Technical Support and Assistance for the FHWA's Human Centered Systems Team

Task Order No. 1

Requirements for Transportation Management Center (TMC) Human Factors Guidelines

Project Report (Final)

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List of Acronyms

AASHTO	American Association of State Highway and Transportation Officials
ATIS	Advanced Traveler Information Systems
CADS	Computer Assisted Dispatching System
CARS	Computer Assisted Response Systems
CMS	Changeable Message Sign
CVO	Commercial Vehicle Operations
DOT	Department of Transportation
FHWA	Federal Highway Administration
HF	Human Factors
HTML	Hypertext Markup Language
NTIS	National Technical Information Service
TMC	Transportation Management Center
TRB	Transportation Research Board

Introduction

This document provides a project report for the "Requirements for Transportation Management Center (TMC) Human Factors Guidelines" project. This report identifies:

- The methods used to collect and analyze relevant information, including:
  - A literature review.
  - Information obtained directly from TMC pooled fund members.
  - Identification of guideline topics.
  - Development of sample guidelines.
- The key results from this effort, including:
  - An overall approach for developing a comprehensive guidelines document.
  - A recommendation regarding the development of a web-based version of the guidelines.
  - A recommended outreach plan to inform city, county, and state DOTs about this work.
  - An outline of proposed Guideline topics/table of contents.
  - Three sample guidelines.

Background

Traffic management centers are increasing in number and are receiving significant upgrades to respond to growing congestion in the roadway system. This growth in traffic management activity entails the installation of more and different types of traffic sensor and control systems. The integration of these systems leads to greater dependence on automation and intelligent systems to monitor and process large quantities of data, to assist decision making and to control traffic. In turn, this growing reliance on automation raises Human Factors (HF) issues on how traffic management operators share tasks with automation and what kind of environment is necessary for their work to be effectively completed.

The success of TMC operations ultimately depends on how the human operator interacts with the system devices. The human operator is a critical component whose capabilities and limitations must be integrated into the design and operation of the TMC. *Preliminary Human Factors Guidelines for TMCs* were developed in 1999 to incorporate HF principles to the design and operation of TMCs. For instance, chapters are provided for job design, the user-computer interface, workspace, controls and displays. Sections are also provided on the systems engineering design process. As TMCs coordinate with each other to devise new strategies and to meet regional traffic demands, new issues and new perspectives on the role of the human in traffic management will evolve. These guidelines are intended to form a basis for further examination of future operator requirements and thus continue to support effective user-system design. However, these guidelines are dated and do not meet current user needs. Current guidelines include http://ergotmc.gtri.gatech.edu/ and Federal Highway Administration (FHWA) publication FHWA-JPO-99-042.

Objectives

The objective of this project has been to provide a detailed description of what a comprehensive HF guidelines document for TMC operators, designers, managers, and supervisors would cover and how it would be structured. In this effort, we conducted a requirements analysis to identify and prioritize needs for HF guidance in the design and operation of TMCs.

Methods and Results

Tasks

This project consisted of three (3) technical tasks:

- Task A: Kickoff Meeting and Work Plan
  - A.1. Kickoff Meeting
  - A.2. Work Plan
- Task B: Execution of the Work Plan
- Task C: Develop Project Report

Overview of Key Activities

Below, we describe the methods used to collect and analyze relevant information—as well as the results—from the following activities:

- Conduct literature review.
- Obtain information directly from TMC pooled fund members.
- Identify guideline topics.
- Develop sample guidelines.

Conduct Literature Review

Search Strategy

A literature search was conducted to identify relevant documents that could aid in our understanding of the issues to be addressed by a revised guideline. Publication data sources searched were Transportation Research (TRIS) from 1990 to October 2008, National Technical Information Service from 1990 to October 2008, Engineering Information Compendex (Ei Compendex) from 1990 to November 2008, and the comprehensive science and technology database INSPEC from 1990 to October 2008.

Terms used in the literature search are summarized in table 1 below.

Table 1. Literature search terms.

Set 1	Set 2
▪ Traffic Management Center ▪ Traffic Control Center ▪ Traffic Operations Center ▪ Control Center(s) ▪ Control Room ▪ Operations Center	▪ Design ▪ Planning ▪ Operation(s) ▪ Supervision ▪ Management ▪ Training

Search Results

There were 1,575 documents that included one or more elements of the Set 1 search terms and the Set 2 search terms. The titles for these documents were reviewed and were excluded if they referred to later reports or if they documents primarily dealt with any of the following topics:

- Traffic modeling and modeling evaluations.
- Incident detection technologies and evaluations.
- Traffic management information system design and architecture.
- Inter-agency agreement issues.
- Site-specific development and/or evaluation reports.

The review of titles resulted in the identification of 144 potentially relevant topics. The abstracts of these potentially relevant documents were then reviewed and 36 individual documents were obtained and reviewed in more detail. The relevance of these 36 documents to the current effort is summarized in table 2 below.

In addition to the documents identified through the initial literature search, additional documents were identified and obtained as a result of reviewing the initial set; as well as the result of focused reviews of selected potential design guideline topics.

Relevant Document Acquisition

Table 2 below summarizes the highly-relevant documents that were identified in the public domain literature search. A key is provided that identifies the specific area(s) of relevance.

Table 2. Summary of highly-relevant documents.

Document Relevance Key
1: TMC HF Guideline Development Issues
2: TMC HF Guideline User Group Characteristics
3: Definition of TMC Operational Function
4: Potential HF Guideline User Activities that Influence TMC Operational Effectiveness
5: Definition of Human Factors that affect TMC Operational Effectiveness
6: Current HF Guidance that is Relevant to TMC Operational Effectiveness

Area(s) of Relevance	Author	Year	Title	Source
1	Carvell, J.D., Jr., Balke, K, Ullman, J., Fitzpatrick, K., Nowlin, L., Brehmer, C.,	1997	Freeway Management Handbook	FHWA-SA-97-064 Report No. 472810-F

Area(s) of Relevance	Author	Year	Title	Source
1, 5, 6	Charara, H.A., Brydia, R.E., Balke, K.N.	2003	Advanced Transportation Management System (ATMS) Evaluation--User Interface	FHWA/TX-04/0-1752-10, Letter Report 0-1752-10 http://tti.tamu.edu/publications/catalog/record_detail.htm?id=6155
1, 5, 6	Cheng, D.	2002	Development of Guidelines for Designing a Freeway Transportation Management Center Building.	In: Compendium: Papers on Advanced Surface Transportation Systems, 2002
1, 3, 5	Cluett, C., Kitchener, F., Shank, D., Osborne, L., Conger, S.	2006	Integration of Emergency and Weather Elements into Transportation Management Centers	FHWA-HOP-06-090
1, 5, 6	Colorado Department of Transportation Safety and Traffic Engineering Branch	2003	Guidelines for Developing Traffic Incident Management Plans for Work Zones	Pat Noyes & Associates 1566 County Road 83 Boulder CO 80302- Colorado Department of Transportation Safety and Traffic Engineering Branch, 4201 East Arkansas Avenue Denver CO 80222
4, 6	Dudek, C.L.	2006	Dynamic Message Sign Message Design and Display Manual 0-4023-P3	Texas Transportation Institute
6	Dudek, C.L., Ullman, B.R., Trout, N.D., Finley, M.D., Ullman, G.L.	2006	Effective Message Design for Dynamic Message Signs 0-4023-5	Texas Transportation Institute
3, 6	Dudek, C.L., Ullman, B.R.; Trout, N.D., Finley, M.D,, Ullman, G.L.	2006	Effective Message Design for Dynamic Message Signs	FHWA/TX-06/0-4023-5 Report 0-4023-5
3	Farradyne, P.B.	2000	Traffic Incident Management Handbook	FHWA Office of Travel Management
3	Farradyne, P.B., Alltech, Inc., & Gresham Smith & Partners	2002	Tennessee Department of Transportation Region 3 – Nashville Transportation Management Center Operations Policy Manual, Draft.	
3	Federal Highway Administration (FHWA)	1993	Comparable Systems Analysis: Evaluation of Ten Command Centers as Potential Study Sites.	FHWA-RD-93-158 (Very Brief Summary Report)
3	Federal Highway Administration (FHWA)	1994	Comparable Systems Analysis: Design and Operations of Advanced Control Centers.	FHWA-RD-94-147
3, 6	Finley, M.D., Gates, T.J., Dudek, C.L.	2001	DMS Message Design and Display Procedures	FHWA/TX-02/4023-1, Research Report 4023-1, TTI: 0-4023
5	Folds, D.J.	1995	A Comparison of Four Interfaces for Selecting and Controlling Remote Cameras	Human Factors and Ergonomics Society. Proceedings of the Human Factors and Ergonomics Society 39th Annual Meeting (1995), Vol. 2.
1, 5, 6	Guttromson, R.T., Greitzer, F.L., Paget, M.L., Schur, A.	2007	Human Factors for Situation Assessment in Power Grid Operations, PNNL-16780	Order this product from the National Technical Information Service (NTIS)

Area(s) of Relevance	Author	Year	Title	Source
1	Institute of Traffic Engineers, Inc.	2001	An Annotated Outline for a Traffic Management Center Operations Manual	
6	International Organization for Standardization (ISO)		ISO 11064 Standard: Ergonomic Design of Control Centers	http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=19042
1, 3	Jacobsen, L.	2003	Highway Traffic Operations and Freeway Management: State-of-the-Practice Final Report	FHWA-OP-03-076
5, 6	Kelly, M.	1999	Preliminary Human Factors Guidelines for Traffic Management Centers	FHWA-JPO-99-042. McLean, VA: Turner-Fairbank Highway Research Center
3	Kraft, W., Klucens, R., Hartman, M., Levesque, C.	2001	An Annotated Outline for a Traffic Management Center Operations Manual: A[N] Informational Report	Informational report (Institute of Transportation Engineers); 107
3	Kraft, W.H.	1998	Transportation Management Center Functions	NCHRP Synthesis of Highway Practice Project 20-5, FY 1996, Topic 28-10
3, 6	Mounce, J.M., Ullman, G.L., Pesti, G., Pezoldt, V.J.	2007	Guidelines for the Evaluation of Dynamic Message Sign Performance 0-4772-1	Texas Transportation Institute
1, 3, 6	Neudorff, L.G., Randall, J.E., Reiss, R., Gordon, R.	2003	Freeway Management and Operations Handbook	FHWA-OP-04-003, Final Report Available in html at: http://www.ops.fhwa.dot.gov/freewaymgmt/publications/frwy_mgmt_handbook/index.htm
5, 6	Nowakowski, C., Green, P., Kojima, M.	1999	Human Factors in Traffic Management Centers: A Literature Review	UMTRI-99-5
5, 6	Ohara, Brown, Stubler, Higgins, Wachtel	2000	Human Factors Guidance for Control Room Evaluation	Refer to NUREG 0700
5	Pearce, V.	1999	Transportation Management Center Design: Lessons Learned from Operations and Management Experience	World Congress on Intelligent Transport Systems (6th: 1999: Toronto Ont.) Item held at Univ. of Calif., Berkeley, Inst Transp Studies Library. Refer to: http://www.lib.berkeley.edu/ITSL/services.html
1	Pearce, V., Subramaniam, S	1998	Intelligent Transportation Systems Field Operational Test Cross-cutting Study Incident Management: Detection, Verification, and Traffic Management	FHWA-RD-JPO-034
1, 6	Rowshan, S., Sauntry, W.C, Wood, T.M, Churchill, B., Levine, S.R.	2005	Reducing Security Risk for Transportation Management Centers	Transportation Research Record: Journal of the Transportation Research Board http://pubsindex.trb.org/document/view/default.asp?lbid=781216

Area(s) of Relevance	Author	Year	Title	Source
1, 6	Sullivan, E.D., Gerfen, J.E.D., Recker, W., Yazdan, F.	2004	Upgrading the Technology Of Simulation-Based Training for Traffic Management In California	Applications of Advanced Technologies in Transportation Engineering. Proceedings of the Eighth International Conference, Beijing, China, pp 39-44 Proceedings available at University of Washington Library
5, 6	Ullman, G.L., Ullman, B.R., Dudek, C.L., Nelson, A.A., Pesti, G.	2005	Advanced Notification Messages and Use of Sequential Portable Changeable Message Signs in Work Zones (0-4748-1)	Texas Transportation Institute
3, 4	USDOT, ITS Office.	1999	Transportation Management Center Concepts of Operation Implementation Guide.	Washington, DC: Intelligent Transportation Systems, U.S. DOT
3, 6	USDOT, ITS Office. Washington, DC:	1999	Metropolitan Transportation Management Center Concepts of Operations: A Cross-Cutting Study.	Intelligent Transportation Systems, U.S. DOT
3	USDOT, ITS Washington, DC:	2000	Incident Management Successful Practices: A Cross-Cutting Study.	Intelligent Transportation Systems, U.S. DOT
5, 6	Van Laar, D., Deshe, O.	2007	Color Coding of Control Room Displays: The Psychocartography of Visual Layering Effects	Human Factors Journal
1, 5	Wright, M.	1998	Review of Traffic Operations/Management Center Design	Institute of Transportation Engineers. District 6. Meeting (51st: 1998: San Diego, Calif.) Item owned at Univ. of Calif., Berkeley, Inst Transp Studies Library. Refer to: http://www.lib.berkeley.edu/ITSL/services.html
3	WSP/ WASHDAO	2002	A Joint Operations Policy Statement	Prepared and agreed to by the Washington State Patrol and the Washington State Department of Transportation

Obtain Information Directly from TMC Pooled Fund Members

Initial TMC Pooled Fund Member Information Collection

A brief initial information collection form was distributed to TMC pooled fund members to obtain a preliminary understanding of the roles and responsibilities of members and the potential value of revised TMC HF guidelines. Responses were received from 19 individuals representing 12 separate states. Following is a summary of the responses to selected information collection items. A full copy of the initial information collection form can be found in appendix A.

1. Please check all responsibilities that apply to your position:

<u>Frequency</u> of position responsibilities:

10: TMC equipment specification

8: TMC work space specification or design

12: TMC operations definition

15: TMC operations management/ supervision

4: Other:

- *Assistant to TMC Manager & Lead Engineer*
- *Statewide Traveler Information*
- *District Emergency Operations Staff*
- *TMC Systems Support*
- *Central Office Program Manger*

2. Who do you see as being the primary users of the guidelines? (Please number all potential users, with “1” indicating the primary user, “2” indicating the secondary user, etc.).

Median rating:

2: TMC Hardware Developers

2: TMC Software Developers

1: TMC System Integrators

1: TMC Development Managers

1: TMC Operations Managers/ Supervisors

3: Other Users

3. What are the specific Human Factors issues or topics that affect TMC operational effectiveness? ((Please review the partial list below, add any additional items that you consider important, and then number all relevant issues/topics, with "1" indicating the primary issue/topic, "2" indicating the secondary issue/topic, etc.).

<u>Median</u> rating:

1: Task Complexity and Workload
1: Displays and Controls
1: Communications
1: System Information Accuracy and Access
2: Written Operations Procedures
2: Alarm Presentation and Management
1: Operator Training
1: Operator Alertness
2: Automation Design
2: TMC Design and Staffing
3: Other:
  - *System Back-up/ Failover and Disaster recovery procedure for systems in TMC*
  - *Impatient Management requesting info while trying to manage incident*

4. Are you currently using any Human Factors standards or references to support your role in TMC design and/or operations?

<u>Frequency</u> of responses:

15: No
4: Yes (If Yes, please indicate the standards or references used below)
  - *Wall display aspect ratio & Operators workstation/ monitor*
  - *Ergonomic issues and Software integration*
  - *Human factors studies*

5. How do expect to use a final TMC Human Factors Guidelines document in your job? (please check all that apply)

<u>Frequency</u> of responses:

8: A general reference on human factors topics
9: A specific reference on important TMC Human Factors topics
7: A design handbook that can help guide the design and development of a new TMC
13: A design handbook that can help guide the re-design and development of new TMC elements
0: Other:

6. Which of the following do you think are important characteristics of an effective final TMC Human Factors Guidelines document? (please check all that apply)

Frequency of responses:

14: References to authoritative publications
17: Pictures and graphics that help illustrate important concepts
8: Hard-copy versions of the guidelines
14: Electronic format of the guidelines
0: Other:

Overall, the pooled fund member's responses to these items suggest that the end-users of the TMC Human Factors Guidelines:

- Occupy a range of positions within TMCs encompassing a similar range of responsibilities and needs for HF information,
- Are interested in a host of human factors topics including equipment design, training, operator state, and procedures—the guidelines will need to address a broad set of topics,
- Are familiar with human factors issues, but do not generally (4 respondents out of 19) use human factors reference materials in their job,
- Would expect to use TMC Human Factors Guidelines as a reference on HF topics, as well as a guide for design, development, and re-design of TMCs, and
- Have a preference for the guidelines to: provide references, incorporate pictures and graphics, and be available in electronic form.

