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Human Factors Guidelines for Intelligent Transportation Systems at the Highway-Rail Intersection: Technical Report

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6. AUTHOR(S)
Neil D. Lerner, James W. Jenness, Jeremiah P. Singer, Richard W. Huey, and Robert E. Llaneras

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Westat*
1650 Research Blvd.
Rockville, MD 20850

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13. ABSTRACT (Maximum 200 words)
This technical report documents the development of a set of human factors guidelines to aid designers and implementers of intelligent transportation systems (ITS) at highway-rail intersections (HRIs). The focus was specifically on roadway user human factors issues. In addition to providing immediate benefit, the guidelines were also designed to serve as a resource and impetus for the development of consensus standards, approved practices, industry guidelines, and other more formal guidance. The set of potential human factors issues was derived from a review of existing literature and research studies, as well as contacts with experts and ITS implementers. The guidelines document was arranged in three major sections: Section 1 introduces the major issues and considerations that the guidelines address; Section 2 provides general human factors guidance for messages and displays; and Section 3 provides specific guidance for applications, including train arrival warnings, advance information about the HRI, enforcement and control of vehicles, and light rail transit. Each guidelines chapter begins with an introduction to the background and major issues of the application. Next, a set of human factors guidelines statements is presented, along with supporting discussion and rationales for each statement.

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1 foot (ft) = 30 centimeters (cm)	1 centimeter (cm) = 0.4 inch (in)
1 yard (yd) = 0.9 meter (m)	1 meter (m) = 3.3 feet (ft)
1 mile (mi) = 1.6 kilometers (km)	1 meter (m) = 1.1 yards (yd)
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1 square yard (sq yd, yd^2) = 0.8 square meter (m^2)	1 square kilometer (km^2) = 0.4 square mile (sq mi, mi^2)
1 square mile (sq mi, mi^2) = 2.6 square kilometers (km^2)	10,000 square meters (m^2) = 1 hectare (ha) = 2.5 acres
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	= 1.1 short tons
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1 pint (pt) = 0.47 liter (l)	
1 quart (qt) = 0.96 liter (l)	
1 gallon (gal) = 3.8 liters (l)	
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1 cubic yard (cu yd, yd^3) = 0.76 cubic meter (m^3)	1 cubic meter (m^3) = 1.3 cubic yards (cu yd, yd^3)
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[(x-32)(5/9)] °F = y °C	[(9/5) y + 32] °C = x °F

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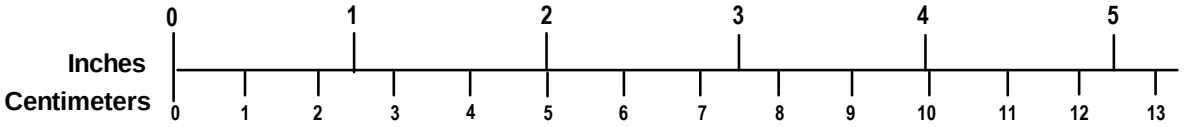

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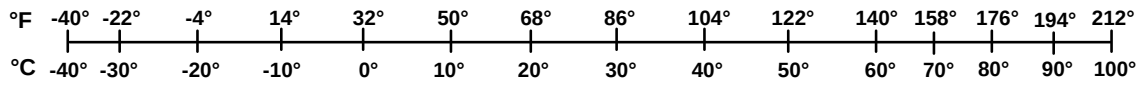

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Acknowledgements

This report documents the activities and findings of a project that developed human factors guidance recommendations and supporting material to assist the designers and implementers of intelligent transportation system applications for the highway-rail intersection. A separate document, titled *Human Factors Guidance for Intelligent Transportation Systems at the Highway-Rail Intersection*, provides the guidelines themselves. The guidelines document is available upon request from the project's sponsor, Dr. Thomas Raslear (thomas.raslear@dot.gov). Westat conducted the work for the Federal Railroad Administration (FRA), as subcontractor to Foster-Miller, Inc., under contract DTFR53-00-R-00017. The report authors gratefully thank Dr. Raslear and the staff of the FRA Office of Research and Development for its support, guidance, and critical review throughout the course of the work. The authors also wish to thank Judith Gertler of Foster-Miller, Inc., for support at many points during this effort.

The final set of guidance recommendations produced in this project benefited from the insightful comments of numerous outside reviewers. The authors deeply thank these individuals for generously sharing their time and critical insights. The authors also gratefully acknowledge the assistance of organizations that helped distribute the request for qualified reviewers.

Executive Summary

The highway-rail intersection (HRI), where a highway and railroad tracks intersect, is a point of potential conflict between highway traffic and trains. In 2004, 3,133 events, 1,131 injuries, and 377 fatalities occurred at HRIs in the United States. With increasing traffic on highways and on rail lines, safety and operational efficiency at the HRI are important concerns. In 1997, the National Intelligent Transportation Systems (ITS) Program Plan identified the HRI as a location that could reap important benefits in safety, mobility, and productivity through the use of innovative communications and electronics technologies known as ITS. Like all systems, ITS must be designed with the human user in mind. The field of human factors specifically addresses issues of human interaction with systems.

This technical report documents the development of a set of guidelines entitled *Human Factors Guidance for Intelligent Transportation Systems at the Highway-Rail Intersection*. The guidelines have two objectives: (1) to provide preliminary guidance that would be of immediate use to designers and implementers of ITS at HRIs and (2) to serve as a resource and impetus for the development of consensus standards, approved practices, industry guidelines, and other more formal guidance. The scope of the guidelines is limited to human factors issues for ITS systems that are applicable to roadway user safety at HRIs.

The first step in guidelines development was to define the set of potential human factors requirements that need to be addressed through guidelines. These issues were derived from a 1999 workshop entitled "ITS Standards for the Highway-Rail Intersection;" a literature search and review; contacts with key experts, ITS implementers, and organization representatives; and a review of guidelines in related fields.

Once the key human factors applications and guidance needs were defined, guidance recommendations were developed, and the guidelines document structure was established. In the guidelines document, *Human Factors Guidance for Intelligent Transportation Systems at the Highway-Rail Intersection*, Chapters 1 through 3 introduce the purpose and scope of the guidelines, describe the road user for whom the ITS systems are intended, and review current and past ITS systems implemented at HRIs. Chapters 4 through 7 provide general human factors considerations, including message factors, roadside displays, in-vehicle displays, and displays for pedestrians. Chapters 8 through 11 provide human factors considerations for specific applications, including warnings about train arrival, advance information about the HRI and dynamic route guidance, enforcement and control of vehicles, and light rail transit.

Each of the guidance chapters (Chapters 4 through 11) has a similar structure. The Background section describes the application and the relevant safety and operational concerns; this section also reviews relevant research, practice, and field experience. The Key Human Factors Issues and Need for Guidance section identifies the major human factors issues of particular concern for the application and why guidance is needed. The Recommendations section provides actual guidance statements with supporting discussions and rationales, as well as cross references to other sections of the guidelines and citations of key documents, where appropriate.

The draft guidelines were reviewed by a multidisciplinary group of outside reviewers, including potential users of the guidelines, stakeholder groups, and experts in relevant disciplines. Reviewers generally responded favorably to the organization, format, and content of the

guidelines, with the most frequent critical comments concerning conciseness or redundancy. Very few cases of outright disagreement existed with the guidance provided. The guidelines authors reviewed all comments and made edits to the document where appropriate.

The guidelines document, *Human Factors Guidance for Intelligent Transportation Systems at the Highway-Rail Intersection*, is an intermediate step toward the development of further guidelines, consensus standards, or other products for those with a stake in safety and efficiency at HRIs. The guidelines document provides sound human factors principles to aid in the development of ITS at HRIs, and the innovations and lessons learned from these projects should in turn be incorporated into the guidelines to enhance and improve them for future use.

1. Introduction

Emerging intelligent technologies and communication systems make many innovations in traffic management and transportation safety feasible. The HRI is one infrastructure feature for which a variety of ITS concepts are being explored. As these new systems develop, it is essential that they be designed with the human user in mind. Products and systems that are not well understood, readily usable, and acceptable to the roadway users who encounter them can put the ITS enterprise at risk. The field of human factors (or ergonomics) is the discipline that specifically addresses such issues. It is "the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and other methods to design in order to optimize human well-being and overall system performance" (International Ergonomics Association, 2000). The purpose of this Federal Railroad Administration (FRA) project was to develop human factors guidance for the use of ITS at the HRI. It specifically focused on roadway user human factors issues (in contrast to issues related to train cabs, train crews, rail operations centers, traffic control centers, maintenance operations, and so forth). This guidance is a step toward an ultimate goal of consensus standards development. Thus this project had the dual objectives of providing preliminary guidance that would be of immediate use to designers and implementers of ITS for the HRI, as well as of serving as a resource and impetus for the development of consensus standards, approved practices, industry guidelines, and other more formal guidance.

1.1 Background

The HRI is a point of potential conflict between rail and roadway traffic and as such is an important safety and operational concern. In 2004, HRIs (highway-rail at-grade crossings and light rail transit) accounted for an estimated 3,133 events, with 1,131 injuries and 377 fatalities (FRA, 2005).

ITS offers opportunities to bring technology-based innovations to improve the safety of HRIs and to facilitate the operational compatibility of rail and roadway traffic. The U.S. Department of Transportation's ITS Joint Program Office (2005) defines ITS as follows:

> ITS improves transportation safety and mobility and enhances productivity through the use of advanced communications technologies. Intelligent transportation systems (ITS) encompass a broad range of wireless and wire line communications-based information and electronics technologies. When integrated into the transportation system's infrastructure, and in vehicles themselves, these technologies relieve congestion, improve safety and enhance American productivity.

The National ITS Program Plan defined a list of ITS user services as jointly defined by the U.S. Department of Transportation and ITS America. The initial (1995) list of 29 user services expanded to include the HRI in 1997 and now has reached 33 user services (Federal Highway Administration, 2005). User services are surface transportation services that can be provided by some aspect of ITS. The individual services are viewed as building blocks that may be combined for deployment. Section 3.1.10 of the January 2005 version of the *ITS User Services Document* (Federal Highway Administration, 2005) describes the HRI user service. This

document points out the needs for HRI ITS services and describes a variety of service concepts for train control functions, highway control detection and warning device functions, highway control dynamic message sign functions, highway control in-vehicle services functions, and automated collision notification. Although the *ITS User Services Document* does not explicitly deal with human factors issues, the HRI discussion notes that "a number of human factors and motorist behavior issues need to be addressed" and cites some examples. Human factors concerns are implicit in the discussion of various operational concepts. Clearly, the developers of ITS HRI user services will need to resolve numerous human factors concerns if the deployments are going to be successful.

