Human Factors Guidelines for Transportation Management Centers

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FOREWORD

Transportation management centers (TMCs) are complex environments with regular changes in technology, and they apply concomitant demands on TMC operators and designers to stay current. Rapid changes in TMCs create the need for guidance that is current, clear, practical, and easy to use. Human factors guidelines tailored to TMCs are necessary to prevent TMC staff from neglecting human factors considerations, developing inaccurate and biased guidelines internally, making false assumptions regarding operators/drivers, and incorrectly applying human factors guidelines from other domains. An efficient, safe, and successful TMC depends on how humans interact with the variety of technology and information in the environment. This report brings together comprehensive, state-of-the-art information on human factors aspects in TMCs in a format that is readily usable by TMC personnel.

The goal of this report is to provide a flexible, powerful, clear, and easy-to-use guide for any practitioners involved in planned or existing TMCs, using the needs of the end user as a guiding principle. As such, practitioners and organizations interested in developing, evaluating, or modifying their TMCs would benefit from reading this report.

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16. Abstract Transportation management centers (TMCs) have traditionally served as the real-time interface between motorists and transportation agencies. Their mission has broadened to encompass a variety of goals and management approaches. This document presents a set of human factors guidelines to be used by organizations interested in developing, evaluating, or modifying their TMCs. The guidelines herein provide human factors considerations based on empirical research, meta-analyses, usability testing, and standards to create the optimal work environment for TMC operators, managers, and supervisors in attempts to improve decisionmaking and mitigate human errors. The goal is to provide human factors guidelines that will bring together comprehensive, state-of-the-art information on human factors aspects in TMCs in a format that will be readily usable to a wide range of practitioners. This report is divided into several chapters, each focused on a particular type of human factors issue within the TMC. The first chapter begins with the TMC operator, describing an operator's strengths, limitations, and biases when interfacing with technology. Next, chapter 2 describes how operators interact with automated systems, including issues of staying in the loop, trust in system automation, and monitoring. Chapter 3 provides an overview of TMC infrastructure, physical layout, organizational structure, workflow, and how the locations of TMC elements (onsite or offsite) affect performance. Next, chapter 4 describes the systems and tools used within a TMC. Finally, chapter 5 includes information about communications with the public, colleagues, and agencies and addresses content and delivery mechanisms for messages along with recommendations for facilitating communication across organizations.			
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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
^oC	Celsius	1.8C+32	Fahrenheit	^oF
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

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LIST OF ABBREVIATIONS

ANSI	American National Standards Institute
ATMS	advanced traffic management system
CAD	computer-aided dispatch
CCTV	closed-circuit television
CTA	cognitive task analysis
DMS	dynamic message sign
EOC	emergency operations center
FHWA	Federal Highway Administration
GOMS	goals, operators, methods, and selection rules
HAR	highway advisory radio
HFES	Human Factors and Ergonomics Society
ITS	intelligent transportation system
KLM	keystroke level model
KSA	knowledge, skills, and abilities
NASA	National Aeronautics and Space Administration
OSD	operational sequence diagram
OSHA	Occupational Safety and Health Administration
PSA	public safety announcement
RITIS	Regional Integrated Transportation Information System
SWAT	subjective workload assessment technique
SIT	system integration testing
ST	system testing
TIM	traffic incident management
TLX	Task Load Index
TMC	transportation management center
TMOT	transportation management operations technician
UAT	user acceptance testing
VDOT	Virginia Department of Transportation
WisDOT	Wisconsin Department of Transportation
WPT	Wonderlic Personnel Test
WWD	wrong-way driving

CHAPTER 1. INTRODUCTION

This report presents a set of human factors guidelines to be used by organizations interested in developing, evaluating, or modifying their transportation management centers (TMCs). TMCs vary greatly by institution and location, but all make critical financial investments in personnel, equipment, technology, and procedures. The intersection of those investment areas is vital to an efficiently run TMC and is at the heart of what is referred to as human factors. The guidelines herein provide human factors considerations based on empirical research, meta-analyses, usability testing, and standards to create the optimal work environment for TMC operators, managers, and supervisors in an attempt to improve decisionmaking and mitigate human errors. These factors are examined by raising awareness of design fallacies and human biases while endorsing performance by integrating adaptive automation, setting standard procedures, and designing for human limitation.

OBJECTIVES

The Federal Highway Administration (FHWA) wants to provide updated human factors guidelines that will bring together comprehensive, state-of-the-art information on human factors aspects in TMCs in a format that will be readily usable to a wide range of practitioners.

The *Preliminary Human Factors Guidelines for Traffic Management Centers* served as a starting point for these guidelines.(1) However, much has changed since those guidelines were originally published. For example, user interface design and website usability have changed dramatically. Social media was not a commonly understood tool, and website access was only available on desktop devices. Today, typical computer and Web interfaces begin where the older guidelines left off. For instance, in 1999, there was a need to discuss resizing windows and websites. Having a guideline and discussion of this feature is no longer as important given that the most basic websites incorporate that design feature, with which users of all levels of expertise are familiar. In addition, some technology may be moving toward obsolescence. Note that basic human capabilities do not change as fast as technology; therefore, some of the principles upon which previous guidelines were based are still relevant. This report presents updated material focused on providing comprehensive and easy-to-use guidelines that are justified by a rich literature review and professional expertise and input.

DEVELOPMENT OF GUIDELINES

The guidelines were developed using the following four-part process:

1. Topics for inclusion were identified, and an outline was developed. The authors attempted to balance sufficiently broad attention to the variety of TMC issues without sacrificing sufficient depth so readers could take action on any guideline.

2. Literature on traffic operations and human factors was reviewed to identify the most useful information regarding the design of the human work environment. In addition, several TMC site visits were used to gather best practices information as well as feedback on user needs.

3. Guidelines were developed and rationalized in each topic area using the input from the literature and expert human factors judgment.

4. Each guideline was cross-referenced with other closely related guidelines, and supporting diagrams and pictures were provided as appropriate. Expert input and feedback from TMC visits were used to guide the document throughout.

INTENDED AUDIENCE

This report is intended to be used by any practitioner involved in planned or existing TMCs. It is assumed that these practitioners will have varied levels of decision authority, ranging from executive leadership, to operations supervisors, to shift workers—people who will have a variety of goals, including designing a workspace, purchasing software tools, overcoming a communication problem, or understanding a decision process. These staff members will be from varied backgrounds in transportation, including those who are new to transportation. While readers may be unfamiliar with the discipline of human factors, they will all have a rudimentary understanding of traffic issues and TMC objectives.

BACKGROUND

TMCs have traditionally served as the real-time interface between motorists and transportation agencies. TMC staff use information about travel conditions to select strategies that improve mobility and safety in a region. Over time, TMCs have evolved, and their mission has broadened to encompass a variety of goals and management approaches. More often, TMCs consider strategies in light of the environmental and economic impacts of congestion. TMCs are becoming the hub for a more integrated management approach, which involves supporting alternative routes and mode shifts across a corridor. This frequently involves less reactive traffic management techniques and more proactive thinking. TMCs also serve a broadening role in homeland security and emergency management. Technologies have supported and driven these developments as intelligent transportation systems (ITSs) and advanced traffic management systems (ATMSs) have become the norm.

TMCs are complex environments with multiple channels of dynamic information flowing in and out at all times. Data sources can include visual inspection of roadways through cameras, radio chatter from responders in the field, messages from other agencies, phone calls from citizens, and sensor data indicating speeds and travel times. Outputs can vary, including posting messages on dynamic message signs (DMSs), adjusting ramp metering, implementing a new signal timing plan, updating a 511 website, or dispatching a motorist assist vehicle using automatic vehicle location.

Operators must be able to multitask and work effectively as part of onsite and remote teams, within their own agency, and with other organizations. Being able to respond quickly and effectively is critical to network performance. The degree to which a TMC is successful affects its credibility with customers and its ability to receive consistent funding and support. When a TMC is successful, it can have a meaningful impact on the quality of life in the region.

Because humans are the mediators of the information within a TMC, it is important to understand how they work and to design their environment to serve their goals. In this way, the TMC is the central nervous system for the transportation network. Information from various sources must be sensed and interpreted, judgments about data and decisions about how to act must be made, and responses must be implemented and evaluated.

In 1999, FHWA released the *Preliminary Human Factors Guidelines for Traffic Management Centers.*(1) This was a first step in considering how the work environment can affect operator and system performance. The human operator has capabilities and limitations that should be considered in the design and operation of the TMC. While many of these 1999 guidelines remain true, much has changed in the last 2 decades to define the work environment. Some examples of these changes include the following:

- In September 2001, the 9/11 attacks on American cities changed how regions think about security. TMCs, with their ability to reach across a wide region to gather information about traffic movements and provide instructions to motorists, are taking an increasingly integrated role with first responders and emergency management personnel.

- Traffic incident management (TIM) has matured as a discipline, developing and testing methods for interagency communication, cooperation, and multidisciplinary response to traffic incidents.

- Integrated corridor management is becoming a near-term vision for many regions with a goal of focusing on multijurisdictional, multimodal coordination that will result in more consideration of harmonized relationships among arterial and freeway management.

- Active traffic demand management is a domain providing a robust set of strategies for actively managing demand, traffic, and parking (e.g., dynamic pricing, adaptive ramp metering).

- Advances in the capabilities, availability, and affordability of technologies, including ITSs, have facilitated many of the programs previously described and allow a variety of regions to implement and test new operational approaches. Decision support systems and automated systems are becoming increasingly accessible, as well.

- Likewise, travelers have more access to technology, including mobile- and vehicle-integrated technologies, which have created numerous ways of providing traveler information in advance of trips and in real time.

- As technology has advanced and become readily available, user expectations (in the TMC and among travelers) have become more sophisticated. Users have high expectations about the utility, ease of use, speed, accuracy, and reliability of transportation data.

Although the mission and techniques of TMCs have evolved over time, it is important to remember that TMCs have great variability in their institutional maturity. Operating a TMC is still a new and unproven endeavor in some regions. Conversely, some TMCs have operated for multiple decades and have much wisdom about operations but are faced with change and must update antiquated systems and procedures. Thus, TMCs are not homogeneous but varied and are constantly progressing as a result of technology; Federal, State, and local initiatives; customer needs; funding availability; and operational developments.

HUMAN FACTORS IN TMCs

Sanders and McCormick describe human factors as follows: "Human Factors seeks to enhance the effectiveness and efficiency of things and environments that people use to maintain or enhance certain desirable values (e.g., health, safety, satisfaction)."[(2)](p. 4) To this end, human factors professionals seek to learn how humans sense, perceive, think about, and move within their environment. The domain focuses on understanding and improving the cognitive, physical, and organizational experience of the human. Research in these areas is used to improve the user experience by designing the environment, processes, and interfaces to be easier to learn, use, and understand.

Underlying most of these guidelines is an understanding of the human user, but characterizing a large heterogeneous group of TMC users is not simple. Several key human factors topics were considered in the development of these guidelines. There is also a logical structure for the sequence throughout the document—beginning with the user, to technology, to the larger environment and overall displays, and then to the user technology organization used for communicating with the public, colleagues, and agencies.

This report considers the TMC operator (chapter 2) and provides an overview of factors affecting operator performance. These factors include understanding human limitations, ensuring proper task allocation and decisionmaking, and implementing training programs. Chapter 3 focuses on the usability of equipment and technology used by a TMC to perform tasks as varied as incident identification, dispatch, updating of DMS messages, sensor and camera management, and incident response.

This document also considers the TMC environment (chapter 4), including physical ergonomics and anthropometrics factors that influence performance and workflow. Successful operator performance can be influenced by the physical, sensory, perceptual, and cognitive abilities of the user. The human factors guidelines consider these user factors and suggest ways to design displays and controls, as outlined in chapter 5. Finally, this report considers how users communicate with one another. This includes interagency communication and messages with the public. Communication and coordination with the public, colleagues, and agencies (chapter 6) is important to consider when a TMC designs communication procedures and tools that guide the content and delivery of effective messages.

GLOSSARY OF HUMAN FACTORS TERMS

The following terms are significant human factors concepts that were considered in the development of these guidelines:

- **Cognitive processes**: Human factors is concerned with cognitive processes, such as attention, memory load, distraction, workload, management of interruption, problem solving, computation, judgment, and decisionmaking. To understand cognition, human factors draws from many disciplines, including linguistics, neuroscience, psychology, biology, and computer science. Studies of shift work and fatigue provide good examples of when and how judgment and decisionmaking can degrade within a TMC and how to mitigate this problem with timely breaks and limited shift assignments.(3,4)

- **Usability**: Human factors is concerned with usability. This concept of human–computer interaction can be applied to any tool or device. International Organization for Standardization Standard 9241-11 defines usability as "The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use."(5) Usability is evaluated by direct inspection or a variety of user testing methods. In a TMC, usability of interfaces on management software, reporting tools, or phone and radio systems are important to a satisfying and productive user experience.

- **Workflow**: Human factors is concerned with how a task is accomplished and may include a hierarchical breakdown of how a task is accomplished using manual and mental activities. Task analysis can be used to document the tasks and subtasks required and their duration, frequency, complexity, and necessary resources. Understanding a user's workflow can be helpful for identifying barriers to task completion as well as developing communication procedures, workspace layouts, staff selection criteria, training protocols, software, checklists, automation, and decision support tools. An example of understanding TMC workflow might involve assessing how efficient different operator roles are by comparing efficiency when an individual zone (i.e., area of responsibility) is assigned to just one operator versus operators having shared responsibility for all zones.

- **Workspace design and anthropometry**: Human factors is concerned with the layout and arrangement of a user's workspace, including the placement, dimensions, and characteristics of tools such as furniture, lighting, keyboards, monitors, and other equipment. Anthropometry is particularly concerned with understanding human physical variation and its effect on performance. An example of applying human factors to the TMC workspace involves using data-based standards to determine functional and comfortable lighting levels within the operations space.

- **Teamwork and communication**: Human factors is concerned not only with how individuals think and behave, but also how being part of a team affects individual and overall performance. Teams, whether they are formally organized or composed of informal collaborators, can add complexity into understanding tasks by distributing knowledge, workload, and resources. An example of understanding TMC teamwork involves considering how undesirable event closure times are affected by inefficiencies in communications between responders in the field and in the operations center.

CHAPTER 2. THE TMC OPERATOR

Understanding the TMC operator is a key factor in designing an efficient TMC. Without understanding the user and designing for the user's needs, the latest technology will not be useful. Of course, TMC operators are not a homogenous group. Instead, operators have individual differences with varying strengths, weaknesses, expectations, and biases. Operators will have different education, training, experiences, and demographic backgrounds. This chapter presents guidelines that can be referenced in understanding and differentiating users so that the environment, workspace, technology, and many other aspects of TMC operations can be designed to optimize performance. A general theme of this chapter highlights the basis of performance decrements, including operator overload, workplace interruptions and distractions, vigilance, and decisionmaking biases while offering techniques to mitigate these decrements in performance.

OPERATOR KNOWLEDGE, SKILLS, AND ABILITIES

Operators come from multiple types of backgrounds and have varying levels of experience and expertise in the transportation arena. These differences can lead to communication and performance barriers within a TMC. With the operator in mind, tasks should be allocated to operators possessing the necessary knowledge, skills, and abilities (KSA) to successfully complete their assigned tasks. When assigning a task to an operator, his/her status and experience need to be considered. When examining the following guidelines, it is important to understand and design for individual differences that contribute to operator performance and his/her ability to complete various tasks. An overview of a cognitive task analysis (CTA) (which focuses on the operator) is presented in guideline 3, but TMC staff are not expected to be able to perform this procedure based solely on this specific guideline. The guideline is presented to provide basic background and additional references along with the caveat that professional guidance should be included in performing this procedure correctly. The following guidelines are included in this section:

- **Guideline 1**: Possessing Operator KSA.
- **Guideline 2**: Assigning Job Categories and Associated Roles.
- **Guideline 3**: Performing a CTA.

Guideline 1: Possessing Operator KSA

> Operators possess individual differences in training, background, and organizational experience, which may affect performance, communication, and decisionmaking. New and proficient operators must possess the KSA outlined in table 1.