TMC Follow-up Discussions

Follow-up discussions were conducted via telephone with five individuals from among the 19 Pooled Fund Study members who provided responses to the initial information request. These follow-up discussions followed a prepared set of questions and guideline examples, which is provided in appendix B.

These follow-up discussions were conducted to better understand:

- The ways in which Pooled Fund Study members influence the design and operation of TMCs.
- Some of the critical challenges that are dealt with in supporting TMC operational effectiveness.
- Some of the particular aspects of human factors that affect the effectiveness of TMC operations.
- How Human Factors Guidelines documents could best support TMC operational effectiveness.

TMC Roles, Responsibilities, and Functions

The follow-up discussions began with a review of the roles, responsibilities, and activities performed by each of the discussants. The job titles of discussion participants were: TMS Operations Manger, Mobility Services Engineer, Assistant State Traffic Engineer, Traffic Systems Center Manager, and Operations Supervisor.

Each discussion continued with a review of the area of responsibility, general facilities layout, and major functions supported by the discussant's TMC. Discussants represented a mix of 24-hour and morning-through-evening operations centers. Functions housed within a facility included freeway traffic management, urban roadway management, assistance dispatching, and communications with the media and related agencies.

Human Factors Affecting TMC Operational Effectiveness

A selected number of specific human factors topics were reviewed to gain an understanding of the challenges faced with respect to each. Following is a very brief summary of identified issues.

TMC Facilities Design and Staffing

- Many of the TMCs appear to be designed in the same way—more emphasis should be placed on considering the function of the individual center and let that determine the design.
- Lack of available qualified staff.
- Balancing operator skills, experience levels, and aptitudes across shifts.
- Traffic management shares resources with other users and work stations must support multiple functions.
- Individual lighting and heating is preferred by operators.
- Staffing assignments are best if they match operators with different skill levels or complementary capabilities—some operators are better suited to multi-tasking than others.

TMC Workstation Displays and Controls

- Large screens can be difficult to configure into current work areas.
- The value of video walls is questionable for some centers—they are not matching the center operational requirements—what would be wrong with a set of large screen video monitors?
- Negative aspects of video walls include both the initial cost and maintenance cost.
- How many CCTV monitors can an operator track?
- What is the right number of monitors at a work station?
- Is there a value to controlling CCTVs with a joystick? Mouse controls seem to work fine.

- The work station telephones have 70 speed dial buttons—these should probably by computer controlled to reduce operator workload.
- It can be a problem to know which mouse goes with which display.
- Generic displays and interfaces are much easier to use.
- Mice can stick.
- What do operators need versus what they say they want.

The Design of Automated TMC Functions

- Operators should be kept in the loop, rather than having them only monitor automated functions.
- Automation can support CCTV monitor display by using established cycling patterns and pre-defined situation-based priorities.
- Provide built-in support and recommended actions, but require action on the part of the operator.
- Automated activities can require too many steps.
- Automation should be designed so that it is intuitive and obvious.
- Some control functions (such as Amber Alert message preparation) can require too many steps that are difficult to follow.
- A rule-based suggested contacts list helps operators identify seldom-used contacts.
- It is important to design flexibility into automation to allow a response to infrequent situations.

TMC Operator Task Complexity and Workload

- “Semi-automation” works very well in this environment—where the automation suggests a course of action and the operator accepts or revises the plan.
- It is important to assign the right people for the peak workload periods, such as storms, rush hour, and HAZMAT events.
- If a supervisor is involved, they can help to balance operator workload.
- If an operator gets overloaded, they can ask for support from an adjacent sector operator.
- The critical issue in workload is having the right number of staff for the situation.
- One discussant had high-school graduate operators, requiring a limitation in the level of job complexity.
- The basic measure of performance is the frequency that there is a response failure or a failure to publicize an incident.

Internal and/or External TMC Communications

- Staff must coordinate between internal functions and across groups.
- Notification of upper management can often be a burden that interrupts operations—this would be good candidate for automation.
- Trying to reduce shouting between consoles by co-locating operators with other staff responsible for the same geographic area.
- Operators are requesting the use of instant messaging for internal communications
- Traffic management is increasingly an information sharing function as the public has more real-time access to information.
- A substantial challenge is the lack of proactive communications of upcoming maintenance activities.

TMC Information Accuracy and Access

- There are some challenges obtaining timely information from roadway maintenance personnel.
- The quality and timeliness of 911 call information can vary substantially across the state.
- Telephone-based loop detectors sometimes fail and it takes about 15 minutes to determine whether there is a traffic incident or a telephone line failure.
- There are no issues with the reliability or quality of information coming into the center.

TMC Written Operations Procedures

- Developing clear and concise procedures that operators can use as aids during their shifts.
- Use a common language across agencies—avoid jargon, which is misunderstood.

TMC Operator Training

- Minimize the complexity of the operator interface and thereby minimize the training.
- Tailoring the training to the skills and capabilities of operators.
- Developing adequate training with limited resources.
- Training was recently shifted to a contractor and this has seemed to improve morale and reduce turn-over.
- Certification programs have been established to maintain quality and recognize capabilities.
- Operator training is provided to a broad cross-section of agency staff—this improves communications and provides back-up staff during severe weather.

TMC Operator Alertness

- What is a good facility temperature to best maintain alertness.
- Some staff occasionally work until 7PM and then return at 5AM, which can create a challenge when a work commute further reduces time available for sleep.

Alarm Presentation and Management

- It is important that alarms do not distract the operator—they should be visual only, or very low auditory volume.
- The frequency of alarms is highly variable from day-to-day.
- All alarms tend to be considered very low priority.
- There is no way to select high-priority alarms on the alarm display screen.

Critical Incidents

Discussants were asked to share past incidents when a challenging situation might have been handled more effectively if the human factors that support operational effectiveness were in place to better match operator job requirements and capabilities. Some general incidents identified and the lessons learned were:

Operator over-load in response to a freeway shut down. Important lesson was to fully understand the impact of the situation on traffic in order to determine the most appropriate response.

Incomplete communications across state borders. There were two separate incidents identified by different discussants that involved a neighboring state closing a highway without notification. One incident resulted in substantial traffic delays. The other incident occurred in a rural area without alternative routes and traffic was stopped for approximately a day without prior warning. The important lesson was cross-state communications; as well as face-to-face activities that help foster those lines of communications.

Slow response to a major accident on a downtown freeway. The delayed response occurred when the experienced staff was on a lunch break and the supervisor was on a meeting, leaving a relatively inexperienced operator with insufficient back-up. Lessons learned were to improve internal coordination of activities out of the control center and better mixing of staff on shifts.

Major maintenance work traffic delays. This was used as a positive example, where a lot of pre-planning, inter-agency communications, and live incident drills helped to reduce subsequent traffic delays.

Getting caught up in events. This discussant experienced a major bridge failure. Initial responses were appropriate, but information was not fully shared with the highway service patrol, since operators were ‘captured’ by the event. One lesson learned was that procedures were in place and operators need to be trained in dealing with such high-stress events. Another lesson learned was to make sure that a very senior and calm operator is always working each shift.

Preferred HF Guidance Content, Format, and Medium

Discussants were asked to identify their general preferences regarding the content, format, and medium of a potential revised TMC HF guideline. Following are summaries of their comments.

Content

- Provide guidance regarding the need to understand the function of the TMC before specifying its components and systems.
- Include basic features of facilities—flooring and layout.
- Address the need for a flexible facility design to accommodate future changes.
- Many areas should be well understood: screen size, number of CCTVs, monitor placement, keyboard placement, use of telephone headsets, chairs, floors, acoustics.
- Workstation ergonomics.

Format

- Providing information graphically is very important.
- The ‘wiki’ format is a good model—extensive linking is valuable.

Medium

- An electronic format that includes an intelligent search component would be valuable.
- Has a slight preference for on-line guidance, but hard-copy is also useful.
- Either on-line or CD format would provide adequate electronic functionality.
- This discussant recommended designing the guidelines to match an electronic medium and then adapt that format to the less-used print version.

Review of Alternative Guideline Styles

Discussants were provided with three example guideline styles, referred to as Text Book Style, Structured On-line Style, and Structured Two-page Style. (The specific examples provided are included in appendix B.) Following is a summary of comments pertaining to each of these examples.

Text Book Style

- This doesn’t work. The information is not accessible and it is not compatible with an electronic format.
- It is very difficult to search and digest book style information.
- This is a familiar style, but the lack of graphics and examples is a big draw-back.
- Provide graphics and hyperlinks.
- Prefer a design for web or electronic display, rather than a paper-based design.

Structured On-line Style

- Web-based media are too expensive, but useful.
- This would support an on-line search; and important portions could be printed and shared.
- This is a good design.

Structured Two-page Style

- I like this a lot (three discussants).
- This meets the need of conveying information succinctly.
- This is the best design—adapt this to a web-based format.
- Use this format, but provide a legible print-out version.

Preliminary TMC Site Visits

Informal site visits were conducted at four TMC sites: Seattle, Chicago, Northwest Washington, and Minneapolis-St. Paul. These visits were conducted to obtain first-hand familiarity with TMC facilities, organization, staffing, functions, and operations; as well as to discuss some specific human factors issues and lessons learned. The site visit protocol is presented in appendix C. Following is a brief description of each TMC and a summary of some informal observations.

Visited TMC Descriptions

Seattle Department of Transportation's Traffic Management Center currently houses traffic incident communications and signal engineering workstations. A situation wall consisting of eight large rear-projected monitors configured in two rows of four monitors provides a large, flexible, re-configurable display, which normally presents a roadway status overview map, two incident summary tables, and selected video feeds from within the Seattle area.

The center monitors the status of approximately 300 traffic signals, three variable message signs, 65 video cameras, sensor-based roadway occupancy data for selected major arterials, and incoming incident data. The incident communications workstation is nominally staffed from 7:00-9:00 AM and 4:00-6:00 PM weekdays, although interns provide additional staffing during most weekdays. The signal engineering workstation is staffed on an as-needed basis. The primary current function of the communications workstation is to monitor incident information from both 911 call summaries and a commercial incident database, and to disseminate relevant incidents through emails to Seattle DOT personnel and Seattle DOT web site postings. The primary function of the signal engineering workstation is to monitor the status of programmed signals and to make necessary adjustments to set of signals in order to reduce congestion.

Illinois State Department of Transportation's Chicago Metropolitan Area Traffic Systems Center houses the traffic operations center for the six-county metropolitan area. Separate facilities located elsewhere in the Chicago area house the regional communications and incident response centers. Traffic operations are housed in a separate control center that includes space for up to four operators and a supervisor. Individual workstations each include two or more video monitors, control devices, and telephones. The Traffic Systems Center is primarily staffed between 5:00 AM to 7:00 PM on weekdays by one or two operators and supporting technical and management staff. Operators monitor over 150 miles of public roadways, which include over 2400 detector locations, over 100 ramp controls, and over 20 variable message signs.

The primary functions of the operations center can be divided into monitoring and response functions. Operators monitor automated systems that provide real-time traffic travel time data on the web, variable message sign travel time information, and ramp metering adjustments based on roadway occupancy. Response functions include incident detection and verification through the use of video monitors; active control of variable message sign content; review, resolution, and clearing of ramp meter and video status alarms; and providing roadway usage archival data to traffic engineering.

Washington State Department of Transportation's Northwest Region Traffic Management Center includes workstations dedicated to communications, traffic flow, and public information. The center has wall displays that consist of one large rear-projected screen and approximately 24 individual video display monitors in a semi-circle around the approximately eight operator work stations and two supervisor stations.

The traffic flow group has three workstations and one supervisor station, with one workstation dedicated to detection and response to traffic incidents. Workstations are staffed from early morning through the evening commuting period. This group applies a relatively proactive approach towards responding to traffic incidents and minimizing their impact on traffic flow through the active control of variable message signs, traffic flow and incident information dissemination, 511 and radio advisory messages, ramp metering, monitoring and control of selected state roadway signals, as well as the monitoring and control of relatively new variable speed zones and variable toll lanes. Input to the traffic flow group includes 380 video cameras, an extensive network of highway occupancy sensors, freeway ramp meters, and approximately 210 roadway traffic signal status indicators.

The communications group has three operator workstations and one supervisor station. It operates on a 24/7 basis with its primary function being the monitoring, fire suppression, and control of the three area tunnels and the two floating bridges in the area; and its secondary function serving as a nighttime backup to the traffic flow group. One public information workstation is dedicated to the management of the direct video feeds made available to local media, as well as providing media messages and responding to medial queries.

Minnesota State Department of Transportation's Regional Traffic Management Center Traffic Operations is housed in a large open control center that includes six traffic operations work stations in addition to separate groups of co-located State Patrol Dispatch and Maintenance Dispatch workstations, which allows these three groups to work together to support roadway safety and travel. In addition to the individual workstations, the center has a large 'wall display, consisting of a 2X2 grid of four large digital displays surrounded by two 5X6 grids of individual video monitors that are viewable from all workstations.

The Traffic Operations unit is responsible for managing traffic on the Twin Cities metro freeways with the use of ramp meters, variable message signs, lane control signals and loop detectors. The Operations unit is staffed Monday through Friday from 5:30 a.m. to 8:30 p.m., Saturday from 10 a.m. to 6 p.m., and on Sunday from 11 a.m. to 7 p.m. The mission of the Traffic Operations unit is summed up by the three principles of Detect, Display, and Deploy.

Incident detection is supported by 911 call center incident summaries, commercial incident reporting systems, roadway occupancy detection based on approximately 4,000 loop detectors, 419 ramp meters, and 320 video cameras. Active incidents are displayed on selected video monitors, entered into an incident log, and communicated to the traveling public via the web, variable message signs, advisory radio, public radio, and dedicated commercial traffic communications channels. The primary functions of the operations center can be divided into monitoring and response functions. Operators monitor automated systems that provide real-time traffic travel time data on the web, variable message sign travel time information, and ramp metering adjustments based on roadway occupancy. Response functions include incident detection and verification through the use of video monitors; active control of variable message sign content; review, resolution, and clearing of ramp meter and video status alarms; and providing roadway usage archival data to traffic engineering.

Deployment activities may be facilitated by the Traffic Operations unit, but most of these activities are led by individuals at the co-located State Patrol Dispatch and Maintenance Dispatch workstations.

Noteworthy Informal Observations

These visits were not conducted as comprehensive operational reviews. However, during the course of the visits some noteworthy observations were made through the comparison of various aspects of operation between two or more sites. Following is a summary of some observations which may warrant closer consideration in the future.

Center functions varied along several important dimensions, including: the extent of roadway under the center’s area of responsibility, the amount of incoming sensor information, and degree to which operations extended beyond system monitoring to communicating roadway conditions and the active deployment of resources aimed at mitigating roadway congestion. This range of function was logically related to center staffing and workload.

Operator’s engagement and workload varies substantially between centers. Centers with a more limited area of responsibility, more emphasis on monitoring functions over incident management functions, and higher level of automated control tended to have operators who were not actively engaged in traffic operations management. In some cases, this was recognized as an area requiring future emphasis to more actively engage operators and manage traffic. In other cases, operators had a very fast-paced job that kept them fully engaged and required a strong aptitude for maintaining awareness of multiple ongoing situations and the status of corresponding subsystems.

Operator staffing was highly variable, as noted above. In the relatively high-paced centers, supervisors were available to assist during periods of high workload. In addition, it was observed that at one two-sector center, the two operators worked in close collaboration, dividing their surveillance and response activities in a highly fluid manner in order to accommodate real-time changes in workload and to take advantage of individual task aptitudes and preferences.

Operator training varied substantially between sites, although most sites relied primarily upon informal on-the-job mentoring and training. One noteworthy exception was one of the larger centers where other transportation center staff completed structured operations center orientation and training, and occasionally staffed workstations in order to provide a pool of qualified staff to support the highly demanding periods associated with winter storms.

Operating procedure documentation varied from next-to-none, to extensive hard-copy procedures, to a full set of formal computer-based procedures available at all workstations. This is consistent with the observed range of operator job complexity. Operators demonstrated good knowledge and ability to access both the hard-copy and computer-based procedures.

Situation 'wall' display configurations. A full range of situation wall displays were observed in this small sample, which would be expected given the wide range of center functions. However, it is also noteworthy that questions regarding the analysis that led up to the selection of the current design also revealed in a broad range of functional requirements analysis used as the basis for the selected display. Some operators could clearly benefit from guidance regarding factors to consider in defining center display requirements.