Although the development of ITS applications for the HRI has begun and continues to expand, no comprehensive source of standards or guidance for addressing the related human factors issues exists. Various sources of general guidance exist for human factors displays and some guides, regulations, or statements of principle for certain types of in-vehicle displays and warnings, changeable message signs, and other areas. These sources, however, are scattered and not tailored for HRI applications. Developers of ITS applications for the HRI lack the guidance required to assure that their systems are usable and safe for the range of roadway users who will encounter them.

In July 1999, FRA, the ITS Joint Program Office of the U.S. Department of Transportation, and the Federal Highway Administration (FHWA) Office of Motor Carriers and Highway Safety sponsored a 2-day workshop on ITS Standards for the Rail Highway Intersection. The primary purpose of the workshop was to "characterize and move toward the establishment of a program to develop industry-consensus standards for the use of Intelligent Transportation System technologies in the Highway-Rail Intersection" (Weiland, 1999). Human factors issues were raised throughout the discussions. The *Report for the Workshop on ITS Standards for the Highway-Rail Intersection* documented the findings of the workshop (Weiland, 1999).

The workshop provided the impetus for the present project. Although the workshop described requirements for HRI/ITS-related human factors standards, it did not identify a process for the development of standards, and little progress has occurred on this matter. Therefore, FRA initiated this project, *Human Factors Guidelines for the Development of Intelligent Transportation System Standards for the Highway-Rail Intersection.* It represented a logical next step in the effort to provide consensus standards and other improved guidance to help assure that emerging ITS applications for the HRI are consistent with good human factors practice.

1.2 Objectives

The primary purpose of this project was to develop human factors guidelines for ITS at the HRI. The project statement of work recognized that these guidelines would be an intermediate step between the identification of general human factors standardization needs (e.g., Weiland, 1999) and consensus standards. In order to accomplish this purpose, the project had the following objectives:

- Refine and expand the set of human factors standards needs identified in previous work
- Identify source material for the development of guidelines
- Develop recommendations and guidelines for the range of roadway user human factors issues

- Develop a guidance document

The objective of the guidance document itself was a key consideration. It was intended to serve two purposes, and these were not always entirely compatible. One purpose was to provide a set of recommendations that would be of immediate use for those who design and implement ITS for HRI applications. The other purpose was to provide comprehensive background, analysis, straw man recommendations, and rationale for subsequent use by stakeholders and expert groups in developing consensus standards and other formal guidance. The researchers expect a continuing process that will debate, refine, and reorganize the recommendations put forth in the guidance document developed under this report. Various distinct sets of standards or guidelines may emerge that are tailored to the needs of different audiences, or particular guidelines might find their way into existing reference documents or into design specifications. The guidelines document resulting from this project was thus meant to serve as a source of immediate guidance and as a resource for further standards and guidelines efforts.

1.3 Overall Approach

To accomplish the objectives of the project, the approach was structured as a series of six primary tasks:

Task 1: Review and identify human factors requirements. This task identified the issues that require treatment in human factors guidance for ITS at the HRI. It critically analyzed previous efforts that explored human factors needs; this task also expanded and refined this based on additional literature. In practice, Task 1 was concurrent with and integrated with Task 2.

Task 2: Identify and obtain source material for development of guidelines. This task encompassed a wide-ranging search for information that would support guideline development, including literature search, Web search, guidelines review, field evaluation reports, and contacts with key organizations and experts.

Task 3: Develop limits for critical variables. This task represented the analytic stage where key data were brought to bear on particular issues and the implications for guidance were drawn. In practice, this task was concurrent with Task 4 as the analysis and guidance statement development were iterative.

Task 4: Develop guidelines. In this task, the researchers developed specific guidance statements. Guidance statements did not necessarily map one-to-one with human factors issues. A given guidance statement might address multiple issues, and a given issue might have several related guidance statements. This task also included the broader effort of making the collection of recommendations internally compatible, integrating the various guidelines, and eliminating conflicts.

Task 5: Reports. This task incorporated the guidelines into a comprehensive document that presented recommendations in the context of background and rationale. An initial draft guidelines document was circulated for comment (see Task 6), and a final version was developed reflecting reviewer comments.

Task 6: Guidelines users and stakeholders feedback. Key stakeholder groups, professional organizations, and individuals were identified as sources of potential feedback on the draft guidance document. The project team distributed the document to interested reviewers and evaluated their comments.

1.4 Scope

Numerous domains exist in which standards are required regarding ITS for the HRI. The workshop on ITS Standards for the Highway-Rail Intersection (Weiland, 1999) broke out categories of wayside equipment and rail operations, roadway subsystem, vehicle subsystem, traffic management subsystem, human factors, and special cases (e.g., high-speed rail, light rail transit). Within these categories, needs may be related to equipment, operations, communications, data, training, and protocols. The project team specifically focused on human factors needs, although human factors issues may cut across some of these other areas.

The scope of this effort was specifically restricted to the conjunction of the areas of human factors, HRI, and ITS (Figure 1). The human factors issues of concern for the development of guidance were those related to the roadway user, including passenger vehicle and motorcycle operators, operators of large vehicles (such as buses and tractor trailers), bicyclists, and pedestrians. Human factors issues related to traffic control center/rail operations center, train crew, communications protocols, and maintenance operations were not within this scope, but treatments exist elsewhere (e.g., Askey & Sheridan, 1996; Multer, Rudich, & Yearwood, 1998; Oriol, Sheridan, & Multer, 2004). Although the initial tasks of the project did help to identify general human factors standards needs related to the train crew/train cab and to operations centers, the guidance focused specifically on how to design systems that effectively and safely communicate to the road users that encounter the ITS application.

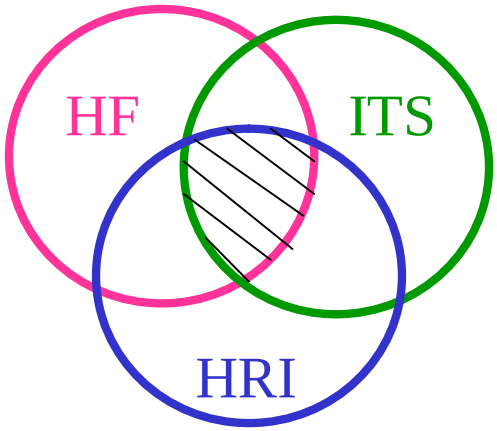

Figure 1. Scope of the project

Despite the specific focus on the human factors of ITS applications for the HRI, some human factors principles may be broadly important for all ITS applications, not just the HRI. These had to be addressed to some degree in the recommendations or they would not serve the purpose of providing immediate guidance for HRI ITS designers and implementers. Such issues as display location, choice of modality, and so forth are relevant for any ITS application. While the guidance document is not a general reference for human factors design, it needed to discuss general principles to some degree.

Many human factors concerns are related to road user safety at the HRI, independent of any ITS component. A variety of reports and research studies over the past 25 years have addressed these concerns (e.g., Lerner, Ratte, & Walker, 1989; Mortimer, 1988; Dewar, 2001). Consensus standards groups and regulatory agencies have considered many of these concerns in the development of current practice. The factors addressed by current standards and practice may be

important to HRIs with ITS elements, but not because of the ITS element. For example, features of automatic gates (markings, timing, etc.) should meet human factors concerns, regardless of whether the HRI is traditional or incorporates ITS. For purposes of this project, the project team only developed guidance if some unique aspect of the ITS application existed. No intent to contradict or modify general practices for HRI existed, which already reflect consensus or regulation.

In summary, the scope of the recommendations developed in this project encompasses human factors requirements for road users related to ITS applications at HRIs. User-centered design is important for all types of HRI and for all human users within all component elements of ITS systems, but such general concerns were beyond the scope of this project.

1.5 Organization of the Report

This report describes the project's methods and findings. The guidance document produced as the primary product of the project is available as a separate document: *Human Factors Guidance for Intelligent Transportation Systems at the Highway-Rail Intersection* (Jenness, Lerner, Singer, Huey, Llaneras, 2005).

Six chapters are in the body of this report, including this introductory chapter (Chapter 1). Chapter 2 (Human Factors Requirements and Resources for HRI Applications of ITS) describes the efforts of Tasks 1 and 2; it also identifies and structures the key human factors issues that need to be addressed in guidance. Chapter 3 (Development of a Human Factors Guidance Document for HRI Applications of ITS) describes the process of developing the guidance and integrating it into a structured document (Tasks 3, 4, and 5). Chapter 4 describes the process of soliciting outside review of the guidance document and presents the outcome of that review. Chapter 5 summarizes the efforts of this project and provides conclusions about the outcome. It also addresses the question of what subsequent steps might be taken. Chapter 6 lists the reference citations.

2. Human Factors Requirements and Resources for HRI Applications of ITS

The initial efforts of this project were to identify key human factors requirements for applications of ITS to HRI functions and to identify and obtain source material for the development of guidelines. In fact, these tasks (Tasks 1 and 2) were closely related and were done concurrently. Section 2.1 describes the general activities and methods involved in the effort, and Section 2.2 presents the preliminary set of human factors requirements developed from the findings. In this analytic effort, the analysis included not only human factors issues related to the roadway user, but also issues related to the train crew/train cab and to rail operations centers and traffic management centers. As noted in Section 1.4, the subsequent project activity focused on roadway user human factors concerns.

2.1 Identification of Human Factors Issues

The objective of Task 1 was to identify the set of potential human factors requirements that need to be addressed through guidelines. This set of requirements provided the basis for expansion in the subsequent work of the project. Several steps were involved in this task, which included:

- Identification of human factors requirements raised in a July 1999 workshop on ITS Standards for the Rail Highway Intersection
- Literature search and critical review
- Contacts with experts and key organizations
- Review of other guidelines documents related to ITS and/or human factors in transportation safety
- Integration of the findings into an organized set of human factors considerations for ITS at the HRI

2.1.1 Human Factors Issues Raised in the 1999 Workshop on *ITS Standards for the Highway-Rail Intersection*

In July 1999, FRA, the ITS Joint Program Office of the U.S. Department of Transportation, and the FHWA Office of Motor Carriers and Highway Safety sponsored a 2-day workshop on *ITS Standards for the Rail Highway Intersection.* The primary purpose of the workshop was to "characterize and move toward the establishment of a program to develop industry-consensus standards for the use of Intelligent Transportation System technologies in the Highway-Rail Intersection." The workshop involved a variety of presentations and breakout group working sessions. Participants raised human factors issues throughout the discussions, although most particularly in the human factors breakout group. The report FRA/RRS-00/01, *Report for the Workshop on ITS Standards for the Highway-Rail Intersection* documents the workshop findings (Weiland, 1999).

The workshop provided an important starting point for this project to identify human factors considerations that may require treatment through guidelines. The project team carefully reviewed the workshop report to identify any issues that directly or indirectly relate to human

factors. As a first step, the project team constructed a simple organizational outline to organize the citations. Table 1 shows this scheme. Using this organizational scheme, all references to human factors-related issues in the workshop report were identified and placed under appropriate sections of the outline. Many of these citations were redundant, overlapping, vague, or beyond the specific focus of the project (human factors of ITS at the HRI). An interim project report documented the complete set of citations as excerpted quotations. Another outline consolidated and simplified the range of citations, and it provided a basic list of human factors considerations that emerged from the workshop. Table 2 provides this set of considerations.