Rationale

Operators come from different backgrounds and have varying levels of experience and expertise in the transportation arena. These differences can lead to communication and performance barriers within a TMC. Agencies need to account for these barriers in their training programs and communication protocols in a way that takes advantage of unique perspectives without inhibiting sharing of information within a team. Table 1 contains information adapted from FHWA's *TMC Operator Requirements and Position Descriptions*.[(6)]

Table 1. New and proficient operator KSA.[(6)]

KSA	New Operator	Proficient Operator*
Knowledge	• Understand TMC policies and procedures. • Comprehend traffic laws and highway operations. • Be aware of technical terms. • Comprehend operator systems and system applications. • Understand software, hardware, and automation.	• Use computer programs (word processors, spreadsheets, etc.). • Understand TMC management systems. • Comprehend traffic flow and time frames. • Understand technical terms.
Skills	• Deal with stressful situations. • Possess strong knowledge of mathematics and English grammar. • Read and interpret maps.	• Detect changes in traffic and text-based information and classify traffic incidents. • Possess human relations skills. • Follow standards and procedures. • Possess advanced map reading skills.
Abilities	• Communicate clearly and concisely. • Make quick decisions. • Learn and apply traffic control procedures. • Read and listen to technical information. • Write and speak using technical information. • Adjust to varying levels of activity.	• Make quick, rational decisions. • Provide suggestions and ideas to improve efficiency. • Switch quickly between different communications systems. • Use data to create advanced traveler information system messages.

*The proficient operator category also includes the new operator items.

OTHER CLOSELY RELATED GUIDELINES
Chapter 2 (guidelines 2–4 and 8).

SPECIAL CONSIDERATIONS
Download questionnaires that are used to measure KSA on O*NET's website.[(7)]

Guideline 2: Assigning Job Categories and Associated Roles

Tasks should be assigned to operators who have the proper training, experience, and knowledge of how to complete the task.

Rationale

TMC tasks and roles vary depending on organizational structure, location and size of TMC, resources, training, and operators' KSA. Generally, operators have varying levels of experience and training and, thus, perform different tasks. Table 2 shows examples of job categories broken down into specific tasks for each type of operator.(6)

Table 2. Job categories and associated roles.(6)

Job Category	Entry	Full Performance	Advanced/Supervisor
Information dissemination	Update DMS, media, highway advisory radio, and website.	Create, monitor, and update messages; send data to other agencies.	Create and approve new messages; send data to other agencies.
Traffic flow monitoring	Monitor external conditions.	Monitor detectors, closed-circuit televisions, and maps.	Monitor detectors, closed-circuit televisions, and maps.
Congestion management	Inform supervisor of sudden congestion.	Determine plan; respond to police notifications.	Implement response plan.
Incident management	Prepare execution plan.	Communicate and coordinate with responders.	Communicate and coordinate with responders.
Failure management	Record failures and inform supervisor.	Dispatch information to appropriate agency.	Dispatch information to appropriate agency.
Special events management	Archive and retrieve data.	Monitor and respond to crises and incidents.	Coordinate operations.
Environmental/ road weather information systems monitoring	N/A.	Observe and detect conditions.	Coordinate, observe, and detect conditions.
Record keeping	Update traffic logs.	Generate and provide reports.	Generate performance reports.

N/A = Not applicable.

OTHER CLOSELY RELATED GUIDELINES
Chapter 2 (guidelines 1 and 6).

SPECIAL CONSIDERATIONS
Clearly delineated roles that map to specific tasks will help avoid confusion.

Guideline 3: Performing a CTA

A CTA should be performed to identify the processes, procedures, and underlying KSA required to perform tasks in the TMC.

Rationale

Understanding the elements in table 3 can help agencies determine the type of software, staffing requirements, training, or TMC design that may overcome inefficiencies and improve performance and satisfaction. CTAs should be implemented with care and training to avoid bias and error or to rely too heavily on the intuitions in expert verbal reports. CTAs are more suited for understanding operator KSA than traditional task analyses due to the nonphysical and decision- or thinking-focused work performed in a TMC.

Table 3. Guidelines for selecting a CTA method.[8]

Scenario	Observation and Interview	Process Tracing	Conceptual Techniques
Tasks or procedures not well defined	X	N/A	N/A
Task process or performance needs tracking	N/A	X	N/A
Domain knowledge and structures need defining	N/A	N/A	X
Multiple operators used and tasks require less verbalization	N/A	N/A	X
Task performance affected by interference	N/A	X	X
Operators lack knowledge and techniques	X	X	X

N/A = Not applicable.

There are four major categories of knowledge elicitation methods as follows:[9]

- **Observations**: Observations provide an overview of how tasks are performed under real-world constraints.
- **Interviews**: Interviews are useful for understanding observed behaviors.
- **Process tracing**: Process tracing is useful in identifying necessary KSA for performing specific tasks.
- **Conceptual techniques**: Conceptual techniques identify interrelationships among task concepts and knowledge through outlining procedures and KSA required for a specific tasks and related subtasks.

OTHER CLOSELY RELATED GUIDELINES
Chapter 2 (guidelines 1 and 2).

SPECIAL CONSIDERATIONS
Process tracing can be performed by using concurrent verbal protocol where operators verbally annotate steps in a task and associated mental processes.

OPERATOR SELECTION

The following set of guidelines focuses on the topics of selection and qualifications, which are not traditional human factors topics but, nevertheless, are important considerations. Note that these topics are dealt with in other resources cited in the appropriate place in much greater detail. The goal is to provide a high-level overview of these topics with direction to resources for further review by personnel needing additional information. Staffing a TMC with the right personnel is essential to a productively functioning facility. Selecting those personnel should contain both qualitative (e.g., interviews) and quantitative (e.g., written skills exams) measures that can be combined to develop the best candidate. In addition, having an accurate position description that accounts for the range of duties expected of a staff member can yield the best pool of potential job candidates from which to select. Finally, a clear understanding of job experience needs and relevant qualifications (even if not directly in a TMC setting) can help identify the optimal personnel. This section includes the following guidelines:

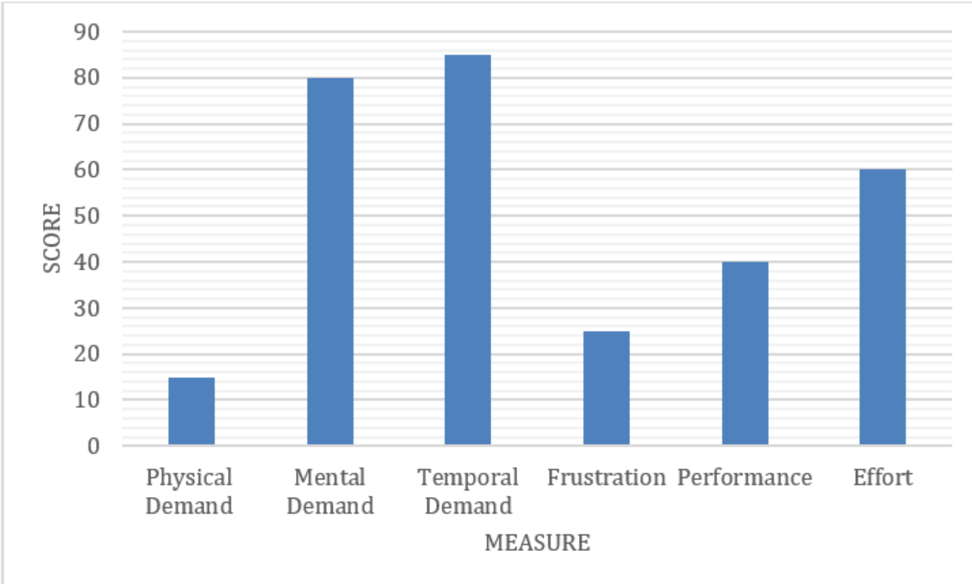
- **Guideline 4**: Assessing Operator Selection.
- **Guideline 5**: Developing Position Descriptions.
- **Guideline 6**: Evaluating Job Experience and Qualifications.

Guideline 4: Assessing Operator Selection

In addition to operator candidate interviews, a reliable, quantitative test should be administered to further assess performance, KSA, and mental workload/working memory capacity.

Rationale

Quantitative tests are useful for testing strengths and weaknesses of potential candidates. Using a reliable test helps reduce biases and increase fairness and consistency throughout the entire hiring process. Such tests are also effective when multiple TMC employees are interviewing candidates since these tests are relatively unaffected by extraneous factors. When selecting candidates, it is beneficial to use both qualitative (interviews) and quantitative (performance measurements) measures to better gauge operator fitness. Examples of quantitative measures include the National Aeronautics and Space Administration (NASA) Task Load Index (TLX) (figure 1) and the Wonderlic Personnel Test (WPT) (table 4).[10,11]



Source: FHWA.

Figure 1. Graph. Sample NASA-TLX scores.

Table 4. Example of acceptable minimum scores on the WPT for various occupations.

Position	Number of Correct Answers
Administrator	30
Engineer	29
Accountant	28
Programmer	28
Salesman	26
Secretary	25
Policeman	20
Telephone operator	18
Skilled laborer	17

NASA-TLX was designed by NASA to measure operator workload. NASA has created free online and paper versions (appendix A) that can be employed to measure both prospective and existing operators' mental, physical, and temporal (time) demands; performance; effort; and frustration while performing various tasks.(10)

OTHER CLOSELY RELATED GUIDELINES
Chapter 2 (guidelines 1, 2, and 6).

SPECIAL CONSIDERATIONS
TMCs may want to bring on a new hire in a probationary status, evaluating him/her every 3 mo for 6 mo prior to tenure.

Guideline 5: Developing Position Descriptions

Position descriptions should be developed that reflect the true requirements of the TMC by using a clear, methodical approach based on KSA required for proper performance.

Rationale

TMC managers should develop position descriptions that accurately reflect the day-to-day requirements of personnel working in the TMC. These descriptions will help civil service representatives, human resources personnel, and hiring managers select the best candidates for jobs. This topic is dealt with in considerably more detail in other sources published by FHWA.(12) Baxter provides examples of each level of position description for a TMC and includes clear guidance for development.(12) Baxter gives a high-level overview of developing position descriptions for managers. Those who are interested should refer to the publication for additional information.

Baxter developed a step-by-step process for writing position descriptions that accurately reflect the desired KSA for a particular position.(12) The suggested steps were assigned to properly utilize the transportation management operations technician (TMOT) guidelines matrices and include the following:

1. Select and prioritize TMC functions/tasks.
2. Select the subtask descriptions for each function.
3. Identify KSA for each operator level (entry, full performance, and advanced; see descriptions in guidelines 1 and 2).
4. Identify all KSA by level for the TMC functions selected.
5. Compile the KSA text from the KSA table.

OTHER CLOSELY RELATED GUIDELINES
Chapter 2 (guidelines 1 and 2).

SPECIAL CONSIDERATIONS
KSA requirements should be clearly organized before writing a position description to determine desired role.

Guideline 6: Evaluating Job Experience and Qualifications

The candidate pool should not be limited to only those with direct TMC experience when selecting candidates for a new or existing position.

Rationale

When selecting candidates for a new or existing position, the candidate pool should not be limited to only those with direct TMC experience. Experience in both a traditional TMC as well as relevant and comparable experiences in other positions should be taken into account when selecting candidates. For example, control center operators in the commercial industry or public safety and dispatch (i.e., emergency operations, law enforcement, fire and rescue, military, etc.) may have relevant experience that can be valuable. Directly relevant and potentially comparable experiences may include the following:(13)

- Bachelor's degree in engineering and/or master's degree in transportation.
- Minimum of 5 yr of experience in traffic engineering and/or ITS.
- Microsimulation traffic modeling experience.
- Traffic safety and operations study experience.
- Signal timing experience.
- Traffic maintenance experience.
- Transit planning and operations experience.
- Relevant experience in commercial, military, or public safety operations.

OTHER CLOSELY RELATED GUIDELINES
Chapter 2 (guidelines 1, 2, 4, and 5).

SPECIAL CONSIDERATIONS
Experience from other positions can be valuable in a TMC.

ORGANIZATIONAL STRUCTURE AND SHIFTS

The following guidelines revolve around larger organizational issues. Although these topics are not traditionally human factors topics, per se, they are important in increasing the efficiency of a TMC. In addition, understanding the benefits of strategically placed breaks and proper shift schedules are often overlooked when planning a rotation in a TMC. The overall organizational structure can also go a long way toward improving the functioning of a TMC, especially when there are limited technological or financial resources or other challenges. Immediate, near-term, and longer-term tradeoffs should be considered when deciding how to structure the organization. This section includes the following guidelines:

- **Guideline 7**: Scheduling Shifts and Breaks.
- **Guideline 8**: Determining Organizational Structure.

Guideline 7: Scheduling Shifts and Breaks

When scheduling staff, it is important that shifts do not exceed 10 h and that 5- to 10-min breaks are given every 30–60 min.

Rationale

TMCs that operate 24/7 typically have three shifts, each lasting 8 h.[1,14,15] There is no absolute measurement for the number of staff needed per shift as this need varies based on the size of the TMC, the number of operations performed, and the organizational structure. There should be a balance of operators based on skills and experience across shifts correlated with the amount of work/tasks to be performed. It is also important to account for the number of staff needed during peak operational and high-demand hours while complying with Federal, State, and local laws.

Break times need to be coordinated and determined prior to shift changeovers. It is suggested that operators take brief (e.g., 5–10 min) breaks in order to stay vigilant and sustain performance.[1,14] During shift changeovers, it is important to have a 30-min overlap so the staff from the previous shift can brief those taking over. This can be done by staggering the shifts by 30 min or by arranging the schedule so that staff from the previous shift stay a few minutes late or the staff from the new shift arrive a few minutes early. This will guarantee an overlap between staff from both shifts. It is also advantageous to schedule at least one senior operator per shift to provide guidance and fill-in when operators are overloaded.

OTHER CLOSELY RELATED GUIDELINES
Chapter 2 (guidelines 1, 2, and 8–10).

SPECIAL CONSIDERATIONS
A technique should be developed for exchanging information during shift changeovers.

Guideline 8: Determining Organizational Structure

Immediate, near-term, and longer-term tradeoffs should be considered when choosing how to structure the organization. Tradeoffs include the following:

- Number of personnel and shift length.
- Training requirements and expertise.
- Size and characteristics of region.
- Fatigue and workload.

Rationale

Many TMCs have flat organizational structures. An advantage of a flat organizational structure over a tall organizational structure is faster response times for decisionmaking, which leads to quicker implementation of changes. However, the speediness of responses to proposed changes may also depend on the TMC’s jurisdiction.

Determining how to structure the TMC is often driven by financial factors and desired efficiency. Making financial and efficiency tradeoffs can result in unexpected consequences in other areas. For instance, understaffing a TMC in an effort to save costs might be effective in the short term but could affect operator workload, fatigue, and ultimately performance or attrition.

While a small staff may be effective for light traffic periods, having limited (or fatigued) staff during peak periods could result in inefficiencies at the most important and dangerous times. Additionally, failure to have a sufficient number of trained operators could be problematic if operators resign, take a leave of absence, or go on vacation.

However, balancing financial and performance factors is not a simple task. Regional characteristics play an important role in these decisions. A TMC in a large, multijurisdictional, metropolitan area may choose to subdivide operators into specializations based on incident type, subregion (i.e., zone), or subtask (e.g., dispatch, DMS, event management, and construction). Doing so enables operators to become experts and have exposure to particular specialties. In turn, cross-training may be an effective management structure for large TMCs, especially at peak times, but is unnecessary during nonpeak hours.

OTHER CLOSELY RELATED GUIDELINES
Chapter 2 (guidelines 1, 2, and 7).

SPECIAL CONSIDERATIONS
For more detailed information about TMC operations and organizational structure, see *Handbook for Developing a TMC Operations Manual*.[16]

OPERATOR PERFORMANCE

The following guidelines include issues related to operator performance. Giving people the proper tools and structure will only go so far without also assisting them in achieving and maintaining optimal performance. Several performance categories are important to consider from a human factors perspective, including performance decrement, optimizing automation and related performance issues, and ways of assessing performance. Performance can be negatively impacted by a variety of factors, including straining mental workload, issues of boredom that must be mitigated through increased vigilance, multitasking demands, and the downside of constant interruptions (which are particularly prevalent in today's society of instant messaging, email, and smartphones). Automation can assist in alleviating some of these decrement pressures, but a delicate balance needs to be struck between automation and task allocation. Finally, performance should be assessed and monitored utilizing subjective and objective measures. This section includes the following guidelines:

- **Guideline 9**: Understanding Mental Workload.
- **Guideline 10**: Sustaining Operator Vigilance.
- **Guideline 11**: Understanding Multitasking.
- **Guideline 12**: Minimizing Interruptions.
- **Guideline 13**: Determining Automated Task Allocation.
- **Guideline 14**: Assessing Performance Techniques.

