG

TABLE A-54. SUMMARY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 35
SDHPT DISTRICT 15 *** BEXAR COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	ROADWAY GEOMETRICS			
			LANES	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
	0.00	0.00	6	48	68	251-300
	0.31	0.31	4	48	48	151-200
	0.53	0.53	4	48	48	151-200
	0.62	0.62	4	48	48	151-200
	0.79	0.79	4	48	48	151-200
	0.93	0.93	4	48	48	151-200
	1.06	1.06	4	48	48	151-200
	1.32	1.32	4	48	48	201-250
	1.39	1.39	6	74	74	201-250
	1.60	1.60	6	74	74	201-250
	1.96	1.96	6	74	74	201-250
	2.99	2.99	5	60	60	201-250
	3.09	3.09	6	72	72	201-250
	3.18	3.18	6	72	72	201-250
	3.19	3.19	6	72	72	201-250
	3.35	3.35	4	48	48	201-250
	3.40	3.40	4	48	48	201-250
	3.44	3.44	4	48	48	201-250
	3.71	3.71	5	60	60	201-250
	3.81	3.81	5	60	60	201-250
	4.12	4.12	4	48	48	251-300
	4.22	4.22	4	48	48	251-300
	4.53	4.53	6	74	98	251-300
	4.63	4.63	6	74	98	251-300
	5.20	5.20	6	74	98	251-300
	5.56	5.56	6	74	74	251-300
	5.77	5.77	6	74	74	251-300
	5.82	5.82	6	74	74	251-300
	6.09	6.09	6	74	74	251-300
	6.33	6.33	6	74	74	251-300
	6.35	6.35	6	74	74	251-300
	6.59	6.59	6	74	74	251-300
	7.15	7.15	6	74	74	251-300
161	7.21	7.21	6	74	74	251-300
	7.41	7.41	6	74	74	251-300
	7.62	7.62	6	74	74	251-300
	7.68	7.68	6	74	74	251-300
	8.34	8.34	6	74	74	201-250
	8.45	8.45	6	74	74	201-250
	9.53	9.53	6	74	74	201-250
	9.58	9.58	6	74	74	201-250
	9.80	9.80	6	74	74	201-250
	10.06	10.06	6	74	94	301-350
	10.33	10.33	6	74	94	301-350
	10.40	10.40	6	74	94	301-350
	10.59	10.59	6	74	94	301-350
	11.28	11.28	6	74	94	301-350
	12.18	12.18	6	74	94	301-350
	12.26	12.26	6	74	94	301-350
	12.44	12.44	6	74	94	301-350
	12.71	12.71	4	56	56	251-300
	12.97	12.97	4	96	96	151-200
	13.03	13.03	4	96	96	151-200
	13.24	13.24	4	59	59	151-200
	13.50	13.50	4	48	56	251-300
	13.77	13.77	4	48	56	251-300
	15.09	15.09	4	48	56	251-300
	17.21	17.21	4	48	74	251-300
	17.66	17.66	4	48	74	251-300
	19.05	19.05	4	48	76	251-300
	20.14	20.14	4	72	72	151-200
	20.29	20.29	4	72	72	151-200

SOURCE : SDHPT RI2-TLOG

TABLE A-55. SUMMARY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 35
SDHPT DISTRICT 15 *** GUADALUPE COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	ROADWAY GEOMETRICS LANES	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
	0.00	20.29	4	48	78	251-300
175	1.03	21.32	4	48	78	251-300
	1.85	22.14	4	48	78	251-300
	2.21	22.50	4	48	78	251-300
	2.68	22.97	4	48	78	251-300
	3.19	23.48	4	48	78	251-300

SOURCE : SDHPT RI2-TLOG

TABLE A-56. SUMMARY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 35
SDHPT DISTRICT 15 *** COMAL COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	ROADWAY GEOMETRICS			
			LANES	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
	0.00	23.48	4	48	76	251-300
	0.08	23.56	4	48	76	251-300
	0.31	23.79	4	48	76	251-300
178	0.72	24.20	4	48	76	251-300
	1.54	25.02	4	48	76	251-300
	2.20	25.68	4	48	76	251-300
	2.57	26.05	4	48	76	251-300
180	2.73	26.21	4	48	76	251-300
	3.26	26.74	4	48	76	251-300
	3.45	26.93	4	48	76	251-300
	3.81	27.29	4	48	76	251-300
	5.15	28.63	4	48	76	251-300
	5.38	28.86	4	48	76	251-300
	6.44	29.92	4	48	76	251-300
	6.49	29.97	4	48	76	251-300
184	6.69	30.17	4	48	76	251-300
	7.50	30.98	4	48	76	251-300
	7.62	31.10	4	48	76	251-300
	8.55	32.03	4	52	52	251-300
	9.58	33.06	4	52	52	251-300
	9.61	33.09	4	52	52	251-300
	10.61	34.09	4	52	52	251-300
	10.71	34.19	4	52	52	251-300
	11.74	35.22	4	52	52	251-300
	12.72	36.20	4	48	76	251-300
	12.79	36.27	4	48	76	251-300
191	13.70	37.18	4	48	76	251-300
	14.01	37.49	4	48	76	251-300
	14.83	38.31	4	48	76	251-300
	15.76	39.24	4	48	76	251-300
	18.28	41.76	4	48	76	251-300
	18.69	42.17	4	48	76	251-300
	19.57	43.05	4	48	76	251-300
	20.29	43.77	4	48	76	251-300

SOURCE : SDHPT RI2-TLOG

TABLE A-57. SUMMARY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 35
SDHPT DISTRICT 14 *** HAYS COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	ROADWAY GEOMETRICS			
			LANES	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
	0.00	43.77	4	48	78	251-300
198	0.41	44.19	4	48	78	251-300
	0.97	44.74	4	48	78	251-300
	1.54	45.32	4	48	78	251-300
	2.03	45.80	4	48	78	251-300
200	2.37	46.15	4	48	78	251-300
	2.57	46.35	4	48	78	251-300
	3.09	46.87	4	48	78	251-300
	3.71	47.49	4	48	78	251-300
	4.15	47.92	4	48	78	251-300
	5.36	49.14	4	48	78	251-300
	6.49	50.27	4	48	76	301-350
	6.85	50.63	4	48	76	301-350
	7.11	50.89	4	48	76	301-350
	7.88	51.66	4	48	76	301-350
	8.09	51.87	4	48	76	301-350
	8.39	52.16	4	48	76	301-350
	8.75	52.53	4	48	76	301-350
	9.44	53.21	4	48	76	301-350
	10.30	54.08	4	48	76	351-400
	10.35	54.13	4	48	76	351-400
209	11.33	55.11	4	48	76	351-400
	11.56	55.33	4	48	76	351-400
	12.98	56.76	4	48	76	351-400
	13.39	57.17	4	48	76	351-400
	13.60	57.38	4	48	76	351-400
	13.68	57.45	4	48	76	351-400
	14.11	57.89	4	48	76	351-400
212	14.32	58.10	4	48	76	351-400
	15.86	59.64	4	48	80	301-350
	16.94	60.72	4	48	80	301-350
215	17.30	61.08	4	48	80	301-350
	17.72	61.50	4	48	80	301-350
	18.02	61.80	4	48	80	301-350
	19.57	63.35	4	48	80	301-350
	22.15	65.92	4	48	80	301-350
	22.76	66.54	4	48	80	301-350
	23.21	66.98	4	48	80	301-350
	23.48	67.26	4	48	80	301-350
	24.26	68.04	4	48	80	301-350

