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Shared Right-of-Way Safety Issues

Battelle Memorial Institute
Columbus Division
Columbus, Ohio



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13. ABSTRACT (Maximum 200 words) One of the most important issues in the debate over the viability in the United States of high-speed guided ground transportation (HSGGT) systems, which include magnetic levitation (maglev) and high-speed rail (HSR), is the feasibility of using existing right-of-ways (ROWs). A major potential benefit of shared ROWs would be the substantial amount of time and money saved by minimizing the acquisition of new real estate. In fact, the ROW issue may be the most critical factor for assessing the cost-effectiveness of HSGGT. A methodology for assessing the safety risks associated with shared ROWs for high-speed guided ground transportation has been developed and applied. The first task in assessing the safety of shared ROWs involved characterizing a baseline HSGGT system. Features of existing HSGGT system corridors, as well as those of other potential ROW users, were considered in defining a baseline system for the study. The primary safety issues associated with shared ROWs were then evaluated for the baseline system. The baseline system defined for this study is a 645 km (400 mile) long, 7 million passengers/year HSGGT network, of which as much as 50 percent could be shared ROW with any single other user (roadways, railroads, waterways, pipelines, or transmission lines).		
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PREFACE

One of the most important issues in the debate over the viability in the United States of high-speed guided ground transportation (HSGGT) systems, which includes magnetic levitation (maglev) and high-speed rail (HSR), is the premise that they can be deployed along existing right-of-ways (ROWs) such as the Interstate Highway System, railroad, pipeline, powerline, etc. It is believed by some that judicious use of existing ROWs will minimize the need for acquiring new ROWs, thereby reducing the cost and time associated with deploying HSGGT systems.

To what extent these existing ROWs can be used for HSGGT deployment is a function of many factors, some technical, some economic, some operational, and some safety-oriented. A key issue from an operational/technical viewpoint is the ability of an HSGGT system to maintain high average speeds with the rates of curvature (horizontal and vertical) associated with existing ROWs, thus remaining attractive to a potential user as a viable transportation alternative. The availability, cost, and accessibility of land to establish a new ROW needs to be factored into the economics of HSGGT. Only safety oriented factors associated with use of shared ROWs are to be considered in this report. Several safety issues arise when two transportation systems share an ROW, such as the impact of an accident on one system upon the traffic on the other and the hazards of a dropped power transmission line, electromagnetic interference between operating systems, and pipeline rupture and/or fire.

This report is concerned with the safety issues associated with an HSGGT system sharing the same ROW as another mode of transportation, i.e., automobile, mass transit, commuter rail and/or rail freight, pipeline, or transmission line.

The report contains analyses of these issues and their effect on the safety assessment of each shared ROW scenario. It includes measures and approaches for minimizing or eliminating threats to safety from shared use of ROW.

This report was prepared for the Volpe National Transportation Systems Center (VNTSC) in support of the United States Department of Transportation, Federal Railroad Administration Office of Research and Development. The authors wish to thank Norman Knable of VNTSC and Arne Bang of the FRA Office of Research and Development for their guidance and input during the preparation of this document. The authors also wish to thank Stephanie Markos of VNTSC for important input and critical review.

METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in.) = 2.5 centimeters (cm)
 1 foot (ft) = 30 centimeters (cm)
 1 yard (yd) = 0.9 meter (m)
 1 mile (mi) = 1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in²) = 6.5 square centimeters (cm²)
 1 square foot (sq ft, ft²) = 0.09 square meter (m²)
 1 square yard (sq yd, yd²) = 0.8 square meter (m²)
 1 square mile (sq mi, mi²) = 2.6 square kilometers (km²)
 1 acre = 0.4 hectares (he) = 4,000 square meters (m²)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz) = 28 grams (gr)
 1 pound (lb) = .45 kilogram (kg)
 1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp) = 5 milliliters (ml)
 1 tablespoon (tbsp) = 15 milliliters (ml)
 1 fluid ounce (fl oz) = 30 milliliters (ml)
 1 cup (c) = 0.24 liter (l)
 1 pint (pt) = 0.47 liter (l)
 1 quart (qt) = 0.96 liter (l)
 1 gallon (gal) = 3.8 liters (l)
 1 cubic foot (cu ft, ft³) = 0.03 cubic meter (m³)
 1 cubic yard (cu yd, yd³) = 0.76 cubic meter (m³)

TEMPERATURE (EXACT)

$$[(x - 32) (5/9)]^{\circ}\text{F} = y^{\circ}\text{C}$$

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm) = 0.04 inch (in)
 1 centimeter (cm) = 0.4 inch (in)
 1 meter (m) = 3.3 feet (ft)
 1 meter (m) = 1.1 yards (yd)
 1 kilometer (km) = 0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm²) = 0.16 square inch (sq in, in²)
 1 square meter (m²) = 1.2 square yards (sq yd, yd²)
 1 square kilometer (kn²) = 0.4 square mile (sq mi, mi²)
 1 hectare (he) = 10,000 square meters (m²) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gr) = 0.036 ounce (oz)
 1 kilogram (kg) = 2.2 pounds (lb)
 1 tonne (t) = 1,000 kilograms (kg) = 1.1 short tons

VOLUME (APPROXIMATE)

1 milliliter (ml) = 0.03 fluid ounce (fl oz)
 1 liter (l) = 2.1 pints (pt)
 1 liter (l) = 1.06 quarts (qt)
 1 liter (l) = 0.26 gallon (gal)
 1 cubic meter (m³) = 36 cubic feet (cu ft, ft³)
 1 cubic meter (m³) = 1.3 cubic yards (cu yd, yd³)

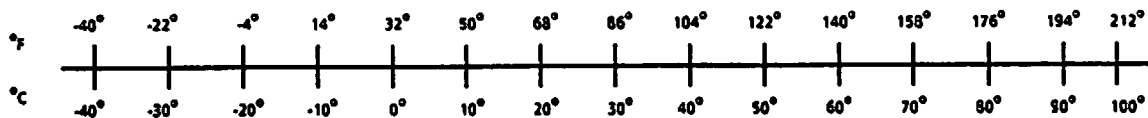
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EXECUTIVE SUMMARY

One of the most important issues in the debate over the viability in the United States of high-speed guided ground transportation (HSGGT) systems, which includes magnetic levitation (maglev) and high-speed rail (HSR), is the feasibility of using existing right-of-ways (ROWs). A major potential benefit of shared ROWs would be the substantial amount of time and money saved by minimizing the acquisition of new real estate. In fact, the ROW issue may be the most critical factor for assessing the cost-effectiveness of HSGGT.

At the request of the U.S. Department of Transportation's Volpe National Transportation Systems Center (VNTSC), the team of Battelle, Booz-Allen & Hamilton, and Carnegie Mellon Research Institute have developed and applied a methodology for assessing the safety risks associated with shared ROWs for high-speed guided ground transport.

The first task in assessing the safety of shared ROWs involved characterizing a baseline HSGGT system. Features of existing HSGGT system corridors, as well as those of other potential ROW users, were considered in defining a baseline system for the study. The primary safety issues associated with shared ROWs were then evaluated for the baseline system.

The baseline system defined for this study is a 645 km (400-mile) long, 7 million passenger/year HSGGT network, of which as much as 50 percent could be shared ROW with any single other user. The HSGGT baseline characteristics were chosen to cover the range of parameters associated with the following HSGGT systems and other users:

- **HSGGT SYSTEMS: HIGH-SPEED RAIL (HSR)**
TGV-Atlantique
IC Express
Shinkansen - 200 Series
ETR 500
ETR 450 (Tilt)
ABB X-2000 (Tilt)

- **HSGGT SYSTEMS: MAGLEV**
JNR Chuo (MLU-002)
HSST
Transrapid (TR07)
Magneplane

- **OTHER USERS**
Roadways
Railroads
Waterways
Pipelines
Transmission Lines

The following six safety issues associated with sharing ROW were evaluated for the baseline system:

1. **Physical infringement of vehicles or structures**
2. **Electromagnetic field (EMF) effects**
3. **Dynamic interference**
4. **Infringement of operating envelope involving common trackage (HSR only)**
5. **Contact with hazardous materials (HAZMAT)**
6. **Accessibility of HSGGT vehicles or guideways for inspection, emergency access, evacuation, and trespassers**

A risk assessment methodology was then developed to score and rank sets of realistic scenarios that involve these safety issues. A set of 85 scenarios was developed to cover the literally thousands of possible scenarios associated with these safety issues. Risk scores were calculated for each of the 85 scenarios.

Candidate mitigation measures were identified for scenarios with unacceptably high risk scores. Estimates were made of the risk associated with each safety issue if mitigation measures were applied. The results of this scoring are provided below:

Electromagnetic Field Effects

- Shield the HSGGT system from electromagnetic fields generated by both the system and Other Users and, in addition, ensure that the HSGGT emits sufficiently weak electromagnetic fields that the effect on Other Users is negligibly small.
- Reduce EMF effects by maintaining sufficient separation distances between the “emitter” and “receivers.”
- Place electromagnetic shields or barriers at locations where other mitigation measures are not effective.

Dynamic Interference

- Perform a rigorous engineering assessment of critical structures (bridges, support structures, etc.) on existing systems and develop a carefully planned inspection, maintenance, and rehabilitation program for the existing systems so that weak areas of the structures can be monitored, diagnosed, and corrected.
- Reduce speeds of the HSGGT in the vicinity of railroad stations to reduce turbulence effects.
- Install tree or artificial barriers to mitigate the startle effect, blown snow, and turbulence.

Infringement of the Operating Envelope on Common Trackage

- Use fail-safe signalling systems, including Automatic Train Protection (ATP), to reduce the risk of collisions between trains, along with carefully designed operating procedures that ensure adequate separation in space and time between successive trains.
- Review and modify current inspection and maintenance procedures on existing railroads for shared usage by the HSR vehicles.

Contact with Hazardous Materials

- Restrict HSGGT trains and trucks or trains carrying HAZMAT from using the shared ROW at the same time. Rescheduling of trucks or trains will need to be negotiated with the truck or train operators on a case-by-case basis.

Accessibility

- Mitigate accessibility-related hazards by:
 1. Restricting the performance of inspection, maintenance, and repair activities to times when Other User traffic is light.

2. **Installing permanent personnel barriers (fences, walls, etc.) between systems in areas where trespassing and vandalism may be attempted and temporary barriers on any portion of the system where maintenance, inspection, or repair activities may be needed.**
 3. **Developing a formal training program for HSGGT workers, emphasizing potential hazards and mandatory procedures associated with working in shared ROW locations.**
 4. **Installing personnel and equipment intrusion detectors in shared ROW areas where trespassing and vandalism may be attempted.**
 5. **Using security procedures and devices to protect critical equipment on the HSGGT system, including on-site or video surveillance of selected locations on the system and barriers and enclosures to protect switchgears, controls, and supplies.**
 6. **Ensuring authorized access to both systems for maintenance, inspection, repair and emergency activities (e.g., evacuation).**
- **Many of the mitigation measures recommended - particularly those involving physical devices or structures - must be tailored to particular sites. Design guidelines such as those published by the American Railroad Engineering Association (AREA) and the American Association of State Highway and Transportation Officials (AASHTO) are required to be adapted to individual sites.**
 - **Significant additional work is required to quantify many aspects of shared ROW usage before a decision is made to deploy a HSGGT system in the United States. This additional work should focus on developing data to replace the many assumptions necessary for this study. Some of these data will become available at the conclusion of several related studies, which are currently under way and funded by the FRA and the National Maglev Initiative (NMI) program.**
 - **Several in-progress studies are addressing shared ROW issues. The results of these studies should be consolidated to establish a clear and accurate perception of shared ROW with HSGGT. One of the initial activities should be a shared ROW Workshop, which would provide a forum for the interchange of the results of the shared ROW studies and for identifying specific directions for further study.**

<u>Safety Issue</u>	<u>Number of Scenarios Scored</u>	<u>Number of High-Risk Scenarios</u>	
		<u>Before Mitigation</u>	<u>After Mitigation</u>
Physical Infringement	16	12	5
EMF Effects	18	17	5
Dynamic Interference	12	11	4
Common Trackage	3	3	3
HAZMAT	8	7	1
Accessibility	<u>28</u>	<u>24</u>	<u>1</u>
Totals	85	74	19

Based on the results of the study, the following conclusions were reached:

- From the standpoint of safety, shared ROW with HSGGT is generally feasible in the United States.
- The risk scores for all of the scenarios can be reduced by applying one or more mitigation measures.
- Almost without exception, it will be more effective to mitigate against the frequency of an event occurring rather than to mitigate against the consequence if the event does occur.
- Because this study evaluated relative risk rather than absolute risk, a high post-mitigation risk score should not be taken to mean that a particular shared ROW mode is not feasible from a safety perspective. A high risk score simply means that the risk associated with one safety issue is greater than the risk associated with the others.
- Reductions in absolute risk for all of the high-risk events identified in this study ultimately will be achieved by the development and implementation of guidelines and regulations based on the recommended mitigation measures.
- Specific mitigation measures recommended are listed below for each safety issue identified.

Physical Infringement

- HSGGT system designers should demonstrate through engineering analyses and testing that the probability of derailment on their system falls into the "remote" category defined in this report and in MIL-STD-882B. The risk assessment methodology must be adjusted for HSGGT designs that have a probability of derailment other than "remote."

2. **Installing permanent personnel barriers (fences, walls, etc.) between systems in areas where trespassing and vandalism may be attempted and temporary barriers on any portion of the system where maintenance, inspection, or repair activities may be needed.**
 3. **Developing a formal training program for HSGGT workers, emphasizing potential hazards and mandatory procedures associated with working in shared ROW locations.**
 4. **Installing personnel and equipment intrusion detectors in shared ROW areas where trespassing and vandalism may be attempted.**
 5. **Using security procedures and devices to protect critical equipment on the HSGGT system, including on-site or video surveillance of selected locations on the system and barriers and enclosures to protect switchgears, controls, and supplies.**
 6. **Ensuring authorized access to both systems for maintenance, inspection, repair and emergency activities (e.g., evacuation).**
- **Many of the mitigation measures recommended - particularly those involving physical devices or structures - must be tailored to particular sites. Design guidelines such as those published by the American Railroad Engineering Association (AREA) and the American Association of State Highway and Transportation Officials (AASHTO) are required to be adapted to individual sites.**
 - **Significant additional work is required to quantify many aspects of shared ROW usage before a decision is made to deploy a HSGGT system in the United States. This additional work should focus on developing data to replace the many assumptions necessary for this study. Some of these data will become available at the conclusion of several related studies, which are currently under way and funded by the FRA and the National Maglev Initiative (NMI) program.**
 - **Several in-progress studies are addressing shared ROW issues. The results of these studies should be consolidated to establish a clear and accurate perception of shared ROW with HSGGT. One of the initial activities should be a shared ROW Workshop, which would provide a forum for the interchange of the results of the shared ROW studies and for identifying specific directions for further study.**

1. INTRODUCTION

One of the most important issues in the debate over the viability of high-speed guided ground transportation (HSGGT) systems in the United States is the feasibility of using existing right-of-ways (ROW). At the request of the U.S. Department of Transportation's Volpe National Transportation Systems Center (DOT/VNTSC), the team of Battelle, Booz-Allen & Hamilton, and the Carnegie Mellon Research Institute Rail Systems Center have developed and applied a methodology for assessing the safety risks associated with shared ROW for high-speed guided ground transport.

1.1 OBJECTIVES

The objectives of this study were to analyze threats to the safety of passengers and to the integrity of equipment of HSGGT and other modes of transportation sharing ROW, and to recommend measures to make sharing ROW a feasible and safe approach to HSGGT. In this study, sharing was defined as using the same ROW as that of the candidate Other Users listed below or using the space adjacent to existing ROW.

1.2 SCOPE

The study considers generic HSGGT systems that could operate on shared ROW in the United States. HSGGT systems include Magnetic Levitation (maglev) and High-Speed Rail (HSR). Shared ROW is used here to mean parallel, adjacent rights of way of an HSGGT system and a traditional transportation or transmission system. It includes only those intersections and crossings typical of traditional systems (e.g., overpasses, underpasses) that are related to shared ROW situations (e.g., departures from and returns to the shared ROW). This study assesses only the safety aspects of shared ROW and focuses on identifying the most promising mitigation measures. The actual design and engineering of mitigation devices and practices will need to be addressed in future work. Operational and economic considerations of shared ROW are being addressed in concurrent studies.

1.3 ORGANIZATION OF REPORT

Section 2 of this report describes the selection of candidate HSGGT modes and Other Users for shared ROW, development of a baseline HSGGT system, the methodology developed for the risk assessment, and candidate mitigation measures for shared ROW. Section 2 also describes the assumptions which formed the basis for the study and additional related studies which are currently under way. The results of this study are provided in Section 3. For each of the six safety issues, relevant scenarios were developed and the risks associated with them were assessed. Mitigation measures are identified for each of the safety issues. Conclusions and recommendations are presented in Section 4. Detailed risk assessment summaries for each scenario used in this study are provided in the Appendices.

2. APPROACH

The general approach used in this study consisted of the following steps:

- **Development of a Baseline HSGGT System based on Candidate HSGGT Modes and Other Users**
- **Development and Application of a Risk Assessment Methodology**
- **Recommendations for Mitigation Measures and Post-Mitigation Rating of High-Risk Scenarios**

These steps are described in detail in Sections 2.1 to 2.3. The assumptions that were made for the conduct of this study are described in Section 2.4, and a description of ongoing related studies is provided in Section 2.5.

2.1 DEVELOPMENT OF A BASELINE HSGGT SYSTEM

A baseline HSGGT system was developed based on reviews of candidate HSGGT and Other User systems. A baseline HSGGT system is needed as a common reference for scaling relevant safety data (accident statistics, failure rates, etc.) from candidate systems of different sizes and operating characteristics. Further, it provides a realistic and practical setting for comparing the safety risks of a wide range of shared ROW combinations and events. However, it does not limit the validity of the risk assessment methodology to HSGGT systems that have the same characteristics as the baseline system; the results of the risk assessment can be adjusted to accommodate changes in the parameters that describe the baseline HSGGT system.

The process that was used to develop the baseline HSGGT system consisted of:

1. **Identifying the salient characteristics of candidate HSGGT and Other User modes for shared ROW operation in the United States (these characteristics were considered in developing and evaluating risk scenarios), and**
2. **Defining the basic characteristics of the baseline HSGGT system, including route length, traffic density and percentage of the system that shares the ROW.**

This process is described below in greater detail.

2.1.1 Selection of Candidate HSGGT Modes

A primary criterion for selecting candidate HSGGT systems was that they cover the range of design, operating and performance characteristics that are desirable for HSGGT operation in the United States. A primary requirement for consideration as an HSGGT system was operating speed of at least 200 km/hr (125 mi/hr).

Two categories of HSGGT were defined: High-Speed Rail (HSR) and maglev. Features of the following systems were considered in this study:

High-Speed Rail:

TGV/Atlantique (France)
IC Express (Germany)
Shinkansen 200 Series (Japan)
ETR 500 (Italy)
ETR 450 (Italy)
ABB X-2000 (Sweden)

Maglev:

Transrapid TR07 (Germany)
JNR Chuo MLU-002 (Japan)
HSST (Japan)
Magneplane (USA)

Design and operating characteristics of these systems are listed in Tables 2-1 and 2-2.

Among the HSR systems, the TGV and Shinkansen systems represent some of the more mature, proven technologies. The ABB X-2000 has been a candidate system for the Miami-Orlando-Tampa corridor and also was the basis for an FRA safety study [1]¹. The IC Express system recently began revenue operation in Germany and was a leading candidate for HSR in Texas. The Italian ETR systems represent the latest Italian HSR technology and are part of the development of an extensive HSR network in that country. The four systems listed under the maglev category represent

¹ Numbers in brackets designate references listed in the References section of this report.

Table 2-1. High-speed Rail Comparison Matrix

HIGH SPEED RAIL COMPARISON MATRIX						
	TGV	IC Express	Shinkansen 200 series	ETR 500	ETR 450	ABB X-2000
Train Parameters	Atlantique			Type B	Tilt	Tilt
Standard Consist Makeup	1- 10 -1	1- 12 -1	12	1- 12 -1	1- 9 -1	1 - 5
For Standard Consist:						
Length (meters)	237.4392	333.7	300	352		140
Passenger Capacity	505	630	885	640	460	255
Empty Weight (metric tons)	448.965	762.88	743.74	624	510.64	318
Full Weight (metric tons)	483.325	805.74	803	667.55		338
Top Operating Speed (kmph)	300	300	240	275	250	200
For Top Operating Speed						
Noise Level (@50m) dB(A)	92	87				< 94 @ 25m
Emergency Stop Dist (km)	3.5	6.94		9	3.4 @ 8% downgrade	1.1
Min. Horiz. Radius (meters)	4400	4320	4000	4550		1200
Maximum Gradient (%)	5	4				
Maximum Superlevation (degrees)	7.1	7.1		6.4		6
Brake Type:						
Power Cars	rheostatic & tread	elect-pneum/regen	rheostatic	tread & rheostat	synth shoe & disk	disc/track/regen
Non-Powered Cars	4 disks/axle	3 or 4 disks/axle	disk	3 disks/axle	2 disks/axle	disc & magnetic
Communication / Control Type			ATC			ATC
Power Car:						
Length (meters)	22.15	20.81		20		17
Width (meters)	2.92	3.07		2.96		3.08
Height (meters)	4.0132	3.82/3.65		3.85		3.8
Weight (metric tons)	67.67	78.2		72		73
Wheel Diameter (mm)		1000		1100		1100
Traction Motor:						
Type	AC synch	AC asynch		AC asynch		AC asynch
Power per Motor (kW)	800	1050	230	1000	1250	815
Total Power Rating (kW)	6400	4200	11040	4000	6250	3260
Starting Tractive Effort (kN)	106.752	135		160	184	160
Trailer Car:						
Length (meters)	18.7	26.51	25	26	25.6	24.4
Width (meters)	2.92	2.93		2.84	2.82	3.08
Height (meters)	4.0132	3.65		3.7	3.2	3.8
Empty Weight (metric tons)		50.54	68	40		47
Full Weight (metric tons)		53.8/55		43.26/44.63		51
Passenger Capacity (class 1/2)	38 / 60	48/66		48/68	46	51/76
Tilt Car Train Parameters:						
Type					active	active
Effective Tilt (degrees)					8	6.5

Table 2-2. Maglev Comparison Matrix

MAGLEV COMPARISON MATRIX						
	Magnaplane	JNR Chuo (MLU-002) Linear	HSST	Transrapid (TR07)		
Maglev Train Parameters						
Vehicle Section	1 car	1 car	2-car train	1 car		
For Standard Consist:						
Length (meters)	50	27.43	36.576	25.603		
Passenger Capacity	140	68	160	72 - 100		
Empty Weight (metric tons)	30.74	26.94	39.4545	45.35		
Full Weight (metric tons)	44.8058	31.57	53.876	53.513		
Top Operating Speed (kmph)	500	500	300	500		
For Top Operating Speed						
Min. Horiz. Radius (meters)		6004.56	2500	6530.34		
Maximum Gradient (%)		4	6	10		
Maximum Superlevation (degrees)	45			12		
Air Gap (mm)	149.86 - 248.92	101.6	9.525	8		
Magnetic Fields:						
Seat Level (Gauss)		100 - 200		.01 - .03		
Floor Level (Gauss)			70	.1 - 1		
Noise (dB(A)):						
@Distance (meters)			25	84		
@Speed (kmph)			300	25		
Energy: (Wh/seat/km)		55	17.2	400		
@speed (kmph)		125	37	60		
Switches	vert. switch for off-line stations / one-mile activated horiz. switch	Traverse articulated	Hydraulic	Wayside steel bending		
Operational Control			ATO	auto block control		
Propulsion Type	LSM	long-stator LSM	Short-stator LIM	Long Stator LSM		
Levitation Magnet Type	superconductors	superconductors	electromagnets	electromagnets		

the range of technologies currently under consideration for operation in the United States. The Transrapid system, perhaps the most extensively developed Electromagnetic Suspension (EMS) technology, has been chosen for operation between Disney World and the Orlando airport and is a leading candidate for the California-Nevada and Pennsylvania HSGGT systems. The Transrapid system also was the focus of a safety study performed by VNTSC [2]. The Japanese currently have two high-speed maglev systems under development, one by the JNR, and the other by the Japanese Airlines. The Magneplane design is in the early stages of development and is a U.S.-based design under consideration for operation in this country.

2.1.2 Selection of Candidate Other Users

Using existing ROW in the design of a future HSGGT system will likely become necessary or desirable to achieve one or more of the following objectives:

- To realize capital cost savings
- To gain access to urban centers
- To gain passage through congested areas

A shared ROW situation occurs whenever an HSGGT system runs alongside another user on an existing occupied ROW. For the purpose of this study, only conditions which result in an extended proximity of HSGGT system to existing infrastructure were considered. Situations involving intermittent contact (e.g., overpasses, underpasses) or more than one Other User were not considered.

The following existing ROW were considered in this study as the Other Users:

- Highways
- Railroads
- Waterways
- Pipelines
- Transmission lines

Other existing ROW were identified but not included in this study because they were considered impractical for HSGGT operation. These included bike ways and hiking trails.

Each candidate ROW listed above has inherent limitations with regard to compatibility with HSGGT, but is considered to have reasonable potential to be host corridors for HSGGT systems. More detailed analyses of the viability of an HSGGT system following these Other Users are being performed in a concurrent study by Martin Marietta [3]. Each of these candidates is described below and its features are summarized in Table 2-3.

2.1.2.1 Highways. These highway ROW can be identified for shared HSGGT use:

- Interstate roadways
- Local roadways
- Roadway structures

The U.S. Interstate Highway System comprises of nearly 72,600 km (45,000 miles) of highways built over the last 35 years to fairly uniform standards. These ROW commonly are between 46 to 91 meters (150 to 300 feet) wide. Horizontal curves of interstate highways typically are designed to maintain roadway vehicle speeds up to 113 km/hr (70 mi/hr), and generally include grades below 5 percent. Grades of 7 percent may occur in mountainous terrain. Most interstate highways include median strips while traversing rural areas, and these medians usually have a minimum width of about 15 meters (50 feet). Interstates generally have a lateral clearance distance of 23 meters (75 feet) on either side of the roadway. Overhead bridges are typically designed for a 4.9 meter (16-foot) minimum clearance. HSGGT guideways would have to pass over or under these overpasses. A possible layout of a highway ROW sharing with an HSGGT system is shown in Figure 2-1.

Typical local roadways are configured as two 3.7 meter (12-foot) lanes flanked with small lateral ROW, usually less than 3 meters (10 feet). However, there are some four lane roadways that use median strips and may have more substantial lateral ROW available. Most applications of shared ROW with local roadways and HSGGT will likely occur where extra ROW is available.

Table 2-3. Comparison of Existing ROW ("Other Users") Characteristics

Right-Of-Way Type	Total ROW Width (ft)		Width Available for SROW	Typical Considerations	Most Effective Application
	Min	Max			
High Voltage Transmission Line	40	200	2 @ 40	Follows Severe Terrain Electromagnetic Fields	Urban access where terrain/alignment permits
Pipeline	40	60	2 @ 15	Limited lateral ROW available Follows severe terrain Corrosion Structural integrity	Urban access where terrain/alignment permits
Roadway	150	300	1 @ 50 1 @ 75	Horizontal/Vertical curves Underpasses/Overpasses	Extensive intercity use
Railroad	30	100	2 @ 15 # Tracks @ 24	Horizontal/Vertical curves Follows Circuitous path Underpasses/Overpasses	Urban access intercity where terrain permits
Waterway	100	300	N/A	Limited Lateral ROW available Follows Circuitous path use over ww expensive/unlikely	urban access

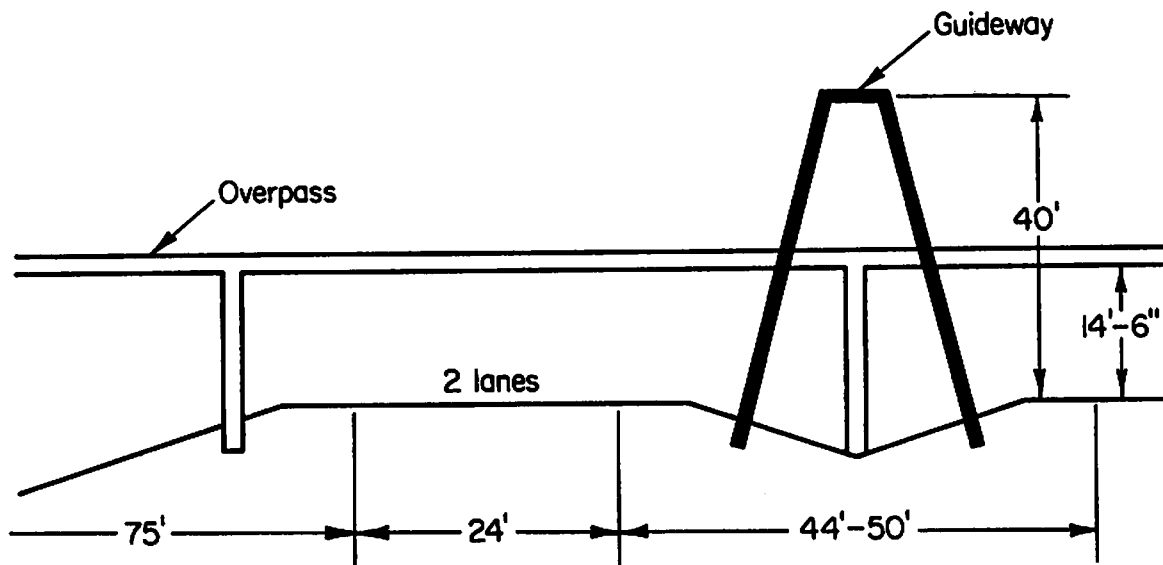


Figure 2-1. Example of HSGGT/Highway Configuration

Roadway structures include bridges, tunnels, and grade-separated intersections. One example of a candidate HSGGT/roadway structure shared ROW is the Golden Gate Bridge in San Francisco, where a study concluded that shared use with Bay Area Rapid Transit (BART) trains is feasible [4]. However, most existing bridges probably are not designed to withstand anticipated HSGGT loads and would either need modifications or substantial rebuilding to enable shared roadway/HSGGT use.

2.1.2.2 Railroads. Existing freight and passenger railroads may be considered for shared ROW use with HSGGT. HSGGT could be designed alongside or above an existing railroad infrastructure or, in the case of HSR, could be operated on the same infrastructure. An example of a possible shared ROW configuration is shown in Figure 2-2.

Railroad ROW are almost entirely privately owned and normally vary in width from 9.1 to 30.5 meters (30 to 100 feet). Roadbed widths range from 5.5 to 7.3 meters (18 to 24 feet) for a single track line, plus an additional 4.3 meter (14-foot) center-to-center spacing for each multiple track line.

2.1.2.3 Waterways. Two waterway ROW can be identified for shared use with an HSGGT system: canals and rivers. Examples of these shared ROW situations are shown in Figures 2-3 and 2-4.

Urban canal waterways and irrigation and drainage systems are generally 30 to 90 meters (100 to 300 feet) wide and of varying depth. Drainage canals are used primarily to prevent flooding

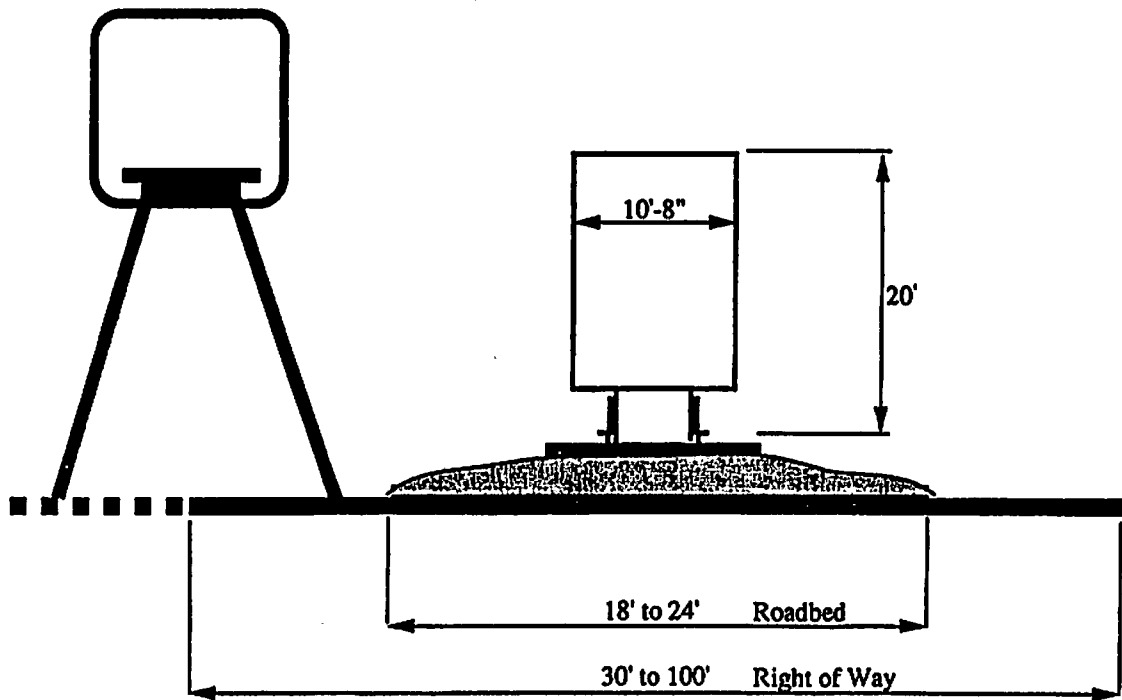


Figure 2-2. Example of Shared ROW Layout for HSGGT and Railroad

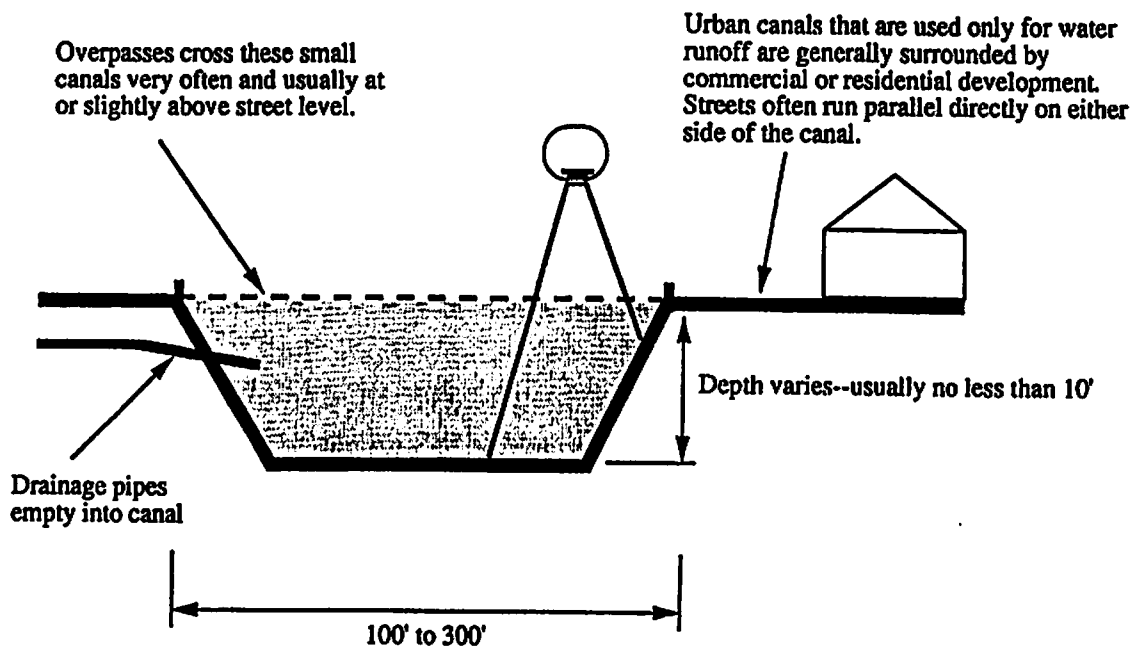


Figure 2-3. Example of Shared ROW Configuration for HSGGT with Urban Canals and Drainage Systems

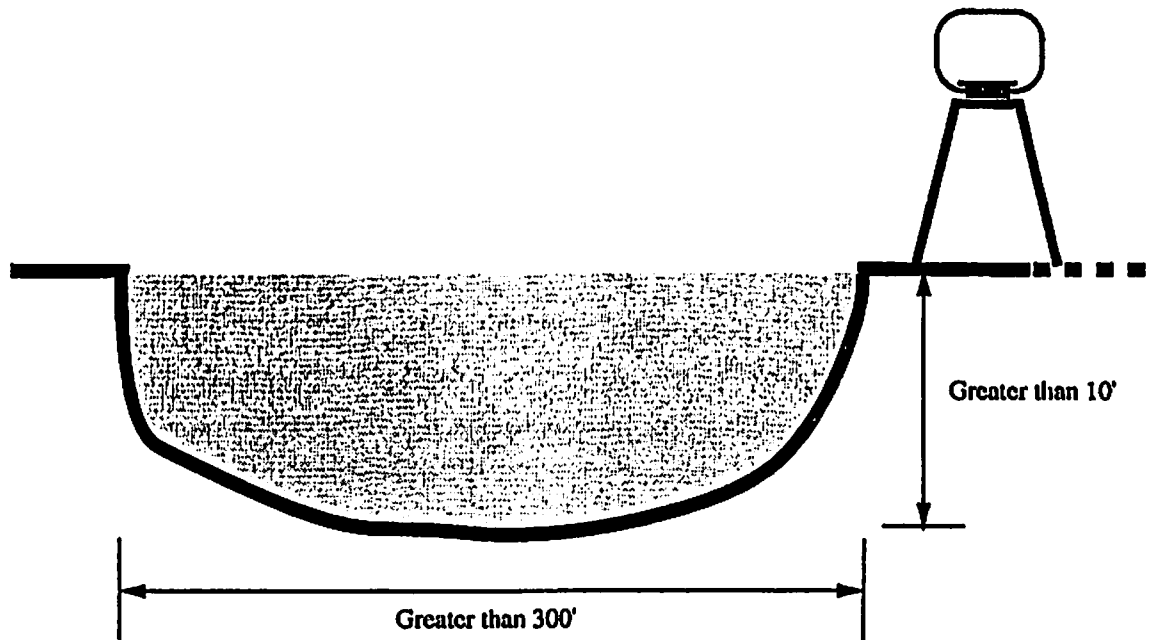


Figure 2-4. Example of Shared ROW Configuration for HSGGT with Rivers and Canals

during heavy rains and are often empty. They are typically lined with cement and are flat at the bottom with slanting sides. Canals are built below ground level so that in most cases no levee is required and streets can run on each side.

Navigable rivers include all bodies of water at least 90 meters (300 feet) wide with minimum depths of 2.7 to 4.3 meters (9 to 14 feet). At present, many railroads share ROW with natural waterways, which conveniently cut a fairly level path. Conventional train systems can easily follow the winding curvature of a river. This, however, will be limited with HSGGT systems and frequent deviation from the river may be necessary. One option is to follow a river ROW only when travelling through a city.

2.1.2.4 Pipelines. Pipelines can be found in a variety of situations, both rural and urban. Pipelines are typically from 25 to 51 cm (10 to 20 inches) in diameter and are buried at depths of 0.6 to 0.9 meters (2 to 3 feet), but can sometimes be found above ground. ROW widths average between 12 to 18 meters (40 to 60 feet) to allow for maintenance access. Examples exist of shared ROW use

between railroads and pipelines; in these cases, a minimum lateral separation distance of 3 meters (10 feet) is maintained. An example of a shared ROW configuration with HSGGT and pipeline is shown in Figure 2-5.

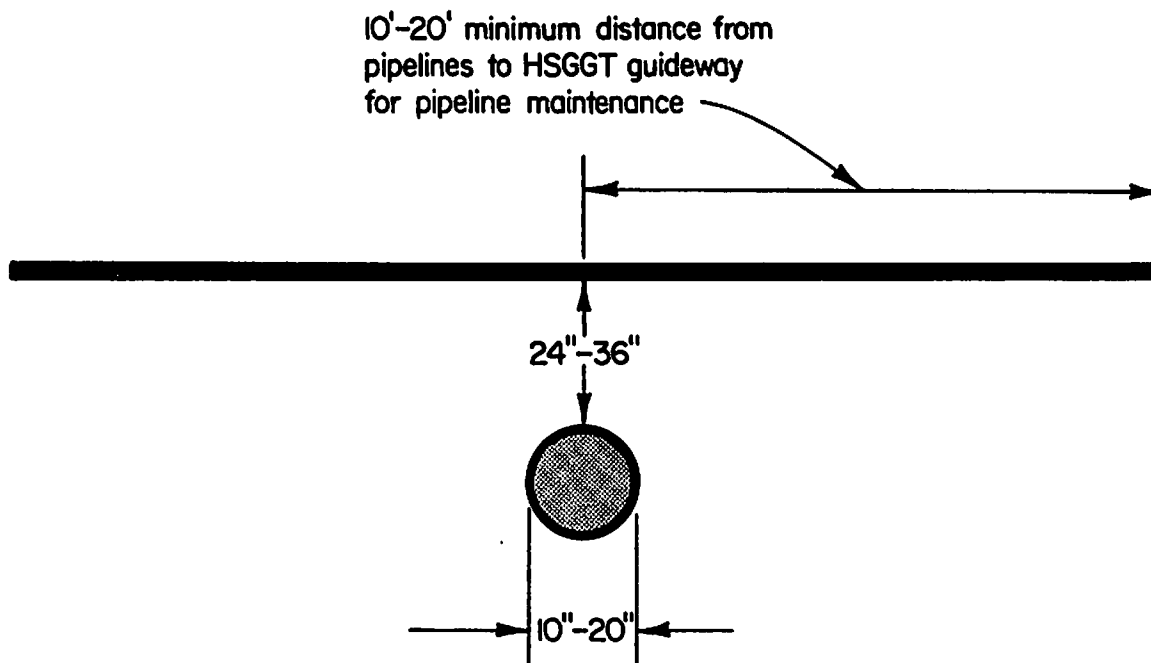


Figure 2-5. Example of Shared ROW Configuration with HSGGT and Pipelines

2.1.2.5 Transmission Lines. High Voltage Transmission Lines (HVTL), used for distribution of electrical power to both urban and rural population centers, typically carry from 15 kv to as high as 250 kv. For most situations this is 60 Hz AC power. However, in isolated circumstances, such as extremely long distance high voltage lines, the primary AC power may be converted to DC power before transmission. Typically, HVTL ROW widths will vary from 12 to over 61 meters (40 to over 200 feet). HVTLs tend to follow the most direct path to their destination, often passing through valleys or over small mountains. An example of a shared ROW configuration between an HSGGT system and an HVTL is shown in Figure 2-6.