Guideline 9: Understanding Mental Workload

> Tasks should be allocated in a way that operators' mental workload remains in a mid-level range. In this range, operators are able to engage in their current tasks while reserving additional mental resources that are needed to react to sudden events.

Rationale

Mental workload is the amount of demand a task places on an operator under time constraints.(17) The factors affecting mental workload include the number of staff, task demands, time constraints, stress, and fatigue. Having an adequate number of staff permits efficient task allocation and reduces the likelihood that operators will perform an unmanageable number of tasks. Additionally, a TMC manager should be conscious of operator workload when allocating tasks.(14)

Two common subjective techniques to measure mental workload are the subjective workload assessment technique (SWAT) and NASA-TLX.(18,10) Guideline 14 includes several methods to assess mental workload demands for specific tasks.

Performance is best when mental workload is in the midrange. When the operator is overloaded, interruptions and distractions are more disruptive. Additionally, performing a task or multiple tasks that are highly demanding causes an increase in stress, which may result in poor performance and more errors.(1) There are other situations in which demands may be so low that the operator experiences boredom, fatigue, and mind wandering. Under conditions of operator underload, unexpected events, incidents, and emergencies may cause the operator to experience sudden stress.(1)

> **OTHER CLOSELY RELATED GUIDELINES**
> Chapter 2 (guidelines 10–14 and 17).

> **SPECIAL CONSIDERATIONS**
> Environmental factors that may degrade performance, including noise, thermal environment, workstation design, and labels, should be monitored.

Guideline 10: Sustaining Operator Vigilance

> Operator vigilance can be sustained by performing the following:
>
> - Assigning varying tasks.
> - Allowing frequent breaks.
> - Making incidents on visual displays salient and easy to detect.

Rationale

Warm, Parasuraman, and Matthews define vigilance as “the degree to which an operator is alert.”[19] The degree of alertness is most commonly measured through vigilance tasks, which are tasks that involve continuous monitoring over a long period of time. Performance decrements are noticeable after 30 min of performing such tasks.[19] This occurs for several reasons: boredom, low and high workload, and level of automation. It is important to note that high levels of automation will cause performance decrements regardless of the task (guideline 13).[20] Under high levels of automation, operators are less likely to detect incidents, are more prone to making errors, and are at a higher risk of fatigue and boredom. Fortunately, there are several efficient solutions to mitigate performance decrements during task monitoring. For example, assigning varying tasks and allowing operators to take brief breaks during their shifts are known to improve alertness and concentration.[14]

It may be appropriate to allocate more automated functions to operators during nonpeak hours in attempts to reduce vigilance decrements. The level of accuracy and the severity of errors should be evaluated to determine which tasks require peak alertness. For example, a high level of alertness is optimal for less demanding tasks to combat boredom and fatigue. Contrarily, low levels of alertness are acceptable for urgent tasks (e.g., emergencies and unexpected/unusual events) because these tasks are more salient. For peak performance, the overall optimal level of alertness is in the midrange.[14] Contextual and environmental factors that decrease the likelihood of vigilance decrement include the following:[21]

- Access to tools designed to support information processing and decisionmaking.
- Adequate staffing and staff cohesiveness.
- Thoughtful shiftwork management.
- Management support.
- Assertive approach to managing errors and risks.
- Informed policy and procedures.
- Training opportunities.
- Physical environment (overall comfort level and attention to ergonomics).

OTHER CLOSELY RELATED GUIDELINES
Chapter 2 (guidelines 13, 17, and 18) and chapter 3 (guideline 24).

SPECIAL CONSIDERATIONS
For easier detection, one should try varying the color, display size, and type or level of alert for different types of incidents and traffic flow maintenance.

Guideline 11. Understanding Multitasking

When performing multiple tasks at once, be sure the tasks are simple, and only perform dissimilar tasks simultaneously.

Rationale

Working memory has a limited capacity, making it difficult to distribute resources equally among multiple tasks. Additionally, when operators are required to perform two tasks simultaneously, varying task modalities makes the operator less susceptible to performance decrements. For example, it is generally easier to perform two tasks simultaneously if one task requires auditory/vocal resources (e.g., conversing with a coworker) and the other requires visual/manual resources (e.g., computer interaction). It is more challenging if both tasks require the same resources. This occurs because each modality uses different working memory resources. Contrarily, if an operator performs two tasks of the same modality (e.g., two visual tasks), each task competes for shared working memory resources, resulting in performance decrements in one or both tasks.(22)

Guideline 12. Minimizing Interruptions

> The disruptiveness of interruptions can be minimized by performing the following:
>
> - Keeping excess noise to a minimum.
> - Completing one task before moving on to a new task.
> - Turning off or silencing cellphones.

Rationale

An interruption is an external source (e.g., email, phone call, operators shouting) that causes an operator to stop performing the current task to attend to the interruption. For example, an operator may be notifying a local law enforcement agency of a new incident (primary task) while another operator is asking questions or conversing with him/her (interruption task). Performance decrements occur when the operator attempts to resume the primary task.

Observational research has shown that office workers are interrupted, on average, 12 times per h.(23) Research has shown that interruptions can increase task completion time, errors, and perceived workload and decrease quality of work.(24–26) Additionally, research has shown that interruptions can decrease job satisfaction and increase job frustration.(27) Many interruptions cannot be prevented, but following these guidelines can help minimize or control the disruptiveness of interruptions.(17)

> **OTHER CLOSELY RELATED GUIDELINES**
> Chapter 2 (guidelines 9 and 13), chapter 3 (guideline 24), chapter 4 (guideline 55), and chapter 6 (guidelines 73 and 74).

> **SPECIAL CONSIDERATIONS**
> A performance trade-off model should be created to prioritize tasks by cost of errors and severity, urgency, importance, and duration.(17)

Guideline 13. Determining Automated Task Allocation

When distributing tasks to automation, the following should be considered:

- It is important to be conservative when assigning tasks to automation.
- Automated tasks should be simple and low risk.
- Automated systems need to be reliable and error free.

Rationale

A good automation interface improves operator performance and efficiency while reducing errors and mental and physical workload. However, when too many functions are automated, operators become dependent on the automation, causing a decrease in the ability and knowledge of manual performance. Figure 2 and figure 3 can be used as qualitative and conceptual aids in determining which tasks to automate.[20]

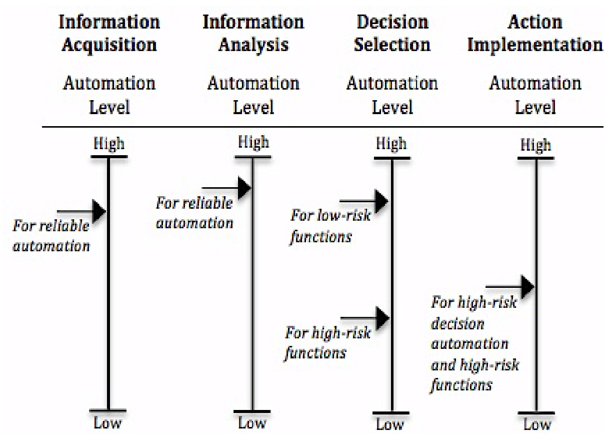


Figure 2. Illustration. Suggested relative levels of automation.[20]

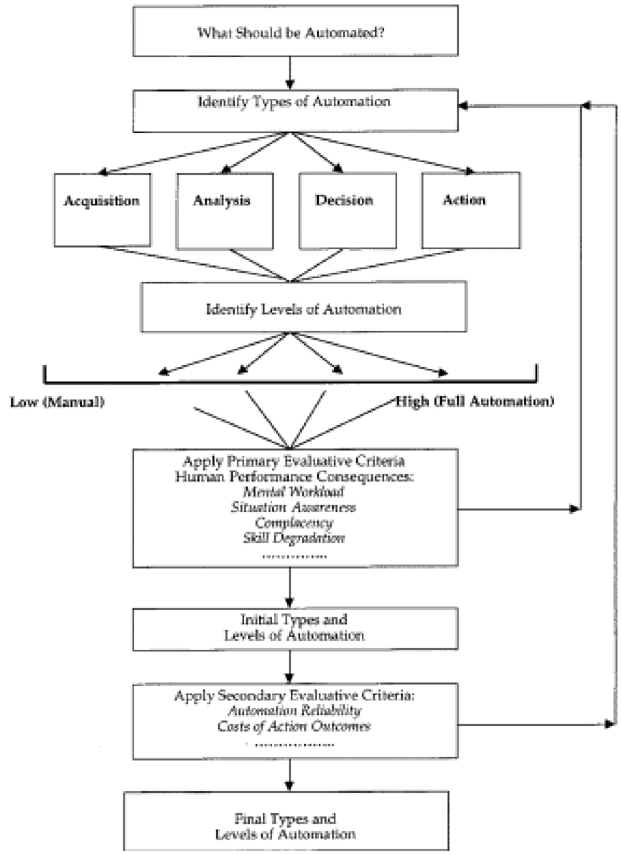


Figure 3. Flowchart. Steps to determine automated task allocation.[20]

OTHER CLOSELY RELATED GUIDELINES
Chapter 2 (guideline 9) and chapter 3 (guidelines 23 and 24).

SPECIAL CONSIDERATIONS
When the workload is low, the operators should be given more tasks. Alternatively, when the workload is high, tasks should be allocated to automation.

Guideline 14. Assessing Performance Techniques

Both subjective and objective measures should be used to assess operator performance.

Rationale

Assessing operator performance is beneficial for both the operator and supervisor. The supervisor is kept in the loop while the operator receives feedback on the quality of his/her work. Why are performance measures important? According to Osborne and Gaebler, it is necessary to measure results in order to distinguish success from failure.[28] Identifying success is a prerequisite for rewarding it. Alternatively, identifying failures is the first step in correcting them.

There are generally two types of performance assessments: subjective and objective. It is best to use a combination of both techniques to ensure that operators are fairly assessed. The following are examples of subjective performance assessment techniques:

- Assess the mental workload using the following:[29]
  - SWAT.[18]
  - NASA-TLX (appendix A).[10]

- Measure motivation by answering the following questions:
  - Do operators receive supervisor feedback?
  - Are operators able to practice a variety of skills?
  - Do operators have some degree of freedom? Are they trusted to work independently?

- Track operator performance using the following:
  - Performance development reviews.
  - Phone call reviews.
  - Question/answer process about incidents.

Objective performance assessment measures include the following:

- Percent or number of operator errors.
- Average time to manually post or update DMS messages.
- Time to notify agencies.
- Average time to confirm incident.

OTHER CLOSELY RELATED GUIDELINES
Chapter 2 (guideline 9) and chapter 3 (guideline 37).

SPECIAL CONSIDERATIONS
Some operators perform better on objective measures, while others are better on subjective measures. Both are valuable.

OPERATOR TRAINING

Selecting quality personnel and matching them to the right tasks are only part of what it takes to build an efficient TMC. It is also important to improve any deficiencies through training and ensure consistent approaches for the staff. This section focuses on training and training program components and implementation. Similar to the previous section, operator training may not be considered a strict human factors area and is often more related to organizational development and operations. Nevertheless, it is important to the overall behavioral interactions throughout the TMC and ways in which the staff utilize technology, the latter being particularly relevant to human factors. This section includes the following guidelines:

- **Guideline 15**: Developing Training Program Components.
- **Guideline 16**: Implementing a Training Program.

Guideline 15. Developing Training Program Components

A standardized training program should be developed for new and existing operators.

Rationale

Training programs can be monotonous and overwhelming and, if not properly designed, will provide little benefit. Fortunately, many well-designed training programs exist that should be considered when designing or selecting various training programs.

Baxter presents a model training program example that is based on the TMOT KSA matrix (table 1).[(12)] This program and similar ones should be considered when developing a cohesive training program for the TMC. The following components are contained in the program and should be tailored for each TMC:

- **Orientation to the TMC**: Organizational structure, rules, policies, work environment, etc. (2–4 h the first day).
- **Control room basics**: Equipment, duties, various staff, etc. (2–4 h the first day and a refresher the second day).
- **Transportation system knowledge**: Area transportation system, potential impediments to traffic flow, general familiarity with other agencies involved in traffic control, and other transportation modes affecting highways (16 h the first week and 8 h during the next 6 mo).
- **Knowledge of the transportation management system**: Variable message signs, dispatching, use of logs, shift transfer procedures, etc. (16 h the first week and 4 h/mo for the next 6 mo).
- **Public and media communications**: Proper responses to media requests, professionalism, etc. (4 h the first week and 1 h/mo for the next 6 mo).
- **Software and equipment**: Proper use of software and equipment (timing varies).
- **Technical traffic engineering principles (full performance level)**: Fundamental theory and hands-on practice (8 h over a 6- to 18-mo period).
- **Advanced training options (full performance to advanced level)**: Traffic planning, hazardous materials, creative problem solving, team building, etc. (20–30 h per course).

OTHER CLOSELY RELATED GUIDELINES
Chapter 2 (guideline 16) and chapter 6 (guidelines 82 and 83).

SPECIAL CONSIDERATIONS
Consider implementing a training program evaluation process to determine the usefulness of individual training programs.

Guideline 16. Implementing a Training Program

Before implementing a training program, the areas of training needed should be determined by surveying operators or by direct observations.

Rationale

Training should account for questions regarding who, what, when, and where while providing standardization through certification programs when possible.

To further address these questions, Neudorff et al. listed the following specifications that should be considered for optimizing training:(15)

- How many people are needed/desired to attend each session?
- How many days are required to complete the program?
- When should training be conducted?
- Who will develop outlines of lectures and demonstrations and create samples of all training materials?
- Who will develop any supply manuals, displays, class notes, visual aids, and other instructional materials?
- When will training be held and who will pay for transportation and other related costs?

Training can be implemented via simulated exercises, TMC site visits, videos, and in-person or online lectures. There should be standardization through certification programs when possible, and there should be the opportunity for a wide cross section of staff to get training. This will improve communication and yield a larger pool of backup staff during severe weather.(14)

To learn more about various training programs and example tutorials, the following can be referenced:

- *Post-Course Assessment and Reporting Tool for Trainers and TIM Responders Using the SHRP 2 Interdisciplinary Traffic Incident Management Curriculum*.(30)
- *Utah Department of Transportation Traffic Operation Center Operator Training*.(31)

OTHER CLOSELY RELATED GUIDELINES
Chapter 2 (guideline 15) and chapter 6 (guidelines 82 and 83).

SPECIAL CONSIDERATIONS
New operators should be trained side-by-side with an advanced operator and be trained on several different scenarios.

PROPER DECISIONMAKING AND AVOIDING BIASES

Decisionmaking is key to optimizing human factors and organizational considerations in a TMC. It is difficult enough in optimal settings but may be particularly challenging in the sometimes stressful TMC environment. Stress, in particular, can negatively influence decisionmaking and should be mitigated when possible. This section focuses on the factors that affect decisionmaking, common biases that can negatively impact performance (as well as strategies to reduce these biases), proper decisionmaking pointers, and the use of decision aids. This topic is rarely given the attention it deserves, but it can be a vital part of improving TMC functions and requires few financial or technological resources. This section includes the following guidelines:

- **Guideline 17**: Understanding Factors that Affect Decisionmaking.
- **Guideline 18**: Understanding the Signal Detection Theory.
- **Guideline 19**: Understanding Framing Bias.
- **Guideline 20**: Understanding Confirmation Bias.
- **Guideline 21**: Understanding Anchoring Bias.
- **Guideline 22**: Using Proper Design and Decision Aids.

Guideline 17. Understanding Factors that Affect Decisionmaking

Operators should be educated on factors that affect proper decisionmaking, including fatigue, stress, lack of information, and time pressure.

Rationale

Decisionmaking is a complicated process with myriad potential influences that should be taken into account. Although not exhaustive, the following list contains a variety of possible influences on an operator's decisionmaking, many of which can lead to suboptimal outcomes:[1,32]

- Fatigue (including sleep deprivation), which can be minimized by adjusting schedules.
- Stress, which can be avoided by removing personnel from extended stressful situations where possible.
- Perceived or real time pressure.
- Erratic eating habits (leading to high or low blood sugar).
- Caffeine.
- Lack of information, conflicting information, or uncertainty.
- Demographic variables such as age, personality, language, and culture.