The project team then conducted subsequent information-gathering activities to expand and refine the list of considerations derived from the workshop. These activities included literature searches, contacts with key organizations and experts, and critical examination of other guidelines documents.

Table 1. Organizational outline of general human factors categories for ITS issues at the HRI

1.0 ROADWAY USER
- 1.1 Warnings related to train presence
- 1.2 Warnings and advisories related to HRI attributes
- 1.3 Presentation of warnings and advisories
- 1.4 System considerations

2.0 TRAIN CREW
- 2.1 Specific warnings and advisories
- 2.2 Presentation of warnings and advisories
- 2.3 Communications

3.0 TMC/RAIL OPERATIONS CENTER
- 3.1 Communications and information format
- 3.2 Displays and controls

Table 2. Consolidated human factors categories from *Report for the Workshop on ITS Standards for the Highway-Rail Intersection*

1.0 ROADWAY USER

1.1 Warnings related to train presence

- Provision of information about train presence, not just HRI presence
- Unique train presence warning signal for in-vehicle systems
- Incorporation of dynamic aspects of vehicles and trains (speed, distance, control capabilities) into warning algorithms
- Incorporation of driver perceptions (speed, distance, time to contact) into warning strategies
- Incorporation of train attributes (length, direction of travel, speed) in warning algorithms and/or warning messages
- Provision of a second train coming message, especially for LRT
- Provision of appropriate warnings for pedestrians and other non-motorized roadway users, especially for LRT

1.2 Warnings and advisories related to HRI attributes

- Provision of cautionary advisory for presence of an HRI
- Provision of information regarding the type of crossing (active or passive)
- Advance information and re-routing of commercial vehicles where high profile (humped) crossings exist
- Alerting about the presence of an obstacle in the crossing

1.3 Presentation of warnings and advisories

- Uniformity of messages, abbreviations, icons, and ear-cons within applications (in-vehicle, dynamic message signs, etc.)
- Uniformity of display and control attributes within applications (color, shape, location, etc.)
- Uniqueness (or not) of TCDs for HRI versus TCDs for other intersections
- Message prioritization
- False alarm effects on driver response, public acceptance
- Behavioral effects of distraction, complacency, risk perception
- Appropriate driver mental model of the system

1.4 System considerations

- Compatibility of messages across applications and system elements
- Coordination of in-vehicle and external warnings and messages
- Avoidance of systems that assume partial control of vehicle
- Inclusion of HRI information within in-vehicle navigation or information systems
- Integration of HRI interface into general ITS environment
- Driver workload management
- Interconnection of HRI signals with road intersection signals
- Consistency of meaning of signals (e.g., red flashing) for HRI and road intersection applications
- Provision of routing information/recommendations
- Design of system to accommodate only partial fleet penetration of in-vehicle technologies
- Behavioral effects of increasing the proportion of situations for which warnings are provided (complacency)
- Effects of system unreliability
- Fail-safe modes
- Coordination with law enforcement, driver education, public information, media

Table 2. (continued)

2.0 TRAIN CREW

2.1 Specific warnings and advisories

- Provision and display of information on operational status of crossings, presence of obstacles

2.2 Presentation of warnings and advisories

- Design of displays and controls
- Message timing
- Equipment/message reliability
- Manual and automated responses (allocation of function)

2.3 Communications

3.0 TMC/RAIL OPERATIONS CENTER

3.1 Communications and information format

- Types of data to be transmitted between centers
- Data and message compatibility among users: content and format

3.2 Displays and controls

- Design of displays and controls
- Decision aids
- Timing and prioritization of messages

3.3 Allocation of functions, workload

- System operator resource management
- Operator performance requirements and fitness

2.1.2 Literature Search

The project team conducted several automated keyword literature searches to identify additional or more specific human factors considerations for ITS at the HRI; and to identify existing guidelines in the areas of human factors and/or ITS and/or HRI that might provide insights on issues or format for the guidelines to be developed under this project.

The databases searched included the Transportation Research Information Service (TRIS), National Technical Information Service (NTIS), California Partners for Advanced Transit and Highways (PATH), and PsycFirst. Table 3 presents the keywords used in the literature searches. Keywords were divided into four categories: (a) rail crossings, (b) human factors, (c) ITS, and (d) guidelines. Three general types of searches were conducted:

- Human factors aspects of rail crossings (A and B)
- ITS aspects of rail crossings (A and C)
- Human factors guidelines (B and D)

Table 3. Keywords used in literature searches, by category

A. Rail Crossings	B. Human Factors	C. ITS	D. Guidelines
Railroad/Railway	Human Factors	ITS	Standard(s)
Rail-Highway	User-Centered	Intelligent Transportation	Guideline(s)
Rail/Highway	Ergonomic(s)	Intelligent System(s)	Architecture
Highway-Rail	Driver	Intelligent Technology(ies)	Best Practice(s)
Highway/Rail	Motorist	In-Vehicle	Best Method(s)
Grade Crossing	Engineer	IVIS	Recommended Practice(s)
At-Grade Crossing	(Train) Crew	ATIS	
HRI	Dispatcher		
Train	Warning(s)		
Light Rail	Display(s)		
LRT	Safety		

The project team identified more than 300 documents using automated keyword searches. This list was narrowed through a review of abstracts to determine which documents should be acquired for thorough review.

The automated keyword searches were augmented by online keyword searches of publication libraries. These searches were conducted primarily at Federal and State agencies' Web sites, where large catalogs of published reports are often available for request or immediate download. The project team identified and acquired a number of relevant documents in this way.

In addition to library database searches, the project team also gathered information by scanning relevant Web sites for documents, contact information, current events, and examples of ITS implementations at HRIs. This search included Federal and State government agencies, professional societies, private industries, academic institutions, advocacy groups, and private contractors. Table 4 presents a list of visited Web sites.

Table 4. Web sites searched

Organization	Web Address
American Association of State Highway and Transportation Officials	www.aashto.org
American Public Transportation Association	www.apta.com
American Railway Engineering and Maintenance-of-Way Association	www.arema.org
Association of American Railroads	www.aar.org
ATTVenture	www.attventure.com/CrossingSafety.htm
Brotherhood of Locomotive Engineers	www.ble.org
Bureau of Transportation Statistics	www.bts.gov/
Burlington Northern Santa Fe	www.bnsf.com/
Federal Highway Administration	www.safety.fhwa.dot.gov/programs/x-ing.htm
Federal Railroad Administration	www.fra.dot.gov
Federal Transit Administration	www.fta.dot.gov
Human Factors and Ergonomics Society Surface Transportation Group	www.sttg.hfes.org/
Institute of Transportation Engineers	www.ite.org
Iteris	www.iteris.com/itsarch/
ITS Resource Guide 2001	www.its.dot.gov/guide.html
ITS Standards	www.its-standards.net/AA-Hri.htm
ITS-America	www.itsa.org
Los Angeles County Metro Transportation Authority ITS Projects	www.fra.dot.gov/o/dev/its/its2k/Khawani/sld001.htm
Maryland MTA	www.bcpl.net/~vhartsoc/stcweb.htm
Minnesota DOT Guidestar	www.dot.state.mn.us/guidestar/
National Associates Working Group for ITS	www.nawgits.com
National Transportation Safety Board	www.ntsb.gov
Operation Lifesaver	www.oli.org
Rail Transit Interface Standards	www.tsd.org/rsc/index.htm
Railroad Commission of Texas	www.rrc.state.tx.us/divisions/rail/vtstats.html
Railroad Progress Institute	www.rpi.org
Railroad-Highway Grade Crossing Handbook	www.fhwa.dot.gov/tfhrc/safety/pubs/86215/intro.htm
Richards and Associates	www.hwyrail.com/
Texas DOT Transguide	www.transguide.dot.state.tx.us/
Texas Transportation Institute	www.tti.tamu.edu/researcher/v35n2/TPS.stm
Texas Transportation Institute	www.tti.tamu.edu/researcher/v37n2/quick_fix.stm
The National Railroad Construction and Maintenance Association, Inc.	www.nrcma.org/
TransLink Research Center	translink.tamu.edu/
TransLink Train Monitoring Project	www.railview.tamu.edu/Rail_Monitoring_xml.htm
Transport Canada	www.tc.gc.ca/Quebec/ns_a/part1_a.htm
Transportation Research Board	www.trb.org
U.S. Department of Transportation ITS Joint Program Office	www.its.dot.gov/

2.1.3 Contacts with Key Organizations and Experts

The project team contacted experts to help identify the current issues relevant to professionals and to gain insight into specific ITS projects and the human factors concerns that shaped their development. More than 40 individuals were contacted through mail, e-mail, phone calls, and personal meetings. The experts represented a variety of organizations, including ITS system implementers, Federal and State agencies, industry professionals, railroads, unions, standards organizations, and technical/professional societies. The list of expert contacts represented the full range of interested parties, knowledgeable experts, and key stakeholders.

Experts described what they perceived to be the most pressing human factors needs for ITS at the HRI and provided referrals to relevant information sources. Experts involved in ITS implementation projects described the structure of the system, its effectiveness, and the human factors considerations that affected its development.

2.1.4 Review of Other Guidelines

The project team identified various human factors guidelines documents for use in the project. These guidelines were useful in helping to identify potential issues and/or for use in subsequent tasks for determining critical limits and developing specific guidelines. They also provided possible models for the organization or format of the guidelines.

Table 5 summarizes the primary human factors guidelines documents that deal with ITS issues (additional guidelines documents deal with basic human factors design issues, without specific regard to the ITS application). The rows show general topic areas, and the columns show particular guidelines documents. The X indicates where a particular guidelines document relates to a particular topic. The project team did not find any human factors guidelines relevant to ITS applications for rail operations center/dispatch.

Table 5. Topic areas covered by relevant human factors guidelines documents

	Campbell et al., 1998	Dudek, 1991	Dudek & Huchingson, 1986	Green et al., 1995	Kelly, 1999	Lerner et al., 1996	Lerner & Llaneras, 2000	Multer, 1998	Nowakowski et al., 1999
In-Vehicle Displays-Warnings	X			X		X			
In-Vehicle Displays-Informational	X			X			X		
Web Displays-Informational							X		X
Changeable Message Signs		X	X				X		
Locomotive Cab Displays								X	
Traffic Management Center					X				
Rail Operations Center/Dispatch									

2.2 Initial Outline of Human Factors Requirements for ITS at the HRI

The search for human factors considerations conducted in Task 1 encompassed more than 90 documents, more than 40 expert contacts, and more than 40 Web sites. The information sources were systematically reviewed and documented using a standard form. The form divided relevant information gained through the review into three general categories, as they relate to the development of guideline content and structure:

- Implications for changes/additions to the 1999 workshop set of human factors requirements (Table 2)
- Implications for specific guideline content
- Implications for organization and format of the guidelines

The set of human factors considerations derived from the workshop on ITS Standards for the Highway-Rail Intersection (Table 2) was expanded based on the findings of the various Task 1 activities. Table 6 shows the expanded set of considerations. This table provided the basic set of working issues from which guidelines development took place. The outline structure used in Table 6 is somewhat different from that of Table 2 in order to better accommodate and organize the issues.

