Comprehensive Human Factors Guidelines for Road Systems (Research Results Digest)

DETAILS

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COMPREHENSIVE HUMAN FACTORS GUIDELINES FOR ROAD SYSTEMS

This digest presents the results of NCHRP Project 17-18(8), "Comprehensive Human Factors Guidelines for Road Systems." This project developed an outline, two chapters, and a work plan for the first edition of the *Human Factors Guidelines.* This digest is based on a draft final report authored by the principal investigator, Neil Lerner, Westat, Inc.; Robert Llaneras, Westat, Inc.; Alison Smiley, Human Factors North; and Fred Hanscom, Transportation Research Corporation.

SUMMARY

This digest summarizes the final report for NCHRP Project 17-18(8) (available as *NCHRP Web Document 70*). This is the initial project to develop a new resource document for highway designers, traffic engineers, and other practitioners. The *Human Factors Guidelines* (HFG) will provide the best factual information and insight on road users' characteristics to facilitate safe roadway design and operational decisions. Project 17-18(8) developed an outline for the first edition of the HFG, a work plan, and Chapters 1 and 5, "Introduction" and "From Driver Reaction Time, Maneuver Time, and Speed to Design Distances: General Guidelines," respectively.

An interim edition of the HFG will be available in late 2007.

INTRODUCTION

The effort to significantly reduce highway fatalities and injuries is a huge undertaking, especially in the United States and Europe, which each experience more than 40,000 highway fatalities each year. Effective and acceptable solutions to this problem require that consideration be given to the three key components of highway transportation: road, vehicle, and road user. Often forgotten are the needs and constraints of the road user. The impetus behind this project was the recognition that current design references have limitations in providing the practitioner with adequate guidance for incorporating road user needs and capabilities when dealing with design and operational issues. These limitations may be of various sorts. Design guidelines may represent minimum requirements that are not always appropriate over the full range of roadway users or applications. Guidance may not be based on adequate human factors data. Guidance documents may not offer sufficient explanation so that practitioners can make effective use of behavioral factors. Conflicting requirements or unusual conditions may make it difficult to comply with ideal design parameters and require some basis for a compromise. Design practice may be driven by concerns about cost and compliance, without a basis for also incorporating safety benefits through user-centered design. Because of such limitations to current design guides, it would be beneficial to provide guidelines to assist the practitioner in identifying and

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addressing human-centered safety concerns in roadway design and operations. The HFG is seen as a complement to other primary design guides, such as the 2001 *AASHTO Geometric Design Guide* and the FHWA's 2003 *Manual on Uniform Traffic Control Devices* (MUTCD).

The HFG is seen as a collaborative, evolving document that is expected to be the product of many contributing authors over a period of years. The document may continue to expand and be refined over subsequent versions. The development and growth of TRB's 2000 *Highway Capacity Manual* provides a successful model for this type of approach.

RESEARCH OBJECTIVE

The objective of NCHRP Project 17-18(8) was to lay the groundwork for a first edition of the HFG. The project developed recommendations for the content, format, organization, and capabilities of the HFG. It developed an outline of the document and a detailed work plan for the effort required to produce a first edition. As part of this effort, a draft introduction and one sample chapter were written.

GENERAL RECOMMENDATIONS FOR DESIGNING THE HFG

Target Users of the HFG

The general purpose of the HFG, as defined in the project Statement-of-Work, is to provide the "best factual information and insight" regarding road user characteristics so as to "facilitate safe roadway design and operational decisions." Therefore, although there may be many groups who may make use of the document, the primary audience is practitioners dealing with design and operational issues in their normal course of work.

This audience is not assumed to have expertise in human factors. There may be little understanding of what the field is and little motivation to seek insights, data, or guidance in this area. While the need to incorporate road user capabilities into design and operational decision making has certainly become more widely appreciated in recent years, appreciation and knowledge are by no means universal. Therefore, if the HFG is to be used as an everyday resource, it must appeal to and be understood by the range of practitioners, including those with little background in human factors issues. It should also be noted that not all those providing traffic engineering functions are trained engineers. The HFG should be written in a straightforward and nonacademic manner, but must remain appropriate for trained professionals. It should be at the level of an introductory textbook.