Other forms of transmission lines include copper and fiber-optic cables (FOC) for telephone and data transmissions. These typically have a more narrow ROW than is needed for HVTL systems. FOC towers are not allowed closer than 9.1 meters (30 feet) from the edge of the interstate highway pavement.

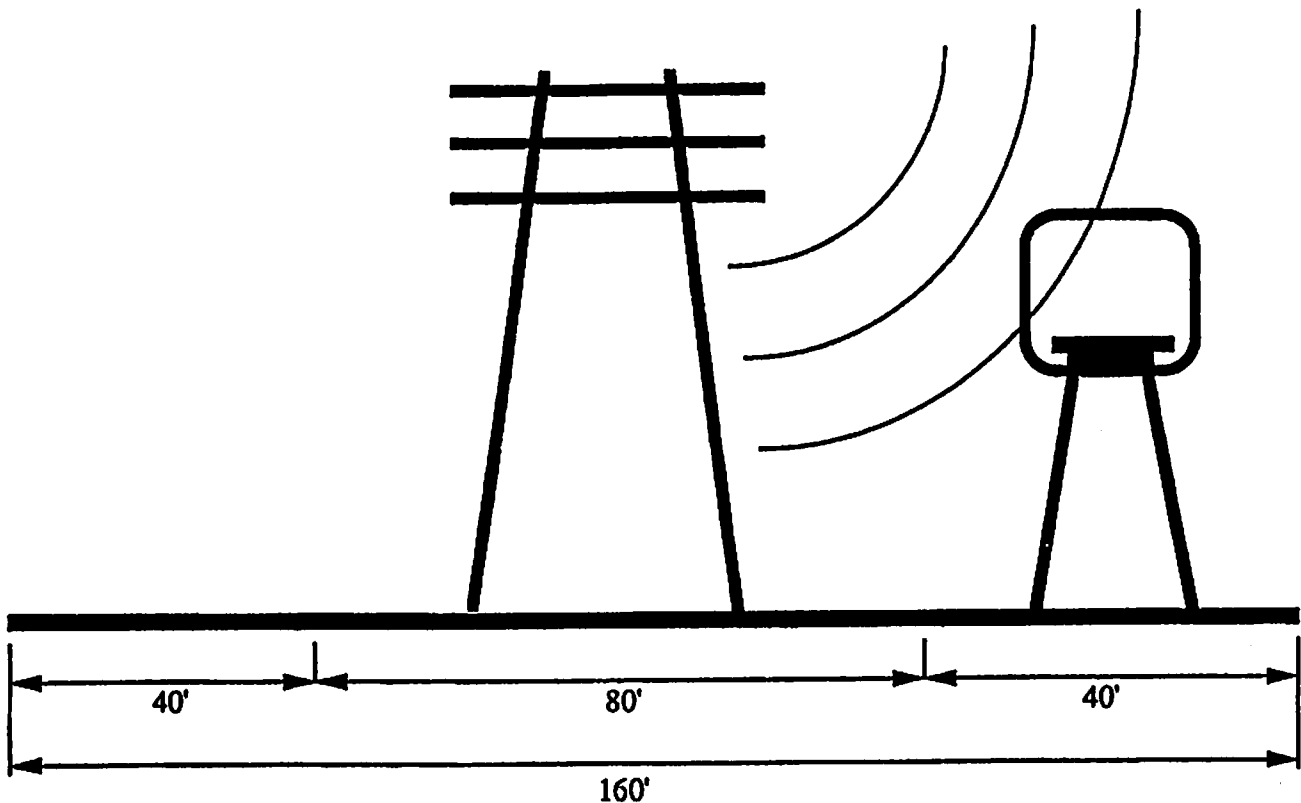


Figure 2-6. Example of Shared ROW Configuration with HSGGT and HVTL Systems

2.1.3 Baseline HSGGT System Definition

In order to develop risk scores for the scenarios associated with the safety issues, it was necessary to define a baseline HSGGT system. However, it is important to note that the resulting risk scores are also meaningful for other HSGGT system characteristics—as described in Section 2.2.3, the results are scaleable for different system lengths and riderships. Therefore, the approach used in this study is flexible, and can be adapted to future changes in HSGGT system characteristics.

The definition of a baseline HSGGT system was based primarily on reviews of the characteristics of candidate HSGGT corridors and of existing HSR and conventional transportation modes. Summaries of these reviews are provided below. The system length, portion of system that has shared ROW, and annual ridership were defined based on these reviews.

2.1.3.1 Proposed HSGGT Systems. A recent article identified eleven HSGGT systems under consideration in the United States and Canada [5]. These candidate systems ranged in length from about 290 km (180 miles) (Seattle to Moses Lake, WA) to over 807 km (500 miles) (Dallas-Houston-

San Antonio). The average and median system lengths were roughly 597 and 548 km (370 and 340 miles), respectively. A summary of the projected ridership for four proposed U.S. systems is provided in Table 2-4. These systems range in length from 427 to 713 km (265 to 442 miles), with projected annual ridership in the year 2000 of from 5 million to 8.8 million passengers.

Table 2-4. Ridership Projections for Selected Candidate HSGGT Systems

Route	Length, km (miles)	Projected Ridership,		Source
		Millions/Yr.		
Anaheim-Las Vegas	427 5 (265)			[6]
Chicago-Minneapolis	702 (435)	8.5		[7]
New York City-Buffalo	713 5 (442)			[8]
Pittsburgh-Philadelphia	548 (340)	8.8		[9]

2.1.3.2 Existing Systems. Ridership data was obtained for two of the more popular high-speed rail systems in use today: Amtrak's North East Corridor (NEC) and TGV-Atlantique. In fiscal year 1991, Amtrak's ridership in the NEC was 10.9 million passengers and 1.5 billion passenger-miles [10]. These figures are for the combined Boston-Washington, Philadelphia-Harrisburg, Philadelphia-Atlantic City, and Richmond-Atlantic City routes, which comprise a 1,190 km (738-mile) system. The TGV-Atlantique's ridership in 1990 was about 20 million passenger-trips over its 284 km (176-mile) system [11].

2.1.3.3 Shared ROW Characteristics. Detailed data could not be found on the portion of existing HSR systems that have shared ROW. However, shared ROW situations involving railroads, highways, waterways, pipelines and transmission lines do exist in many countries including the United States. Results of the Pennsylvania High-Speed Rail Feasibility Study estimated that about 22 percent

of the total proposed system under study could be adapted to shared ROW [12]. A report from the United States General Accounting Office [13] implied that the shared ROW portions of three potential maglev systems (Orlando, California-Nevada, and Pittsburgh) could range from about 45 percent to 90 percent. One of the goals in the current system concept design phase of the National Maglev Initiative (NMI) is to use shared ROW wherever practical. Therefore, the approach taken was to define a portion of the entire hypothetical HSGGT system over which a shared ROW situation may exist with any of the candidate existing modes.

Based on this information, the following characteristics were defined for the baseline HSGGT system:

- System Length: 645 km (400 miles)
- Shared ROW Portion of System: 323 km (200 miles) (50 percent of system)
- Annual Ridership: 7 million passengers.

This hypothetical system is considered representative of those under consideration for deployment in the United States. The system length and ridership level is within the ranges for the proposed systems. Further, preliminary results of a recent cost versus performance study of deploying HSGGT in the United States suggested that HSGGT systems with operating speeds above about 323 km/hr (200 mi/hr) are more cost-effective than lower speed systems for route distances greater than about 565 km (350 miles) [14]. An important assumption made for the analysis was that 50 percent of the entire system may be shared with any single existing mode. Thus, depending on shared ROW situation for each scenario, 323 km (200 miles) of the hypothetical system is designated as shared with either highways, waterways, transmission lines, pipelines, or railroads. It is also important to note that although the final risk assessment scores are based on the system characteristics defined above, the methodology was designed so that the raw frequency scores associated with each scenario could be adjusted easily for different system lengths, ridership levels, and portions of shared ROW. Thus, the methodology is flexible and generic and remains a credible “platform” for additional risk assessment work of shared ROW with HSGGT.

2.2 DEVELOPMENT OF THE RISK ASSESSMENT METHODOLOGY

The approach to the risk assessment of shared ROW concepts involved four steps. These following steps were applied to each shared ROW concept:

- Safety issue identification
- Scenario definition and consequence description
- Risk assessment
- Risk estimation

2.2.1 Safety Issue Identification

The following definition of a “safety issue” was used in the risk assessment methodology:

A *safety issue* is the principal undesirable event that has the potential for passenger or employee injury, property damage, or system loss in either of the transport modes associated with the shared ROW concept [2].

Safety issues can be associated with both normal operations and actual accidents. Only safety issues directly related to the shared ROW concept were considered. Safety issues that would occur without the shared ROW are being addressed in a separate study [3].

Based on this definition, the following six safety issues were identified in the risk assessment approach.

1. Physical infringement of vehicles or structures from one user onto another
2. Electromagnetic field (EMF) effects
3. Dynamic interference between users
4. Infringement of operating envelope involving common trackage (HSR only)
5. Transportation of hazardous materials (HAZMAT) by the Other User
6. Accessibility of HSGGT vehicles or guideways for inspection, emergency access, evacuation, and trespassers

These safety issues are discussed in detail in Section 3 of this report.

2.2.2 Scenario Definition and Consequence Description

The scenario definition process is the most important step in the risk assessment process. The event scenarios form the structure of the subsequent risk comparisons, thus the definition of the event scenarios determines the success of the risk comparison.

A major challenge is to develop a manageable number of typical scenarios, which represent the literally thousands of possible scenarios. Figure 2-7 shows the conceptual elements of an event scenario. The event scenario description relates the possible causes to the frequency and consequence of potential accidents. The description includes the influence of both protection and mitigation efforts. Protection efforts usually influence event frequency with little change to the consequence of the event; risk is reduced because the consequence occurs less often. Mitigation measures usually act on consequence severity (after occurrence) but do not change the event frequency; risk is reduced because a lesser impact occurs. Protection and mitigation are considered in combination as “mitigation” in this study.

The event scenario definition must consider the dual nature of the shared ROW concepts. That is, scenario descriptions and consequences must consider both:

- Characteristics of the HSGGT system that might be a threat to the existing transportation mode, and
- Characteristics of the existing transportation mode that might be a threat to the HSGGT system.

For example, an HSR vehicle sharing an ROW with an existing freight railroad could derail and collide with a freight train, which in turn could spill hazardous materials that would hamper passenger evacuation efforts. In contrast, events that do not include both modes—such as a derailment of a high-speed train that does not affect the power line on the shared ROW—are excluded from this analysis. This is illustrated in the flow chart shown in Figure 2-8, which was originally developed for the WMATA Common Corridor Study [15].

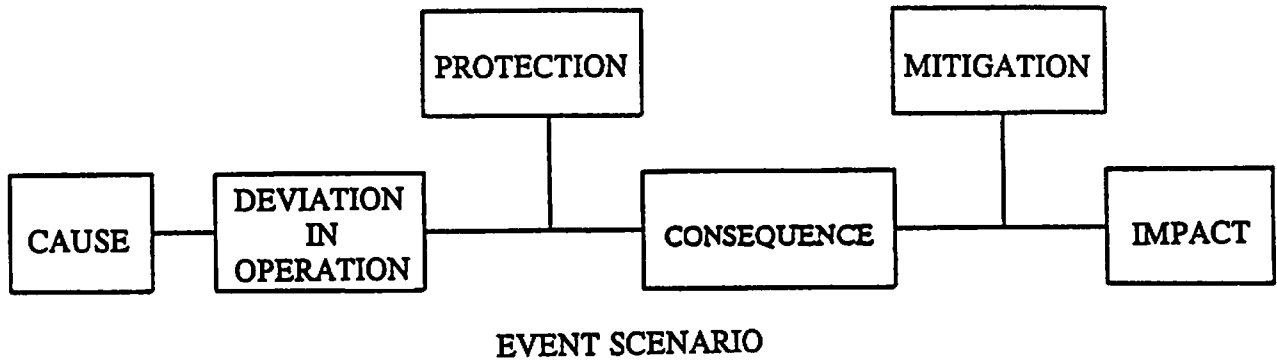


Figure 2-7. Conceptual Elements of the Event Scenario

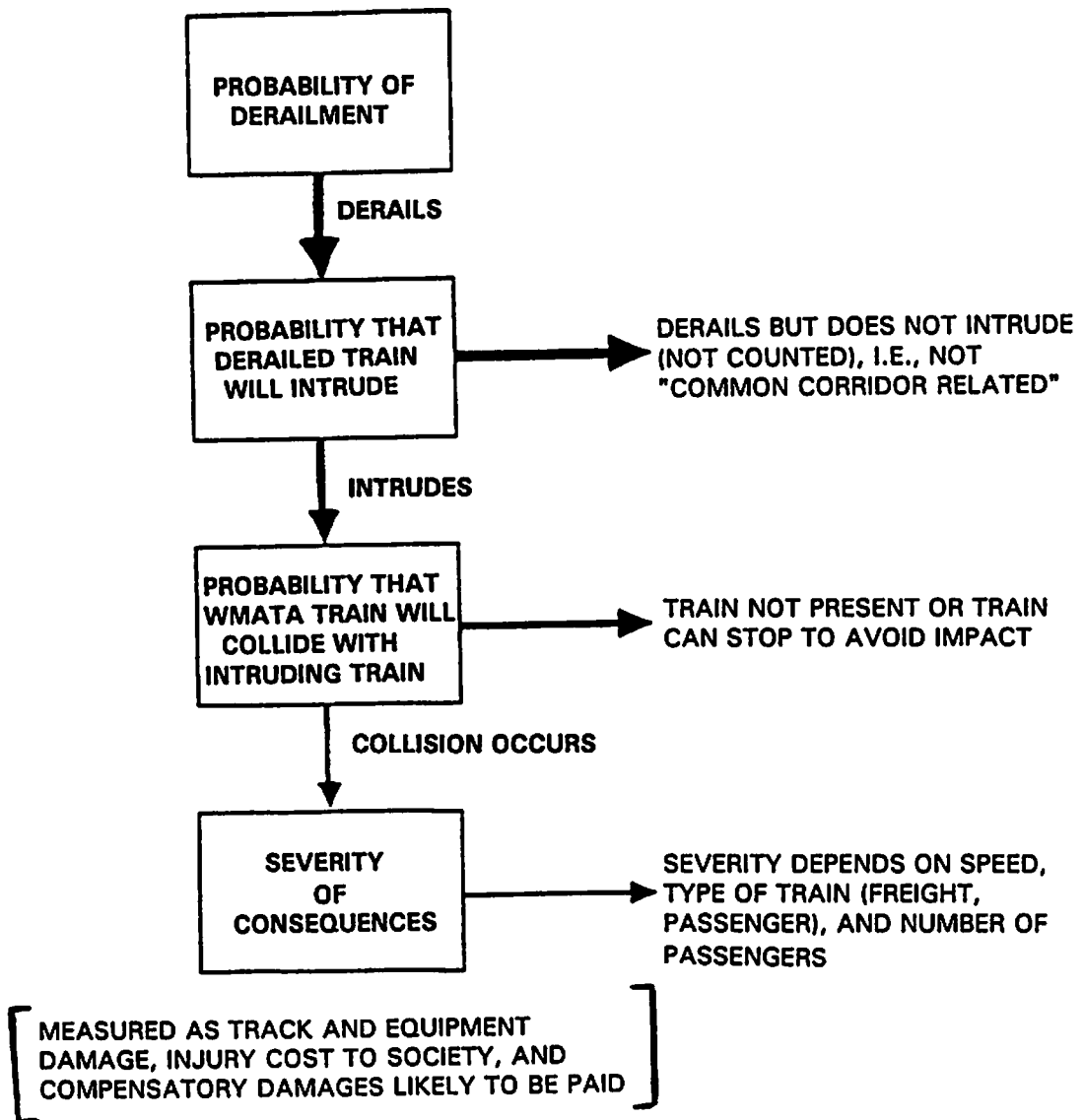


Figure 2-8. Risk Assessment Model Overview

The comparative risk assessment requires a well-defined set of event scenarios in order to compare the shared ROW concepts. Literally thousands of event scenarios are possible. With careful selection, however, a subset of typical scenarios can be identified and used to compare risks on a consistent basis. This is possible because the comparison is based on relative, rather than absolute, risk. Another benefit of the selection process, which is described below, is that it considers a broad spectrum of scenarios and thus prevents significant events from being overlooked.

The process of defining event scenarios has three parts: First, all possible combinations of HSGGT Types, Other Users, and Instigators are developed for each safety issue. As shown in Figure 2-9, 20 possible combinations were created for each of 6 safety issues. Second, scenarios are developed for each combination based on expert judgement as to what events are plausible and represent worst-case safety risks. In some cases where similar events could occur, the scenarios are developed to be typical and representative of those other events. Finally, a frequency and consequence of each event is assessed according to guidelines drawn from MIL-STD-882B [16]. This standard is frequently used in assessing the risk of new, relatively unproven technological systems. Its use here is consistent with recent safety studies of transportation systems.

Frequency and consequence were categorized according to definitions used in MIL-STD-882B, as shown in Tables 2-5 and 2-6.

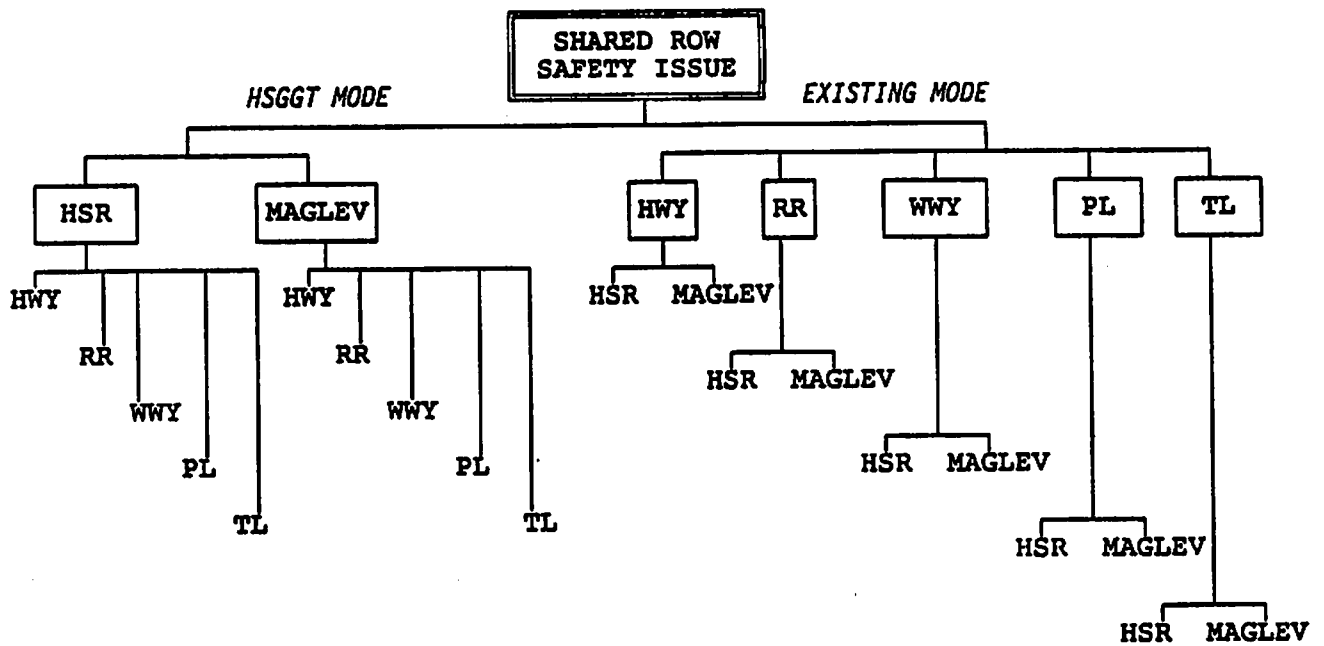
2.2.3 Risk Assessment

Risk is commonly defined as the combination of an event's frequency of occurrence and its consequence. These same principles are used in this model by constructing well-defined categories for both event frequency and consequence in a risk matrix approach.

This approach permits:

- Segregating the safety issues and shared ROW concepts into high risk and low risk categories relative to the safety of people and equipment
- Identifying where mitigation measures can be most effective

This process requires well-defined categories of both event frequency of occurrence and consequence severity to allow comparison of the risk related to the shared ROW concepts. Categories of



Legend: HSGGT = Maglev or High-Speed Rail
 HSR = High-Speed Rail
 HWY = Highway
 RR = Railroad
 WWY = Waterway
 PL = Pipeline
 TL = Transmission Line

Figure 2-9. Breakdown of General Scenario Categories

Table 2-5. Consequence Category Descriptions (Based on MIL-STD-882B, Notice 1)

Description	Category	Mishap Definition
Catastrophic	I	Death or system loss.
Critical	II	Severe injury or major system damage.
Marginal	III	Minor injury or minor system damage.
Negligible	IV	Less than minor injury or system damage.

Table 2-6. Frequency Category Descriptions (Based on MIL-STD-882B, Notice 1)

Description	Level	Generic Description	Frequency (Events/Year)	
			Greater Than	Less Than
Frequent	A	Continuously experienced.	1	--
Probable	B	Will occur frequently.	0.1	1
Occasional	C	Will occur several times.	0.01	0.1
Remote	D	Unlikely, but can reasonably be expected to occur.	0.001	0.01
Improbable	E	Unlikely to occur, but possible.	∞	0.001

consequence severity used for the assessment of shared ROW concepts are shown in Table 2-5 for this application. These categories recognize that some shared ROW concepts will contain two transportation modes and the consequence descriptions distinguish between possible damage to one or both transportation modes. Table 2-6 lists the categories used for frequency of occurrence scoring. These frequency and consequence categories were derived from MIL-STD-882B [16], which has been used successfully in similar transportation safety studies [2].

Each scenario was assigned a specific consequence and frequency. Because of the new technologies involved and the almost unique concept of a shared ROW, this process required expert judgment and was somewhat subjective. Available historical data on analogous accident occurrences and severity were an important resource for developing these scores.

The frequency scoring matrix described in Table 2-6 is referenced to the hypothetical system defined for this study. For example, a frequency score of “Improbable” describes an event that is expected to occur less than once in 1,000 years on the 400-mile baseline system. The criterion for an “Improbable” frequency category on several HSGGT systems of, say, 4,000 miles, would be less

than once per 100 years. Thus, the frequency scoring approach used in this study is applicable to HSGGT systems of nearly any size.

2.2.4 Risk Estimation

The risk estimation procedure was developed to produce ratings of sets of scenarios related to shared ROW safety issues. Using these ratings, both the overall safety issues and the individual high risk scenarios were examined for relevance to currently existing issues in today's transportation environment. This allowed the quick identification of mitigation measures that may be readily available or already in practice within the transportation industry.

A key issue associated with effective risk scoring is the definition of a baseline HSGGT network. This is necessary to develop meaningful scores for frequency of occurrence for each scenario. The frequency scores are based largely on existing statistics for recent operations of the Other Users in nonshared ROW situations. These statistics in turn are associated with the size and operating characteristics of the transportation modes that are involved. Equivalent frequencies can be determined by comparing statistics on the basis of number of occurrences per passenger-mile, route-mile, or similar units. The frequency categories listed in Table 2-6 are in terms of number of occurrences per year, based on the baseline HSGGT network defined for the study and described in Section 2.1.2.

The scoring system used for estimating the relative risk of each scenario was taken directly from MIL-STD-882B. The scoring matrix is illustrated in Table 2-7. The matrix combines the frequency and severity scenes to create a risk score.

2.3 CANDIDATE MITIGATION MEASURES

A comprehensive list of candidate mitigation measures was developed based on consideration of availability, effectiveness, and general feasibility. They included:

- Fail-safe signalling and control systems
- Design considerations
- Physical separation
- Grade separation
- Time separation

Table 2-7. Risk Scoring Matrix

Frequency of Occurrence	Hazard Categories			
	I Catastrophic	II Critical	III Marginal	IV Negligible
A Frequent	1	3	7	13
B Probable	2	5	9	16
C Occasional	4	6	11	18
D Remote	8	10	14	19
E Improbable	12	15	17	20

Hazard Risk Index

Suggested Criteria

1 - 5	Unacceptable
6 - 9	Undesirable (Mgt. decision required)
10 - 17	Acceptable with review by Mgt.
18 - 20	Acceptable without review

- Speed reduction
- Sensors
- Ditches
- Redirecting barriers
- Crash barriers
- Tree barriers
- Turbulence barriers
- Railroad equipment maintenance
- Operating procedures
- EMF mitigation

Recommended mitigation measures were drawn from this list for each high-risk scenario. The recommended mitigation measures were assumed to be able to reduce the frequency or consequence of each high-risk scenario by two levels (for example, from “Probable” to “Remote”).

2.3.1 Fail-Safe Design

Fail-safe design of safety critical systems provides the means for automatic response to unsafe failures within the system or within subordinate systems. By definition, fail-safe design refers to configurations and procedures that cause the system to revert to a safe state after any failure or a set of failures resulting from a single event.

Fail-safe design is a commonplace requirement for controlled transportation systems. Fail-safe design principles have a long-established implementation history in railroad systems throughout the world. Fail-safe design could reduce the probability of occurrence of a hazardous condition in scenarios involving HSR and railroad systems.

The cost of implementing fail-safe design criteria for HSGGT systems is expected to be marginally higher than for existing transportation systems.

2.3.2 Design Considerations

Those portions of the shared ROW that are purposely built for shared ROW must be developed with appropriate dual criteria. For example, bridge designs to carry HSGGT and highway traffic must consider particular HSGGT requirements for minimal vibrations and sag tolerances. Structures originally designed for single-mode use must be thoroughly analyzed to verify that their design limits will accommodate shared use. In some cases, it may be more cost-effective to build separate, side-by-side structures that conform to one set of criteria rather than dual criteria for shared ROW.

2.3.3 Physical Separation

The effectiveness of physical separation depends strongly on the operating speeds of the shared ROW modes. In general, physical separation must be wide enough to allow for dispersion of a worst-case, full-loaded derailing guided vehicle or a crashing highway vehicle. The dispersion space will vary based on the worst-case operating parameters of the modes involved and the expected maximum speeds for each section of the shared ROW.

Use of physical separation as a mitigation measure is primarily limited by availability of ROW space and may not be feasible at all for city center access shared ROW. These corridors typically are narrow with limited space even for alongside corridors. However, the usefulness of physical separation declines when a highway accident involves vehicles that are out of control as a result of some sudden incapacity of the driver. These instances are expected to be rare (no statistical information has been located); nevertheless, they should be considered if physical separation is the chosen mitigation measure.

Work performed by the AREA involving data on the lateral dispersion of derailed conventional trains revealed that the dispersion distances varied widely with the conditions associated with the accidents. Lateral dispersions of train equipment of over 100 feet were noted [17].

2.3.4 Grade Separation

Grade separation involves a vertical separation between users of a shared ROW, such as by placing one user on an elevated structure or in a cut or tunnel. For maglev systems, elevated structures are often assumed as part of the system design criteria.

Grade separation by itself will not eliminate physical infringement, because grade separation introduces new risks. For example, in 1977, a Chicago transit train collided with another train on an elevated structure and several cars fell to the street below.

For effectiveness, grade separation involving elevated structures will require support columns that are reinforced to withstand collisions with derailling or crashing vehicles. In general, columns represent a greater danger to crashing highway vehicles than barriers which distribute the crash force. As a result, impact force absorption and distribution measures should be evaluated for columns laid out along a highway ROW. Placement of intrusion detecting devices around guideway columns also should be evaluated for immediate detection of a collision with the column. A tie-in to the ATC should be considered for automatic intrusion response. Means to detect guideway misalignment also must be included, particularly for maglev systems.

Perhaps the most expensive grade separation technique is the use of tunnels. From a performance standpoint, tunnels potentially can mitigate the risks associated with all of the safety issues considered in this study. Tunnels could be designed to virtually eliminate the possibility for physical infringement, unauthorized access, HAZMAT-related accidents and some forms of dynamic interference. Further, the tunnel can provide an effective barrier for undesired EMF effects. Possible disadvantages of tunnels include more difficult access for workers and startle effect of the existing HSGGT vehicles. Because of the very high expense and the time required for tunnel construction, it is assumed the purposes of this study that tunnels are a "last resort" mitigation measure, i.e., to be considered only if all other more cost-effective measures cannot mitigate risks adequately.

Grade separation is one of the most expensive mitigation measures considered. A recent study by Booz, Allen & Hamilton for WMATA found that vertical separation of 3 meters (10 feet) between WMATA's Metro guideway and adjacent railroad tracks would cost approximately \$31 to \$37 million per km (\$50 to \$60 million per mile) [15]. The tighter design and construction criteria required for HSGGT elevated guideways would increase the cost of grade separation for HSGGT systems considerably. The construction challenges and costs of placing one user in a tunnel would be extreme and probably unreasonable.

2.3.5 Time Separation

Time separation refers to scheduling of existing mode operations outside the operating window of HSGGT trains or vice versa. This measure could only be used for tracks that carry HAZMAT and railroads.

Time separation may be an effective mitigation measure for HAZMAT scenarios involving highway vehicles. Rerouting of HAZMAT shipments away from the shared ROW corridor also may be effective. Wide-scale rescheduling of HAZMAT trains to achieve time separation may not be feasible because most freight trains carry some hazardous materials. Even rescheduling of non-HAZMAT trains will be difficult due to the 24-hour operation of railroads and their private ownership.

Cost of time separation would be low to the HSGGT operator but probably significant to the Other User.

2.3.6 Speed Reduction

Speed reduction of railroad operations could be considered as a mitigation measure in some cases. Since lateral dispersion and severity of a train derailment is a direct function of train speed, derailment of a slower moving train would reduce the relative consequences of any railroad train derailment scenario.

The feasibility of speed reduction as a mitigation measure depends on the length of the common corridor section as well as on the type of traffic on the adjacent railroad. For short distances, a significant decrease in the operating speed of the railroad generally will not adversely

to-end operating schedules. However, over longer distances, this effect can be significant. For example, assuming a common corridor length of 194 km (120 miles), with the railroad operating speed of 97 km/hr (60 mi/hr), a 50 percent speed reduction for all trains would result in a 2-hour increase in travel times. This may hurt the railroad's competitive advantages in intermodal, perishable, and other time-dependent markets. Also, since only a small percentage of railroad accidents occur in stretches of high-speed running, wholesale speed reduction requirements may not be effective. Locally imposed speed limits in areas particularly prone to derailments should be reviewed with the railroads on an individual site-by-site basis.

Costs of speed reduction would be small to the HSGGT operator, but could be significant to the railroads.

2.3.7 Sensors

Sensor systems can be used effectively to reduce the frequency of hazardous shared ROW scenarios. Sensors can be used throughout the shared ROW to provide early warning of many of the potentially dangerous situations described in the scenarios developed in this study. The following sensor systems are candidates for shared ROW applications:

- Guideway misalignment sensors
- Intrusion sensors
- Flood sensors
- Pipeline leak sensors

Linking of sensor systems to the automatic train control equipment can provide the additional benefit of automated response to a dangerous situation. As part of the NMI Program, several ongoing studies are evaluating the feasibility of sensor systems for various maglev applications. These include:

- BAA Project 146: "Maglev Guideway and Route Integrity Requirements" (Martin Marietta): The study includes an investigation of active sensors as a guideway integrity mitigation measure.
- BAA Project 154: "Verification Methodology for Fault Tolerant, Fail-Safe Computers Applied to Maglev Control Systems" (Charles Stark Draper Labs): The study includes sensors as part of maglev control systems.

- **BAA Project 98: “Guideway Sensor Systems” (Babcock & Wilcox):** The study investigates the use of various types of sensors for guideway diagnostics and control systems.

Although these studies are focusing specifically on potential maglev applications, the results are directly related to both maglev and HSR systems.

2.3.7.1 Guideway Misalignment and Intrusion Sensors. Guideway misalignment and intrusion sensors may be used as a mitigation against elevated guideway damage or HSGGT ROW intrusion. The basic function of the sensors is to detect when an elevated portion of an HSR or maglev guideway is misaligned beyond the tolerances specific to the two HSGGT modes. The guideway misalignment may be caused by several shared ROW events, such as a highway vehicle collision with a support post or ground erosion caused by a waterway flood. Intrusion sensors would be used to detect physical infringement of the HSGGT operating envelope by vehicles from the adjacent mode. Sensors are effective only if the detected problem is communicated to the approaching HSGGT trains for immediate response. This action may be manual with status of the detected problem shown on a display panel in the HSGGT central control facility followed by verbal communication to the train operators. Automatic response may be provided with a link into the train control system and automatic braking of approaching trains.

Train control systems have become increasingly more sophisticated. While fully automatic, driverless operation of HSR trains has not been implemented, Automatic Train Protection (ATP) and Automatic Train Supervision (ATS) systems are provided on existing HSR systems. Typical ATP and ATS equipment is microprocessor-based with the capability to process large volumes of data quickly and accurately. The system could be configured such that trains immediately approaching misaligned guideway or track section would be commanded to emergency brake. Trains moving toward the affected area would be controlled to a service stop. Automatic response would eliminate human reaction time following detection of a problem.

Sensor systems, especially intrusion detectors, must be made robust to preclude false alarms as a result of vandalism and tampering. False alarms must be minimized if automatic response is provided via the ATP system.

Intrusion sensors may provide a further benefit to highway vehicle operators approaching the accident scene by giving a warning of the impending delay or possible danger in areas with limited visibility. Remotely controlled warning signs, installed at frequent intervals throughout the shared ROW length, could be tied into the intrusion sensor system or alarm signals could be sent directly to an automobile equipped with Intelligent Vehicle Highway System (IVHS) technology.

The feasibility and cost of guideway misalignment sensors for HSGGT systems are currently under evaluation by Martin Marietta [3]. ROW intrusion sensors are used in several places in North America. The Washington Metropolitan Area Transit Authority (WMATA) has installed intrusion detecting systems on several of its common corridor routes, where Metro trains share the ROW with Amtrak and freight train operations. The WMATA system is tied into the automatic train control system providing automatic response to intrusion.

Cost of this equipment has been reported at about \$56,000 per km (\$90,000 per mile). Similar costs could be expected in an HSGGT system.

2.3.7.2 Flood Sensors. Flood sensors would be implemented to detect the rising level of a waterway. Flood sensors would be used in HSGGT/waterway shared ROW. Based on the detected water activity, an alarm would be triggered in the HSGGT operations control center. Information provided by the flood sensor system would signal that operations be restricted or stopped in the endangered section of the HSGGT/waterway shared ROW. In general, waterway levels do not increase at a rapid rate. As a result, automatic response to dangerous conditions is not necessary.

Water level detectors have been in use for many years and do not represent significant technical challenges. Complete flood sensor systems are expected to cost less than comparable lengths of guideway intrusion sensor systems, which are similar in concept.

2.3.7.3 Pipeline Leak Sensors. Pipeline leak sensors would be implemented to detect significant leaks through the pipeline structure. Pipeline leak sensors would be used in HSGGT/pipeline shared ROW. When a leak is detected, an alarm would be triggered in the HSGGT operations control center. The information provided by the pipeline leak sensor system would signal that operations be stopped through the endangered section of the shared ROW. Since massive pipeline ruptures which endanger the adjacent HSGGT ROW may begin abruptly, automatic response to a pipeline leak sensor system would be desirable. The automatic response system would be integrated into the train control

equipment, where a command would be issued to stop an HSGGT train approaching that section of the shared ROW where a leak has occurred.

Various types of water flow sensors are in use today. These devices have been demonstrated to be reliable and will form the main portion of a leak detecting system. Overall, the technology is not expected to present significant technical challenges. Pipeline leak sensors, similar in complexity to guideway intrusion detection systems, are not expected to be more costly than comparable lengths of the intrusion system implementations.

2.3.8 Ditches

In the context of shared ROW with HSGGT, ditches are considered to be good candidates for preventing the Other Users from entering the HSGGT envelope.

A ditch that is approximately “V” shaped in cross section is an effective technique for containing a derailing guided vehicle such as a railroad train or a highway vehicle. In general, the ditch should contain a worst-case derailing guided vehicle or a crashing highway vehicle, thereby preventing it from infringing on the HSGGT system. The ditch depth and specific contours will vary based on the environmental and operating conditions associated with the two modes that share the ROW. Ditches are used as an intrusion mitigation technique by SNCF, the French National Railroad, between their TGV-Atlantique high-speed line and an adjacent highway.

Ditches require less space than physical separation and are relatively inexpensive to build. The ditch simply may be a V-shaped wedge in the ground, with natural soil slopes. It is important that the use of a ditch to protect the HSGGT system from physical infringement does not create a safety hazard for the other user. Thus, ditch design should consider factors such as the tendency for highway or conventional rail vehicle to roll over, somersault or collide with the side of the ditch.

Ditch designs are expected to be a minimum of 9.1 meters (30 feet) wide and therefore will require some real estate space. As such, ditches may not be feasible for city access corridors, where space is at a premium. With the exception of potential additional real estate costs, ditches are not expected to cost more than the barriers discussed below in Section 2.3.9.

2.3.9 Redirecting Barriers

A special redirecting barrier—that is, a crash barrier designed to absorb impact energy by deforming or “crushing”—may be considered for mitigation. The barrier design should be developed such that it will contain a worst-case accident. The design criteria will vary based on the type of equipment (e.g., freight trains versus highway vehicles) and on the operating parameters. The impact-absorbing feature may be provided through a variety of means, for example:

- Placement of sand barrels alongside the barrier wall
- Use of collapsible materials layered on the side of the barrier wall
- Design of a collapsible metal structure next to the barrier wall.

Site-specific evaluations would be necessary to determine the effectiveness of each approach.

Redirecting barriers are frequently used on the highways to protect highway construction zones from vehicle traffic. While narrower than ditches, redirecting barriers require more space than crash barriers. A redirecting barrier may not be feasible in cases where city center corridors are extremely constrained by space limitations, or on overpasses.

Costs of redirecting barrier designs will vary widely based on the modes and operating parameters involved. Mitigation against highway vehicles is expected to be least expensive, with barrier designs for heavy, fast freight trains the most costly.

2.3.10 Crash Barriers

An example of barrier placement in a highway-railroad-HSR shared ROW situation is provided in Figure 2-10 [18]. Similarly to the redirecting barrier, the crash barrier should be developed such that it will contain a worst-case derailling guided vehicle or a crashing highway vehicle. The specific design depends on several factors, including the type of equipment operating on the mitigated mode and the speeds of the modes involved.

Crash barriers are in wide use today on highways, railroads, and other transportation modes. In terms of space requirements, crash barriers provide the most space-conservative means for protecting

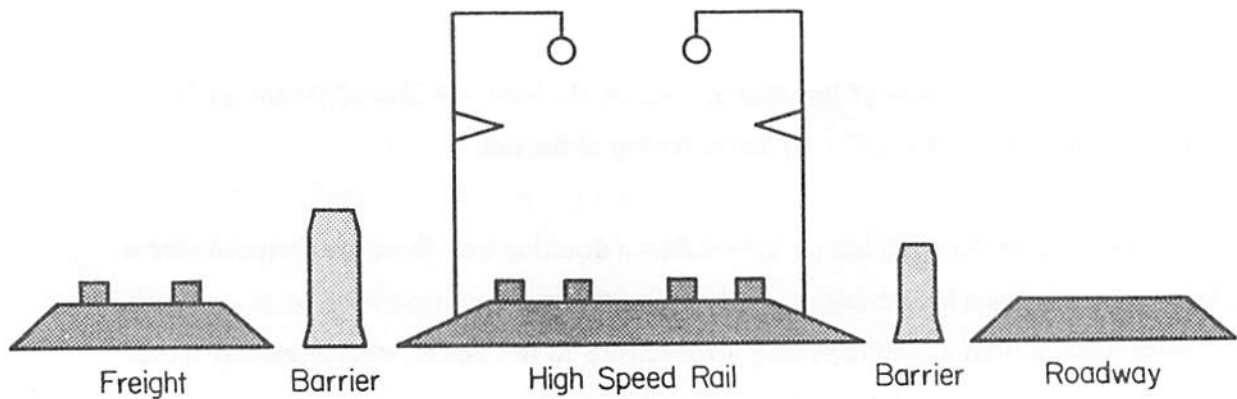


Figure 2-10. Example of Barrier Placement in Highway-Railroad-HSR Shared ROW Situation (from Reference 18)

against physical infringement. In space-constrained city center access corridors, crash barriers may be the only feasible mitigation measure.

Costs of barrier designs are related directly to wall size and impact performance requirements. For example, the Maryland Department of Transportation estimates that a 61 cm high, 25 cm wide (2-foot high, 10-inch wide) barrier for highway traffic containment costs about \$327,000 per km (\$528,000 per mile). Barriers with higher performance criteria required for railroad traffic containment will be more expensive.

The most relevant existing guidelines for crash barriers are contained in Chapter 8, Part 2 of the AREA Manual for Railway Engineering [15]. The specifications contained in this manual are written purposely in general terms, primarily because of the site-specific nature of the requirements for crash barriers (e.g., alignment, embankment, train speeds and masses, nearby structures, acceptable risk). One of the active assignments of AREA's Committee 8 is to refine this specification for the range of environmental and operating conditions that exist on railroad systems [17].

The current focus of the specification is on pier-supported highway bridges that pass over the railroad ROW. The AREA recommends that reinforced concrete crash barriers be considered "as conditions warrant" for piers located within 15.2 meters (50 feet) of the track centerline, and be required for piers located within 7.6 meters (25 feet) of the track centerline. It is recommended that the crash barriers be at least 0.8 meters (2.5 feet) thick, 3.7 meters (12 feet) long and "firmly" anchored to the pier footing. For separation distances of from 3.7 to 7.6 meters (12 to 25 feet), it is recommended that the height of the crash barriers be at least 1.8 meters (6 feet) above the top of the

rail. For separation distances of less than 3.7 meters (12 feet), the Manual recommends crash barrier heights of at least 3.7 meters (12 feet) above the top of the rail.

The intent of the crash barrier is to deflect a derailing train from the protected pier at relatively large oblique impact angles. It is generally considered impractical to design crash barriers to absorb impacts from a train impacting perpendicular to the barrier, even at modest speeds.

It is apparent that crash barrier designs to mitigate physical infringement of an HSGGT vehicle on the Other User must be developed on a case-by-case basis. For example, the kinetic energy associated with an HSGGT train with a mass similar to that of a conventional train but impacting at three times the velocity will be nine times greater than for the conventional train. The crash barrier design for the conventional train impact would need to be modified to withstand the greater impact from the HSGGT train. This could be accomplished in several ways. For example, the same basic dimensions could be maintained but different, stronger materials used. Alternatively, the appropriate dimensions of the crash barrier could be increased, depending on how it responds to the applied impact loads (e.g., in bending, shear, torsion, or combinations thereof).