SOURCE : SDHPT RI2-TLOG

TABLE A-58. SUMMARY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 35
SDHPT DISTRICT 14 *** TRAVIS COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	ROADWAY GEOMETRICS			
			LANES	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
	0.00	68.04	4	48	78	251-300
223	1.03	69.06	4	48	78	251-300
	1.06	69.10	4	48	78	251-300
	2.57	70.60	4	72	102	251-300
	2.78	70.81	4	72	102	251-300
225	2.99	71.02	4	72	102	251-300
	3.18	71.22	4	72	102	251-300
	3.71	71.74	4	72	102	251-300
	3.91	71.94	4	72	102	251-300
	4.94	72.97	4	72	102	251-300
	5.56	73.60	6	72	102	251-300
	6.62	74.66	6	76	76	251-300
	6.80	74.83	6	76	76	251-300
	7.00	75.03	6	76	76	251-300
	7.47	75.50	6	72	102	251-300
	7.72	75.75	6	72	102	251-300
	8.21	76.25	6	72	102	251-300
	8.86	76.89	6	80	80	251-300
	9.48	77.51	6	76	76	301-350
	10.30	78.33	6	76	76	251-300
	10.81	78.84	6	76	76	251-300
	10.86	78.90	6	76	76	251-300
	11.33	79.36	6	76	76	251-300
	11.43	79.46	6	79	79	251-300
	11.91	79.95	6	79	79	251-300
	12.18	80.22	6	79	79	251-300
	12.36	80.39	6	79	79	251-300
	12.93	80.96	6	79	79	251-300
	13.49	81.52	6	76	102	151-200
	13.70	81.73	6	76	102	151-200
	15.91	83.94	8	100	120	151-200
	16.42	84.46	8	100	120	151-200
	16.69	84.72	6	72	104	151-200
	17.47	85.51	6	72	104	251-300
	17.51	85.54	6	72	104	251-300
	17.74	85.78	4	51	59	251-300
	18.00	86.04	4	51	59	251-300
	18.02	86.05	4	51	59	251-300
	18.27	86.31	4	48	78	251-300
	19.57	87.60	4	48	78	251-300
243	20.91	88.94	4	48	78	251-300
	21.01	89.04	4	48	78	251-300
	21.78	89.81	4	48	78	251-300
	21.94	89.97	4	48	78	251-300
	21.97	90.01	4	48	78	251-300
	22.24	90.28	4	48	78	251-300
	22.56	90.59	4	48	78	251-300
	23.12	91.15	4	48	78	251-300
	23.28	91.31	4	48	78	251-300
	24.36	92.39	4	48	80	251-300
	25.42	93.46	4	48	80	251-300
	25.44	93.47	4	48	80	251-300
	26.57	94.60	4	48	80	251-300
	27.53	95.57	4	48	80	251-300
	28.22	96.25	4	48	80	251-300

SOURCE : SDHPT RI2-TLOG

TABLE A-59. SUMMARY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 35
SDHPT DISTRICT 14 *** WILLIAMSON COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	ROADWAY GEOMETRICS LANES	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
	0.00	96.25	4	48	82	401-450
	0.67	96.92	4	48	82	401-450
252	1.60	97.85	4	48	80	251-300
	1.96	98.21	4	48	80	251-300
	2.16	98.41	4	48	80	251-300
	2.37	98.62	4	48	80	251-300
	2.68	98.93	4	48	80	251-300
	3.55	99.80	4	48	80	251-300
	3.56	99.81	4	48	80	251-300
254	3.60	99.85	4	48	80	251-300
	3.91	100.16	4	48	80	251-300
	4.62	100.87	4	48	76	351-400
	4.94	101.19	4	48	76	351-400
	5.25	101.50	4	48	76	351-400
256	5.51	101.76	4	48	76	351-400
	5.87	102.12	4	48	76	351-400
	6.74	102.99	4	48	76	351-400
	6.85	103.10	4	48	76	351-400
	6.90	103.15	4	48	76	351-400
	7.80	104.05	4	48	76	351-400
	8.96	105.21	4	48	76	251-300
	9.68	105.93	4	48	76	251-300
	9.94	106.19	4	48	76	251-300
	10.20	106.45	4	48	76	251-300
262	10.58	106.83	4	48	76	251-300
	10.71	106.96	4	48	76	251-300
	10.97	107.22	4	48	76	251-300
	11.12	107.37	4	48	76	251-300
	11.69	107.94	4	48	76	251-300
	12.15	108.40	4	48	76	251-300
	13.65	109.90	4	48	76	251-300
	14.01	110.26	4	48	76	251-300
	15.30	111.55	4	48	76	351-400
	16.02	112.27	4	48	76	351-400
	16.27	112.52	4	48	76	351-400
267	16.48	112.73	4	48	76	351-400
	17.61	113.86	4	48	76	351-400
	18.49	114.74	4	48	76	351-400
271	20.45	116.70	4	48	76	351-400
	21.22	117.47	4	48	76	351-400
	23.59	119.84	4	48	76	351-400
	24.74	120.99	4	48	76	351-400
	24.98	121.23	4	48	76	351-400
276	25.44	121.69	4	48	76	351-400
	25.80	122.05	4	48	76	351-400
	26.47	122.72	4	48	76	351-400
	27.35	123.60	4	48	76	351-400