There is an important distinction to be made between the role of the highway designer and that of the traffic engineer. They address road user requirements at different points in the process and use their own distinct tools in addressing driver needs. Both groups need to be cognizant of user-centered concerns in the design and operation of roadways. Designers and traffic engineers are likely to approach the HFG in different ways and for different reasons. Both groups must be recognized as distinct parts of the audience for the document.

Functions and Objectives of the HFG

There are various functions that a document called *Human Factors Guidelines* might serve. Questions about exactly what the HFG will attempt to accomplish were quite in evidence at the workshop conducted by the TRB Joint Subcommittee for Development of International Human Factors Guidelines for Road Systems, A3B02(2). There were questions such as, Is this material "tutorial or referential in nature?" The emphasis placed on various functions will guide the shape of the document. The general functions that the HFG might serve include the following:

- Identify the probable causes and countermeasures when faced with a problem related to road user characteristics.
- Provide proactive guidance to include human-centered concerns in design and planning and to avoid potential user-related problems.
- Promote the understanding of an appropriate road user–centered perspective of safe design.
- Educate about fundamental human factors principles related to highway safety.
- Provide a defensible basis for deviating from normal practice when that normal practice is not optimal from a road user–based, highway safety standpoint.
- Provide adequate documentation as a resource for defense of a design or operational decision.
- Provide an independent and authoritative basis to reject politically pressured, inappropriate design or operational suggestions.

All of these functions are interrelated, and all must be addressed to some degree by the HFG. The first two functions (probable causes and proactive design guidance) are the day-to-day uses of the HFG and should be the primary drivers of the document's structure. While the HFG will serve an important educational function, it should not be viewed as a textbook or a source of technical literature. There already exist a variety of substantial books on human factors for highway safety and traffic engineering. The HFG is not intended to be a repository for all relevant human factors concepts and differs from these more didactic references. Its focus is on guidance, and the guidelines are organized around traffic engineering/highway design concepts, rather than around human factors concepts. The HFG must include educational material on human factors concepts, but it must be streamlined and the guidelines themselves must be structured around engineering factors.

The HFG should be viewed as a complement to major design references. It should not duplicate or replace them. This means that the HFG does not have to explicitly address every design aspect treated in other sources. For example, it may not be appropriate to specify the placement of a particular traffic control device (e.g., arrow board) for a work zone if this is specified elsewhere. However, the HFG does need to deal with the limitations of existing guidance, define conditions where other factors come into play, and help the practitioner in recognizing the need for trade-offs and making decisions. While guidance should include quantitative information wherever possible, the guideline should not be prescriptive. In many cases, the need for additional human factors consideration comes from the fact that there is an unusual situation or conflict among guidelines so that a "cookbook" approach is not appropriate. The guidelines need to provide the principles and data to allow the engineer to work through the problem. The HFG should serve as a supplement to primary design guides, and as such the specific guidance needs to be problem based or treated on a by-exception basis, rather than attempting to specify and justify every aspect of roadway design and operations. The HFG must be more of a tool than a cookbook.

Because the HFG may often serve a problem-solving need rather than an educational one, it should not be assumed that users will enter the document at the beginning and read the introductory and background chapters. Users will typically enter searching for specific guidance on a particular issue. Therefore, it will be important to provide cross-referencing to sections that deal with fundamental human factors principles that may relate to some specific guideline. The early sections of the HFG should be written in an inviting manner and at a level of detail that does not deter prospective readers. Nonetheless, no guideline statement should presume that background chapters have been read.