Table 6 may serve as a useful set of human factors issues for consideration by developers of ITS applications with regard to roadway users, train crews, and traffic management centers/rail operations centers. The set of human factors requirements from Section I (Roadway User) of this outline provided a starting point in this project for organizing the development of guidelines and structuring the guidance document itself. The content and structure of the guidance document then continued to evolve throughout the guidelines efforts (Tasks 3, 4, and 5).

Table 6. Outline of human factors requirements for ITS at the HRI

1. ROADWAY USER
    1.1. Applications
        1.1.1. Warnings about train arrival or presence
            1.1.1.1. Information provision
                1.1.1.1.1. Train/no train
                1.1.1.1.2. Train time to arrival, time to gate signal/gate activation
                1.1.1.1.3. Train attributes: Direction, speed, length
                1.1.1.1.4. Train time to clear crossing
                1.1.1.1.5. Unusual signal timing (longer than normal warning time)
                1.1.1.1.6. Vehicle-related factors
                    1.1.1.1.6.1. Speed, location, time to arrival
                    1.1.1.1.6.2. Vehicle characteristics (type, braking)
                1.1.1.1.7. Train arrival warning signal characteristics
                    1.1.1.1.7.1. Uniqueness of train presence signal
                        1.1.1.1.7.1.1. Visual icon
                        1.1.1.1.7.1.2. Auditory signal
                        1.1.1.1.7.1.3. In-vehicle, external
                    1.1.1.1.7.2. Signal placement
        1.1.2. Multiple train warning (second train)
            1.1.2.1. Display: Message, icons, color, strobe
            1.1.2.2. Presentation: Sign placement, message timing
        1.1.3. Gates
            1.1.3.1. Preventing gate running
            1.1.3.2. Avoiding entrapment
            1.1.3.3. Escape modes
            1.1.3.4. Pedestrian gates
        1.1.4. Signal preemption and phasing issues
            1.1.4.1. Motorist response to preemption and phase interruption
            1.1.4.2. Pedestrian clearance times
            1.1.4.3. Pre-signals
        1.1.5. Warnings and advisories about crossing presence and attributes
            1.1.5.1. Presence and location of crossing
            1.1.5.2. Type of crossing (active or passive)
            1.1.5.3. Characteristics of the crossing
                1.1.5.3.1. Fixed characteristics
                    1.1.5.3.1.1. Sight distance
                    1.1.5.3.1.2. High-speed trains
                    1.1.5.3.1.3. High-profile (humped) crossings
                    1.1.5.3.1.4. Acute crossing
                    1.1.5.3.1.5. Multiple tracks
                    1.1.5.3.1.6. Roadway geometry

Table 6. (continued)

- 1.1.5.3.2. Transient characteristics
  - 1.1.5.3.2.1. Road surface condition (wet, icy)
  - 1.1.5.3.2.2. Obstacles
  - 1.1.5.3.2.3. Queued traffic
- 1.1.6. Routing and re-routing as a function of crossing status
  - 1.1.6.1. Avoidance of delay, congestion
  - 1.1.6.2. Vehicle-specific routing (e.g., trucks at high-profile crossings)
  - 1.1.6.3. Motorist information requirements and compliance with route guidance
- 1.1.7. Special considerations for LRT
- 1.1.8. Controlling vehicle approach
  - 1.1.8.1. Vehicle speed control
    - 1.1.8.1.1. Variable speed limits (intelligent speed control)
    - 1.1.8.1.2. Vehicle-triggered speed or caution warnings
    - 1.1.8.1.3. System assumption of full or partial vehicle control
  - 1.1.8.2. Vehicle arresting barriers
    - 1.1.8.2.1. Criteria for activation
    - 1.1.8.2.2. Driver information needs
      - 1.1.8.2.2.1. Information regarding barrier presence and implications
      - 1.1.8.2.2.2. Effects of barrier system on requirements for TCD placement
- 1.1.9. Reporting malfunctions
- 1.1.10. Provision for non-motorized road users

1.2. General considerations for warnings and advisories

- 1.2.1. Need for uniqueness of rail crossing versus roadway intersection displays
- 1.2.2. Fostering compliance and safe behavior
  - 1.2.2.1. Warning message attributes
    - 1.2.2.1.1. Message reliability, relevance, false alarms
    - 1.2.2.1.2. Levels of warning
    - 1.2.2.1.3. Message comprehension, message set
    - 1.2.2.1.4. Message prioritization
  - 1.2.2.2. Incorporation of driver perceptions into warning strategies
    - 1.2.2.2.1. Perception of speed, distance, time to contact
    - 1.2.2.2.2. Perception of risk
    - 1.2.2.2.3. Driver mental model of warning system
  - 1.2.2.3. Unintended consequences
    - 1.2.2.3.1. Distraction
    - 1.2.2.3.2. Driver complacency, risk perception
    - 1.2.2.3.3. Risky acts
      - 1.2.2.3.3.1. Effects of information on trying to beat train
      - 1.2.2.3.3.2. Induced erratic maneuvers, traffic conflicts

Table 6. (continued)

- 1.2.3. Requirements for display uniformity
  - 1.2.3.1. Roadside TCDs
  - 1.2.3.2. In-vehicle displays
  - 1.2.3.3. Dynamic message signs
- 1.2.4. Temporal aspects
  - 1.2.4.1. Timing of the onset and termination of signals and controls
  - 1.2.4.2. Repetition rates, duty cycles
  - 1.2.4.3. Coding of time or distance information
- 1.2.5. Display requirements: External signals
  - 1.2.5.1. Display requirements: Roadside TCDs
    - 1.2.5.1.1. Display attributes
    - 1.2.5.1.2. Placement of TCDs
    - 1.2.5.1.3. Environmental considerations
  - 1.2.5.2. Display requirements: Dynamic message signs
    - 1.2.5.2.1. Display attributes
    - 1.2.5.2.2. Temporal aspects of dynamic displays
    - 1.2.5.2.3. Placement of sign
    - 1.2.5.2.4. Environmental considerations
  - 1.2.5.3. Display requirements: Acoustic signals
- 1.2.6. Display requirements: In-vehicle displays
  - 1.2.6.1. Choice of mode
  - 1.2.6.2. Visual display
    - 1.2.6.2.1. General
      - 1.2.6.2.1.1. Display attributes
      - 1.2.6.2.1.2. Display location
      - 1.2.6.2.1.3. User control
        - 1.2.6.2.1.3.1. Visual aspects (brightness, location, color)
        - 1.2.6.2.1.3.2. Functions and features
    - 1.2.6.2.2. Text
    - 1.2.6.2.3. Icon
    - 1.2.6.2.4. Map
  - 1.2.6.3. Auditory (non-speech)
    - 1.2.6.3.1. Signals, ear-cons
    - 1.2.6.3.2. Source, direction, localization
    - 1.2.6.3.3. Environmental considerations
      - 1.2.6.3.3.1. External to vehicle
      - 1.2.6.3.3.2. Internal to vehicle
    - 1.2.6.3.4. User control and adjustment

Table 6. (continued)

- 1.2.6.4. Speech
  - 1.2.6.4.1. Voice and speech characteristics
  - 1.2.6.4.2. Message attributes
  - 1.2.6.4.3. Alerting tone
  - 1.2.6.4.4. Environmental considerations
    - 1.2.6.4.4.1. External to vehicle
    - 1.2.6.4.4.2. Internal to vehicle
  - 1.2.6.4.5. User control and adjustment
- 1.2.6.5. Haptic
  - 1.2.6.5.1. Source, location
  - 1.2.6.5.2. Signal attributes
  - 1.2.6.5.3. Environmental considerations
  - 1.2.6.5.4. User control and adjustment
- 1.2.7. Considerations for non-motorized road users
  - 1.2.7.1. Warning needs and appropriateness of messages for motorized traffic
  - 1.2.7.2. Display visual or auditory effectiveness for non-motorized users
  - 1.2.7.3. Timing of information and control (e.g., pedestrian clearance time)
  - 1.2.7.4. Considerations for those with disabilities (ADA)

1.3. System considerations

- 1.3.1. Coordination of in-vehicle and external (roadway) warnings and messages
  - 1.3.1.1. Compatibility of message, meaning, format, timing
  - 1.3.1.2. Interconnection of rail crossing TCDs with road intersection TCDs
- 1.3.2. Integration of rail crossing information into the general ITS environment
  - 1.3.2.1. Compatibility of in-vehicle functions, displays, controls
  - 1.3.2.2. Provision of crossing-related routing information/guidance
  - 1.3.2.3. Workload and distraction management
  - 1.3.2.4. Driver awareness of system capabilities, operational status, options
- 1.3.3. Automated enforcement
- 1.3.4. System performance
  - 1.3.4.1. Information quality
    - 1.3.4.1.1. Reliability of information
    - 1.3.4.1.2. Fail-safe modes
  - 1.3.4.2. Implementation effects
    - 1.3.4.2.1. Partial penetration of vehicle fleet
    - 1.3.4.2.2. Partial implementation at crossing sites
    - 1.3.4.2.3. Coordination with other activities
      - 1.3.4.2.3.1. Enforcement
      - 1.3.4.2.3.2. Education, public information

Table 6. (continued)

2. Train Crew
    2.1. Specific warnings and advisories
        2.1.1. Operational status of crossings
        2.1.2. Obstacles
        2.1.3. Predictive displays
            2.1.3.1. Braking level required
            2.1.3.2. Braking distance
    2.2. Presentation of warnings and advisories
        2.2.1. Displays and controls
            2.2.1.1. Compatibility of ITS displays with current displays and practice
            2.2.1.2. In-cab displays
            2.2.1.3. Wayside displays
            2.2.1.4. Special considerations for high-speed rail
        2.2.2. Message timing
        2.2.3. Reliability
            2.2.3.1. Information
            2.2.3.2. Equipment
            2.2.3.3. Fail-safe operation
    2.3. Communications
    2.4. Allocation of functions, workload
3. TMC/Rail Operations Center
    3.1. Communications and information format
        3.1.1. Types of data
        3.1.2. Protocols for sharing information between organizations
        3.1.3. Data and message compatibility among users
            3.1.3.1. Content, definitions
            3.1.3.2. Format
    3.2. Warnings, alerts, and advisories
        3.2.1. Warnings/alerts at the TMC/ROC
        3.2.2. Warnings/alerts issued by the TMC/ROC
    3.3. Procedures for incident verification
    3.4. Displays and controls
        3.4.1. Design and layout of displays, controls, workstations
        3.4.2. Decision aids
        3.4.3. Timing and prioritization of messages
    3.5. Allocation of functions, workload
        3.5.1. System operator resource management
        3.5.2. Operator performance requirements and fitness

3. Development of a Human Factors Guidance Document for HRI Applications of ITS

Before developing specific guidance, the project team had to resolve several key issues regarding the guidance document itself:

- What information needs to be included in the guidance document?
- How should the document be organized?
- To what extent are background information, rationale, and literature citations required in guidelines?
- What format should the guidelines take?