Based on these considerations, it seemed to be beyond the scope of this study to develop specific design specifications for crash barriers in shared ROW situations. As a point of reference, the AREA Committee 8 identified about 400 different impact cases associated only with conventional trains impacting pier-supported bridges [17]. The number of cases associated with the candidate shared ROW combinations considered in this report is expected to be much greater than 400.

Cost of barriers is related to the impact performance requirements and characteristics of the site, which in turn dictate the specific design.

2.3.11 Tree Barriers

Trees could be placed in a continuous or intermittent row between the two Users to reduce visual “startle” effects and, to some degree, turbulence effects. Trees or artificial barriers similar in height also could reduce the effect of blown snow. Some concern has been expressed that the trees or other barriers might cause a “strobe” effect, which would annoy or distract HSGGT passengers or crew. Costs of this mitigation measure would be relatively low.

2.3.12 Turbulence Barriers

Turbulence barriers could be used to reduce turbulence effects caused by HSGGT trains passing conventional railroad passenger platforms. These barriers could be built from corrugated or flat sheet metal panels or concrete panels.

Turbulence barriers could be used through passenger station platform areas and other parts of the shared ROW where persons may be present on a regular basis. The French Railways have installed similar barriers on the approaches to the Paris Montparnasse terminus of the TGV-Atlantique. Their function is to abate noise and to isolate the TGV and shared railroad tracks from neighboring apartment subdivisions. A similar barrier concept is used throughout the United States to isolate urban freeways from surrounding communities. The Maryland Department of Transportation estimates the cost of such barriers to be \$291 per square meter (\$27 per square foot). Assuming that a typical noise abatement barrier is 3.7 meters (12-feet) high, the cost for such barriers would be approximately \$1,050,000 per km (\$1,700,000 per mile). Costs for shared ROW turbulence barriers are expected to be in the same range.

2.3.13 Railroad Equipment Maintenance

HSGGT systems could employ a full range of failed equipment detectors. Several types of equipment and train defects are monitored by detectors on mainline railroads. Railroad defect detectors serve a variety of purposes and have a wide range of sophistication. Detectors are used typically for overheated car axles, dragging equipment, and excessive car weight. While these systems are unable to detect some equipment-caused derailments, they are effective in reducing the overall frequency of railroad accidents.

The detection of equipment defects on railroad trains reduces the two front-end elements of the risk cycle probability of derailment and probability of intrusion. Railroad equipment failure sensors have been installed throughout the U.S. rail system. These systems use mature technology and may be readily implemented in shared ROW.

The market for this equipment is fully developed, with competitive pricing from numerous companies. Examples of prices for railroad equipment failure sensors are:

- Overheated car axle (hot box) detectors - \$24,000
- Dragging equipment detectors - \$1,100
- Excessive car or lading dimensions detectors - up to \$10,000.

Sensors for HSGGT shared ROW applications are expected to fall in these ranges.

Locomotives and rail cars are subject to Federal Railroad Administration (FRA) regulations which govern the safety of train operations nationwide. Records are kept for locomotives which require special inspections and repairs for varying time periods ranging from daily to annually. Requirements are less stringent and much less detail is maintained for freight cars. The FRA enforces its regulations through a staff of field inspectors using random, surprise visits to railroad facilities. The AAR [20] prescribes additional regulations which govern the condition of freight cars for the interchange between railroad carriers.

Certain aspects of train operations are also governed by federal regulation. For example, the braking system must be known to be in working condition. A thorough visual inspection by qualified personnel is required at least every one thousand miles for long-distance train operation. On most railroads, visual roll-by inspections by railroad employees also occur for trains between terminals and interchanges.

Strict enforcement of railroad maintenance practices should not bring any additional costs to the operating railroads involved in shared ROW operations. Strict adherence to maintenance procedures will supplement equipment failure sensors in preventing railroad accidents caused by equipment failures.

2.3.14 Operating and Maintenance Procedures

New procedures may be developed to address those specific scenarios where new operating practices could decrease the frequency of occurrence. The procedures would address the specific requirements of shared ROW operations. New procedures and regulations may be considered for HAZMAT traffic as well as for maintenance personnel involved in maintaining the ROW adjacent to the HSGGT system.

Established operating and maintenance practices can help in both risk prevention and risk reduction. Railroads throughout the country have established an extensive set of operating and maintenance standards and procedures designed to keep the infrastructure and equipment in proper operating condition. These procedures should be evaluated carefully for applicability to the shared ROW operating and maintenance practices. Frequent inspections of the condition of infrastructure and equipment, as well as enforcement of adherence to procedure must take place to ensure that standards and safety are not compromised.

2.3.15 EMF Mitigation

Frequency of detrimental EMF effects could be diminished by reducing the strength of the electromagnetic field or by increasing the tolerance to the electromagnetic field. For maglev systems, strength reduction can be achieved by energizing the guideway only when a train is present, shielding the motors to reduce electromagnetic emissions, increasing the distance between the guideway and the Other User (either horizontally or vertically), or installing an electromagnetic shield to absorb or reflect the field. This can be done by erecting a steel or concrete wall or by placing the maglev in a tunnel. Tolerance of the field could be increased by proper grounding to dissipate the electromagnetic field or using nonconductive or corrosion-resistant materials. Because of the common use of structural steel in transportation structures, the last mitigation measure could be impractical.

2.4 ASSUMPTIONS AND RATIONALE FOR RISK ASSESSMENT

The accuracy and precision of a risk assessment of shared ROW is influenced strongly by the historical rarity of HSR accident events (due partly to the relatively recent development of HSGGT systems) and by the absence of a high-speed maglev system in commercial use today. Therefore, it was necessary to develop assumptions that supplement available data and enable the assignment of risk scores.

The following set of general assumptions were developed for the study:

1. Only the effects of the shared ROW are considered. Events that would occur without a shared ROW are ignored.

2. **The HSGGT system can share the ROW with each of the five Other User modes described in Section 2.2 of this report.**
3. **The environmental conditions associated with the system include periods of ice, snow, rain, high winds, and extreme temperatures typical of the continental United States.**
4. **The HSGGT system operates in urban, suburban and rural areas.**
5. **The HSGGT system operates both at grade and on elevated guideways.**
6. **The HSGGT system includes curvatures (vertical and lateral) up to the maximum design values associated with the candidate HSGGTs, including those associated with departures and returns to the shared ROW portions of the system.**
7. **The HSGGT system design is sufficiently robust that accidents caused by design weaknesses are neglected.**
8. **The HSGGT system is designed, built and maintained with sufficient rigor that derailment of an HSGGT vehicle is remote. Analyses used to develop a frequency score for HSGGT derailment are provided in Appendix G. Since no maglev systems are in commercial operation, it was assumed that their derailment probability is the same as for HSR.**
9. **Because of the high operating speeds associated with the HSGGT, and the corresponding long available operator reaction times, the operator cannot brake the vehicle to avoid another vehicle or obstacle.**
10. **HSGGT and Other Users' workers require access to all parts of the system for inspection, maintenance, and repair activities.**
11. **Initially, the HSGGT system is located as close as physically possible and permitted by existing ROW specifications, with no barriers or mitigation devices except those that already exist and were installed for Other User (i.e., physical separation of the two modes is used only as a mitigation measure).**
12. **The burden of mitigation is placed primarily on the HSGGT system and not on the Other User. Further, the approach to mitigation involves identifying whatever measures are required to reduce safety risks to the minimum acceptable level. Cost-benefit analyses of mitigation were beyond the scope of this study.**
13. **Events caused by natural disasters such as earthquakes, hurricanes, and tornadoes are neglected. It is assumed that the system design accounts for such extreme, site-specific events, which would occur without the presence of the shared ROW.**
14. **The application of mitigation measures will reduce risk by two levels of frequency or consequence unless circumstances suggest otherwise.**

15. An HSGGT system deployed in the U.S. will meet or exceed the safety criteria established for existing HSGGT systems. There are three HSGGT systems currently in operation. These are:

- Shinkansen lines in Japan
- TGV lines in France
- High-speed lines for the ICE train in Germany

Each country has established design criteria for its high-speed equipment and infrastructure, as well as strict operating procedures and guidelines. These criteria and operating rules have proven effective through years of successful and safe operation.

2.5 RELATED ONGOING STUDIES

Several concurrent studies are focusing to some extent on issues related to shared ROW safety with HSGGT systems. The final results of these studies were not available for consideration in this project. However, when the results of these other studies are available, the data and assumptions used to develop the risk scores presented in this report should be reviewed and refined as needed.

Related ongoing studies, which are being funded through the FRA's Broad Agency Announcement (BAA) Program under the National Maglev Initiative (NMI) are listed in Table 2-8. In addition to these studies, related work on HSGGT technologies currently is under way by Arthur D. Little on a contract to VNTSC entitled "Collision Avoidance and Accident Survivability." Furthermore, research to refine the AASHTO and AREA guidelines for barrier design is a continuous process and will influence the development of specifications for barrier design for shared ROW with HSGGT systems.

Table 2-8. Concurrent Maglev Studies Which are Related to Shared ROW with HSGGT

BAA No.	Contractor	Title	Relevance to Shared ROW Safety with HSGGT
35	General Electric Company	Novel Cryogen-Free, Actively Shielded Superconducting Magnets for Maglev Vehicles	EMF Shielding Requirements
49	Kaman Science Corporation	Parametric Studies of Suspension and Propulsion Subsystems in a Maglev Transportation System	Passive and Active EMF Shielding Requirements
98	Babcock & Wilcox	Guideway Sensor Systems	Sensor Requirements for Control and Detection
111	Martin Marietta	Maglev Guideway Route Alignment and Right-of-Way Requirements	Cost-Benefit Assessment of Route Alignment
129	West Virginia University	State-of-the-Art Assessment of Guideway System for Maglev Applications	EMF Effects on Structures and Control Systems
138	Battelle	Evaluation of Concepts for Safe Speed Enforcement	Requirements for Speed Control Systems
146	Martin Marietta	Maglev Guideway and Route Integrity Requirements	Requirements for Active Sensors
154	Charles Stark Draper Labs	Verification Methodology for Fault Tolerant, Fail-Safe Computers Applied to Maglev Control Systems	Requirements for Fault Tolerant, Fail-Safe Control Systems
187/8	Electric Research & Management	Sample Measurement and Analysis of Magnetic Fields from Several Existing Transportation Systems	EMF Characteristics of Transportation Systems
191	Harris Miller Miller & Hanson	Noise from High-Speed Maglev Systems	Mitigation of Noise as a Startle Effect
206	Parsons Brinckerhoff	Maglev-Rail Intermodal Equipment & Suspension	ROW Access to Large Cities
223	University of Washington	Design Assessment of Alternate Feeder Systems for Maglev Intermodal Stations	Requirements for Intermodal Stations

3. RESULTS

The results of the study are presented in Sections 3.1 to 3.6 for the six safety issues. For each safety issue, the results are presented in the following format:

- Detailed description of safety issue
- Scenario descriptions
- Risk scores
- Recommended mitigation measures

The Appendices to this report contain the “working papers” that were used to evaluate each scenario. These provide detailed descriptions of the processes used to develop scores for frequency, consequence, and risk; discussions of the assumptions and judgements used in the scoring process; and descriptions of the candidate mitigation measures that were considered appropriate for each high-risk scenario.

3.1 PHYSICAL INFRINGEMENT

Physical infringement in a shared ROW situation involves the encroachment of one user onto the other user. This definition excludes HSR-related events that involve the use of common trackage; these events are covered under the Infringement on Common Trackage safety issue (see Section 3.4).

A critical assumption was that a “derailment” of an HSGGT vehicle from its track or guideway was remote (between once per 100 years and once per 1000 years). This assumption is based on the following considerations:

- There have been no known derailments of any of the existing HSGGT systems at high operating speeds.
- No maglev system has been in commercial operation.

An analysis was performed in this study to substantiate this assumption using actual HSGGT ridership data. This analysis is provided in Appendix G.

This assumption implies that any HSGGT design will be sufficiently robust to ensure a very low probability of derailment. A similar assumption was made by the VNTSC preliminary safety review of the Transrapid system [2], although it was assumed that derailment of the system was improbable.

The following information and assumptions on the Other Users were used in risk assessment:

- High Voltage Transmission Lines: Limited data for the Midwestern U.S. suggest that the probability of a down transmission line over an 81 km (50-mile) stretch is once in 5 years [21].
- Highways: Fatal accidents on interstate highways occur at an annual rate of about 0.058 per km (0.094 per mile) [Highway Statistics].
- Railroads: Trains on U.S. railroads derail at an annual rate of about 0.0026 per route-km (0.0042 per route-mile) per year, excluding yard tracks, sidings, and derailments below 16 km/hr (10 mi/hr) [22]. Lateral dispersion of a derailed train can exceed 30 meters (100 feet) [17].
- Waterways: Flood-prone rivers are assumed to flood once per decade, even in urban areas.
- Pipelines: There are 789,006 km (489,184 miles) of natural gas and oil pipeline in the United States [23]. There were 454 failure accidents reported in 1989 [24]. Half of these were assumed to be bursts which could result in pipeline material entering the HSGGT system.

3.1.1 Scenario Descriptions

Sixteen scenarios were developed for this safety issue. Detailed descriptions of each scenario are provided in Appendix A. These descriptions were based on the following events:

- A truck leaves the highway and enters into the path of an HSGGT vehicle.
- A rail vehicle derails into the path of an HSGGT vehicle.
- A high-voltage transmission line falls on an HSGGT track or guideway.
- A pipeline bursts and sends liquid onto the HSGGT system.

- A waterway floods and sends water onto the HSGGT system.
- An HSGGT vehicle derails into any of the Other Users.

Collisions between HSR trains that result in physical infringement on the other mode were considered in the scenario identification process. However, in the shared ROW sense trains infringing as a result of derailment or collision are not different. At speeds above 300 kph (186 mi/hr), the lateral dispersion distances of a derailed train are a train that has collided with another train are probably similar. Therefore, the consequence category would be the same, with perhaps increased severity. A slow-speed collision, which does not result in physical infringement is outside the scope of this study.

3.1.2 Risk Assessment Summary

A summary of the risk scores developed for the physical infringement scenarios is provided in Table 3-1. As indicated in the table, 12 of the 16 scenarios were scored as high-risk and requiring mitigation. Risk scores in the unacceptable category were associated with scenarios involving either a highway vehicle or train leaving its system and entering the HSGGT operating envelope, failure of a transmission line or pipeline, oversize loads on a railroad, and scenarios involving flooding. Scenarios with risk scores that are undesirable (a lower rating that still requires mitigation) were associated with the derailment of an HSR vehicle into a highway or railroad, and pipeline bursts. The other scenarios were determined to have acceptable risk levels.

3.1.3 Recommended Mitigation Measures

The following mitigation measures are recommended for treating high-risk events related to physical infringement:

3.1.3.1 Highways. Measures are necessary to reduce the probability of encroachment of a highway vehicle into the HSGGT operating envelope. Several levels of mitigation can be effective for this purpose, and their suitability depends primarily on the maximum available separation distance between systems. As discussed earlier in this report, AASHTO's Roadside Design Guide [25] provides guidelines for designing a wide range of barriers and guard rails as well as "clear zones" which provide enough distance for drivers to navigate their vehicles safely back onto the highway.

Table 3-1A. Summary of Scenario Risk Assessment Safety Issue: Physical Infringement (Reference: Appendix A)

Instigator**	Affected Mode**	Scenario Code*	Pre-Mitigation Frequency Score	Pre-Mitigation Consequence Score	Pre-Mitigation Risk Score	Post-Mitigation Frequency Score	Post-Mitigation Consequence Score	Post-Mitigation Risk Score
HWY	HSR	1.3.1	B - Probable	I - Catastrophic	2 - Unacceptable	D - Remote	I - Catastrophic	8 - Undesirable
HWY	MAGLEV	1.3.2	B - Probable	I - Catastrophic	2 - Unacceptable	D - Remote	I - Catastrophic	8 - Undesirable
RR	HSR	1.4.1.a	B - Probable	I - Catastrophic	2 - Unacceptable	D - Remote	I - Catastrophic	8 - Undesirable
RR	MAGLEV	1.4.2	B - Probable	I - Catastrophic	2 - Unacceptable	D - Remote	I - Catastrophic	8 - Undesirable
TL	HSGGT	1.7.0	B - Probable	I - Catastrophic	2 - Unacceptable	D - Remote	I - Catastrophic	8 - Undesirable
WWY	HSR	1.5.1	C - Occasional	I - Catastrophic	4 - Unacceptable	E - Improbable	I - Catastrophic	12 - Acceptable
WWY	MAGLEV	1.5.2	C - Occasional	I - Catastrophic	4 - Unacceptable	E - Improbable	I - Catastrophic	12 - Acceptable
PL	HSGGT	1.6.0	C - Occasional	I - Catastrophic	4 - Unacceptable	E - Improbable	I - Catastrophic	12 - Acceptable
HSGGT	HWY	1.1.3.a	D - Remote	I - Catastrophic	8 - Undesirable	E - Improbable	I - Catastrophic	12 - Acceptable
HSGGT	RR	1.1.4.a	D - Remote	I - Catastrophic	8 - Undesirable	E - Improbable	I - Catastrophic	12 - Acceptable
HSGGT	TL	1.1.7	D - Remote	I - Catastrophic	8 - Undesirable	E - Improbable	I - Catastrophic	12 - Acceptable
RR	HSR	1.4.1.b	D - Remote	I - Catastrophic	8 - Undesirable	E - Improbable	I - Catastrophic	12 - Acceptable
HSGGT	PL	1.1.6	D - Remote	II - Critical	10 - Acceptable	-	-	-
HSGGT	HWY	1.1.3.b	E - Improbable	I - Catastrophic	12 - Acceptable	-	-	-
HSGGT	RR	1.1.4.b	E - Improbable	I - Catastrophic	12 - Acceptable	-	-	-
HSGGT	WWY	1.1.5	E - Improbable	I - Catastrophic	12 - Acceptable	-	-	-

* Scenario Descriptions and Risk Assessment Summaries for this Safety Issue Are Provided in Appendix A.

**HSGGT = Maglev + High-Speed Rail
 HSR = High-Speed Rail
 HWY = Highway
 RR = Railroad

WWY = Waterway
 PL = Pipeline
 TL = Transmission Line

Table 3-1B. Abstracts of Physical Infringement Issue

- 1.3.1 - A fully loaded semi-trailer truck leaves the highway and goes onto the HSR track. An HSR train at its cruising speed collides with the truck. Casualties include truck occupants and HSR train passengers.
- 1.3.2 - A fully loaded semi-trailer truck leaves the highway and goes onto the maglev guideway. A maglev train at its cruising speed collides with the truck. Casualties include truck occupants and maglev passengers.
- 1.4.1.a - fully loaded railroad train derailed at its cruising speed and the railroad vehicles scatter onto the HSR track. An HSR train at its cruising speed collides with the railroad vehicles. Casualties include railroad train occupants and HSR passengers.
- 1.4.2 - Railroad train derailed at its cruising speed and the vehicles scatter onto the maglev guideway. A maglev train at its cruising speed collides with the railroad vehicles. Casualties include railroad train occupants and maglev passengers.
- 1.7.0 - A transmission line falls onto the HSGGT ROW. An HSGGT train at its cruising speed collides with the cable and sustains major damage.
- 1.5.1 - The waterway floods the HSR track. An HSR train then derailed at its cruising speed. Casualties include HSR train passengers.
- 1.5.2 - The waterway floods the maglev guideway. A maglev train derailed at its cruising speed. Casualties include maglev train passengers.
- 1.6.0 - A non-HAZMAT pipeline bursts and the flood causes a HSGGT train to derail at cruising speed. Casualties include HSGGT train passengers.
- 1.1.3.a - An HSGGT train derailed at cruising speed and HSGGT vehicles scatter onto the highway. Numerous highway vehicles crash into the derailed HSGGT vehicles. Casualties include HSGGT passengers and occupants of highway vehicles.
- 1.1.4.a - An HSGGT train derailed at cruising speed and HSGGT vehicles scatter on the railroad track. A railroad train collides at its cruising speed with the derailed HSGGT vehicles. Casualties include HSGGT train passengers and those on the railroad train.
- 1.1.7 - The shared ROW is located in an urban area. An HSGGT train derailed at its cruising speed and the HSGGT vehicles collide with the transmission line tower. The tower collapses onto nearby houses. Casualties include HSGGT train passengers and inhabitants of the affected houses.

Table 3-1B. Abstracts of Physical Infringement Issue (Continued)

- 1.4.1.b - A railroad car with shifted cargo infringes on the HSR ROW. An HSR train crashes at its cruising speed into the shifted cargo. Casualties include the HSR train operators.
- 1.1.6 - An HSGGT train derails at its cruising speed and the HSGGT vehicles break an underground pipeline. Delivery of pipeline product is interrupted. Casualties include HSGGT train passengers.
- 1.1.3.b - An HSGGT train derails at cruising speed and collides with support columns of a highway. The columns collapse together with a section of the elevated highway. Highway vehicles collides with the collapsed section. Casualties include HSGGT train passengers and occupants of highway vehicles.
- 1.1.4.b - An HSGGT train derails at cruising speed and the derailed HSGGT vehicles strike support columns of the railroad ROW. A section of track collapses. A railroad train at its cruising speed falls into collapsed section. Casualties include HSGGT train passengers and occupants of the railroad train.
- 1.1.5 - An HSGGT train derails at its cruising speed and HSGGT vehicles scatter into the waterway. Boats collide with the HSGGT vehicles. Casualties include HSGGT train passengers and boat occupants.

The most cost-effective mitigation technique would be to locate the HSGGT system outside the clear zones. For situations where the HSGGT system occupies space that was previously in the clear zone, other mitigation techniques must be used to prevent encroachment of the highway vehicle. The AASHTO Roadside Design Guide [25] would be used as the primary source for designing appropriate highway vehicle barriers on a site-specific basis. The cost of barriers will increase with impact performance (i.e., the ability to absorb energy from impact of an X ton vehicle at Y mi/hr and Z impact angle). Therefore, cost/benefit analyses should be performed to determine the extent to which barriers are useful to prevent worst-case impacts (e.g., a 100 km/hr (65 mi/hr) direct impact of a fully loaded semi-trailer into a crash wall). Additional work involving the cost/benefit aspects of mitigating physical infringement is being performed by Martin-Marietta under BAA Project No. 111, entitled "Maglev Guideway Route Alignment and ROW Requirements." The results of their work should be factored into decisions regarding mitigating the risk of physical infringement in a shared ROW situation.

A hierarchy of recommended mitigation measures is presented below in order of decreasing lateral distance between systems sharing the ROW:

- Construct system beyond all highway clear zones.
- Construct a ditch between systems that contains encroaching highway vehicles.
- Construct redirecting barriers with impact force absorption systems to restrain encroaching highway vehicles.
- Construct crash barriers with no impact force absorption systems to restrain encroaching highway vehicles.
- Provide sufficient grade separation of systems.

In addition to these treatments, intrusion sensors are recommended for detecting the presence of a vehicle in the HSGGT operating envelope. This treatment would be effective only in situations where there is sufficient stopping distance for the HSGGT to avoid a collision.

3.1.3.2 Railroads. Mitigation measures are based on reducing the probability of derailed trains from encroaching on the HSGGT operating envelope, and are generally similar to those for the Highway category. Since the lateral dispersion of derailed trains has been reported to be greater than 30 meters (100 feet) in at least one case, lateral separation alone probably is not an effective

mitigation measure. Guidelines for crash barriers are provided in the AREA Manual for Railway Engineering [15]. These guidelines should be applied to the design of crash walls on a site-specific basis. A hierarchy of recommended mitigation measures is presented below in order of decreasing lateral distance between systems that share the ROW:

1. Construct a ditch between the two systems that contains encroaching railroad vehicles.
2. Construct redirecting barriers with impact force absorption systems to restrain encroaching railroad vehicles.
3. Construct crash barriers with no impact force absorption systems to restrain encroaching railroad vehicles.
4. Provide sufficient grade separation of systems.

In addition to these treatments, intrusion sensors are recommended for detecting the presence of a vehicle in the HSGGT operating envelope. This treatment would be effective only in situations where there is sufficient stopping distance for the HSGGT to avoid a collision.

3.1.3.3 Pipelines. Mitigation measures are necessary to reduce the probability of a massive pipeline leak encroaching onto the HSGGT operating envelope. Where possible, grade separation should be applied to eliminate paths from the leaking pipeline to the HSGGT system (this includes burying the pipeline). If this is not possible, then leak sensors should be installed in the pipeline system to provide early warning of an impending hazardous event. Furthermore, appropriate pipeline maintenance, inspection, and repair procedures must be in place to handle the leak situation without creating a hazardous situation on the HSGGT system.

3.1.3.4 Transmission Lines. Mitigation measures are necessary to prevent fallen wires from fouling the HSGGT track or guideway. This could be done by “boxing” the track or guideway - placing the HSGGT system in an aboveground tunnel whenever the transmission line is directly overhead or by using intrusion sensors to immediately inform the HSGGT operator of a fallen wire.

Using these mitigation measures, the risk scores of all scenarios could be reduced. However, some scenarios would still have unacceptable risk based on the general assumption that mitigation can reduce risk by two levels of frequency or consequence. The scenarios that remain unacceptable or undesirable include the HSR infringing on a railroad and those where the Other User infringes on the

HSGGT. This result seems reasonable, given the large number of individual Other Users and the relatively little control that the HSGGT operation would have over their activities.

3.2 ELECTROMAGNETIC FIELD EFFECTS

This safety issue involves the unintentional and negative effects of electromagnetic fields (EMF) on equipment and people. Many of these effects have not been well defined or quantified and are now becoming the subject of scientific and popular debate.

Generally speaking, there are three types of electromagnetic fields: electrical, magnetic, and a combination of these, electromagnetic. Each of these types can affect equipment or people that enter the fields. Exposure to the fields can be short- or long-term depending on the nature of the originator and the target. For example, exposure to electromagnetic fields from a passing HSR motor would be short-term for a stationary target such as a highway maintenance worker while exposure to electromagnetic fields from an energized catenary could be long-term for a highway maintenance worker who frequently works near the HSR. Similarly, the effect of that exposure can be short- or long-term. For example, a passing HSR train could cause interference on an AM radio in an automobile but the effect would disappear after the train passed; in contrast, stray currents from an HSR power distribution system could permanently corrode nearby steel structures.

Electromagnetic fields will be created by the HSGGT systems and by the Other Users. The HSGGT systems will create fields from the catenary (for HSR) or the guideway (for maglev), and from any motors installed on the vehicles. Other Users also will create fields from catenaries or motors on conventional railroads, high-powered communication equipment or inadequately shielded electrical systems in highway vehicles, and the transmission of electricity on power lines. Electromagnetic fields created by pipeline and waterway users are expected to be negligible.

Equipment that can be affected by EMF include control and signalling equipment, cellular phones, citizen band radios, police and other emergency service radios, and other communication equipment. Effects could range from simple inconvenience (e.g., a lost cellular call) to a threat to life (e.g., a train switched to an occupied track). Electronic engine and brake control systems on automobiles and trucks also could be degraded or shut down due to electromagnetic interference (EMI). Effects could range from simple inconvenience (e.g., a highway vehicle running poorly) to a

threat to life (e.g., a shutdown of an emergency vehicle or a runaway locomotive). Depending on its strength at the source, electromagnetic fields can affect equipment up to 1 kilometer (.62 miles) away.

Undesirable effects on existing equipment have generally been mitigated as they became known. For example, guidelines exist for designing automobiles to accept outside EMI and to reduce the creation of electromagnetic interference; transmission companies shield their pipelines to reduce corrosion from stray currents from electric railroads; and radiotelescope operators locate their equipment away from likely sources of interference [9].

The Department of Transportation has initiated three studies to quantify or mitigate the electromagnetic fields that could be developed by HSGGT systems. A contractor, Electric Research & Management (ERM), is measuring the electromagnetic fields of several existing transportation systems and creating a database of EMF characteristics for use in designing HSGGT systems. Another contractor, West Virginia University (WVU), is investigating the impact of electromagnetic fields on structural steel and possible interference with control systems. Finally, Kaman Science Corporation is developing passive and active shielding schemes to reduce the level of magnetic fields in electronics compartments.

In contrast to effects on equipment, effects of electromagnetic fields on people are less well understood. While some extreme effects of electromagnetic fields have been well documented, such as the effects of electrocution or acute exposure to microwaves, the effects of long-term or low-level exposure to electromagnetic fields are not well defined. This is particularly true for extremely low-frequency (less than 1000 Hz) electromagnetic fields (ELF) that are expected with HSGGT systems. As reported by Gyuk and Brecher [26,27], recent studies suggest that some biological effects (microscopic changes in cells) will occur due to such exposure but does not suggest that health effects (adverse or beneficial changes to an organism) will occur. The report concludes that there is no scientific basis at this time for regulatory action in response to electromagnetic field health issues.

The DOT has begun a special EMF research program to define and assess health effects of HSGGT systems. These include the two studies described above: ERM is quantifying possible exposure to electromagnetic fields while the Kaman Science Corporation is developing passive and active shielding schemes to reduce the level of magnetic fields in passenger compartments. Additionally, the Environmental Protection Agency (EPA) is developing an "EMF exposure profile" for passengers, workers, and the public and will assess relevant electromagnetic field health effect

research, while Argonne National Laboratory (ANL) is investigating electromagnetic effects on animals.

The lack of information on the nature and extent of health effects relevant to the electromagnetic fields of HSGGT systems precludes creating scenarios to assess the relevant risk. The development of this safety issue covers only the effects of electromagnetic fields on equipment.

The primary assumptions, which were made to evaluate the EMF-related scenarios were:

- The maglev system is a stronger source of electromagnetic fields than a conventional railroad system or HSR system.
- The designs of HSGGT systems do not include features to contain or attenuate any electromagnetic fields, except those necessary to protect HSGGT equipment and passengers.

3.2.1 Scenario Descriptions

Eighteen scenarios were developed for this safety issue and are described in Appendix B. The general events were:

- EMF from an HSR or maglev system disturbs vehicle electronics on the other system, causing a crash.
- EMF from an HSR or maglev system causes corrosion and structural failure of adjacent pipelines, buildings, or structures.
- EMF from an HSR or maglev system disrupts railroad electrical equipment, causing signalling and control problems that lead to a rail vehicle crash.
- EMF from an HSR or maglev system interferes with nearby data transmission lines, causing major disruption of the data transmission system.

3.2.2 Risk Assessment Summary

Table 3-2 shows the risk scores of the Electromagnetic Field Effects scenarios. Seventeen of the eighteen scenarios were scored as high risk and will require mitigation. Fifteen scenarios had risk scores in the Unacceptable category. These were associated with electromagnetic fields emitted from a maglev system and an existing railroad system, that either disrupted critical equipment of the Other

Table 3-2A. Summary of Scenario Risk Assessment Safety Issue: Electromagnetic Field (EMF) Effects (Reference: Appendix B)

Instigator**	Affected Mode**	Scenario Code*	Pre-Mitigation Frequency Score	Pre-Mitigation Consequence Score	Pre-Mitigation Risk Score	Post-Mitigation Frequency Score	Post-Mitigation Consequence Score	Post-Mitigation Risk Score
MAGLEV	HWY	2.2.3.a	B - Probable	I - Catastrophic	2 - Unacceptable	D - Remote	I - Catastrophic	8 - Undesirable
MAGLEV	HWY	2.2.3.b	B - Probable	I - Catastrophic	2 - Unacceptable	D - Remote	I - Catastrophic	8 - Undesirable
MAGLEV	RR	2.2.4.a	B - Probable	I - Catastrophic	2 - Unacceptable	D - Remote	I - Catastrophic	8 - Undesirable
MAGLEV	RR	2.2.4.b	B - Probable	I - Catastrophic	2 - Unacceptable	D - Remote	I - Catastrophic	8 - Undesirable
MAGLEV	WWY	2.2.5	B - Probable	I - Catastrophic	2 - Unacceptable	D - Remote	I - Catastrophic	8 - Undesirable
MAGLEV	PL	2.2.6	B - Probable	II - Critical	5 - Unacceptable	D - Remote	II - Critical	10 - Acceptable
MAGLEV	TL	2.2.7	B - Probable	III - Marginal	9 - Undesirable	D - Remote	III - Marginal	14 - Acceptable
HSR	HWY	2.1.3.a	C - Occasional	I - Catastrophic	4 - Unacceptable	E - Improbable	I - Catastrophic	12 - Acceptable
HSR	HWY	2.1.3.b	C - Occasional	I - Catastrophic	4 - Unacceptable	E - Improbable	I - Catastrophic	12 - Acceptable
HSR	RR	2.1.4.a	C - Occasional	I - Catastrophic	4 - Unacceptable	E - Improbable	I - Catastrophic	12 - Acceptable
HSR	RR	2.1.4.b	C - Occasional	I - Catastrophic	4 - Unacceptable	E - Improbable	I - Catastrophic	12 - Acceptable
HSR	WWY	2.1.5	C - Occasional	I - Catastrophic	4 - Unacceptable	E - Improbable	I - Catastrophic	12 - Acceptable
RR	HSR	2.4.1	C - Occasional	I - Catastrophic	4 - Unacceptable	E - Improbable	I - Catastrophic	12 - Acceptable
RR	MAGLEV	2.4.2	C - Occasional	I - Catastrophic	4 - Unacceptable	E - Improbable	I - Catastrophic	12 - Acceptable
TL	HSR	2.7.1	C - Occasional	I - Catastrophic	4 - Unacceptable	E - Improbable	I - Catastrophic	12 - Acceptable
TL	MAGLEV	2.7.2	C - Occasional	I - Catastrophic	4 - Unacceptable	E - Improbable	I - Catastrophic	12 - Acceptable
HSR	PL	2.1.6	C - Occasional	II - Critical	6 - Undesirable	E - Improbable	II - Critical	15 - Acceptable
HSR	TL	2.1.7	C - Occasional	III - Marginal	11 - Acceptable	--	--	--

*Detailed Scenario Descriptions and Risk Assessment Summaries for this Safety Issue Are Provided in Appendix B.

**HSGGT = Maglev or High-Speed Rail
 HSR = High-Speed Rail
 HWY = Highway

WWY = Waterway
 PL = Pipeline
 TL = Transmission Line

Table 3-2B. Abstracts of EMF Effects Issue

- 2.2.3.a - The maglev system generates electromagnetic fields which disturb electronic equipment in a highway vehicle. The highway vehicle collides with other highway vehicles. Casualties include occupants of the highway vehicles.
- 2.2.3.b - The maglev system generates stray currents which corrode steel structures of the highway. A highway structure collapses and highway vehicles fall into the collapsed section. Casualties include occupants of the highway vehicles.
- 2.2.4.a - The maglev system generates electromagnetic fields which disturb electronic equipment on the railroad. A railroad train does not receive a stop signal and collides with another train stopped in a station. Casualties include railroad train occupants.
- 2.2.4.b - The maglev system generates stray currents which corrode steel structures of the railroad. A railroad structure collapses and a railroad train collides with the collapsed structure. Casualties include occupants of the railroad train.
- 2.2.5 - Maglev system equipment generates electromagnetic fields signals which disturb equipment on a boat. A captain is unable to control his boat and it collides with another boat. Casualties include boat occupants.
- 2.2.6 - The maglev system generates stray currents which corrode steel structures of the pipeline. The pipeline fractures and delivery of the pipeline product is interrupted.
- 2.2.7 - The maglev system generates electromagnetic fields signals which disturb data transmission on the adjacent transmission line. Data transmission is interrupted.
- 2.1.3.a - An HSR train equipment generates electromagnetic fields which disturbs electronic equipment in a vehicle on the adjacent highway. The highway vehicle collides with other highway vehicles. Casualties include occupants of the highway vehicles.
- 2.1.3.b - The HSR system generates stray currents which corrode steel structures of the highway. Corrosion weakens the structure followed by a collapse of a structure section. Highway vehicles fall into the collapsed section. Casualties include occupants of the highway vehicles.
- 2.1.4.a - The HSR system generates electromagnetic fields which disturb electronic equipment on the adjacent railroad. A railroad train does not receive a stop signal and collides with another train stopped in a station. Casualties include railroad train occupants.
- 2.1.4.b - The HSR system generates stray currents which corrode steel structures of the railroad. A structure collapses and a railroad train collides with the collapsed structure. Casualties include occupants of the railroad train.
- 2.1.5 - The HSR system generates electromagnetic fields signals which disturb equipment on the boats operating on the adjacent waterway. A captain is not able to control his boat and it collides with another boat. Casualties include boat occupants.

Table 3-2B. Abstracts of EMF Effects Issue (Continued)

- 2.4.1 -** The railroad generates electromagnetic fields signals which disturb equipment on the HSR system. An HSR train ignores a stop signal and collides with another HSR train stopped at a station. Casualties include HSR train passengers.
- 2.4.2 -** The railroad generates electromagnetic fields signals which disturb equipment on the maglev system. One maglev train ignores a stop signal and collides with another maglev train stopped at a station. Casualties include maglev train passengers.
- 2.7.1 -** The transmission line generates electromagnetic fields signals which disturb equipment on the HSR system. One HSR train ignores a stop signal and collides with another HSR train stopped at a station. Casualties include HSR passengers.
- 2.7.2 -** The transmission line generates electromagnetic fields signals which disturb equipment on the maglev system. A maglev train ignores a stop signal and collides with another maglev train in a station. Casualties include maglev train passengers.
- 2.1.6 -** The HSR system generates stray currents which corrode the pipeline. The pipeline fractures and delivery of the pipeline product is interrupted.
- 2.1.7 -** The HSR system generates electromagnetic fields which disturb data transmission on the adjacent transmission line. Data transmission is interrupted.

User or contributed to corrosion and structural failure of nearby steel structures. The other high-risk scenarios were rated as Undesirable and were associated with similar consequences caused by electromagnetic fields emitted from an HSR system and high-voltage transmission lines.

3.2.3 Recommended Mitigation Measures

The most effective mitigation of electromagnetic field effects is to increase the distance between the source and the receiver. This is probably impractical in the shared ROW concept, however, where much of the benefit comes from the proximity of the two systems. The next best mitigation measures would be to: (1) design the HSGGT system to minimize electromagnetic fields and (2) contain the electromagnetic fields that occur. Methods to achieve the former include energizing the catenary or guideway only for occupied “blocks” and selecting the type of current (AC or DC) that reduce the most undesirable forms of electromagnetic fields. Methods to achieve the latter include shielding the HSGGT motors, installing barriers, and, in certain cases, working with the Other User to increase acceptance of electromagnetic fields (such as with proper grounding or shielding).

These mitigation measures would reduce the risk scores of most scenarios to an acceptable level. The scenarios that would return an undesirable risk score are those involving strong electromagnetic fields or currents that affect Other Users.

3.3 DYNAMIC INTERFERENCE

This safety issue involves interference between the shared ROW users caused by normal operation of the systems. Thus, it does not include the encroachment of users of one system onto the other system (this is covered under the Physical Infringement safety issue category) nor any other events caused by an accident or mishap. It also does not include EMF effects, which are covered under a separate category.

3.3.1 Scenario Descriptions

Twelve scenarios were developed for this safety issue. Detailed descriptions of each scenario are provided in Appendix C. These descriptions include the following events:

- A passing HSGGT vehicle startles vehicle operators on the other system, causing loss of concentration or control and a subsequent accident.

- A passing HSGGT vehicle displaces snow into the field of view of adjacent highway motorists, causing loss of concentration and/or control and a subsequent accident.
- Turbulence caused by a passing HSGGT vehicle hits passengers waiting at a station, resulting in casualties.
- Vibrations created by either the HSGGT system or the Other User are transmitted to the other system and cause structural failures.
- Erosion due to the adjacent waterway or due to a pipeline leak leads to structural failures in the HSGGT system.

3.3.2 Risk Assessment Summary

A summary of the risk scores developed for the Dynamic Interference scenarios is provided in Table 3-3. As indicated in the table, 11 of the 12 scenarios were scored as high risk and requiring mitigation. Six scenarios had risk scores in the Unacceptable category. These were associated with turbulence and startle effect and displaced snow caused by a passing HSGGT or by erosion of the river basin by the waterway users, which results in track/guideway failure. The other high-risk scenarios were rated as Undesirable, and were associated with vibration-induced failures and erosion effects. The remaining scenario — vibration-induced fatigue of pipelines — was determined to have an acceptable risk level.

3.3.3 Recommended Mitigation Measures

Mitigation measures to reduce high-risk events associated with Dynamic Interference must satisfy several requirements:

- **Reduction in Vibration-Induced Structural Fatigue:** For new HSGGT designs in which shared ROW environments are known and can be characterized during the design phase, the risk of vibration-induced structural failures in the HSGGT system should be minimal.

Table 3-3A. Summary of Scenario Risk Assessment Safety Issue: Dynamic Interference (Reference: Appendix C')

Instigator**	Affected Mode**	Scenario Code*	Pre-Mitigation Frequency Score	Pre-Mitigation Consequence Score	Pre-Mitigation Risk Score	Post-Mitigation Frequency Score	Post-Mitigation Consequence Score	Post-Mitigation Risk Score
HSGGT	HWY	3.0.3.a	A - Frequent	I - Catastrophic	1 - Unacceptable	C - Occasional	I - Catastrophic	4 - Unacceptable
HSGGT	HWY	3.0.3.c	A - Frequent	I - Catastrophic	1 - Unacceptable	C - Occasional	I - Catastrophic	4 - Unacceptable
HSGGT	RR	3.0.4.a	A - Frequent	I - Catastrophic	1 - Unacceptable	C - Occasional	I - Catastrophic	4 - Unacceptable
HSGGT	WWY	3.0.5	B - Probable	I - Catastrophic	2 - Unacceptable	D - Remote	I - Catastrophic	8 - Undesirable
WWY	HSGGT	3.5.0	C - Occasional	I - Catastrophic	4 - Unacceptable	E - Improbable	I - Catastrophic	12 - Acceptable
HSGGT	HWY	3.0.3.b	D - Remote	I - Catastrophic	8 - Undesirable	E - Improbable	I - Catastrophic	12 - Acceptable
HSGGT	RR	3.0.4.b	D - Remote	I - Catastrophic	8 - Undesirable	E - Improbable	I - Catastrophic	12 - Acceptable
HSGGT	TL	3.0.7	D - Remote	I - Catastrophic	8 - Undesirable	E - Improbable	I - Catastrophic	12 - Acceptable
HWY	HSGGT	3.3.0	D - Remote	I - Catastrophic	8 - Undesirable	E - Improbable	I - Catastrophic	12 - Acceptable
RR	HSGGT	3.4.0	D - Remote	I - Catastrophic	8 - Undesirable	E - Improbable	I - Catastrophic	12 - Acceptable
PL	HSGGT	3.6.0	D - Remote	I - Catastrophic	8 - Undesirable	E - Improbable	I - Catastrophic	12 - Acceptable
HSGGT	PL	3.0.6	D - Remote	II - Critical	10 - Acceptable	-	--	--

* Scenario Descriptions and Risk Assessment Summaries for this Safety Issue Are Provided in Appendix C.