Stress, in particular, can negatively influence decisionmaking and should be mitigated when possible. Decisionmakers under stress can exhibit a variety of behaviors, including the following:

- Seek out certainty, are less tolerant of ambiguity, and look for fast choices.
- Experience greater conflict in social interactions.
- Develop tunnel vision (narrowed perception due to sensory overload).
- Experience distorted perception.
- Have a decreased ability to handle complex or difficult tasks.
- Focus on short-term survival goals, sometimes at the expense of long-term benefits.
- Choose riskier alternatives.

OTHER CLOSELY RELATED GUIDELINES
Chapter 2 (guidelines 9 and 18–22).

SPECIAL CONSIDERATIONS
Policies, procedures, and training should help guard against any of these factors compromising decisionmaking ability.

Guideline 18. Understanding the Signal Detection Theory

Specific criteria should be determined regarding the degree of certainty needed to make a proper response and the situations where operators should respond in a liberal or conservative fashion.

Rationale

Signal detection theory posits that errors in decisionmaking result in misses and false alarms. The signal detection theory explains the four decision outcomes: hit, correct rejection, false alarm, and miss (table 5). A hit means that the signal (i.e., critical event, alarm, etc.) was present, and the operator made the correct decision. A miss refers to the presence of a signal, but the operator failed to detect it. A false alarm means that there was not a signal, but the operator made a response. A correct rejection refers to the absence of a signal, and the operator did not respond.(33,17)

Table 5. Signal detection theory.

Response	Signal Present	Signal Absent
Yes	Hit	False alarm
No	Miss	Correct rejection

When operators are tasked with making a decision about a critical event through visual detection or an auditory alarm, there is usually limited time to cross-reference other sources to gain a higher degree of certainty. In such instances, there is an equal probability that the operator will make the correct or incorrect decision. When operators make an incorrect decision, they tend to lose trust in automation.(34)

In some instances, it may be beneficial to respond in a more conservative or a more liberal pattern. A conservative response increases the probability of misses and correct rejections. Responding in a conservative manner is best when the outcome of making a false alarm is detrimental. A liberal response increases the probability of hits and false alarms. Responding in a liberal manner is best when the outcome of not responding to the event is severe.[33]

OTHER CLOSELY RELATED GUIDELINES
Chapter 2 (guideline 17) and chapter 3 (guidelines 43–45).

SPECIAL CONSIDERATIONS
A high number of false alarms may cause operators to ignore or respond slower to signals or events.

Guideline 19. Understanding Framing Bias

Framing effects can be detrimental to proper decisionmaking. The effects of framing can be mitigated by shifting labels, colors, and phrases (when it is necessary to shift mode or approach).

Rationale

A very common decisionmaking bias involves people reacting differently to information depending on the phrasing, context, or framing.[35] A modified version of the classic framing problem is shown in table 6.

Table 6. Example of framing bias.

Framing	Treatment A	Treatment B
Positive	There are 200 people who need to be evacuated.	There is a 33 percent chance of evacuating all 600 people and a 66 percent possibility that no one will be evacuated.
Negative	There are 400 people left who need to be evacuated.	There is a 33 percent chance that no one will be evacuated and a 66 percent probability that all 600 people will be evacuated.

In treatment A, someone can choose a plan to either evacuate 200 people (out of 600) or leave behind 400 people (out of 600). In either case, 400 people will likely be left behind. This is similarly explained in treatment B, although probabilities of success are included. Depending on the frame (i.e., whether things are presented in a positive light or a negative light), someone will make drastically different decisions even though the underlying facts are the same.

This bias can have profound impacts on a transportation system, especially when switching or transitioning operations during a major incident or emergency. A strategy to mitigate the effect of this bias is to clearly change labels, colors, or codes to indicate the context has changed (e.g., from normal operations to emergency operations). In addition, one should be aware of how information is presented and whether it may be framed in a negative or positive way. For example, if an operator states that a corridor can be cleared in 1 h if all goes according to plan, a manager should ask about possible outcomes if things do not go as planned. The initial report may have been framed positively, but when operating a TMC, one must also consider risks. Each situation may be framed positively or negatively, and both types of frames should be considered when making a decision.

OTHER CLOSELY RELATED GUIDELINES
Chapter 2 (guidelines 17, 18, and 20–22).

SPECIAL CONSIDERATIONS
Framing can be a bias, but it also can be a tool to improve decisions, especially in novel circumstances.

Guideline 20. Understanding Confirmation Bias

Use the following strategies to mitigate confirmation biases:

- Clearly conceptualize assumptions.
- Seek out falsifying information.
- Reward disagreeing opinions.
- Ground information in the proper context.

Rationale

People often favor or seek out information that confirms a prior hypothesis or belief. This inclination is known as confirmation bias.[36] This bias can affect operations when operators/managers focus more on reports/data that support an initial approach or only listen to opinions that support their plans. Thus, operators may not seek out alternate explanations and indirectly ignore other useful information. For example, one could assume that, if an area has been evacuated, then the evacuation route has been opened. However, Is this always the procedure? In this example, confirmation bias would explain why someone would only check places where a site has been evacuated and where evacuation routes have been opened (assuming, if one occurs, then the other must have occurred).

Instead, the correct decisionmaking process would be to sample all of the possibilities and would include the following steps:

1. Check sites that have been evacuated (to ascertain if the evacuation route was opened).

2. Check instances where a route has not been opened to determine whether the site was evacuated (presumably by some other method or route).

The second step is a key one that people often overlook—check the false or opposite condition to see if the precondition still occurred. One should check for negative instances or find weaknesses in arguments instead of just searching for supporting evidence. Seeking falsifying information when faced with a decision often provides better evidence and allows for a better logical examination, thereby avoiding confirmation bias.

OTHER CLOSELY RELATED GUIDELINES
Chapter 2 (guidelines 17–19, 21, and 22).

SPECIAL CONSIDERATIONS
Always question information, and look for alternative perspectives.

Guideline 21. Understanding Anchoring Bias

To mitigate anchoring bias, one should be careful about weighting early or limited information and should generate alternative/counterfactual options.

Rationale

Individuals have the tendency to rely on the first piece or on limited pieces of information when making a plan or forming an estimate. This tendency is known as anchoring.[37,38] If someone is shown a series of numbers such as 8 × 7 ×…× 1 and asked to guess the sum, his/her guess would be higher than if shown the series of numbers 1 × 2 ×…× 8 (though the two products are identical); leading with the larger number influences guesses to be higher than leading with a smaller number. Similarly, when working in a TMC, if an operator is asked for the last two digits of his/her social security number and then asked to guess how long it will take to clear a traffic incident, it is very likely that operators with higher social security numbers will create higher estimates of incident clearance time (a variation of a task used in Ariely).[37] Seemingly unrelated or insignificant numbers can have a profound influence on someone's decisionmaking in a variety of contexts.

This bias often manifests in operational situations when the first incoming field reports will drive estimates or the more salient images will affect planning. To mitigate this bias, one should be careful about weighting early or limited information and should generate alternative/counterfactual options. Another option is to constantly refine estimates as data become more reliable over time.

OTHER CLOSELY RELATED GUIDELINES
Chapter 2 (guidelines 17–20 and 22).

SPECIAL CONSIDERATIONS
Operators should always try to gather more information and be mindful of overweighting the first piece of information encountered.

Guideline 22. Using Proper Design and Decision Aids

Decision aids should be designed and implemented to improve decision quality. The following guidelines should be used to offset some of the typical biases that arise when making decisions:

- Present all diagnostic and alternative information simultaneously.
- Prioritize information and present the most important parts.
- Make the operator aware of alternative hypotheses.
- Provide interpretation of statistics.
- Provide simple decision aids and streamlined presentation of complex information.
- Provide information on automation limitations to avoid operator overconfidence.

Rationale

Decision aids can help with early data processing and improve overall decision quality, which can offset some of the typical biases that arise when making decisions. Also, decision aids can be automated (i.e., programs) or nonautomated (procedures, checklists, etc.). Decision aids have a variety of advantages, including the following:

- Minimizing the influence of biases on decisions.

- Forcing structure and consideration of alternatives as well as quantitative weighing of options.

There are also several disadvantages that one should keep in mind when employing decision aids, including the following:

- Discounting of intuition/experience.
- Lack of use if inaccurate.
- Lack of adaptation in unusual circumstances.
- Increased decision time and evaluation difficulties.

Regardless, properly designed decision aids can be valuable assets to an operator in the TMC.

OTHER CLOSELY RELATED GUIDELINES
Chapter 2 (guidelines 17–21) and chapter 3 (guidelines 46 and 47).

SPECIAL CONSIDERATIONS
Protocols or procedures should be developed to implement when operators make errors in decisionmaking.

CHAPTER 3. USERS AND INTERFACES OF AUTOMATION SYSTEMS

TMCs use software and applications to obtain, process, and act on data, such as maps, with roadway sensor or weather data, incident management logs, dispatch tools, device management tools, and instant messaging and email tools. This chapter focuses on the user interface and system interactions. Inadequate consideration of the user can lead to poor user acceptance of systems, decline in job satisfaction, and ultimately poor performance when the interface is not intuitive, efficient, responsive, or well understood. This chapter emphasizes the importance of designing the system to fit the user and presents guidelines related to effective interface design and human–computer interaction. It also provides guidelines for effective interface design and human–computer interaction, the role of the operator in automated or computer-assisted activities, and the effects of applications such as websites and social media within the TMC.

MATCHING USER AND SYSTEM DESIGN

Introducing any level of automation changes the task for TMC operators by adding a barrier between the operator and the task. The following section ties together the operator and the overall system (including software and hardware). There are guidelines addressing how a human operator interacts with a mechanical system, including the concept of "operator in the loop," which can be understood as a human operator who acts as a system component in the decisionmaking path. In addition, there is information about what tasks and duties to allocate to operators versus machines and how to identify the appropriate balance. This section then focuses on user interface design, including a basic introduction with additional references, and then includes information on task analysis to help improve system design. The type of task analysis presented in this section focuses on the machine, whereas the task analysis presented in guideline 3 in chapter 2 focuses on the operator. In addition, the TMC staff are not expected to be able to perform this procedure based solely on this specific guideline. The guideline is presented to provide basic background and additional references along with the caveat that professional guidance should be included in performing this procedure correctly. One has to evaluate the user interface and the tasks for which a system is designed to improve overall design. Regardless of how well a system is designed, it is also important to understand whether users are accepting of the technology (and ways to increase acceptance to optimize use). Guidelines are presented to lead the reader through the basic concepts and conduct of user acceptance testing (UAT) as it relates to TMCs. This section includes the following guidelines:

- **Guideline 23**: Keeping Operators in the Loop.
- **Guideline 24**: Implementing Human Versus Machine Allocation.
- **Guideline 25**: Considering User Interface Design.
- **Guideline 26**: Performing a Task Analysis for System Design.
- **Guideline 27**: Performing Usability Testing for System Design.
- **Guideline 28**: Performing UAT.
- **Guideline 29**: Designing and Conducting UAT.

Guideline 23. Keeping Operators in the Loop

Automated systems should be designed to alert operators when incidents, emergencies, and unusual events are detected. The system should allow operators to make the final decision about how to proceed.

Rationale

It might appear that introducing automation into the TMC can improve efficiency and decrease operator workload. One major drawback of automation is that it does not keep the operator sufficiently in the loop. For instance, automated systems that perform tasks without any human interference or human decisionmaking will create a barrier between operators and their assigned tasks. Additional potential problems of keeping the operator out of the loop include the following:[20,19,22]

- Skill degradation caused by automation complacency.
- Loss in job satisfaction.
- Boredom and fatigue.
- Confusion or loss of awareness for manual and automated tasks.
- Missed events.
- Overreliance or mistrust in automation.

Instead, automated systems should alert operators to the detected information and allow them to make the decision. Routine operations are best left to machine automation, while more interactive emergency situations in a TMC require more intense operator-run activities. While TMC functions have increasingly relied on the use of decision support systems, it is foreseen that, in the immediate future, operators will need to remain in the loop until such a time when automated systems can sense, interpret, and control all variables in the environment that influence traffic flow.

OTHER CLOSELY RELATED GUIDELINES
Chapter 2 (guidelines 9, 10, and 13) and chapter 3 (guideline 24).

SPECIAL CONSIDERATIONS
It is important to clearly understand what the automated system can and cannot do. That should be a point of emphasis during training.

Guideline 24. Implementing Human Versus Machine Allocation

Machine-allocated tasks should be implemented to reduce operator workload. The machine design should allow operators to bypass or turn off the automation. It is also important that automation failures be tracked and logged.

Rationale

Research has shown that humans are better at recognizing than remembering information.[39] Human working memory has a limited capacity, making it difficult for people to retain information in memory. Computers and automated systems can be used in situations where memory is necessary. Automated systems are proficient and relatively error free. It is important, however, that operators are well equipped to perform automated tasks for instances when there are system failures. The following lists present scenarios of optimal task allocation.[15]

Machines outperform humans in the following:

- Multitasking.
- Performing rapid, complex, long, repetitive, and meticulous tasks.
- Operating under a variety of environmental conditions without decrements.
- Recalling and storing large amounts of information.

Humans outperform machines in the following:

- Reacting to unexpected events.
- Making judgments, applying reasoning, and exhibiting flexibility.
- Experiencing sensitivity to a wide variety of stimuli.
- Integrating previous knowledge and experience.

OTHER CLOSELY RELATED GUIDELINES
Chapter 2 (guidelines 9–11 and 13) and chapter 3 (guideline 23).

SPECIAL CONSIDERATIONS
In the event that the automated system malfunctions, operators should be trained and possess the skills necessary to manually perform these automated functions.

Guideline 25. Considering User Interface Design

The user interface should be designed to complement operators. It should reduce workload and errors and permit operators to monitor, detect, or perform multiple tasks.

Rationale

Good user interface designs reduce operator workload and errors and permit operators to monitor, detect, or perform multiple tasks at once. Conversely, poorly designed user interfaces increase physical and mental demands, increase errors and response times, and decrease job satisfaction.

The following components should be considered when designing a user interface:[40]

- **Visibility of system status**: Users should be able to easily detect functions, intuitively understand their use, and perform a limited number of steps to accomplish a goal.
- **Feedback**: Users should be kept informed about the system status in a timely manner.
- **Consistency**: Location of functions and text and actions performed should be uniform throughout the entire interface.
- **Clearly marked exits**: A cancel or exit button would allow users to return to a previous menu without having to start from the beginning.
- **Good error messages**: Errors should be explicitly stated, and concrete solutions should be provided.
- **Shortcuts**: Users should be able to bypass or activate functions using shortcuts.

The preceding considerations can be evaluated by performing a heuristic evaluation.[41] A heuristic evaluation is a type of usability testing that allows designers of interfaces and products to identify any potential errors or design flaws that need to be addressed. It is advised that persons with training in usability perform heuristic evaluations as well as other types of usability testing. See guideline 27 for further information on usability testing.

OTHER CLOSELY RELATED GUIDELINES
Chapter 2 (guidelines 9 and 13) and chapter 3 (guidelines 26, 27, and 38).

SPECIAL CONSIDERATIONS
Standard development kits should be used to create an interface similar to widely used TMC software.

Guideline 26. Performing a Task Analysis for System Design

The question of interest for a task analysis can be determined from the following:

- **Knowledge based**: What does the operator know?
- **Action based**: What does the operator need to do?
- **Interface based**: What does the operator interact with?
- **Error based**: What might the operator do wrong?

Rationale

Goals, operators, methods, and selection rules (GOMS) is a type of action-based task analysis. A more specific version of GOMS that is easier to conduct is a keystroke level model (KLM). A KLM may be used to determine how long it takes to perform a task, identify unnecessary task steps, identify errors that impact performance, and identify processes that lead to high workload.[42] The following list highlights accepted execution times for specific actions:

- **Keystroke (K)** = 0.28 s.
- **Point mouse toward target (P)** = 1.1 s.
- **Mouse click or press button on touchscreen (B)** = 0.2 s.
- **Draw a line segment (D)** = 1.9 s.
- **Mental action preparation (M)** = 1.2 s.
- **Wait for system to respond (W)** = Estimate for given system.