Video camera labeling and control was quite variable. In all but the smallest area of operation, some degree of disorientation by operators regarding the location and direction of individual video images was reported, either spontaneously or in response to direct questioning. This is linked to the limited labeling of video cameras; which most frequently have some form of identification (be it by identification number or location), but seldom have an indication of the direction of view (which results from the complications resulting from manual camera panning). Standard mouse, trackball mouse, and joystick control systems were observed. The real-time control capability appeared to vary substantially across centers, although this appeared to be more affected by the nature of the control hardware and software, rather than the type control device.

Incident logs were a central component of all operations. The timely entry and removal of active incidents from one or more sources or logs was seen as a critical function at all centers. However, no integrated tools to support maintaining the overall status of incidents across multiple systems were observed. That is, if multiple incident posting and removal was required, the separate system entries and logs would be managed individually. Similarly, in those cases where a central incident log was maintained, there was no system to compare incident status across information systems and highlight outdated or discrepant incidents.

Alarm display and response also varied substantially among the group of observed centers. In most cases, alarms were limited to status alarms of traffic signals, video monitors, and ramp meters. Although some centers had various alarm priorities, these appeared to have limited functional value in most cases. Alarms were often identified as representing transmission problems that did not warrant immediate attention. In reviewing alarm logs, alarms over a week old were observed at some sites. The exception to this general observation alarms having a low priority was the one group with a primary responsibility of monitoring tunnel and bridge alarms, including fire, ventilation, and fire suppression alarms. Here, alarms were actively monitored, acknowledged, and cleared on a real-time basis.

Road maintenance communications appeared to represent a significant challenge and workload requirement at some centers. The need to track road maintenance activities in real-time and update variable message signs in a timely manner was seen as a high-priority traffic safety function at those centers assigned this responsibility. However, input from road maintenance crews was very limited, resulting in substantial traffic operator workload being invested in the active tracking of activities via video monitors.

External communications required access to a large number of telephone numbers and email addresses. Both hard-copy and computer-based aids to support the identification of appropriate points of contact were observed. However, no instance of computer-based calling was observed. When questioned about this, it was either reported that system compatibility issues made computer-based telephone dialing cost-prohibitive, or it was on the list of future development activities.

Message preparation automation varied substantially across the centers. For variable message signs, one extreme involved typing-in separate messages line-by-line for each sign while the other extreme involved an easy-to-use menu-driven process for designing messages that corresponded to standard content and format guidelines. Similar differences were seen for audio 511 and radio messages, where a menu-based system could be used to quickly prepare a message that would then be compiled into a digital recording; whereas the other extreme involved manual dialing-in and voice recording of messages for each individual transmission site.

Identify Guideline Topics

Reviews of the documents listed in table 2, as well as the information obtained directly from TMC pooled-fund members were used to generate lists of "macro" topics for which human factors guidelines would be beneficial. These "macro" topics reflected critical technical elements of the TMC Guidelines, including:

- Key TMC functions
- User activities that influence TMC operational effectiveness
- HF issues that affect TMC operational effectiveness

The topics were refined and eventually became candidate chapters in our preliminary outline for a Handbook of TMC Human Factors Guidelines. In particular, we wanted each chapter to have a clear, well-defined objective that would be seen as valuable by TMC pooled-fund members. Within these chapters, specific "micro" topics reflecting (again) reviews of the documents listed in table 2, as well as the information obtained directly from TMC pooled-fund members were generated and refined.

The preliminary outline for a Handbook of TMC Human Factors Guidelines is provided in appendix D.

Develop Sample Guidelines

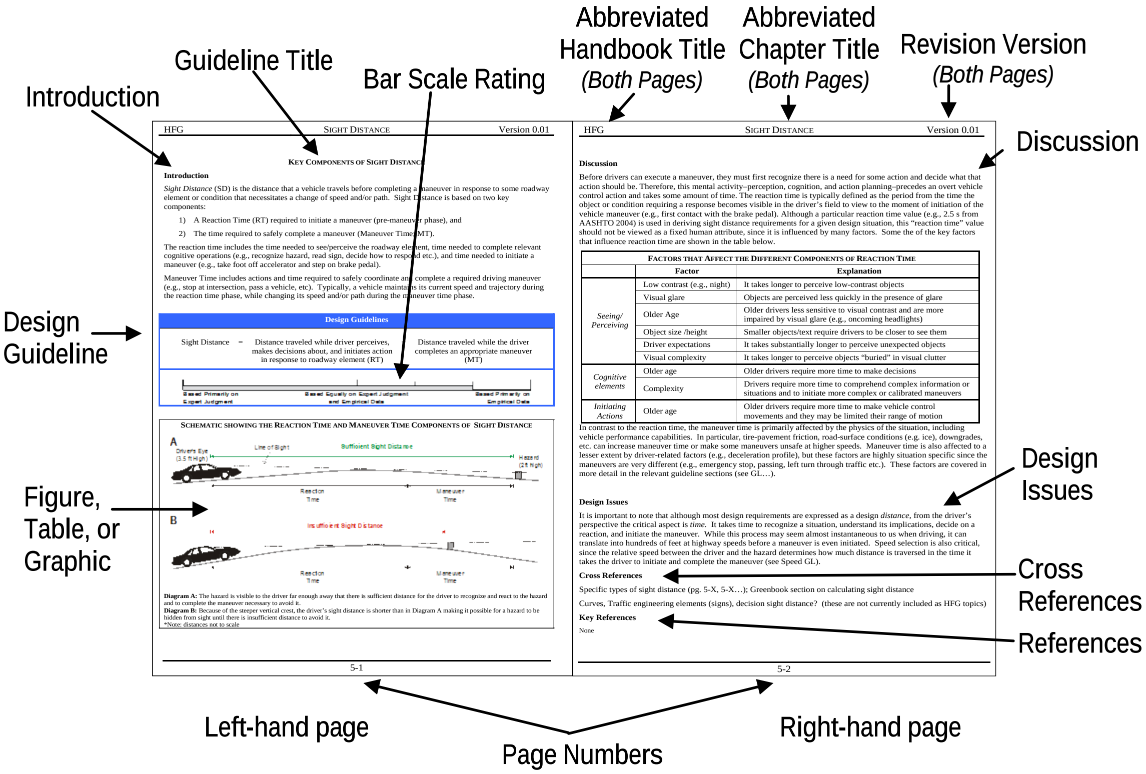
In selecting specific guidelines topics, we wanted topics that would—first and foremost—be viewed by TMC pooled fund members as useful and valuable. We reviewed our notes and findings from the questionnaire, phone-call and TMC activities and, combining these data with the lists of documents that we had on-hand from which guidelines could be developed, identified the following sample guideline topics:

- Changeable Message Signs
- Visual Display Configuration
- Video Camera Control Devices

For each of these topics, we reviewed the relevant literature and generated sample guidelines using the guideline development procedures discussed in Campbell (1995 & 1996). Several review/revision cycles were conducted with each sample guideline to insure accuracy and quality.

Importantly, the sample guidelines are only intended to illustrate the general content and format of future human factors guidelines for TMCs. The specific content of each sample is not final, and may be revised or even expanded into multiple guidelines in future versions of the TMC guidelines document. For example, the sample guideline on changeable message signs (CMSs) provides only a high-level summary of CMS topics and design principles. In the actual, future guidelines, it is very likely that the general CMS topic would be addressed in multiple guidelines covering topics such as: *When CVMS Devices Should be Used*, *Designing CMS to Influence Driver Behavior*, *Using CMS to Reduce Speeding*, and *Using CMS to Present Weather Behavior*.

Consistent with the information obtained from TMC pooled fund members, the sample guidelines were designed to be similar in form to past guidelines that we have developed for the FHWA and other Department of Transportation agencies. This guideline format is shown below in figure 1. The sample TMC human factors guidelines are provided in appendix E.



HFG SIGHT DISTANCE Version 0.01

KEY COMPONENTS OF SIGHT DISTANCE

Introduction

Sight Distance (SD) is the distance that a vehicle travels before completing a maneuver in response to some roadway element or condition that necessitates a change of speed and/or path. Sight Distance is based on two key components:

1) A Reaction Time (RT) required to initiate a maneuver (pre-maneuver phase), and
2) The time required to safely complete a maneuver (Maneuver Time; MT).

The reaction time includes the time needed to see/perceive the roadway element, time needed to complete relevant cognitive operations (e.g., recognize hazard, read sign, decide how to respond etc.), and time needed to initiate a maneuver (e.g., take foot off accelerator and step on brake pedal).

Maneuver Time includes actions and time required to safely coordinate and complete a required driving maneuver (e.g., stop at intersection, pass a vehicle, etc). Typically, a vehicle maintains its current speed and trajectory during the reaction time phase, while changing its speed and/or path during the maneuver time phase.

Design Guidelines

Sight Distance = Distance traveled while driver perceives, makes decisions about, and initiates action in response to roadway element (RT) + Distance traveled while the driver completes an appropriate maneuver (MT)

SCHEMATIC SHOWING THE REACTION TIME AND MANEUVER TIME COMPONENTS OF SIGHT DISTANCE

Diagram A: The hazard is visible to the driver far enough away that there is sufficient distance for the driver to recognize and react to the hazard and to complete the maneuver necessary to avoid it.
Diagram B: Because of the steeper vertical crest, the driver's sight distance is shorter than in Diagram A making it possible for a hazard to be hidden from sight until there is insufficient distance to avoid it.
*Note: distances not to scale

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HFG SIGHT DISTANCE Version 0.01

Discussion

Before drivers can execute a maneuver, they must first recognize there is a need for some action and decide what that action should be. Therefore, this mental activity–perception, cognition, and action planning–precedes an overt vehicle control action and takes some amount of time. The reaction time is typically defined as the period from the time the object or condition requiring a response becomes visible in the driver's field to view to the moment of initiation of the vehicle maneuver (e.g., first contact with the brake pedal). Although a particular reaction time value (e.g., 2.5 s from AASHTO 2004) is used in deriving sight distance requirements for a given design situation, this "reaction time" value should not be viewed as a fixed human attribute, since it is influenced by many factors. Some the of the key factors that influence reaction time are shown in the table below.

FACTORS THAT AFFECT THE DIFFERENT COMPONENTS OF REACTION TIME

	Factor	Explanation
Seeing/ Perceiving	Low contrast (e.g., night)	It takes longer to perceive low-contrast objects
	Visual glare	Objects are perceived less quickly in the presence of glare
	Older Age	Older drivers less sensitive to visual contrast and are more impaired by visual glare (e.g., oncoming headlights)
	Object size /height	Smaller objects/text require drivers to be closer to see them
	Driver expectations	It takes substantially longer to perceive unexpected objects
	Visual complexity	It takes longer to perceive objects "buried" in visual clutter
Cognitive elements	Older age	Older drivers require more time to make decisions
	Complexity	Drivers require more time to comprehend complex information or situations and to initiate more complex or calibrated maneuvers
Initiating Actions	Older age	Older drivers require more time to make vehicle control movements and they may be limited their range of motion

In contrast to the reaction time, the maneuver time is primarily affected by the physics of the situation, including vehicle performance capabilities. In particular, tire-pavement friction, road-surface conditions (e.g. ice), downgrades, etc. can increase maneuver time or make some maneuvers unsafe at higher speeds. Maneuver time is also affected to a lesser extent by driver-related factors (e.g., deceleration profile), but these factors are highly situation specific since the maneuvers are very different (e.g., emergency stop, passing, left turn through traffic etc.). These factors are covered in more detail in the relevant guideline sections (see GL…).

Design Issues

It is important to note that although most design requirements are expressed as a design *distance*, from the driver's perspective the critical aspect is *time*. It takes time to recognize a situation, understand its implications, decide on a reaction, and initiate the maneuver. While this process may seem almost instantaneous to us when driving, it can translate into hundreds of feet at highway speeds before a maneuver is even initiated. Speed selection is also critical, since the relative speed between the driver and the hazard determines how much distance is traversed in the time it takes the driver to initiate and complete the maneuver (see Speed GL).

Cross References

Specific types of sight distance (pg. 5-X, 5-X…); Greenbook section on calculating sight distance

Curves, Traffic engineering elements (signs), decision sight distance? (these are not currently included as HFG topics)

Key References

None

5-2

Figure 1. Presentation format used in past Battelle guideline efforts.

Recommendations

The recommendations from this project include:

- An overall approach for developing a comprehensive TMC guidelines document.
- A recommendation regarding the development of a web-based version of the guidelines.
- A recommended outreach plan to inform city, county, and state DOTs about this work.
- An outline of proposed Guideline topics/table of contents.
- Three sample TMC human factors guidelines.

Each of these recommendations is presented and discussed below.

Approach for Developing a Comprehensive Guidelines Document

Campbell (1996) summarizes the importance of a systematic approach to the development of human factors guidelines and describes such an approach. For the TMC Human Factors Guidelines in particular, the increasing complexity of TMC operations and the consequent demands that are placed on operators and supervisors underscore the importance of providing TMC staff with valuable human factors information. Without human factors guidelines tailored to the TMC design and operational environment, TMC planners and TMC staff may: (1) make false assumptions regarding operator or driver characteristics, (2) consult existing human factors reference sources that are inapplicable to TMC design (e.g., military human factors standards for human information processing that do not reflect the visual characteristics or decision-making behavior of older drivers), (3) develop their own "human factors" guidelines based on their individual experiences and biases, or (4) simply ignore human factors considerations altogether.

The variety of topics that will be included in a Handbook of TMC Human Factors Guidelines, as well as the non-uniformity of data sources relevant to candidate topics, preclude any precise and invariant description of the development process associated with guideline development. However, while the precise process associated with developing each guideline will be topic-specific, the general procedures will include a combination of *integrative review* and *analytical activities*. In general, an *integrative review* summarizes previous research or existing information by aggregating the results of a number of similar data sources. With respect to a specific guideline topic, this means that the results, recommendations, or guidelines from reviewed data sources will be qualitatively compared, contrasted, and perhaps combined. To the extent that goals (or research methods) are similar, relatively consistent results/recommendations will provide strong direction for the formulation of the guidelines contained within the new chapters. However, with inconsistent methods and/or results, the goals, theoretical orientations, methods, and results of data sources must be considered more carefully. In the case of true inconsistencies (i.e., those for which there is no apparent methodological reason for the differences in results), descriptions of primary sources, expert judgment, design convention, or a description of opposing viewpoints will form the basis for final guideline content.

The term "*analytical activities*" is used here to describe the general task of reducing all guideline development process inputs to intelligible and interpretable form. These activities will include categorizing, ordering, manipulating, and summarizing the sources reviewed. The analytical component of the design objective development process can be characterized as the method by which the more “objective” inputs (integrative review, quality, applicability) are combined with the more “subjective” inputs (human factors heuristics, expert judgment) to formulate the final guideline content (c.f., Campbell, 1996). In order to formalize the integrative review and analytical activities to the extent possible, we propose to derive the guideline content from the data sources having the greatest quality and applicability. As appropriate, the guidelines will be supplemented with constraints, trade-offs, caveats, exceptions, and special human performance issues.

The general approach to developing guidelines is shown below in figure 2.