** HSGGT = Maglev + High-Speed Rail

HSR = High-Speed Rail

HWY = Highway

RR = Railroad

WWY = Waterway

PL = Pipeline

TL = Transmission Line

Table 3-3B. Abstracts of Dynamic Interference Issue

- 3.0.3.a - A passing HSGGT train at cruising speed startles motorists, leading to loss of concentration and a multi-vehicle accident. Casualties include highway vehicle occupants. | | |
- 3.0.3.c - During winter operations, a HSGGT train at cruising speed disturbs the snow along the ROW. The swirling snow momentarily blinds motorists and causes a multi-vehicle accident. Casualties include highway vehicle occupants.
- 3.0.4.a - A passing HSGGT train at cruising speed causes turbulence at a platform occupied by passengers waiting to board a railroad train. Several passengers lose their balance and fall onto the railroad tracks in front of an approaching railroad train. Casualties include the fallen passengers.
- 3.0.5 - A passing HSGGT train at cruising speed startles boatmen and causes a loss of concentration and a multi-boat accident. Casualties include boat occupants.
- 3.5.0 - The waterway causes a gradual erosion of the bank by the HSGGT track/guideway. A section of track/guideway collapses and causes an HSGGT train to derail at cruising speed. Casualties include HSGGT train passengers.
- 3.0.3.b - HSGGT system operations cause stress fatigue to the highway structures and a section of the highway collapses. Highway vehicles fall into the collapsed section. Casualties include highway vehicle occupants.
- 3.0.4.b - HSGGT operations cause stress fatigue to the railroad structures and a section of the railroad track collapses. A railroad train falls into the collapsed section at cruising speed. Casualties include railroad train occupants.
- 3.0.7 - The shared ROW is located in an urban area. HSGGT operations cause stress fatigue to the transmission line support tower structures. A transmission line tower falls onto houses. Casualties include residents.
- 3.3.0 - Highway traffic cause stress fatigue to the structures of the HSGGT system. A section of the HSGGT track collapses and an HSGGT train falls into the collapsed section at cruising speed. Casualties include HSGGT train passengers.
- 3.4.0 - Railroad operations cause stress fatigue to the structures of the HSGGT system. A section of the HSGGT track/guideway collapses and an HSGGT train falls into the collapsed section at cruising speed. Casualties include HSGGT train passengers.
- 3.6.0 - A pipeline leaks and gradually erodes the ground under the HSGGT Track/guideway. A section of track/guideway collapses and an HSGGT train at cruising speed falls into the collapsed section. Casualties include HSGGT train passengers.
- 3.0.6 - HSGGT operations cause stress fatigue to the pipeline structures. The pipeline begins to leak and delivery of pipeline product is interrupted.

However, for existing systems that 1) were not designed initially for dynamic loading from an adjacent system, and 2) already have experienced some cumulative damage from in-service loading since construction, there may be a high risk of vibration-induced failures. Thus, a set of procedures-based mitigation measures are recommended and should include:

- During the HSGGT design phase, a rigorous engineering assessment of critical structures (bridges, support structures, etc.) on the existing systems that will share ROWs. This assessment should include but not be limited to evaluations of the existing condition and estimates of remaining life both with and without the shared ROW situation.
- A carefully planned inspection, maintenance and rehabilitation program for the existing systems, so that structurally weak areas can be monitored, diagnosed, and corrected. Such a plan should include sensors (e.g., strain gauges, pipeline leak sensors) installed at critically loaded locations that can detect changes in condition of the structure that may indicate impending damage or failure.
- **Turbulence Effect** — Turbulence barriers or speed reductions in the vicinity of a railroad station should be used to reduce the turbulence effect during common corridor operation with HSR. The area of turbulence surrounding the HSGGT vehicle is assumed to be sufficiently small that the loading effect on highway vehicles and moving railroad trains is acceptable.
- **Startle Effect** — In this analysis, the source of the startle effect on Other Users is considered to be visual. The noise levels associated with maglev HSGGT systems are currently under evaluation by Harris, Miller, Millerd Hansen under BAA Project No. 191, "Noise from High-Speed Maglev Systems." The results of this study will provide valuable insight into the need to mitigate noise as a startle effect. Therefore, measures to mitigate a noise effect are not recommended. In locations where sufficient space is available, tree barriers should be installed to mitigate the startle effect. In locations with insufficient space to install trees, other barriers should be deployed. For example, on State Route 315 in Central Ohio, a series of long, thin green metal strips are installed along a very narrow median to reduce the startle effect of opposing traffic, particularly at night. A similar startle effect barrier has been suggested for Maglev/Highway systems in a separate study [28].
- **"Blown Snow"** — The primary hazard associated with snow is the blinding of adjacent highway motorists by snow kicked-up by a passing or oncoming HSGGT vehicle. Similar measures as those described above for the startle effect are recommended in shared ROWs with highways where snowfall is expected during the winter season. Artificial barriers required for locations with small separation distances between adjacent systems should be designed as both a visual barrier and a snow barrier.

These mitigation measures could reduce the risk scores of all scenarios. However, four scenarios would still have unacceptable or undesirable risk scores based on the general assumption that mitigation can reduce risk by reducing the frequency for some scores by two levels of frequency or consequence. Those scenarios refer to startle, snow, and turbulence effects of the HSGGT on the

Other User. Given the number of Other Users and the relative inability of the HSGGT operator to modify their response to certain events, this is not unexpected.

3.4 INFRINGEMENT ON COMMON TRACKAGE

This safety issue involves the sharing of common railroad track by conventional rail vehicles and HSR vehicles. The importance of this issue lies in the potentially great savings in both time and cost to deploy an HSR system in the United States. This is because use of existing track would minimize guideway construction costs. From a practical standpoint, major rework of most existing track would be required to improve the track condition and geometry to a level that would allow very high-speed operation of the candidate HSR vehicles. For example, the allowable track geometry errors for 177 km/hr (110 mi/hr) operation on the NEC are significantly greater than those allowed for 323 km/hr (200 mi/hr) operation of the TGV. Thus, the ability to establish and to maintain this high level of track geometry for mixed passenger traffic is a critical factor associated with the feasibility of using shared trackage for HSR systems.

3.4.1 Scenario Descriptions

Three scenarios were developed for this safety issue. Detailed descriptions of each scenario are provided in Appendix D. These descriptions were based on a failure of the safe separation system which causes a high-speed collision between a conventional passenger train and an HSR vehicle, and failure of track due to deterioration caused by heavy haul operations that leads to a derailed HSR train.

Collisions between tilting trains were considered initially as candidate scenarios. The tilting action of tilt HSR trains is one of the normal operating conditions of such trains. Tilt trains must conform to the dynamic envelope of the operating railroad under worst-case conditions such as failure of the tilt mechanism in the extreme position, failed air bags, maximum canting, etc. Therefore, either existing infrastructure will need to be changed to accommodate the dynamic envelope of a tilt train, or tilt trains will need to be designed within the limits of existing infrastructure. Existing tilt-train designs, such as the Swedish X-2000, British APT, an Italian ETR-450, have all taken the latter approach. It was assumed in this study that proper design and engineering will prevent collisions resulting from tilt failure. Therefore, these scenarios were not evaluated.

3.4.2 Risk Assessment Summary

A summary of the risk scores developed for the Common Trackage scenarios is provided in Table 3-4. As indicated in the table, all scenarios were scored as Unacceptable and require mitigation.

3.4.3 Recommended Mitigation Measures

Mitigation measures are required to reduce the risk of collisions between trains on common trackage. Some form of ATP equipment should be installed. ATP equipment that is designed based on fail-safe principles will ensure that the HSR equipment reverts to a predefined safe state when an unsafe condition has been detected. For example, British Rail (BR) is in the process of implementing ATP equipment on all of its 200 km/hr (125 mi/hr) lines. In fact, BR will not begin higher speed operation (at 225 km/hr) until ATP is fully deployed. Carefully designed operating procedures that ensure adequate spatial and time separation between successive trains also should be developed to supplement the ATP system.

The most practical and direct mitigation measure for common track deterioration caused by railroad operations is to adjust the existing inspection and maintenance procedures on the existing railroad to compensate for use by the HSR vehicles.

Although these mitigation measures would reduce the risk of all three scenarios, each scenario would still have risk scores in the undesirable category.

3.5 HAZMAT

Although hazardous materials (HAZMAT) rarely cause transportation accidents, they often compound the consequence and complicate the recovery of an accident. HSGGT trains are not expected to carry HAZMAT, but trains and trucks running on shared ROW would frequently be carrying HAZMAT. In fact, most trains—other than unit coal or grain trains—and about one out of five trucks carry some form of HAZMAT. These scenarios address accidents involving HSGGT trains and railroad trains or highway trucks that have causes unrelated to HAZMAT, but that subsequently involve their HAZMAT cargo.

Table 3-4A. Summary of Scenario Risk Assessment Safety Issue: Infringement on Common Trackage (Reference: Appendix D)

Instigator**	Affected Mode**	Scenario Code**	Pre-Mitigation Frequency Score	Pre-Mitigation Consequence Score	Pre-Mitigation Risk Score	Post-Mitigation Frequency Score	Post-Mitigation Consequence Score	Post-Mitigation Risk Score
HSR	RR	4.1.4	B - Probable	1 - Catastrophic	2 - Unacceptable	D - Remote	1 - Catastrophic	8 - Undesirable
RR	HSR	4.4.1.a	B - Probable	1 - Catastrophic	2 - Unacceptable	D - Remote	1 - Catastrophic	8 - Undesirable
RR	HSR	4.4.1.b	B - Probable	1 - Catastrophic	2 - Unacceptable	D - Remote	1 - Catastrophic	8 - Undesirable

* Scenario Descriptions and Risk Assessment Summaries for the Safety Issue Are Provided in Appendix D.

** HSGGT = Maglev or High-Speed Rail

HSR = High-Speed Rail

HWY = Highway

WWY = Waterway

PL = Pipeline

TL = Transmission Line

Table 3-4B. Abstracts of Infringements on Common Trackage Issue

- 4.1.4 - HSR and railroad operations share the same track, similar to Amtrak's Northeast Corridor. The safe separation system of an HSR train fails at cruising speed and the train collides with a stopped railroad train. Casualties include occupants of the railroad train and HSR passengers.
- 4.4.1.a - HSR and railroad operations share the same track, similar to Amtrak's Northeast Corridor. The safe separation system of the railroad train fails, causing the railroad train to crash into a stopped HSR train at posted speed. Both trains derail. Casualties include occupants of the railroad train and HSR passengers.
- 4.4.1.b - HSR and railroad operations share the same track, similarly to Amtrak's Northeast Corridor. Common track degraded by heavy railroad operations causes an HSR train to derail at cruising speed. Casualties include HSR train passengers.

3.5.1 Scenario Descriptions

Eight scenarios were developed for this safety issue. Detailed descriptions of each scenario are provided in Appendix E. These descriptions were based on the following events:

- Derailement of an HSGGT vehicle onto a vehicle or pipeline carrying HAZMAT causes a HAZMAT spill which contaminates the surrounding area.
- Collision of two boats, one of which carries HAZMAT, results in an explosion that damages a nearby HSGGT guideway and causes a derailment.
- Physical infringement of a HAZMAT-carrying truck or rail vehicle into the HSGGT operating envelope causes a collision and HAZMAT spill that contaminates the surrounding area.

3.5.2 Risk Assessment Summary

A summary of the risk scores developed for the HAZMAT scenarios is provided in Table 3-5. As indicated in the table, seven of the eight scenarios were scored as high risk, i.e., requiring mitigation. The unacceptable scenarios involve a HAZMAT truck or railroad vehicle entering the track or guideway of an HSGGT and a pipeline burst. The undesirable scenarios involve an HSR train that derails and is then struck by a railroad train or highway truck carrying HAZMAT, the collision of two barges, which causes an explosion that damages the HSGGT track/guideway, and an HSR train derailing and damaging an aboveground pipeline. The remaining scenario was determined to have acceptable risk levels.

3.5.3 Recommended Mitigation Measures

The recommended approach to mitigating the high-risk events associated with HAZMAT is time separation of the HSGGT system from a HAZMAT-carrying railroad train truck. In addition to the mitigation measures described previously for physical infringement hazards, the frequency of occurrence of a HAZMAT-carrying highway vehicle collision with an HSGGT vehicle should be minimized by mandating operating procedures for both systems, whereby the HAZMAT-carrying railroad highway vehicles travel along the shared ROW portions of the system during times when there is no HSGGT traffic (e.g., during the predawn hours).

Table 3-5A. Summary of Scenario Risk Assessment Safety Issue: HAZMAT (Reference: Appendix E)

Instigator**	Affected Mode**	Scenario Code*	Pre-Mitigation Frequency Score	Pre-Mitigation Consequence Score	Pre-Mitigation Risk Score	Post-Mitigation Frequency Score	Post-Mitigation Consequence Score	Post-Mitigation Risk Score
RR	HSGGT	5.4.0	B - Probable	1 - Catastrophic	2 - Unacceptable	D - Remote	1 - Catastrophic	8 - Undesirable
HWY	HSGGT	5.3.0	C - Occasional	1 - Catastrophic	4 - Unacceptable	E - Improbable	1 - Catastrophic	12 - Acceptable
PL	HSGGT	5.6.0	C - Occasional	1 - Catastrophic	4 - Unacceptable	E - Improbable	1 - Catastrophic	12 - Acceptable
HSR	HWY	5.1.3	D - Remote	1 - Catastrophic	8 - Undesirable	E - Improbable	1 - Catastrophic	12 - Acceptable
HSR	RR	5.1.4	D - Remote	1 - Catastrophic	8 - Undesirable	E - Improbable	1 - Catastrophic	12 - Acceptable
HSR	PL	5.1.6	D - Remote	1 - Catastrophic	8 - Undesirable	E - Improbable	1 - Catastrophic	12 - Acceptable
WWY	HSGGT	5.5.0	D - Remote	1 - Catastrophic	8 - Undesirable	E - Improbable	1 - Catastrophic	12 - Acceptable
HSR	WWY	5.1.5	E - Improbable	1 - Catastrophic	12 - Acceptable	--	--	--

* Scenario Descriptions and Risk Assessment Summaries for this Safety Issue Are Provided in Appendix E.

- ** HSGGT = Maglev + High-Speed Rail
 HSR = High-Speed Rail
 HWY = Highway
 RR = Railroad
 WWY = Waterway
 PL = Pipeline
 TL = Transmission Line

Table 3-5B. Abstracts of HAZMAT Issue

- 5.4.0 - A railroad train carrying HAZMAT derailed at cruising speed in an urban area. The train scatters onto the HSGGT track and HAZMAT spills. The HAZMAT contaminates the area around the accident. An HSGGT train crashes at its cruising speed into the derailed railroad train. Casualties include railroad train occupants, HSGGT passengers, and nearby residents.
- 5.3.0 - The shared ROW is in an urban area. A large semi-trailer HAZMAT truck leaves the highway and enters the HSGGT track. An HSGGT train at cruising speed collides with the truck and causes the HAZMAT to spill and contaminate the area around the accident. Casualties include highway vehicle occupants, HSGGT train passengers, and nearby residents.
- 5.6.0 - The shared ROW is in an urban area. The aboveground pipeline ruptures and spills HAZMAT onto the HSGGT track/guideway. A passing HSGGT train causes the HAZMAT to explode. The HSGGT train derailed at cruising speed. Casualties include HSGGT train passengers and inhabitants in the area near the accident site.
- 5.1.3 - The shared ROW is in an urban area. An HSR train derailed at cruising speed and HSR vehicles scatter onto the highway. A truck carrying HAZMAT collides with the derailed HSR train and contaminates the surrounding area. Casualties include HSR train occupants, passengers in highway vehicles, and nearby residents.
- 5.1.4 - The shared ROW is in an urban area. An HSR train derailed at cruising speed and scatters onto the railroad track. A railroad train carrying HAZMAT at its cruising speed collides with the HSR vehicles. The spilled HAZMAT contaminates the surrounding area. Casualties include HSR train passengers, occupants of the conventional train, nearby residents.
- 5.1.6 - The shared ROW is in an urban area. An HSR train derailed at cruising speed and scatters onto the pipeline. The aboveground pipeline, which carries HAZMAT, explodes and contaminates the surround area. Casualties include HSR train passengers and nearby residents.
- 5.5.0 - The shared ROW is in an urban area. A barge carrying HAZMAT collides with another barge and explodes near the HSGGT track. An HSGGT train derailed at cruising speed on the damaged track. The HAZMAT contaminates the area around the accident. Casualties include boat occupants, HSGGT train passengers, and nearby residents.
- 5.1.5 - The shared ROW is located in an urban area. An HSR train derailed at cruising speed, scatters into the waterway, and collides with a barge carrying HAZMAT. The spilled HAZMAT contaminates the surrounding area. Casualties include HSR train passengers, occupants in the boat, and nearby residents.

As discussed in Section 2.3.9, wide-scale rescheduling of railroad shipments is not feasible. However, it may be possible to schedule some volume of HAZMAT shipments during times when the HSGGT is shut down (e.g., at night) or during off-peak traffic periods such as evenings or early mornings. Rescheduling should not be mandated, but negotiated on a case-by-case basis with the participating and affected railroads.

For pipelines, where time separation is obviously infeasible, ditches or redirecting barriers are recommended.

Risk scores will be reduced with these mitigation measures. One scenario involving a railroad train and either HSR or maglev would still have an undesirable level of risk, based on the general assumption that mitigation will reduce risk by two levels of frequency or consequence.

3.6 ACCESSIBILITY

This safety issue involves events that would either provide undesirable access or prevent authorized access to the HSGGT system or Other User. All transportation modes have problems caused by unintended or intended but malicious interference or infringement by persons or equipment. For example, railroads are plagued by vandals dropping objects onto trains from highway overpasses. Shared ROW could allow persons or equipment (particularly maintenance-of-way equipment) on one mode to cause accidents on the other mode. These scenarios address accidents caused by trespassers or maintenance-of-way workers and equipment on one user of the shared ROW causing accidents on the user.

3.6.1 Scenario Descriptions

Twenty-eight scenarios were developed for this safety issue. Detailed descriptions of each scenario are provided in Appendix F. These descriptions were based on the following events:

- An accident or damage is caused by maintenance workers and/or their equipment of one system entering the other system.
- An HSGGT vehicle is stopped between stations, requiring evacuation of passengers that interferes with operations on the Other User.

- Trespassers from the Other User enter the HSGGT system and cause damage that results in a derailment or the sudden and uncontrolled stop of an HSGGT train.

3.6.2 Risk Assessment Summary

A summary of the risk scores developed for the Accessibility scenarios is provided in Table 3-6. As indicated in the table, 24 of the 28 scenarios were scored as high risk and will require mitigation. Twelve scenarios had risk scores in the Unacceptable category and almost all involved trespassers. Most scenarios involving maintenance workers were rated as Undesirable. The between-station evacuation scenarios were determined to have Acceptable risk levels.

3.6.3 Recommended Mitigation Measures

Recommendations for mitigating accessibility-related hazards primarily address the prevention of unauthorized access to the HSGGT system and are listed below:

- The performance of inspection, maintenance and repair activities should be restricted to times during which Other User traffic is light.
- Personnel barriers (fences, walls, etc.) should be installed between systems. Permanent barriers should be installed in areas where trespassing and vandalism may be attempted. Temporary barriers should be available for use on any portion of the systems where maintenance, inspection, or repair activities may be needed.
- A formal training program should be developed and given to our system workers. The program's emphasis should include the potential hazards and mandatory procedures associated with working in shared ROW locations.
- Personnel and equipment intrusion detectors should be installed in shared ROW areas.
- Security procedures and devices should be used to protect critical equipment on the HSGGT system. Procedures should include on-site or video surveillance of selected locations on the system. Devices should include barriers and enclosures to protect switch gear, controls, and supplies.

In addition, measures must be taken to ensure authorized-only access to both systems for maintenance, inspection, repair, and emergency activities (e.g., evacuation).

Table 3-6A. Summary of Scenario Risk Assessment Safety Issue: Accessibility (Reference: Appendix F)

Instigator**	Affected Mode**	Scenario Code*	Pre-Mitigation Frequency Score	Pre-Mitigation Consequence Score	Pre-Mitigation Risk Score	Post-Mitigation Frequency Score	Post-Mitigation Consequence Score	Post-Mitigation Risk Score
HSGGT	TL	6.0.7	B - Probable	I - Catastrophic	2 - Unacceptable	D - Remote	I - Catastrophic	8 - Undesirable
HSGGT	HWY	6.0.3.a	C - Occasional	I - Catastrophic	4 - Unacceptable	E - Improbable	I - Catastrophic	12 - Acceptable
HWY	HSR	6.3.1.b	C - Occasional	I - Catastrophic	4 - Unacceptable	E - Improbable	I - Catastrophic	12 - Acceptable
HWY	MAGLEV	6.3.2.b	C - Occasional	I - Catastrophic	4 - Unacceptable	E - Improbable	I - Catastrophic	12 - Acceptable
RR	HSR	6.4.1.b	C - Occasional	I - Catastrophic	4 - Unacceptable	E - Improbable	I - Catastrophic	12 - Acceptable
RR	MAGLEV	6.4.2.b	C - Occasional	I - Catastrophic	4 - Unacceptable	E - Improbable	I - Catastrophic	12 - Acceptable
WWY	HSR	6.5.1.b	C - Occasional	I - Catastrophic	4 - Unacceptable	E - Improbable	I - Catastrophic	12 - Acceptable
WWY	MAGLEV	6.5.2.b	C - Occasional	I - Catastrophic	4 - Unacceptable	E - Improbable	I - Catastrophic	12 - Acceptable
PL	HSR	6.6.1.b	C - Occasional	I - Catastrophic	4 - Unacceptable	E - Improbable	I - Catastrophic	12 - Acceptable
PL	MAGLEV	6.6.2.b	C - Occasional	I - Catastrophic	4 - Unacceptable	E - Improbable	I - Catastrophic	12 - Acceptable
TL	HSR	6.7.1.b	C - Occasional	I - Catastrophic	4 - Unacceptable	E - Improbable	I - Catastrophic	12 - Acceptable
TL	MAGLEV	6.7.2.b	C - Occasional	I - Catastrophic	4 - Unacceptable	E - Improbable	I - Catastrophic	12 - Acceptable
HSGGT	PL	6.0.6	C - Occasional	II - Critical	6 - Undesirable	E - Improbable	II - Critical	15 - Acceptable
HSGGT	HWY	6.0.3.b	C - Occasional	III - Marginal	11 - Acceptable	-	-	-
HSGGT	RR	6.0.4.a	D - Remote	I - Catastrophic	8 - Undesirable	E - Improbable	I - Catastrophic	12 - Acceptable
HWY	HSR	6.3.1.a	D - Remote	I - Catastrophic	8 - Undesirable	E - Improbable	I - Catastrophic	12 - Acceptable
HWY	MAGLEV	6.3.2.a	D - Remote	I - Catastrophic	8 - Undesirable	E - Improbable	I - Catastrophic	12 - Acceptable
RR	HSR	6.4.1.a	D - Remote	I - Catastrophic	8 - Undesirable	E - Improbable	I - Catastrophic	12 - Acceptable
RR	MAGLEV	6.4.2.a	D - Remote	I - Catastrophic	8 - Undesirable	E - Improbable	I - Catastrophic	12 - Acceptable
WWY	HSR	6.5.1.a	D - Remote	I - Catastrophic	8 - Undesirable	E - Improbable	I - Catastrophic	12 - Acceptable
WWY	MAGLEV	6.5.2.a	D - Remote	I - Catastrophic	8 - Undesirable	E - Improbable	I - Catastrophic	12 - Acceptable

Table 3-6A. Summary of Scenario Risk Assessment Safety Issue: Accessibility (Reference: Appendix F) (Continued)

Instigator**	Affected Mode**	Scenario Code**	Pre-Mitigation Frequency Score	Pre-Mitigation Consequence Score	Pre-Mitigation Risk Score	Post-Mitigation Frequency Score	Post-Mitigation Consequence Score	Post-Mitigation Risk Score
PL	HSR	6.6.1.a	D - Remote	I - Catastrophic	8 - Undesirable	E - Improbable	I - Catastrophic	12 - Acceptable
PL	MAGLEV	6.6.2.a	D - Remote	I - Catastrophic	8 - Undesirable	E - Improbable	I - Catastrophic	12 - Acceptable
TL	HSR	6.7.1.a	D - Remote	I - Catastrophic	8 - Undesirable	E - Improbable	I - Catastrophic	12 - Acceptable
TL	MAGLEV	6.7.2.a	D - Remote	I - Catastrophic	8 - Undesirable	E - Improbable	I - Catastrophic	12 - Acceptable
HSGGT	WWY	6.0.5.b	D - Remote	II - Critical	10 - Acceptable	--	--	--
HSGGT	RR	6.0.4.b	D - Remote	III - Marginal	14 - Acceptable	--	--	--
HSGGT	WWY	6.0.5.a	E - Improbable	I - Catastrophic	12 - Acceptable	--	--	--

* Scenarios Descriptions and Risk Assessment Summaries for this Safety Issue are Provided in Appendix F.

** HSGGT = Maglev + High-Speed Rail

HSR = High-Speed Rail

HWY = Highway

RR = Railroad

WWY = Waterway

PL = Pipeline

TL = Transmission Line

Table 3-6B. Abstracts of Accessibility Issue

- 6.0.7 - HSGGT maintenance workers wander onto the transmission line right-of-way in areas of high voltage and are electrocuted. Casualties include maintenance workers.**
- 6.0.3.a - HSGGT maintenance workers wander onto the highway or HSGGT maintenance of way equipment fouls the highway and causes a multi-vehicle accident. Casualties include maintenance workers and vehicle occupants.**
- 6.3.1.b - Trespassers who gain access from the highway cause an HSR train to derail at cruising speed. Casualties include HSR passengers and trespassers.**
- 6.3.2.b - Trespassers who gain access from the highway cause a maglev train to derail. Casualties include maglev train passengers and the trespassers.**
- 6.4.1.b - Trespassers who gain access from the railroad cause a HSR to derail at cruising speed. Casualties include HSR train passengers and the trespassers.**
- 6.4.2.b - Trespassers who gain access from the railroad cause a maglev train to derail. Casualties include maglev train passengers and the trespassers.**
- 6.5.1.b - Trespassers who gain access from the waterway cause an HSR train to derail at cruising speed. Casualties include HSR train passengers and the trespassers.**
- 6.5.2.b - Trespassers who gain access from the waterway cause a maglev train to derail. Casualties include maglev train passengers and the unauthorized intruders.**
- 6.6.1.b - Trespassers who gain access from the pipeline cause an HSR train to derail at cruising speed. The HSR train derails at cruising speed. Casualties include HSR train passengers and trespassers.**
- 6.6.2.b - Trespassers who gain access from the pipeline cause a maglev train to come to a sudden and uncontrolled stop from its cruising speed. Casualties include maglev train passengers and the trespassers.**
- 6.7.1.b - Trespassers who gain access from the transmission line cause an HSR train to derail at cruising speed. Casualties include HSR train passengers and the trespassers.**
- 6.7.2.b - Trespassers who gain access from the transmission line cause a maglev train to derail. Casualties include maglev train passengers and the trespassers.**

Table 3-6B. Abstracts of Accessibility Issue (Continued)

- 6.0.6 - HSGGT maintenance workers damage the pipeline and interrupt delivery of the pipeline product.
- 6.0.3.b - An HSGGT train is forced to stop between safe havens and passengers are evacuated. Because of the proximity of the highway, highway operations must be shut down for several hours to evacuate passengers and recover equipment.
- 6.0.4.a - HSGGT maintenance workers wander onto the railroad track or HSGGT maintenance of way equipment fouls the railroad and is struck by an oncoming train. Casualties include maintenance workers.
- 6.3.1.a - Highway maintenance workers wander onto the HSR track and are struck by an oncoming HSR train. Casualties include maintenance workers.
- 6.3.2.a - Highway maintenance workers wander onto the maglev guideway and are struck by a maglev train. Casualties include maintenance workers.
- 6.4.1.a - Railroad maintenance workers wander onto the HSR track or railroad maintenance of way equipment fouls the HSR track and is struck by an oncoming HSR train. Casualties include maintenance workers.
- 6.4.2.a - Railroad maintenance workers wander onto the maglev guideway or railroad maintenance of way equipment fouls the maglev guideway and is struck by an oncoming maglev train. Casualties include maintenance workers.
- 6.5.1.a - Waterway maintenance workers wander onto the HSR track and are struck by a train. Casualties include maintenance workers.
- 6.5.2.a - Waterway maintenance workers wander onto the maglev guideway and are struck by a train. Casualties include maintenance workers.
- 6.6.1.a - Pipeline maintenance workers wander onto the HSR track and are struck by an oncoming HSR train or pipeline maintenance equipment fouls the HSR and is struck by an oncoming train. Casualties include maintenance workers.
- 6.6.2.a - Pipeline maintenance workers wander onto the maglev guideway and are struck by an oncoming maglev train or pipeline maintenance equipment fouls the guideway and is struck by an oncoming train. Casualties include maintenance workers.
- 6.7.1.a - Transmission line maintenance workers wander onto the HSR track and are struck by an oncoming HSR train. Casualties include maintenance workers.

Table 3-6B. Abstracts of Accessibility Issue (Continued)

- 6.7.2.a -** Transmission line maintenance wander onto the maglev guideway and are struck by an oncoming maglev train. Casualties include maintenance workers.
- 6.0.5.b -** An HSGGT is forced to stop between safe havens and passengers are evacuated. Evacuation is hampered because the track/guideway is over water.
- 6.0.4.b -** An HSGGT train is forced to stop between safe havens and passengers are evacuated. Because of the proximity of the railroad, railroad operations must be shut down for several hours to evacuate passengers and recover equipment.
- 6.0.5.a -** An HSGGT maintenance worker falls into the waterway and drowns.

With one exception, all scenarios could be reduced to an acceptable level of risk with these mitigation measures. The exception is the scenario where HSGGT workers wander onto a transmission line ROW and risk being electrocuted.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

The following conclusions have been developed based on the results of this study:

1. **Viability of Shared ROW with HSGGT:** From the standpoint of safety, shared ROW with HSGGT is generally feasible in the United States.
2. **Response to Mitigation Efforts:** All of the scenarios will respond to mitigation efforts, i.e., the risk score for each scenario can be reduced by the application of one or more mitigation measures.
3. **Frequency and Consequence Effects:** Almost without exception, it will be more effective to mitigate against frequency of an event occurring rather than to mitigate against the consequence if the event does occur. This reflects the limited control that the HSGGT operator would have over the Other User.
4. **Post-Mitigation Risk Scores:** Even with the application of one or more mitigation measures, 19 of the 85 scenarios still would be classified as “Unacceptable” or “Undesirable,” based on the categories developed in MIL-STD-882B. However, because this study evaluated relative risk rather than absolute risk, the “Undesirable” and “Unacceptable” ratings are used to indicate the relative difficulty in mitigating these risks, and should not be taken to imply that a particular shared ROW mode is not feasible from a safety perspective.
5. **Specific Design of Mitigation Measures:** Many of the recommended mitigation measures—particularly those involving physical devices or structures—must be tailored to each particular site. The engineering design of mitigation devices and structures is beyond the scope of this study. The number of different mitigation measures needed to ensure acceptable safety depends strongly on the amount of available separation distance. However, because of the wide range of characteristics of shared ROW locations, it is not practical to specify designs to cover all possible situations. At the same time, design guidelines such as those published by the AREA and AASHTO are required for the design of specific treatments. These documents are adequate for designing barriers to prevent intrusion of the respective Other Users into the HSGGT operating envelope, but do not cover barriers to prevent encroachment at HSGGT speeds.

6. As a result of the risk assessment activities, the following mitigation measures are recommended:

a. **Encroachment of Highway Vehicles** - Measures are necessary to reduce the probability of encroachment of a highway vehicle into the HSGGT operating envelope. The AASHTO Guide should be used as the primary source for designing appropriate highway vehicle barriers on a site-specific basis. A hierarchy of recommended mitigation measures is presented below in order of decreasing lateral distance between systems sharing the ROW:

- i. Construct system beyond all highway clear zones
- ii. Construct a ditch between systems that contains encroaching highway vehicles
- iii. Construct redirecting barrier systems to restrain encroaching highway vehicles
- iv. Construct crash barrier systems to restrain encroaching highway vehicles
- v. Provide sufficient grade separation of systems

In addition to these treatments, intrusion sensors are recommended for detecting the presence of a vehicle in the HSGGT operating envelope. This treatment would be effective only in situations where there is sufficient stopping distance for the HSGGT to avoid a collision.

b. **Encroachment of Railway Vehicles** - The guidelines provided in the **AREA Manual for Railway Engineering** should be used for the design of crash walls on a site-specific basis. A hierarchy of recommended mitigation measures is presented below in order of decreasing lateral distance between systems sharing the ROW:

- i. Separate the systems sufficiently to minimize the probability of infringement.
- ii. Construct a ditch between systems that contain potentially encroaching railroad vehicles.
- iii. Construct redirecting barrier systems to restrain encroaching railroad vehicles.
- iv. Construct crash barrier systems to restrain encroaching railroad vehicles.
- v. Provide sufficient grade separation of systems.

Intrusion sensors also are recommended for detecting the presence of a vehicle in the HSGGT operating envelope.

- c. **Physical Infringement Involving Pipelines** - Recommended mitigation measures in the case of a massive pipeline leak encroaching onto the HSGGT operating envelope are grade separation, leak sensors, and appropriate pipeline maintenance, inspection, and repair procedures for handling leak situations without creating a hazardous situation on the HSGGT system.
- d. **EMF Effects** - A rigorous HSGGT system design is required that shields the HSGGT system from electromagnetic fields generated by both the HSGGT system and the Other Users, and in addition emits sufficiently weak electromagnetic fields so that the effects on the Other Users are negligibly small. These measures should be supplemented by operating procedures that reduce EMI, by maintaining sufficient separation distances between emitter and “receivers,” and by placing electromagnetic shields or barriers at locations where these other mitigation measures are not effective.
- e. **Reduction of Vibration-Induced Structural Fatigue** — During the HSGGT design phase, a rigorous engineering assessment of critical structures (bridges, support structures, etc.) should be performed on existing systems that will share ROW. This assessment should include but not be limited to evaluations of the existing condition and estimates of remaining life both with and without the shared ROW situation. Furthermore, a carefully planned inspection, maintenance, and rehabilitation program for the existing systems should be developed so that structurally weak areas can be monitored, diagnosed, and corrected.
- f. **Excessive Wear on Common Track** - Current inspection and maintenance procedures on existing railroads should be reviewed and modified for shared usage by the HSR vehicles.
- g. **Turbulence Effect** - Speed reductions in the vicinity of the railroad station should be used to reduce the turbulence effect during shared track operation with HSR. The turbulence zone surrounding the HSGGT vehicle is assumed to be sufficiently small that the loading effect on highway vehicles and moving railroad trains is negligible.
- h. **Startle Effect** - In locations where sufficient space is available, tree barriers should be installed to mitigate the startle effect. In locations with insufficient space to install trees, other artificial barriers should be deployed.
- i. **Blown Snow** - To mitigate hazards caused by snow “kicked up” by the HSGGT, tree barriers or artificial barriers should be used in shared ROW locations with highways where snowfall is expected during the winter season.
- j. **Infringement of the Operating Envelope on Common Corridors** - To reduce the risk of collisions between trains, fail-safe signalling systems should be

used, along with carefully designed operating procedures that ensure adequate spatial and time separation between successive trains.

k. **HAZMAT** - Procedures should be developed to restrict HSGGT vehicles and **HAZMAT** - carrying trains or trucks from using the shared ROW at the same time. Rescheduling of trucks and trains would have to be negotiated with these Other Users on a case-by-case basis.

l. **Accessibility to Workers and Trespassers** - The following recommendations are made for mitigating accessibility-related hazards:

- The performance of inspection, maintenance, and repair activities should be restricted to times when Other User traffic is light.
- Personnel barriers (fences, walls, etc.) should be installed between systems. Permanent barriers should be installed in areas where trespassing and vandalism may be attempted. Temporary barriers should be available for use on any portion of the systems where maintenance, inspection, or repair activities may be needed.
- A formal training program should be developed and given to all system workers. The program's emphasis should include the potential hazards and mandatory procedures associated with working in shared ROW locations.
- Personnel intrusion detectors should be installed in shared ROW areas where trespassing and vandalism may be attempted.
- Security procedures and devices should be used to protect critical equipment on the HSGGT system. Procedures should include on-site or video surveillance of selected locations on the system. Devices should include barriers and enclosures to protect switchgear, controls, and supplies.

In addition, measures must be taken to ensure authorized access to both systems for maintenance, inspection, repair, and emergency activities (e.g., evacuation).

7. **Concurrent Studies** - Several concurrent studies are focusing to some extent on issues related to shared ROW safety with HSGGT systems. The final results of these studies were not available for consideration in this project. However, when the results of these other studies are available, the data and assumptions used to develop the risk scores presented in this report should be reviewed and refined.

4.2 RECOMMENDATIONS FOR FURTHER RESEARCH

The results of this study have provided an initial assessment of the viability of using shared ROW for HSGGT. Significant additional work is required to quantify many aspects of shared ROW usage before a decision is made to deploy an HSGGT system in the United States. As described throughout this report, several assumptions and "engineering judgments" were made to develop risk scores for many of the scenarios. This was necessary primarily because 1) a U.S.-based HSGGT system has not been defined, and 2) Other User accident and hazards data either do not exist or could not be put in a form suitable for the risk assessment. Therefore, it will be necessary to reevaluate the risk assessments performed in this study as more and better information becomes available.

A significant amount of new information is forthcoming from the many maglev studies being funded by the NMI program. Several of these studies have been described in detail throughout this report. Some of this information may already exist but for some reason could not be obtained during this study (information was considered proprietary, contacts with appropriate individuals could not be established, etc.).

Additional research is recommended in several related areas. The results of this research also will be useful in nonshared ROW design and engineering programs. The following activities would support the refinement of the risk assessments performed in this study:

1. Evaluation of HSGGT derailment probabilities and dispersion distances for specific vehicle and guideway designs - The analysis used to develop derailment probabilities on HSGGT systems is presented in Appendix G. This analysis required several assumptions, and the most significant assumption probably was that maglev derailments will be as frequent as HSR derailments. Additional work should be performed to assess the technical approach used to design each of the candidate HSGGT systems considered in this study. The assumptions used to design these systems (safety factors, dimensional tolerances, inspection, maintenance, and repair practices, etc.) should be evaluated to determine with good accuracy the derailment probabilities and dispersion distances for deployment in the United States.
2. Assessment of dispersion distances for highway vehicles, railway vehicles, transmission line components, waterway vehicles, and pipeline materials - The results of reviews of available literature and interviews with industry experts have indicated that an accurate and comprehensive database does not exist for dispersion distances of these Other Users. This information is vital for the accurate determination of required separation distances and barrier characteristics between systems that share the ROW. Additional work should focus on developing such a database.

3. Development of material and structural requirements for crash and redirecting barriers used to protect HSGGT guideway structures - The AASHTO and AAR guidelines for barriers should be expanded and tailored for collisions between shared ROW users. The guidelines describe sound engineering practices that should be used in barrier designs. These practices should be reviewed in the context of the potentially very high-speed collisions and unique guideway designs associated with HSGGT systems. The cost for conventional barriers increases with impact velocity and impacting mass, and may become very expensive to resist impacts at HSGGT speeds. Additional work should focus on unconventional, cost-effective barrier designs for HSGGT systems. Engineering analyses should also be performed to develop material and structural performance criteria for barriers used with HSGGT systems in shared ROW situations.
4. Application of risk assessment methodology to a candidate HSGGT system - This study used a hypothetical baseline HSGGT system for the development of risk scores and mitigation measures. This methodology should be applied to a specific HSGGT network that is under consideration in the United States. Actual shared ROW situations could be identified, those sites evaluated and specific mitigation measures selected and tailored for that network.
5. Evaluation of Consequences of Shared ROW Accidents - Existing estimates of fatalities, injuries, and property damage from HSGGT accidents generally do not address shared ROW situations. Additional work should focus on developing accurate estimates of shared ROW accident consequences. For example, results from analyses of casualties in an HSGGT-only derailment should be extended to include running into or being struck by highway traffic as a consequence of the derailment. In this manner, the influence of the shared ROW situation on resulting casualties could be determined.
6. Consolidation of Results from Shared ROW Studies - Several in-progress studies are addressing shared ROW issues. These studies have been performed essentially in parallel and have not benefitted fully from each other's activities and results. The results of these studies should be consolidated to establish a clear and accurate perception of shared ROW with HSGGT (both safety and nonsafety issues). One of the initial activities should be a Shared ROW Workshop, which would provide a forum for the interchange of the results of the shared ROW studies and for identifying specific directions for further study.

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APPENDIX A PHYSICAL INFRINGEMENT

<u>Scenario Number:</u>	1.1.3.a												
<u>Safety Issue:</u>	Physical infringement												
<u>Instigator:</u>	HSGGT												
<u>Affected Mode:</u>	Highway												
<u>High-Risk Event:</u>	An HSGGT train derailed at cruising speed and HSGGT vehicles scatter onto the highway. Numerous highway vehicles crash into the derailed HSGGT vehicles. Casualties include HSGGT passengers and occupants of highway vehicles.												
<u>Frequency:</u>	D (Remote) No derailments of HSGGT trains were identified in France, Germany, Italy, or Japan. There were no derailments of trains travelling over 147 km/hr (91 mph) (the highest reported speed category) in the United States from 1988 through 1990 [Source: FRA Accident/Incident Bulletins, 1988, 1989, 1990, p. 20 in each volume]. It was assumed that HSGGT trains on a 320 km (200 miles) shared ROW would derail once every 118 years. See Appendix G.												
<u>Consequence:</u>	I (Catastrophic) Collisions between highway vehicles and a large mass object (such as an HSGGT vehicle) can result in fatalities. In 1989, there were 3,400 fatalities from collisions between motor vehicles and fixed objects [Source: MVMA Motor Vehicle Facts & Figures 1990, p. 1].												
<u>Score:</u>	<table><tr><td>Frequency:</td><td>Remote</td><td>D</td><td></td></tr><tr><td>Consequence:</td><td>Catastrophic</td><td>I</td><td></td></tr><tr><td>Hazard Risk:</td><td></td><td>8</td><td>Undesirable, management decision required</td></tr></table>	Frequency:	Remote	D		Consequence:	Catastrophic	I		Hazard Risk:		8	Undesirable, management decision required
Frequency:	Remote	D											
Consequence:	Catastrophic	I											
Hazard Risk:		8	Undesirable, management decision required										
<u>Mitigation:</u>	<p>Frequency can be reduced by:</p> <ul style="list-style-type: none">• Redirecting barriers and crash barriers to prevent the HSGGT vehicles from going onto the highway.• Ditches to prevent the HSGGT vehicles from going onto the highway. <p>Consequence probably could not be reduced.</p> <p>Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable with management review).</p>												

Scenario Number: 1.1.3.b

Safety Issue: Physical infringement

Instigator: HSGGT

Affected Mode: Highway

High-Risk Event: An HSGGT train derailed at cruising speed and collides with support columns of a highway. The columns collapse together with a section of the elevated highway. Highway vehicles collide with the collapsed section. Casualties include HSGGT train passengers and occupants of highway vehicles.