Figure 4 provides an example of a KLM for searching within a document. The optimal choice is to use option 2 because there are fewer steps and a faster execution time.

Option 1:	Option 2:
1. Point mouse towards a document (1P). 2. Double click to open the document (2B). 3. Point mouse towards the Find button on the ribbon (1P). 4. Press the Find button with the mouse (1B). 5. Type search word Research (8K). 6. Press Enter (1K).	1. Point mouse towards a document (1P). 2. Double click to open the document (2B). 3. Press ctrl+F on the keyboard to open finder (2K). 4. Type search word Research (8K). 5. Press Enter (1K).
Total time = 2P + 3B + 9K = 5.32 s	Total time = 1P + 2B + 11K = 4.58 s

Source: FHWA.

Figure 4. Illustration. Example of a KLM showing two options for searching within a document.

OTHER CLOSELY RELATED GUIDELINES
Chapter 2 (guidelines 3, 9–11, and 13) and chapter 3 (guidelines 23, 25, 27, and 45).

SPECIAL CONSIDERATIONS
The person performing the task that is being analyzed should have a sufficient level of competence and experience to perform the task properly.

Guideline 27. Performing Usability Testing for System Design

Usability testing should be performed early in the design process when changes are easier and less costly to make.

Rationale

Usability testing consists of several techniques, all aimed at assessing how users interact with an interface. More specifically, performing usability testing will allow designers to address the key usability features, including learnability, efficiency, memorability, errors, and satisfaction.[42] Table 7 defines these features.

Table 7. Key features of usability testing defined by questions addressed and measurements.

Key Features of Usability	Questions Addressed	Measurements
Learnability	• Is the system usable by the intended audience? • How easily can users perform actions? • Are functions, menus, and buttons intuitive to use or do users need training and instructions to be able to use the system?	• Think aloud protocol. • System usability scale. • Cognitive walkthrough. • Speed of performance.
Efficiency	• Does the system perform what it is supposed to? • How quickly can users perform actions? • Are any functions or features missing from the design?	• Scenario-based testing. • Time on task and input rate. • Mental error. • Contextual interview.
Memorability	• Does information need to be remembered for later use or does the system cue users? • Do users have to relearn how to use the system each time it is used?	• Recall. • Description of strategy.
Errors	• What errors do users make and why are these errors made?	• Heuristic evaluation.
Satisfaction	• What do users like or dislike about the system? • Do users accept and trust the system?	• Interviews and focus groups. • Questionnaires (ease of use, user acceptance, frustration/ expectations, etc.). • Perception of interaction.

Usability.gov is the leading resource for user experience best practices and guidelines, serving practitioners and students in the Government and private sectors.[43]

OTHER CLOSELY RELATED GUIDELINES
Chapter 3 (guidelines 25, 26, 28, 29, 39, 42, 46, and 47).

SPECIAL CONSIDERATIONS
It may be necessary to consult with usability experts to perform usability testing.

Guideline 28. Performing UAT

Perform UAT for the following advances to accomplish the following:

- Establish agency and contractor expectations.
- Tie acceptance testing to contractor payments.
- Build expected trust of TMC systems.

Rationale

The three elements of acceptance testing involve system testing (ST), system integration testing (SIT), and UAT. Establishing acceptance testing as part of a system design and purchase process helps create a more transparent relationship with vendors and a more satisfactory product. When the system is designed correctly, many problems associated with human–computer interaction become magnified during formal UAT and can be resolved before systems go live. Through structured UAT, the reliability of the system should match sponsor expectations and build trust between the TMC operators and their expected human–machine interaction.[20] To clarify routinely used testing practices, several definitions are provided in table 8.[44]

Table 8. Common testing definitions for ST, SIT, and UAT.[44]

Type	ST	SIT	UAT
Objectives	Verify the information system as a whole is functionally complete and satisfies both functional and nonfunctional design requirements.	Verify the design and assembly of subsystem components and its interactions with the overall system.	Perform real-world testing by intended audience.
Goals	Detect defects and errors.	Verify inputs and outputs across systems and external organization interfaces.	Verify business functionality from users' perspectives.

OTHER CLOSELY RELATED GUIDELINES
Chapter 3 (guidelines 23–25, 27, and 29).

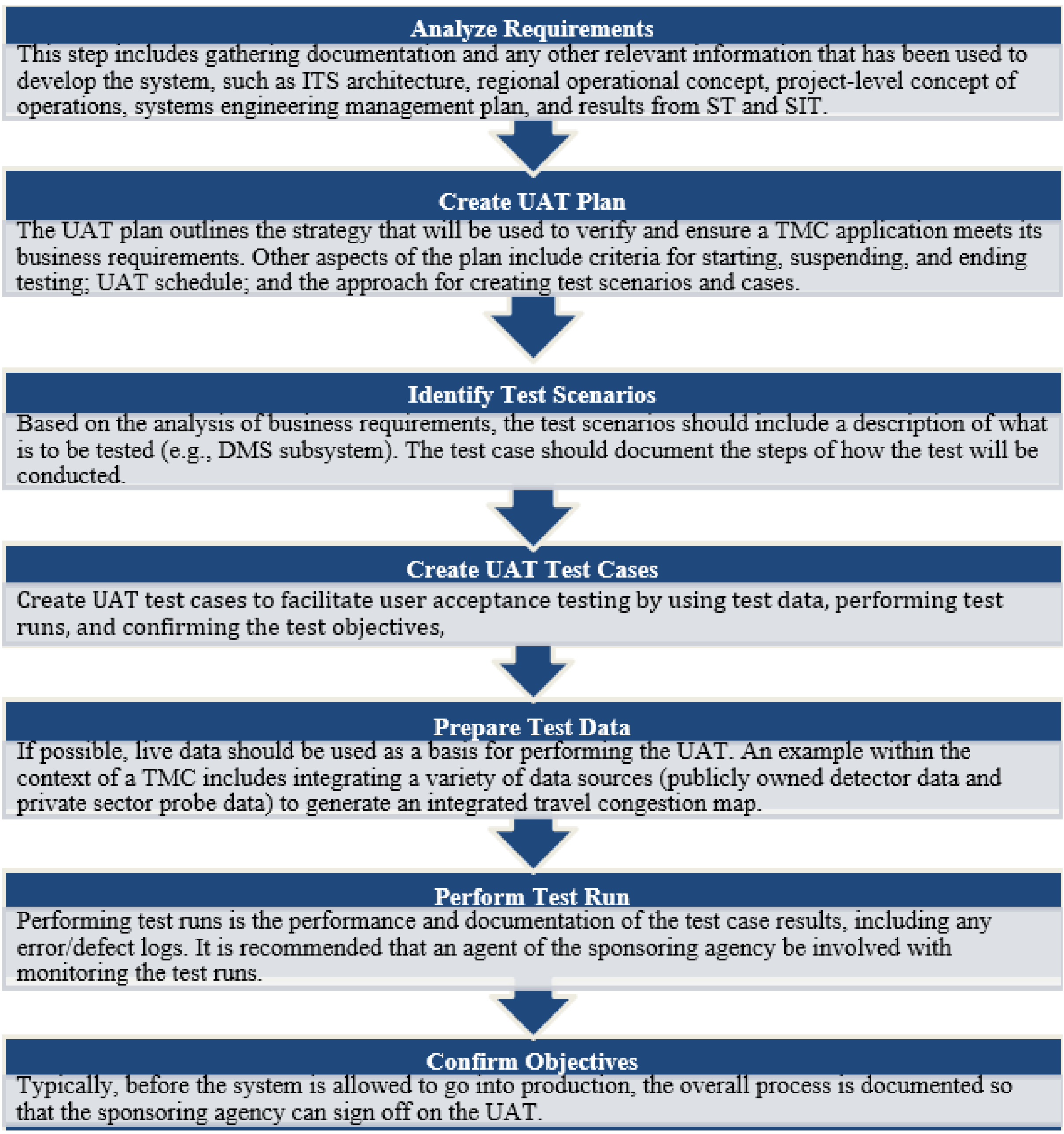
SPECIAL CONSIDERATIONS
Without well-defined TMC change management policies, procedures, and tools, the UAT becomes even more important.

Guideline 29. Designing and Conducting UAT

The seven-step process shown in figure 5 should be used as a UAT technique to analyze existing information technology standards within the TMC.

Rationale

The seven-step process of conducting UAT is depicted in figure 5, which illustrates the logical steps within a UAT. First, one should analyze the requirements, including gathering background documentation. Next, the person conducting the assessments should create a plan (which includes a plan to verify a TMC is meeting its business requirements) while identifying various test scenarios for investigation. These test scenarios are then created, and the test data are prepared. Next, a test run is performed. Finally, before a system is allowed to go into production, the overall process is documented and objectives are confirmed by the sponsoring agency.



Source: FHWA.

Figure 5. Flowchart. Seven-step UAT process.

OTHER CLOSELY RELATED GUIDELINES
Chapter 3 (guidelines 23–25, 27, and 28).

SPECIAL CONSIDERATIONS
Software as a service and cloud-based computing software require common UAT techniques to be modified.

INCIDENT IDENTIFICATION AND TRACKING

Tracking and assisting with responding to traffic incidents is one of the most important activities a TMC performs. Consequently, an effective TMC must have an efficient structure for recording incidents and generating incident reports as well as keeping logs. With the overall emphasis on incident management increasing for TMCs, these reports and log protocols will gain in importance. There are also systems available to overall TIM. Both of these topics are covered in the following guidelines included in this section:

- **Guideline 30**: Creating Incident Reports.
- **Guideline 31**: Using TIM Systems.

Guideline 30. Creating Incident Reports

The level of verification should be determined for each source of incident reports. Additionally, incident reports should be recorded in a tracking log for later retrieval.

Rationale

Depending on the source of information, incidents may need to be verified through closed-circuit television (CCTV) or by field personnel.[16] Table 9 provides various sources of incident reports with the corresponding level of verification.

Table 9. Suggested levels of verification for sources of incident reports.

Incident Report Source	Level of Verification
Field-located agency staff	Low
Police two-way radio	Low
Police scanner	Low
Nonagency personnel	Medium
Commercial radio	Medium
Citizen cellphone or landline call	High
Social media (individual reports and crowd sourced)	High

TMCs capture a variety of critical response information throughout the duration of a traffic incident. Incident reports should be recorded in a tracking log for later retrieval. Incident tracking logs can be helpful in learning and improving efficiency, especially in stressful incident management situations.

Studies have shown that for effective and useful tracking logs, the following incident information should always be recorded:[45]

- Timestamp for detection, notification, arrivals, and departures.
- Incident identification number.
- Agencies involved.
- A detailed timeline of the events.
- Any prevalent information about the environmental state.

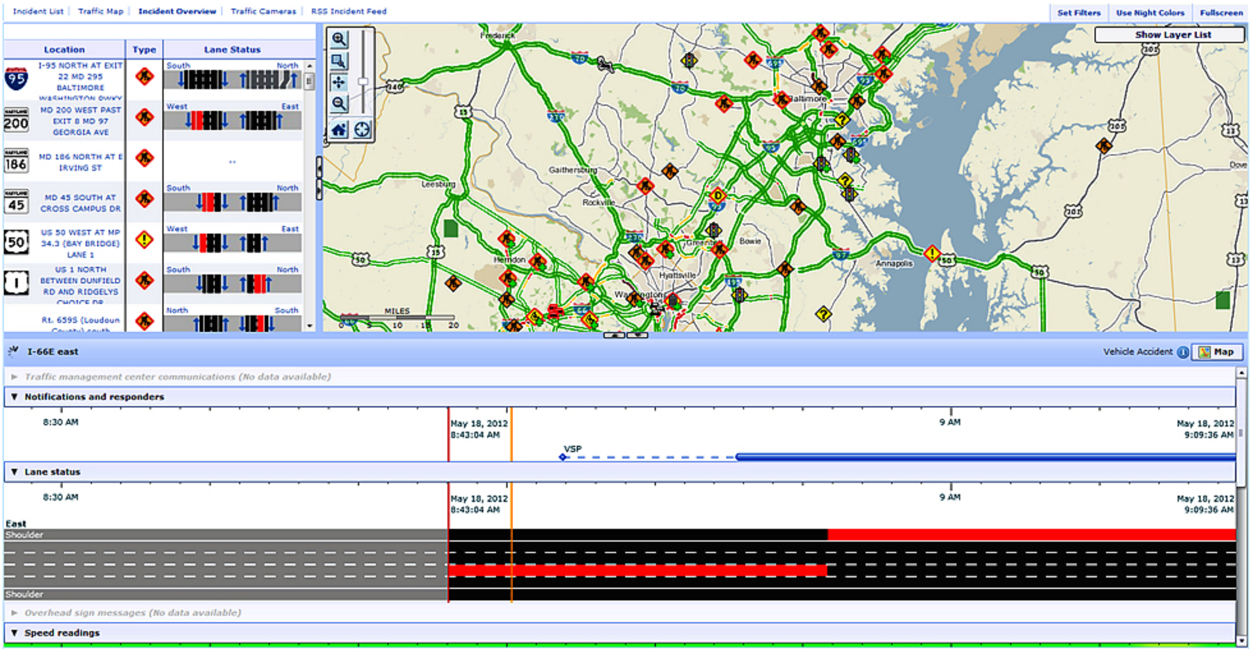
OTHER CLOSELY RELATED GUIDELINES
Chapter 3 (guideline 31).

SPECIAL CONSIDERATIONS
Information from multiple sources can yield better insights.

Guideline 31. Using TIM Systems

A TIM system should include the following components (figure 6):

- Location of the incident.
- Type of incident.
- Affected lanes and speed readings.
- Relationship of incident to overall region.
- TMC role and communication (e.g., updating of DMS and performance measures, including timestamp of notification to responders and clearance time).



Reproduced with permission from CATT Lab © (2009) Regional Integrated Transportation Information System (RITIS).

Figure 6. Screenshot. Interface for incident tracking software showing detailed incident information.[46]

Rationale

Tracking and assisting with traffic incident responses is one of the most important activities a TMC performs. The National ITS Architecture and Regional Integrated Transportation Information System (RITIS) illustrate the range of traffic incident–related activities a TMC can perform, including tracking of incidents through detection, verification, and coordination with public safety and maintenance partners.[47]

OTHER CLOSELY RELATED GUIDELINES Chapter 4 (guideline 30).

SPECIAL CONSIDERATIONS Use multiple data sources to monitor congestion, including travel time data.

COMPUTER-ASSISTED RESPONSE SYSTEMS

There are a variety of ways the TMC operator or manager may communicate with the public about special events, delays, or incidents. These methods include 511 traveler information systems, DMSs, and highway advisory radio (HAR). All of these methods can be placed under the general category of computer-assisted response systems. There are several human factors considerations as well as procedural issues that operators should be aware of when interacting with the public through these channels. The following guidelines are not an exhaustive treatment but rather a general overview with pointers that take into account operator preferences or limitations and additional references.[14] Issues related to the software interface, layout, and operation are found later in guidelines 36–45. This section includes the following guidelines:

- **Guideline 32**: Designing Telephone-Based 511 Traveler Information Systems.
- **Guideline 33**: Employing a DMS Interface.
- **Guideline 34**: Using HAR Input Systems.

Guideline 32. Designing Telephone-Based 511 Traveler Information Systems

The user interface should be designed to include the following:

- Short initial greeting.
- Top-level prompts, including highways, public transportation, weather, and help.
- No more than six options per level.
- Three or fewer entries to get to desired information.
- The option for users to go back.
- Shortcuts and barge-ins so users can jump to desired level.
- Floodgates for major emergencies or events of region-wide significance.

Rationale

The most successful agencies supporting 511 traveler information systems invest in evolving technology and have recognized the need for a customer-based focus.[48] Voice recognition systems have become the primary interface with telephone-based 511 traveler information services. However, touch-tone services are occasionally needed when users are in noisy environments, have speech impairments or very strong accents, or when the voice recognition system is down or reaches capacity.

The following should be considered when developing or deploying a 511 traveler information system:

- Providing properly sized bursting capabilities to accommodate large-scale incidents.
- Providing accurate lane closure and traffic incident information.
- Providing location-specific weather information.
- Providing opportunities for user feedback.
- Bundling traveler information services using landline phone, Web pages, and smartphone applications.