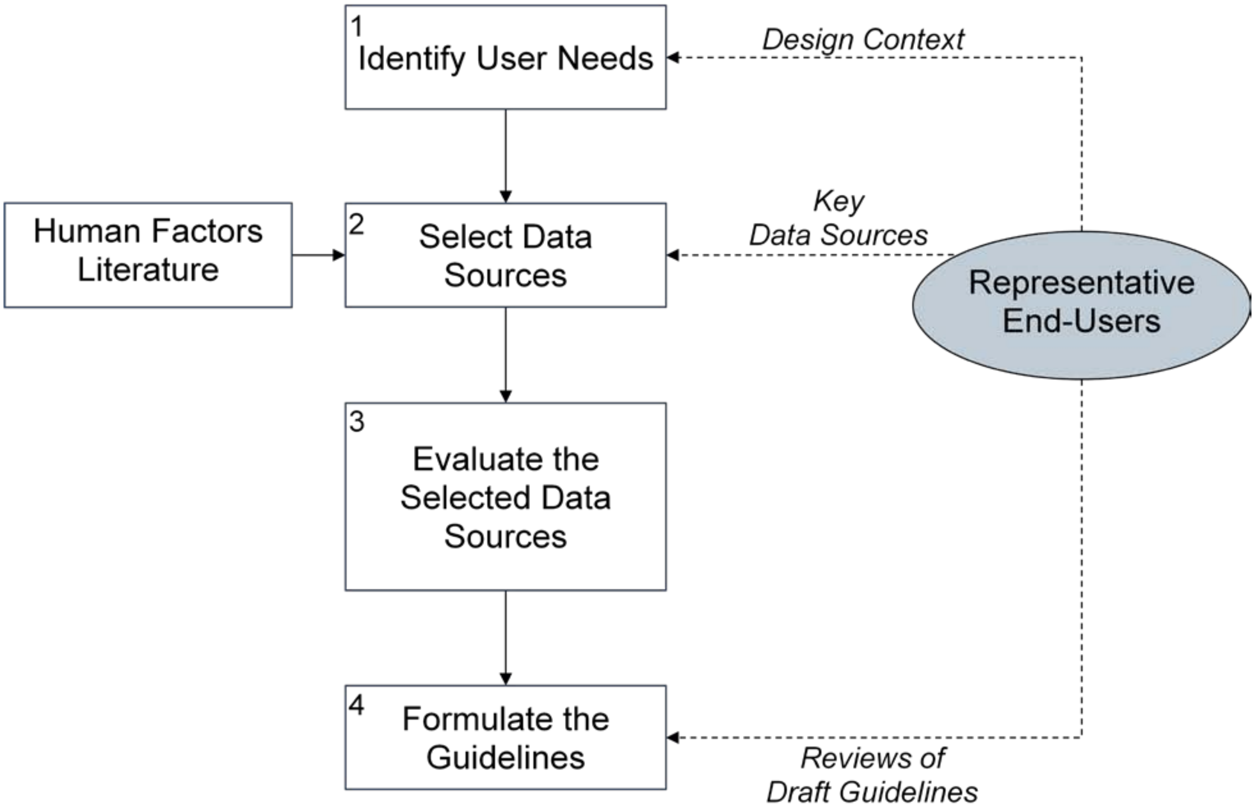


Figure 2. General procedures for developing human factors design guidelines.

The next phase of this effort should include the following tasks:

- Prioritize topics and identify chapters targeted for completion in this phase through a survey of end-users
- Conduct detailed literature searches and develop summaries of research findings in key topic areas
- Develop annotated outlines for future guidelines
    - Should include: purpose of guideline, ideas for graphics, key references and findings, special issues

- Develop the TMC HF guidelines; develop and distribute draft versions, revise to reflect TMC pooled-fund member comments and suggestions

Approach for Developing a Web-based Version of the Guidelines

The process of preparing the Web-based version will be divided into five main subtasks as follows:

- Design the Web-based version
- Prepare a Web-specific Word version of the Handbook of TMC Human Factors Guidelines for conversion to HTML
- Implement the Web-based version as designed
- Test the Web-based version
- Review and revise the Web-based version

Each of these subtasks is described below and includes the major steps that are required to accomplish each subtask.

Design the Web-based Version

The objective of this subtask is to design the Web site structure and user interface, including navigation strategies, general content layout, and overall look and feel. Also, the file structure for storing and presenting documents will be determined in this subtask. Finally, this subtask includes preparing a mock-up or demonstration Web site for approval by TMC pooled-fund members.

Existing guideline document Web sites developed by Battelle for the U.S. DOT provide examples of a general “look and feel” that supports the user-requirements and preferences of a similar target-user population (the automotive engineering and design community). These specific sites include human factors guidelines for Advanced Traveler Information Systems (http://www.fhwa.dot.gov/tfhrc/safety/pubs/atis/index.html) and in-vehicle icons (www.tfhrc.gov/safety/pubs/03065/index.htm).

Determine strategy for Web site structure and format. In this step, the Project Team will define the overall look and structure of the Web site. Some elements that will be included in this plan are:

- Use of frames vs. navigation bar on each page.
- Fixed-width vs. variable-width page layout.
- Navigation strategies.
- Discrete pages for each guideline vs. pages with full sections that have inline bookmarks for each guideline.
- Content to be included in document templates (e.g., “previous” and “next” navigation hyperlinks, header/footer, etc.).

Design file-name and maintenance protocols. In this step, the Project Team will establish a workable file naming protocol in order to easily identify individual files within the file structure by name. The names will be brief, have no spaces, and will describe the location of the file within the file structure or Web site. This step will also include the design of a protocol for tracking the creation, maintenance, and testing of the Web site pages. Methods for tracking hyperlinks will also be included.

Develop Web site map. In this step, the Project Team will develop a site map for the Web site. This site map will be presented in the form of an organizational block diagram identifying the relationships between pages and frames in the Web site. The site map will include a definition of the file structure, which will determine how the various files for the Web pages and their associated graphics, style sheets, and other elements are stored. Each block in the diagram will include the file and directory names and will be connected to other blocks in the diagram according to hyperlink relationships.

Prepare demonstration for approval. Before implementing the Web site design, the Project Team will present the overall design to the TMC pooled fund members for review and approval in the form of a demonstration Web site that represents a small portion of the document. The demonstration will include the top-level Web page and will drill down to the lowest level for one guideline. The user interface will include enough information in the menu frame or panel to provide a clear demonstration of how the interface will work. The implementation of the demonstration Web site will necessarily entail performing at least a subset of each of the subtasks outlined below.

Prepare Web-specific Word Version of the TMC Guidelines

This section describes the specific steps the Project Team will perform to prepare a Web-specific Word version that can be converted into HTML in a form that requires the least amount of subsequent alteration. The description of each step includes the rationale for performing the step. Note that many of these steps outlined are related to a specific set of software tools used to prepare the Word document for conversion to HTML (Adobe® DreamWeaver®, CorelDraw®, and WC3 HTML Validator®), and that these steps may be different if a different approach is used.

Apply styles to text. In this step, the Project Team will assign either custom or standardized styles to the text in the document as is appropriate. Conversion from Word to HTML can be greatly facilitated by applying the appropriate styles to body text and other elements that require specific formatting. Text that is formatted with user-defined styles usually retains its formatting after conversion and filtering. Also, standardized heading and body text styles can reduce the time and effort required to convert the document to HTML and generally produces superior HTML code. Specifically, headings that are tagged with standard heading styles (i.e., Heading 1, Heading 2, etc.) are converted to HTML heading tags. Also, the standardized style for producing Web-oriented body text produces the most efficient code, which reduces error in editing the HTML, facilitates making global changes, improves accessibility, and improves performance when loading the finished page. If the appearance of the Word heading or body text styles is inappropriate for the document, the related style will be modified to reflect the desired formatting.

To maximize readability on high resolution screens, most fonts will be set to 12 point Arial style. Because the limitations of page size are somewhat relaxed in Web-based documents, text that is required to be small on the hard-copy page may be larger on a Web page. Also, Web pages that use san-serif fonts are easier to read than those with serif fonts (Slatin & Rush, 2003, p. 505).

Adjust tables. In this step, the Project Team will adjust tables for layout formatting. The change in font size and style in Step *Apply styles to text* may require some adjustment of column widths in tables to accommodate the larger type when changing the font size to 12 points. The Project Team will make the required adjustments to ensure the quality of appearance and consistency.

To facilitate conversion to HTML, it is recommended that table header rows be set to "repeat at header row top of each page." Tables with header rows that include this setting are automatically given table header tags when converted to HTML. A significant amount of time and expense can be saved by performing this step in Word (where it is easy to locate and change this parameter) rather than in the HTML editor.

Convert text boxes to layout tables. In this step, the Project Team will convert any text boxes in the document to layout tables. The contents of text boxes—including text—are converted to graphic elements when the document is converted to HTML. Textual information does not appear as visually appealing and may be difficult to read for some users when presented as a graphic. The exception to this step relates to equations contained in text boxes. Some internet browsers may have difficulty accurately displaying equations; therefore, equations will be converted to graphic images for presentation on the Web site.

Modify bullets and numbered lists. In this step, the Project Team will modify any bullets and numbered lists to ensure conversion of the list to appropriate HTML markup. Bulleted lists may not convert properly to HTML, depending on the style that is applied to the bulleted items. In many cases, the converted HTML will include a circle symbol followed by spaces, and the left margins will not align properly. Similar margin alignment problems can occur with numbered lists. Manual reapplication of numbers and bullets will ensure that the correct HTML markup for lists is generated and that the margins will align properly.

In addition to modifying lists within the text, the Project Team will remove automatic numbering from headings and manually provide heading numbers. Hard-coding of heading numbers is required because automatic numbering in headings generally do not survive the conversion to HTML.

Implement the Web-based Version

In this subtask, the Project Team will implement the Web-based version based on the design in Subtask Design the Web-based Version. This process will include preparing the directory structure, document templates, and blank pages and then populating the blank pages with content. In order to provide a workplan with sufficient details for determining required project cost and hours, a particular process was specified.

Create Web site directory structure and templates. In this step, the Project Team will create folders for all documents and support files based on the file structure defined in Step *Develop Web site map*. In addition, templates will be prepared for any frames used and for the Web pages. If the document design described in Step *Determine strategy for Web site structure and* *format* requires the use of frames, the main frame template will be developed using an HTML editor. If the document requires an overall template, it also will be prepared in this step. Finally, templates will be developed for the document pages as required by the design in Step *Determine strategy for Web site structure and format*. Templates will contain editable and non-editable regions in order to allow changes that are specific to the individual Web page but prevent the inadvertent alteration of common, fixed elements.

Create blank Web pages. In this step, the Project Team will create a blank Web page from the appropriate template for each page in the Web site. The blank page will be saved with a name that is based on the naming protocol developed in Step *Design file-name and maintenance protocols*, and at the location in the file structure that is specified for that file as determined in Step *Develop Web site map*.

Insert content into pages. In this step, the Project Team will convert the content in the Word document to HTML. One method for accomplishing this is to save the Word document as a filtered Web page and then edit the result. There are significant problems, however, with using this method. Specifically, the HTML content must be broken into individual Web pages that comprise the Web site and the resultant code requires substantial alteration to fix elements such as bullets, numbering, and tables.

A more efficient way to import the content from the Word document is to cut sections of content from the Word document and paste them into the appropriate Web page. This method offers several advantages over saving the document as a filtered HTML file.

- The import filter for cut and paste produces HTML code that is substantially more accessible than when saved in Word as an HTML file.
- The process of placing the content into Web pages is more intuitive and less error prone than breaking one large HTML file into multiple pages.
- The time required to make the conversion is reduced.

Steps for inserting content into the pages include importation of the content into each Web page and filtering the resultant HTML markup to remove residual Word-specific code.

Prepare hyperlinks. In this step, the Project Team will prepare all of the hyperlinks. After the Web pages are created, the hyperlink from the main menu to the individual pages will be created. In addition, hyperlinks in the individual pages will be altered from the template defaults to their respective locations. The creation of each hyperlink will be recorded according to the tracking protocol defined in Step *Develop Web site map*.

Optimize graphics and layout. In this step, the Project Team will optimize the graphic images presented in the Web pages. Often, graphics in Word documents do not convert well in the final HTML document, particularly graphics that were originally created in Windows metafile (.wmf) format. To provide a set of acceptable images, the original graphics often need to be converted and sized in an auxiliary program and inserted into the folder for the support files of the HTML document. Any graphic image that is considered unacceptable will be made presentable through this process.

In addition to optimizing all graphic images, any layout or formatting issues that are not consistent with the overall document appearance will be resolved in this step.

Test the Web-based Version

This subtask includes an exhaustive test of the Web-based version once all pages have been created. The Project Team will verify all Web site content, test all hyperlinks, and verify graphics. In addition, the Project team will validate the HTML code for compliance with standards for HTML markup developed by the World Wide Web Consortium (W3C).

Validation of document content. In this step, the Project Team will verify that each Web page contains exactly the document content that is intended for the page (i.e., contains all intended content and no other). To accomplish this, the content of each Web page will be compared to the paper-based document. In addition to the verification of informational content, the formatting will be checked for overall consistency, including the correctness of bullet placement and style, numbering of lists, font style and size, table column widths, etc.

Test all hyperlinks. In this step, the Project Team will test every hyperlink to verify that it points to the appropriate location. Each hyperlink will be verified against the hyperlink design from Step *Develop Web site map*, and recorded according to the hyperlink tracking protocol. Broken links or links that navigate to the wrong page will be repaired in this step.

Verify correctness of graphics. In this step, the Project Team will cross-check the graphics on each page against the paper-based document to make sure that the correct graphics are in place and that graphics are clear and readable. Graphic images that are overly pixilated, fuzzy, or have jagged edges will be optimized per Step *Optimize graphics and layout*.

Validation of HTML markup. In this step, the Project team will verify that the HTML code conforms to standards developed by the W3C. Each Web page in the site will be tested using the W3C’s Web-based markup validation tool. Any code that does not meet W3C standards for HTML will be repaired in this step.

Review and Revise the Web-based Version

After the Web version has been completed, the Project Team will present it to the TMC pooled fund members for review. In this task, the Project Team will make any revisions or alterations requested by the TMC pooled fund members following this review. The scope of this task largely depends on the number and type of changes to the Web version that the TMC pooled fund members recommend. Minor changes can be made in an HTML editor. Large changes may require alteration of the Word document and re-importation of the affected pages into the Web page. The most efficient course of action will be decided on a case-by-case basis.

Because the overall layout and Web site design will have been approved by the TMC pooled fund members in Step *Prepare demonstration for approval*, we expect that the majority of revisions will be minor and not require extensive modification. In any case, all changes will be tested according to the requirements in Task *Test Web-based Version*. The final web-based version will reflect both the TMC pooled fund members’ comments on the draft version.

Outreach Plan to Inform City, County, and State DOTs about the Guidelines

Developing and implementing an outreach plan for the TMC Human Factors Guidelines reflects larger goal of *attracting*, *engaging*, and *involving* the TMC community in the on-going process of developing, using, and improving the guidelines.

Our past experience in developing human factors guidelines strongly suggests that there is a need to be proactive about making the user community aware of the TMC guidelines and making it easy for users to access and use the guidelines as they are being developed. Thus, a *user-centered approach* should guide the development and implementation of any outreach activities. With regards to our past Advanced Traveler Information Systems and Commercial Vehicle Operations (ATIS/CVO) guidelines developed for the FHWA, real “saturation” within the ATIS/CVO design community was achieved only when the web-based version of the ATIS/CVO guidelines was made available to everyone. The rapid transition from hardcopy to electronic form for the ATIS/CVO project can serve as a useful model for the TMC guidelines.

The *user-centered* approach will translate into the future engagement of the targeted TMC Guidelines users through the definition, design, implementation, and assessment of individual outreach efforts. Based on our experiences in past guideline projects, we anticipate that any number of outreach methods may be needed in order to properly engage and inform the larger TMC guidelines user community. These methods include:

- Workshops (at the Transportation Research Board (TRB) annual meeting or other venues).
- Conference presentations.
- Journal articles.
- Presentations to State or Regional DOT meetings/gatherings (e.g., American Association of State Highway and Transportation Officials (AASHTO) meetings).
- Symposiums at select State DOT gatherings with interest in the TMC guidelines
- Websites and web-based forums.
- E-mail the TMC guidelines directly to State DOTs.
- Provide links to the TMC guidelines on AASHTO, TRB, or other relevant websites.

Even a cursory review of these methods reveals that there is no single outreach method that minimizes cost and time, while maximizing outreach efficacy. Indeed, all of the methods have their limitations and none—in isolation—provide a high likelihood of success.

To augment these outreach activities the TMC pooled fund members should develop short 1-2 page flyers, brochures, etc. that describe the TMC guidelines project and products. These can be distributed at meetings and conferences—at both the state and federal levels—to heighten awareness of the project. The project can also be discussed in relevant TRB, AASHTO, and DOT newsletters.

With the outreach activities listed above, workshops, journal articles, presentations, and web-based forums could draw from the same basic set of materials provided to the TMC pooled fund members as products from funded projects, and would therefore be available at a relatively low cost overall. While each of these outreach methods is limited to a relatively narrow portion of the TMC end-user community, they might—together and across a timeframe of 18-24 months—reach a majority of the user community. E-mailing the TMC guidelines and providing links to the effort on relevant websites are simple, low-cost outreach methods and, because they would be targeted specifically to end-users, can be expected to at least provide the guidelines themselves to city, county, and state DOTs.

Intended Audience

The intended audience of the outreach efforts should be city, county and state DOTs—especially those organizations and individuals responsible for the design and operations of TMCs. Outreach activities should also be directed at these entities, as well as professional organizations and government organizations such as the FHWA, AASHTO, and TRB.

Outreach materials may also be of interest to those responsible for developing human factors guidelines for use by both human factors and non-human factors practitioners on other system design topics.