Frequency: E (Improbable) No derailments of HSGGT trains were identified in France, Germany, Italy, or Japan. There were no derailments of trains traveling over 147 km/hr (91 mph) (the highest reported speed category) in the United States from 1988 through 1990 [Source: FRA Accident/Incident Bulletins, 1988, 1989, 1990, p. 20 in each volume]. It was assumed that HSGGT trains on a 320 km (200 miles) shared ROW would derail once every 118 years. See Appendix G. It was also assumed that only 10 percent of the 320 km (200 miles) of highway would be elevated, thereby reducing the frequency to once per 1,180 years.

Consequence: I (Catastrophic) A high-speed collision with a large mass, fallen structure can result in fatalities. In 1989, there were 3,400 fatalities from collisions between motor vehicles and fixed objects [Source: MVMA Motor Vehicle Facts & Figures 1990, p.90].

Score:

Frequency:	Improbable	E
Consequence:	Catastrophic	I
Hazard Risk:		12

Acceptable with management review

Mitigation: None required.

Scenario Number: 1.1.4.a

Safety Issue: Physical infringement

Instigator: HSGGT

Affected Mode: Railroad

High-Risk Event: An HSGGT train derailed at cruising speed and HSGGT vehicles scatter on the railroad track. A railroad train collides at its cruising speed with the derailed HSGGT vehicles. Casualties include HSGGT train passengers and those on the railroad train.

Frequency: D (Remote) No derailments of HSGGT trains were identified in France, Germany, Italy, or Japan. There were no derailments of trains travelling over 147 km/hr (91 mph) (the highest reported category) in the United States from 1988 through 1990 [Source: FRA Accident/Incident Bulletins, 1988, 1989, 1990, p. 20 in each volume]. It was assumed that HSGGT trains on a 320 km (200 miles) shared ROW would derail once every 118 years. See Appendix G. It was assumed that a railroad train would be present to collide with the derailed HSGGT train.

Consequence: I (Catastrophic) Collision accidents between railroad trains can cause multiple fatalities. For example, in 1990 there were 8 railroad employees killed in 4 train collisions [Source: FRA Accident/Incident Bulletin, 1990, pp. 72, 84]. and in 1987, 16 employees and passengers were killed in a high-speed collision between Amtrak and Conrail trains on the Northeast Corridor [Source: Railroad Accident Report, NTSB/RAR-88/01]. HSGGT accidents probably will be at least as severe as conventional railroad accidents. In fact, the higher speeds and lighter vehicle construction may contribute to higher severity accidents.

Score:

Frequency:	Remote	D	
Consequence:	Catastrophic	I	
Hazard Risk:		8	Undesirable, management decision required

Mitigation: Frequency can be reduced by:

- Redirecting barriers or crash barriers to prevent the HSGGT vehicles from going onto the highway.
- Ditches to prevent the HSGGT vehicles from going onto the highway.

Consequence probably could not be reduced.

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable with review by management).

Scenario Number: 1.1.4.b

Safety Issue: Physical infringement

Instigator: HSGGT

Affected Mode: Railroad

High-Risk Event: An HSGGT train derails at cruising speed and the derailed HSGGT vehicles strike support columns of the railroad ROW. A section of track collapses. A railroad train traveling at its cruising speed falls into collapsed section. Casualties include HSGGT train passengers and occupants of the railroad train.

Frequency: E (Improbable) No derailments of HSGGT trains were identified in France, Germany, Italy, or Japan. There were no derailments of trains travelling over 147 km/hr (91 mph) (the highest reported category) in the United States from 1988 through 1990 [Source: FRA Accident/Incident Bulletins, 1988, 1989, 1990, p. 20 in each volume]. It was assumed that HSGGT trains on a 320 km (200 miles) shared ROW would derail once every 118 years. See Appendix G. It was also assumed that only 10 percent of the railroad track would be elevated on the shared ROW and therefore the frequency of derailment and structure loss would be once in 1,180 years.

Consequence: I (Catastrophic) A collision between a railroad train and railroad structures probably will have effects similar to collisions between trains. Collision accidents between railroad trains can cause multiple fatalities. For example, in 1990 there were 8 railroad employees killed in 4 train collisions [Source: FRA Accident/Incident Bulletin Calendar Year 1990, pp. 72, 84] and in 1987 16 employees and passengers were killed in a high-speed collision between Amtrak and Conrail trains on the Northeast Corridor [Source: Railroad Accident Report, NTSB/RAR-88/01].

<u>Score:</u>	Frequency:	Improbable	E	
	Consequence:	Catastrophic	I	
	Hazard Risk:		12	Acceptable, with management review

Mitigation: None required.

Scenario Number:

1.1.5

Safety Issue:

Physical infringement

Instigator:

HSGGT

Affected Mode:

Waterway

High-Risk Event:

An HSGGT train derails at its cruising speed and HSGGT vehicles scatter into the waterway. Boats collide with the HSGGT vehicles. Casualties include HSGGT train passengers and boat occupants.

Frequency:

E (Improbable) No derailments of HSGGT trains were identified in France, Germany, Italy, or Japan. There were no derailments of trains travelling over 147 km/hr (91 mph) (the highest reported speed category) in the United States from 1988 through 1990 [Source: FRA Accident/Incident Bulletins, 1988, 1989, 1990, p. 20 in each volume]. It was assumed that HSGGT trains on a 320 km (200 miles) shared ROW would derail once every 118 years. See Appendix G. Based on observations of the Rhein River (a heavily used waterway) in Germany, it was assumed that there would be one boat in each direction every 15 minutes moving at 10 mph. Therefore, there would be a 1 in 60 chance of a boat being present when and where an HSGGT train derails. The frequency of derailment and boat presence is therefore once in 7,080 years.

It is assumed that waterway boat casualties will occur only if the HSGGT vehicles crash into boats on the waterway and that approaching boats will be able to avoid the accident scene.

Consequence:

I (Catastrophic) Multiple deaths and total loss of equipment.

Score Frequency:

Frequency:	Improbable	E	
Consequence:	Catastrophic	I	
Hazard Risk:		12	Acceptable, with management review

Mitigation:

None required.

Scenario Number: 1.1.6

Safety Issue: Physical infringement

Instigator: HSGGT

Affected Mode: Pipeline

High-Risk Event: An HSGGT train derailed at its cruising speed and the HSGGT vehicles break an underground pipeline. Delivery of pipeline product is interrupted. Casualties include HSGGT train passengers.

Frequency: D (Remote) No derailments of HSGGT trains were identified in France, Germany, Italy, or Japan. There were no derailments of trains travelling over 147 km/hr (91 mph) (the highest reported speed category) in the United States from 1988 through 1990 [Source: FRA Accident/Incident Bulletins, 1988, 1989, 1990, p. 20 in each volume]. It was assumed that HSGGT trains on a 320 km (200 miles) shared ROW would derail once every 118 years. See Appendix G.

Consequence: II (Critical) An underground, non-HAZMAT pipeline would not increase the consequence of an HSGGT derailment. Therefore, any HSGGT casualties would have occurred without the other mode being present. The pipeline would be severely damaged and the pipeline distribution would be disrupted.

Score:

Frequency:	Remote	D
Consequence:	Critical	II
Hazard Risk:		10

Acceptable, with management review

Mitigation: None required.

Scenario Number: 1.1.7

Safety Issue: Physical infringement

Instigator: HSGGT

Affected Mode: Transmission lines

High-Risk Event: The shared ROW is located in an urban area. An HSGGT train derailed at its cruising speed and the HSGGT vehicles collide with the transmission line tower. The tower collapses onto nearby houses. Casualties include HSGGT train passengers and inhabitants of the affected houses.

Frequency: D (Remote) No derailments of HSGGT trains were identified in France, Germany, Italy, or Japan. There were no derailments of trains travelling over 147 km/hr (91 mph) (the highest reported speed category) in the United States from 1988 through 1990 [Source: FRA Accident/Incident Bulletins, 1988, 1989, 1990, p. 20 in each volume]. It was assumed that HSGGT trains on a 320 km (200 miles) shared ROW would derail once every 118 years. See Appendix G. It was assumed that 25 percent of the shared ROW would be in urban areas, so the frequency for the tower collapsing onto houses would be once in 472 years.

Consequence: I (Catastrophic) Multiple deaths and total loss of equipment. The HSGGT fatalities probably would occur without the shared ROW unless they are the direct result of the falling tower. The residential fatalities probably would not have occurred without the shared ROW.

Score:

Frequency:	Remote	D	
Consequence:	Catastrophic	I	
Hazard Risk:		8	Undesirable, management decision required

Mitigation: Frequency can be reduced by:

- Redirecting barriers or crash barriers to prevent the HSGGT vehicles from going onto the highway.
- Ditches to prevent the HSGGT vehicles from going onto the highway.

Consequence probably could not be reduced.

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable with review by management).

Scenario Number: 1.3.1

Safety Issue: Physical infringement

Instigator: Highway

Affected Mode: HSR

High-Risk Event: A fully loaded semitrailer truck leaves the highway and goes onto the HSR track. An HSR train at its cruising speed collides with the truck. Casualties include truck occupants and HSR train passengers.

Frequency: B (Probable) In 1990, there were 4,223 fatal accidents on 72,700 km (45,074 miles) of urban and rural interstate highways [Source: Highway Statistics, 1990, p. 198]. This is a rate of 0.058 accidents per km per year (0.094 accidents per mile per year). On all highways, 28 percent of all accidents are collisions with fixed objects [Source: Accident Facts, 1991, p. 75]. Assuming that these vehicles left the road to strike the fixed object, and that a vehicle could leave the road on either side, and that fatalities are similarly distributed to the types of accidents, there would be 591 accidents on Interstate Highways each year where a vehicle left the road towards the HSR track. This is a rate of 0.0081 accidents per km per year (0.013 accidents per mile per year), or 2.6 accidents per year on the 320 km (200 miles) shared ROW. In 1990, 9.9 percent of all vehicle miles on urban and rural interstates were combination trucks (such as the semitrailer truck described above) [Source: Highway Statistics, 1990, p. 192]. Therefore, there would be 0.26 relevant accidents per year on the shared ROW or 1 accident every 3.9 years.

Consequence: I (Catastrophic) Collisions between trains and motor vehicles can cause multiple fatalities. From 1988 through 1990, 2,188 persons were killed in collisions between trains and motor vehicles at grade crossings. Nine of those killed were railroad employees.

Score:	Frequency:	Probable	B
	Consequence:	Catastrophic	I
	Hazard Risk:		2 Unacceptable

Mitigation: Frequency could be reduced by:

- Physical separation. Physical separation should be wide enough to allow a runaway vehicle to stop after leaving the highway at cruising speed
- Ditch. The ditch should contain the largest fully loaded highway vehicle allowed in the jurisdiction of the shared ROW.
- Redirecting barrier or crash barrier constructed such that it will contain the largest fully loaded highway vehicle allowed in the jurisdiction of the shared ROW. The impact force absorption material should be capable of preventing the majority of types of vehicle from hitting the wall itself.
- Grade separation.

- **Guideway misalignment and infringement sensors.**

Consequence probably could not be reduced.

The recommended mitigation measure for Scenario 1.3.1 is a ditch, if adequate ROW space is available. Physical separation may not be as effective as a ditch since certain highway accidents involving runaway vehicles are caused by drivers who experience a severe health problem, such as a heart attack. Over favorable terrain, physical separation alone may not be useful. If enough space for a ditch is not available, a redirecting barrier should be built. In limited ROW separation space sections, the third recommended mitigation measure is a crash barrier. A case-by-case study should be made to analyze the cost-effectiveness of the crash barrier against grade separation. If grade separation is chosen, then column impact protection and guideway misalignment sensors should be used.

Post-mitigation score would be Remote/Catastrophic: 8 (undesirable, management review required).

Scenario Number: 1.3.2

Safety Issue: Physical infringement

Instigator: Highway

Affected Mode: Maglev

High-Risk Event: A fully loaded semitrailer truck leaves the highway and goes onto the maglev guideway. A maglev train traveling at its cruising speed collides with the truck. Casualties include truck occupants and maglev passengers.

Frequency: B (Probable) In 1990, there were 4,223 fatal accidents on 72,700 km (45,074 miles) of urban and rural interstate highways [Source: Highway Statistics, 1990, p. 198]. This is a rate of 0.058 accidents per km per year (0.094 accidents per mile per year). On all highways, 28 percent of all accidents are collisions with fixed objects [Source: Accident Facts, 1991, p. 75]. Assuming that these vehicles left the road prior to striking the fixed object, and that a vehicle could leave the road on either side, and that fatalities are similarly distributed to the types of accidents, there would be 591 accidents on Interstate Highways each year where a vehicle left the road towards the HSR track. This is a rate of .0081 accidents per km per year (0.013 accidents per mile per year), or 2.6 accidents per year on the 320 km (200 miles) shared ROW. In 1990, 9.9 percent of all vehicle miles on urban and rural interstates were combination trucks (such as the semitrailer truck described above) [Source: Highway Statistics, 1990, p. 192]. Therefore, there would 0.26 relevant accidents per year on the shared ROW, or 1 accident every 3.9 years.

Consequence: I (Catastrophic) Collisions between trains and motor vehicles can cause multiple fatalities. From 1988 through 1990, 2,188 persons were killed in collisions between trains and motor vehicles at grade crossings. Nine of those killed were railroad employees.

<u>Score:</u>	Frequency:	Probable	B
	Consequence:	Catastrophic	I
	Hazard Risk:		2 Unacceptable

Mitigation: Frequency can be reduced by the same measures described in Scenario 1.3.1:

- Physical separation
- Ditch
- Redirecting barrier
- Grade separation
- Crash barrier
- Guideway misalignment and infringement sensors

Consequence probably could not be reduced.

Post-mitigation score would be Remote/Catastrophic: 8 (undesirable, management decision required).

Scenario Number:

1.4.1.a

Safety Issue:

Physical infringement

Instigator:

Railroad

Affected Mode:

HSR

High-Risk Event:

A fully loaded railroad train derailed at its cruising speed and the railroad vehicles scatter onto the HSR track. An HSR train at its cruising speed collides with the railroad vehicles. Casualties include railroad train occupants and HSR passengers.

Frequency:

B (Probable) From 1988 through 1990 there were a total of 1,880 derailments [Source: FRA Accident/Incident Bulletins, 1988, 1989, 1990, p. 20 in each volume] over 238,700 route-km (148,000 route miles) in the U.S. [Source: Transportation in America, 1991, p. 641]. This count excludes derailments on yard track, sidings, and industry track, and derailments that occur below 16 km/hr (10 mph) because those generally do not cause the cars to leave the immediate track structure. This is a rate of 0.0026 derailments per km per year (0.0042 derailments per mile per year). For a 645 km (400 miles) HSR system with 320 km (200 miles) of shared ROW, there would be 0.85 railroad derailments per year or 1 derailment every 1.2 years.

Consequence:

I (Catastrophic) Collision accidents between railroad trains can cause multiple fatalities. For example, in 1990 there were 8 railroad employees killed in 4 train collisions [Source: FRA Accident/Incident Bulletin Calendar Year 1990, pp. 72, 84] and in 1987, 16 employees and passengers were killed in a high-speed collision between Amtrak and Conrail trains on the Northeast Corridor [Source: Railroad Accident Report, NTSB/RAR-88/011]. HSR accidents probably will be as severe as conventional railroad accidents. In fact, the higher speeds and lighter vehicle construction may contribute to higher severity accidents.

Score:

Frequency:	Probable	B
Consequence:	Catastrophic	I
Hazard Risk:		2 Unacceptable

Mitigation:

Frequency could be reduced by:

- Physical separation. Physical separation should be wide enough to allow for dispersion of a fully loaded derailed train, which derailed at the posted speed.
- Crash barrier. The crash barrier should be constructed such that it will contain a fully loaded derailed train which is travelling at posted speed at the moment of derailment.
- Ditch. The ditch should contain a fully loaded, derailed train, travelling at posted speed.
- Guideway misalignment and intrusion sensors

- **Time separation**
- **Speed reduction**
- **Railroad sensors. Hotbox and other rail equipment failure sensors may be implemented.**

The recommended mitigation measure is a ditch if adequate space is available. Otherwise, a crash barrier should be constructed.

Consequence probably could not be reduced.

Post-mitigation score would be Remote/Catastrophic: 8 (undesirable, management decision required).

Scenario Number: 1.4.1.b

Safety Issue: Physical infringement

Instigator: Railroad

Affected Mode: HSR

High-Risk Event: A railroad car with shifted cargo infringes on the HSR ROW. An HSR train crashes at its cruising speed into the shifted cargo. Casualties include the HSR train operators.

Frequency: C (Occasional) From 1988 through 1990, there were 54 train accidents caused by shifted loads or misrouted oversized loads [Source: FRA Accident/Incident Bulletin, 1988, 1989, 1990, p. 31 in each volume] over 238,700 route-km (148,000 route miles). This is a rate of 0.000074 accidents per km per year (0.00012 accidents per mile per year). For a 645 km (400 miles) HSR system with 320 km (200 miles) of shared ROW, there would be 0.024 accidents per year or 1 accident every 41 years.

Consequence: I (Catastrophic) Collision accidents between railroad trains can cause multiple fatalities. For example, in 1990 there were 8 railroad employees killed in 4 train collisions [Source: FRA Accident/Incident Bulletin Calendar Year 1990, pp. 72, 84] and in 1987, 16 employees and passengers were killed in a high-speed collision between Amtrak and Conrail trains on the Northeast Corridor [Source: Railroad Accident Report, NTSB/RAR-88/01] HSR accidents probably will be as severe as conventional railroad accidents. In fact, the higher speeds and lighter vehicle construction may contribute to higher severity accidents.

Score:

Frequency:	Occasional	C	
Consequence:	Catastrophic	I	
Hazard Risk:		4	Unacceptable

Mitigation: Frequency could be reduced by:

- Shifted cargo detectors.
- Procedures. Strict procedures should be enforced to ensure that flatbed or exposed cargo is properly tied down.

Consequence probably could not be reduced.

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable with management review).

Scenario Number: 1.5.1

Safety Issue: Physical infringement

Instigator: Waterway

Affected Mode: HSR

High-Risk Event: The waterway floods the HSR track. An HSR train then derails at its cruising speed. Casualties include HSR train passengers.

Frequency: C (Occasional) Flood-prone rivers flood once per decade. According to the National Oceanic and Atmospheric Administration (NOAA), large rivers in the United States flood even in urban areas where the HSR is likely to share ROW with a waterway. Therefore, it was assumed that the waterway would inundate a portion of the HSR track once every 10 to 20 years.

Canals usually are controlled for maximum water level and are therefore unlikely to flood and are not considered in this scenario.

Consequence: I (Catastrophic) Train derailments can cause fatalities. From 1988 through 1990, 9 persons were killed in railroad derailments. Moreover, in one accident in 1991, 8 persons were killed in an Amtrak derailment at Lugoff, South Carolina, on July 31, 1991 [Source: Howard Robertson, Amtrak, telephone conversation, 1/92].

Score:

Frequency:	Occasional	C	
Consequence:	Catastrophic	I	
Hazard Risk:		4	Unacceptable

Mitigation: Frequency could be reduced by:

- Flood sensors. Highly reliable flood sensors would be used in conjunction with centralized HSR operations control systems to stop HSR operations in the event of a flood.
- Grade separation. Elevated HSR guideway could permit limited reduced speed operation under strict procedures, even during flood conditions.
- Procedures. HSR operation procedures would be required to train operators to report any signs of flooding.

Consequence probably could not be reduced.

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable with management review).

Scenario Number: 1.5.2

Safety Issue: Physical infringement

Instigator: Waterway

Affected Mode: Maglev

High-Risk Event: The waterway floods the maglev guideway. A maglev train derails at its cruising speed. Casualties include maglev train passengers.

Frequency: C (Occasional) Flood-prone rivers flood once per decade. According to the National Oceanic and Atmospheric Administration (NOAA), large rivers in the United States flood even in urban areas where the HSR is likely to share ROW with a waterway. Therefore, it was assumed that the waterway would inundate a portion of the maglev track once every 10 to 20 years.

Consequence: I (Catastrophic) Train derailments can cause fatalities. From 1988 through 1990, 9 persons were killed in railroad derailments. And, in one accident in 1991, 8 persons were killed in an Amtrak derailment at Lugoff, South Carolina, on July 31, 1991 [Source: Howard Armstrong, Amtrak, telephone conversation, 1/92].

Score:

Frequency:	Occasional	C	
Consequence:	Catastrophic	I	
Hazard Risk:		4	Unacceptable

Mitigation: Frequency could be reduced by the same measures described for 1.5.2:

- Flood sensors
- Grade separation. Elevated maglev guideway could permit limited operation during flood conditions.
- Procedures

Consequence probably could not be reduced.

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with review by management).

Scenario Number: 1.6.0

Safety Issue: Physical infringement

Instigator: Pipeline

Affected Mode: HSGGT

High-Risk Event: A non-HAZMAT pipeline bursts and the flood causes an HSGGT train to derail at cruising speed. Casualties include HSGGT train passengers.

Frequency: C (Occasional) There were 789,006 km (489,184 miles) of natural gas and oil pipelines in the United States [Source: National Transportation Statistics Annual Report, July 1990]. Only information about natural gas and oil pipelines was available. For these pipelines, there were 454 failure accidents. [Source: Transportation Safety Information Report, 1980]. Therefore, there were 0.00058 accidents per km per year (0.00093 accidents per mile per year). Assuming that all of these accidents were bursts, and that half of those bursts were of sufficient volume to damage the HSGGT track/guideway structure before detection, there would be 0.093 relevant bursts per year, or 1 burst every 10.8 years, on a 320 km (200 miles) shared ROW.

Consequence: I (Catastrophic) Train derailments can cause fatalities. From 1988 through 1990, 9 persons were killed in railroad derailments. Moreover, in one accident, 8 persons were killed in an Amtrak derailment at Lugoff, South Carolina, on July 31, 1991 [Source: Howard Armstrong, Amtrak, telephone conversation, 1/92].

Score:

Frequency:	Occasional	C
Consequence:	Catastrophic	I
Hazard Risk:		4 Unacceptable

Mitigation: Frequency could be reduced by:

- Leak sensors. Highly reliable leak sensors would be used in conjunction with centralized HSGGT operations control systems to stop HSGGT operations in the event of a burst pipeline in the shared ROW.
- Procedures. Scheduled maintenance inspections would supplement the leak sensing system.

Consequence probably could not be reduced.

Post-mitigation score would be: Improbable/Catastrophic: 12 (acceptable with review by management).

Scenario Number: 1.7.0

Safety Issue: Physical infringement

Instigator: Transmission line

Affected Mode: HSGGT

High-Risk Event: A transmission line falls onto the HSGGT ROW. An HSGGT train at its cruising speed collides with the cable and sustains major damage.

Frequency: B (Probable) Transmission lines fall about once per 403 km (250 miles) per year [Source: Alex Schneider, Commonwealth Edison, telephone conversation, 1/92]. For a 645 km (400 miles) HSGGT system with 320 km (200 miles) of shared ROW, there would 0.80 failures per year, or 1 failure every 1.25 years.

Consequence: I (Catastrophic) Objects on or fouling track can cause accidents and fatalities. From 1988 through 1990, there were 84 train accidents and 1 fatality caused by objects on or fouling the track. These accidents cause \$4.1 million in damages [Source FRA Accident/Incident Bulletin, 1988, 1989, 1990, pp. 31 and 89 in each volume].

Score:

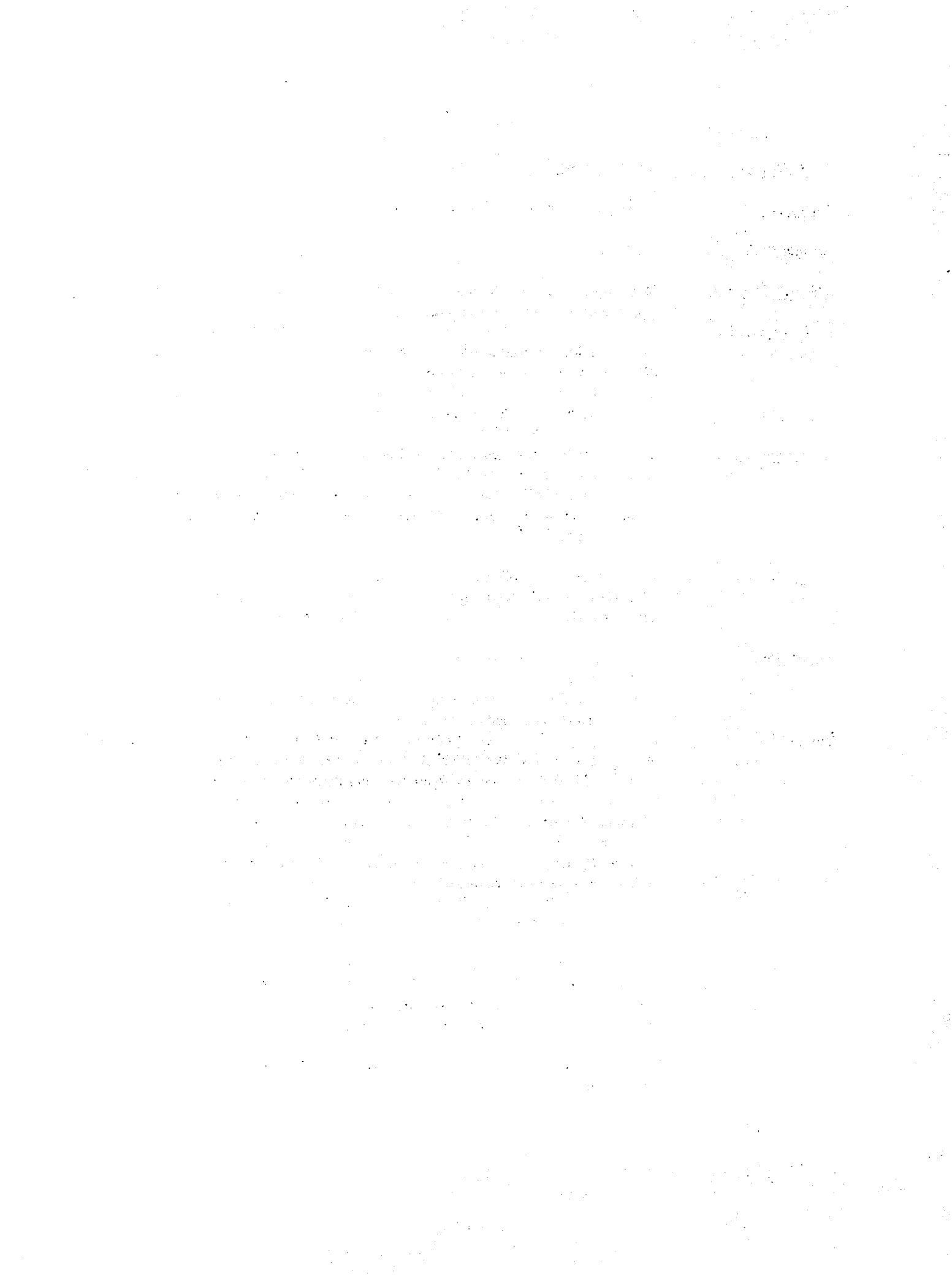
Frequency:	Probable	B
Consequence:	Catastrophic	I
Hazard Risk:		2 Unacceptable

Mitigation: Frequency could be reduced by:

- “Boxing” the track/guideway under transmission lines. This is similar to using snowsheds in avalanche areas.
- Instant communication with the transmission line operators so that the HSGGT operator is informed of any fallen wire.

Consequence probably could not be reduced.

Post-mitigation score would be: Remote/Catastrophic: 8 (undesirable, management decision required).



APPENDIX B EMF EFFECTS

<u>Scenario Number:</u>	2.1.3.a												
<u>Safety Issue:</u>	Electromagnetic Field Effects												
<u>Instigator:</u>	HSR												
<u>Affected Mode:</u>	Highway												
<u>High Risk Event:</u>	An HSR train generates electromagnetic fields which disturb electronic equipment in a vehicle on the adjacent highway. The highway vehicle collides with other highway vehicles. Casualties include occupants of the highway vehicles.												
<u>Frequency:</u>	C (Occasional) Similar catenaries and motors have been in use for many years. Likewise, electronic controls have been used on motor vehicles for several years. Those controls are engineered to SAE standards to tolerate common outside interference without loss of service. Electromagnetic fields have not been shown to cause loss of control in this manner. It was assumed that there would be 1 instance of electromagnetic field interference per 40 years for a 320 km (200 miles) shared ROW.												
<u>Consequence:</u>	I (Catastrophic) High-speed, multi-vehicle highway crashes can result in multiple fatalities. In 1989, there were 20,300 fatalities from collisions between motor vehicles [Source: MVMA Motor Vehicle Facts & Figures 1990, p. 90].												
<u>Score:</u>	<table><tr><td>Frequency</td><td>Occasional</td><td>C</td><td></td></tr><tr><td>Consequence</td><td>Catastrophic</td><td>I</td><td></td></tr><tr><td>Hazard Risk</td><td></td><td>4</td><td>Unacceptable</td></tr></table>	Frequency	Occasional	C		Consequence	Catastrophic	I		Hazard Risk		4	Unacceptable
Frequency	Occasional	C											
Consequence	Catastrophic	I											
Hazard Risk		4	Unacceptable										
<u>Mitigation:</u>	<p>Frequency can be reduced by decreasing the strength of the electromagnetic field or by increasing the motor vehicles' tolerance of the electromagnetic field. Strength reduction can be achieved by energizing the catenary only when a train is present, shielding the motors to reduce electromagnetic emissions, increasing the distance between the tracks and the highway (either horizontally or vertically), or installing an electromagnetic barrier to absorb or reflect the field. This can be done by erecting a steel or concrete wall or by placing the HSR in a cut or tunnel. Tolerance of the field by highway vehicles requires changes outside the normal management scope of the HSR system and also might be impractical given the number of highway vehicles using present technology.</p> <p>Consequence probably cannot be reduced except as part of the general, ongoing improvements in highway safety. For example, it would be impractical to require more crash-resistant cars on highways that share an ROW. Similarly, it would be undesirable to lower speed limits on highways that share an ROW.</p> <p>Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with management review).</p>												

Scenario Number: 2.1.3.b

Safety Issue: Electromagnetic Field Effects

Instigator: HSR

Affected Mode: Highway

High Risk Event: The HSR system generates stray currents which corrode steel structures of the highway. Corrosion weakens the structure followed by a collapse of a structure section. Highway vehicles fall into the collapsed section. Casualties include occupants of the highway vehicles.

Frequency: C (Occasional) Stray electric fields have been shown to corrode structures. For example, pipelines in the Chicago area have been corroded by stray currents from the electrified railroads. Although many existing electric rail systems use direct current (DC) (in the catenary) which is more prone to induce this type of corrosion, most new rail systems have been proposed with alternating current (AC). Similar problems have not been found with AC. It was assumed that there would be 1 instance of electromagnetic field corrosion per 40 years for a 320 km (200 miles) shared ROW.

Consequence: I (Catastrophic) A high-speed collision with a large mass, fallen structure can result in fatalities. In 1989, there were 3,400 fatalities from collisions between motor vehicles and fixed objects [Source: MVMA Motor Vehicle Facts & Figures 1990, p. 90]. The collapse of a bridge on the New York Thruway in 1987 killed numerous drivers and passengers.

Score:

Frequency	Occasional	C
Consequence	Catastrophic	I
Hazard Risk		4 Unacceptable

Mitigation: Frequency could be reduced by decreasing the strength of the electromagnetic field or by increasing the structure's tolerance of the electromagnetic field. Strength reduction can be achieved by energizing the catenary only when a train is present, shielding the motors to reduce electromagnetic emissions, increasing the distance between the tracks and the highway (either horizontally or vertically), or installing an electromagnetic barrier to absorb or reflect the field. This can be done by erecting a steel or concrete wall or by placing the HSR in a cut or tunnel. Tolerance of the field by the structure could be increased by proper grounding of the structure to dissipate the electromagnetic field or by building the structure of nonconductive or corrosion-resistant materials. Given the common use of structural steel in transportation structures, however, the last mitigation seems infeasible.

Consequence probably cannot be reduced except as part of the general, ongoing improvements in highway safety. For example, it would be impractical to require more crash resistant cars on highways that share an ROW.

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with management review).

Scenario Number: 2.1.4.a

Safety Issue: Electromagnetic Field Effects

Instigator: HSR

Affected Mode: Railroad

High Risk Event: The HSR system generates electromagnetic fields which disturb electronic equipment on the adjacent railroad. A railroad train does not receive a stop signal and collides with another train stopped at a station. Casualties include railroad train occupants.

Frequency: C (Occasional) HSR railroads would emit electromagnetic fields similar to present electrified railroads. Various combinations of electrified and non-electrified railroads have been operated without known adverse electromagnetic fields effects. Further, the occurrence of the event requires that a railroad train be present and may also require an HSR train to be present (if the electromagnetic fields comes from the HSR train rather than the HSR catenary) which further reduces the likelihood of the event. It was assumed that there would be 1 instance of electromagnetic field interference per 40 years for a 320 km (200 miles) shared ROW.

Consequence: I (Catastrophic) Railroad accidents can cause multiple fatalities among train occupants. For example, in 1990 there were 8 railroad employees killed in 4 train collisions [Source: FRA Accident/Incident Bulletin Calendar Year 1990, pp. 72, 84] and in 1987, 16 employees and passengers were killed in a high-speed collision between Amtrak and Conrail trains on the Northeast Corridor [Source: Railroad Accident Report, NTSB/RAR-88/01].

<u>Score:</u>	Frequency	Occasional	C	
	Consequence	Catastrophic	I	
	Hazard Risk		4	Unacceptable

Mitigation: Frequency can be reduced by decreasing the strength of the electromagnetic field or by increasing the railroad's tolerance of the electromagnetic field. Strength reduction can be achieved by energizing the catenary only when a train is present, shielding the motors to reduce electromagnetic emissions, increasing the distance between the HSR and railroad (either horizontally or vertically), or installing an electromagnetic barrier to absorb or reflect the field. This can be done by erecting a steel or concrete wall or by placing the HSR in a cut or tunnel. Tolerance of the field by the railroad requires changes outside the normal management scope of the HSR system and also might be impractical given the number of railroad vehicles using present technology.

Consequence probably cannot be reduced except as part of the general, ongoing improvements in railroads. For example, it would be impractical to require more crash-resistant locomotives or cars on railroads that share an ROW. Similarly, it would be undesirable for the railroad to lower its speed limits on shared ROWs.

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with management review).

Scenario Number: 2.1.4.b

Safety Issue: Electromagnetic Field Effects

Instigator: HSR

Affected Mode: Railroad

High Risk Event: The HSR system generates stray currents which corrode steel structures of the railroad. A structure collapses and a railroad train collides with the collapsed structure. Casualties include occupants of the railroad train.

Frequency: C (Occasional) Stray electric fields have been shown to corrode structures. For example, pipelines in the Chicago area have been corroded by stray currents from the electrified railroads. Although many existing electric rail systems use direct current (DC) (in the catenary) which is more prone to induce this type of corrosion, most new rail systems have been proposed with alternating current (AC). Similar problems have not been found with AC. It was assumed that there would be 1 instance of electromagnetic field corrosion per 40 years for a 320 km (200 miles) shared ROW.

Consequence: I (Catastrophic) A high-speed collision with a large mass, fallen structure can result in fatalities. For example, in 1990 there were 8 railroad employees killed in 4 train collisions [Source: FRA Accident/Incident Bulletin Calendar Year 1990, pp. 72, 84] and in 1991 two employees were killed when their train struck a landslide [Source: Trains, January 1992].

Score:	Frequency	Occasional	C	
	Consequence	Catastrophic	I	
	Hazard Risk		4	Unacceptable

Mitigation: Frequency could be reduced by decreasing the strength of the electromagnetic field or by increasing the structure's tolerance of the electromagnetic field. Strength reduction can be achieved by energizing the catenary only when a train is present, shielding the motors to reduce electromagnetic emissions, increasing the distance between the tracks and the highway (either horizontally or vertically), or installing an electromagnetic barrier to absorb or reflect the field. This can be done by erecting a steel or concrete wall or by placing the HSR in a cut or tunnel. Tolerance of the field by the structure could be increased by proper grounding of the structure to dissipate the electromagnetic field or by building the structure of nonconductive or corrosion-resistant materials. Given the common use of structural steel in transportation structures, however, the last mitigation seems infeasible.

Consequence probably cannot be reduced except as part of the general, ongoing improvements in railroads. For example, it would be impractical to require more crash-resistant locomotives or cars on railroads that share an ROW. Similarly, it would be undesirable for the railroad to lower its speed limits on shared ROWs.

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with management review).

Scenario Number: 2.1.5

Safety Issue: Electromagnetic Field Effects

Instigator: HSR

Affected Mode: Waterway

High Risk Event: The HSR system generates electromagnetic fields signals which disturb equipment on the boats operating on the adjacent waterway. A captain is not able to control his boat and it collides with another boat. Casualties include boat occupants.

Frequency: C (Occasional) Similar catenaries and motors have been in use for many years. Likewise, electronic controls have begun to be used on marine vehicles in recent years. These controls are designed to tolerate common outside interference without loss of service. It was assumed that there would be 1 instance of electromagnetic interference per 40 years for a 320 km (200 miles) shared ROW.

Consequence: I (Catastrophic) Marine accidents can result in multiple fatalities.

<u>Score:</u>	Frequency	Occasional	C	
	Consequence	Catastrophic	I	
	Hazard Risk		4	Unacceptable

Mitigation: Frequency can be reduced by decreasing the strength of the electromagnetic field or by increasing marine tolerance of the electromagnetic field. Strength reduction can be achieved by energizing the catenary only when a train is present, shielding the motors to reduce electromagnetic emissions, increasing the distance between the HSR and river (either horizontally or vertically), or installing an electromagnetic barrier to absorb or reflect the field. This can be done by erecting a steel or concrete wall or by placing the HSR in a cut or tunnel. Tolerance of the field by the marine vehicles would require changes outside the normal management scope of the HSR system and also might be impractical given the number of marine vehicles using present technology.

Consequence probably cannot be reduced except as part of the general, ongoing improvements in marine safety. For example, it would be impractical to require more crash-resistant boats on shared ROWs. Similarly, it would be unpopular among marine users to lower speed limits on shared ROWs.

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with management review).

Scenario Number: 2.1.6

Safety Issue: Electromagnetic Field Effects

Instigator: HSR

Affected Mode: Pipeline

High Risk Event: The HSR system generates stray currents which corrode the pipeline. The pipeline fractures and delivery of the pipeline product is interrupted.

Frequency: C (Occasional) Stray electric fields have been shown to corrode structures. For example, pipelines in the Chicago area have been corroded by stray currents from the electrified railroads. Although many existing electric rail systems use direct current (DC) (in the catenary) which is more prone to induce this type of corrosion, most new rail systems have been proposed with alternating current (AC). Similar problems have not been found with AC. It was assumed that there would be 1 instance of electromagnetic field corrosion per 40 years for a 320 km (200 miles) shared ROW.

Consequence: II (Critical) Service would be interrupted until the pipeline could be repaired. Given the nature of the failure, the pipeline company might choose to test adjacent pipe sections for impending failure. Both the test, and any additional repairs, would increase the service delay of the pipeline. If the material carried were water which was needed for firefighting, additional damage might result from this accident.

Score:

Frequency	Occasional	C	
Consequence	Critical	II	
Hazard Risk		6	Undesirable, management decision required

Mitigation:

Frequency could be reduced by decreasing the strength of the electromagnetic field or by increasing the pipeline's tolerance of the electromagnetic field. Strength reduction can be achieved by energizing the track only when a train is present, shielding the motors to reduce electromagnetic emissions, increasing the distance between the track and the pipeline (either horizontally or vertically), or installing an electromagnetic barrier (such as a steel or concrete wall) to absorb or reflect the field. Tolerance of the field by the pipeline could be increased by proper grounding of the structure to dissipate the electromagnetic field or by building the structure of nonconductive or corrosion-resistant materials (such as concrete pipe). Regular testing of the pipeline could disclose wall thinning or stress fractures before a rupture occurs.

Consequence could be reduced by ensuring alternative sources of supply of the pipeline product (which, for certain essentials such as water, probably is already the case), stockpiling replacement pipe to expedite repairs, and developing faster testing procedures.

Post-mitigation score would be Improbable/Critical: 15 (acceptable, with management review).

Scenario Number: 2.1.7

Safety Issue: Electromagnetic Field Effects

Instigator: HSR

Affected Mode: Transmission line

High Risk Event: The HSR system generates electromagnetic fields which disturb data transmission on the adjacent transmission line. Data transmission is interrupted.

Frequency: C (Occasional) Similar catenaries and motors have been in use for many years. Likewise, data transmission lines have also been in use for many years. Presumably those transmission lines were engineered to tolerate this type of electromagnetic field since it would occur wherever railroad and transmission lines cross. If this type of interference occurs, however, it is likely to reoccur whenever a train passes. It was assumed that there would be 1 instance of electromagnetic field interference per 40 years for a 320 km (200 miles) shared ROW.

Consequence: III (Marginal) Service loss probably would be momentary and could be resumed as soon as the train is past. Most data transmission systems have error checking protocols and alternate routes can be used on networks if more-than-momentary delays occur. Exceptions include "live" radio and television transmission feeds, where momentary interruptions or service quality degradations must be accepted, and air traffic control landlines, where a missed or misunderstood communication could cause problems with aerial navigation. If air traffic control services were interrupted, consequences could be much higher than estimated here.