Allowing users to provide feedback (e.g., via a survey) is a highly effective tool to gauge the usability of the service. Specifically, when reviewing feedback, one should look for trends that may help detect errors or usability problems with the 511 system.

OTHER CLOSELY RELATED GUIDELINES
Chapter 3 (guidelines 36 and 38) and chapter 6 (guidelines 75 and 78–81).

SPECIAL CONSIDERATIONS
It is necessary to address accessibility needs of deaf or hearing-impaired users and non-English speakers.

Guideline 33. Employing a DMS Interface

It is necessary to employ a DMS response system that includes the following features:[49]

- Displays predefined default messages (or blank display) during normal conditions.
- Automatically updates travel times.
- Assigns message priority, where urgent, time-sensitive messages override lower-priority messages.
- Informs operator of intended actions and allows the operator to modify or reject message.

Rationale

DMSs provide a way for TMCs to communicate real-time information, including traffic incidents, congestion, travel times, safety alerts, weather advisories, alternative routes, construction, new traffic laws, and Amber alerts, to the public.[50,51] For example, some vendors offer software that allows the user to modify one sign at a time. More sophisticated DMS control systems, when integrated into a broader ATMS, include a variety of features such as a scheduler, DMS plans, and even connections to decision support systems based on a variety of situational conditions. Automated computer-assisted response systems are preferred over manual systems for their ease of use, reliability, and benefits in reducing operator performance demands. One major drawback to manual systems is that some operators may post different terms or different formatting than other operators for the same event. For example, one operator may use the terms "accident" or "congestion," while another operator may post "crash ahead" or "incident."[49]

The DMS system should present operators with a graphical user interface detailing the intended action and allow the operator to approve, modify, or reject the message. This feature will allow the operator to remain in the loop while detecting and modifying any system-generated errors.

OTHER CLOSELY RELATED GUIDELINES
Chapter 3 (guideline 38) and chapter 6 (guidelines 75, 76, and 81).

SPECIAL CONSIDERATIONS
For timely updates, it is important to develop preexisting templates for each of the previously mentioned scenarios.

Guideline 34. Using HAR Input Systems

HAR should be used to disseminate information to a large population of motorists. It is important that HAR employment is used in a conservative manner by broadcasting only urgent information.

Rationale

While some State transportation departments are scaling back on their use of HAR with the proliferation of location-based smartphone applications, HAR messages are audible, and drivers experience less sensory overload compared to looking at a smartphone or another device. HAR also allows for longer messages to be shared with motorists.

From an application perspective, many agencies are employing reverse engineering to transmit messages to HAR sites. In early deployments, HAR messages had to be created in the TMC by voice recording and sent to each transmitter. Now, messages are being created using 511-based text-to-voice technology to generate location specific messages for each transmitter location. It is advantageous to connect HAR to information from 511 traveler information to reduce the operators needed to monitor and update information. Additionally, automating inputs prevents operators from making dual entries during incident response. Only under special circumstances are TMC operators required to record and broadcast HAR messages.

HAR is effective in getting the attention of motorists using flashing beacon signs (fixed or portable) when an alert is available with messages such as “Traffic Advisory—Tune to 1610 AM.” It can be accessed by telephone, so it does not require any access to a computer or other TMC system. Messages should be standardized and may include the roadway affected, direction, location and lanes impacted, incident cause description, and delay duration and alternate routes.[52] Messages that are vague or may be easily misunderstood should be avoided.

OTHER CLOSELY RELATED GUIDELINES
Chapter 6 (guideline 75).

SPECIAL CONSIDERATIONS
HAR should be promoted through static roadside signing and DMS use.

COMPUTER-AIDED DISPATCH SYSTEMS

Sending automated messages from computer-aided dispatch (CAD) systems to TMC-based ATMSs is very important to reducing the dispatcher’s or the operator’s burden and responsibility. From a user interface perspective, applying the correct level of CAD record filters is critical in responding to a traffic incident. The following section highlights several human factors and behavioral issues to be aware of when establishing, choosing, or operating a CAD system. This section includes the following guideline:

- **Guideline 35**: Integrating CAD with TMC Software.

Guideline 35. Integrating CAD with TMC Software

CAD systems should be automated to perform the following procedures:

- Filter CAD information to only information needed by TMC operators.
- Eliminate and control for duplicate entries.
- Convert roadway classification terms to those used within the TMC.
- Send automated messages of incident-relevant information to coordinating agencies.

Rationale

A primary method of detecting incidents is through mobile 911 calls. Increasingly, freeway management systems have access to CAD systems that display incident information to TMC operators nearly as soon as the public safety agency becomes aware of an incident.[53] The CAD systems of State highway patrol or police officers may input different terms (e.g., classifying an incident) and road names than those used by a TMC CAD system. To reduce the confusion and errors this may cause within the TMC, the TMC CAD system should be designed to convert these terms and road names into the standardized State department of transportation language.

Additionally, displaying too many incidents and lengthy descriptions on CAD-integrated software negatively affects performance as follows:

- Increases operator workload and time on task.
- Reduces operator vigilance and increases the likelihood of missing information.
- Reduces the operator's attentional resources that need to be allocated to other tasks.

OTHER CLOSELY RELATED GUIDELINES
Chapter 3 (guidelines 30 and 31).

SPECIAL CONSIDERATIONS
TMCs should consider purchasing an enhanced CAD system.

WEBSITE INTERFACE

An attractive and well-designed website projects a positive image to the public and exemplifies the customer focus that many agencies emphasize. There are particular protocols for website content that agencies should follow, which are addressed in this section. In addition, it is important to properly measure the performance of the website to verify that it is user friendly and that the public can access needed information. Furthermore, the TMC operator should have access to user-friendly website software that is consolidated for different messages and purposes and minimizes input steps for generating or updating a website.

This section includes the following guidelines:

- **Guideline 36**: Updating Website Content.
- **Guideline 37**: Tracking Website Performance.

- **Guideline 38**: Using Website Content Management Software.
- **Guideline 39**: Minimizing Website Input Steps.

Guideline 36. Updating Website Content

> Traveler information updates that meet FHWA section 1201 rule for real-time system management information should be provided, including the following:(54)
>
> - A quality control process should be established to ensure updated and accurate content posted to the TMC website.
> - Content should be filtered to prevent information overload on the TMC website.

Rationale

FHWA section 1201 rule provides minimum requirements for States to make traveler information available.(54) It also requires States to define metropolitan areas and routes of significance since the timeframes for reporting are dependent on the location of the closures or condition. The type of reporting information includes the following:

- **Construction road/lane closures**: These closures should be reported within 20 min of closure outside metropolitan areas and within 10 min of closure within metropolitan areas.
- **Traffic incident road/lane closures**: These closures should be reported within 20 min of incident verification outside metropolitan areas and within 10 min of incident verification within metropolitan areas.
- **Road weather conditions**: These conditions should be reported within 20 min of observation.
- **Travel times**: These times should be reported within 10 min of calculation completion for limited access segments within the defined metropolitan areas.

Oftentimes, information is automatically fed into website databases through Web services, Extensible Markup Language feeds, or other methods. For a variety of technical and human error reasons, disruptions in these data feeds may occur. It is important that these feeds be monitored with alerts provided when information has not been updated or is incomplete or incorrect. Data quality and consistency are important features for website users. In order to maintain visitors to the website, the data must be continually monitored for accuracy.(54)

For example, a planned lane closure due to construction may be valuable information to post on the website. However, other construction activities, such as shoulder closures or short-term (less than 30 min) impacts, may be less valuable. To prevent information overload, it is important to identify the critical information to display on the website and have a strategic plan for which information should be filtered.

OTHER CLOSELY RELATED GUIDELINES
Chapter 3 (guidelines 32 and 37) and chapter 6 (guidelines 78–81).

SPECIAL CONSIDERATIONS
The website should allow users to access all information during high usage periods, including evacuations, major incidents, weather events, etc.

Guideline 37. Tracking Website Performance

Website performance measures should be established to track customer usage. These may include analytics that track the number of visits, bounce rate, time spent on site, etc.

Rationale

Moving Ahead for Progress in the 21st Century Act outlines a variety of initiatives to track performance measures.(55) Tracking is equally important for traveler information websites to assess the data's value and understand the trends in use. Google Analytics™ is a tool that may assist in tracking website performance. Some suggested performance measures include the following:

- Number of visits.
- Number of pages per visit.
- Bounce rate.
- Time spent on site.
- New and returning visitors.
- Top pages viewed.
- Top referrers.

In addition, accessibility with various internet browsers is an important aspect of website development and use. Over time, browser usage has changed.(56) Website accessibility to various browsers should be considered when measuring website performance. The TMC may want to examine cost differentials when attempting to design a program that reaches the 1.3 percent who may use Opera™, for example, and then determine if it adds value to take that course of action. Table 10 shows browser usage for five different browsers for the first 3 mo of 2016.

Table 10. Percent of browser usage for January–March 2016.(56)

Month	Chrome™ (%)	Internet Explorer™ (%)	Firefox™ (%)	Safari™ (%)	Opera™ (%)
January	68.4	6.2	18.8	3.7	1.4
February	69.0	6.2	18.6	3.7	1.3
March	69.9	6.1	17.8	3.6	1.3

OTHER CLOSELY RELATED GUIDELINES
Chapter 3 (guideline 32).

SPECIAL CONSIDERATIONS
The minimum requirements should be determined for traveler information that is displayed on a public website versus third-party vendors.

Guideline 38. Using Website Content Management Software

All website content management inputs should be consolidated into one interface.

Rationale

TMC operators may manage public website content for various alerts, including the following:

- Construction lane closures.
- Traffic incidents.
- Road conditions.
- Inclement weather.
- Floodgate alerts.
- System maintenance tickets.

Since rapid response and operators' quick dissemination of information to stakeholders are important, it is imperative that information is entered into one field or program. For example, if separate systems are used for road conditions, floodgate alters, and maintenance tickets, managing several logins and interfaces will be more challenging when trying to quickly input information. When possible, these user interfaces should be consolidated.

Guideline 39. Minimizing Website Input Steps

A user interface should be designed to minimize the number of clicks and steps required of operators.

Rationale

There are many tasks conducted by TMC operators that require repetitive entry, monitoring, or notifications. Software interfaces can assist operators in presenting more efficient functionalities. Several examples include the following:

- Providing a map or graphic for entry and verification of information as opposed to a list.

- After selecting a function, redirecting the program to a more logical and efficient page to minimize the operator's need to locate the desired software.

- Allowing operators to make multiple selections or entries prior to final submission. For example, selecting all road conditions for a specified region prior to submission as opposed to selecting and submitting each individually.

- Identifying opportunities to develop user interface efficiencies as technology changes, such as utilizing applications for tablet use.

OTHER CLOSELY RELATED GUIDELINES
Chapter 2 (guideline 13) and chapter 3 (guidelines 25–27, 37, and 39).

SPECIAL CONSIDERATIONS
Information entered into one field or program should automatically sync websites and related applications.

SOCIAL MEDIA INTERFACES

TMCs should utilize social media channels to effectively provide outreach to the media, the traveling public, and agency staff. Social media is now an important channel of communication between TMCs and the public. Traditional methods were only one-directional—from the TMC to the public via its website, signs, and other messages. Now, social media allows for bi-directional communication—from the TMC to the public and from the public to the TMC. In addition, social media allows for more targeted information dissemination. The following section provides guidance on dissemination times, social media use, content management software, and ways to minimize the input steps for social media. Note that these technologies are rapidly changing, but the general principles and guidance should stay relevant even if the particular technology platform or channel continues to evolve. This section includes the following guidelines:

- **Guideline 40**: Using Social Media.
- **Guideline 41**: Using Social Media Content Management Software.
- **Guideline 42**: Minimizing Social Media Software Input Steps.

Guideline 40. Using Social Media

> Social media channels should be utilized to effectively provide outreach to the media, drivers, and agency staff. Timely responses are important to engage social media users. Suggested response times are as follows:
>
> - **Twitter**®: 30 min.
> - **Facebook**®: 90 min.
> - **Blog**: 3 h.

Rationale

Facebook® and Twitter® are the most utilized social media channels for TMC operations. These profiles currently offer the most opportunity for TMCs to provide real-time information. However, agencies may use other social media profiles, which require monitoring and responding to traffic-related information. Effective incident notification to the media, drivers, and agency staff is an important role of TMC operators. Individuals are most likely to continue to follow or begin following official TMC social media channels if the content provided is limited to critical traffic information and is consistently updated. The following example shows text from a Virginia Department of Transportation (VDOT) Facebook® post:[57]

> NORTHERN VIRGINIA: Crews will be out tonight monitoring for slick spots on bridges, ramps & overpasses due to refreezing. Please continue to take it slow on such structures and use caution while driving everywhere.

The following example shows text from a VDOT Twitter® traffic alert:[58]

> Heading SB on I-95 in #Hanover? Take Exit 98 (Down Boulevard/Rt 30) EB to Rt 301 SB back to I-95 SB. Multiple crashes in area. #RVAtraffic.

OTHER CLOSELY RELATED GUIDELINES
Chapter 3 (guidelines 33, 34, 36, 41, and 42) and chapter 6 (guidelines 75 and 77).

SPECIAL CONSIDERATIONS
Social media provides the opportunity to receive traffic-related information from the media, police, and drivers.

Guideline 41. Using Social Media Content Management Software

Social media content management software should be used to manage various social media profiles.

Rationale

There are various tools available that can assist with the management and analysis of social media information.[59] These software tools include the following:

- Enhanced service portals.
- Facebook Insights®.
- Hootsuite™.
- TweetDeck®.
- Twilert®.
- Twitter Analytics®.
- Radian6™.

An agency may have multiple Twitter® accounts by geographic area. To be more efficient, accurate, and timely in managing social media profiles, TMC operations should utilize content management software.

OTHER CLOSELY RELATED GUIDELINES
Chapter 3 (guidelines 32, 33, and 42).

SPECIAL CONSIDERATIONS
Inputs from TMC operators should be automated to limit dual entry during incident response.

Guideline 42. Minimizing Social Media Software Input Steps

Social media management for TMC operators should be a combination of automated and manual input depending on the content.

Rationale

There are many routine incidents or lane closures that occur on a day-to-day basis. These situations should require automated posting of information to social media channels such as Facebook® and Twitter®. There should be a standard template for these postings with a 140-character threshold for Twitter®, which allows a limited number of characters. Existing systems should be identified to create an automated connection to input traveler information to social media channels. These systems may include existing ATMS software or 511 systems.

Social media is traditionally intended to provide more efficient alerts and communication to followers. With prior approval, operators should be able to disseminate information to various social media channels that are not otherwise automated. The methods of posting information could be dispersed through social media content management software, individual social media sites (e.g., Twitter®), or other software systems. The following examples highlight Facebook® and Twitter® posts. The Facebook® post is a manual entry, while the Twitter® post is an automated alert. For example, a Wisconsin Department of Transportation (WisDOT) manual Facebook® post is as follows:(60)

> TRAVEL ALERT: with heavy rain sweeping across much of Wisconsin, this morning, be prepared for possible flash flooding. Each year, the majority of flood-related deaths occure in vehicles. Do not drive on Water-covered roads, you never know what's beneath you. As safety slogan goes, "Turn Around, Don't Drown.

WisDOT automated Twitter® posts include the following:(61)

> Cleared | WAUKESHA Co | Crash | WIS 16 EB | JJ | All Lane Blocked (One Direction) | 511wi.gov.

> Alert | WAUKESHA Co | Crash | WIS 16 EB | JJ | All Lane Blocked (One Direction) | 511wi.gov.

OTHER CLOSELY RELATED GUIDELINES
Chapter 3 (guidelines 32, 40, and 41).

SPECIAL CONSIDERATIONS
Operators should be able to use social media software to enter unique traffic-related information during system failures.

SYSTEM ALARMS

Special attention needs to be given when designing alarm metrics and determining the appropriate uses within a TMC to reduce errors and increase operator efficiency. As described in chapter 2, signal detection theory explains the outcomes for responding or not responding to alarms, including hits, correct rejections, misses, and false alarms. The scenarios that need to be carefully controlled and designed for in alarm systems are the likelihood of committing misses and false alarms. For example, a system that presents a high number of false alarms may cause operators to ignore or respond more slowly to signals or events. By properly coding, presenting, and prioritizing alarms, operators should be less likely to commit such errors. These key features are presented in the following guidelines. These guidelines cover the appropriate uses and frequency of alarms, the different channels of presenting alarms (auditory, visual, etc.), and how to prioritize alarms based on level of urgency. The specific alarms and alarm systems may vary between TMCs, but the general principles outlined in this section can help streamline and organize notifications. This section includes the following guidelines:

- **Guideline 43**: Using Alarms.
- **Guideline 44**: Presenting Alarms.
- **Guideline 45**: Prioritizing Alarms.