SOURCE : SDHPT RI2-TLOG

TABLE A-60. SUMMARY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 35
SDHPT DISTRICT 9 *** BELL COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	ROADWAY GEOMETRICS			
			LANES	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
	0.00	123.60	4	48	80	201-250
278	0.10	123.70	4	48	80	201-250
	0.57	124.17	4	48	80	201-250
	2.37	125.97	6	68	80	201-250
	2.69	126.29	4	48	80	201-250
	3.50	127.10	4	48	80	201-250
	3.74	127.34	4	48	80	201-250
282	4.12	127.72	4	48	80	201-250
	4.33	127.93	4	48	80	201-250
	4.94	128.54	6	68	80	201-250
	6.08	129.68	6	68	80	201-250
	6.59	130.19	4	48	80	201-250
	6.69	130.29	6	72	72	201-250
	6.92	130.52	6	72	72	201-250
	7.00	130.60	6	72	72	201-250
	7.72	131.32	6	72	72	201-250
	7.83	131.43	4	48	80	201-250
	8.29	131.89	6	68	80	201-250
	9.17	132.77	4	48	80	201-250
	9.68	133.28	6	68	80	201-250
288	10.09	133.69	4	48	80	201-250
	10.10	133.70	4	48	80	201-250
	11.16	134.76	6	68	80	201-250
	11.43	135.03	6	68	80	201-250
	11.64	135.24	4	48	80	201-250
	12.22	135.82	4	48	80	201-250
	12.77	136.37	6	68	80	201-250
	13.28	136.88	4	48	80	201-250
	13.96	137.56	6	68	80	201-250
	14.33	137.93	4	48	80	201-250
	14.93	138.53	4	48	96	301-350
	15.09	138.69	4	48	96	301-350
	15.76	139.36	6	72	120	301-350
	15.96	139.56	6	72	120	301-350
	16.07	139.67	6	72	120	301-350
	16.45	140.05	6	72	120	301-350
	16.48	140.08	6	72	120	301-350
	16.58	140.18	6	72	120	301-350
	16.99	140.59	4	48	80	201-250
295	17.05	140.65	4	48	80	201-250
	17.46	141.06	4	48	80	201-250
	17.82	141.42	4	48	80	201-250
	19.16	142.76	4	48	80	201-250
	19.21	142.81	4	48	80	201-250
	19.63	143.23	4	48	80	201-250
	20.39	143.99	4	48	92	251-300
	20.81	144.41	4	48	92	251-300
299	21.01	144.61	4	48	92	251-300
	21.32	144.92	4	48	80	151-200
	21.75	145.35	4	48	80	151-200
	22.14	145.74	6	72	104	151-200
	22.71	146.31	4	48	80	351-400
	22.81	146.41	4	48	82	201-250
	22.87	146.47	4	48	82	201-250
	23.54	147.14	4	48	82	201-250
	24.10	147.70	4	48	82	201-250
	24.67	148.27	4	48	82	201-250
	24.82	148.42	4	48	82	201-250
	25.13	148.73	4	48	82	201-250
	25.34	148.94	4	48	82	201-250
	25.34	148.94	4	48	82	201-250
	26.52	150.12	4	48	80	201-250
305	26.99	150.59	4	48	80	201-250
	27.19	150.79	4	48	80	251-300
	27.81	151.41	4	48	80	251-300
	28.89	152.49	6	68	68	251-300

TABLE A-60. SUMMARY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 35
SDHPT DISTRICT 9 *** BELL COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	ROADWAY GEOMETRICS			
			LANES	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
	29.16	152.76	4	48	80	251-300
	30.95	154.55	6	68	68	151-200
	32.34	155.94	4	48	80	201-250
	33.27	156.87	4	68	80	201-250
312	33.78	157.38	4	48	80	201-250
	35.48	159.08	4	48	80	201-250

SOURCE : SDHPT RI2-TLOG

TABLE A-61. SUMMARY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 35
SDHPT DISTRICT 9 *** FALLS COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	ROADWAY GEOMETRICS			
			LANES	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
	0.00	159.08	4	48	80	251-300
	0.03	159.11	4	48	80	251-300
	0.05	159.13	4	48	80	251-300
314	0.51	159.59	4	48	80	251-300
	1.18	160.26	4	48	80	251-300
	1.96	161.04	4	48	80	251-300

SOURCE : SDHPT RI2-TLOG

TABLE A-62. SUMMARY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 35
SDHPT DISTRICT 9 *** MCLENNAN COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	ROADWAY GEOMETRICS LANES	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
	0.00	161.04	4	48	80	251-300
	0.21	161.25	4	48	80	251-300
316	0.46	161.50	4	48	80	251-300
	1.25	162.29	4	48	80	251-300
	1.44	162.48	4	48	80	251-300
	2.16	163.20	4	48	80	251-300
	2.31	163.35	4	48	80	251-300
	2.68	163.72	4	48	80	251-300
	3.09	164.13	4	48	80	251-300
	3.40	164.44	4	48	80	251-300
319	3.50	164.54	4	48	80	251-300
	3.60	164.64	4	48	80	251-300
	5.49	166.53	4	48	80	251-300
	5.87	166.91	4	48	80	251-300
	5.92	166.96	4	48	80	251-300
	6.55	167.59	4	48	70	251-300
	6.59	167.63	4	48	70	251-300
	7.57	168.61	4	48	80	251-300
324	8.45	169.49	4	48	80	251-300
	9.37	170.41	4	48	80	251-300
	9.68	170.72	4	48	80	251-300
326	10.40	171.44	4	52	70	251-300
327	11.43	172.47	4	52	70	251-300
	12.26	173.30	4	52	70	251-300
	12.46	173.50	4	52	70	251-300
	12.77	173.81	4	48	80	251-300
	14.63	175.67	4	48	80	251-300
	15.14	176.18	4	48	80	251-300
	16.33	177.37	4	48	80	251-300
	17.14	178.18	4	48	80	251-300
	17.30	178.34	4	48	80	251-300
	17.61	178.65	4	48	80	251-300
	17.66	178.70	4	48	80	251-300
	17.72	178.76	5	60	90	251-300
	18.20	179.24	5	60	90	251-300
	18.33	179.37	5	60	90	251-300
	18.39	179.43	5	60	90	251-300
	18.85	179.89	6	72	100	251-300
	19.21	180.25	6	72	100	251-300
	19.25	180.29	6	72	100	251-300
	19.42	180.46	6	72	100	251-300
	19.78	180.82	6	72	100	251-300
	19.93	180.97	6	72	100	251-300
	20.24	181.28	6	72	100	251-300
	20.31	181.35	6	72	100	251-300
	20.50	181.54	6	72	100	251-300
	20.55	181.59	6	72	100	251-300
	20.86	181.90	6	72	100	251-300
	21.32	182.36	6	72	100	251-300
	21.37	182.41	6	72	100	251-300
	21.94	182.98	6	72	100	251-300
	22.43	183.47	6	72	100	251-300
	22.76	183.80	6	72	100	251-300
	23.38	184.42	6	72	104	251-300
	23.59	184.63	6	72	104	251-300
	23.64	184.68	6	72	104	251-300
	24.10	185.14	6	72	104	251-300
340	24.36	185.40	6	72	104	251-300
	24.55	185.59	6	72	104	251-300
	25.08	186.12	4	48	80	251-300
	25.61	186.65	4	48	80	251-300
	25.90	186.94	4	48	80	251-300
342	26.32	187.36	4	48	80	251-300
	26.78	187.82	4	48	80	251-300
	28.17	189.21	4	48	80	251-300
	28.79	189.83	4	48	80	251-300

TABLE A-62. SUMMARY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 35
SDHPT DISTRICT 9 *** MCLENNAN COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	ROADWAY GEOMETRICS			
			LANES	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
	29.30	190.34	4	48	80	251-300
	29.77	190.81	4	48	80	251-300
	30.18	191.22	4	48	80	251-300
346	30.33	191.37	4	48	80	251-300
	31.21	192.25	4	48	80	251-300
	32.14	193.18	4	48	80	251-300
	33.02	194.06	4	48	80	251-300
	33.84	194.88	4	48	80	251-300
351	35.33	196.37	4	48	80	251-300
	36.15	197.19	4	48	80	251-300
	37.26	198.30	4	48	80	251-300
	37.29	198.33	4	48	80	251-300
	38.37	199.41	4	48	80	251-300
355	39.29	200.33	4	48	80	301-350
	39.38	200.42	4	48	80	301-350
	39.71	200.75	4	48	80	301-350