Score:

Frequency	Occasional	C	
Consequence	Marginal	III	
Hazard Risk		11	Acceptable with review by management

Mitigation: None required.

Scenario Number: 2.2.3.a

Safety Issue: Electromagnetic Field Effects

Instigator: Maglev

Affected Mode: Highway

High Risk Event: The maglev system generates electromagnetic fields which disturb electronic equipment in a highway vehicle. The highway vehicle collides with other highway vehicles. Casualties include occupants of the highway vehicles.

Frequency: B (Probable) An energized maglev guideway is likely to emit a stronger electromagnetic field than a conventional railroad catenary. Likewise, maglev motors (if any) on vehicles are likely to emit stronger electromagnetic fields than conventional electric railroad motors. Electronic controls on highway vehicles that have been designed to present SAE standards may not be able to tolerate these fields without loss of service. It was assumed that there would be more than 1 instance of electromagnetic field interference per 10 years for a 320 km (200 miles) shared ROW.

Consequence: I (Catastrophic) High-speed, multi-vehicle highway crashes can result in multiple fatalities. In 1989, there were 20,300 fatalities from collisions between motor vehicles [Source: MVMA Motor Vehicle Facts & Figures 1990, p. 90].

<u>Score:</u>	Frequency	Probable	B	
	Consequence	Catastrophic	I	
	Hazard Risk		2	Unacceptable

Mitigation: Frequency can be reduced by decreasing the strength of the electromagnetic field or by increasing the motor vehicles' tolerance of the electromagnetic field. Strength reduction can be achieved by energizing the guideway only when a train is present, shielding the motors to reduce electromagnetic emissions, increasing the distance between the guideway and the highway (either horizontally or vertically), or installing an electromagnetic barrier to absorb or reflect the field. This can be done by erecting a steel or concrete wall or by placing the maglev in a cut or tunnel. Tolerance of the field by highway vehicles requires changes outside the normal management scope of the maglev system (such as more stringent SAE standards on electronic engine and brake systems) and also might be impractical given the number of highway vehicles using present technology.

Consequence probably cannot be reduced except as part of the general, ongoing improvements in highway safety.

Post-mitigation score would be Remote/Catastrophic: 8 (undesirable, management decision required).

Scenario Number: 2.2.3.b

Safety Issue: Electromagnetic Field Effects

Instigator: Maglev

Affected Mode: Highway

High Risk Event: The maglev system generates stray currents which corrode steel structures of the highway. A highway structure collapses and highway vehicles fall into the collapsed section. Casualties include occupants of the highway vehicles.

Frequency: B (Probable) Stray electric fields have been shown to corrode structures. For example, pipelines in the Chicago area have been corroded by stray currents from the electrified railroads. Although many existing electric rail systems use direct current (DC) (in the catenary) which is more prone to induce this type of corrosion, most new rail systems have been proposed with alternating current (AC). Similar problems have not been found with AC. It was assumed that there would be more than 1 instance of electromagnetic field corrosion per 10 years for a 320 km (200 miles) shared ROW.

Consequence: I (Catastrophic) A high-speed collision with a large mass, fallen structure probably would result in fatalities. In 1989, there were 3,400 fatalities from collisions between motor vehicles and fixed objects [Source: MVMA Motor Vehicle Facts & Figures 1990, p. 90]. The collapse of a bridge on the New York Thruway in 1987 killed numerous drivers and passengers.

<u>Score:</u>	Frequency	Probable	B	
	Consequence	Catastrophic	I	
	Hazard Risk		2	Unacceptable

Mitigation: Frequency could be reduced by decreasing the strength of the electromagnetic field or by increasing the structure's tolerance of the electromagnetic field. Strength reduction can be achieved by energizing the guideway only when a train is present, shielding the motors to reduce electromagnetic emissions, increasing the distance between the guideway and the highway (either horizontally or vertically), or installing an electromagnetic shield to absorb or reflect the field. This can be done by erecting a steel or concrete wall or by placing the maglev in a cut or tunnel. Tolerance of the field by the structure could be increased by proper grounding of the structure to dissipate the electromagnetic field or by building the structure of nonconductive or corrosion-resistant materials. Given the common use of structural steel in transportation structures, however, the last mitigation seems infeasible.

Consequence probably cannot be reduced except as part of the general, ongoing improvements in highway safety. For example, it would be impractical to require more crash-resistant cars on highways that share an ROW.

Post-mitigation score would be Remote/Catastrophic: 8 (undesirable, management decision required).

Scenario Number: 2.2.4.a

Safety Issue: Electromagnetic Field Effects

Instigator: Maglev

Affected Mode: Railroad

High Risk Event: The maglev system generates electromagnetic fields which disturb electronic equipment on the railroad. A railroad train does not receive a stop signal and collides with another train stopped at a station. Casualties include railroad train occupants.

Frequency: B (Probable) An energized maglev guideway is likely to emit a stronger electromagnetic field than a conventional railroad catenary. Likewise, maglev motors (if any) on vehicles are likely to emit stronger electromagnetic fields than conventional electric railroad motors. Electronic controls on railroad vehicles that have been designed to present standards may not be able to tolerate these fields without loss of service. It was assumed that there would be more than 1 instance of electromagnetic field interference per 10 years for a 320 km (200 miles) shared ROW.

Consequence: I (Catastrophic) Railroad accidents can cause multiple fatalities among train occupants. For example, in 1990 there were 8 railroad employees killed in 4 train collisions [Source: FRA Accident/Incident Bulletin Calendar Year 1990, pp. 72, 84] and in 1987, 16 employees and passengers were killed in a high-speed collision between Amtrak and Conrail trains on the Northeast Corridor [Source: Railroad Accident Report, NTSB/RAR-88/01].

<u>Score:</u>	Frequency	Probable	B	
	Consequence	Catastrophic	I	
	Hazard Risk		2	Unacceptable

Mitigation: Frequency can be reduced by decreasing the strength of the electromagnetic field or by increasing the railroad's tolerance of the electromagnetic field. Strength reduction can be achieved by energizing the catenary only when a train is present, shielding the motors to reduce electromagnetic emissions, increasing the distance between the maglev and railroad (either horizontally or vertically), or installing an electromagnetic shield to absorb or reflect the field. This can be done by erecting a steel or concrete wall or by placing the maglev in a cut or tunnel. Tolerance of the field by the railroad requires changes outside the normal management scope of the maglev system and also might be impractical given the number of railroad vehicles using present technology.

Consequence probably cannot be reduced except as part of the general, ongoing improvements in railroad safety. For example, it would be impractical to require more crash-resistant locomotives or cars on railroads that share an ROW. Similarly, it would be undesirable for the railroad to lower its speed limits to reduce crash damage on shared ROWs.

Post-mitigation score would be Remote/Catastrophic: 8 (undesirable, management review required).

Scenario Number: 2.2.4.b

Safety Issue: Electromagnetic Field Effects

Instigator: Maglev

Affected Mode: Railroad

High Risk Event: The maglev system generates stray currents which corrode steel structures of the railroad. A railroad structure collapses and a railroad train collides with the collapsed structure. Casualties include occupants of the railroad train.

Frequency: B (Probable) Stray electric fields have been shown to corrode structures. For example, pipelines in the Chicago area have been corroded by stray currents from the electrified railroads. Although many existing electric rail systems use direct current (DC) (in the catenary) which is more prone to induce this type of corrosion, most new rail systems have been proposed with alternating current (AC). Similar problems have not been found with AC. It was assumed that there would be 1 instance of electromagnetic field corrosion per 10 years for a 320 km (200 miles) shared ROW.

Consequence: I (Catastrophic) A high-speed collision with a large mass, fallen structure can result in multiple fatalities. For example, in 1990 there were 8 railroad employees killed in 4 train collisions [Source: FRA Accident/Incident Bulletin Calendar Year 1990, pp. 72, 84] and in 1991 two employees were killed when their train struck a landslide [Source: Trains, January 1992].

Score:

Frequency	Probable	B	
Consequence	Catastrophic	I	
Hazard Risk		2	Unacceptable

Mitigation: Frequency could be reduced by decreasing the strength of the electromagnetic field or by increasing the structure's tolerance of the electromagnetic field. Strength reduction can be achieved by energizing the guideway only when a train is present, shielding the motors to reduce electromagnetic emissions, increasing the distance between the guideway and the highway (either horizontally or vertically), or installing an electromagnetic shield to absorb or reflect the field. This can be done by erecting a steel or concrete wall or by placing the maglev in a cut or tunnel. Tolerance of the field by the structure could be increased by proper grounding of the structure to dissipate the electromagnetic field or by building the structure of nonconductive or corrosion-resistant materials. Given the common use of structural steel in transportation structures, however, the last mitigation seems infeasible.

Consequence probably cannot be reduced except as part of the general, ongoing improvements in railroads. For example, it would be impractical to require more crash-resistant locomotives or cars on railroads that share an ROW. Similarly, it would be undesirable for the railroad to lower its speed limits to reduce crash damage on shared ROWs.

Post-mitigation score would be Remote/Catastrophic: 8 (undesirable, management review required).

Scenario Number: 2.2.5

Safety Issue: Electromagnetic Field Effects

Instigator: Maglev

Affected Mode: Waterway

High Risk Event: Maglev system equipment generates electromagnetic field signals which disturb equipment on a boat. A captain is unable to control his boat and it collides with another boat. Casualties include boat occupants.

Frequency: B (Probable) An energized maglev guideway is likely to emit a stronger electromagnetic field than a conventional railroad catenary. Likewise, maglev motors (if any) on vehicles are likely to emit stronger electromagnetic fields than conventional electric railroad motors. Electronic controls on marine vehicles that have been designed to present standards may not be able to tolerate these fields without loss of service. It was assumed that there would be 1 instance of electromagnetic field interference per 10 years for a 320 km (200 miles) shared ROW.

Consequence: I (Catastrophic) Marine accidents can result in multiple fatalities.

<u>Score:</u>	Frequency	Probable	B	
	Consequence	Catastrophic	I	
	Hazard Risk		2	Unacceptable

Mitigation: Frequency can be reduced by decreasing the strength of the electromagnetic field or by increasing marine tolerance of the electromagnetic field. Strength reduction can be achieved by energizing the guideway only when a train is present, shielding the motors to reduce electromagnetic emissions, increasing the distance between the Maglev and river (either horizontally or vertically), or installing an electromagnetic shield to absorb or reflect the field. This can be done by erecting a steel or concrete wall or by placing the maglev in a cut or tunnel. Tolerance of the field by the marine vehicles would require changes outside the normal management scope of the maglev system and also might be impractical given the number of marine vehicles using present technology.

Consequence probably cannot be reduced except as part of the general, ongoing improvements in marine safety. For example, it would be impractical to require more crash-resistant boats on shared ROWs. Similarly, it would be unpopular among marine users to lower speed limits to reduce crash damage on shared ROWs.

Post-mitigation score would be Remote/Catastrophic: 8 (undesirable, management review required).

Scenario Number: 2.2.6

Safety Issue: Electromagnetic Field Effects

Instigator: Maglev

Affected Mode: Pipeline

High Risk Event: The maglev system generates stray currents which corrode steel structures of the pipeline. The pipeline fractures and delivery of the pipeline product is interrupted.

Frequency: B (Probable) Stray electric fields have been shown to corrode structures. For example, pipelines in the Chicago area have been corroded by stray currents from the electrified railroads. Although many existing electric rail systems use direct current (DC) (in the catenary) which is more prone to inducing this type of corrosion, most new rail systems have been proposed with alternating current (AC). Similar problems have not been found with AC. It was assumed that there would be more than 1 instance of electromagnetic field corrosion per 10 years for a 320 km (200 miles) shared ROW.

Consequence: II (Critical) Service would be interrupted until the pipeline could be repaired. Given the nature of the failure, the pipeline company might choose to test adjacent pipe sections for impending failure. Both the test and any additional repairs, would increase the service delay of the pipeline. If the material carried were water which was needed for firefighting, additional damage might be incurred through this accident.

Score:

Frequency	Probable	B	
Consequence	Critical	II	
Hazard Risk		5	Unacceptable

Mitigation: Frequency could be reduced by decreasing the strength of the electromagnetic field or by increasing the pipeline's tolerance of the electromagnetic field. Strength reduction can be achieved by energizing the guideway only when a train is present, shielding the motors to reduce electromagnetic emissions, increasing the distance between the guideway and the pipeline (either horizontally or vertically), or installing an electromagnetic barrier (such as a steel or concrete wall) to absorb or reflect the field. Tolerance of the field by the pipeline could be increased by proper grounding of the structure to dissipate the electromagnetic field or by building the structure of nonconductive or corrosion-resistant materials (such as concrete pipe). Regular testing of the pipeline could disclose wall thinning or stress fractures before product is lost.

Consequence could be reduced by ensuring alternative sources of supply of the pipeline product (which, for certain essentials such as water, probably is already the case), stockpiling replacement pipe to expedite repairs, and developing faster testing procedures.

Post-mitigation score would be Remote/Critical: 10 (acceptable, with management review).

Scenario Number: 2.2.7

Safety Issue: Electromagnetic Field Effects

Instigator: Maglev

Affected Mode: Transmission line

High Risk Event: The maglev system generates electromagnetic fields signals which disturb data transmission on the adjacent transmission line. Data transmission is interrupted.

Frequency: B (Probable) An energized maglev guideway is likely to emit a stronger electromagnetic field than a conventional railroad catenary. Likewise, maglev motors (if any) on vehicles are likely to emit stronger electromagnetic fields than conventional electric railroad motors. Fault detection and correction processes on transmission networks may not be able to tolerate these fields without loss of service. It was assumed that there would be 1 instance of electromagnetic field interference per 10 years for a 320 km (200 miles) shared ROW.

Consequence: III (Marginal) Service loss probably would be momentary and could be resumed as soon as the train is past. Most data transmission systems have alternative routes that can be used on networks if more-than-momentary delays occurs. Exceptions include "live" radio and television transmission feeds, where momentary interruptions or service quality degradations must be accepted, and air traffic control landlines, where a missed or misunderstood communication could cause problems with aerial navigation. If air traffic control services were interrupted, consequences could be much higher than estimated here.

Score:

Frequency	Probable	B	
Consequence	Marginal	III	
Hazard Risk		9	Undesirable, management decision required

Mitigation: Frequency can be reduced by decreasing the strength of the electromagnetic field or by increasing marine tolerance of the electromagnetic field. Strength reduction can be achieved by energizing the catenary only when a train is present, shielding the motors to reduce electromagnetic emissions, increasing the distance between the HSR and river (either horizontally or vertically), or installing an electromagnetic shield to absorb or reflect the field. This can be done by erecting a steel or concrete wall or by placing the HSR in a cut or tunnel. Tolerance of the field by the marine vehicles would require changes outside the normal management scope of the HSR system and also might be impractical given the number of transmission lines using present technology.

Consequence probably cannot be reduced.

Post-mitigation score would be Remote/Marginal: 14 (acceptable, with review by management).

Scenario Number: 2.4.1

Safety Issue: Electromagnetic Field Effects

Instigator: Railroad

Affected Mode: HSR

High Risk Event: The railroad generates electromagnetic fields signals which disturb equipment on the HSR system. An HSR train ignores a stop signal and collides with another HSR train stopped at a station. Casualties include HSR train passengers.

Frequency: C (Occasional) Similar catenaries and motors have been in use for many years. Various combinations of electrified and non-electrified railroads have been operated without known adverse electromagnetic fields effects. Further, the occurrence of the event requires that a railroad train be present and may also require an HSR train to be present (if the electromagnetic fields comes from the HSR train rather than the HSR catenary) which further reduces the likelihood of the event. It was assumed that there would be more than 1 instance of electromagnetic field interference per 40 years for a 320 km (200 miles) shared ROW.

Consequence: I (Catastrophic) Collision accidents between railroad trains can cause multiple fatalities. For example, in 1990 there were 8 railroad employees killed in 4 train collisions [Source: FRA Accident/Incident Bulletin Calendar Year 1990, pp. 72, 84] and in 1987, 16 employees and passengers were killed in a high-speed collision between Amtrak and Conrail trains on the Northeast Corridor [Source: Railroad Accident Report, NTSB/RAR-88/01]. HSR accidents probably will be as severe as conventional railroad accidents. In fact, the higher speeds and lighter vehicle construction may contribute to higher severity accidents.

<u>Score:</u>	Frequency	Occasional	C	
	Consequence	Catastrophic	I	
	Hazard Risk		4	Unacceptable

Mitigation: Frequency can be reduced by increasing the HSR's tolerance of the railroad's electromagnetic field. This can be done by engineering and shielding the control systems on the HSR. Frequency can also be reduced by increasing the distance between the railroad and HSR systems or by erecting barriers to reflect or absorb the electromagnetic field before it reaches the HSR system. The latter can be achieved with steel or concrete barriers or by putting the HSR in a cut or tunnel. Although the electromagnetic field could also be reduced by energizing the railroad catenary only when a train is present and shielding the motors to reduce electromagnetic emissions, these changes are outside the normal management scope of the HSR system and also might be impractical given the number of railroads using present technology.

Consequence probably cannot be reduced except as part of the general, ongoing improvements in HSR safety. For example, it would be impractical to require more crash-resistant locomotives or cars on HSR systems that share an ROW. Likewise, it would defeat much of the advantage of HSR if train speeds were restricted to reduce damage in accidents.

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with management review).

Scenario Number: 2.4.2

Safety Issue: Electromagnetic Field Effects

Instigator: Railroad

Affected Mode: Maglev

High Risk Event: The railroad generates electromagnetic fields signals which disturb equipment on the maglev system. One maglev train ignores a stop signal and collides with another maglev train stopped at a station. Casualties include maglev train passengers.

Frequency: C (Occasional) Similar catenaries and motors have been in use for many years. Various combinations of electrified and non-electrified railroads have been operated without known adverse electromagnetic fields effects. It was assumed that there would be 1 instance of electromagnetic field interference per 40 years for a 320 km (200 miles) shared ROW.

Consequence: I (Catastrophic) Maglev accidents probably will be as severe as conventional railroad accidents. In fact, the higher speeds and lighter vehicle construction may contribute to higher severity accidents. Collision accidents between conventional railroad equipment can cause multiple fatalities. For example, in 1990 there were 8 railroad employees killed in 4 train collisions [Source: FRA Accident/Incident Bulletin Calendar Year 1990, pp. 72, 84] and in 1987, 16 employees and passengers were killed in a high-speed collision between Amtrak and Conrail trains on the Northeast Corridor [Source: Railroad Accident Bulletin, NTSB/RAR-88/01].

<u>Score:</u>	Frequency	Occasional	C
	Consequence	Catastrophic	I
	Hazard Risk		4 Unacceptable

Mitigation: Frequency can be reduced by increasing the maglev's tolerance of the railroad's electromagnetic field. This can be done by engineering and shielding the control systems on the maglev. Frequency can also be reduced by increasing the distance between the railroad and maglev systems or by erecting barriers to reflect or absorb the electromagnetic field before it reaches the maglev system. The latter can be achieved with steel or concrete barriers or by putting the maglev in a cut or tunnel. Although the electromagnetic field could also be reduced by energizing the railroad catenary only when a train is present and shielding the motors to reduce electromagnetic emissions, these changes are outside the normal management scope of the maglev system and also might be impractical given the number of railroads using present technology.

Consequence probably cannot be reduced except as part of the general, ongoing improvements in maglev safety. For example, it would be impractical to require more crash-resistant locomotives or cars on maglev systems that share an ROW. Likewise, it would defeat much of the advantage of maglev if train speeds were restricted to reduce damage in accidents.

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with management review).

Scenario Number: 2.7.1

Safety Issue: Electromagnetic Field Effects

Instigator: Transmission line

Affected Mode: HSR

High Risk Event: The transmission line generates electromagnetic field signals which disturb equipment on the HSR system. One HSR train ignores a stop signal and collides with another HSR train stopped at a station. Casualties include HSR passengers.

Frequency: C (Occasional) Similar powerlines have been in use for many years. There are several examples of conventional electric railroads presently sharing ROWs with powerlines without operational problems. It was assumed that there would be 1 instance of electromagnetic field interference per 40 years for a 320 km (200 miles) shared ROW.

Consequence: I (Catastrophic) HSR accidents probably will be as severe as conventional railroad accidents. In fact, the higher speeds and lighter vehicle construction may contribute to higher severity accidents. Collision accidents between conventional railroad equipment can cause multiple fatalities. For example, in 1990 there were 8 railroad employees killed in 4 train collisions [Source: FRA Accident/Incident Bulletin Calendar Year 1990, pp. 72, 84] and in 1987, 16 employees and passengers were killed in a high-speed collision between Amtrak and Conrail trains on the Northeast Corridor [Source: Railroad Accident Report, NTSB/RAR-88/01].

<u>Score:</u>	Frequency	Occasional	C	
	Consequence	Catastrophic	I	
	Hazard Risk		4	Unacceptable

Mitigation: Frequency can be reduced by increasing the HSR's tolerance of the powerline's electromagnetic field. This can be done by engineering and shielding the control systems on the HSR. Frequency can also be reduced by increasing the distance between the powerline and the HSR system or by erecting barriers to reflect or absorb the electromagnetic field before it reaches the HSR system. The latter can be achieved with steel or concrete barriers or by putting the HSR in a cut or tunnel. Reducing the strength of the electromagnetic field—such as by increasing the height of the support towers or poles—are beyond the normal management scope of the HSR system.

Consequence probably cannot be reduced except as part of the general, ongoing improvements in HSR safety. For example, it would be impractical to require more crash-resistant locomotives or cars on HSR systems that share an ROW. Likewise, it would defeat much of the advantage of HSR if speeds were restricted to reduce damage in accidents.

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with management review).

Scenario Number: 2.7.2

Safety Issue: Electromagnetic Field Effects

Instigator: Transmission line

Affected Mode: Maglev

High Risk Event: The transmission line generates electromagnetic fields signals which disturb equipment on the maglev system. A maglev train ignores a stop signal and collides with another maglev train in a station. Casualties include maglev train passengers.

Frequency: C (Occasional) Similar powerlines have been in use for many years. There are several examples of conventional electric railroads presently sharing ROWs with powerlines without operational problems. It was assumed that there would be 1 instance of electromagnetic field interference per 40 years for a 320 km (200 miles) shared ROW.

Consequence: I (Catastrophic) Maglev accidents probably will be as severe as conventional railroad accidents. In fact, the higher speeds and lighter vehicle construction may contribute to higher severity accidents. Collision accidents between conventional railroad equipment can cause multiple fatalities. For example, in 1990 there were 8 railroad employees killed in 4 train collisions [Source: FRA Accident/Incident Bulletin Calendar Year 1990, pp. 72, 84] and in 1987, 16 employees and passengers were killed in a high-speed collision between Amtrak and Conrail trains on the Northeast Corridor [Source: Railroad Accident Report, NTSB/RAR-88/01].

<u>Score:</u>	Frequency	Occasional	C	
	Consequence	Catastrophic	I	
	Hazard Risk		4	Unacceptable

Mitigation: Frequency can be reduced by increasing the maglev's tolerance of the powerline's electromagnetic field. This can be done by engineering and shielding the control systems on the maglev. Frequency can also be reduced by increasing the distance between the powerline and the maglev system or by erecting barriers to reflect or absorb the electromagnetic field before it reaches the maglev system. The latter can be achieved with steel or concrete barriers or by putting the maglev in a cut or tunnel. Reducing the strength of the electromagnetic field—such as by increasing the height of the support towers or poles—are beyond the normal management scope of the maglev system.

Consequence probably cannot be reduced except as part of the general, ongoing improvements in maglev safety. For example, it would be impractical to require more crash-resistant locomotives or cars on maglev systems that share an ROW. Likewise, it would defeat much of the advantage of maglev if speeds were restricted to reduce damage in accidents.

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with management review).

APPENDIX C DYNAMIC INTERFERENCE

<u>Scenario Number:</u>	3.0.3.a									
<u>Safety Issue:</u>	Dynamic interference									
<u>Instigator:</u>	HSGGT									
<u>Affected Mode:</u>	Highway									
<u>High-Risk Event:</u>	A passing HSGGT train at cruising speed startles motorists, leading to loss of concentration and a multivehicle accident. Casualties include highway vehicle occupants.									
<u>Frequency:</u>	A (Frequent) Data on startle effect accidents could not be located. It was assumed that there would be one instance per month on the 320 km (200 miles) shared ROW when the HSGGT service is started and that the frequency will diminish as drivers become familiar with the trains.									
<u>Consequence:</u>	I (Catastrophic) High-speed, multi-vehicle highway crashes can result in multiple fatalities. In 1989, there were 20,300 fatalities from collisions between motor vehicles [Source: MVMA Motor Vehicle Facts & Figures 1990, p. 90].									
<u>Score:</u>	<table><tr><td>Frequency:</td><td>Frequent</td><td>A</td></tr><tr><td>Consequence:</td><td>Catastrophic</td><td>I</td></tr><tr><td>Hazard Risk:</td><td></td><td>1 Unacceptable</td></tr></table>	Frequency:	Frequent	A	Consequence:	Catastrophic	I	Hazard Risk:		1 Unacceptable
Frequency:	Frequent	A								
Consequence:	Catastrophic	I								
Hazard Risk:		1 Unacceptable								
<u>Mitigation:</u>	<p>Frequency could be reduced by:</p> <ul style="list-style-type: none">• Physical separation. The startle effect scenario frequency is inversely proportional to the distance separating the HSGGT and highway ROWs.• Tree barriers. Intermittent or continuous tree barriers would provide a natural visual separator for mitigation of the startle effect. Tree barriers require only a limited width of land, and they improve the aesthetic appearance of the shared ROW. A disadvantage is the possible stroboscopic effect on HSGGT passengers as the trees intermittently block automobile headlights. <p>Consequence probably could not be reduced.</p> <p>The recommended mitigation measure for scenario 3.0.3.a is placement of natural tree barriers between the HSGGT and the highway ROWs. An intermittent barrier may be considered along with physical separation, if the latter is chosen as mitigation for other scenarios.</p> <p>Post-mitigation score would be Occasional/Catastrophic: 4 (unacceptable)</p>									

Scenario Number: 3.0.3.b

Safety Issue: Dynamic interference

Instigator: HSGGT

Affected Mode: Highway

High-Risk Event: HSGGT system operations cause stress fatigue to the highway structures and a section of the highway collapses. Highway vehicles fall into the collapsed section. Casualties include highway vehicle occupants.

Frequency: D (Remote) Data on total failure due to stress fatigue could not be identified. It was assumed that such a failure would occur on the 645 km (400 miles) HSGGT system once per 100 years. Since 320 km (200 miles) are shared ROW, there would be 1 failure per 200 years.

Consequence: I (Catastrophic) A high-speed collision with a large mass, fallen structure probably would result in fatalities. In 1989, there were 3,400 fatalities from collisions between motor vehicles and fixed objects [Source: MVMA Motor Vehicle Facts & Figures 1990, p. 90]. More specifically, the collapse of a bridge on the New York Thruway in 1987 killed several persons when their cars and trucks fell through the fallen span.

Score:

Frequency:	Remote	D	
Consequence:	Catastrophic	I	
Hazard Risk:		8	Undesirable, management decision required

Mitigation: Frequency could be reduced by:

- Design considerations. A thorough examination of the feasibility of shared ROW use should be made for highway structures originally designed to carry highway traffic only.
- Procedures. Maintenance procedures to periodically verify integrity of the shared structure should be developed.

Consequence probably could not be reduced.

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, management decision required).

Scenario Number: 3.0.3.c

Safety Issue: Dynamic interference

Instigator: HSGGT

Affected Mode: Highway

High-Risk Event: During winter operations, an HSGGT train at cruising speed disturbs the snow along the ROW. The swirling snow momentarily blinds motorists and causes a multivehicle accident. Casualties include highway vehicle occupants.

Frequency: A (Frequent) A large number of proposed HSGGT systems are located in the northern areas of the country, where substantial snowfall is likely. Also, conventional trains operating in winter conditions generate substantial turbulence forces to significantly disturb the snowpack around the ROW. Therefore, it can be expected that HSGGT trains travelling at three times the speed of the majority of U.S. railroad trains today would increase the frequency and severity of this scenario. It was assumed that this would occur once per month on the 320 km (200 miles) shared ROW.

Consequence: I (Catastrophic) High-speed, multi-vehicle highway crashes can result in multiple fatalities. In 1989, there were 20,300 fatalities from collisions between motor vehicles [Source: MVMA Motor Vehicle Facts & Figures 1990, p. 90].

Score:

Frequency:	Frequent	A
Consequence:	Catastrophic	I
Hazard Risk:		1 Unacceptable

Mitigation: Frequency could be reduced by:

- Physical separation
- Tree barriers
- Turbulence barriers

Consequence probably could not be reduced.

The recommended mitigation measure is tree barriers. Tree barriers also are effective against the startle effect hazard (scenario 3.0.3.a). Turbulence barriers may be considered if shared ROW space is limited. Physical separation also may be considered in areas where space constraints are not an issue.

Post-mitigation score would be Occasional/Catastrophic: 4 (unacceptable)

Scenario Number: 3.0.4.a

Safety Issue: Dynamic Interference

Investigator: HSGGT

Affected Mode: Railroad

High-Risk Event: A passing HSGGT train at cruising speed causes turbulence at a platform occupied by passengers waiting to board a railroad train. Several passengers lose their balance and fall onto the railroad tracks in front of an approaching railroad train. Casualties include the fallen passengers.

Frequency: A (Frequent) It was assumed that one person a month would fall onto the tracks because of the turbulence on the 320 km (200 miles) shared ROW, but that 9 times out of 10 the person could get back onto the platform before being struck by the commuter train. Therefore, 1.2 persons per year would be killed or 1 fatality every 0.83 years.

Consequence: I (Catastrophic) Persons struck by moving trains are often killed. From 1988 through 1990, 1,321 people were struck and killed by trains other than at highway grade crossings [Source: FRA Accident/Incident Bulletin, 1988, 1989, 1990, p. 94 in each volume].

Score:

Frequency:	Frequent	A
Consequence:	Catastrophic	I
Hazard Risk		1 Unacceptable

Mitigation: Frequency could be reduced by:

- Physical separation. Severity of turbulence effects is inversely proportional to the distance separating the HSGGT and the adjacent railroad.
- Speed reduction. Turbulence is proportional to speed.
- Turbulence barriers.

Consequence probably could not be reduced.

Physical separation may be difficult to achieve in cities because available space is limited. Therefore, since speed reduction already may be required by the curvature of the existing ROW, it is the recommended mitigation measure. Additional turbulence barriers may be added in straight sections of the shared ROW.

Post-mitigation score would be Occasional/Catastrophic: 4 (unacceptable)

Scenario Number: 3.0.4.b

Safety Issue: Dynamic interference

Instigator: HSGGT

Affected Mode: Railroad

High-Risk Event: HSGGT operations cause stress fatigue to the railroad structures and a section of the railroad track collapses. A railroad train falls into the collapsed section at cruising speed. Casualties include railroad train occupants.

Frequency: D (Remote) Railroad structures are designed for long lives. It was assumed that there would be one failure per 100 years for the 645 km (400 miles) HSGGT system. Since 320 km (200 miles) of that system are shared ROW, there would be one failure every 200 years.

Consequence: I (Catastrophic) A high-speed collision with a large mass, fallen structure can result in fatalities. For example, in 1990 there were 8 railroad employees killed in 4 train collisions [Source: FRA Accident/Incident Bulletin Calendar Year 1990, pp. 72, 84] and in 1991, 2 employees were killed when their train struck a landslide [Source: Trains, January 1992].

Score:

Frequency:	Remote	D
Consequence:	Catastrophic	I
Hazard Risk:		8 Undesirable, management decision required

Mitigation: Frequency can be reduced by the measures that were described for scenario 3.0.3.b:

- Design considerations
- Procedures

Consequence probably cannot be reduced.

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with management review).

Scenario Number: 3.0.5

Safety Issue: Dynamic interference

Instigator: HSGGT

Affected Mode: Waterway

High-Risk Event: A passing HSGGT train at cruising speed startles boatmen and causes a loss of concentration and a multiboat accident. Casualties include boat occupants.

Frequency: B (Probable) It was assumed that there would be one startle effect accident per 4 years for the 320 km (200 miles) shared ROW. The frequency would diminish as boaters became familiar with the HSGGT operations.

Consequence: I (Catastrophic) Collisions between boats can cause fatalities.

Score:

Frequency:	Probable	B
Consequence:	Catastrophic	I
Hazard Risk:		2 Unacceptable

Mitigation: Frequency could be reduced by the measures described for scenario 3.0.3.a:

- Physical separation
- Tree barriers

Consequence probably could not be reduced.

Post-mitigation score with waterway width would be Occasional/Catastrophic: 4 (unacceptable); with an intermittent tree barrier the score would be Remote/Catastrophic 8: (undesirable, management decision required).

Scenario Number: 3.0.6

Safety Issue: Dynamic interference

Instigator: HSGGT

Affected Mode: Pipeline

High-Risk Event: HSGGT operations cause stress fatigue to the pipeline structures. The pipeline begins to leak and delivery of pipeline product is interrupted.

Frequency: D (Remote) Pipelines are designed for long lives. It was assumed that there would be one failure per 100 years for the 645 km (400 miles) HSGGT system. Since 320 km (200 miles) of that system are shared ROW, there would be one failure every 200 years.

Consequence: II (Critical) Service would be interrupted until the pipeline could be repaired. Given the nature of the failure, the pipeline company might choose to test adjacent pipe sections for impending failure. Both the test, and any additional repairs, would increase the service delay of the pipeline. If the material carried were water which was needed for firefighting, additional damage might result from this accident.

Score:

Frequency:	Remote	D	
Consequence:	Critical	II	
Hazard Risk:		10	Acceptable, with review by management

Mitigation: None required.

Scenario Number: 3.0.7

Safety Issue: Dynamic interference

Instigator: HSGGT

Affected Mode: Transmission line

High-Risk Event: The shared ROW is located in an urban area. HSGGT operations cause stress fatigue to the transmission line support tower structures. A transmission line tower falls onto houses. Casualties include residents.

Frequency: D (Remote) Transmission lines are designed for long lives. It was assumed that there would be one failure per 100 years for the 645 km (400 miles) HSGGT system. Since 320 km (200 miles) of that system are shared ROW, there would be one failure every 200 years.

Consequence: I (Catastrophic) People could be crushed by large objects and die.

Score:

Frequency:	Remote	D
Consequence:	Catastrophic	I
Hazard Risk:		8 Undesirable, management decision required

Mitigation: Frequency could be reduced by the same measures described for scenario 3.0.3.b:

- Design considerations. New transmission line towers should be built to accept the dynamic stresses of closely located HSGGT trains. Existing towers should be inspected.
- Procedures. Inspectors should specifically check for stress failures.

Consequence probably could not be reduced.

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with management review).

Scenario Number: 3.3.0

Safety Issue: Dynamic interference

Instigator: Highway

Affected Mode: HSGGT

High-Risk Event: Highway traffic causes stress fatigue to the structures of the HSGGT system. A section of the HSGGT track collapses and an HSGGT train falls into the collapsed section at cruising speed. Casualties include HSGGT train passengers.

Frequency: D (Remote) HSGGT structures will be designed for long lives. It was assumed that there would be one failure per 100 years for the 645 km (400 miles) HSGGT system. Since 320 km (200 miles) of that system are shared ROW, there would be one failure every 200 years.

Consequence: I (Catastrophic) A high-speed collision with a large mass, fallen structure can result in fatalities. For example, in 1990 there were 8 railroad employees killed in 4 train collisions [Source: FRA Accident/Incident Bulletin Calendar Year 1990, pp. 72, 84] and in 1991, 2 employees were killed when their train struck a landslide [Source: Trains, January 1992].

Score:

Frequency:	Remote	D
Consequence:	Catastrophic	I
Hazard Risk:		8 Undesirable, management decision required

Mitigation: Frequency could be reduced by:

- Design considerations. HSGGT structures should be designed and built to accept the dynamic stresses of closely located highways.
- Procedures. HSGGT inspectors should be trained to observe impending stress failures.

Consequence probably could not be reduced.

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with review by management).

Scenario Number: 3.4.0

Safety Issue: Dynamic interference

Instigator: Railroad

Affected Mode: HSGGT

High-Risk Event: Railroad operations cause stress fatigue to the structures of the HSGGT system. A section of the HSGGT track/guideway collapses and an HSGGT train falls into the collapsed section at cruising speed. Casualties include HSGGT train passengers.

Frequency: D (Remote) HSGGT structures will be designed for long lives. It was assumed that there would be one failure per 100 years for the 645 km (400 miles) HSGGT system. Since 320 km (200 miles) of that system are shared ROW, there would be one failure every 200 years.

Consequence: I (Catastrophic) A high-speed collision with a large mass, fallen structure can result in fatalities. For example, in 1990, there were 8 railroad employees killed in 4 train collisions [Source: FRA Accident/Incident Bulletin Calendar Year 1990, pp. 72, 84] and in 1991 two employees were killed when their train struck a landslide [Source: Trains, January 1992].

Score:

Frequency:	Remote	D
Consequence:	Catastrophic	I
Hazard Risk:		8 Undesirable, management decision required

Mitigation: Frequency could be reduced by:

- Design considerations. HSGGT structures should be designed and built to accept the dynamic stresses of closely located highways.
- Procedures. HSGGT inspectors should be trained to observe impending stress failures.

Consequence probably could not be reduced.

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with review by management).

Scenario Number: 3.5.0

Safety Issue: Dynamic interference

Instigator: Waterway

Affected Mode: HSGGT

High-Risk Event: The waterway causes a gradual erosion of the bank by the HSGGT track/guideway. A section of track/guideway collapses and causes an HSGGT train to derail at cruising speed. Casualties include HSGGT train passengers.

Frequency: C (Occasional) Bank erosion is a slow process and can generally be detected. It was assumed that there would be 1 erosion caused failure along the 320 km (200 miles) portion of shared ROW each 40 years.

Consequence: I (Catastrophic) A high-speed collision with a large mass, fallen structure can result in fatalities. For example, in 1990 there were 8 railroad employees killed in 4 train collisions [Source: FRA Accident/Incident Bulletin Calendar Year 1990, pp. 72, 84] and in 1991, 2 employees were killed when their train struck a landslide [Source: Trains, January 1992].

Score:

Frequency:	Occasional	C
Consequence:	Catastrophic	I
Hazard Risk:		4 Unacceptable

Mitigation: Frequency could be reduced by:

- Strict maintenance procedures. The procedures must be developed to include more frequent maintenance inspection of the ROW.

Consequence probably could not be reduced.

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, management review required).

Scenario Number: 3.6.0

Safety Issue: Dynamic interference

Instigator: Pipeline

Affected Mode: HSGGT

High-Risk Event: A pipeline leaks and gradually erodes the ground under the HSGGT Track/guideway. A section of track/guideway collapses and an HSGGT train at cruising speed falls into the collapsed section. Casualties include HSGGT train passengers.

Frequency: D (Remote) Pipelines are designed for long lives. It was assumed that there would be one failure per 100 years for the 645 km (400 miles) HSGGT system. Since 320 km (200 miles) of that system are shared ROW, there would be one failure every 200 years.

Consequence: I (Catastrophic) A high-speed collision with a large mass, fallen structure can result in fatalities. For example, in 1990 there were 8 railroad employees killed in 4 train collisions [Source: FRA Accident/Incident Bulletin Calendar Year 1990, pp. 72, 84] and in 1991, 2 employees were killed when their train struck a landslide [Source: Trains, January 1992].

Score:

Frequency:	Remote	D
Consequence:	Catastrophic	I
Hazard Risk:		8 Undesirable, management decision required

Mitigation: Frequency could be reduced by:

- Pipeline leak sensors
- Maintenance procedures

Consequence probably could not be reduced.

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, management review required).

APPENDIX D INFRINGEMENT OF OPERATING ENVELOPE

<u>Scenario Number:</u>	4.1.4									
<u>Safety Issue:</u>	Infringement of operating envelope									
<u>Instigator:</u>	HSR									
<u>Affected Mode:</u>	Railroad									
<u>High-Risk Event:</u>	HSR and railroad operations share the same track, similar to Amtrak's Northeast Corridor. The safe separation system of an HSR train fails at cruising speed and the train collides with a stopped railroad train. Casualties include occupants of the railroad train and HSR passengers.									
<u>Frequency:</u>	B (Probable) There were 315 collisions between railroad trains in the United States in 1990. Of these, 15 involved Amtrak intercity passenger trains. [Source: FRA Accident/Incident Bulletin, Calendar Year 1990, p. 27]. The Amtrak/Conrail collision at Chase, MD on January 4, 1987 was between a relatively high speed train (202 km/hr (125 mph)) and a slow freight train on extensively signaled track [Source: Railroad Accident Report, NTSB/RAR-88/01]. It was assumed that there would be 1 such collision every 4 years on a 320 km (200 miles) shared ROW.									
<u>Consequence:</u>	I (Catastrophic) Multiple fatalities on trains that collide are possible. The Amtrak/Conrail accident cited above resulted in 16 fatalities.									
<u>Score:</u>	<table><tr><td>Frequency:</td><td>Probable</td><td>B</td></tr><tr><td>Consequence:</td><td>Catastrophic</td><td>I</td></tr><tr><td>Hazard Risk:</td><td></td><td>2 Unacceptable</td></tr></table>	Frequency:	Probable	B	Consequence:	Catastrophic	I	Hazard Risk:		2 Unacceptable
Frequency:	Probable	B								
Consequence:	Catastrophic	I								
Hazard Risk:		2 Unacceptable								
<u>Mitigation:</u>	<p>Frequency can be reduced by upgrading signalling systems to full Automatic Train Protection (ATP), providing greater spatial separation, or restricting the two types of trains to different times of day. All of these mitigations place some burden on the railroad to participate in reducing the frequency of accidents. For example, extra signalling systems might require modifications to the railroad locomotives and extra training of crews. Likewise, restricting operations to different times of day reduce the flexibility of the railroad to serve its customers.</p> <p>Consequence can be reduced only by increasing the general safety of the HSR and railroad trains. Each of these modes could also be in a collision with another train in the same mode, so it is not reasonable to make safety improvements that only affect collisions between modes.</p> <p>Post-mitigation score would be Remote/Catastrophic: 8 (undesirable, management review required).</p>									

Scenario Number: 4.4.1.a

Safety Issue: Infringement of operating envelope

Instigator: Railroad

Affected Mode: HSR

High-Risk Event: HSR and railroad operations share the same track, similar to Amtrak's Northeast Corridor. The safe separation system of the railroad train fails, causing the railroad train to crash into a stopped HSR train at posted speed. Both trains derail. Casualties include occupants of the railroad train and HSR passengers.