In order to meet the various objectives of the document (see Section 1.2), the project team determined that in addition to specific guidance sections, the document needed to provide some overview of road user behavior and general human factors concerns relevant to the HRI. The project team also chose to provide an overview of the various types of ITS applications that have been developed, or are under development, for the HRI user service. This can help make the applications more concrete and provides the opportunity to examine real-life lessons learned from early implementations. While such sections may not be required in an ultimate, more streamlined set of consensus standards, they were important at this point in providing a resource and impetus for subsequent standardization and guidance efforts. They also provide useful context for document users who are not familiar with human factors concepts and user-centered design approaches.

Finding an organizational structure around which to arrange the guidelines proved to be a difficult problem. Some human factors considerations broadly apply to many or all specific ITS applications. Other guidance may be narrowly relevant to a particular type of HRI service (e.g., warning pedestrians about the possibility of a second train coming). Therefore the guidance could not be organized solely around the specific applications without requiring the more general recommendations to be repeated multiple times. The project team decided to structure the chapters that provide guidance in a hierarchical manner. Figure 2 shows the overall structure and interrelationships between guidance chapters (Chapters 4 through 11 of Jenness et al., 2005). The chapters are grouped into a rough hierarchy according to the level of generality and content of the recommendations. Chapters containing more widely applicable recommendations are closer to the top of the figure. The double-sided arrows connecting the three levels indicate that similar or related recommendations in different chapters are cross referenced. Within the chapters, references to related recommendations in other chapters are located within brackets (for example, the note: [Also see: 6.3.2] refers to Recommendation 6.3.2 in Chapter 6).

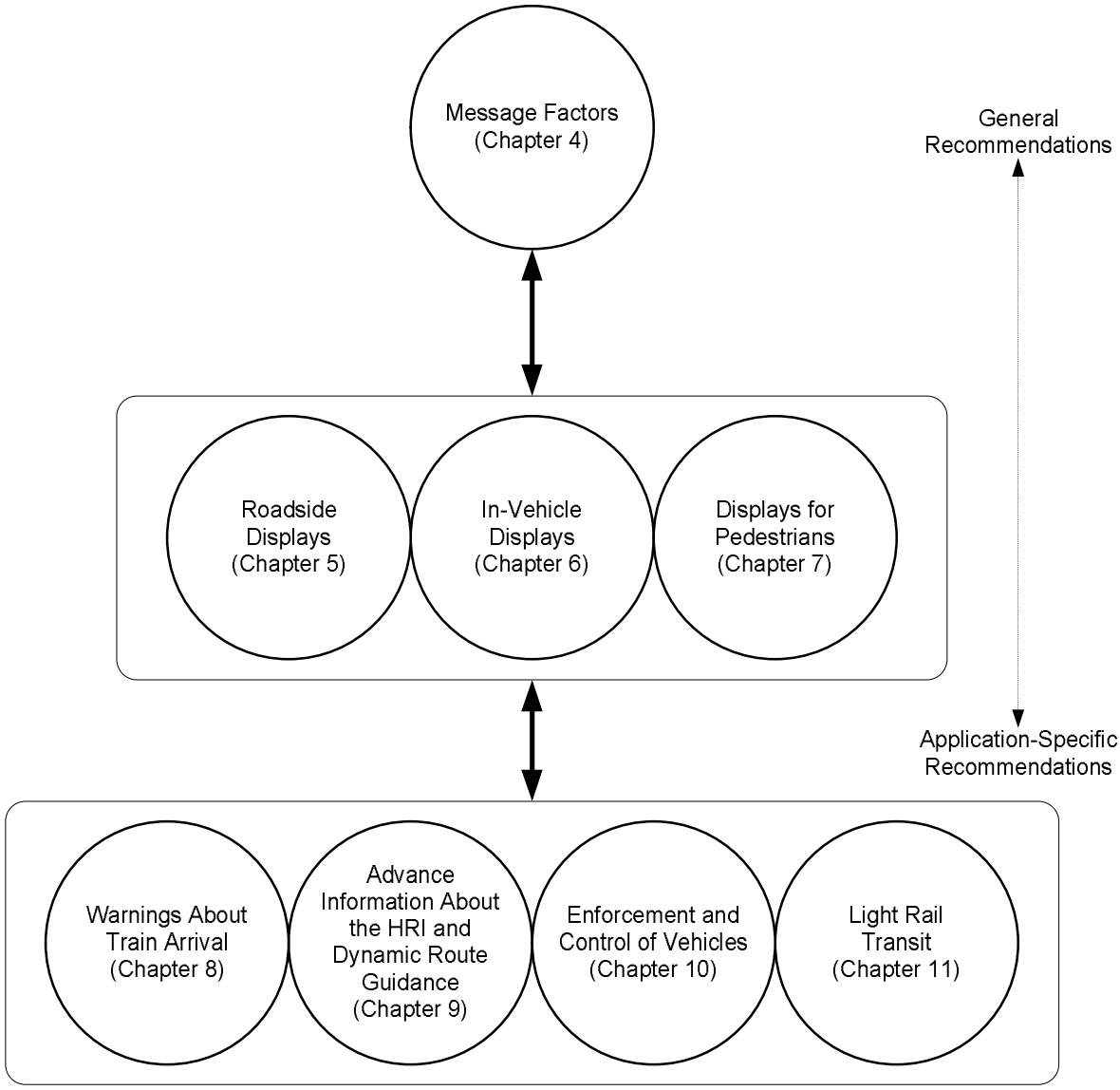

Figure 2. Guidance chapters and their interrelationship

The final general structure of the guidance document had four parts, with chapters under each part:

Part I: Introduction

Chapter 1: Purpose and Scope

Chapter 2: Conceptualizing the Road User

Part II: Overview of ITS Systems Implemented at the Highway-Rail Intersection

Chapter 3: Implemented Systems

Part III: General Human Factors Considerations for Application of ITS to Highway-Rail Intersections

Chapter 4: Message Factors

Chapter 5: Roadside Displays

Chapter 6: In-Vehicle Displays

Chapter 7: Displays for Pedestrians

Part IV: Human Factors Considerations for Specific Applications

Chapter 8: Warnings About Train Arrival

Chapter 9: Advance Information About the HRI and Dynamic Route Guidance

Chapter 10: Enforcement and Control of Vehicles

Chapter 11: Light Rail Transit

Each guidance chapter (4-11) shares a common structure. Within these chapters, the general structure is to provide some background discussion on a given topic or application, followed by an explicit statement of the major human factors issues and needs for guidance. The next section is specific guidance recommendations. Sometimes these recommendations can be quite specific. At other times, they can only provide a general principle or set of limits at this point. An accompanying rationale statement supports each recommendation. For some, cross references to closely related guidelines may also exist.

More specifically, the Background section of each guidance chapter contains a description of the application. It provides any required definitions and discusses the safety concerns and typical criteria for use. The section provides a discussion of relevant research, practice, and field experience. It indicates limitations, problems, and gaps in knowledge. The section focuses on the functional aspects relevant to human factors rather than the technology used.

The Key Human Factors Issues and Need for Guidance section of each guidance chapter identifies the major human factors issues of particular concern for this application. General human factors considerations common to many applications are treated elsewhere. For each issue, there is explanation of why this is a particular concern and why there is a need for guidance.

The Recommendations section of the chapters provides the actual guidance statements. This section is loosely organized around the key human factors issues identified in the preceding section, although a one-to-one mapping of issues to recommendations does not necessarily exist. Each guidance chapter presents from 7 to 29 specific recommendations. The section begins with a list of guidance statements for all of the recommendations in that chapter and is followed by the expanded presentation of each one.

The specific guidance elements are in the form of recommendation statements followed by supporting discussion. The recommendation itself is in the form of a bold text statement, stated in terms of principles for design or performance, and expanded as necessary by further text to clarify the meaning or details. Where some quantitative aspect to the requirement exists, the guideline indicates the general considerations and boundary conditions. The recommendation

statement is in turn followed by a Rationale section, which briefly presents the logic behind the guidance and cites supporting research or standards where relevant.

Figure 3 shows an example recommendation taken from the draft guidelines document. This is taken from Chapter 8 of Jenness et al. (2005), "Warnings About Train Arrival," in the subsection (8.4) on "Specific Recommendations for Multiple Train Warnings." This example illustrates the structure of the recommendations. A bolded statement of the recommendation is used, followed by a short clarifying and amplifying paragraph. A cross reference to another related recommendation in one of the more general guidance chapters is listed (Chapter 4, Message Factors). This is followed by the rationale statement, which explains the logic of the requirement and the basis of the quantitative aspects. This example also illustrates how some recommendations attempt to provide quantitative component where possible while acknowledging that only a limited basis exists for such quantification.

8.4.10 Recommendation: Limit the length of message phase times.
If a dynamic display is comprised of a sequence of phases, the initial phase should be designed to inhibit the initiation of movement by the road user. This phase should be of sufficient duration so that the viewer has opportunity to orient toward the display and interpret the text or image. Subsequent phases should each allow enough time for the viewer to process the information, but the total duty cycle for the display should not be so long that road users are discouraged from attending to the full cycle. Phase times will generally be in the 1.5 to 3.5 second range, depending on complexity.

[Also see: 4.3.14]

Rationale: Some approaches to signing for multiple train warnings have employed a sequence of phases. This may have the advantage of simplifying the image and message for any given phase and the disadvantage of requiring the viewer to attend to multiple displays in order to get the full message. There is a need for the sign to quickly inhibit driver action. For this reason, the initial phase should do this effectively with an easily perceived message or image (e.g., "stop," "warning," "danger," lights or sounds). The duration of the phase should include time to orient toward the sign and time to process the image. Processing times may be taken as a minimum of about 1 second; allowing for orientation, this suggests a minimum phase of 1.5 seconds for simple messages or images. Complex images may require substantially longer times (some formulas for roadway signs suggest estimating 1 second per symbol and 0.5 second per word or number). An upper bound on the order of 3.5 seconds is suggested based on the assumption that if a phase takes longer than this, the image may be too complex to warrant being part of a phased sequence. The total duty cycle for the display is the sum of the durations of all the phases. An impatient road user needs to "get" the message in a reasonable time, but there is little empirical basis for defining an acceptable maximum for this application.