Specific Information Needs Being Met

Collectively, the outreach activities and materials should provide the following information:

- Objectives of the Handbook of TMC Human Factors Guidelines.
- Benefits and limitations of the Handbook of TMC Human Factors Guidelines.
- Content and format of the Handbook of TMC Human Factors Guidelines.
- Ways to use the Handbook of TMC Human Factors Guidelines.
- Development procedures and timeframe for the Handbook of TMC Human Factors Guidelines.
- Case studies, sample problems, areas of application, success stories
- How user involvement has impacted the Handbook of TMC Human Factors Guidelines and its development.
- Ways that end-users can participate in the Handbook of TMC Human Factors Guidelines development process.
- Names and contact information for Handbook of TMC Human Factors Guidelines points-of-contact.

Methods for Preparing the Outreach Materials

As noted above, we believe that much—though not all—of the outreach materials for workshops, journal articles, presentations, and web-based forums could draw from the same basic set of deliverables from projects funded to develop the Handbook of TMC Human Factors Guidelines. Workshops and web-based forums, due to their interactive nature, might require the development of additional materials. All outreach materials could be developed as part of on-going development projects funded by the TMC pooled fund effort.

Methods for Assessing User Satisfaction / Success of the Outreach Approach

Upon implementation of any outreach plan, it is critically important that the success of the plan be assessed on a regular basis. The FHWA and the TMC pooled fund effort should vigorously seek out honest, objective feedback from practitioners and others on the value and utility of the products developed in this project. Key methods for measuring the success of the TMC guidelines, and of associated outreach activities include the following:

- *Evaluation of the Handbook of TMC Human Factors Guidelines by the user-community.* Since the primary results from this project have both an intended use and an intended target audience, perceptions, case studies, and feedback from the user-community will be key to determining whether or not the TMC guidelines are a success. User evaluations on the overall value of the guidelines, the value of individual chapters, and feedback on where and how often the products from this research have been used, will provide useful information on the progress and consequences of implementation.
- Objective indices of interest and application. These could include:
  - Number of workshops, presentations, and web-forums provided on the TMC guidelines within a particular time period—such as 18-24 months from when implementation of the outreach plan begins. Attendance at these events should also be included as outcome measures.
  - Number of journal or conference articles published.
  - Number of download requests for the TMC guidelines from the various websites hosting a link to the document, as well as the nature (domain, connect time, content viewed) of web site "hits."
- *City-, County-, and State-level application of the Handbook of TMC Human Factors Guidelines.* The results from this research provide limited benefits if not applied at the city, county and state levels, given their respective responsibilities for roadway design. Following completion of the project, its success could hinge on the number of states actively using the Handbook of TMC Human Factors Guidelines to design and operate TMCs.

Proposed Guideline Topics/Table of Contents

The preliminary outline for a Handbook of TMC Human Factors Guidelines is provided in appendix D.

This outline reflects:

- Reviews of the documents listed above in table 2.
- Information obtained directly from TMC pooled-fund members that was used to generate lists of "macro" topics for which human factors guidelines would be beneficial.

- Topics relevant to critical technical elements such as:
  - Key TMC functions.
  - User activities that influence TMC operational effectiveness.
  - HF issues that affect TMC operational effectiveness.

Sample TMC Human Factors Guidelines

The sample TMC human factors guidelines are provided in appendix E; they consist of sample guidelines for:

- Changeable Message Signs
- Visual Display Configuration
- Video Camera Control Devices

As noted above, the sample guidelines are only intended to illustrate the general content and format of future human factors guidelines for TMCs. The specific content of each sample is not final, and may be revised or even expanded into multiple guidelines in future versions of the TMC guidelines document. For example, the sample guideline on changeable message signs provides only a high-level summary of CMS topics and design principles. In the actual, future guidelines, it is very likely that the general CMS topic would be addressed in multiple guidelines covering topics such as: *When CVMS Devices Should be Used*, *Designing CMS to Influence Driver Behavior*, *Using CMS to Reduce Speeding*, and *Using CMS to Present Weather Behavior*.

References

Campbell, J.L. (1995). Development of human factors design guidelines: Science and art. In A.C. Bittner, Jr. & P.C. Champney (Eds.), *Advances in Industrial Ergonomics and Safety VII* (pp. 105-112). London: Taylor & Francis.

Campbell, J.L. (1996). The development of human factors design guidelines. *International Journal of Industrial Ergonomics, 18*(5-6), 363-371.

Slatin, J.M. and Rush, S. (2003). *Maximum accessibility.* Boston: Addison-Wesley.

Appendix A.
Initial Information Collection Form

Requirements for Transportation Management Center (TMC) Human Factors Guidelines

Initial TMC Pooled Fund Member Information Collection Request

Introduction

Traffic management centers are increasing in number and are receiving significant upgrades to respond to growing congestion in the roadway system, including the introduction and integration of automated and intelligent systems to assist decision making and to control traffic. This growing reliance on automation raises Human Factors issues regarding how traffic management operators interact with automation and what kind of environment is necessary for their work to be performed effectively. The success of TMC operations ultimately depends on the human operator, whose capabilities and limitations must be integrated into the design and operation of the TMC.

The objective of this project is to provide a detailed description of what a comprehensive HF guidelines document for TMC operators, designers, managers, and supervisors would cover and how it would be structured. This effort is building upon the *Preliminary Human Factors Guidelines for TMCs* developed in 1999.

One of the initial steps in defining the requirements for TMC Human Factors guidelines is the collection of background information from pooled fund members so that the guidelines can be developed to meet your requirements.

Initial Background Questions

Responses to the following initial questions are requested from all pooled fund members who are being contacted. Your responses to these questions will be reviewed and the project team will be contacting a subset of respondents in the near future for follow-up clarification and elaboration of your initial responses.

The following questions have been formatted to allow you to download a Word version of the document, provide your input, save the document file, and then return it to your point of contact.

1. Your Name: _____
2. Your Organization: _____
3. Your TMC Affiliation: _____
4. Your Position/ Title: _____
5. Your Contact Information:

Phone: _____

Email: _____

6. Please check all responsibilities that apply to your position:
   - ☐ TMC equipment specification
   - ☐ TMC work space specification or design
   - ☐ TMC operations definition
   - ☐ TMC operations management/ supervision
   - ☐ Other: _____

7. Who do you see as being the primary users of the guidelines? (Please number all potential users, with “1” indicating the primary user, “2” indicating the secondary user, etc.).

   _____ TMC Hardware Developers
   _____ TMC Software Developers
   _____ TMC System Integrators
   _____ TMC Development Managers
   _____ TMC Operations Managers/ Supervisors
   _____ Other users

8. What are the specific Human Factors issues or topics that affect TMC operational effectiveness? ((Please review the partial list below, add any additional items that you consider important, and then number all relevant issues/topics, with “1” indicating the primary issue/topic, “2” indicating the secondary issue/topic, etc.).

   _____ Task Complexity and Workload
   _____ Displays and Controls
   _____ Communications
   _____ System Information Accuracy and Access
   _____ Written Operations Procedures
   _____ Alarm Presentation and Management
   _____ Operator Training
   _____ Operator Alertness
   _____ Automation Design
   _____ TMC Design and Staffing
   _____ Other: _____
   _____ Other: _____
   _____ Other: _____

9. Are you currently using any Human Factors standards or references to support your role in TMC design and/or operations?

   ☐ No

   ☐ Yes (If Yes, please indicate the standards or references used below)

   _____

   _____

   _____

10. How do expect to use a final TMC Human Factors Guidelines document in your job? (please check all that apply)

    ☐ A general reference on human factors topics

    ☐ A specific reference on important TMC Human Factors topics

    ☐ A design handbook that can help guide the design and development of a new TMC

    ☐ A design handbook that can help guide the re-design and development of new TMC elements

    ☐ Other: _____

11. Which of the following do you think are important characteristics of an effective final TMC Human Factors Guidelines document? (please check all that apply)

    ☐ References to authoritative publications

    ☐ Pictures and graphics that help illustrate important concepts

    ☐ Hard-copy versions of the guidelines

    ☐ Electronic format of the guidelines

    ☐ Other: _____

Appendix B.
TMC Follow-up Discussion Questions

TMC Information Collection Follow-up Protocol

The following is a general discussion protocol that was tailored for each discussant prior to the telephone call.

Background & Introduction

The growing reliance on automation in TMCs raises Human Factors issues regarding how traffic management operators interact with automation and what kind of environment is necessary for their work to be performed effectively.

The success of TMC operations ultimately depends on the human operator, whose capabilities and limitations must be integrated into the design and operation of the TMC.

In support of the Pooled Fund Study, Battelle is conducting this scoping study to develop a detailed description of what a comprehensive Human Factors guidelines document for TMC operators, designers, managers, and supervisors would cover and how it would be structured.

We recently distributed an initial information collection form that was completed and returned by 19 Pooled Fund Study members.

This follow-up discussion is being held to better understand:

- *The ways in which Pooled Fund Study members influence the design and operation of TMCs;*
- *Some of the critical challenges that you may face in supporting TMC operational effectiveness;*
- *Some of the particular aspects of human factors that you think affect the effectiveness of TMC operations; and*
- *How you think a Human Factors Guidelines documents could best support you in supporting TMC operational effectiveness.*

Respondent Information

Name:	
Job Title:	
Organization:	
Work Location:	
Telephone:	
Email:	

Descriptions of activities affecting TMC operational effectiveness

You've listed your Position/Title as __________________. Could you please describe your specific responsibilities and activities that directly affect TMC design and/or operations?

Human Factors Affecting TMC Operational Effectiveness

The earlier survey listed 10 general human factors areas that could potentially affect TMC operational effectiveness.

*In your response, you identified several of these as affecting TMC operational effectiveness. Specifically, (**check those mentioned**).*

Could you describe specific challenges related to each of these human factors topics that you face in your job in ensuring TMC operational effectiveness?

	TMC Facilities Design and Staffing
	TMC Workstation Displays and Controls
	The Design of Automated TMC Functions
	TMC Operator Task Complexity and Workload
	Internal and/or External TMC Communications
	TMC Information Accuracy and Access
	TMC Written Operations Procedures
	TMC Operator Training
	TMC Operator Alertness
	Alarm Presentation and Management
	TMC Design and Staffing

Critical Incidents

One useful way to gain an understanding of the requirements of supporting effective TMC operations is to review specific instances where a challenging situation might have been handled more effectively if the human factors that support operational effectiveness were in place to better match operator job requirements and capabilities.

Can you think of a specific instance when the TMC's response to a situational challenge was less than optimal, due to one or more human factors—that may have either resulted in the TMC staff not having the information, procedures, tools, or facilities that would have better supported their performance?

If so, could you describe:

- *The situation;*
- *What an optimal response to the situation would be;*
- *How the operator's response was less than optimal; and*
- *How limitations in information, procedures, tools, or facilities, or other factors contributed to the less-than-optimal performance.*

In many instances, critical incidents have been the catalyst for identifying new requirements and/or implementing changes in the TMC. Can you think of such an example in your experience? If so, what was the lesson learned?

Human Factors Guidance Experience

In your response, you noted that you

- ☐ Have
- ☐ Have not

used any human factors guidance in your work with TMC design, equipment, or operations.

Could you expand on your earlier response; either in regards to how you identified relevant HF guides, what you found useful, and/or why you haven't used any guides in the past?

One specific question we'd like to ask is whether or not you are familiar with the Preliminary HF Guidelines for TMCs published by the FHWA in 1999, and, if so, why you have not used them to support your activities that affect operational effectiveness.

Preferred HF Guidance Content, Format, and Medium

The responses to the earlier information collection form were pretty clear with respect to the preferred content, format, and medium of a TMC Design Guide.

In a nutshell, the most important purpose of a HF Guide was identified as supporting the re-design and development individual TMC elements; but nearly half of all respondents also saw value in a Guide serving as a reference on HF topics related to TMC design, and as a basic guide in the design of new TMCs. Do you have anything you'd like to add on these findings?

Respondents also favored a range of formats and mediums, with electronic formats that included graphical representations of concepts and the inclusion of references to authoritative publications as important elements.

Do you have anything you'd like to add on these findings?

Review of Alternative Guideline Styles

I'd like to review three example guideline styles with you and obtain your input regarding each of them.

The three examples are:

- *Text Book Style;*
- *Structured On-line Style; and*
- *Structured Two-page Style.*

I've provided examples of each of these styles for your review.

Obviously, we will need to address topics and organization at a later date, but for now, we thought that it would be useful to consider general style requirements and preferences.

Keeping in mind how you might use a future TMC human factors guidelines document, how would you evaluate each of the three example styles with respect to:

- *Providing the detail of human factors information that would meet your needs.*
- *Explaining the concepts underlying the human factors guidance.*
- *Explaining the evidence supporting the human factors guidance.*
- *Explaining how to apply human factors information.*

Example 1 – Text Book Style

CHAPTER 8: DISPLAY DEVICES

CONTENTS

8.2 Visual displays

The bulk of numerical, spatial and system condition-related information is presented to operators using visual displays. Visual display systems in a modem control center encompass a range of technologies from simple signs to complex digital and screen displays. Care must be taken to select or design display types and formats to meet the requirements of the task. Selection of a visual display mode should be based on three fundamental criteria:

- The type of information to be displayed (map information, sensor status, VMS messages).
- The degree of operator interaction (advisory, integrated control, etc.)
- The workspace conditions (lighting, distances, etc.).

The discussions and guidelines that follow provide criteria for selecting and specifying the configuration of visual displays.

Specifying visual displays requires some understanding of the principles that underlie light and vision. A visual display must meet certain guidelines with respect to the *amount* of light, its *quality*, and the configuration.

This section deals exclusively with the characteristics of visual displays. A general treatment of light in the workspace is found in Chapter 9. Discussions of color and other human/computer interface issues are in Chapter 11.

8.2.1 Pictorial displays

Most TMC’S employ large-scale maps, situation boards, and other information displays of significant size, designed to be viewed from a distance. Such designs should be guided by two fundamental considerations: (l) *what information does the user need, and (2) how should that information best be presented?* (101)

Example 1 – Text Book Style, continued

Big board displays are configured to provide an overview of the highway system map and infrastructure that can be observed by most or all operators. These displays usually are one of three types:

- **Static wall maps.** Often displayed as "wallpaper" maps in the TMC, these are generally less useful than displays that show changes in traffic or system status. Within a fairly short time, most operators master the layout of the highway system under TMC management, and the static map quickly becomes more decorative than informative.
- **Dynamic wall maps.** These map displays show changing status information such as traffic volume or signal status by colored lights. These may not be cost effective in small TMC's; however, at larger and more complex facilities where coordination among operators is important, these maps are said to be useful for maintaining situational awareness.

A disadvantage of such displays is that, because of the complex electrical circuits, they are difficult and expensive to produce and maintain. Map changes typically involve cutting a hole in the map, patching it, and drawing in the revisions. These maps are often not updated with changes in tile infrastructure. One innovative system in which the roadway map is computer-printed on a matrix of small plastic tiles provides a partial solution. Map changes require only that the outdated tile be popped out of the matrix and an updated tile popped into the empty spot to replace it. This approach is commonly used by the railroad industry in the United States.