Guideline 43. Using Alarms

Detailed concept of operations procedures should be incorporated for system alarms requiring action from TMC operators. Urgent alarms should be quickly recognizable and comprehensible as well as clearly distinguishable from other messages.

Rationale

Since many TMCs operate 24/7/365, system alarms are often monitored by TMC operators. These system alarms may be for security, flooding, wrong-way driving (WWD), power outages, etc. The frequency of alarm notifications may vary from daily to infrequent. Therefore, it is important that TMC operators have specific and clear instructions on how to proceed. Typically, this may involve sending an email or making a phone call to a specific person, agency, or group.

The parameters of the alarm interface should be intuitive for operators to utilize, and procedures should ensure that the workload demands correspond with other operator tasks.[62] Other important alarm features to consider include the following:

- Control availability.
- Type of user interaction.
- Device type and layout.
- Alarm administrative features.
- Automatic features.

Guideline 44. Presenting Alarms

Alarms should be presented in the following ways:

- Audible indication.
- Light indication.
- Email notification.
- Telephone and text notification.

Rationale

Alarm notification may be made to the TMC through various methods such as phone call, email, text message, audible alert, or visual alert. Depending on the type of alarm, the urgency of response, and the concept of operations for operators, the type of notification should be carefully considered.[62] The alarm format should indicate the following features:

- Alarm should be quickly detected and interpreted.

- Alarm priority should be evident (i.e., the highest priority should be the most conspicuous).

- Alarm type variations should be minimized to avoid confusion.

OTHER CLOSELY RELATED GUIDELINES
Chapter 2 (guidelines 9 and 17) and chapter 3 (guidelines 23 and 43–45).

SPECIAL CONSIDERATIONS
Simple alarms with clearly associated actions that everyone is aware of are key to efficient operation.

Guideline 45. Prioritizing Alarms

Alarms should be reserved for conditions where immediate attention and action are needed. Alarm messages should be presented in a prioritized order to indicate urgency.

Rationale

Alarm messages should clearly indicate priority, where the priority is determined based on safety of TMC operators, building infrastructure/personnel, and transportation system infrastructure and users. The prioritization of alarms should be logical to the TMC operators and highlight the high-priority messages while de-emphasizing the lower-priority messages. This will allow operators to focus their time and resources on the more important alarm.[62]

Utilizing a form of dynamic priority coding allows operators to determine the most urgent incidents. With adequate training, operators should be able to determine when a response is required. For example, if the operator is working on signing for an incident with a disabled car on the shoulder, a WWD alarm would take priority.

A variety of different coding alternatives should be carefully considered prior to selecting an alarm coding system. The code selected should allow the operators to achieve rapid detection with minimized complexity and consistency among all alarms. These coding features include the following:

- Color.
- Lights or luminance.
- Flash.
- Auditory.
- Size.
- Test, number, symbol, or shape.

Additionally, alarms may vary across TMC operations, including the following:

- Inclement weather, flooding, or hazardous materials.
- Railroads.
- Power outages or signal malfunctions.
- Pavement, tunnel, or bridge monitoring.

OTHER CLOSELY RELATED GUIDELINES
Chapter 3 (guidelines 23, 43, and 44) and chapter 5 (guidelines 59, 60, 70, and 71).

SPECIAL CONSIDERATIONS
Presenting too many alarms, including low-urgency alarms, may increase false alarms.

DECISION AIDS

Every TMC has different tasks required of the staff. The following section provides guidance on several types of decision aids that can go a long way to improving the operational efficiency of a TMC as well as reducing human capacity errors in sequential tasks or miscommunication. Checklists can be utilized to ensure an operator completes each required action. Flowcharts may be used to depict the decisionmaking path of an event, incident, or action. With the wide variety of tasks, these are critical elements that should be incorporated into a TMC operator manual to clearly identify expected roles and responsibilities. The goal of this section is to develop methods for TMC staff to confirm their actions prior to implementation. In addition, software can be vital in preventing an operator from inputting inaccurate information or missing a required task. This section includes the following guidelines:

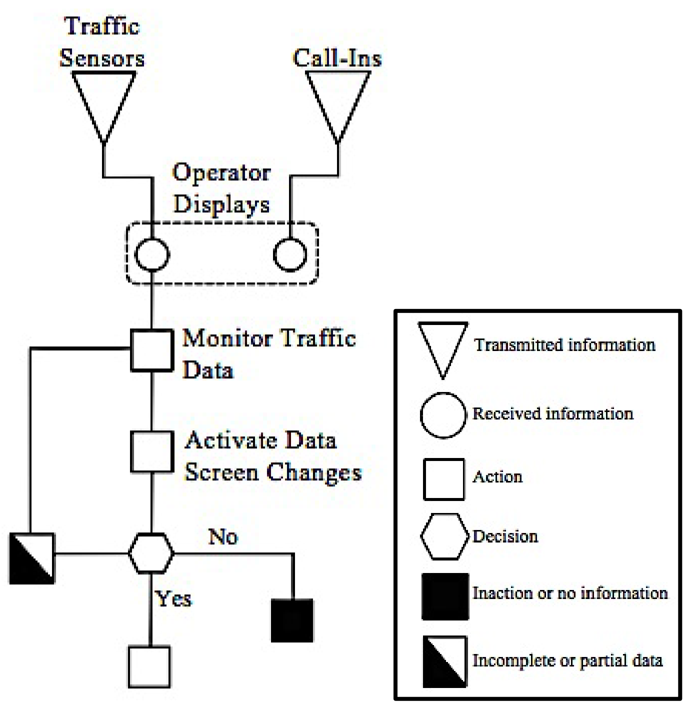
- **Guideline 46**: Developing Checklists and Flowcharts.
- **Guideline 47**: Utilizing Software Support.

Guideline 46. Developing Checklists and Flowcharts

Job aids, such as checklists and flowcharts, should be developed based on each TMC's concept of operations for operator response.

Rationale

Every TMC has different tasks required of the operators. Checklists can be utilized to ensure an operator completes each required action. Flowcharts may be used to depict the decisionmaking path of an event, incident, or action. With the wide variety of tasks, these are critical elements that should be incorporated into a TMC operator manual to clearly identify expected roles and responsibilities. The goal is to develop methods for operators to confirm their actions prior to implementation. Figure 7 is an example of an operational sequence diagram (OSD). An OSD is a type of task analysis that can be used as a tool to ensure decisions are based on complete and accurate information.



Source: FHWA.

Figure 7. Flowchart. Example OSD for detecting incidents.[(48)]

OTHER CLOSELY RELATED GUIDELINES
Chapter 2 (guidelines 17 and 22) and chapter 3 (guideline 47).

SPECIAL CONSIDERATIONS
An OSD is especially useful for new operators as well as for tasks requiring serial operations.

Guideline 47. Utilizing Software Support

When possible, computer automation should be used to prompt operators with the correct input or response.

Rationale

Software can prevent an operator from inputting inaccurate information or missing a required task. An example of a decision aid is filtering drop-down menus within software applications. For example, if the operator selects a county for an incident, then he/she should only be allowed to select highways that are located within that county. This example, as displayed in figure 8, shows options only for highways available within the preselected county. Figure 9 shows another example where selecting "Restriction" prompts operators with a dropdown menu to select the type and impact of the restriction. If "Full Closure" is selected instead, then the menu is disabled (figure 10). These examples show a user-friendly interface that is both easy to understand and prompts operators to make a decision only when applicable.

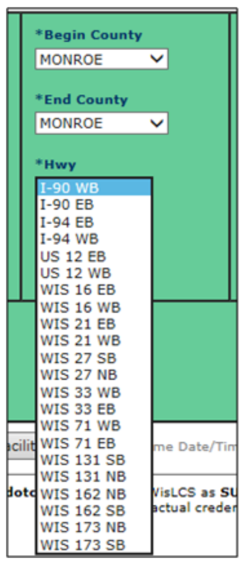


Figure 8. Screenshot. Available highway options for selected county.[(63)]

Figure 9. Screenshot. Type of closure and impact of the restriction.(63)

Figure 10. Screenshot. Disabled dropdown menu for full closure.(63)

OTHER CLOSELY RELATED GUIDELINES
Chapter 3 (guidelines 25 and 46).

SPECIAL CONSIDERATIONS
Error messages must detail the specific error(s).

CHAPTER 4. THE TMC ENVIRONMENT

The TMC environment includes the physical and operational conditions in which traffic management occurs. TMCs vary considerably based on the region, organization, and associated needs, capabilities, and limitations. The TMC should be designed to reflect these characteristics while optimizing performance. The guidelines presented here emphasize how different decisions in structuring the TMC environment can impact performance. This chapter includes guidelines related to the physical workspace design.

INFRASTRUCTURE

The TMC (and its staff) does not operate alone and in a bubble. It is an integral part of the overall transportation system. Understanding the human factors needs for a TMC requires an understanding of the overall system and the demands placed on the TMC staff. The following section gives a high-level overview of the overall ITS structure, where TMC services fit, and the importance of TMC location. While these topics are traditionally not human factors, it is important to look at the broader picture in order to understand the specific human factors needs. This section includes the following guidelines:

- **Guideline 48**: Defining TMC Services.
- **Guideline 49**: Selecting a TMC Location.

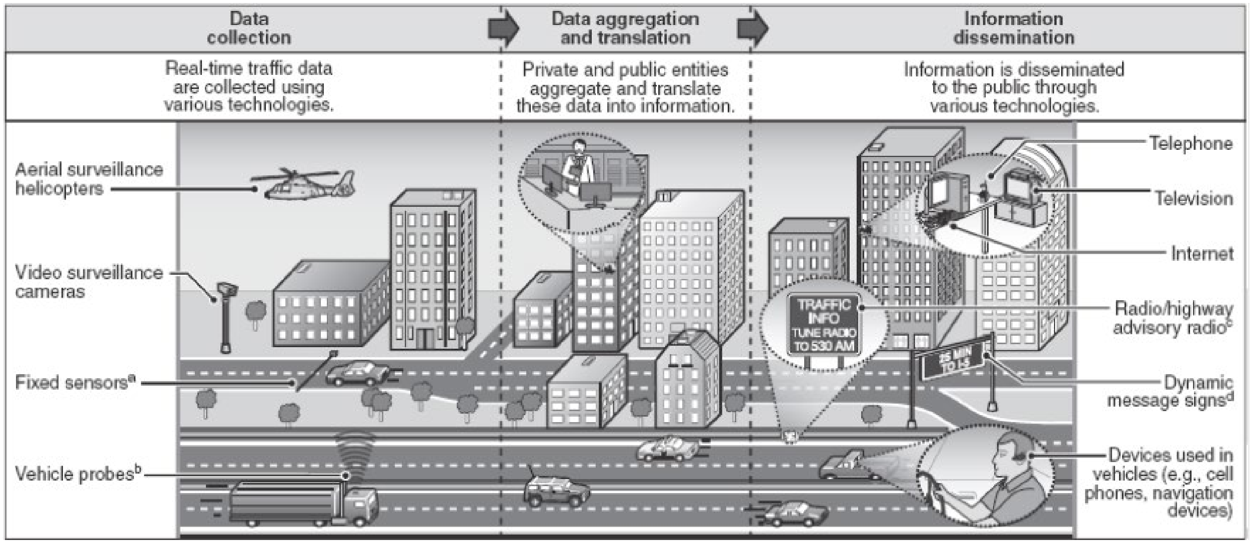
Guideline 48. Defining TMC Services

A variety of supporting technologies should be integrated for ITSs to perform the following three basic functions:

1. Collect data.
2. Aggregate and translate data.
3. Disseminate information.

Rationale

The TMC's primary services revolve around ITSs. TMC operators must first collect or detect data via CCTVs, sensors, incident reports, and various other sources. Then, the operators are tasked with translating these data and giving meaning to the situation. In human factors terms, this stage can be thought of as a top–down approach where operators must use their prior knowledge and experience in dealing with similar incidents or events to be able to formulate the best plan of action. Once the operators have detected an incident and formulated a plan, the plan is then disseminated to the public and coordination agencies. Operators can disseminate information through various technologies, including DMS, HAR, 511, and social media. Figure 11 provides an overview of the three basic functions, including the types of technology used and the role of the TMC operator.



Reproduced with permission from The Information Technology & Innovation Foundation © 2010 Explaining international IT application leadership: intelligent transportation systems.

[a]A fixed sensor is a technology that is stationary at the roadside or embedded in the road to monitor traffic flow; [b]Vehicle probes use roaming vehicles and portable devices to collect data on travel times. Vehicle probes include cellphones and Global Positioning System devices; [c]Highway advisory radio uses radio stations to broadcast traffic- and travel-related information to travelers using amplitude-modulated radio; [d]DMSs are permanent or portable electronic traffic signs that give travelers information on traffic conditions and travel times among other things.(64)

Figure 11. Illustration. Data collection, data aggregation and translation, and information dissemination.(64)

OTHER CLOSELY RELATED GUIDELINES
Chapter 3 (guidelines 31, 33, and 34).

SPECIAL CONSIDERATIONS
Visit the Cross-Cutting Support: National ITS Architecture website for further information.(65)

Guideline 49. Selecting a TMC Location

The following should be considered when selecting the candidate TMC location:

- Access to transportation systems and infrastructure.
- Proximity to stakeholder and other units of organization.
- Parking availability, accessibility, and security.

Rationale

The location of a TMC may be predetermined; however, some elements to consider include the following:

- Is the nearby transportation infrastructure reliable, or is it prone to closure for severe weather events such as flooding or snow?
- Are multiple access points or modes of transportation (including public) available to the location?
- Is the location in close proximity to other agencies, units of government, or business areas that will require regular communication, coordination, and/or collaboration such as traffic engineering, public works/maintenance, first responders, or media?
- Will there be adequate parking for employees and visitors?
- Does the facility have adequate accessibility for people with disabilities?
- Can convenient parking be provided to accommodate a large number of people for meetings or tours?
- What will be the TMC hours of operation (e.g., 24/7/365, nighttime, or weekends)? Is a secure parking area/access point available for employees?
- How accessible is the building to the ATMS communication network?
- Can the building/location receive large pieces of equipment (e.g., servers, uninterruptible power supply, video wall, consoles)?

OTHER CLOSELY RELATED GUIDELINES
Chapter 4 (guideline 48).

SPECIAL CONSIDERATIONS
When selecting a TMC location, it is important to avoid areas without quick access to the covered interstate network.

TMC DESIGN AND CONFIGURATION

The previous section addressed the location of a TMC and how it fits into the overall ITS. This section delves into the inner design and workings of a TMC. Guidance is provided about the overall size and layout of a TMC, which can have a profound impact on TMC operations—seating arrangement, number of staff for any given room or space, number and use of rooms, etc. In addition, several issues related to furniture selection, lighting, and environmental controls are also addressed. These topics may not seem like the most exciting and are often not attended to if they are within proper parameters. Uncomfortable chairs, poor lighting, hard-to-navigate workstations, uncomfortable temperatures, etc., can have a crippling effect on TMC operations (e.g., increased errors related to suboptimal temperature). Effective planning for these areas can go a long way toward optimizing TMC performance. This section includes the following guidelines:

- **Guideline 50**: Configuring the TMC.
- **Guideline 51**: Selecting a Workstation.
- **Guideline 52**: Selecting a Chair.
- **Guideline 53**: Selecting Workstation Lighting.
- **Guideline 54**: Controlling the TMC Thermal Environment.
- **Guideline 55**: Controlling Noise Levels Within the TMC.