Figure 3. Example recommendation from section on warnings about train arrival: specific recommendations for multiple train warnings

4. Outside Review of the Draft Guidance Document

The initial draft of the guidance document, titled *Human Factors Guidance for Intelligent Transportation Systems at the Highway Rail Intersection*, was sent to a multidisciplinary group of outside reviewers. This section describes how reviewer feedback was solicited and summarizes the comments received.

4.1 Solicitation of Feedback

Upon completion of the initial draft of the guidance document, the project team sought critical feedback on the document from a range of potential users of the guidance, stakeholder groups, and experts in the related technical disciplines. A request for reviewers was distributed through key organizations, as well as directly to selected experts. The organizations included the following:

- Transportation Research Board Committees

  AHB15 Intelligent Transportation Systems

  AHB60 Highway/Rail Crossings

  AND10 Vehicle User Characteristics

  AND20 User Information Systems

  AR030 Railroad Operating Technologies
- ITS-America
- Operation Lifesaver
- Human Factors and Ergonomics Society (HFES)/Surface Transportation Technical Group
- Association of American Railroads (AAR)
- American Association of State Highway and Transportation Officials (AASHTO)
- American Traffic Safety Services Association (ATSSA)
- Transport Canada

The request was sent to a key individual within the organization or to the chair of the committee, for circulation to appropriate individuals. All of these groups distributed the request to their membership or key elements of the organization, with the exception of one TRB Committee (AR030), which felt it was not directly relevant to the membership. While the number of individual experts who received the request is not known, it is undoubtedly several hundred.

Figure 4 shows the reproduction of the request for reviewers. It described the document and the type of review being requested. Recognizing that the length of the document might discourage some reviewers, the request noted that reviewers had the option of focusing their review on selected sections. Forty qualified individuals requested to serve as reviewers and were sent the document along with review instructions. Of these individuals, 18 responded with review comments. Of the remaining individuals, 4 later declined, 3 indicated they would provide comments at a later date, and 15 never responded.

NOTICE REQUESTING REVIEWERS

Reviewers Sought for Draft Document on Human Factors Guidance for ITS at Highway-Rail Intersections

Reviewer copies of a draft document titled *Human Factors Guidance for Intelligent Transportation Systems at the Highway-Rail Intersection* will be distributed to selected individuals who would like to review and comment on the draft. The document has been developed under a Federal Railroad Administration contract and provides preliminary recommendations regarding human factors issues in the use of intelligent transportation system concepts at highway-rail intersections. The recommendations deal specifically with designing systems that will be effective and usable for the range of roadway users, including drivers, pedestrians, truckers, and others. The document does not deal with traffic control center or rail center operations or train crew considerations.

At this stage, the recommendations in the document are preliminary, which is one reason for the requested review. The guidance is intended only as a recommendation and in no way suggests standards or policy. The draft document is for review purposes only and is not for distribution or citation.

We are seeking reviewers to provide feedback on this draft. Comments are sought regarding the content (specific recommendations) and the format of the document. The full document is approximately 175 pages, but reviewers may focus on selected sections of interest if they are unable to review the full document.

If you are interested in reviewing a copy, please provide the following information to:

Dr. James Jenness, Westat, at JamesJenness@westat.com.

Name: _____

Email: _____

Organization: _____

Your interest/expertise in topic area: _____

Figure 4. Request for reviewers

The project team sent a not-for-distribution review copy of the guidance document to interested reviewers, along with instructions for review. Figure 5 shows the instructions, and Figure 6 shows the reviewer response form. The instructions indicated a number of questions of interest, and the response form requested general comments about the document and specific comments on individual items within the document.

Instructions for Reviewers

Human Factors Guidance for Intelligent Transportation Systems

at the Highway-Rail Intersection

Thank you for agreeing to serve as a reviewer for the draft document *Human Factors Guidance for Intelligent Transportation Systems at the Highway-Rail Intersection.* This is a draft contractor report, prepared by Westat, for the Federal Railroad Administration. The recommendations in this report are preliminary and are not intended to serve as current guidance. The suggested practices are based on Westat's review of literature and practice and do not necessarily represent any position of FRA on these topics. *The draft document is for review purposes only and is not for distribution or citation.*

We hope you will be able to review the entire document but you may limit your review to sections for which you feel most knowledgeable or have most interest. Please indicate the portions you have reviewed on the Reviewer Form.

The reviewer form has sections where you may provide general comment on the document. There is a section for your comments on the organization and content of the report, another section for your general comments on the guidance and recommendations, and a section for other general comments. You may provide specific comments on document sections by listing your comments, indicating the page or section numbers or by making hard-copy comments on the document.

In your review, please consider the following:

- Document organization and format
  - Is the document structure logical? Any suggested improvements?
  - Is the format of the recommendations OK? Suggestions?
  - Improvements to the usability of the document and its recommendations
- Content
  - Is the information complete? Is any of it unnecessary?
  - Agreement/disagreement with specific recommendations
  - Are there updates or missing key references to any of the background or rationale material?
- Development of standards, specifications, guidelines
  - This document is an initial effort to identify human factors issues related to the use of ITS at highway-rail intersections and to provide guidance for dealing with the issues. While intended to be of some immediate use for practitioners, it is also seen as a step toward the development of standards, guidelines, and engineering specifications. We recognize that this document covers a very broad range of considerations and will not be ideal for all end user applications. How can progress move forward from here to result in properly tailored and well-specified standards/guidelines and optimal end-user reference documents?
  - What needs are there for consensus standards, formal specifications, regulatory requirements? Who should lead this?
  - Do you see the sort of guidance provided here as something that should be provided in a single source of end-user guidance, or in multiple reference documents, or integrated within other (possibly existing) references?

Please return your review electronically or in hard copy to:

James Jenness

Westat

1650 Research Blvd

Rockville, MD 20850

Email: JamesJenness@westat.com

Figure 5. Reviewer instructions

Reviewer Form

Human Factors Guidance for Intelligent Transportation Systems

at the Highway-Rail Intersection

Date:

Reviewer name (or anonymous):

Reviewer affiliation (or anonymous):

Briefly describe your area of expertise or practice as related to this document:

What sections of the document have you reviewed?

Entire Document ___

Only the Following Sections: _____

Please enter any general comments you have on the document under the headings below. At the end of this form, indicate where you have treated specific comments on particular sections of the document.

General Comments

General comments on organization and format

General comments on content

General comments on the guidance/recommendations provided

Comments on how to move forward from here in developing standards, guidelines, specifications, reference documents

Other general comments

Specific Comments

My specific comments are

___ Listed on attached page(s)

___ Hard-copy mark-up

Figure 6. Reviewer response form

4.2 Reviewer General Comments on the Guidance Document

As shown in Figure 5 (reviewer instructions) and Figure 6 (reviewer form), the project team requested that reviewers provide general comments on the overall document and specific comments on particular sections of the document. There were several sub-topics of general comments:

- Organization and format
- Content
- Guidance/recommendations provided
- How to move forward from here in developing standards, guidelines, specifications, reference documents
- Other general comments

This section summarizes the reviewer general comments on each of these sub-topics. The points raised under other general comments were typically appropriate to one of the other headings or were specific to a particular section of the report, and so the summary does not include this category. The project team's responses to various reviewer comments are also provided (*shown as indented italic text*). As would be expected with a spectrum of reviewers, many comments represent the opinion of a single reviewer, and the comments of various reviewers may be inconsistent with one another. Overall, the reviews were broadly positive concerning the organization of the report, the format of the guidance and supporting information, and the comprehensiveness and appropriateness of the guidance. The most frequent concerns related to the lengthiness of the document and the amount of information, as well as redundancies within the guidance.

4.2.1 General Comments on Organization and Format

Reviewers generally responded favorably to the document's organization and format. They generally felt that the structure was logical and easy to follow. Reviewer comments on the format of the guidance, including the provision of rationale and the use of cross-referencing, were generally favorable. Reviewers also responded favorably to the language and lack of technical jargon and acronyms, although others felt the treatment was sometimes wordy, and one reviewer suggested including a glossary.

Although comments on the organization and format were generally favorable, some criticisms and suggestions for revision occurred. The lengthiness of the document was itself an issue, and several readers felt that certain recommendations or discussions were repetitive. The following lists some suggestions for helping the reader to navigate the document:

- Consider adding an index
- Make the appendix (complete list of recommendations) an earlier part of the document, preceding the complete guidelines
- Hyperlink the recommendation title in the complete listing (appendix) to the appropriate supporting section

- Within each chapter, move the list of recommendations from where it is (before the set of complete recommendation information) to the end of the chapter
- Include the appropriate set of references at the end of each chapter, rather than a master reference section at the end of the document

  Project Team Response: The guidance document developed in this project is lengthy, as noted by reviewers. One reason for this is simply the range of the applications and issues included within its scope. However, another reason is that this document was intended to serve multiple purposes and multiple audiences. On one hand, one goal of this project was to provide recommendations that may be of immediate use to ITS designers or implementers. On the other hand, this project was also seen as an intermediate step in the development of consensus standards and guidelines, regulations, design guides, reference tools/handbooks, and so forth. The guidance provided is in this sense a set of straw man arguments that may be debated by the larger community. For this reason, it was desirable to include adequate background, illustrative applications, a listing and discussion of human factors issues related to each chapter, and spelled-out rationale for each recommendation. The project team would hope that from this work, the recommendations will be refined and find their way into various end-user products that might be more narrowly tailored for a particular audience and application. Such documents might be briefer and designed for greater usability for the target application. For the present guidance document, however, the project team gave more emphasis to comprehensiveness.

  Usability features, such as hyper-linking and indexing, are helpful and may be considered at a later stage when consensus guidance is developed and a more formal guidance document is produced. As some reviewers noted, however, the document provided a rather detailed Table of Contents, and cross-referencing within sections, to aid the user in navigating this report.

  The project team does not concur with the suggestions to move the list of recommendations or the citations. The tabled list of recommendation statements in each chapter is intended to immediately precede the detailed presentation of the full recommendations. Appendix A provides a complete list of all recommendation statements that can be referred to at any point. Adding a reference section within each chapter would provide no additional information to the user but would increase the size of the document and add to the redundancy, since citations will overlap considerably from chapter to chapter.

  The suggestion to move the complete list of recommendations to some point early in the document has both positive and negative features. Moving it up and making it a report section would give the list more prominence, if that is desired. At the same time, it is less compatible with the document structure, which begins with the non-guidance portion of the document (purpose/scope, conceptualizing the road user, overview of ITS systems implemented for HRIs).

Two reviewers felt that a tighter link should exist between the issues identified early in the chapter and the specific recommendations related to that issue. One specifically recommended that the related recommendations follow each stated issue.