Media and Capabilities

The project Statement-of-Work specified that the HFG would be developed in a CD-ROM format. While a variety of alternative media were reviewed as part of this project, CD-ROM has been the focus and offers a variety of virtues as a format for the HFG. Although some users may simply want to print hard-copy versions of the handbook (or relevant sections), others may want to access more advanced features of the HFG (search the handbook, gather in-depth reference materials, view graphic illustrations or simulations of guideline concepts, or link to other resources). The tool must support these levels of interaction while retaining high-end features and capabilities that can be accessed by others desiring the full range and functionality of multimedia. A multimedia program can provide a nonlinear environment with a united structure that is easy to use and that provides depth of content for the user.

The CD-ROM is a convenient format for delivering high-quality visual and interactive multimedia content. As a result of the large file sizes that can be used on a CD-ROM, the content can be far more media oriented, providing video clips, detailed three-dimensional animations, and a host of other technologies. CD-ROM can also be linked to the Internet, providing additional advantages of fast delivery from a CD-ROM and ability to update from the Internet. This combination is ideal for accessing related information and handbooks. Content on a CD-ROM can also be designed and structured so that it can be converted to web-based delivery. The low replication costs of CD-ROMs and the wide availability of computers with CD-ROM drives make this an extremely practical format. While the information stored on CD-ROMs cannot be updated, links to other documents and the Internet can be provided; this flexibility enables time-sensitive information to be readily updated. The flexibility afforded by a CD-ROM and the multimedia capabilities that it brings makes this an ideal tool for this type of application. A CD-ROM–based human factors handbook has the potential to provide traffic engineers with an informative and interactive tool that will help them to apply

known research and guidelines to solve design issues, as well as provide opportunities for them to access extensive reference materials and link to other frequently used resources (manuals, handbooks, etc.).

The ability to search the HFG document is viewed as a crucial and beneficial feature that can help users access desired and relevant information quickly and easily. This capability is greatly facilitated by electronic search engines and is expected to be a significant advantage of the CD-ROM over hard copy. Unfortunately, there is no standardized set of features or user interfaces common to most search engines. Some can possess complex or difficult-to-use interfaces and lack important search features, leading to confusion and frustration. Since providing users with control over their searches increases overall satisfaction and performance, the HFG should provide users with useful features that enable users to quickly access needed information.

Table 1 highlights important features that may help drive the selection of appropriate search engines. Features are organized in terms of capabilities useful

Table 1 Summary of CD-ROM search engine features

Feature	Description
Search	
Define Sources (Advanced Search)	Restricts or limits the scope of the search (specific documents, chapters, entire document, etc.).
Full-Text Search	Conducts searches using free-form words (text strings).
Keyword Search	Searches by specific word. Requires the establishment of "keywords."
Boolean Search	Conducts complex logical searches that combine words using special operators (And, Or, Not).
Phrase Search	Searches for a phrase (usually enclosed in double quotation marks).
Index Search	Guides the search using headings and subheadings. Index linked to search.
Wildcards	Supports use of an asterisk at the end of a word or part of a word to "match anything."
Refine Searches	Tailors the search after the initial search is launched; refines without the need to start over.
Results	
Relevance Raking	Supports a mechanism to prioritize and display results (e.g., most relevant results are shown first).
List of Results with Feedback	Presents results in list form with a brief description of the results.
Number of Hits	Specifies the result set size.
Highlights Search Terms in Context	Highlights the hits (search terms) in the text. May allow user to move between instances of the words on the pages.
Includes Viewer to Display Graphics	Provides a means to view graphics as well as text results.
Abstracts	Provides a condensed description of the document or preview documents (aids in determining relevance).
Others	
Customizable Features	Searches forms and results page.
Stop Function	Stops the search if user feels it is taking too long.
Back Button	Goes to previous screen.
Sequencing Results	Allows user to tailor the order of presented results (grouped or sorted results).

when defining the search itself, as well as characteristics associated with displaying search results.