- **Projection television screens.** These displays are increasing in popularity and have the advantage of being easier to change than fixed dynamic displays. Anything that can appear on a computer or closed-circuit television monitor can be displayed on a projection television monitor. However, limitations in resolution make finer details more difficult to discern. In addition, maintenance and electro-optical adjustment are frequently necessary. (75)

General guidelines. The following approaches are recommended for large-scale displays:

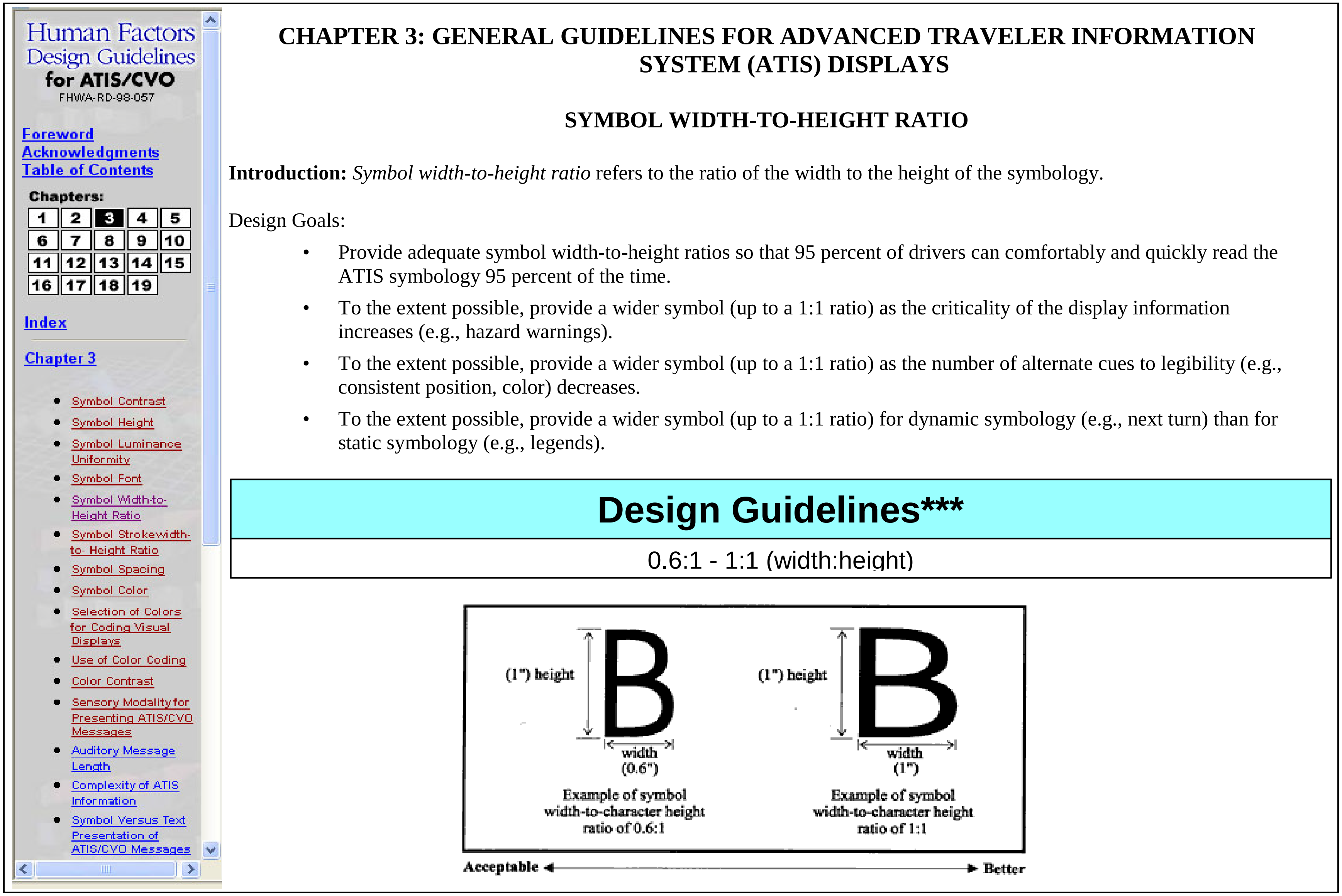
8/1 Amount of Detail (Observation; 125)

Avoid excessive detail on the large map or status board.

Leave the detail to individual operator displays. Packing in detail usually requires reduction in size of individual characters and symbols, which may be hard to discriminate in a TMC control room environment. This is particularly true for video-projection displays, which at present have an inherently limited resolution.

This recommendation cannot be defined in terms of a single, precise, and prescriptive guideline. What constitutes too much detail will be a function of a number of variables such as range of distances from which data will be read, control room illumination, arrangement of information, and other factors. As a general rule, if there is doubt as to the need for detail on a map or big board, put the detail on individual displays and reserve the large display format for *integration of status* (e.g., keep information that pertains to the traffic flow as a whole on the central map, but place detail for a particular area on the operator's personal display).

Example 2 – Structured On-line Style



Human Factors Design Guidelines for ATIS/CVO

FHWA-RD-98-057

- Foreword
- Acknowledgments
- Table of Contents

Chapters:

1	2	3	4	5
6	7	8	9	10
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16	17	18	19	

Index

Chapter 3

- Symbol Contrast
- Symbol Height
- Symbol Luminance Uniformity
- Symbol Font
- Symbol Width-to-Height Ratio
- Symbol Strokewidth-to- Height Ratio
- Symbol Spacing
- Symbol Color
- Selection of Colors for Coding Visual Displays
- Use of Color Coding
- Color Contrast
- Sensory Modality for Presenting ATIS/CVO Messages
- Auditory Message Length
- Complexity of ATIS Information
- Symbol Versus Text Presentation of ATIS/CVO Messages

CHAPTER 3: GENERAL GUIDELINES FOR ADVANCED TRAVELER INFORMATION SYSTEM (ATIS) DISPLAYS

SYMBOL WIDTH-TO-HEIGHT RATIO

Introduction: *Symbol width-to-height ratio* refers to the ratio of the width to the height of the symbology.

Design Goals:

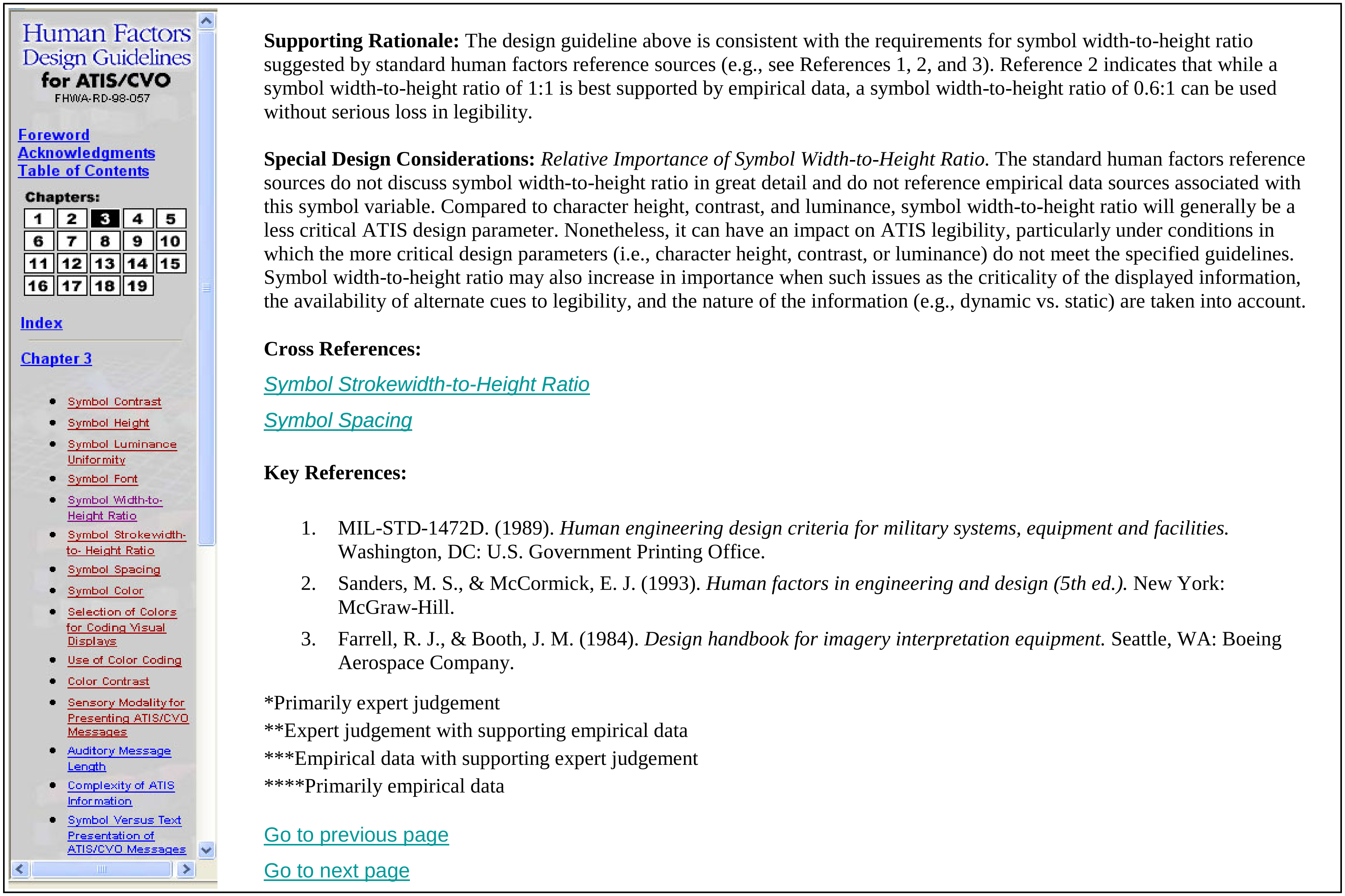
- Provide adequate symbol width-to-height ratios so that 95 percent of drivers can comfortably and quickly read the ATIS symbology 95 percent of the time.
- To the extent possible, provide a wider symbol (up to a 1:1 ratio) as the criticality of the display information increases (e.g., hazard warnings).
- To the extent possible, provide a wider symbol (up to a 1:1 ratio) as the number of alternate cues to legibility (e.g., consistent position, color) decreases.
- To the extent possible, provide a wider symbol (up to a 1:1 ratio) for dynamic symbology (e.g., next turn) than for static symbology (e.g., legends).

Design Guidelines***
0.6:1 - 1:1 (width:height)

Example of symbol width-to-character height ratio of 0.6:1

Example of symbol width-to-character height ratio of 1:1

Example 2 – Structured On-line Style, continued



Supporting Rationale: The design guideline above is consistent with the requirements for symbol width-to-height ratio suggested by standard human factors reference sources (e.g., see References 1, 2, and 3). Reference 2 indicates that while a symbol width-to-height ratio of 1:1 is best supported by empirical data, a symbol width-to-height ratio of 0.6:1 can be used without serious loss in legibility.

Special Design Considerations: *Relative Importance of Symbol Width-to-Height Ratio.* The standard human factors reference sources do not discuss symbol width-to-height ratio in great detail and do not reference empirical data sources associated with this symbol variable. Compared to character height, contrast, and luminance, symbol width-to-height ratio will generally be a less critical ATIS design parameter. Nonetheless, it can have an impact on ATIS legibility, particularly under conditions in which the more critical design parameters (i.e., character height, contrast, or luminance) do not meet the specified guidelines. Symbol width-to-height ratio may also increase in importance when such issues as the criticality of the displayed information, the availability of alternate cues to legibility, and the nature of the information (e.g., dynamic vs. static) are taken into account.

Cross References:

Symbol Strokewidth-to-Height Ratio

Symbol Spacing

Key References:

1. MIL-STD-1472D. (1989). *Human engineering design criteria for military systems, equipment and facilities.* Washington, DC: U.S. Government Printing Office.
2. Sanders, M. S., & McCormick, E. J. (1993). *Human factors in engineering and design (5th ed.).* New York: McGraw-Hill.
3. Farrell, R. J., & Booth, J. M. (1984). *Design handbook for imagery interpretation equipment.* Seattle, WA: Boeing Aerospace Company.

*Primarily expert judgement

**Expert judgement with supporting empirical data

***Empirical data with supporting expert judgement

****Primarily empirical data

Go to previous page

Go to next page

Example 3 – Structured Two-page Style

Left-hand Page

Abbreviated Handbook Title *(Both Pages)*

Guideline

Introduction

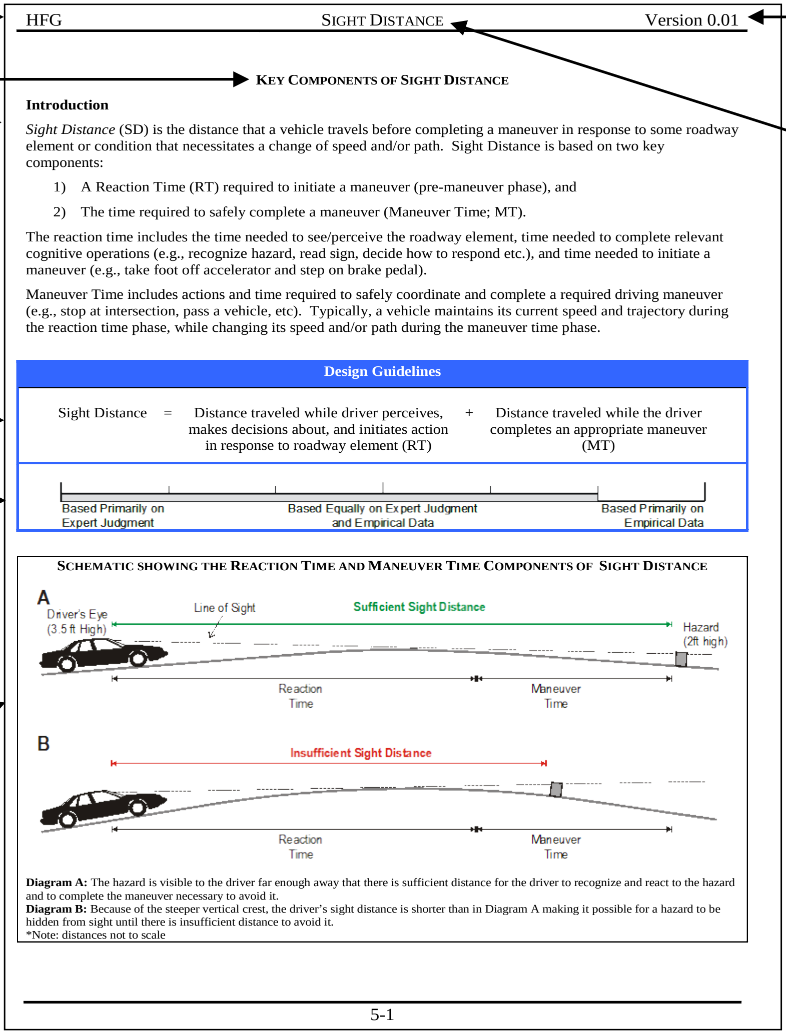
Design Guideline

Bar Scale

Figure, Table, or Graphic

Revision Version *(Both Pages)*

Abbreviated Chapter Title *(Both Pages)*



HFG SIGHT DISTANCE Version 0.01

KEY COMPONENTS OF SIGHT DISTANCE

Introduction

Sight Distance (SD) is the distance that a vehicle travels before completing a maneuver in response to some roadway element or condition that necessitates a change of speed and/or path. Sight Distance is based on two key components:

1) A Reaction Time (RT) required to initiate a maneuver (pre-maneuver phase), and
2) The time required to safely complete a maneuver (Maneuver Time; MT).

The reaction time includes the time needed to see/perceive the roadway element, time needed to complete relevant cognitive operations (e.g., recognize hazard, read sign, decide how to respond etc.), and time needed to initiate a maneuver (e.g., take foot off accelerator and step on brake pedal).

Maneuver Time includes actions and time required to safely coordinate and complete a required driving maneuver (e.g., stop at intersection, pass a vehicle, etc). Typically, a vehicle maintains its current speed and trajectory during the reaction time phase, while changing its speed and/or path during the maneuver time phase.