SOURCE : SDHPT RI2-TLOG

TABLE A-63. SUMMARY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 35
SDHPT DISTRICT 9 *** HILL COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	ROADWAY GEOMETRICS			
			LANES	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
	0.00	200.75	4	48	80	251-300
356	0.62	201.37	4	48	80	251-300
	1.13	201.88	4	48	80	251-300
	1.78	202.53	4	48	80	251-300
358	2.57	203.32	4	48	80	251-300
	3.30	204.05	4	52	72	251-300
	4.43	205.18	4	52	72	251-300
	5.92	206.67	4	48	80	251-300
362	6.59	207.34	4	48	80	251-300
	7.31	208.06	4	52	72	251-300
	8.14	208.89	4	48	80	251-300
	8.60	209.35	4	52	72	251-300
	9.27	210.02	4	48	80	351-400
	9.78	210.53	4	48	78	351-400
366	10.56	211.31	4	48	78	301-350
	11.31	212.06	4	48	78	301-350
	11.84	212.59	4	48	78	301-350
	12.57	213.32	4	48	78	301-350
	13.08	213.83	4	48	78	301-350
	14.11	214.86	4	48	78	301-350
	14.49	215.24	4	48	78	301-350
	14.68	215.43	4	48	78	301-350
	14.99	215.74	4	48	78	301-350
	15.30	216.05	4	48	78	301-350
371	15.55	216.30	4	48	78	301-350

SOURCE : SDHPT RI2-TLOG

TABLE A-64. SUMMARY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 35 W
SDHPT DISTRICT 9 *** HILL COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	ROADWAY GEOMETRICS			
			LANES	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
	0.00	0.00	4	48	80	301-350
	0.46	0.46	4	48	80	301-350
1	0.67	0.67	4	48	80	301-350
	3.04	3.04	4	48	80	301-350
	5.77	5.77	4	48	80	301-350
	6.20	6.20	4	48	80	301-350
	6.95	6.95	4	48	80	301-350
	7.06	7.06	4	48	80	301-350
	8.09	8.09	4	48	80	301-350
	8.19	8.19	4	48	80	301-350
	8.27	8.27	4	48	80	301-350
9	8.60	8.60	4	48	80	301-350
	9.48	9.48	4	48	80	301-350
	12.46	12.46	4	48	80	301-350
	13.03	13.03	4	48	80	301-350
	13.34	13.34	4	48	80	351-400
	13.44	13.44	4	48	80	351-400
14	13.60	13.60	4	48	80	351-400
	13.96	13.96	4	48	80	301-350

SOURCE : SDHPT RI2-TLOG

TABLE A-65. SUMMARY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 35 W
SDHPT DISTRICT 2 *** JOHNSON COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	ROADWAY GEOMETRICS			
			LANES	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
	0.00	13.96	4	48	80	251-300
	0.21	14.16	4	48	80	251-300
15	0.67	14.63	4	48	80	251-300
	1.55	15.51	4	48	80	251-300
	1.60	15.55	4	48	80	251-300
	2.63	16.58	4	48	80	251-300
	2.99	16.94	4	48	80	301-350
	3.50	17.46	4	48	80	301-350
	3.66	17.61	4	48	80	301-350
18	5.36	19.31	4	48	80	301-350
	6.64	20.60	4	48	80	301-350
21	7.42	21.37	4	48	80	301-350
	7.93	21.89	4	48	80	301-350
	8.79	22.75	4	48	80	301-350
	9.27	23.23	4	48	80	301-350
	9.68	23.64	4	48	80	301-350
	10.30	24.26	4	48	80	301-350
	10.86	24.82	4	48	80	301-350
	11.07	25.03	4	48	80	301-350
	11.89	25.85	4	48	80	301-350
	12.10	26.06	4	48	80	301-350
	12.46	26.42	4	48	80	301-350
	13.29	27.24	4	48	80	301-350
	13.70	27.66	4	48	80	301-350
	13.96	27.92	4	48	80	301-350
	14.63	28.58	4	48	80	301-350
29	15.55	29.51	4	48	80	301-350
	16.22	30.18	4	48	80	301-350
	16.58	30.54	4	48	80	301-350
	17.05	31.00	4	48	80	301-350
	17.06	31.02	4	48	80	301-350
	17.92	31.88	4	48	80	301-350
	18.09	32.05	4	48	80	301-350
	18.54	32.50	4	48	80	301-350
	18.85	32.81	4	48	80	301-350
	20.08	34.04	4	48	80	301-350
	20.16	34.12	4	48	80	301-350
	21.20	35.16	4	48	80	301-350
	22.14	36.10	4	48	80	301-350
	22.30	36.26	4	48	80	301-350
	22.35	36.31	4	48	80	301-350
	22.49	36.45	4	48	80	301-350
	22.76	36.72	4	48	80	301-350
	23.07	37.03	4	48	80	301-350

SOURCE : SDHPT RI2-TLOG

TABLE A-66. SUMMARY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 35 W
SDHPT DISTRICT 2 *** TARRANT COUNTY
NORTHBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	ROADWAY GEOMETRICS			
			LANES	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
	0.00	37.03	6	72	104	351-400
	0.71	37.74	6	72	104	351-400
	0.72	37.75	6	72	104	351-400
	1.23	38.26	6	72	104	351-400
	1.34	38.37	6	72	104	351-400
39	1.54	38.57	6	72	104	351-400
	1.75	38.78	6	72	104	351-400
	2.47	39.50	6	72	104	351-400
	2.52	39.55	6	72	104	351-400
	2.57	39.60	6	72	104	351-400
	3.04	40.07	6	72	104	351-400
	3.19	40.22	6	72	104	351-400
41	3.50	40.53	6	72	104	351-400
	3.81	40.84	6	72	104	351-400
	4.22	41.25	6	72	104	351-400
	5.15	42.18	4	48	48	251-300
	5.66	42.69	4	48	48	251-300
	6.39	43.41	4	48	48	251-300
	6.90	43.93	4	48	48	251-300
	7.42	44.44	6	72	72	301-350
	7.69	44.72	6	72	72	301-350
	7.88	44.91	6	72	72	301-350
	8.21	45.24	4	48	48	251-300
	8.47	45.50	4	48	48	251-300
	9.06	46.09	6	76	76	301-350
	9.24	46.27	6	72	92	301-350
47	9.48	46.50	6	72	92	301-350
	9.89	46.92	6	72	92	301-350
	10.35	47.38	4	48	76	301-350
	10.51	47.53	4	48	76	301-350
	11.02	48.05	4	48	76	301-350
	11.12	48.15	4	48	76	301-350
	11.84	48.87	4	48	76	301-350
	11.95	48.98	4	48	76	301-350
	12.36	49.39	4	48	76	301-350
	12.72	49.75	4	48	76	301-350
	12.93	49.96	4	48	76	301-350
	12.98	50.01	4	48	76	301-350
	13.38	50.41	4	48	76	301-350
	13.39	50.42	4	48	76	301-350