Frequency: B (Probable) There were 315 collisions between trains in the United States in 1990. Of these, 15 involved Amtrak intercity passenger trains. [Source: FRA Accident/Incident Bulletin, Calendar Year 1990, p. 27]. The Amtrak/Conrail collision at Chase, MD on January 4, 1987, was between a relatively high-speed train (202 km/hr (125 mph) and a slow-freight train on extensively signaled track. [Source: Railroad Accident Report, NTSB/RAR-88/01]. It was assumed that there would be 1 such collision every 4 years on a 320 km (200 miles) shared ROW.

Consequence: I (Catastrophic) Multiple fatalities on trains that collide are possible. The Amtrak/Conrail accident cited above resulted in 16 fatalities.

Score:

Frequency:	Probable	B	
Consequence:	Catastrophic	I	
Hazard Risk:		2	Unacceptable

Mitigation: Frequency could be reduced by upgrading signalling systems to full Automatic Train Protection (ATP), providing greater spatial separation, or restricting the two types of trains to different times of day. All of these mitigations place some burden on the railroad to participate in reducing the frequency of accidents. For example, extra signalling systems might require modifications to the railroad locomotives and extra training of crews. Likewise, restricting operations to different times of day reduces the flexibility of the railroad to serve its customers.

Consequence can be reduced only by increasing the general safety of the HSR and railroad trains. Each of these modes could also be in a collision with another train in the same mode, so it is not reasonable to make safety improvements that only affect collisions between modes.

Post-mitigation score would be Remote/Catastrophic: 8 (undesirable, management decision required).

Scenario Number: 4.4.1.b

Safety Issue: Infringement of operating envelope

Instigator: Railroad

Affected Mode: HSR

High-Risk Event: HSR and railroad operations share the same track, similarly to Amtrak's Northeast Corridor. Common track degraded by heavy railroad operations causes an HSR train to derail at cruising speed. Casualties include HSR train passengers.

Frequency: B (Probable) From 1988 through 1990, there was 1 train accident caused by track failure for trains operating over 147 km/hr (91 mph) (the highest reported speed category) [Source: FRA Accident/Incident Bulletins, 1988, 1989, 1990, p. 20 in each volume]. This suggests a rate of 0.33 accidents per year or 1 accident every 3 years. U.S. trains operating over 147 km/hr (91 mph) are almost exclusively on the Northeast Corridor which is similar in length to a 645 km (400 mile) HSR system. For the 320 km (200 miles) portion that is shared ROW, there would be 1 accident every 6 years.

Consequence: I (Catastrophic) Train derailments can cause multiple fatalities. For example, 8 persons were killed in an Amtrak derailment at Lugoff, South Carolina, on July 31, 1991 [Source: Howard Robertson, Amtrak, telephone conversation, 1/92].

Score:

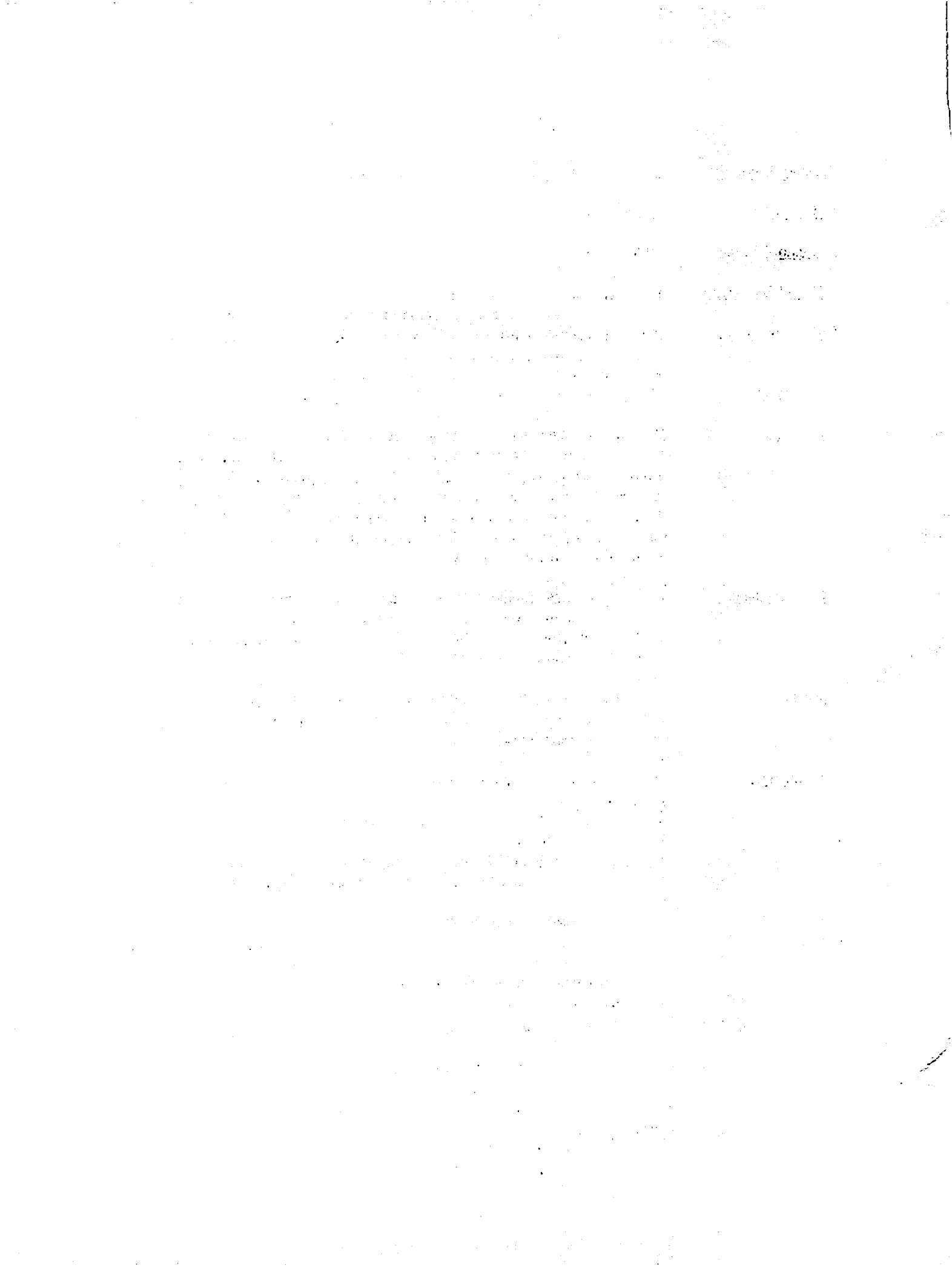
Frequency:	Probable	B	
Consequence:	Catastrophic	I	
Hazard Risk:		2	Unacceptable

Mitigation: Frequency could be reduced by:

- Strict maintenance procedures. The procedures must be developed to include more frequent maintenance inspection of the ROW as well as an inspection of railroad train equipment which, if failed or faulty, could contribute to track deterioration.

Consequence probably could not be reduced.

Post-mitigation score would be Remote/Catastrophic: 8 (undesirable, management decision required).



APPENDIX E HAZMAT

Scenario Number: 5.1.3

Safety Issue: HAZMAT

Instigator: HSR

Affected Mode: Highway

High-Risk Event: The shared ROW is in an urban area. An HSR train derailed at cruising speed and HSR vehicles scatter onto the highway. A truck carrying HAZMAT collides with the derailed HSR train and contaminates the surrounding area. Casualties include HSR train occupants, passengers in highway vehicles, and nearby residents.

Frequency: D (Remote) No derailments of HSGGT trains were identified in France, Germany, Italy, or Japan on high-speed lines. There were no derailments of trains travelling over 147 km/hr (91 mph) (the highest reported speed category) in the United States from 1988 through 1990 [Source: FRA Accident/Incident Bulletins, 1988, 1989, 1990, p. 20 in each volume]. It was assumed that HSR trains on a 645 km (400 miles) system would derail once per 100 years and that therefore there would be one derailment per 200 years on the 320 km (200 miles) portion that is shared ROW.

In 1982, 76 percent of all trucks carried some form of HAZMAT during the year [Sources: Transportation of Hazardous Materials and Highway Statistics, 1991, p. 1921]. In the same year, 18 percent of all ton-miles were HAZMAT [Sources: Transportation of Hazardous Materials, p. 7, and Transportation in America, 1991, p. 441]. If 5 trucks were involved in a post-derailment collision, it would be likely that at least one would contain HAZMAT and that the frequency would remain at 1 per 200 years.

Consequence: I (Catastrophic) HAZMAT can increase the severity of an accident and cause additional fatalities.

<u>Score:</u>	Frequency	Remote	D	
	Consequence	Catastrophic	I	
	Hazard Risk		8	Undesirable, management decision required

Mitigation: Frequency could be reduced by methods described in scenarios 1.3.1 and 5.3.0:

- Redirecting barriers or crash barriers
- Ditches
- Time separation

Consequence could be reduced using the same measures.

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with management review).

Scenario Number: 5.1.4

Safety Issue: HAZMAT

Instigator: HSR

Affected Mode: Railroad

High-Risk Event: The shared ROW is in an urban area. An HSR train derailed at cruising speed and scatters onto the railroad track. A railroad train carrying HAZMAT at its cruising speed collides with the HSR vehicles. The spilled HAZMAT contaminates the surrounding area. Casualties include HSR train passengers, occupants of the conventional train, nearby residents.

Frequency: D (Remote) No derailments of HSGGT trains on high-speed lines were identified in France, Germany, Italy, or Japan. There were no derailments of trains travelling over 147 km/hr (91 mph) (the highest reported speed category) in the United States from 1988 through 1990 [Source: FRA Accident/Incident Bulletins, 1988, 1989, 1990, p. 20 in each volume]. It was assumed that HSR trains on a 645 km (400 miles) system would derail once per 100 years and that therefore there would be one derailment per 200 years on the 320 km (200 miles) portion that is shared ROW.

In 1983, 6.3 percent of all railroad freight traffic was some form of HAZMAT. Since trains are often composed of many types of freight, many trains include at least one car of HAZMAT, but most railroad accidents don't involve all the cars in the train. It was assumed that half of all HSR and Railroad accidents would have some release of HAZMAT. When applied to the frequency of one derailment per 200 years, the frequency of a derailment followed by a HAZMAT release is one in 400 years.

Consequence: I (Catastrophic) HAZMAT can increase the severity of an accident and cause additional fatalities.

<u>Score:</u>	Frequency	Remote	D	
	Consequence	Catastrophic	I	
	Hazard Risk		8	Undesirable, management decision required

Mitigation: Frequency could be reduced by methods described in scenarios 1.3.1 and 5.3.0:

- Redirecting barriers or crash barriers
- Ditches
- Time separation.

Consequence could be reduced using the same measures.

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with management review).

Scenario Number: 5.1.5

Safety Issue: HAZMAT

Instigator: HSR

Affected Mode: Waterway

High-Risk Event: The shared ROW is located in an urban area. An HSR train derailed at cruising speed, scatters into the waterway, and collides with a barge carrying HAZMAT. The spilled HAZMAT contaminates the surrounding area. Casualties include HSR train passengers, occupants in the boat, and nearby residents.

Frequency: E (Improbable) No derailments of HSGGT trains were identified in France, Germany, Italy, or Japan. There were no derailments of trains travelling over 147 km/hr (91 mph) (the highest reported speed category) in the United States from 1988 through 1990 [Source: FRA Accident/Incident Bulletins, 1988, 1989, 1990, p. 20 in each volume]. It was assumed that HSR trains on a 645 km (400 miles) system would derail once per 100 years and that therefore there would be one derailment per 200 years on the 320 km (200 miles) portion that shared an ROW. Based on observations of the Rhein River (a heavily used waterway) in Germany, it was assumed that there would be 1 boat in each direction every 15 minutes moving at 10 mph. Therefore, there would be a 1 in 60 chance of a boat being present where and when an HSR train derailed. The frequency of derailment and boat presence is therefore once in 12,000 years.

With such a low frequency, the presence of HAZMAT on the boat is not an issue.

Consequence: I (Catastrophic) HAZMAT can increase the severity of an accident and cause additional fatalities.

<u>Score:</u>	Frequency	Improbable	E	
	Consequence	Catastrophic	I	
	Hazard Risk		12	Acceptable, with review by management

Mitigation: None required.

Scenario Number: 5.1.6

Safety Issue: HAZMAT

Instigator: HSR

Affected Mode: Pipeline

High-Risk Event: The shared ROW is in an urban area. An HSR train derailed at cruising speed and scatters onto the pipeline. The aboveground pipeline, which carries HAZMAT, explodes and contaminates the surround area. Casualties include HSR train passengers and nearby residents.

Frequency: D (Remote) There have been no derailments of HSGGT trains on high-speed lines in France, Germany, Italy, or Japan. There were no derailments of trains travelling over 147 km/hr (91 mph) (the highest reported speed category) in the United States from 1988 through 1990 [Source: FRA Accident/Incident Bulletins, 1988, 1989, 1990, p. 20 in each volume]. It was assumed that HSR trains on a 645 km (400 miles) system would derail once per 100 years and that therefore there would be one derailment per 200 years on the 320 km (200 miles) portion that is shared ROW.

No data could be identified on percentage of pipeline ton-miles that are HAZMAT. It was assumed that half of all products shipped by pipelines are HAZMAT. This, combined with the frequency of 1 derailment in 200 years, suggests that there will be 1 derailment followed by HAZMAT release every 400 years.

Consequence: I (Catastrophic) A HAZMAT pipeline adds to the severity of an HSR derailment. Clearly, major system damage would result to the pipeline as a consequence of an HSR derailment. Therefore, the consequence Category for this scenario is somewhere between II, critical, and I, catastrophic, with deaths on one system, total equipment loss on both systems, and severe complications to the rescue operation.

Score:	Frequency	Remote	D	
	Consequence	Catastrophic	I	
	Hazard Risk		8	Undesirable, management decision required

Mitigation: Frequency could be reduced by methods described in scenarios 1.3.1 and 5.3.0:

- Redirecting barriers or crash barriers
- Ditches.

Consequence could be reduced using the same measures.

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with management review).

Scenario Number: 5.3.0

Safety Issue: HAZMAT

Instigator: Highway

Affected Mode: HSGGT

High-Risk Event: The shared ROW is in an urban area. A large semitrailer HAZMAT truck leaves the highway and enters the HSGGT track. An HSGGT train at cruising speed collides with the truck and causes the HAZMAT to spill and contaminate the area around the accident. Casualties include highway vehicle occupants, HSGGT train passangers, and nearby residents.

Frequency: C (Occasional) In 1990 there were 4,223 fatal accidents on 72,700 km (45,074 miles) of urban and rural interstate highways [Source: Highway Statistics, 1990, p. 198]. This is a rate of 0.058 accidents per km per year (0.094 accidents per mile per year). Assuming that 10 percent of those accidents involved vehicles leaving the roadway and that half of those would leave the roadway on the side with the HSR, there would be 0.0029 accidents per km per year (0.0047 accidents per mile per year). In 1990, 9.9 percent of all vehicle miles on urban and rural interstates were combination trucks (such as the semitrailer truck described above) [Source: Highway Statistics, 1990, p. 1921]. Therefore, there would be 0.00047 relevant accidents per mile per year. On a 645 km (400 miles) HSR system with 320 km (200 miles) of shared ROW there would be 0.094 accidents per year, or 1 accident every 10.6 years.

Consequence: I (Catastrophic) HAZMAT can increase the severity of an accident and cause additional fatalities.

Score:	Frequency	Occasional	C	
	Consequence	Catastrophic	I	
	Hazard Risk		4	Unacceptable

Mitigation: Frequency reduction by the same measures described for the other highway vehicle infringement scenarios, 1.3.1 and 1.3.2, is applicable to scenario 5.3.0:

- Physical separation
- Ditch
- Redirecting barrier or crash barrier
- Grade separation
- Guideway misalignment and infringement sensors

A further mitigation measure applicable to HAZMAT highway vehicle infringement is time separation. That is, planned operation of most HAZMAT vehicles outside the hours of HSGGT operation.

Consequence probably could not be reduced.

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with review by management).

Scenario Number: 5.4.0

Safety Issue: HAZMAT

Instigator: Railroad

Affected Mode: HSGGT

High-Risk Event: A railroad train carrying HAZMAT derails at cruising speed in an urban area. The train scatters onto the HSGGT track and HAZMAT spills. The HAZMAT contaminates the area around the accident. An HSGGT train crashes at its cruising speed into the derailed railroad train. Casualties include railroad train occupants, HSGGT passengers, and nearby residents.

Frequency: B (Probable) From 1988 through 1990 there were a total of 1,880 derailments [Source: FRA Accident/Incident Bulletins, 1988, 1989, 1990, p. 20 in each volume] over 238,700 route-km (148,000 route miles) in the U.S. [Source: Transportation in America, 1991, p. 641]. This count excludes derailments on yard track, sidings, and industry track, and derailments that occur below 16 km/hr (10 mph) because those generally do not cause the cars to leave the immediate track structure. This is a rate of 0.0026 derailments per km per year (0.0042 derailments per mile per year). For a 645 km (400 miles) HSR system with 320 km (200 miles) of shared ROW there would be 0.85 railroad derailments per year, or 1 derailment every 1.2 years.

In 1983, 6.3 percent of all railroad freight traffic was some form of HAZMAT. Since trains are often composed of many types of freight, many trains include at least one car of HAZMAT, but most railroad accidents don't involve all the cars in the train. It was assumed that half of all HSR and Railroad accidents would have some release of HAZMAT. When applied to the frequency of 1 derailment per 3 years, the frequency of a derailment followed by a HAZMAT release is 1 in 6 years.

Consequence: I (Catastrophic) There would be multiple fatalities and total loss of equipment.

<u>Score:</u>	Frequency	Probable	B
	Consequence	Catastrophic	I
	Hazard Risk		2 Unacceptable

Mitigation: Frequency could be reduced by the measures described for non-HAZMAT infringement scenarios such as 1.4.1.a:

- Time separation
- Physical separation
- Ditch
- Grade separation
- Guideway misalignment and intrusion sensors
- Speed reduction
- Railroad sensors

Railroad operators could be expected to oppose time separation because of the disruption to their business. Since most trains carry some form of HAZMAT,

such a restriction would essentially shut down the railroad during the selected hours.

Consequence probably could not be reduced.

Post-mitigation score would be Remote/Catastrophic: 8 (undesirable).

Scenario Number: 5.5.0

Safety Issue: HAZMAT

Instigator: Waterway

Affected Mode: HSGGT

High-Risk Event: The shared ROW is in an urban area. A barge carrying HAZMAT collides with another barge and explodes near the HSGGT track. An HSGGT train derailed at cruising speed on the damaged track. The HAZMAT contaminates the area around the accident. Casualties include boat occupants, HSGGT train passengers, and nearby residents.

Frequency: D (Remote) In 1982, there were 4,909 tanker barges in the U.S. [Source: Transportation of Hazardous Material] most of which carried some form of hazardous material. No information was found on the accident rate of these barges, but it was assumed that 1/2 of 1 percent of these barges (25) would be involved in some form of accident each year. Further, it was assumed that 10 percent of those accidents (2.5) would involve the hazardous material. There are approximately 40,320 km (25,000 miles) of navigable waterways in the U.S. [Source: National Transportation Statistics, July 1990]. Therefore, this would suggest a relevant accident rate of 0.0001 accidents per mile of waterway per year. It was assumed that there would be a 10 percent chance that an HSGGT train would be present to be affected by the explosion. There would be 0.0000062 accidents per km (0.00001 accidents per mile) of HSGGT per year, or 0.002 accidents per year for a 320 km (200 miles) shared ROW. This is equivalent to one accident every 500 years.

Consequence: I (Catastrophic) Boats and ships can explode. Two of the most notable explosion disasters involved ships with losses of over 300 lives in each accident [Source: Accident Facts, 1991, p. 15].

Score:

Frequency	Remote	D	
Consequence	Catastrophic	I	
Hazard Risk		8	Undesirable, management decision required

Mitigation: Frequency would be reduced by increasing the physical separation between the two modes (such as by moving the HSGGT further "inland") or by time separation (although this would require cooperation of the barge operators).

Consequence could be reduced by placing a crash barrier between the two modes to redirect the force of any explosion.

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with review by management).

Scenario Number: 5.6.0

Safety Issue: HAZMAT

Instigator: Pipeline

Affected Mode: HSGGT

High-Risk Event: The shared ROW is in an urban area. The aboveground pipeline ruptures and spills HAZMAT onto the HSGGT track/guideway. A passing HSGGT train causes the HAZMAT to explode. The HSGGT train derails at cruising speed. Casualties include HSGGT train passengers and inhabitants in the area near the accident site.

Frequency: C (Occasional) There were 789,006 km (489,184 miles) of natural gas and oil pipelines in the United States [Source: National Transportation Statistics Annual Report, July 1990]. Only information about natural gas and oil pipelines was available, but gas and oil are some of the major HAZMAT products handled in pipelines. For these pipelines, there were 454 failure accidents in one year [Source: Transportation Safety Information Report, 1980]. Therefore, there were 0.00058 accidents per km per year (0.00093 accidents per mile per year). Assuming that all of these accidents resulted in release of HAZMAT there would be 0.093 relevant releases of hazardous material each year on the 320 km (200 miles) shared ROW, or 1 release every 10.8 years.

Consequence: I (Catastrophic) As in scenario 5.6.0, the HAZMAT content of a pipeline would add to the severity of any interaction between an HSGGT and a pipeline. Natural gas or petroleum explosions and fires could cause fatalities and total loss of equipment.

<u>Score:</u>	Frequency	Occasional	C	
	Consequence	Catastrophic	I	
	Hazard Risk		4	Unacceptable

Mitigation: Frequency could be reduced by:

- Grade separation in the form of putting the pipeline underground to reduce the chance of rupture (other than dynamic forces or physical infringement by the HSGGT, which was discussed in other scenarios).
- Increasing inspections of pipelines to prevent ruptures.
- Installing leak detectors on pipelines.
- Improving communications between the pipeline and HSGGT operator so that the HSGGT operator can be quickly informed of leaks or any other pipeline problems.

Consequence probably could not be reduced.

Post-mitigation score would be: Improbable/Catastrophic: 12 (acceptable, with review by management).

1. The first part of the document discusses the importance of maintaining accurate records of all transactions and activities. It emphasizes that proper record-keeping is essential for ensuring transparency and accountability in the organization's operations.

2. The second part of the document outlines the various methods and tools used to collect and analyze data. It highlights the need for consistent data collection procedures and the use of advanced analytical techniques to derive meaningful insights from the data.

3. The third part of the document focuses on the role of technology in enhancing data management and analysis. It discusses the benefits of using cloud-based storage solutions and data visualization tools to improve the efficiency and effectiveness of the data analysis process.

4. The fourth part of the document addresses the challenges associated with data security and privacy. It provides guidelines for implementing robust security measures to protect sensitive information and ensure compliance with relevant regulations.

5. The fifth part of the document discusses the importance of data quality and the need for regular data audits. It emphasizes that high-quality data is crucial for making accurate and reliable decisions, and that regular audits help identify and correct any data quality issues.

6. The sixth part of the document explores the role of data in strategic decision-making. It highlights how data-driven insights can help organizations identify new opportunities, optimize their operations, and gain a competitive advantage in the market.

7. The seventh part of the document discusses the importance of data literacy and the need for ongoing training and development. It emphasizes that all employees should have a basic understanding of data and be able to interpret and use data effectively in their work.

8. The eighth part of the document discusses the role of data in customer relationship management. It highlights how data can be used to better understand customer needs and preferences, and to tailor marketing and sales efforts accordingly.

9. The ninth part of the document discusses the role of data in human resources management. It highlights how data can be used to track employee performance, identify talent, and make data-driven decisions about hiring, training, and compensation.

10. The tenth part of the document discusses the role of data in financial management. It highlights how data can be used to track financial performance, identify trends, and make data-driven decisions about budgeting and investment.

APPENDIX F ACCESSIBILITY

<u>Scenario Number:</u>	6.0.3.a.
<u>Safety Issue:</u>	Accessibility
<u>Instigator:</u>	HSGGT
<u>Affected Mode:</u>	Highway
<u>High-Risk Event:</u>	HSGGT maintenance workers wander onto the highway or HSGGT maintenance-of-way equipment fouls the highway and causes a multivehicle accident. Casualties include maintenance workers and vehicle occupants.
<u>Frequency:</u>	C (Occasional) About 700 persons are killed each year in highway construction zones [FHWA, telephone call, 1/22/92]. There are no counts of how many of those fatalities are highway workers or how many involve equipment. If 10 percent of the 700 are highway workers, there would be 70 fatalities of maintenance workers each year over 3,643,000 km (2,259,000 miles) of paved highway [Source: Highway Statistics, 1990, p. 122] in the U.S. This suggests a fatality rate of 0.000019 per km (0.000031 per mile) per year. For a 645 km (400 miles) HSGGT system with 320 km (200 miles) of shared ROW, there would be 0.0025 fatalities per year or 1 fatality every 403 years. Since these are HSGGT workers, they are less likely to be on the highway than highway workers and the frequency would be less than calculated here. Presumably some of these fatalities could come from collisions with HSGGT maintenance-of-way equipment. As a check, it was assumed that highway vehicles running alongside an HSGGT would be as likely to strike fouling maintenance-of-way equipment as an HSGGT train would itself. From 1988 through 1990, there were approximately 10 railroad accidents per year that involved collisions or derailments with maintenance-of-way equipment [Source: Accident/Incident Bulletin, 1988, 1989, 1990, p. 38 all volumes]. This suggests an accident rate of 0.000068 per mile per year on the railroad. For a 645 km (400 miles) HSGGT system with 320 km (200 miles) of shared ROW, there would be 0.0135 accidents per year or 1 accident every 74 years. Since some of these accidents might not cause fatalities, the fatality rate for highway workers and the accident rate for railroad equipment appear similar and fall within the category of 1 incident every 10 to 100 years.
<u>Consequence:</u>	I (Catastrophic) High-speed accidents between automobiles and pedestrians and between automobiles and fixed objects (such as railroad maintenance-of-way equipment) often result in fatalities. In 1990, 7,400 pedestrians were killed when struck by automobiles [Source: Accident Facts, 1991, p. 52]. In 1989, there were 3,400 fatalities from collisions between motor vehicles and fixed objects [Source: MVMA Motor Vehicle Facts & Figures 1990, p. 90].
<u>Score:</u>	Frequency: Occasional C Consequence: Catastrophic I Hazard Risk: 4 Unacceptable

Mitigation:

Frequency could be reduced by maintaining the HSGGT at times that the highway traffic is light. This would suggest that HSGGT maintenance would need to be done at night, or perhaps on weekends, when highway traffic is lighter. Although some rail maintenance is already done at night (such as in heavy commuter areas), generally such work is done during daylight hours for productivity and safety. Frequency could also be reduced by installing personnel barriers between the two modes, installing signs, or by training HSGGT workers about the dangers of working by the highway.

Consequence could not be feasibly reduced.

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with review by management).

Scenario Number: 6.0.3.b

Safety Issue: Accessibility

Instigator: HSGGT

Affected Mode: Highway

High-Risk Event: An HSGGT train is forced to stop between safe havens and passengers are evacuated. Because of the proximity of the highway, highway operations must be shut down for several hours to evacuate passengers and recover equipment.

Frequency: C (Occasional) Total failure of HSGGT trains (due to track, mechanical, or other malfunction) is expected to be rare, as is the need to stop between safe havens, but could occur. It was assumed that HSGGT trains would need to stop between stations once every 10 years on a 645 km (400 miles) system. This suggests that they would have to stop every 20 years on a 320 km (200 miles) shared ROW.

Consequence: III (Marginal) The highway would need to be shut down for several hours (if only evacuation of passengers is required) to several days (if recovery of equipment is required—for example, if a large crane must be brought in). Damage to the highway would be limited to service interruption or, at most, incidental physical damage.

<u>Score:</u>	Frequency	Occasional	C	
	Consequence	Marginal	III	
	Hazard Risk		11	Acceptable, with management review

Mitigation: None required.

Scenario Number: 6.0.4.a

Safety Issue: Accessibility

Instigator: HSGGT

Affected Mode: Railroad

High-Risk Event: HSGGT maintenance workers wander onto the railroad track or HSGGT maintenance-of-way equipment fouls the railroad and is struck by an oncoming train. Casualties include maintenance workers.

Frequency: D (Remote) Track maintenance workers often operate "under traffic," that is, rail service is maintained while repairs are made. Track will be "closed up" just long enough for a train to pass and then repairs are resumed. As a result, maintenance workers are often in the same area as a moving train. Six maintenance-of-way employees have been killed when struck by a locomotive or car from 1988 through 1990 [Source: FRA Accident/Incident Bulletins Calendar Years 1988, 1989, 1990, p. 84 in each volume] over 238,700 route-km (148,000 route miles) [Source: Transportation in America, 1991, p.64]. This suggests a fatality rate of 0.0000087 per km (0.000014 per mile) per year. For a 645 km (400 miles) HSGGT system with 320 km (200 miles) of shared ROW, there would be 0.0028 fatalities per year or 1 fatality every 364 years. Presumably some of these fatalities could come from collisions with HSGGT maintenance-of-way equipment. As a check, it was assumed that railroad trains running alongside an HSGGT would be as likely to strike fouling maintenance-of-way equipment as an HSGGT train would itself. From 1988 through 1990, there were approximately 10 railroad accidents per year that involved collisions or derailments with maintenance-of-way equipment [Source: Accident/Incident Bulletin, 1988, 1989, 1990, p. 38 all volumes]. This suggests an accident rate of 0.000068 per mile per year on the railroad. For a 645 km (400 miles) HSGGT system with 320 km (200 miles) of shared ROW, there would be 0.0135 accidents per year or 1 accident every 74 years.

Consequence: I (Catastrophic) Persons struck by trains at high speed are often killed or seriously injured. For example, in 1990, 511 persons were killed when they were struck or ran into locomotives or cars (not including rail/highway grade crossings). Five of these fatalities were railroad employees, 12 were "non-trespassers," and the remainder were trespassers. [Source: FRA Accident/Incident Bulletin Calendar Year 1990, p. 84].

Score:

Frequency	Remote	D	
Consequence	Catastrophic	I	
Hazard Risk		8	Undesirable, management decision required

Mitigation: Frequency could be reduced by maintaining the HSGGT at times that the railroad traffic is light. This suggests that the HSGGT maintenance would need to be done at night, or perhaps on weekends, when some types of railroad traffic are lighter. Some rail maintenance is already done at night (such as in heavy commuter areas) but generally such work is done during daylight hours for productivity and safety. Frequency could also be reduced by installing personnel

barriers between the modes, installing signs, or by training HSGGT workers about the dangers of working by the railroad.

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with review by management).

Scenario Number: 6.0.4.b

Safety Issue: Accessibility

Instigator: HSGGT

Affected Mode: Railroad

High-Risk Event: An HSGGT train is forced to stop between safe havens and passengers are evacuated. Because of the proximity of the railroad, railroad operations must be shut down for several hours to evacuate passengers and recover equipment.

Frequency: D (Remote) Total failure of HSGGT trains (due to track, mechanical, or other malfunction) between “safe havens” is expected to be rare but could occur. For the 645 km (400 miles) HSGGT system, total failure was assumed to occur once every 100 years. Since only 320 km (200 miles) are shared ROW total failure on the shared right-of-way portion was assumed to be once in 200 years.

Consequence: III (Marginal) The railroad track would need to be shut down for several hours (if only evacuation of passengers is required) to several days (if recovery of equipment is required—for example, if a large crane must be brought in). Damage to the railroad would be limited to service interruption or, at most, incidental physical damage.

<u>Score:</u>	Frequency	Remote	D	
	Consequence	Marginal	III	
	Hazard Risk		14	Acceptable, with management review

Mitigation: None required.

Scenario Number: 6.0.5.a

Safety Issue: Accessibility

Instigator: HSGGT

Affected Mode: Waterway

High-Risk Event: An HSGGT maintenance worker falls into the waterway and drowns.

Frequency: E (Improbable) From 1988 through 1990, no railroad employees fell from a bridge into water. Two trespassers were known to have fallen during that same time [Source: FRA Accident/Incident Bulletins Calendar Years 1988, 1989, 1990, p. 95 in each volume]. There were 238,700 route-km (148,000 route miles) of railroads during those years [Source: Transportation in America, 1991, p. 64]. Including the trespassers, this suggests a fatality rate of 0.0000028 per km (0.0000045 per mile) per year. For a 645 km (400 miles) HSGGT system with 320 km (200 miles) of shared ROW, and assuming that the shared ROW has about the same percentage of overwater structures as conventional railroads, there would be 0.00068 fatalities per year or 1 fatality every 1,481 years.

Consequence: I (Catastrophic) Persons who fall into water can drown. For example, in 1980, there were 5,712 accidental drownings, excluding water transport and bathtubs. [Source: Accident Facts, 1984, National Safety Council].

<u>Score:</u>	Frequency	Improbable	E	
	Consequence	Catastrophic	I	
	Hazard Risk		12	Acceptable, with management review

Mitigation: None required.

Scenario Number: 6.0.5.b

Safety Issue: Accessibility

Instigator: HSGGT

Affected Mode: Waterway

High-Risk Event: An HSGGT is forced to stop between safe havens and passengers are evacuated. Evacuation is hampered because the track/guideway is over water.

Frequency: D (Remote) Total failure of HSGGT trains (due to track, mechanical, or other malfunction) between "safe havens" is expected to be rare but could occur. For the 645 km (400 miles) HSGGT system, total failure was assumed to occur once every 100 years. Since only 320 km (200 miles) are shared ROW, total failure on the shared ROW portion was assumed to be once in 200 years.

Consequence: II (Critical) Evacuation over water probably would be considerably more difficult than evacuation over land. Depending on the design of the equipment and track or guideway, it could be difficult or impossible to evacuate out the ends of a train (because of the power units) or the sides of a train (because of the lack of a safe walkway). Such an evacuation, especially at night, could cause at least one severe injury to a passenger or crew member. In most cases, any traffic on the river probably could continue uninterrupted.

<u>Score:</u>	Frequency	Remote	D	
	Consequence	Critical	II	
	Hazard Risk		10	Acceptable, with management review

Mitigation: None required.

Scenario Number: 6.0.6

Safety Issue: Accessibility

Instigator: HSGGT

Affected Mode: Pipeline

High-Risk Event: HSGGT maintenance workers damage the pipeline and interrupt delivery of the pipeline product.

Frequency: C (Occasional) There has been an average of 27 instances each year from 1985 through 1989 where natural gas pipelines were damaged by mechanical equipment such as bulldozers and backhoes. This is over about 500,000 km (310,000 miles) of natural gas distribution and gathering pipelines. [Source: An Analysis of Reportable Incidents for Natural Gas Transmission and Gathering Lines—June 1984 through 1989, p. 31]. This suggests a relevant accident rate of 0.00054 per km (0.00087 per mile) per year. Applied to the 645 km (400 miles) HSGGT system with 320 km (200 miles) of shared ROW, there would be 0.0175 accidents per year or 1 accident every 57 years.

Consequence: II (Critical) Service would be interrupted until the pipeline could be repaired. Given the nature of the failure, the pipeline company might choose to test adjacent pipe sections for impending failure. Both the test and any additional repairs would increase the service delay of the pipeline. If the material carried were water which was needed for firefighting, additional damage might result from this accident.

Score:

Frequency	Occasional	C	
Consequence	Critical	II	
Hazard Risk		6	Undesirable, management decision required

Mitigation: Frequency could be reduced by installing warning signs to indicate the location of the pipeline, training HSGGT workers about pipeline locations and dangers, and by providing greater physical separation a barrier between the HSGGT and the pipeline.

Consequence possibly could not be reduced.

Post-mitigation score would be Improbable/Critical: 15 (acceptable, with review by management).

Scenario Number: 6.0.7

Safety Issue: Accessibility

Instigator: HSGGT

Affected Mode: Transmission line

High-Risk Event: HSGGT maintenance workers wander onto the transmission line right-of-way in areas of high voltage and are electrocuted. Casualties include maintenance workers.

Frequency: B (Probable) In 1988, 165 persons were electrocuted at generating plants, distributing stations, or through contact with transmission lines. It was assumed that 1/3 of these fatalities related to transmission lines and that HSGGT workers would have less familiarity with safety precautions pertaining to transmission lines than transmission line workers. It was also assumed that the crowded conditions of a shared ROW might contribute to an electrocution hazard. Based on this, it was assumed that 1 HSGGT worker would be electrocuted by the transmission line along a 320 km (200 miles) shared ROW every 4 years.

Consequence: I (Catastrophic) Persons who come in contact with high-voltage equipment can be killed. For example, in 1988, 165 persons were electrocuted at generating plants, distributions stations, or due to contact with transmission lines. Railroad workers can be electrocuted. From 1988 through 1990, a total of 16 railroad employees were electrocuted. Of these, 11 were due to contact with a third rail or catenary and 5 were due to other electrical contact. One or more of the 5 other fatalities could have resulted from electrical sources not related to the railroad itself, such as could happen in this scenario [Source: FRA Accident/Incident Bulletins Calendar Years 1988, 1989, 1990, p. 102 in each volume].

Score:

Frequency	Probable	B	
Consequence	Catastrophic	I	
Hazard Risk		2	Unacceptable

Mitigation: Frequency could be reduced by installing personnel barriers between the HSGGT track/guideway and the transmission line and by training HSGGT workers about the dangers of the transmission line.

Consequence probably could not be reduced.

Post-mitigation score would be Remote/Catastrophic: 8 (undesirable, management decision required).

Scenario Number: 6.3.1.a

Safety Issue: Accessibility

Instigator: Highway

Affected Mode: HSR

High-Risk Event: Highway maintenance workers wander onto the HSR track and are struck by an oncoming HSR train. Casualties include maintenance workers.

Frequency: D (Remote) Track maintenance workers often operate "under traffic," that is, rail service is maintained while repairs are made. Track will be "closed up" just long enough for a train to pass and then repairs are resumed. As a result, railroad maintenance workers are often in the same area as a moving train. Six railroad maintenance-of-way employees have been killed when struck by a locomotive or car from 1988 through 1990 [Source: FRA Accident/Incident Bulletins Calendar Years 1988, 1989, 1990, p. 84 in each volume]. For the 238,710 railroad route-km (148,000 route miles) in the U.S. [Source: Transportation in America, 1991, p. 64], this is a fatality rate of 0.0000087 per km (0.000014 per mile) per year. Assuming that the highway maintenance workers would have a fatality rate similar to railroad maintenance workers when working along the shared ROW, for the 645 km (400 miles) HSR system with 320 km (200 miles) of shared ROW, there would be 0.0027 fatalities per year or 1 fatality every 364 years.

Consequence: I (Catastrophic) Persons struck by trains at high speed are often killed or seriously injured. For example, in 1990, 511 persons were killed when they were struck or ran into locomotives or cars (not including rail/highway grade crossings). Five of these fatalities were railroad employees, 12 were "non-trespassers," and the remainder were trespassers [Source: FRA Accident/Incident Bulletin Calendar Year 1990, p. 84].

<u>Score:</u>	Frequency	Remote	D	
	Consequence	Catastrophic	I	
	Hazard Risk		8	Undesirable, management decision required

Mitigation: Frequency could be reduced by maintaining highways at times that the HSR is not in operation. This would suggest that highway maintenance would need to be done at night, or perhaps on weekends, when the HSR is not operating. Some highway maintenance is already done at night to reduce potential conflicts (and congestion) between highway traffic and highway workers. Frequency could also be reduced by installing personnel barriers between the two modes, installing signs, or by training highway workers about the dangers of HSR operations.

Consequence could not be feasibly reduced.

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with review by management).

Scenario Number: 6.3.1.b

Safety Issue: Accessibility

Instigator: Highway

Affected Mode: HSR

High-Risk Event: Trespassers who gain access from the highway cause an HSR train to derail at cruising speed. Casualties include HSR passengers and the trespassers.

Frequency: C (Occasional) Derailments can be caused by vandalism. In the U.S. there have been 41 (1988), 32 (1989) and 39 (1990) derailments caused by vandalism [Source: FRA Accident/Incident Bulletins Calendar Years 1988, 1989, 1990, p. 31 in each volume]. For 238,710 railroad route-km (148,000 route miles) in the U.S. [Source: Transportation in America, 1991, p. 64], this would be a derailment rate of 0.00014 per km (0.00023 per mile) per year. Assuming that derailments caused by vandalism for HSR would be similar to conventional railroads, there would be 0.045 derailments per year on a 645 km (400 miles) HSR system with 320 km (200 miles) of shared ROW, if vandals had no other access to the HSR. This would be equivalent to 1 derailment every 2 years.

Consequence: I (Catastrophic) Train derailments can cause fatalities. From 1988 through 1990, 9 persons were killed in railroad derailments. Moreover, in one accident in 1991, 8 persons were killed in an Amtrak derailment at Lugoff, South Carolina, on July 31, 1991, [Source: Howard Robertson, Amtrak, telephone conversation, 1/92].

<u>Score:</u>	Frequency	Occasional	C	
	Consequence	Catastrophic	I	
	Hazard Risk		4	Unacceptable

Mitigation: Frequency of access by trespassers is difficult to control because of the long, mostly unattended right of way. Fences and detectors can be added to discourage or detect trespassers before they create damage.

Consequences of trespassers access can be reduced by locking all switches, housing track side equipment in tamperproof boxes, and maintaining a clean right of way (no old rail or wires left handy).

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with review by management).

Scenario Number: 6.3.2.a

Safety Issue: Accessibility

Instigator: Highway

Affected Mode: Maglev

High-Risk Event: Highway maintenance workers wander onto the maglev guideway and are struck by a maglev train. Casualties include maintenance workers.

Frequency: D (Remote) Track maintenance workers often operate "under traffic," that is, rail service is maintained while repairs are made. Track will be "closed up" just long enough for a train to pass and then repairs are resumed. As a result, railroad maintenance workers are often in the same area as a moving train. Six railroad maintenance-of-way employees have been killed when struck by a locomotive or car from 1988 through 1990 [Source: FRA Accident/Incident Bulletins Calendar Years 1988, 1989, 1990, p. 84 in each volume]. For the 238,710 railroad route-km (148,000 route miles) in the U.S. [Source: Transportation in America, 1991, p. 64] this is a fatality rate of 0.0000087 per km (0.000014 per mile) per year. Assuming that the highway maintenance workers would have a fatality rate similar to railroad maintenance workers when working along the shared ROW, for the 645 km (400 miles) maglev system with 320 km (200 miles) of shared ROW, there would be 0.0027 fatalities per year or 1 fatality every 354 years.