Design Guidelines

Sight Distance = Distance traveled while driver perceives, makes decisions about, and initiates action in response to roadway element (RT) + Distance traveled while the driver completes an appropriate maneuver (MT)

Based Primarily on Expert Judgment | Based Equally on Expert Judgment and Empirical Data | Based Primarily on Empirical Data

SCHEMATIC SHOWING THE REACTION TIME AND MANEUVER TIME COMPONENTS OF SIGHT DISTANCE

Diagram A: The hazard is visible to the driver far enough away that there is sufficient distance for the driver to recognize and react to the hazard and to complete the maneuver necessary to avoid it.
Diagram B: Because of the steeper vertical crest, the driver's sight distance is shorter than in Diagram A making it possible for a hazard to be hidden from sight until there is insufficient distance to avoid it.
*Note: distances not to scale

5-1

Example 3 – Structured Two-page Style, continued

Right-hand Page

Abbreviated Handbook Title *(Both Pages)*

Discussion

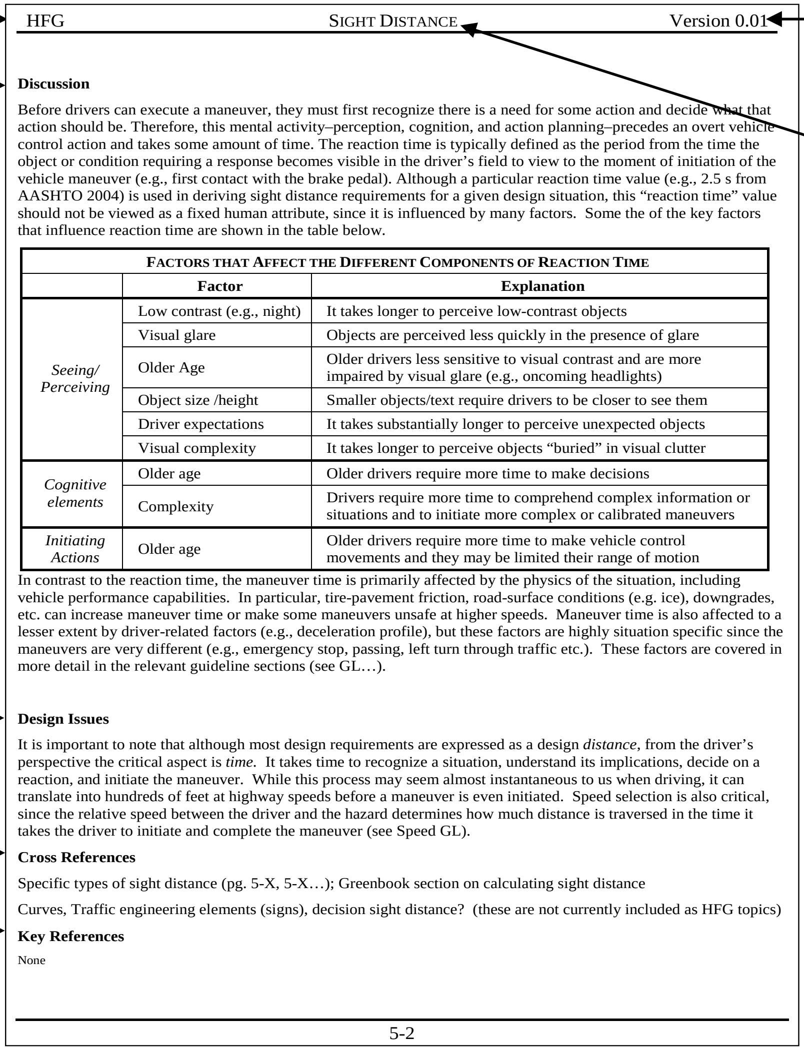
Revision Version *(Both Pages)*

Abbreviated Chapter Title *(Both Pages)*

Design Issues

Cross References

References



HFG SIGHT DISTANCE Version 0.01

Discussion

Before drivers can execute a maneuver, they must first recognize there is a need for some action and decide what that action should be. Therefore, this mental activity–perception, cognition, and action planning–precedes an overt vehicle control action and takes some amount of time. The reaction time is typically defined as the period from the time the object or condition requiring a response becomes visible in the driver's field to view to the moment of initiation of the vehicle maneuver (e.g., first contact with the brake pedal). Although a particular reaction time value (e.g., 2.5 s from AASHTO 2004) is used in deriving sight distance requirements for a given design situation, this "reaction time" value should not be viewed as a fixed human attribute, since it is influenced by many factors. Some the of the key factors that influence reaction time are shown in the table below.

FACTORS THAT AFFECT THE DIFFERENT COMPONENTS OF REACTION TIME

	Factor	Explanation
Seeing/ Perceiving	Low contrast (e.g., night)	It takes longer to perceive low-contrast objects
	Visual glare	Objects are perceived less quickly in the presence of glare
	Older Age	Older drivers less sensitive to visual contrast and are more impaired by visual glare (e.g., oncoming headlights)
	Object size /height	Smaller objects/text require drivers to be closer to see them
	Driver expectations	It takes substantially longer to perceive unexpected objects
	Visual complexity	It takes longer to perceive objects "buried" in visual clutter
Cognitive elements	Older age	Older drivers require more time to make decisions
	Complexity	Drivers require more time to comprehend complex information or situations and to initiate more complex or calibrated maneuvers
Initiating Actions	Older age	Older drivers require more time to make vehicle control movements and they may be limited their range of motion

In contrast to the reaction time, the maneuver time is primarily affected by the physics of the situation, including vehicle performance capabilities. In particular, tire-pavement friction, road-surface conditions (e.g. ice), downgrades, etc. can increase maneuver time or make some maneuvers unsafe at higher speeds. Maneuver time is also affected to a lesser extent by driver-related factors (e.g., deceleration profile), but these factors are highly situation specific since the maneuvers are very different (e.g., emergency stop, passing, left turn through traffic etc.). These factors are covered in more detail in the relevant guideline sections (see GL…).

Design Issues

It is important to note that although most design requirements are expressed as a design *distance*, from the driver's perspective the critical aspect is *time.* It takes time to recognize a situation, understand its implications, decide on a reaction, and initiate the maneuver. While this process may seem almost instantaneous to us when driving, it can translate into hundreds of feet at highway speeds before a maneuver is even initiated. Speed selection is also critical, since the relative speed between the driver and the hazard determines how much distance is traversed in the time it takes the driver to initiate and complete the maneuver (see Speed GL).

Cross References

Specific types of sight distance (pg. 5-X, 5-X…); Greenbook section on calculating sight distance

Curves, Traffic engineering elements (signs), decision sight distance? (these are not currently included as HFG topics)

Key References

None

5-2

Appendix C. TMC Site Visit Protocol

TMC Site Visit Protocol

The following protocol was used in conducting each of the site visits. These meetings consisted of an initial discussion with the TMC operations manager, followed by a period of observation and discussion, as appropriate, with the TMC operators and/or their supervisors.

Initial Discussion Topics

- What are the primary TMC functions of this center?
- How are this TMC's functions integrated with related functions within the area?
- What infrastructure do you currently have to support these functions
- What is your staffing schedule?
- What is the history of the design, construction, and retrofit of this facility?
- Who developed and provided input into the facility designs?
- What were the major system acquisitions associated with this TMC?
- Who developed and provided input into the design and configuration of these systems?
- What are the major operational challenges this TMC currently faces?
- What do you see with respect to future TMC upgrading or remodeling at this site in the coming years?

Observation Objectives

- Incident monitoring and tracking process
- Incident inputs
- Incident verification
- Incident communication
- Incident tracking and 'close-out'
- Use of display wall
- Displays directly controlled by operators
- Additional 'situational' displays
- Video camera use and control
- How are individual cameras identified?
- How is directional view of camera identified?
- What interface is used for camera control?

- Ramp metering monitoring and control
- How is status of ramp meters monitored?
- Are ramp meters directly controlled? -- If so, what is the process?
- Message preparation, actuation, and verification
- VMS
- Radio
- Telephone 511
- Use of alarms
- Typical low- and high-volume alarm levels
- Alarm acknowledgement and clearing process
- Level of operator involvement
- Pace of operations
- Sharing of functions between individuals

Appendix D.
Preliminary Outline / Table of Contents for a Handbook of Traffic Management Center (TMC) Human Factors Guidelines

Preliminary Outline/Table of Contents for a Handbook of Traffic Management Center (TMC) Human Factors Guidelines

Introduction

Overview: provide an introduction to the purpose, organization, and content of the handbook. Include a description of the format of individual guidelines, as well as a summary of where and how specific guidelines could be applied.

Candidate Topics:

- Objectives of the TMC Human Factors Guidelines
- How to Use this Document
- Applications for New Facility Design
    - Facility Life
    - Designing for Flexibility
- Applications for Facility Review and Upgrading
- Applications for Individual System Introduction or Upgrading
- Applications for Operations

Operator Selection and Training

Overview: provide guidelines that aid in the selection and training of TMC operators, as well as provide guidance on tools, procedures, and resources for maintaining operator alertness.

Candidate Topics/Guidelines:

- Operator Selection
    - Operator Skill Requirements
    - Operator Knowledge Requirements
    - Operator Experience Requirements
    - Operator Abilities Requirements
- Operator Training
    - Determining Training Requirements
    - Novice Training (i.e., Detect, Define, Deliver / Detect, Diagnose, Dispatch)
    - Qualified Operator Expertise Growth
    - Personnel Cross-training
    - TMC Performance Metrics
        - Incident detection and response latency, incident response adequacy
- Operator Fatigue & Alertness

TMC Facilities Design

Overview: provide human factors recommendations relevant to the design of TMC facilities and control rooms. The focus will be on topics and information needs identified by end-users.

Candidate Topics/Guidelines:

- Infrastructure Issues

  - Co-location of Related Organizations
  - Location and Identification of Roadway Sensors
  - Location and Access to Information Data Inputs/Outputs
- Traffic Management Center Design
  - Overall Layout
  - Entryways
  - Walkways and Hallways
  - Stairs and Ramps
- Traffic Management Control Center Design
  - Overall Size and Layout (e.g., Major Components, Shared Displays, Verbal Communications)
  - Ceilings
  - Lines of Sight
  - Lighting
  - Acoustics
  - Thermal Environment
  - Chairs
  - Work Surfaces
  - Control Panels

TMC Communications

Overview: provide human factors recommendations relevant to the need to continually communicate within and outside a TMC's immediate organization. The focus will be on timely and effective communication and coordination.

Candidate Topics/Guidelines:

- Intra-organizational Communications
  - Operator Coordination and Communication
  - Related Intra-regional Organizations
    - Call centers
    - Roadway engineering and maintenance
    - Roadway management
  - Amber Alerts
- Inter-organizational Communications
  - Facilitating Good Communications
    - Value of 'face time'
    - Use of common language to avoid misinterpretation
  - Other Traffic Management Centers
  - Other Intra-state Organizations
  - Media Communications
  - Inter-state Communications
    - Road closures

- Communications Devices
    - Telephones
        - Headsets
        - Dialing aids
        - Contact lists
        - Speed dialing
        - Computer-assisted contacts and dialing
- Instant Messaging
- Email
    - Internal
    - External

TMC Automation and User-Computer Interface

Overview: provide human factors recommendations relevant to the implementation of automation in TMC's. Focus on identifying appropriate functions for automation and adaptive interfaces that balance the benefits of automation with the need to maintain operator involvement and situation awareness.

Candidate Topics/Guidelines:

- Matching the Automation to Operator Capabilities and Limitations
    - Balancing Operator Job Support and Involvement
    - Level and Type of Language
    - Decision-making Requirements
    - Memory Demands
    - Number of Control Steps
- Supporting Operational Flexibility
- Incident Identification and Tracking
    - Incident Detection Systems
    - Incident Tracking Logs
        - Need to track and update incident status across multiple systems (i.e., CARS & CADS)
- Computer Assisted Response Systems(CARS)
    - Changeable Message Signs *(Example Guideline Developed)*
    - 511 Messages
- Computer Assisted Dispatching System (CADS)
- Ramp Meter Control Systems
- Web Site Traffic Status
- Tracking Roadway System Identification and Location
    - Close Circuit Video Monitors
    - Roadway Loop Detectors
    - Ramp Meter Status Indicators
- Alarm Presentation and Management
    - Alarm Priority and Coding
    - Alarm Display Sorting (Priority, Age, Status)
    - Alarm Acknowledgement and Clearing

Displays and Controls

Overview: provide human factors recommendations for the range of displays and controls used in TMCs TMC's. Address the range of options and configurations for displays and controls across larger and smaller TMCs, and provide both HF principles and tools that will aid in the selection and design of these devices.

Candidate Topics/Guidelines:

- Situation (Wall) Displays
    - Matching Situation Display Requirements to TMC Functions
        - Matching display layout to TMC activities
        - Matching display layout to roadway architecture
    - Determining Visual Display Configuration *(Example Guideline Developed)*
        - Number of displays that can be viewed and processed
        - Lines of sight
        - Viewing distance
    - Controlling Situation Display Content
        - Display priority, grouping, and sequencing
- Workstation Displays
    - Determining the Number of Displays
    - Display Size and Location
- Workstation Controls
    - Keyboards
    - Multiple Trackball or Mouse Controls
    - Video Camera Controls *(Example Guideline Developed)*

Non-automated User Aids

Overview: provide lists of—or links to—relevant documents, decision aids, standards, procedures, etc.

Candidate Topics:

- Standard Operating Procedures
- Decision Aids
- Standards
- Contact Lists

Tutorials

Glossary

References

Index

Appendix E.
Sample TMC Human Factors Guidelines

Requirements for TMC Human Factors Guidelines

(Example Guidelines)

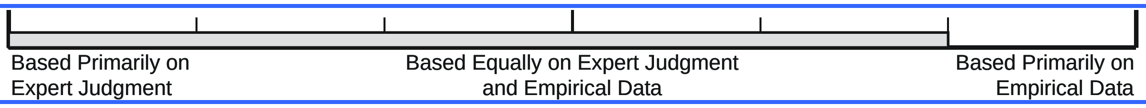
CHANGEABLE MESSAGE SIGNS

Introduction

Changeable Message Signs (CMS) are traffic control devices used for traffic warning, regulation, routing and management, and are intended to effect the behavior of drivers by providing real-time traffic related information (1). Inappropriate application and use can reduce the effectiveness of these signs, particularly at times when they would otherwise be highly effective. Fortunately, considerable research findings are available to support guidelines on a variety of topics.

Design Guidelines

CMS Design Topic	Guidelines
When should CMSs be used? (from Reference 2)	● To display essential, short-term information about unusual, temporary, or variable conditions. ● In conjunction with fixed signs to display extensive or complex messages. ● Judiciously, to display emergency security or AMBER alert messages. ● In situations where adverse conditions are not obvious to drivers.
How can CMSs be designed to maximize their influence on driver decisions? (from References 3 & 4)	The CMS messages should indicate the specific location of a crash or reason for delay, the expected delay time, and the best detour strategy. In general, messages that provide time-saving benefits are the most likely to affect diversion. Drivers are more likely to divert when presented messages related to crashes than when presented with messages related to roadwork or congestion. Messages must be reliable and updated regularly to keep them current; incorrect or out of date messages will diminish confidence in the signs, leading drivers to ignore the messages.
How can CMS devices be used to reduce speeds? (from References 5 & 6)	Use CMS to display variable speed limits in locations where changes in speed limit due to recurrent peak traffic or adverse weather conditions will facilitate traffic flow and safety. Radar-equipped, speed-activated CMS can be effective in areas that require significant speed reductions. Use CMS to display variable speed limits in work zones where safe speeds may vary depending on conditions of night, day, working hours, level of congestion, etc.



Discussion

When to use CMS Devices. CMS devices can be used to effectively manage travel, control traffic, identify current and anticipated roadway conditions, and regulate access (7). However, inappropriate application and use can reduce the effectiveness of these signs, particularly at times when otherwise they would be highly effectual. References 1 & 2 synthesize decades of survey, focus group, laboratory, and field studies on the topic of CMS use and design.

Designing CMSs to Maximize their Influence on Driver Decisions. Changeable message signs are often used to divert traffic onto a specific route because of roadwork, special events, or traffic incident, or to indicate a preferred exit based on current congestion levels. Characteristics of CMS that influence route choice refers to the attributes of CMS messages that influence drivers' to follow a desired course of action under these conditions. The content and credibility of the message play key roles in the effectiveness of these signs.

Using CMSs for Speed Reduction. CMS for speed reduction refers to applications for which CMS can be used effectively to encourage reductions in speeds in areas with potential hazards, inclement weather, or heavy congestion. Applications that are temporary or variable in nature, such as works zones, incident control, and speed reduction due to adverse weather conditions, are the primary candidates for using speed-reduction CMS. Areas that experience recurring heavy peak traffic also can benefit from the proper application of speed controlling CMS.

Design Issues

A survey of state transportation agencies (8) found that when portable CMSs are used to alert motorists of future changes in traffic or roadway conditions, they are placed some time prior to the date work begins. However, drivers may grow accustomed to signs with messages that are presented for extended periods of time and not notice or ignore new messages.

There are two schools of thought when considering what to display on a CMS when no unusual conditions exist or when there are no essential messages. One is to always display a message on the CMS regardless of whether there is an incident or unusual condition (e.g., to present current travel times to a destination ahead), while the other is to display messages only when an incident or other situation warrants a message and to blank the CMS at all other times.

The MUTCD (9) provides specific guidance about letter height, minimum legibility distance, and lists of abbreviations for general use in signs. Because CMS characters or symbols typically are constructed using a relatively course matrix of pixels, the requirements for visibility and legibility are more demanding than for standard, fixed signs. Also, the fixed matrix introduces limitations to character size, height-to-width ratio, spacing, and other geometric characteristics available for presenting messages.