SOURCE : SDHPT RI2-TLOG

TABLE A-67. SUMMARY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 30
SDHPT DISTRICT 2 *** TARRANT COUNTY
EASTBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	ROADWAY GEOMETRICS			
			LANES	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
	0.00	0.00	6	72	112	351-400
	0.21	0.21	6	72	112	351-400
	0.46	0.46	6	72	112	351-400
	0.57	0.57	6	72	112	351-400
	0.62	0.62	6	72	112	351-400
	0.82	0.82	6	72	112	351-400
	1.00	1.00	6	72	112	351-400
	1.34	1.34	6	72	112	351-400
	1.44	1.44	6	72	112	351-400
	1.65	1.65	6	72	112	351-400
17	1.85	1.85	4	48	80	301-350
	2.00	2.00	4	48	80	301-350
	2.25	2.25	4	48	80	301-350
	2.50	2.50	4	48	80	301-350
	3.25	3.25	4	48	80	301-350
	3.40	3.40	4	48	80	301-350
19	3.86	3.86	4	48	80	301-350
	4.69	4.69	4	48	80	301-350
	4.75	4.75	4	48	80	301-350
	5.00	5.00	4	48	80	301-350
	5.25	5.25	4	48	80	301-350
	5.77	5.77	4	48	80	301-350
	5.97	5.97	4	48	80	301-350
	6.18	6.18	6	72	92	301-350
	7.16	7.16	6	72	92	301-350
	7.52	7.52	6	72	92	301-350
23	7.83	7.83	6	72	92	301-350
	7.98	7.98	6	72	92	301-350
	8.55	8.55	6	72	92	151-200
	8.91	8.91	6	72	92	151-200
	9.42	9.42	6	72	92	151-200
	9.75	9.75	4	48	48	251-300
	9.78	9.78	4	48	48	251-300
	9.89	9.89	4	48	48	251-300
	10.71	10.71	4	48	48	201-250
	10.97	10.97	4	48	48	201-250
	11.48	11.48	4	48	48	201-250
27	11.79	11.79	4	48	48	201-250
	11.95	11.95	4	48	48	201-250
	12.62	12.62	4	48	48	151-200
	12.98	12.98	4	48	48	301-350
	14.21	14.21	8	106	126	201-250
	14.52	14.52	8	106	126	201-250
	14.93	14.93	8	106	126	201-250
	15.24	15.24	8	106	126	201-250
	15.96	15.96	4	48	48	101-150
	16.38	16.38	8	100	100	201-250
	16.48	16.48	8	100	100	201-250
	16.69	16.69	4	48	48	201-250

SOURCE : SDHPT RI2-TLOG

TABLE A-68. SUMMARY OF THE TEXAS TRIANGLE ROUTE
FOR INTERSTATE HIGHWAY 30
SDHPT DISTRICT 18 *** DALLAS COUNTY
EASTBOUND DIRECTION

MILE POST	COUNTY MILE	CUM MILE	ROADWAY GEOMETRICS LANES	SURFACE WIDTH	ROAD BED WIDTH	R-O-W WIDTH
	0.00	16.69	6	74	102	301-350
	0.26	16.94	6	74	102	301-350
	0.72	17.41	6	74	102	301-350
	1.18	17.87	6	74	102	301-350
	1.56	18.25	6	74	102	301-350
	1.81	18.50	6	74	102	301-350
	2.21	18.90	6	74	102	301-350
	2.31	19.00	6	74	102	301-350
	2.56	19.25	6	74	102	301-350
	2.68	19.36	6	74	102	301-350
	3.31	20.00	6	74	102	301-350
	3.56	20.25	6	74	102	301-350
	4.06	20.75	6	74	102	301-350
	4.27	20.96	6	74	102	301-350
	4.47	21.16	6	74	102	301-350
	4.81	21.50	6	74	102	301-350
	5.06	21.75	6	74	102	301-350
	5.78	22.46	6	74	102	301-350
	5.81	22.50	6	74	102	301-350
	6.22	22.91	6	74	102	301-350
38	6.27	22.96	6	74	102	301-350
	6.56	23.25	6	74	102	301-350
	6.87	23.56	6	74	102	301-350
	7.22	23.91	6	74	102	301-350
	7.62	24.31	6	74	102	301-350
	7.78	24.46	6	74	102	301-350
	7.81	24.50	6	74	102	301-350
	8.06	24.75	6	74	102	301-350
40	8.18	24.86	6	74	102	301-350
	8.31	25.00	6	74	102	301-350
	8.56	25.25	6	74	102	301-350
	8.88	25.56	6	74	102	301-350
	9.30	25.99	6	74	102	301-350
	10.06	26.75	6	74	102	301-350
	10.28	26.97	6	74	102	301-350
	10.32	27.01	6	74	102	301-350
	10.70	27.39	6	74	102	301-350
	10.81	27.50	6	74	102	301-350
	11.06	27.75	6	74	102	301-350
	11.17	27.85	6	74	102	301-350
	11.31	28.00	6	74	102	301-350
	11.63	28.31	6	72	92	201-250
44	12.23	28.91	6	72	92	201-250
	12.37	29.06	6	72	92	201-250
	12.42	29.11	6	72	92	201-250
	12.81	29.50	6	72	92	201-250
	13.31	30.00	6	72	92	201-250
	13.56	30.25	6	72	92	201-250
	13.81	30.50	6	76	96	101-150
	15.66	32.34	6	76	96	101-150

SOURCE : SDHPT RI2-TLOG

APPENDIX B

SIMULATION OF HSR SERVICE ON THE TEXAS TRIANGLE

- Reasons for Simulation
- Simulation Overview
- Operation Parameter Selection
- Superelevation
- Maximum Speed
- Data
- Results

APPENDIX B

Simulation of HSR Service on the Texas Triangle

Reason For Simulations

Travel time between cities is affected by the combination of the physical route and the performance characteristics of the trains. Human factors and mechanical limitations determine the maximum speeds at which the trains can traverse curves and grades. Train operational and performance characteristics determine the time and distance necessary to accelerate and decelerate as dictated by curve and grade-imposed speed restrictions. These constraints will have such a strong impact on travel times that it was decided to simulate train operation to allow reasonable evaluation of operation times on the highway-based routes of the Texas Triangle. These constraints will also affect energy consumption, but this consideration was not analyzed within the scope of this study.

Simulation Overview

A simplified deterministic train performance simulation program was available to the research team which had been written in BASIC programming language (using a Radio Shack TRS-80 Model III microcomputer) by H. C. Petersen. The program generates train performance velocity profiles and operational summaries by reading route data from a disk file. This data included milepost (to the nearest 0.25 mile), percent grade, degree of curvature, and any externally-imposed speed restrictions. Data was initiallized and then read into a moving array, with speed limits and restrictions calculated and entered into the array. The computer calculated train performance parameters averaged over each quarter-mile segment of the route, and compared these with previously-calculated acceleration and decleration requirements in conjunction with the route up to ten miles ahead to determine operation state and performance. The results were then printed on a continuous profile sheet, including milepost, performance parameters, time, the velocity profile marked by performance state: A(cceleration), C(onstant speed), and D(eceleration). Any curvature and speed restrictions were also printed on the profile. Train performance data was input at the beginning of each run, and a performance summary was printed upon completion.