Project Team Response: The project team had previously considered this alternative when developing the document, but it was rejected because there is not a one-to-one mapping of guidance to issues. A given recommendation may relate to several issues, and a given issue may relate to only a portion of a recommendation.

One reviewer felt the type of guidance in the document was not made clear and suggested an alternative title for the document (*Guidance on Designing and Implementing ITS Applications at Highway-Rail Intersections*).

Project Team Response: Should the recommendations provided here remain in the form of a stand-alone report, the project team has no objection to a change in title if it clarifies the scope or purpose of the document. The team feels, however, that the title should continue to reflect the human factors focus of the guidance. Many other aspects of ITS design and implementation exist beyond human factors, and readers may be misled as to scope.

4.2.2 General Comments on Content

The reviewers had many comments to the effect that the document content was comprehensive, extensive, reasonable, and useful. Several reviewers noted redundancies in the some of the guidance. Although the general tenor of the comments was positive, individual reviewers cited additional areas of content that they felt might be included. Generally only one or two reviewers mentioned the same item. The suggestions included the following:

- Provide a list of suggested reading at the end of each chapter

  Project Team Response: The introductory discussion section of each chapter goes over relevant literature; where appropriate, references are cited in the Rationale section of individual recommendations. Hopefully the discussion within each chapter provides adequate, if minimal, background for understanding the issues and arguments presented, and the references cited can be consulted for greater depth. The project team does not see a need for a suggested reading section in each chapter.

- Include more information on highway/rail crash patterns

  Project Team Response: It would be possible to include specific discussion of crash patterns in Chapter 2, but this would necessarily be a general discussion of highway/rail crashes and not specific to ITS or specific applications. The project team is not convinced this would contribute to the helpfulness of the document.

- Add guidance on interfaces within train cabs

  Project Team Response: This project confined its focus to ITS human factors issues related to the roadway user (i.e., motorist, pedestrian, cyclist). Human factors issues that are related to ITS deal with the train cab, train crew, rail operations center, traffic management center, and maintenance and operations. These other areas were deemed to be beyond the scope of this project. Furthermore, good human factors guides already exist for train cab interface (Multer et al., 1998) and traffic operations centers (Kelly, 1999), although these guides are not specific to ITS for HRI applications.

- Add a subsection in Chapter 1 that defines "intelligent transportation systems" and explains its meaning and implications

- Add discussion of the role of trust in automation
- Give greater attention to dynamic routing for emergency vehicles
- Include more consideration of design needs for older drivers
- Include consideration of color vision anomalies (e.g., protanopia) in the guidance
- Include more attention to fail safe indication and how drivers will recognize when an ITS function is present at a crossing and whether it is operational or off-line

  Project Team Response: All of the issues listed above are already reflected in the recommendations and/or discussions to some degree. Individual reviewers suggested greater emphasis on some particular item. The project team does not see a clear need to expand on any of these but can reconsider this if a shortcoming is evident. Given that each item above was cited by only one individual (except for older drivers, mentioned by two), there does not seem to be any common perception among the group of reviewers regarding expanded treatment of any of these issues.

- Provide more supporting citations for the guidelines

  Project Team Response: While cases of particular recommendations might bear further citations, the general degree of citation reflects the project team's best judgment of the necessary references and appropriate degree of literature citation. Given the scope of the document and its length, the team was concerned that the individual subsections and recommendations not turn into mini-literature reviews.

- Include some discussion of FRA responsibility for the regulation of highway-rail grade crossings (the reviewer specifically alluded to recently amended Part 234.275, which mandates that new and novel technology must meet the safety regulations of Part 236 Subpart H)

  Project Team Response: It is not clear to the project team whether this concern is procedural and not related to human factors guidance or whether it is in fact important to include. If it is appropriate, do other FRA regulations (or regulations of other DOT agencies) exist that should also be included? The team defers to FRA judgment on this matter.

- Provide discussion of the relationship among time of warning, vehicle speed, and distance

  Project Team Response: This issue is discussed in the section on location of signs (Section 5.3.1), as well as in the section on providing adequate response time and distance (Section 4.3.11). The introductory section the report could highlight and discuss this issue (Chapter 2). However, it is not specific to ITS or HRI; rather it is one of several broader highway design/operations issues that could be so treated, such as legibility factors, sight distance, and so forth. The project team felt that discussing such general issues in depth would move this document toward being a human factors in highway design guide rather than a more focused ITS/HRI guide. The team therefore feels that the level of detail already in the recommendations is probably appropriate.

- Consider the issue of motorists learning about the operational environment, such as with drivers learning to ignore speed limits

Project Team Response: The project team is not certain exactly what learning issues the reviewer is alluding to. They may already be treated in Chapter 2 (Conceptualizing the Roadway User).

Some reviewers noted that some guidance was not specific to ITS applications at the HRI.

Project Team Response: In developing the content of the guidance, the project team faced a recurring problem of where to delimit the scope of the guidance. Section 1.2 of the report discusses this issue. This section defined the focus of interest to be the intersection of human factors, ITS, and the HRI. However, the section went on to state,

> *It must be acknowledged that there are some human factors principles that may by broadly important for all ITS applications, not just the HRI. These have to be addressed to some degree or this document will not serve its purpose of providing immediate guidance for HRI ITS designers and implementers.*

So while the reviewers are correct in pointing out that some guidance was not specific to the HRI, the content reflects the best judgment of the project team as to what information is essential to include in this document in order for it to be most useful.

Some reviewers took issue with the use of the term "highway-rail intersection" and promoted the use of "highway-rail grade crossing."

Project Team Response: The terminology for describing the at-grade intersection of a roadway and railroad right-of-way is a point of some controversy, and it is evident from comments that some reviewers have strong feelings about the most appropriate term. The issue is not specific in any way to the ITS applications under consideration in this document but is a more general concern of terminology. The project team used the term "highway-rail intersection" as it was designated in the contractual Statement of Work that directed this project. The final choice of terminology might be made subject to consensus among potential users. Whatever the choice, it will not directly affect the recommendations put forth here.

4.2.3 General Comments on the Guidance/Recommendations Provided

The following notes general comments on the recommendations. The revised document (Jenness et al., 2005) incorporates comments on specific points of guidance within the document as described in Section 4.3. A number of reviewers provided an overall favorable comment regarding the adequacy of the recommendations, indicating that it was well-founded, accurate, valid, and consistent with practice. The only negative general comment regarding the appropriateness of the recommendations was from a reviewer who felt that the guidance was very general and that it could benefit from "specific solutions, examples or use cases." Several reviewers specifically pointed to the rationale sections as a strength, although some felt that more citations would be helpful. As noted above, some reviewers found redundancies in the guidance. Some wanted the guidance to be more concise.

Project Team Response: Although the recommendations in the document were seen as straw man guidance, with sometimes limited supporting data, it is encouraging that reviewers were generally positive regarding the appropriateness of the recommendations. Of course, specific points of concern were raised by individuals for

some selected sections (see Section 4.3). The comments requesting additional citations and rationale are in conflict with comments to make the content more concise. This was a trade-off that the project team was continually dealing with throughout the course of developing the document. Ultimately, the optimal content will depend on the final form(s) in which the guidance is provided, which is an issue in the section that immediately follows.

4.2.4 General Comments on How to Move Forward In Developing Standards, Guidelines, Specifications, Reference Documents

As part of the review process for the document, the project team asked reviewers for comments on how to move the process forward from this point. Reviewers provided relatively few comments on this. The points raised included the following:

- Refine recommendations and develop consensus through efforts of the broader community of stakeholders and experts
- Categorize the recommendations based on need for consensus and subject matter (limited to HRI ITS or broader than that), then involve the appropriate groups (e.g., National Committee on Uniform Traffic Control Devices [NCUTC]) in developing consensus for a particular category
- Test the recommendations and conduct case studies to confirm and refine the guidance
- Determine the key organization(s) that might have ownership of the guidance; comments mentioned Institute of Transportation Engineers (ITE), Society of Automotive Engineers (SAE), and the NCUTCD
- Incorporate the recommendations of this project into other existing or planned references, rather than promulgate another guide or manual
- Consider making this a living document
- Consider creating an accompanying Web site

<u>Project Team Response</u>: Although this project was intended to provide recommendations that may be of immediate use to ITS designers and implementers, it was always viewed as only a first step toward the development of more refined, consensus guidelines, standards, regulations, and tailored end-user tools. Earlier efforts (Weiland, 1999) defined some of the primary human factors issues; this project refined those requirements and developed initial guidance.

The guidance document produced under this project was intended to provide a comprehensive treatment of the human factors problems associated with ITS at HRIs. This included a general introduction to human factors concepts and issues for road users, a review of implemented ITS systems, background and discussion of issues for each area of guidance, and a discussion of the rationale for each guideline statement. The project team chose this comprehensive and detailed approach because it felt that this would provide the best resource for subsequent work in developing standards, consensus guidance, design specifications, and reference documents. The document itself, however, is not a consensus set of guidance nor is it optimally designed for usability as a design

guide. It was the project team's primary intent to identify the important human factors issues, provide best judgment straw man recommendations, and lay out a rationale in support of the decisions. With this basis, subsequent steps can now be taken to provide more formal guidance and more targeted user resources. This might include consensus standards, integration into existing reference guides, design specifications, regulations, and user guides. The recommendations provided by the reviewers, while somewhat general, are consistent with the needs to move forward with this work.

4.2.5 Reviewer Comments on Specific Sections within the Guidance Document

Reviewers had a variety of comments on specific sections within the document. The revised final document (Jenness et al., 2005) incorporated editorial corrections. Substantive comments regarding content were either implemented in the text of the revision or included as footnotes. Very few cases of outright disagreement actually occurred with details of specific recommendations. The revised guidance document does not include those comments not directly related to substantive changes. For example, such comments may indicate the reviewer's agreement with some point or raise an example of a more general issue already summarized above (Section 4.2).

5. Conclusions and Recommendations

This project conducted information gathering and analytic activities in order to define the needs for human factors guidance for ITS applications for the HRI. It then developed formal recommendations to address these needs and integrated them into a guidance document, *Human Factors Guidance for Intelligent Transportation Systems at the Highway-Rail Intersection.* The project team distributed the document to outside technical experts and potential document end-users for review and comment. The guidance document serves as an intermediate step on the path toward consensus standards.

5.1 Need and Acceptance of Human Factors Guidelines for HRI Applications of ITS

This project focused on human factors issues related to roadway users, and identified potential ITS applications, including warnings about train arrival, advance information about the HRI, dynamic route guidance, enforcement, errant vehicle control, and light rail transit operations. These applications included communications aimed at both motorized and pedestrian traffic and both roadway-based and in-vehicle displays. While many potential ITS applications have been discussed in the literature, relatively few actual deployments have occurred, and most of these have been short-term one-of-a-kind demonstration projects. Thus, while it appears that road user-oriented ITS has the potential to make many contributions to improve HRI safety and operations, this has not yet been taken advantage of, established practices do not exist, and little field experience is available to draw upon.