Not only must a suitable search engine provide desirable search utilities and features, it must also be compatible with a range of user platforms and support a variety of anticipated file types (PDF, HTML, word processor, database, spreadsheet, etc.). The ability to migrate from CD-ROM to web-based application is also beneficial and should be considered when designing the architecture and format of the CD-ROM.

The CD-ROM provides a flexible vehicle for housing the HFG document; the medium is widely available to the user population and is capable of supporting the types of file formats and search utilities envisioned for the HFG document. If structured appropriately, content on the CD-ROM can also be migrated to a web-based environment if future needs demand. Another practical advantage of a CD-ROM is that it facilitates document version control; a web-based tool would be more difficult to manage revisions to the document.

Content and Organization of the HFG

The HFG needs to be streamlined and highly usable as a day-to-day reference. The guidance portions need to be succinct and present only as much background as enables intelligent application of the guidelines. Human factors and systems perspectives need to be readable and useful but not encyclopedic. However, it was quite clear from the user needs workshop conducted under this project that practitioners find it very important to have direct access to more detailed information for times and situations where support is needed. The technical background must be easily related to specific guidelines. The willingness of an engineer to select some optimal design over a minimum specification or usual approach will depend to some extent on the ability of the document to provide "backup" for that decision. For this reason, the HFG is envisioned to be a reasonably streamlined guidance document, but associated with a related companion document or documents. It is assumed that the author of any chapter of the HFG will conduct a detailed technical literature review as a basis for the development of the guidelines. Therefore, it is assumed that these literature reviews will be available as a companion resource, even though not part of the HFG. The FHWA document, *Guidelines and Recommendations to Accommodate Older Drivers and Pedestrians*, serves as a partial model for this approach. This document is essentially a series of guidelines with a few pages of background discussion and many individual guidelines, each about a page or two in length. A related document, *Highway Design Handbook for Older Drivers and Pedestrians*, supplements the guidelines with an extensive literature review from which the guideline recommendations were derived. This larger document is about four times the size of the smaller document. Although the HFG will necessarily contain much more background material than the *Guidelines and Recommendations to Accommodate Older Drivers and Pedestrians*, the FHWA example illustrates the usefulness of the companion document as a means of keeping the guideline document usable. The CD-ROM format will enhance easy access to companion volumes. The proposed approach to the organization of the HFG is based on the assumption that a companion volume approach is an effective way to resolve the desire of users for a streamlined, easily searched, highly usable source of day-to-day guidance with the need for occasional access to detailed backup information and formal research citation and analysis.

For purposes of understanding road user capabilities and the role of user-centered thinking in the highway safety system, it is necessary to organize some portion of the HFG around the roadway user. However, the guidelines themselves should be organized around characteristics and elements of the roadway. This is more consistent with the manner in which the practitioner approaches the task and searches the document. CD-ROM capabilities for internal linking or cross-referencing need to be taken full advantage of here in order to direct the reader to relevant roadway user considerations even though the approach is through a highway design element.

The recommended structure of the HFG is four major parts. The structure meets the various functions of the HFG and provides a meaningful basis for the approach and needs of both the traffic engineer and the highway designer. The structure is intended to be consistent with the manner in which users might approach and search the document, given their likely motivations. Each of the four parts is composed of chapters; 21 chapters are proposed for the initial HFG:

- **Part I: Introduction to the HFG**
  - Chapter 1. Why Have Human Factors Guidelines for Road Systems?
  - Chapter 2. How to Use This Document