As the program operates on a small microcomputer, operation is quite slow (approximately ten seconds per quarter mile). Table lookup was used to initiate the deceleration/acceleration curves which were approximated by straight-line segments. Because analysis indicated that grades would have minimal effects on high speed train operation over relatively flat terrain such as found in the Texas Triangle, the grade portion of the program was not used (although grades were input, as zeros). These limitations can allow for potential performance inaccuracies of plus or minus one quarter of a mile and plus or minus a few minutes, with the possibility of a train entering a speed restriction with a one- or two-miles per hour overspeed. These innaccuracies were considered acceptable for the preliminary analysis of performance requirements, as comapred with increased program complexity and run time.

It is important to note route travel time is minimized by the simulation program, with no attempt to save energy. If the train is not decelerating or operating at maximum speed (considering the guideway geometric and specified speed restrictions), then the train is accelerating at the maximum rate for its current speed. This often leads to a constant accelerate-decelerate velocity profile which would be wasteful of energy and distracting to passengers.

Operation Parameter Selection

Three primary sets of train operating and performance characteristic were selected for the simulations, along with one set of ultra-high performance parameters which would require passengers to remain belted in ther seats for the duration of the trip (MagLev type HSR technology).

The first set of parameters was for a modern AMTRAK train consisting of seven Amcar coaches pulled by a General Electric E 60 CP 6000 horsepower electric locomotive.

The second set of parameters was estimated to approximate the performance of a High Speed (HS) TGV-style train, both with and without the ability to tilt up to 6 degrees on curves (approximating an additional superelevation of 6 inches).

The third set of operating parameters was for the "Ideal" train described in the Rail Technology section. Although these Ideal capabilites have not presently been attained, and may never be attained in general operation with flanged steel wheels on steel rails, they were used as a limiting case for rail, and a possible set of operating parameters for the MagLev technology. Lower performance standards would tend to minimize time savings of higher maximum speeds; the simulations tended to verify this.

The ultra-high performance parameters extend beyond present proven technology, but were included for a "best case" comparison. Such performance would require a MagLev-type of HSR technolgy with a very high power handling capability, so that performance would be limited more by human factors considerations than by vehicle constraints. The acceleration rate combined with the use of 36 inches total superelevation (no attempt was made to isolate superelevation components) would result in longitudinal accelerations closer to those encountered in air travel, and lateral forces of such magnitude that passengers would be requried to remain belted into form-fitting seats for the duration of the trip to avoid injuries, with carry-on objects safely stowed. While the forces experienced would be well within human capabilities, the riders could experience a decided amount of discomfort, especially in turns (see the the Human Factors Section for discussion of passenger comfort considerations).

Superelevation

Superelevations were matched to the maximum speeds allowed and the rail technology being examined. Except for the Ultra-MagLev system, maximum superelevation was considered to be 24 inches, composed of twelve inches actual superelevation plus six degrees (equivalent to six inches) of vehicle tilt and six inches of unbalanced superelevation (which could cause some discomfort to standing passengers, but no real hazard). While feasible, this amount of superelevation would make it difficult if not impossible to utilize highway medians. Minimum superelevation was assumed to be 12 inches total, the sum of four inches unbalanced plus eight inches of actual superelevation for a standard 4' 8-1/2" gage track. This eight inches is two inches in excess of current American Railway Engineering Association (AREA) recommendations and Federal Railroad Administration (FRA) requirements. Eight inches of track superelevation has been used in the past with success, and the HSR would be intended only for passengers except for occasional construction and maintenance trains. The 18 inch total superelevation used assumed the same eight inches actual plus four inches unbalanced superelevation, but with an additional six degree (six inches) tilt capability of train.

Maximum Speed

Except for the 120 MPH maximum AMTRAK speed, which was based on actual performance curves (Hay, 1982) maximum speeds were chosen to be representative in a somewhat arbitrary manner. The 350 MPH speed was chosen because it was assumed to be near the limit of steel-wheel-on-steel-rail capabilities, while the 200 MPH speed was considered to be a good compromise speed which could be attained and held over a significant portion of the runs. These three speeds were the only ones used in order to facilitate comparisons. Their selection in no way constitutes any recommendation nor mechanical analysis.

Data

Performance data defaults, including acceleration/deceleration rates and maximum combined superelevation, were coded directly into the program, with the option to select and/or change default values at the start of each run. Maximum cruise speed was input from the keyboard. Route parameters such as mileposts and degrees of curvature (and, implicitly, the length of tangents) were input into separate route data files used to describe the freeway geometrics on the Texas Traingle.

To eliminate the necessity of coding every quarter mile, the program was designed to require data input only when conditions change. Thus the first quarter mile (times 100 to allow coding and sorting by milepost as a "BASIC program") must be coded, followed by the mileposts where changes occur, (i.e., new grade, new curvature, or externally-imposed speed restrictions). The new maximum speed or curvature is continued for each quarter mile until a new milepost is read with different data. A speed of zero signifies the stop at the end of the run. Due to the use of the look-ahead feature within the program, a dummy milepost must also be coded at least ten miles beyond the stop. Data is then saved in ASCII format under the appropriate file name. This method of data input makes it fairly easy to examine changes, such as a stop at Austin and the effects of flattening geometric curvature near Corsicana.

During the startup for each run, the program asks the user to enter the name of the route data file to be used. An added feature is the capability of entering "NONE" for the file name, which results in generation of a velocity curve composed of acceleration to maximum speed, constant speed operation for 1.25 miles, and deceleration to stop (on level, tangent track with no curve or grade effects). This option results in the perfromance curve profile for a particular HSR technology as illustrated in Figure B-1 for the AMTRAK train and Figure B-2 for MagLev.

VELOCITY PROFILE

MILE	TIME	ACCEL	MPH	Profile (0.0 / 100 / 200 / 300)
0.00	0.0	1.8	0.0	A
0.25	0.5	1.8	56.9	A
0.50	0.8	0.5	64.3	A
0.75	1.0	0.5	71.0	A
1.00	1.2	0.5	77.1	A
1.25	1.4	0.5	82.7	A
1.50	1.6	0.5	88.0	A
1.75	1.7	0.5	93.0	A
2.00	1.9	0.5	97.7	A
2.25	2.0	0.5	102.2	A
2.50	2.2	0.2	103.9	A
2.75	2.3	0.2	105.6	A
3.00	2.5	0.2	107.3	A
3.25	2.6	0.2	109.0	A
3.50	2.7	0.2	110.6	A
3.75	2.9	0.2	112.2	A
4.00	3.0	0.2	113.8	A
4.25	3.1	0.2	115.4	A
4.50	3.3	0.2	117.0	A
4.75	3.4	0.2	118.5	A
5.00	3.5	0.0	120.0	C
5.25	3.6	0.0	120.0	C
5.50	3.8	0.0	120.0	C
5.75	3.9	0.0	120.0	C
6.00	4.0	0.0	120.0	C
6.25	4.1	0.0	120.0	C
6.50	4.3	-2.0	103.9	D
6.75	4.4	-2.0	84.9	D
7.00	4.6	-2.0	60.0	D
7.25	5.1	-2.0	0.1	D
7.50	5.1	-2.0	0.0	D
7.75	TRAIN IS STOPPED			

0.0

SUMMARY

RUN OF 7.75 MILES TOOK 5.14587 MINUTES.
AVERAGE SPEED = 90.3638 MPH.