Consequence: I (Catastrophic) Persons struck by trains at high speed are often killed or seriously injured. For example, in 1990, 511 persons were killed when they were struck or ran into locomotives or cars (not including rail/highway grade crossings). Five of these fatalities were railroad employees, 12 were "non-trespassers," and the remainder were trespassers [Source: FRA Accident/Incident Bulletin Calendar Year 1990, p. 84].

<u>Score:</u>	Frequency	Remote	D	
	Consequence	Catastrophic	I	
	Hazard Risk		8	Undesirable, management decision required

Mitigation: Frequency could be reduced by maintaining highways at times that the maglev is not in operation. This would suggest that highway maintenance would need to be done at night, or perhaps on weekends, when the maglev is not operating. Some highway maintenance is already done at night to reduce potential conflicts (and congestion) between highway traffic and highway workers. Frequency could also be reduced by installing personnel barriers between the two modes, installing signs, or by training highway workers about the dangers of maglev operations.

Consequence could not be feasibly reduced.

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with review by management).

Scenario Number: 6.3.2.b

Safety Issue: Accessibility

Instigator: Highway

Affected Mode: Maglev

High-Risk Event: Trespassers who gain access from the highway cause a maglev train to derail. Casualties include maglev train passengers and the trespassers.

Frequency: C (Occasional) Derailments can be caused by vandalism. In the U.S., there have been 41 (1988), 32 (1989), and 39 (1990) derailments caused by vandalism [Source: FRA Accident/Incident Bulletins Calendar Years 1988, 1989, 1990, p. 31 in each volume]. For 238,710 railroad route-km (148,000 route miles) in the U.S. [Source: Transportation in America, 1991, p. 64], this would be a derailment rate of 0.00014 per km (0.00023 per mile) per year. Assuming that derailment caused by vandalism for maglev would be similar to derailments on conventional railroads, there would be 0.0375 derailments per year on a 645 km (400 miles) maglev system with 320 km (200 miles) of shared ROW, if vandals had no other access to the HSR. This would be equivalent to 1 derailment every 27 years.

Consequence: I (Catastrophic) From 1988 through 1990, 9 persons were killed in railroad derailments. And, in one accident in 1991, 8 persons were killed in an Amtrak derailment at Lugoff, South Carolina, on July 31, 1991 [Source: Howard Robertson, Amtrak, telephone conversation, 1/92].

<u>Score:</u>	Frequency	Occasional	C	
	Consequence	Catastrophic	I	
	Hazard Risk		4	Unacceptable

Mitigation: Frequency of access by trespassers is difficult to control because of the long, mostly unattended right of way. Fences and detectors can be added to discourage or detect trespassers before they create damage.

Consequences of trespassers access can be reduced by locking all switches, housing track side equipment in tamperproof boxes, and maintaining a clean right of way (no old guideway parts or other equipment left handy).

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with review by management).

Scenario Number: 6.4.1.a

Safety Issue: Accessibility

Instigator: Railroad

Affected Mode: HSR

High-Risk Event: Railroad maintenance workers wander onto the HSR track or railroad maintenance-of-way equipment, foul the HSR track, and are struck by an oncoming HSR train. Casualties include maintenance workers.

Frequency: D (Remote) Track maintenance workers often operate "under traffic," that is, rail service is maintained while repairs are made. Track will be "closed up" just long enough for a train to pass and then repairs are resumed. As a result, railroad maintenance workers are often in the same area as a moving train. Six railroad maintenance-of-way employees have been killed when struck by a locomotive or car from 1988 through 1990 [Source: FRA Accident/Incident Bulletins Calendar Years 1988, 1989, 1990, p. 84 in each volume]. For the 238,710 railroad route-km (148,000 route miles) in the U.S. [Source: Transportation in America, 1991, p. 64], this is a fatality rate of 0.0000087 per km (0.000014 per mile) per year. For the 645 km (400 miles) HSR system with 320 km (200 miles) of shared ROW, there would be 0.0027 fatalities per year or 1 fatality every 930 years. Presumably some of these fatalities could come from collisions with railroad maintenance-of-way equipment. As a check, it was assumed that HSR vehicles running alongside a railroad would be as likely to strike fouling maintenance-of-way equipment as a railroad train would itself. From 1988 through 1990, there were approximately 10 railroad accidents per year that involved collisions or derailments with maintenance-of-way equipment [Source: Accident/Incident Bulletin, 1988, 1989, 1990, p. 38 all volumes]. This suggests an accident rate of 0.000068 per mile per year on the railroad. For a 645 km (400 miles) HSR system with 320 km (200 miles) of shared ROW, there would be 0.0054 accidents per year or 1 accident every 74 years.

Consequence: I (Catastrophic) Persons struck by trains at high speed are often killed or seriously injured. For example, in 1990, 511 persons were killed when they were struck or ran into locomotives or cars (not including rail/highway grade crossings). Five of these fatalities were railroad employees, 12 were "non-trespassers," and the remainder were trespassers [Source: FRA Accident/Incident Bulletin Calendar Year 1990, p. 84].

<u>Score:</u>	Frequency	Remote	D	
	Consequence	Catastrophic	I	
	Hazard Risk		8	Undesirable, management decision required

Mitigation: Frequency could be reduced by maintaining railroads at times that the HSR is not in operation. This would suggest that railroad maintenance would need to be done at night, or perhaps on weekends, when the HSR is not operating. However, even though some railroad maintenance is performed at such times (for example, in heavy commuter areas) railroads generally do not perform maintenance at night. Frequency could also be reduced by installing personnel

barriers between the two modes, installing signs, or by training highway workers about the dangers of HSR operations.

Consequence could not be feasibly reduced.

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with review by management).

Scenario Number: 6.4.1.b

Safety Issue: Accessibility

Instigator: Railroad

Affected Mode: HSR

High-Risk Event: Trespassers who gain access from the railroad cause an HSR to derail at cruising speed. Casualties include HSR train passengers and the trespassers.

Frequency: C (Occasional) Derailments can be caused by vandalism. In the U.S. there have been 41 (1988), 32 (1989), and 39 (1990) derailments caused by vandalism [Source: FRA Accident/Incident Bulletins Calendar Years 1988, 1989, 1990, p. 31 in each volume]. For 238,710 railroad route-km (148,000 route miles) in the U.S. [Source: Transportation in America, 1991, p. 64], this would be derailment rate of 0.00014 per km (0.00023 per mile) per year. Assuming that derailments caused by vandalism for HSR would be similar to conventional railroads, there would be 0.045 derailments per year on a 645 km (400 miles) HSR system with 320 km (200 miles) of shared ROW, if vandals had no other access to the HSR. This would be equivalent to 1 derailment every 22 years.

Consequence: I (Catastrophic) Train derailments can cause multiple fatalities. For example, 8 persons were killed in an Amtrak derailment at Lugoff, South Carolina, on July 31, 1991 [Source: Howard Robertson, Amtrak, telephone conversation, 1/92].

<u>Score:</u>	Frequency	Occasional	C	
	Consequence	Catastrophic	I	
	Hazard Risk		4	Unacceptable

Mitigation: Frequency of access by trespassers' is difficult to control because of the long, mostly unattended right of way. Fences and detectors can be added to discourage or detect trespassers before they create damage.

Consequences of trespassers' access can be reduced by locking all switches, housing track side equipment in tamperproof boxes, and maintaining a clean right of way (no old rail or wires left handy).

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with review by management).

Scenario Number: 6.4.2.a

Safety Issue: Accessibility

Instigator: Railroad

Affected Mode: Maglev

High-Risk Event: Railroad maintenance workers wander onto the maglev guideway or railroad maintenance-of-way equipment fouls the maglev guideway and is struck by an oncoming maglev train. Casualties include maintenance workers.

Frequency: D (Remote) Track maintenance workers often operate "under traffic," that is, rail service is maintained while repairs are made. Track will be "closed up" just long enough for a train to pass and then repairs are resumed. As a result, railroad maintenance workers are often in the same area as a moving train. Six railroad maintenance-of-way employees have been killed when struck by a locomotive or car from 1988 through 1990 [Source: FRA Accident/Incident Bulletins Calendar Years 1988, 1989, 1990, p. 84 in each volume]. For the 238,710 railroad route-km (148,000 route miles) in the U.S. [Source: Transportation in America, 1991, p. 64], this is a fatality rate of 0.0000087 per km (0.000014 per mile) per year. For the 645 km (400 miles) maglev system with 320 km (200 miles) of shared ROW there would be 0.0027 fatalities per year or 1 fatality every 364 years. Presumably some of these fatalities could come from collisions with railroad maintenance-of-way equipment. As a check, it was assumed that maglev vehicles running alongside a railroad would be as likely to strike fouling maintenance-of-way equipment as a railroad train would itself. From 1988 through 1990, there were approximately 10 railroad accidents per year that involved collisions or derailments with maintenance-of-way equipment [Source: Accident/Incident Bulletin, 1988, 1989, 1990, p. 38 all volumes]. This suggests an accident rate of 0.000068 per mile per year on the railroad. For a 645 km (400 miles) maglev system with 320 km (200 miles) of shared ROW, there would be 0.0054 accidents per year or 1 accident every 74 years.

Consequence: I (Catastrophic) Persons struck by trains at high speed are often killed or seriously injured. For example, in 1990, 511 persons were killed when they were struck or ran into locomotives or cars (not including rail/highway grade crossings). Five of these fatalities were railroad employees, 12 were "non-trespassers," and the remainder were trespassers. [Source: FRA Accident/Incident Bulletin Calendar Year 1990, p. 84].

Score:

Frequency	Remote	D	
Consequence	Catastrophic	I	
Hazard Risk		8	Undesirable, management decision required

Mitigation: Frequency could be reduced by maintaining railroads at times when the maglev is not in operation. This would suggest that railroad maintenance would need to be done at night, or perhaps on weekends, when the maglev is not operating. However, even though some railroad maintenance is performed at such times (for example, in heavy commuter areas) railroads generally do not perform maintenance at night. Frequency could also be reduced by installing personnel

barriers between the two modes, installing signs, or by training highway workers about the dangers of maglev operations.

Consequence could not be feasibly reduced.

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with review by management).

Scenario Number: 6.4.2.b

Safety Issue: Accessibility

Instigator: Railroad

Affected Mode: Maglev

High-Risk Event: Trespassers who gain access from the railroad cause a maglev train to derail. Casualties include maglev train passengers and the trespassers.

Frequency: C (Occasional) Derailments can be caused by vandalism. In the U.S. there have been 41 (1988), 32 (1989), and 39 (1990) derailments caused by vandalism [Source: FRA Accident/Incident Bulletins Calendar Years 1988, 1989, 1990, p. 31 in each volume]. For 238,710 railroad route-km (148,000 route miles) in the U.S. [Source: Transportation in America, 1991, p. 64], this would be a derailment rate of 0.00014 per km (0.00023 per mile) per year. Assuming that derailments caused by vandalism for maglev would be similar to derailments on conventional railroads, there would be 0.0375 derailments per year on a 645 km (400 miles) maglev system with 320 km (200 miles) of shared ROW, if vandals had no other access to the maglev. This would be equivalent to 1 derailment every 56 years.

Consequence: I (Catastrophic) From 1988 through 1990, 9 persons were killed in railroad derailments. And, in one accident in 1991, 8 persons were killed in an Amtrak derailment at Lugoff, South Carolina, on July 31, 1991 [Source: Howard Robertson, Amtrak, telephone conversation, 1/92].

Score:	Frequency	Occasional	C	
	Consequence	Catastrophic	I	
	Hazard Risk		4	Unacceptable

Mitigation: Frequency of access by trespassers is difficult to control because of the long, mostly unattended right of way. Fences and detectors can be added to discourage or detect trespassers before they create damage.

Consequences of trespassers' access can be reduced by locking all switches, housing track side equipment in tamperproof boxes, and maintaining a clean right of way (no old rail or wires left handy).

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with review by management).

Scenario Number:

6.5.1.a

Safety Issue:

Accessibility

Instigator:

Waterway

Affected Mode:

HSR

High-Risk Event:

Waterway maintenance workers wander onto the HSR track and are struck by a train. Casualties include maintenance workers.

Frequency:

D (Remote) Track maintenance workers often operate "under traffic," that is, rail service is maintained while repairs are made. Track will be "closed up" just long enough for a train to pass and then repairs are resumed. As a result, railroad maintenance workers are often in the same area as a moving train. Six railroad maintenance-of-way employees have been killed when struck by a locomotive or car from 1988 through 1990 [Source: FRA Accident/Incident Bulletins Calendar Years 1988, 1989, 1990, p. 84 in each volume]. For the 238,710 railroad route-km (148,000 route miles) in the U.S. [Source: Transportation in America, 1991, p. 64], this is a fatality rate of 0.0000087 per km (0.000014 per mile) per year. Assuming that the waterway maintenance workers would have a fatality rate similar to railroad maintenance workers when working along the shared ROW, for the 645 km (400 miles) HSR system with 320 km (200 miles) of shared ROW there would be 0.0011 fatalities per year or 1 fatality every 930 years.

Consequence:

I (Catastrophic) Persons struck by trains at high speed are often killed or seriously injured. For example, in 1990, 511 persons were killed when they were struck or ran into locomotives or cars (not including rail/highway grade crossings). Five of these fatalities were railroad employees, 12 were "non-trespassers," and the remainder were trespassers [Source: FRA Accident/Incident Bulletin Calendar Year 1990, p. 84]

Score:

Frequency	Remote	D	
Consequence	Catastrophic	I	
Hazard Risk		8	Undesirable, management decision required

Mitigation:

Frequency could be reduced by maintaining waterways at times when the HSR is not in operation. This would suggest that waterway maintenance would need to be done at night, or perhaps on weekends, when the HSR is not operating. However, even though some waterway maintenance is performed at such times (for example, around-the-clock lock rebuilding) waterways generally are not maintained at night. Frequency could also be reduced by installing personnel barriers between the two modes, installing signs, or by training waterway workers about the dangers of HSR operations.

Consequence could not be feasibly reduced.

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with review by management).

Scenario Number: 6.5.1.b

Safety Issue: Accessibility

Instigator: Waterway

Affected Mode: HSR

High-Risk Event: Trespassers who gain access from the waterway cause an HSR train to derail at cruising speed. Casualties include HSR train passengers and the trespassers.

Frequency: C (Occasional) Derailments can be caused by vandalism. In the U.S. there have been 41 (1988), 32 (1989), and 39 (1990) derailments caused by vandalism [Source: FRA Accident/Incident Bulletins Calendar Years 1988, 1989, 1990, p. 31 in each volume]. For 238,710 railroad route-km (148,000 route miles) in the U.S. [Source: Transportation in America, 1991, p. 64], this would be a derailment rate of 0.00014 per km (0.00023 per mile) per year. Assuming that derailments caused by vandalism for HSR would be similar to conventional railroads, there would be 0.018 derailments per year on a 645 km (400 miles) HSR system with 320 km (200 miles) of shared ROW, if vandals had no other access to the HSR. This would be equivalent to 1 derailment every 56 years.

Consequence: I (Catastrophic) Train derailments can cause multiple fatalities. For example 8 persons were killed in an Amtrak derailment at Lugoff, South Carolina, on July 31, 1991 [Source: Howard Robertson, Amtrak, telephone conversation, 1/92].

<u>Score:</u>	Frequency	Occasional	C	
	Consequence	Catastrophic	I	
	Hazard Risk		4	Unacceptable

Mitigation: Frequency of access by trespassers is difficult to control because of the long, mostly unattended right of way. Fences and detectors can be added to discourage or detect trespassers before they create damage.

Consequences of trespassers' access can be reduced by locking all switches, housing track side equipment in tamperproof boxes, and maintaining a clean right of way (no old rail or wires left handy).

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with review by management).

Scenario Number: 6.5.2.a

Safety Issue: Accessibility

Instigator: Waterway

Affected Mode: Maglev

High-Risk Event: Waterway maintenance workers wander onto the maglev guideway and are struck by a train. Casualties include maintenance workers.

Frequency: D (Remote) Track maintenance workers often operate "under traffic," that is, rail service is maintained while repairs are made. Track will be "closed up" just long enough for a train to pass and then repairs are resumed. As a result, railroad maintenance workers are often in the same area as a moving train. Six railroad maintenance-of-way employees have been killed when struck by a locomotive or car from 1988 through 1990 [Source: FRA Accident/Incident Bulletins Calendar Years 1988, 1989, 1990, p. 84 in each volume]. For the 238,710 railroad route-km (148,000 route miles) in the U.S. [Source: Transportation in America, 1991, p. 64], this is a fatality rate of 0.0000087 per km (0.000014 per mile) per year. Assuming that the waterway maintenance workers would have a fatality rate similar to railroad maintenance workers when working along the shared ROW, for the 645 km (400 miles) maglev system with 320 km (200 miles) of shared ROW there would be 0.0011 fatalities per year or 1 fatality every 930 years.

Consequence: I (Catastrophic) Persons struck by trains at high speed are often killed or seriously injured. For example, in 1990, 511 persons were killed when they were struck or ran into locomotives or cars (not including rail/highway grade crossings). Five of these fatalities were railroad employees, 12 were "non-trespassers," and the remainder were trespassers [Source: FRA Accident/Incident Bulletin Calendar Year 1990, p. 84].

Score:	Frequency	Remote	D	
	Consequence	Catastrophic	I	
	Hazard Risk		8	Undesirable, management decision required

Mitigation: Frequency could be reduced by maintaining waterways at times when the maglev is not in operation. This would suggest that waterway maintenance would need to be done at night, or perhaps on weekends, when the maglev is not operating. However, even though some waterway maintenance is performed at such times (for example, around-the-clock lock rebuilding) waterways generally are not maintained at night. Frequency could also be reduced by installing personnel barriers between the two modes, installing signs, or by training waterway workers about the dangers of maglev operations.

Consequence could not be feasibly reduced.

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with review by management).

Scenario Number: 6.5.2.b

Safety Issue: Accessibility

Instigator: Waterway

Affected Mode: Maglev

High-Risk Event: Trespassers who gain access from the waterway cause a maglev train to derail. Casualties include maglev train passengers and the unauthorized intruders.

Frequency: C (Occasional) Derailments can be caused by vandalism. In the U.S. there have been 41 (1988), 32 (1989), and 39 (1990) derailments caused by vandalism [Source: FRA Accident/Incident Bulletins Calendar Years 1988, 1989, 1990, p. 31 in each volume]. For 238,710 railroad route-km (148,000 route miles) in the U.S. [Source: Transportation in America, 1991, p. 64], this would be a derailment rate of 0.00014 per km (0.00023 per mile) per year. Assuming that derailments caused by vandalism for maglev would be similar to derailments on conventional railroads, there would be 0.01556 derailments per year on a 645 km (400 miles) maglev system with 320 km (200 miles) of shared ROW, if vandals had no other access to the HSR. This would be equivalent to 1 derailment every 56 years.

Consequence: I (Catastrophic) From 1988 through 1990, 9 persons were killed in railroad derailments. Moreover, in one accident in 1991, 8 persons were killed in an Amtrak derailment at Lugoff, South Carolina, on July 31, 1991 [Source: Howard Robertson, Amtrak, telephone conversation, 1/92].

<u>Score:</u>	Frequency	Occasional	C	
	Consequence	Catastrophic	I	
	Hazard Risk		4	Unacceptable

Mitigation: Frequency of access by trespassers is difficult to control because of the long, mostly unattended right of way. Fences and detectors can be added to discourage or detect trespassers before they create damage.

Consequences of trespassers' access can be reduced by locking all switches, housing track side equipment in tamperproof boxes, and maintaining a clean right of way (no old guideway parts or other equipment left handy).

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with review by management).

Scenario Number: 6.6.1.a

Safety Issue: Accessibility

Instigator: Pipeline

Affected Mode: HSR

High-Risk Event: Pipeline maintenance workers wander onto the HSR track and are struck by an oncoming HSR train or pipeline maintenance equipment fouls the HSR and is struck by an oncoming train. Casualties include maintenance workers.

Frequency: D (Remote) Track maintenance workers often operate "under traffic," that is, rail service is maintained while repairs are made. Track will be "closed up" just long enough for a train to pass and then repairs are resumed. As a result, railroad maintenance workers are often in the same area as a moving train. Six railroad maintenance-of-way employees have been killed when struck by a locomotive or car from 1988 through 1990 [Source: FRA Accident/Incident Bulletins Calendar Years 1988, 1989, 1990, p. 84 in each volume]. For the 238,710 railroad route-km (148,000 route miles) in the U.S. [Source: Transportation in America, 1991, p. 64], this is a fatality rate of 0.0000087 per km (0.000014 per mile) per year. Assuming that the pipeline maintenance workers would have a fatality rate similar to railroad maintenance workers when working along the shared ROW, for the 645 km (400 miles) HSR system with 320 km (200 miles) of shared ROW there would be 0.0027 fatalities per year or 1 fatality every 364 years.

Consequence: I (Catastrophic) Persons struck by trains at high speed are often killed or seriously injured. For example, in 1990, 511 persons were killed when they were struck or ran into locomotives or cars (not including rail/highway grade crossings). Five of these fatalities were railroad employees, 12 were "non-trespassers," and the remainder were trespassers [Source: FRA Accident/Incident Bulletin Calendar Year 1990, p. 84].

<u>Score:</u>	Frequency	Remote	D	
	Consequence	Catastrophic	I	
	Hazard Risk		8	Undesirable, management decision required

Mitigation: Frequency could be reduced by pipelines at times when the HSR is not in operation. This would suggest that pipeline maintenance would need to be done at night, or perhaps on weekends, when the HSR is not operating. However, even though some pipeline maintenance is performed at night (such as emergency repairs) pipelines generally are not maintained at night. Frequency could also be reduced by installing personnel barriers between the two modes, installing signs, or by training waterway workers about the dangers of HSR operations.

Consequence could not be feasibly reduced.

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with review by management).

Scenario Number: 6.6.1.b

Safety Issue: Accessibility

Instigator: Pipeline

Affected Mode: HSR

High-Risk Event: Trespassers who gain access from the pipeline cause an HSR train to derail at cruising speed. The HSR train derails at cruising speed. Casualties include HSR train passengers and trespassers.

Frequency: C (Occasional) Derailments can be caused by vandalism. In the U.S. there have been 41 (1988), 32 (1989), and 39 (1990) derailments caused by vandalism [Source: FRA Accident/Incident Bulletins Calendar Years 1988, 1989, 1990, p. 31 in each volume]. For 238,710 railroad route-km (148,000 route miles) in the U.S. [Source: Transportation in America, 1991, p. 64], this would be a derailment rate of 0.00014 per km (0.00023 per mile) per year. Assuming that derailments caused by vandalism for HSR would be similar to conventional railroads, there would be 0.045 derailments per year on a 645 km (400 miles) HSR system with 320 km (200 miles) of shared ROW, if vandals had no other access to the HSR. This would be equivalent to 1 derailment every 22 years.

Consequence: I (Catastrophic) Train derailments can cause multiple fatalities. For example, 8 persons were killed in an Amtrak derailment at Lugoff, South Carolina, on July 31, 1991 [Source: Howard Robertson, Amtrak, telephone conversation, 1/92].

<u>Score:</u>	Frequency	Occasional	C	
	Consequence	Catastrophic	I	
	Hazard Risk		4	Unacceptable

Mitigation: Frequency of access by trespassers is difficult to control because of the long, mostly unattended right of way. Fences and detectors can be added to discourage or detect trespassers before they create damage.

Consequences of trespassers' access can be reduced by locking all switches, housing track side equipment in tamperproof boxes, and maintaining a clean right of way (no old rail or wires left handy).

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with review by management).

Scenario Number: 6.6.2.a

Safety Issue: Accessibility

Instigator: Pipeline

Affected Mode: Maglev

High-Risk Event: Pipeline maintenance workers wander onto the maglev guideway and are struck by an oncoming maglev train or pipeline maintenance equipment fouls the guideway and is struck by an oncoming train. Casualties include maintenance workers.

Frequency: D (Remote) Track maintenance workers often operate "under traffic," that is, rail service is maintained while repairs are made. Track will be "closed up" just long enough for a train to pass and then repairs are resumed. As a result, railroad maintenance workers are often in the same area as a moving train. Six railroad maintenance-of-way employees have been killed when struck by a locomotive or car from 1988 through 1990 [Source: FRA Accident/Incident Bulletins Calendar Years 1988, 1989, 1990, p. 84 in each volume]. For the 238,710 railroad route-km (148,000 route miles) in the U.S. [Source: Transportation in America, 1991, p. 64], this is a fatality rate of 0.0000087 per km (0.000014 per mile) per year. Assuming that the pipeline maintenance workers would have a fatality rate similar to railroad maintenance workers when working along the shared ROW, for the 645 km (400 miles) maglev system with 320 km (200 miles) of shared ROW there would be 0.0027 fatalities per year or 1 fatality every 364 years.

Consequence: I (Catastrophic) Persons struck by trains at high speed are often killed or seriously injured. For example, in 1990, 511 persons were killed when they were struck or ran into locomotives or cars (not including rail/highway grade crossings). Five of these fatalities were railroad employees, 12 were "non-trespassers," and the remainder were trespassers [Source: FRA Accident/Incident Bulletin Calendar Year 1990, p. 84].

<u>Score:</u>	Frequency	Remote	D	
	Consequence	Catastrophic	I	
	Hazard Risk		8	Undesirable, management decision required

Mitigation: Frequency could be reduced by performing pipeline maintenance at times when the maglev is not in operation. This would suggest that pipeline maintenance would need to be done at night, or perhaps on weekends, when the maglev is not operating. However, even though some pipeline maintenance is performed at night (such as emergency repairs) pipelines generally are not maintained at night. Frequency could also be reduced by installing personnel barriers between the two modes, installing signs, or by instructing waterway workers about the dangers of maglev operations.

Consequence could not be feasibly reduced.

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with review by management).

Scenario Number: 6.6.2.b

Safety Issue: Accessibility

Instigator: Pipeline

Affected Mode: Maglev

High-Risk Event: Trespassers who gain access from the pipeline cause a maglev train to come to a sudden and uncontrolled stop from its cruising speed. Casualties include maglev train passengers and the trespassers.

Frequency: C (Occasional) Derailments can be caused by vandalism. In the U.S. there have been 41 (1988), 32 (1989), and 39 (1990) derailments caused by vandalism [Source: FRA Accident/Incident Bulletins Calendar Years 1988, 1989, 1990, p. 31 in each volume]. For 238,710 railroad route-km (148,000 route miles) in the U.S. [Source: Transportation in America, 1991, p. 64], this would be a derailment rate of 0.00014 per km (0.00023 per mile) per year. Assuming that derailments caused by vandalism for maglev would be similar to derailments on conventional railroads, there would be 0.0375 derailments per year on a 645 km (400 miles) maglev system with 320 km (200 miles) of shared ROW, if vandals had no other access to the HSR. This would be equivalent to 1 derailment every 27 years.

Consequence: I (Catastrophic) From 1988 through 1990, 9 persons were killed in railroad derailments. Moreover, in one accident in 1991, 8 persons were killed in an Amtrak derailment at Lugoff, South Carolina, on July 31, 1991 [Source: Howard Robertson, Amtrak, telephone conversation, 1/92].

Score:

Frequency	Occasional	C	
Consequence	Catastrophic	I	
Hazard Risk		4	Unacceptable

Mitigation: Frequency of access by trespassers is difficult to control because of the long, mostly unattended right of way. Fences and detectors can be added to discourage or detect trespassers before they create damage.

Consequences of trespassers' access can be reduced by locking all switches, housing track side equipment in tamperproof boxes, and maintaining a clean right of way (no old guideway parts or other equipment left handy).

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with review by management).

Scenario Number: 6.7.1.a

Safety Issue: Accessibility

Instigator: Transmission line

Affected Mode: HSR

High-Risk Event: Transmission line maintenance workers wander onto the HSR track and are struck by an oncoming HSR train. Casualties include maintenance workers.

Frequency: D (Remote) Track maintenance workers often operate "under traffic," that is, rail service is maintained while repairs are made. Track will be "closed up" just long enough for a train to pass and then repairs are resumed. As a result, railroad maintenance workers are often in the same area as a moving train. Six railroad maintenance-of-way employees have been killed when struck by a locomotive or car from 1988 through 1990 [Source: FRA Accident/Incident Bulletins Calendar Years 1988, 1989, 1990, p. 84 in each volume]. For the 238,710 railroad route-km (148,000 route miles) in the U.S. [Source: Transportation in America, 1991, p. 64], this is a fatality rate of 0.0000087 per km (0.000014 per mile) per year. Assuming that the transmission line maintenance workers would have a fatality rate similar to railroad maintenance workers when working along the shared ROW, for the 645 km (400 miles) HSR system with 320 km (200 miles) of shared ROW there would be 0.0027 fatalities per year or 1 fatality every 364 years.

Consequence: I (Catastrophic) Persons struck by trains at high speed are often killed or seriously injured. For example, in 1990, 511 persons were killed when they were struck or ran into locomotives or cars (not including rail/highway grade crossings). Five of these fatalities were railroad employees, 12 were "non-trespassers," and the remainder were trespassers [Source: FRA Accident/Incident Bulletin Calendar Year 1990, p. 84].

Score:	Frequency	Remote	D	
	Consequence	Catastrophic	I	
	Hazard Risk		8	Undesirable, management decision required

Mitigation: Frequency could be reduced by maintaining transmission lines at times when the HSR is not in operation. This would suggest that transmission line maintenance would need to be done at night, or perhaps on weekends, when the HSR is not operating. However, even though some transmission line maintenance is performed at night (such as emergency repairs) transmission lines generally are not maintained at night. Frequency could also be reduced by installing personnel barriers between the two modes, installing signs, or by training waterway workers about the dangers of HSR operations.

Consequence could not be feasibly reduced.

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with review by management).

Scenario Number: 6.7.1.b

Safety Issue: Accessibility

Instigator: Transmission line

Affected Mode: HSR

High-Risk Event: Trespassers who gain access from the transmission line cause an HSR train to derail at cruising speed. Casualties include HSR train passengers and the trespassers.

Frequency: C (Occasional) Derailments can be caused by vandalism. In the U.S. there have been 41 (1988), 32 (1989), and 39 (1990) derailments caused by vandalism [Source: FRA Accident/Incident Bulletins Calendar Years 1988, 1989, 1990, p. 31 in each volume]. For 238,710 railroad route-km (148,000 route miles) in the U.S. [Source: Transportation in America, 1991, p. 64], this would be a derailment rate of 0.00014 per km (0.00023 per mile) per year. Assuming that derailments caused by vandalism for HSR would be similar to conventional railroads, there would be 0.045 derailments per year on a 645 km (400 miles) HSR system with 320 km (200 miles) of shared ROW, if vandals had no other access to the HSR. This would be equivalent to 1 derailment every 22 years.

Consequence: I (Catastrophic) Train derailments can cause multiple fatalities. For example 8 persons were killed in an Amtrak derailment at Lugoff, South Carolina, on July 31, 1991 [Source: Howard Robertson, Amtrak, telephone conversation, 1/92].

<u>Score:</u>	Frequency	Occasional	C	
	Consequence	Catastrophic	I	
	Hazard Risk		4	Unacceptable

Mitigation: Frequency of access by trespassers is difficult to control because of the long, mostly unattended right of way. Fences and detectors can be added to discourage or detect trespassers before they cause damage.

Consequences of trespassers' access can be reduced by locking all switches, housing track side equipment in tamperproof boxes, and maintaining a clean right of way (no old rail or wires left handy).

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with review by management).

Scenario Number: 6.7.2.a

Safety Issue: Accessibility

Instigator: Transmission line

Affected Mode: Maglev

High-Risk Event: Transmission line maintenance workers wander onto the maglev guideway and are struck by an oncoming maglev train. Casualties include maintenance workers.

Frequency: D (Remote) Track maintenance workers often operate "under traffic," that is, rail service is maintained while repairs are made. Track will be "closed up" just long enough for a train to pass and then repairs are resumed. As a result, railroad maintenance workers are often in the same area as a moving train. Six railroad maintenance-of-way employees have been killed when struck by a locomotive or car from 1988 through 1990 [Source: FRA Accident/Incident Bulletins Calendar Years 1988, 1989, 1990, p. 84 in each volume]. For the 238,710 railroad route-km (148,000 route miles) in the U.S. [Source: Transportation in America, 1991, p. 64], this is a fatality rate of 0.0000087 per km (0.000014 per mile) per year. Assuming that the transmission line maintenance workers would have a fatality rate similar to railroad maintenance workers when working along the shared ROW, for the 645 km (400 miles) HSR system with 320 km (200 miles) of shared ROW there would be 0.0027 fatalities per year or 1 fatality every 364 years. Presumably some of these fatalities could come from collisions with railroad maintenance-of-way equipment. As a check, it was assumed that maglev vehicles running alongside a railroad would be as likely to strike fouling maintenance-of-way equipment as a railroad train would itself. From 1988 through 1990, there were approximately 10 railroad accidents per year that involved collisions or derailments with maintenance-of-way equipment [Source: Accident/Incident Bulletin, 1988, 1989, 1990, p. 38 all volumes]. This suggests an accident rate of 0.000068 per mile per year on the railroad. For a 645 km (400 miles) maglev system with 320 km (200 miles) of shared ROW, there would be 0.0135 accidents per year or 1 accident every 74 years.

Consequence: I (Catastrophic) Persons struck by trains at high speed are often killed or seriously injured. For example, in 1990, 511 persons were killed when they were struck or ran into locomotives or cars (not including rail/highway grade crossings). Five of these fatalities were railroad employees, 12 were "non-trespassers," and the remainder were trespassers [Source: FRA Accident/Incident Bulletin Calendar Year 1990, p. 84].

Score:

Frequency	Remote	D	
Consequence	Catastrophic	I	
Hazard Risk		8	Undesirable, management decision required

Mitigation: Frequency could be reduced by maintaining transmission lines at times when the maglev is not in operation. This would suggest that transmission line maintenance would need to be done at night, or perhaps on weekends, when the maglev is not operating. However, even though some transmission line maintenance is performed at night (such as emergency repairs) transmission lines

generally are not maintained at night. Frequency could also be reduced by installing personnel barriers between the two modes, installing signs, or by instructing waterway workers about the dangers of maglev operations.

Consequence could not be feasibly reduced.

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with review by management).

Scenario Number: 6.7.2.b

Safety Issue: Accessibility

Instigator: Transmission line

Affected Mode: Maglev

High-Risk Event: Trespassers who gain access from the transmission line cause a maglev train to derail. Casualties include maglev train passengers and the trespassers.

Frequency: C (Occasional) Derailments can be caused by vandalism. In the U.S. there have been 41 (1988), 32 (1989), and 39 (1990) derailments caused by vandalism [Source: FRA Accident/Incident Bulletins Calendar Years 1988, 1989, 1990, p. 31 in each volume]. For 238,710 railroad route-km (148,000 route miles) in the U.S. [Source: Transportation in America, 1991, p. 64], this would be a derailment rate of 0.00014 per km (0.00023 per mile) per year. Assuming that derailments caused by vandalism for maglev would be similar to derailments on conventional railroads, there would be 0.0375 derailments per year on a 645 km (400 miles) maglev system with 320 km (200 miles) of shared ROW, if vandals had no other access to the HSR. This would be equivalent to 1 derailment every 22 years.

Consequence: I (Catastrophic) From 1988 through 1990, 9 persons were killed in railroad derailments. And, in one accident in 1991, 8 persons were killed in an Amtrak derailment at Lugoff, South Carolina, on July 31, 1991, [Source: Howard Robertson, Amtrak, telephone conversation, 1/92].

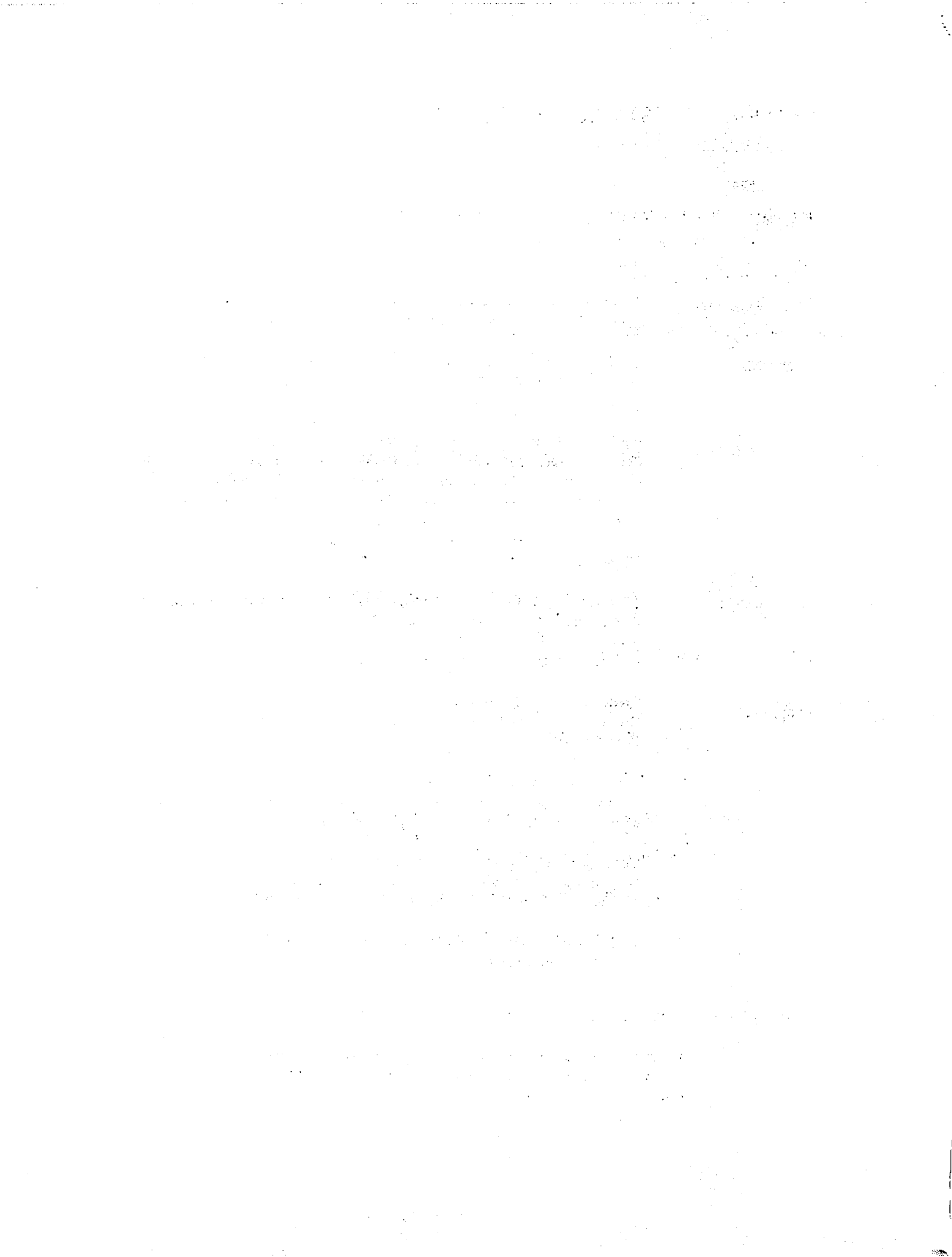
Score:

Frequency	Occasional	C	
Consequence	Catastrophic	I	
Hazard Risk		4	Unacceptable

Mitigation: Frequency of access by trespassers is difficult to control because of the long, mostly unattended right of way. Fences and detectors can be added to discourage or detect trespassers before they create damage.

Consequences of trespassers' access can be reduced by locking all switches, housing trackside equipment in tamperproof boxes, and maintaining a clean right of way (no old guideway parts or other equipment left handy).

Post-mitigation score would be Improbable/Catastrophic: 12 (acceptable, with review by management).



APPENDIX G ESTIMATE OF HSGGT DERAILMENT PROBABILITY WITH CATASTROPHIC CONSEQUENCE

This analysis is based on the Japanese Railways Tokaido Shinkansen line. It is comparable in length to the baseline HSGGT system of 645 km. Similar system length would allow a comparison of train traffic density based on yearly ridership.

Shinkansen Data:

- Route length: 515 km**
- Year opened: 1964**
- Years in operation: 28**
- Ridership: 112,000,000 passengers per year in 1988**
- No high speed, Catastrophic (Category I) accidents since the beginning of revenue service**
- Average Shinkansen ridership: 91,800,000 passengers per year since 1965**
- Total Shinkansen ridership between opening day and March 1991:
2,386,854,000**

Hypothetical U.S. HSGGT Characteristics: **Route length: 645 km**
Ridership: 7,000,000 passengers per year

Assumptions: **Average traffic growth on baseline U.S. HSGGT system: 5 percent per year. This is similar to the growth rates assumed for both short distance air travel and in the Pennsylvania High-Speed Rail Commission study, and corresponds to a ridership of 28,000,000 in the 28th year of commercial service.**

(Note: The expected growth rate for the TGV-PSE passenger traffic between the years 1984 and 1995 is 5 percent. This is based on 14,300,000 passengers in 1984 and 26,600,000 passengers is forecast per year in 1995.)

Train loadings will be similar for the Shinkansen and the baseline HSGGT.

Average speeds will be similar for the Shinkansen and the baseline HSGGT trains.

- Analysis:**
- 1. In 28 years, the Shinkansen carried 2,386,854,000 passengers.**
 - 2. Based on an annual rate of growth of 5 percent per year, the number of years, n required for the baseline system to have carried 2,387,000,000 passengers can be determined by solving the following equation for n. These calculations imply that if a derailment occurred on the Shinkansen tomorrow, then the rate of fatal accidents due to derailment would be one per 2.387 billion**

$$2,387,000,000 = (7,000,000) \sum_{i=0}^n (1.05)^i$$

$n \approx 59 \text{ years}$

passengers. Since it would take 59 years for the baseline U.S. HSGGT system to carry 2.387 billion passengers, this implies a derailment rate of one per 59 years on the entire system. However, the derailment rate on the 50 percent of the system that shares the ROW would be one per $59/0.5 = 118$ years.

3. Based on these calculations, it would take at least 59 years for a Catastrophic accident on the baseline HSGGT system. Based on the 50 percent of the 645 km system suitable for shared ROW use, the frequency of a HSGGT derailment causing a Catastrophic accident within the shared ROW length will be one in 118 years.
4. Considering that:
 - The Tokaido Shinkansen represents less than 25 percent of the Shinkansen route distance (total 2,101 km),
 - All existing line has been in operation since 1981 (length 417 km),
 - The TGV-PSE line has been in operation since 1981 (length 417 km),
 - The TGV-Atlantique line has been in operation since 1990 (length 283 km),
 - High-speed services have operated on 426 km of lines in Germany since 1991,
 - High-speed rail services in commercial service have not derailed at speed,

and based on the analysis outlined above, the conclusion can be reached that for the baseline HSGGT system, the frequency of derailment would be at Remote, or between once in 100 years and once in 1,000 years.

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