- **Part II: Bringing Road User Capabilities into Highway Design and Traffic Engineering Practice**
  - Chapter 3. A System Approach to Highway Safety: Thinking Like a Road User
  - Chapter 4. Basic Road User Capabilities
- **Part III: Human Factors Guidance for Roadway Location Elements**
  - Chapter 5. From Driver Reaction Time, Maneuver Time, and Speed to Design Distances: General Guidelines
  - Chapter 6. Speed Perception, Speed Choice, and Speed Control
  - Chapter 7. Curves (Horizontal Alignment)
  - Chapter 8. Grades (Vertical Alignment)
  - Chapter 9. Tangent Sections and Roadside (Cross Section)
  - Chapter 10. Transition Zones Between Varying Road Designs
  - Chapter 11. Non-Signalized Intersections
  - Chapter 12. Signalized Intersections
  - Chapter 13. Interchanges
  - Chapter 14. Construction and Work Zones
  - Chapter 15. Rail–Highway Grade Crossings
  - Chapter 16. Special Considerations for Urban Environments
  - Chapter 17. Special Considerations for Rural Environments
- **Part IV: Human Factors Guidance for Traffic Engineering Elements**
  - Chapter 18. Signing
  - Chapter 19. Changeable Message Signs
  - Chapter 20. Markings
  - Chapter 21. Lighting

While not exhaustive, these chapters would be reasonably comprehensive and provide an effective aid to designers and traffic engineers.

Part I is introductory and intentionally brief, with two short chapters. The purpose of the first chapter is to describe the needs for the HFG and the purposes it is intended to serve. It will define "human factors" and their role in design and safety in high-level terms (Part II will provide greater detail). The chapter will clarify the relationship of the HFG to other design guides and reference sources and explain its role as a complement to primary standards and engineering guides. The second chapter of Part I will explain to the reader how to use the HFG. It will describe the organization and will detail the automated search capabilities. The availability and role of the companion literature review papers will be explained. The relationship to other sources of guidance will be described, and the system of cross-referencing within the HFG will be discussed. A set of references to other resource materials will be provided, with a capsule description of how each relates to the HFG. A shortcoming of other traffic engineering reference documents that have been produced as CD-ROM or web-based versions is that search capabilities and how to use them are not made evident. Users may not be aware of what functions they have available or exactly how these functions work. For example, there may be Boolean functions that permit a more refined search (using an "and" function) or the ability to screen many irrelevant "hits" (using a "not" function). Yet the document has no description or link to such information. The clarification of how the document can be effectively searched should be an important part of Chapter 2. Overall, then, the intent of Part I is simply to provide a succinct basis for use of the *HFG:* what it is and how it works.

Part II deals with road user capabilities and the role of road user–centered thinking in the systems conception of highway safety. Part II is composed of two chapters. The initial chapter introduces the system approach and emphasizes "thinking like a road user." It is meant to be a very readable chapter, without a lot of jargon, models, or data. One of the real issues for the HFG is how to motivate a practitioner to read it, other than in a very specific problem-solving mode. The HFG should be able to influence the thinking of the traffic engineer, and maybe even more importantly the highway designer, so that they adopt a more global, systems view and the ability to incorporate road user needs into their approach. This chapter is where to accomplish this. While there is no means of forcing someone to read any portion of the HFG, this chapter will be designed to be inviting and readable. It should use "punchy," succinct text and make maximum use of the multimedia capabilities of CD-ROM. For example, these capabilities might include driver's eye view video clips, animations, dynamic graphics, side-by-side comparisons, and so forth. The chapter will include a section on "thinking like a road user" that will introduce a few key concepts and issues in a very practical, jargon-free manner. The second chapter within Part II defines and quantifies basic driver capabilities directly related to engineering practice and decision making.

It explains fundamental behavioral factors, such as perception-reaction time and expectancy. It provides basic empirical data on human perception and performance characteristics. While many readers may not read this chapter beginning to end, it will serve as an essential link to later guidelines and principles and can be cross-referenced as needed.