MAXIMUM SPEED ACHIEVED WAS 120 MILES PER HOUR.

MAXIMUM ALLOWED SPEED WAS 120 MILES PER HOUR.

THE NAME OF THE FILE USED FOR THIS RUN WAS NONE

Superelevation = 12 Inches

Acceleration values (MPH per second):
0 > 50: 1.8 50+ > 100: .5
100+ > 150: .2 150+ > 200: 0
200+ > 250: 0 250+ > 300: 0
300+ > : 0

Deceleration = -2 MPH per second

Figure B-1: Speed Profile for Conventional AMTRAK Train Technology

```
                                            VELOCITY PROFILE
  MILE   TIME  ACCEL  MPH 0.0           100         200         300
-----------------------------------------------------------------------------
  0.00   0.0   7.0   0.0 A           |           |           |              0.0
  0.25   0.3   7.0 112.2 |           |A          |           |
  0.50   0.4   7.0 158.7 |           |      A    |           |
  0.75   0.5   7.0 194.4 |           |          A|           |
  1.00   0.5   7.0 224.5 |           |           | A         |
  1.25   0.6   7.0 251.0 |           |           |     A     |
  1.50   0.7   7.0 275.0 |           |           |       A   |
  1.75   0.7   7.0 297.0 |           |           |          A|
  2.00   0.8   7.0 317.5 |           |           |           | A
  2.25   0.8   7.0 336.7 |           |           |           |   A
  2.50   0.8   0.0 350.0 |           |           |           |     C
  2.75   0.9   0.0 350.0 |           |           |           |     C
  3.00   0.9   0.0 350.0 |           |           |           |     C
  3.25   1.0   0.0 350.0 |           |           |           |     C
  3.50   1.0   0.0 350.0 |           |           |           |     C
  3.75   1.1   0.0 350.0 |           |           |           |     C
  4.00   1.1  -7.6 330.0 |           |           |           |  D
  4.25   1.2  -7.6 308.7 |           |           |           |D
  4.50   1.2  -7.6 285.8 |           |           |         D |
  4.75   1.3  -7.6 260.9 |           |           |      D    |
  5.00   1.3  -7.6 233.4 |           |           |   D       |
  5.25   1.4  -7.6 202.1 |           |           D           |
  5.50   1.5  -7.6 165.1 |           |      D    |           |
  5.75   1.6  -7.6 116.8 |           | D         |           |
  6.00   1.8  -7.6   5.3 D           |           |           |
  6.25   1.8  -7.6   0.0 D           |           |           |
  6.50 TRAIN IS STOPPED
```

SUMMARY

RUN OF 6.5 MILES TOOK 1.83136 MINUTES.
AVERAGE SPEED = 212.957 MPH.

MAXIMUM SPEED ACHIEVED WAS 350 MILES PER HOUR.

MAXIMUM ALLOWED SPEED WAS 350 MILES PER HOUR.

THE NAME OF THE FILE USED FOR THIS RUN WAS NONE

Superelevation = 36 Inches

```
Acceleration values (MPH per second):
  0  >  50:  7     50+ > 100:  7
100+ > 150:  7    150+ > 200:  7
200+ > 250:  7    250+ > 300:  7
300+ >    :  7
```

Deceleration = -7.56 MPH per second

Figure B-2: Speed Profile for Ultra-High Performance HSR Technology (i.e., MagLev System)

Results

Table B-1 summarizes the performance characteristics used in simulating the 8 different HSR Technologies. Included for each rail technology are the superelevation, maximum operating speed, acceleration rates for the different speed ranges, and the deceleration rate.

TABLE B-1: TRAIN PERFORMANCE CHARACTERISTICS FOR SIMULATIONS

Train	Superelevation, Inches				Maximum	Accleration, MPH per Second							Decel.
	Actual	Tilt	Unbalanced	Total	MPH	0-50	50-100	100-150	150-200	200-250	250-300	300+	MPH/sec
AMTRAK	8	0	4	12	120	1.8	0.5	0.2	-	-	-	-	-2.0
HS *	8	0	4	12	200	2.5	1.6	1.1	0.5	-	-	-	-2.0
HS-Tilt	8	6	4	18	200	2.5	1.6	1.1	0.5	-	-	-	-2.0
Ideal	8	6	4	18	200	3.0	3.0	2.0	2.0	-	-	-	-3.0
Ideal	8	6	4	18	350	3.0	3.0	2.0	2.0	1.0	1.0	0.5	-3.0
Ideal	12	6	6	24	200	3.0	3.0	2.0	2.0	-	-	-	-3.0
Ideal	12	6	6	24	350	3.0	3.0	2.0	2.0	1.0	1.0	0.5	-3.0
Ultra	--	-	-	36	350	7.0	7.0	7.0	7.0	7.0	7.0	7.0	-7.5

* High Speed Conventional Train

The simulated travel times, in minutes, are given in Table B-2. The limits of the simulation program must be remembered (deterministic assumptions, plus or minus 1/4 mile, and time errors of a few minutes) when reviewing the results shown in the Table.

TABLE B-2: SIMULATED TRAVEL TIMES (MINUTES PER ROUTE)

TRAIN/MPH/S.E.	Houston to Dallas	Dallas to Fort Worth	Fort Worth to San Antonio	Houston to San Antonio	Total Triangle
AMTRAK/120/12"	130.5	17.5	130.9	110.7	389.6
HS/200/12"	94.0	13.5	96.7	78.5	282.7
HS-Tilt/200/18"	86.5	12.3	87.0	72.6	258.4
Ideal/200/18"	82.4	11.6	85.6	69.4	249.0
Ideal/350/18"	74.1	10.7	78.6	58.8	222.2
Ideal/200/24"	79.6	11.4*	80.7	67.3	239.0
Ideal/350/24"	68.7	10.1*	69.6	55.4	203.8
MAGLEV/350/36"	52.6	NA	NA	NA	NA

* 0.6 Minute was subtracted from computer run due to approximation error in last quarter mile.

In addition, special runs were made on the Fort Worth to San Antonio route and on the Houston to Dallas route. The "Ideal" 350 MPH train, with 18 inches of superelevation was used in both of these special analyses to determine the effect of an intermediate stop in Austin and to investigate the impact of smoothing the horizontal curves on I-45 near Corsicana. With a stop in Austin on I-35, the travel time from Fort Worth to San Antonio increases less than a minute; from 78.6 to 79.2 minutes. The trip time between Fort Worth and Austin is estimated at 55.6 minutes and from Austin to San Antonio at 23.6 minutes. These times, however, do not include station dwell for passenger boarding or debarkation.