If future implementations of ITS for the HRI are to be successful, many human factors considerations will have to be dealt with successfully. Yet this project found little directly-usable guidance for ITS at the HRI. Various human factors guidance documents and some recommended practices deal with aspects of general ITS practice (e.g., in-vehicle displays) or certain types of ITS information (e.g., route guidance). However, the guidance is scattered, often not very detailed, and not tailored to HRI applications. Thus, this project confirmed the immediate need for comprehensive human factors guidance in some form, a clear requirement for consensus standards, and other more refined and formal tools and policies.

This project identified and structured a detailed set of human factors requirements for ITS at the HRI. This set began with the initial findings of a workshop on "ITS Standards for the Highway-Rail Intersection" (Weiland, 1999), which the project team then refined and expanded through literature search, expert contacts, and guidelines document review. The project then proceeded to critically evaluate literature related to the human factors requirements and develop recommended guidance to address the requirements.

The project team incorporated human factors recommendations into *Human Factors Guidance for Intelligent Transportation Systems at the Highway-Rail Intersection.* This document had the dual purposes of (1) providing immediate guidance to assist the designers and implementers of ITS for the HRI and (2) provide background, analysis, issue identification, and guidance rationale that may serve as an impetus and resource for further consensus standard development and/or other formalized guidance.

The project team distributed the guidance document upon request to a wide range of potential outside reviewers representing diverse stakeholder groups and technical disciplines. Forty experts accepted the invitation to review the guidance. The project team ultimately received feedback from 18 reviewers. The reviewer comments, taken together, were helpful in revealing the perceived strengths and weaknesses of the document and the needs for subsequent actions.

The overall perception of the guidance document was clearly positive, with reviewers typically finding the organization and format to be logical and useful, the content to be comprehensive, and the guidance itself appropriate and reasonable. A number of reviewers commented favorably on the potential usefulness of the guidance for ITS developers or regulators. Overall, potential users believed that such a guidance document would provide benefits and that this particular draft document provides a useful initial effort and model.

Although individual reviewers had suggestions for specific sections or features of the document, three broad issues arose among multiple reviewers and hence represent a more general concern. These issues were the length/amount of information in the document, redundancies within the document, and the degree of specificity to HRI services. These concerns all relate to intentional trade-off decisions made by the project team in serving the various objectives of the project. As noted above, this guidance document serves two purposes: to serve as a source of immediate guidance for ITS designers/implementers and to serve as a straw man resource for further refinement and consensus standards. The length of the document in large part reflects the decision to comprehensively provide the sort of information that will be useful to the full range of document users, as both users of guidance and developers of standards, guidelines, regulations, and design specifications. It includes background on roadway user behavior, an overview of implemented ITS systems for the HRI, background on various applications and their human factors issues, guidance statements, and spelled-out rationale. The document covers both general ITS display concerns and specific HRI applications. Very different audiences of document end-users may exist for these various sections. For particular applications and particular guidance users, it is possible to design a much more limited and streamlined guidance document that will be more usable by its audience. Such a document, however, would not meet all of the objectives that this project was trying to accomplish. Therefore the project team chose to be more comprehensive in terms of content, recognizing that the document would be sizable and rich in content. The team recognized that more tailored formats may be preferable for subsequent guidelines efforts (see Section 5.2 below).

Comments about redundancy come from the fact that the guidance document has a hierarchical organization, beginning with the most general ITS/HRI issues and proceeding to the more specific applications. Sometimes a specific application recommendation is closely related to a more general recommendation from which it is derived. In addition, parallel issues may arise for various applications, resulting in closely related guidance. Again, decisions about what to include in the guidance for each section were determined by the multiple goals of the document. The project team believes that as subsequent standards and guidance work proceed and become tailored to the specific end users, this issue will resolve itself. Likewise, the issue of including some ITS guidance that is not specific only to HRI applications is related to the desire to have this initial document function as a stand-alone guidance source. Trade-offs were required between maintaining the specific HRI focus and providing enough of the more general guidance so that the document would remain useful to the range of potential users. The introductory

section (Section 1.1) of the guidance document and the section on project scope (Section 1.4) specifically raise this issue.

In conclusion, the initial draft of *Human Factors Guidance for Intelligent Transportation Systems at the Highway-Rail Intersection* appeared to be well accepted by outside reviewers in terms of objective, content, organization, format, and guidance. The greatest concern is with usability, given the length of the document and the large number of recommendations it contains. This comes in large part from developing an initial document that serves multiple purposes and audiences.

5.2 Subsequent Steps

This project was an important step in providing needed human factors guidance to HRI/ITS developers and implementers. However, it was not seen as a final step. In fact, the FRA's Statement of Work implementing this project was quite explicit about this. Having noted that the 1999 workshop on ITS standards for the HRI (Weiland, 1999) articulated a clear requirement for human factors guidance, it noted that no identified process existed for promoting this and little progress in standards development. Therefore:

> The purpose of this project is to develop HF guidelines for HRI/ITS. Guidelines can be thought of as the next logical step towards standards development….However, as guidelines are used and referenced, known inadequacies can be documented, suggested limits can be refined, and gaps in knowledge can be identified. Consequently, guidelines can form the basis for the development of a consensus on standards and for the development of a community of concerned stakeholders to promote the development of standards.

The guidance developed under this project is not only initial guidance for immediate use but also as a straw man starting point for initiating debate and refinement within the standards communities. Therefore the question arises as to how to proceed from this point.

Two interrelated questions exist: (1) what form might refined guidance take; and (2) what organizations might take responsibility for subsequent efforts?

The guidance provided in *Human Factors Guidance for Intelligent Transportation Systems at the Highway-Rail Intersection* is in the form of recommendations; the majority of which are qualitative. Subsequent guidance might take other forms and may have more authoritative status. These possibilities include:

- Consensus standards
- Engineering requirements
- Design guides/handbooks
- Recommended practices
- Regulations and policy
- Guideline documents
- Model or typical applications
- Case studies

This subsequent guidance may be provided in a variety of ways, related in part to the form of the guidance. The project team developed *Human Factors Guidance for Intelligent Transportation Systems at the Highway-Rail Intersection* as a stand-alone document. Standards and guidance, however, may be carried further as elements of, or supplements to, other existing documents. In this regard, some standards groups or stakeholder groups might be interested in only some portion of the guidance provided in this project's recommendations. For example, one might imagine that only guidance relevant to in-vehicle displays might be relevant to SAE and could be incorporated into its ITS human factors standards activity. Likewise, NCUTCD and FHWA might have a direct interest only in roadway signing aspects and might incorporate such guidance into the Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD). The American Railway Engineering and Maintenance of Way Association (AREMA) might have an interest in integrating only those recommendations that are specifically related to railway infrastructure. The point is that a comprehensive, stand-alone human factors guidance document of the sort developed in this project is not necessarily the model for subsequent refinement, consensus, and standardization. Subsequent steps may deal with the content narrowly or broadly; may provide the guidance in stand-alone or integrated form; and may be formally presented as standards, rules, and design specifications.

Because the application of ITS to HRI cuts across transportation modes and technologies, the development of standards may be of interest to various U.S. Department of Transportation groups, including FRA, FHWA, the National Highway Traffic Safety Administration (NHTSA), and the Joint Programs Office (JPO) [FHWA ITS Joint Programs Office]. Of course, corresponding agencies of other governments (e.g., Transport Canada) and international bodies (e.g., ISO) also share this interest. Among non-government groups with activity in consensus standards or sanctioned practice are ITE, AREMA, SAE, the Institute of Electrical and Electronic Engineers (IEEE), and the National Committee on Uniform Traffic Control Devices. These or similar organizations might lead the development of consensus standards and refined guidance. Leadership may also come from non-standards or regulatory groups that have a technical or advocacy role, such as ITS America or AASHTO.

Subsequent activity in refining the guidance and achieving consensus can occur in a variety of ways:

- Circulate the *Human Factors Guidance for Intelligent Transportation Systems at the Highway-Rail Intersection* and/or make it available through Web sites, and announce its availability. If the document becomes widely available and is used, this will help reveal whether strong interest exists for all or part of the document, where that interest lies, what user experience is in using the guidance, where changes/refinements are needed, and what organizations may have motivation to lead the next steps.
- Consider presentations and papers at selected technical meetings, conferences, workshops, and committees to promote awareness and use of the guidelines, solicit feedback, and motivate consensus-building activity.
- Gather representatives of key Federal agencies with responsibilities related to the ITS/HRI area (e.g., FRA, JPO, FHWA, NHTSA, the Federal Transit Administration [FTA]) and key standards groups. Review the needs and issues, and determine where there may be leadership for advancing all or some of the topics in the guidelines.

- Make a broad outreach for full stakeholder involvement in providing next steps and solicitation of ideas for consensus approaches.
- Conduct spin-off meetings or workshops in conjunction with other major meetings of potentially interested organizations and individuals. Example meetings might include the annual TRB meeting, the ITS America conference, or one of the annual (or one time) rail safety conferences.
- Seek interest or partnership with international standards efforts (e.g., ISO) in telematics or other areas.

ITS activity is burgeoning in many application areas, but the HRI has been the focus of relatively limited development. The development of preliminary guidance in this project has been very timely, providing the opportunity to put a human factors resource in place before substantial field implementation begins. Ideally, the field can also use this as a springboard to proactively provide improved consensus standards in more usable forms.

6. References

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Abbreviations and Acronyms

AAR	Association of American Railroads
AASHTO	American Association of State Highway and Transportation Officials
ADA	Americans with Disabilities Act
AREMA	American Railway Engineering and Maintenance of Way Association
ATIS	advanced traveler information system
ATSSA	American Traffic Safety Services Association
BLE	Brotherhood of Locomotive Engineers
CFR	Code of Federal Regulations
FHWA	Federal Highway Administration
FMVSS	Federal Motor Vehicle Safety Standards
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HFES	Human Factors and Ergonomics Society
HRI	highway-rail intersection
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organization for Standardization
ITE	Institute of Transportation Engineers
ITS	intelligent transportation systems
IVIS	In-Vehicle Information Systems
JPO	Joint Programs Office (FHWA ITS Joint Programs Office)
MUTCD	*Manual on Uniform Traffic Control Devices for Streets and Highways*
MBTA	Massachusetts Bay Transportation Authority
NCUTCD	National Committee on Uniform Traffic Control Devices
NHTSA	National Highway Traffic Safety Administration
NTIS	National Technical Information Service
OSHA	Occupational Safety and Health Administration
PATH	California Partners for Advanced Transit and Highways
SAE	Society of Automotive Engineers
TCD	traffic control device(s)
TMC/ROC	Traffic Management Center/Rail Operations Center

TRB	Transportation Research Board
TRIS	Transportation Research Information Service
UTU	United Transportation Union