Parts III and IV are related in that they provide the set of specific guidelines, organized around factors relevant to the designer or traffic engineer. These parts are the core of the HFG for practical use. The Project 17-18(8) analysis, strongly confirmed in the user workshop, was that the guidelines should be organized around the primary types of roadway locations, but while this is desirable, it is not sufficient. Many of the guidance principles are not location specific and would be redundant to consider within each chapter. Furthermore, the user may conceive of his or her issue in terms of a device or other engineering element and seek guidance with respect to human-centered principles for the device. Therefore, the guidelines are organized under two distinct parts: Human Factors Guidance for Roadway Location Elements and Human Factors Guidance for Traffic Engineering Elements. Cross-referencing and links between these sections are assumed and remain critical for steering the user to all appropriate guidance without an unduly redundant and unwieldy document. Part III organizes the guidelines with respect to some type of roadway location, such as a "signalized intersection" or a "construction and work zone." Part IV then presents a range of cross-cutting issues that relate to traffic engineering elements (e.g., signs and lighting).

Chapter Structure and Features

The guideline chapters (under Parts III and IV) should share a common format and a common approach to presenting the issues and guidance. As the HFG is developed, different authors will be responsible for the various chapters. The individual authors, as topic experts, will have to determine for their chapter precisely what the specific guideline needs are. However, a common format will aid the user and may help ensure a comprehensive treatment.

The core of each chapter in Parts III and IV is a set of guideline statements. Although the guidelines are the major component, there are other sections important to the standard chapter structure. As noted in the previous section, it is assumed that for each chapter there will have been a literature review conducted. The detailed information and citations in that review do not need to be included in the body of the chapter in the HFG, but a link to the full review is necessary. However, each chapter should begin with a brief background section that puts the safety and driver-centered issues in context. This background should highlight the major types of design and operational issues that tend to occur, the nature of the safety problem (i.e., the crash characteristics), road users that may have special needs (e.g., heavy trucks and pedestrians), and the major human factor issues. If kept brief (e.g., 2 pages), this background section will more likely be read. The background section provides the opportunity for the chapter author to set a context in which the specific guidelines will be more understandable and appreciated.

An additional section is suggested for the chapters of Parts III and IV. This was a "Road User Requirements Analysis" that maps human factors needs and strategies in a systematic manner, using headings of

- Required acts,
- Driver information requirements,
- Driver action requirements and decisions,
- Contributing factors, and
- Addressing potential solutions.

In previous projects, this sort of analysis proved to be both a very useful tool for developing recommendations and an effective means of communicating the human factors needs and strategies to an audience without human factors expertise. However, the issues of the sample chapter did not lend themselves readily to this format, and for many planned chapters, the range of issues may simply be too great to employ this technique. Therefore, it is suggested that HFG chapter authors consider a tabular format User Requirements Analysis as a possible feature for a given chapter. However, this need not be a standard part of all chapters.

The project team also considered the inclusion of a decision tree or some other type of diagnostic scheme as an element of each chapter. Such a tool might prove valuable to the practitioner. While the development of diagnostic tools may be beyond the scope of the basic HFG development effort for many topics, it may be appropriate for others. For example, in the sample chapter, the inclusion of a diagnostic procedure was helpful. Therefore, this should be a chapter-by-chapter decision. It has been rec-

ommended that NCHRP or other agencies give serious consideration to parallel development of diagnostic tools and other decision aids that might complement HFG chapters. This would allow more thorough development and validation than might be possible within a limited chapter-writing effort.

The project team, in discussing the details of the chapter structures in Parts III and IV, concluded that NCHRP Project 17-18(8) should not overly specify the organization and specific set of guidelines to be included in the chapter. That is exactly what the authors must do using their expertise, the literature review, and the systematic road user requirements analysis. Also, the relevant TRB technical committees should coordinate with chapter authors to provide input to the needed set of guidelines. The structure of the initial portions of a chapter will help clarify an organization for the individual guidance items and help make more evident where a guideline is required. As noted earlier, the HFG need not try to comprehensively address every aspect of design and operations, which would be redundant with other guides and would result in a voluminous set of guidelines. The guidelines in each chapter should be developed based on a perceived need. Issues are treated by exception or where there are combinations of elements or other concerns not adequately dealt with in other sources.

REPORT AVAILABILITY

The complete report for NCHRP Project 17-18(8) is available on TRB's website as *NCHRP Web Document 70.*

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