The run time between Houston and Dallas was reduced from 74.1 to 72.0 minutes by the flattening of curves near Corsicana. The curve easing over this 20-mile section of the route has only a minor effect on overall schedule performance. Reduction of all curves to 0.5 degrees or less over a 20-mile stretch of track (from Milepost 220 to Milepost 240) had only a 2.1 minute effect on running time.

The following generalizations can be made from the simulation results:

1. Curvature on all routes prevents the maintaining of a constant 350 MPH. The majority of the time is spent accelerating and decelerating when the maximum speed of the HSR system is 350 MPH.
2. Time savings between a 350-MPH "Ideal" train with 24 inches of superelevation and a High Speed train with tilt on 18 inches of superelevation is less than 18 minutes or 25% on any route. The savings are most pronounced on the Houston to San Antonio route (I-10) which has fewer curves for the route length.
3. Time savings bewteen an "Ideal" train with 18 inches of superelevation and the more-conventional High Speed train with tilt was four minutes or less per run.
4. The "MagLev" train with seated and belted passengers saved almost 30 minutes on the Houston to Dallas run compared to the "Ideal" train at 200 MPH. It saved over 41 minutes compared with the non-tilting High Speed train on the same run.
5. Removing the 6 degrees tilt of the High Speed train added 7.6 minutes to the Houston to Dallas run.
6. The AMTRAK train was significantly slower for all runs when compared to the other HSR options. However, the AMTRAK simulation was faster than past scheduled passenger service. The Burlington passenger train required 260 minutes over the Burlington/Rock Island alignment

from Houston to Dallas in 1963 (Burlington 1963 Timetable) and AMTRAK required 335 minutes from Houston to Fort Worth in 1972 (AMTRAK 1972 Timetable). The simulated times following the I-45 and I-30 freeway routes were some 44 to 50 percent of these prior scheduled run times.

The most significant implication of the simulation runs is the suggestion that a maximum speed of 350 MPH along highway medians may not be a practical alternative. Maximum time savings would be marginal while the increase in construction, vehicle, and operating costs would be high. Table B-3 shows the time savings or increases on the Houston to Dallas I-45 route for the various HSR alternatives considered.

TABLE B-3: TRAVEL TIME DIFFERENCE BETWEEN VARIOUS HSR TECHNOLOGIES ON THE DALLAS TO HOUSTON ROUTE (MINUTES)

Train/MPH/S. E.	Time Savings or Increase (Minutes) Compared to:							
	AMTRAK 120/12"	HS 200/12"	HS-Tilt 200/18"	Ideal 200/18"	Ideal 350/18"	Ideal 200/24"	Ideal 350/24"	MagLev 350/36"
MagLev/350/36"	-77.9	-41.4	-33.9	-29.8	-21.5	-27.0	-16.1	NA
Ideal/350/24"	-61.8	-25.3	-17.8	-13.7	- 5.4	-10.9	NA	+16.1
Ideal/200/24"	-50.9	-14.4	- 6.9	- 2.8	+ 5.5	NA	+10.9	+27.0
Ideal/350/18"	-56.4	-19.9	-12.4	- 8.3	NA	- 5.5	+ 5.4	+21.5
Ideal/200/18"	-48.1	-11.6	- 4.1	NA	+ 8.3	+ 2.8	+13.7	+29.8
HS-Tilt/200/18"	-44.0	- 7.5	NA	+ 4.1	+12.4	+ 6.9	+17.8	+33.9
HS/200/12"	-36.5	NA	+ 7.5	+11.6	+19.9	+14.4	+25.3	+41.4
AMTRAK/120/12"	NA	+36.5	+44.0	+48.1	+56.4	+50.9	+61.8	+77.9

As can be seen from the table, a MagLev system (with belted passengers) connecting the CBD's of Dallas and Houston would save between 16 to 78 minutes per run, depending upon the alternative HSR technology to which it is compared. A 350 MPH train with a superelevation of 24 inches would save between 11 and 62 minutes per run over the other HSR systems, with the exception of MagLev. The necessary economic analysis and related engineering studies are beyond the scope of this study. Ridership projections would play a key role in determining the viability of a HSR system in the Texas Triangle. It has been estimated that some 5,000 to 10,000 passengers per day could be expected to ride a HSR system between Dallas and Houston (Cooper, 1984). Considering 6,000 passengers per day, with the value of time at $7.00 per hour, and interest or cost of capital at 10%, a the 16-minute time savings would result in:

6,000 pass/day X 16 min/60 X $7/hr X 250 workdays/year

= $2,800,000 value of time savings per year

This savings would cover the interest on $28 million capital at 10%, if all additional energy costs are ignored. This would be the difference between a MagLev system at 36 inches of superelevation and the Ideal 350 MPH train with 24 inches of superelevation. However, if one were to compare MagLev to the AMTRAK, 120 MPH train option and to accept the 10,000 riders per day, the equation would be:

10,000 pass/day X 78 min/60 X $7/hr X 250 workdays/year

= $22,750,000 value of time savings per year.

This is about an 8 fold increase over the above conservative estimate and equates to some $227.5 million for capital construction or between 10 to 20 miles of elevated construction. If elevated structures were used to provide arrow-straight rights-of-way for a 350 MPH High Speed Rail System, travel time over the 250-mile route from Houston to Dallas would be:

(250 miles/350 MPH) X 60 min/hr = 42.9 minutes

plus acceleration and deceleration time, or around 45 minutes per run. This represents a time savigns of between 24 to 86 minutes per run when compared to the other HSR alternatives considered.

The 200 MPH TGV train took 94 minutes to go from Houston to Dallas without any tilt. If airport access/boarding time of 30 plus 20 minutes is added to flight time, 94 mintues is essentially the same as air travel time between these two cities. The 86.5 minutes possible with a TGV train with tilt beats the total downtown-to-downtown air travel time. Assuming that train fares would be significantly less than air fares, the existing TGV-type of technology (possibly with added 6 degrees tilt) may be adequate to cause a significant diversion of passengers from other modes to the train.

The 200 MPH speed used with the TGV trains was arbitrarily chosen. While 200 MPH appears to be close to a speed which could attract significant numbers of former airplane passengers over these routes, no sensitivity analysis was made. Thus, 200 MPH must NOT be considered as a "Magic Number". If further analysis were to indicate a higher speed (i.e., 250 MPH) as being desirable, this still might be attainable with existing or prototype technology. The TGV has run as fast as 239 MPH, and the British train can tilt up to 9 degrees, which means speeds somewhat in excess of 200 MPH would be feasible with existing operating systems.

It is safe to assume that the significantly longer travel times exhibited by the AMTRAK train would result in much less diversion of the airline traffic, and would be considerably less cost-effective than the High Speed trains (those in the 200 MPH plus category). The simulations suggest that a "conventional" High-Speed train similar to the French TGV, operating with a maximum speed of around 200 MPH would be capable of operating on existing highway rights-of-way at schedule speeds capable of attracting passengers from other modes.