Cross References

511 Messages (*page x*)

Key References

1. Dudek, C. L., (2004). *Changeable Message Sign Operation and Messaging Handbook.* Report No. FHWA-OP-03-070. Federal Highway Administration, Washington, DC.
2. Dudek, C. L. (1992). *Guidelines on the Use and Operation of Changeable Message Signs*. (Report No. FHWA-TX-92-1232-9). College Station: Texas Transportation Institute.
3. Benson, B. G. (1996). Motorist Attitudes About Content of Variable-Message Signs. *Transportation Research Record, 1550*.
4. Erke, A., Sagberg, F., and Hagman, R. (2007). Effects of Route Guidance Variable Message Signs (VMS) on Driver Behaviour. *Transportation Research Part F: Traffic Psychology and Behaviour, 10*(6), 447-457.
5. Garber, N. J., and Srinivasan, S. (1998b). *Effectiveness of Changeable Message Signs in Controlling Vehicle Speeds in Work Zones - Phase II.* (Report No. FHWA/VTRC 98-R10. Final Report). Charlottesville: Virginia Transportation Research Council.
6. Kwon, E., Branna, D., Shouman, K., Isackson, C., and Arseneau, B. (2007). Development and Field Evaluation of Variable Advisory Speed Limit System for Work Zones. *Transportation Research Record, 2015*, 12-18.
7. Johnson, C. M. (2001). *Use of Changeable Message Sign (CMS).* FHWA Policy Memorandum response to James A. Cheatham. Retrieved March 19, 2008 from http://www.fhwa.dot.gov/ legsregs/directives/policy/pame.htm.
8. Halloin, D. M. (1996). Impediments to the Effective Use of Portable Variable Message Signs at Freeway Work Zones. In C. Dudek (Ed.) *Compendium of Graduate Student Papers on Advanced Surface Transportation Systems* (pp. Ci-C34). College Station: Texas A&M University.
9. Federal Highway Administration (FHWA). (2007). *Manual on Uniform Traffic Control Devices (MUTCD)* (2003 Edition, including Revisions 1 (2004) and 2 (2007). Washington, DC: Author.

VIDEO CAMERA CONTROLS

Introduction

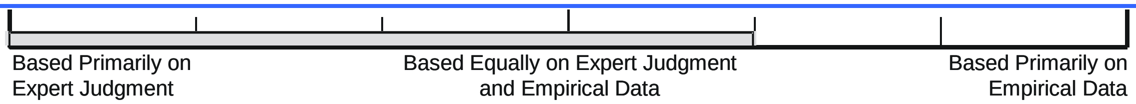
Video Camera Controls refers to the method used to select and assign cameras to monitors within a TMC, as well as the means by which operators manipulate the image presented through the camera. Traffic management centers rely on the efficient selection and control of closed circuit video cameras to detect and verify incidents and determine the nature and extent of the incident prior to taking appropriate action. Major TMCs often have several hundred cameras available to support their mission. Efficient camera selection and control methods support effective incident detection and characterization.

Camera selection functions include both the initial selection of a camera and the assignment of the camera to a specific display monitor. Errors in camera selection impede progress in obtaining access to the appropriate camera. Camera control functions include camera panning, tilting, zooming, and focusing. Extended camera control times reflect decreased efficiency in obtaining the camera view necessary to detect and characterize an incident.

Design Guidelines

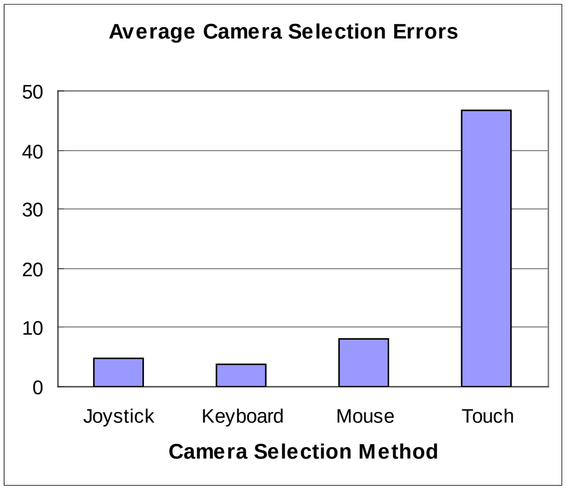
Camera selection can be effectively accomplished with joystick, keyboard, and mouse controls; but has been shown to be less effective with a touch screen interface.

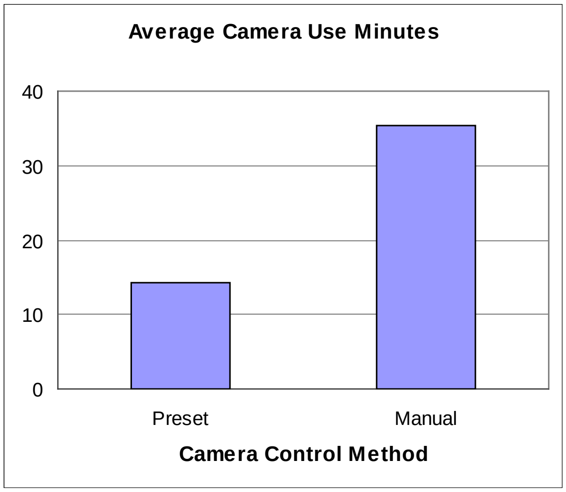
Camera control can be substantially facilitated through the use of preset pan and tilt positions that provide a view of the traffic in opposing directions of the same roadway.



CAMERA SELECTION ERRORS AND USAGE TIMES WITH DIFFERENT SELECTION AND CONTROL METHODS

The two charts below present findings from a simulated TMC camera selection study conducted by Georgia Tech researchers (1). This study compared the performance of trained subjects in selecting and controlling 24 separate cameras employed in a TMC simulator. The results in the left-hand chart depict significant advantages of joystick, keyboard, and mouse camera selection methods over touch screen camera selection. The results in the right-hand chart depict the greater efficiency (reflected in less overall camera usage time) using preset camera pan and tilt positions over full-manual camera control.





Discussion

The Georgia Tech study (1) cited provides unique data regarding the value of alternative camera selection and control methods. However, the limited number of video cameras included in this study limits that applicability of these findings to larger TMCs, which typically have between 100 and 300 video cameras. In these cases, the overall camera selection process will be more dependent upon the operator's initial identification of the correct camera. This suggests that methods that do not rely on operator recall of camera identification codes (the Joystick, Mouse, and Touch methods that were based on operator reference to a roadway map) would have a substantial advantage over the Keyboard method. The relatively high levels of camera selection inaccuracy reported with the Touch method likely reflects the combined impediments of requiring operators to reach and touch the camera icon on the roadway map display screen, plus the inaccuracies associated with the touch screen technology employed in that study. The camera control portion of the cited study was based on the division of 24 simulated cameras into two groups of 12 cameras that required manual control and 12 cameras that had preset fields of view. It is likely that actual implementation of preset camera fields of view would include a manual override condition, introducing an additional required operator control action if manual control were required. This additional action would likely reduce the extent of the observed advantage of preset cameras over manually controlled cameras that was reported in that study.

Design Issues

Camera Selection Issues:

- As the overall number of available cameras increases, the need for a logical and organized identification system also increases, as operator memory demands increase accordingly. Cameras can be identified by identifier codes, which should be logical and meaningful—for example, using the road and route number followed by the milepost (i.e., 99N33). Arbitrary identifier codes can be memorized over time, but increase initial operator training requirements, as well as memory demands during operations.
- A situation map with icons depicting camera positions has proven to be a highly effective method of identifying cameras in both research (1) and practice.
- A mouse control for camera selection has been identified as having the value of making use of an interface device that is most likely already employed at an operator console (2).
- In addition to the manual methods discussed above, cameras can also be selected through pre-defined selection and sequencing procedures to present cameras on the basis of current incidents or high levels of congestion.

Cameral Control Issues:

- The advantages of preset camera fields of view must be considered in the context of the specific roadway applications; as well as the additional development and maintenance costs associated with this method.
- Preset camera fields of view should be accessed with a minimum of control actions—preferably, a single control action will be required to actuate a preset condition. Examples include use of up, down, left, and right arrow keys in combination with a dedicated 'preset' function key.
- Cameras with preset pan and tilt positions should still rotate through a full 360 degree field of view and appropriate tilt angles to accommodate a full search of the roadway and nearby vicinity.
- A cell of grouped keyboard directional arrow control buttons (up, down, left, and right arrows) have been shown to be highly effective control mechanisms for camera panning and tilting. This type of control has also been demonstrated to provide an effective means of controlling zoom and focus functions, when coupled with additional dedicated control buttons.

Cross References

Visual Display Configuration (*page x*)

Key References

1. Folds, D., Beers, T., Stocks, D., Coon, V., Fain, W., & Mitta, D. (1995). A comparison of four interfaces for selecting and controlling remote cameras. In *Proceedings of the Human Factors and Ergonomics Society 39th Annual Meeting—1995*, 1137-1141.
2. Kelly, M. (1999). Preliminary *Human Factors Guidelines for Traffic Management Centers*. Report FHWA-JPO-99-042. McLean VA: Federal Highway Administration.

DETERMINING VISUAL DISPLAY CONFIGURATION

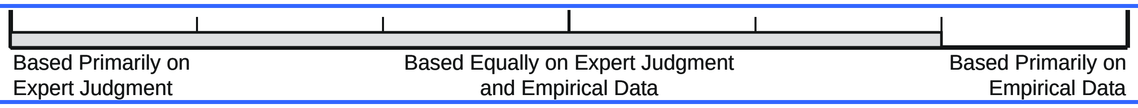
Introduction

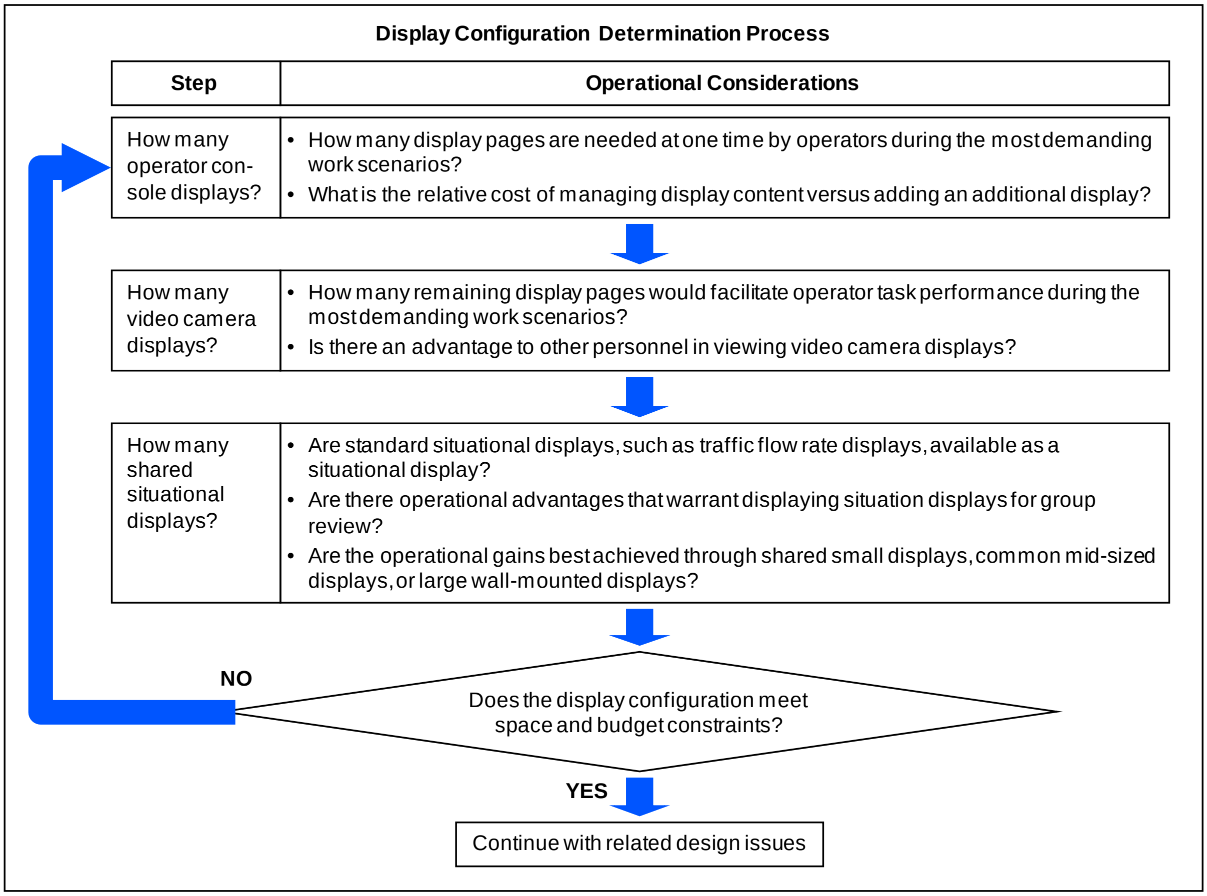
Visual Display Configuration refers to the number, size, and placement of visual displays throughout a TMC. The configuration of TMC displays will affect how quickly TMC operators and other TMC personnel can access the visual information that they need to perform their tasks. Very often the decisions that determine visual display configuration are made during the early stages of TMC design or remodeling. Careful consideration of the tasks performed by individual TMC operators and groups within a TMC will help to ensure that a display configuration that best supports the functions performed within a TMC is selected.

An iterative process for determining a TMC's visual display configuration is outlined in this design guideline. The basic steps reflect the consideration of key operational issues, followed by an assessment of space and budget constraints. More detailed design decisions will require a careful analysis and consideration of the TMC functions, operator(s) jobs and tasks, the visual information that they use to perform those tasks, the means of best providing that visual information, and the alternative means of managing displayed information on TMC visual displays.

Design Guidelines

The basic steps and corresponding operational considerations should be analyzed in sequence to initially determine operator console and situational wall display requirements.





Display Configuration Determination Process

Step	Operational Considerations
How many operator console displays?	• How many display pages are needed at one time by operators during the most demanding work scenarios? • What is the relative cost of managing display content versus adding an additional display?
How many video camera displays?	• How many remaining display pages would facilitate operator task performance during the most demanding work scenarios? • Is there an advantage to other personnel in viewing video camera displays?
How many shared situational displays?	• Are standard situational displays, such as traffic flow rate displays, available as a situational display? • Are there operational advantages that warrant displaying situation displays for group review? • Are the operational gains best achieved through shared small displays, common mid-sized displays, or large wall-mounted displays?

Does the display configuration meet space and budget constraints?

Continue with related design issues

Discussion

Several analytic techniques, including cognitive task analysis can help define the information required by TMC personnel during different operational scenarios so that those information elements can be mapped to the TMC displays.

In determining **the number of operator console displays**, it should be recognized that demanding display management tasks may not be performed during high workload periods. Although consoles may be designed to provide switching between display content during such periods, operators often do not manage display content at such times (1). So, it is advantageous to include the maximum number of displays that are required and can be accommodated by the operator console. Eight individual consoles should not be considered too many, if they are stacked in two rows of four.

In determining **the number of video camera displays**, it should first be determined if there is an operational advantage in providing operators with additional video camera displays within their field of view. This may be useful if there is a benefit in viewing sequences of 'ganged' displays in assessing the overall traffic situation that would not be gained through available traffic volume situational displays. A second consideration should be if there is an operational advantage in providing video displays in a location that facilitates group review. Research indicates that there is an apparent advantage of group displays for tasks requiring rapid team detection of change or anomaly in complex displays (2).

In determining **the number of shared situational displays**, the potential advantage of enhancing shared situational awareness among TMC staff should be considered. These commonly include roadway volume displays, situation summary displays, and emergency call-in summary displays. Shared situational awareness reflects a common understanding of the traffic situation, the incident(s) causing that situation, and the appropriate courses of action to address the situation. Research indicates that shared situational awareness is facilitated by common situational displays available for group viewing; which, in turn, supports greater group flexibility in accomplishing tasks by shifting responsibilities among team members or taking advantage of individual expertise during demanding periods (3). If an operational analysis identifies operational scenarios in which group situational awareness can support TMC effectiveness, then

Design Issues

After the number of desired of displays is initially determined, the design constraint of facility space must be considered, including both available operator console and shared wall display space.

If the determined number of displays can fit the within the available space, budgetary constraints must also be considered. The full range of current display technologies, including rear-screen projection, liquid crystal display, and plasma displays should be considered; since these are associated with a substantial range of acquisition and maintenance costs.

Because the method of managing video camera display selection and controls is a fundamental factor in determining operator display management, it is very closely linked to the determination of video display configuration. Techniques that reduce overall display content management will allow operators to scan additional displays.

Cross References

Designing for Flexibility (*page x*)
TMC Functions and Staff Responsibilities (*page x*)
Overall Layout, and Number of Control Steps (*page x*)
Video Camera Controls (*page x*)

Key References

1. O'Hara, J. , Brown, W., Lewis, P. , & Persensky, J. (2001). Your design probably needs more VDU's. In *Proceedings of the Human Factors and Ergonomics Society 45th Annual Meeting.*
2. Tollner, A, Riley, M., Nelson, W., Shockley, K., & Cummins-Sebree, S. (2006). Change blindness in teams: Are three pairs of eyes better than one? In *Proceedings of the Human Factors and Ergonomics Society 50th Annual Meeting.*
3. Roth, E. Mutler, J., & Taslear, T. (2006). Shared Situation Awareness as a contributor to high reliability performance in railroad operations. *Organization Studies*, 27(7): 967-987.