Guideline 50. Configuring the TMC

The following steps should be utilized when designing the size and layout of the TMC:

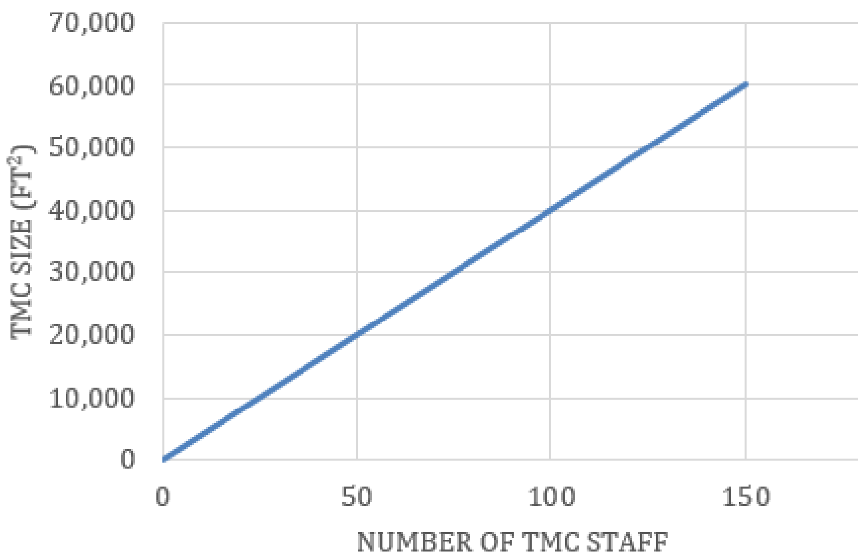
1. Establish clear objectives.
2. Determine the number and types of agencies.
3. Define, prioritize, and outline functions.
4. Determine staff size, equipment needs, and room size requirements.

Rationale

The size of a TMC varies depending on the number of employees, tasks to be performed, required equipment, location, and the size of the reporting district. Many TMC buildings commonly house a control room, offices, conference rooms, an equipment room, a kitchen or break room, a media room, and training rooms.[66,15] Table 11 shows the ratio of the size of specific rooms to the total TMC size.[66] Choosing the appropriate room size as a proportion of the overall TMC operations can be an important determinant of space usage. Figure 12 shows the relationship between the total number of staff and size of a TMC.

Table 11. Ratio of room size to total TMC size (measured by average percent).[66]

Room Type	Average Ratio (Percent)
Control	23
Office	19
Conference	10
Equipment	9



Source: FHWA.

1 ft^2 = 0.093 m^2.

Figure 12. Graph. Relationship between the total number of staff and size of the TMC.

OTHER CLOSELY RELATED GUIDELINES
Chapter 2 (guideline 2) and chapter 5 (guidelines 56 and 68).

SPECIAL CONSIDERATIONS
TMCs should take into consideration space advantages as well as equipment accommodations (wiring, power, video, wall, etc.).

Guideline 51. Selecting a Workstation

Workstations should be at least 27.6 inches (70 cm) wide and at least 19.7 inches (50 cm) deep. The following should also be considered when selecting a workstation:

- Adjustable height for standing and seated positions.
- Adequate clearance (figure 13).
- Matte finish.

Rationale

The American National Standards Institute (ANSI)/Human Factors and Ergonomics Society (HFES) recommends that operators be able to adjust their position to a variety of postures to maintain comfort.(67) Inadequate workstation clearances constrain operators' positions, such as knees touching the workstation and poor posture from restricted chair adjustments. Additionally, inadequate clearances may increase errors as operators accidently touch unintended controls. The size of the workstation should accommodate the suggested clearance dimensions shown in figure 13. These suggested workstation clearance dimensions can accommodate up to the 95th percentile of the male population according to anthropometric guidelines.(67)

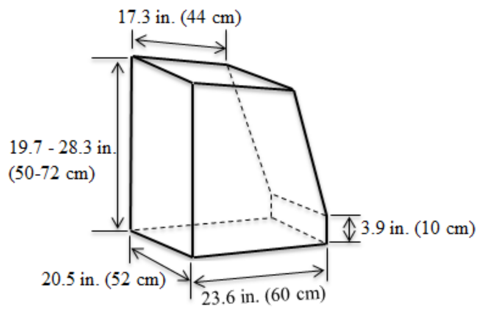


Figure 13. Illustration. Suggested minimum workstation clearance dimensions.(67)

Equally important to adjustability is determining the appropriate workstation dimensions that permit optimal performance. The dimensions of the workstation may vary depending on the number of objects on the work surface (e.g., keyboards, monitors, and mouse) but should be at least 27.6 inches (70 cm) wide and at least 19.7 inches (50 cm) deep. In the case of multiple monitors, even more space should be provided to accommodate the additional monitors. Workstations with adjustable heights allow operators to easily maneuver between standing and sitting. Performance is greatly increased when operators alternate between positions.(68) Risers may be placed underneath fixed-height workstations to allow the same flexibility.

Workstation surfaces with a matte finish are less prone to glare and light reflectance from monitors, visual displays, lighting, and windows. Glossy work surfaces tend to reflect light, causing visual discomfort. Although not advised, if work surfaces have a glossy finish, should have less than 45-percent reflectance.(67)

OTHER CLOSELY RELATED GUIDELINES
Chapter 4 (guidelines 52 and 53) and chapter 5 (guidelines 56, 61, and 69).

SPECIAL CONSIDERATIONS
Operators should review the Occupational Safety and Health Administration's (OSHA's) evaluation, purchasing checklists for computer workstations (appendices B and C), and a workstation evaluation questionnaire (appendix D).

Guideline 52. Selecting a Chair

Chairs should be selected that have an adjustable seat pan, backrest, chair caster, and armrests.

Rationale

Operators spend most of the time sitting at a workstation and need chairs that can support them through their entire shift. Selecting the proper chair is beneficial to performance and health. The suggested lumbar height should range between 5.9 and 9.8 inches (15 and 25 cm).[67] Insufficient lumbar support places compression weight on the spine, causing pain in the lower back and thighs. Additionally, a seat pan that is too high constrains the operator from using the floor or a footrest for feet support. A seat pan that is too low forces the operator's torso-to-thigh angle to be less than 90 degrees, causing more pressure on the lower back.[67]

It is also important to choose a chair with a round seat pan to allow for proper circulation and thigh support.[67] Armrests should be adjustable and detachable so operators have the flexibility to change their posture (figure 14).

Source: FHWA.

Figure 14. Illustration. Components of a chair.

Chair casters allow chairs to be easily maneuvered as long as the type of caster is matched to the type of flooring. Chair casters with hard wheels are appropriate for carpeting, whereas soft wheels should be selected for wood, concrete, or tile floors.[67] An adjustable backrest of at least 90 to 100 degrees helps to reduce spinal pressure (figure 15).

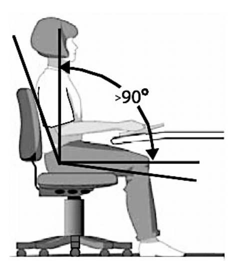


Figure 15. Illustration. Adjustable backrest of 90 to 100 degrees.[67]

OTHER CLOSELY RELATED GUIDELINES
Chapter 5 (guideline 56).

SPECIAL CONSIDERATIONS
Operators should review OSHA's evaluation and purchasing checklists for computer workstations (appendices B and C) and a workstation evaluation questionnaire (appendix D).

Guideline 53. Selecting Workstation Lighting

Display technologies should be matched with the appropriate illuminance levels. Regardless of the type of display, the criteria for workstation lighting include the following:

- Standard workstation illuminance should range from 18.6 to 46.5 ft-c (200 to 500 lux).
- Surrounding luminance of negative polarity screens (bright characters on dark background) should be less than 10 times the display luminance.
- Surrounding luminance of positive polarity screens (dark characters on bright background) should be less than three times the display luminance.
- Hallway light sources should be at least 10 ft-c (108 lux).

Rationale

Illuminance is defined as the measurement of the amount of light falling on a surface per unit area (measured in ft-c or lux), whereas luminance is defined as a photometric measurement of the intensity of light emitted from a surface or light source. For example, a lamp that is placed 1 ft (0.305 m) from the operator's workstation will produce 100 ft-c (1076.39 lux) of light. Luminance can be measured for surfaces that generate light (e.g., a computer screen) and/or reflect other sources of light (e.g., a piece of paper on a desk or a white wall).

The amount of lighting needed varies depending on the type of task, such as reading from a written document, a workstation monitor, or a video wall. Variations in illuminance depend on distance, color, color contrast, age of the operator, and overall design of the TMC. Using the proper illuminance levels, placement, and orientation helps to minimize eye fatigue and eye strain. Additionally, unwanted light can be reduced by use of antiglare screen filters, reflectance coating, and window blinds.(67) Recommended illuminance levels are as follows:(69,62)

- **Liquid crystal display**: 72.5 to 73.4 ft-c (780 to 790 lux).
- **Ceiling panels**: 4.6 ft-c (50 lux).
- **Auxiliary panels**: 4.6 ft-c (50 lux).
- **Maintenance area**: 4.6 ft-c (50 lux).
- **Printed text**: 4.6 ft-c (50 lux).
- **Writing**: 9.3 ft-c (100 lux).

OTHER CLOSELY RELATED GUIDELINES
Chapter 4 (guideline 51) and chapter 5 (guidelines 56, 60, 68, and 70).

SPECIAL CONSIDERATIONS
It is important to protect against wall, ceiling, and floor reflectance.

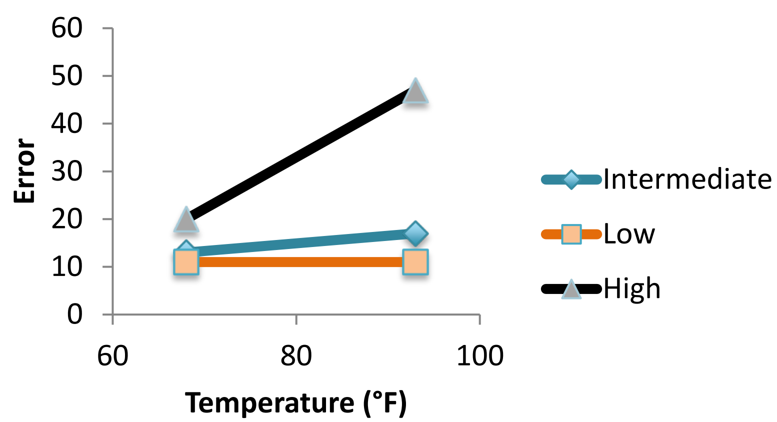
Guideline 54. Controlling the TMC Thermal Environment

The thermal environment within the TMC directly affects operator performance. The thermal environment should be controlled to conform to the following:

- Temperature should range between 68 and 74 °F (20 and 23.33 °C) during warm climates.
- Temperature should range between 73 and 79 °F (22.78 and 26.11 °C) during cool climates.
- Humidity in the control room should range between 30 and 60 percent.
- Floor and ceiling temperatures should have less than a 10-degree difference.

Rationale

These guidelines are based on ANSI/HFES standards for workstation temperatures.[67] Research has shown that operators who perform light physical work prefer temperatures on the lower end of the range.[62] In determining the preferred temperature, the level of work demand needs to be considered. Figure 16 shows the relationship between temperature, task demand, and errors.[70,33] Table 12 provides acceptable surface temperatures.



Recreated from © 1961 Carlson.
1 °F = 1.8 °C + 32.

Figure 16. Graph. Effects of temperature on errors committed while monitoring low-, intermediate-, and high-complexity visual display screens.[70]

Table 12. Acceptable surface temperatures.[71]

Surface	Temperature
External surfaces touchable during operations	Maximum of 122 °F
Surfaces during normal operations	Maximum of 95 °F
Heat build-up from equipment under the work surface	5.5 °F above ambient temperature

1 °F = 1.8°C + 32.

OTHER CLOSELY RELATED GUIDELINES
Chapter 5 (guidelines 9 and 10).

SPECIAL CONSIDERATIONS
Operators should be allowed to control temperature for their workstation.

Guideline 55. Controlling Noise Levels Within the TMC

All sources of noise should be identified to determine which sources can be eliminated or reduced. In instances where noise cannot be eliminated, TMCs should adhere to the following recommendations:

- Occasional communication areas should not exceed 75 dBa.
- Frequent communication areas should be below 65 dBa.
- Quiet areas such as conference rooms should not exceed 45 dBa.
- Maximum sustained noise levels should not exceed 80 dBa.

Rationale

Excess noise is distracting and causes decrements in operator performance (discussed in chapter 2). Operators may find maintaining attention to tasks difficult, make more errors, and suffer reduced job satisfaction.

Noise can be measured through a variety of instruments, including sound level meters and noise dosimeters (both of which need to be properly calibrated). Sources of noise in the TMC may include operator conversations, alarms, electrical equipment, and other communication devices. The level of noise should be controlled so that nearby operator communication is unaffected by the various other sources of noise.[15] Sources of noise may include the following:

- Operator communication.
- Air conditioning units.
- Electrical equipment.
- Alarms or alert notifications.

Suggestions to reduce noise include the following:

- Discourage shouting and provide other sources for operator communication (e.g., instant messaging). Operators who work closely together could also be placed close together.

- Reduce noise by using sound-deadening materials or treatments.

- Upgrade old electrical equipment, desktops, monitors, etc.

- Reduce the number of alarms or alerts to only those most pertinent.

- Locate break rooms and offices outside of the TMC control room.

OTHER CLOSELY RELATED GUIDELINES
Chapter 2 (guidelines 9, 12, and 18), chapter 3 (guidelines 43–45), and chapter 6 (guidelines 72, 73, and 75).

SPECIAL CONSIDERATIONS
Instruments should be calibrated, and the complete room environment should be taken into account when measuring noise levels.

CHAPTER 5. DISPLAYS AND CONTROLS

TMC staff rely on a variety of technologies to detect information, evaluate its value, and implement operational decisions. In order to perform at the highest level of efficiency and accuracy, thoughtful decisions need to be made about the operators' workplace and tools. Humans have a variety of sensory, perceptual, and physical capabilities and limitations. Poorly aligned displays and controls will result in less-than-optimal performance and negatively impact job satisfaction and comfort. In particular, TMCs need to consider how to meet users' needs through layout and placement of equipment, such as viewing distance for monitors and other visual displays. Performance can also be impacted by software and features of tools and instructions, such as color, font type, and size of print; amount and quality of information content; responsiveness to users' actions and feedback about system states; and the use of concise and easily understandable language. This chapter provides guidelines emphasizing the elements of proper workstation designs and the impact of design choice on performance. This chapter also discusses elements of desktop displays and controls (e.g., monitor, mouse, keyboard, and touchscreen) as well as central wall displays.

WORKSTATION DISPLAYS

There are a variety of variables that can affect the comfort and productivity of TMC employees, with workstation configuration and display being two of the most important factors. The workstation is the place where TMC operators and managers spend the majority of their time, so having a comfortable space is vital. The guidelines in this section will provide advice regarding workstation layout and viewing distances, content (and the imperative to minimize complexity), font, and visual display colors. These topics address both hardware and software considerations that must be optimized to create an environment in which TMC employees can excel. This section includes the following guidelines:

- **Guideline 56**: Designing Workstation Layout.
- **Guideline 57**: Determining Workstation Viewing Distances.
- **Guideline 58**: Displaying Content in Workstations.
- **Guideline 59**: Selecting Font for Workstation Displays.
- **Guideline 60**: Selecting Visual Display Colors.

Guideline 56. Designing Workstation Layout

The following should be taken into consideration when designing the workstation layout:

- Number of tasks to be performed.
- Layout and size of TMC.
- Number of monitors per workstation.
- Number of operators and workstations.

Rationale

First, the number of workstations within the TMC should be determined. It is important to note whether operators will have access to all of the input systems from their workstations and can easily communicate with other workers (personalization is also an important feature). TMCs that provide operators with access to all input systems at the workstation will have to pay special attention to ensure that software and interfaces are not compromised (i.e., some visuals are better displayed on video walls).(15) Based on the tasks to be performed, the content and number of monitors needed should be determined. The most commonly displayed information is event managers (e.g., maps, email, and social media), camera feeds, and incident notification systems. Figure 17 displays the optimal workstation layout.(13)

Figure 17. Illustration. Example of an optimal workstation layout with 10 double-stacked monitors.(13)

OTHER CLOSELY RELATED GUIDELINES
Chapter 2 (guidelines 1 and 2), chapter 4 (guidelines 50 and 51), and chapter 5 (guidelines 57 and 68).

SPECIAL CONSIDERATIONS
It is important to determine which functions are best suited for workstations versus central wall displays.

Guideline 57. Determining Workstation Viewing Distances

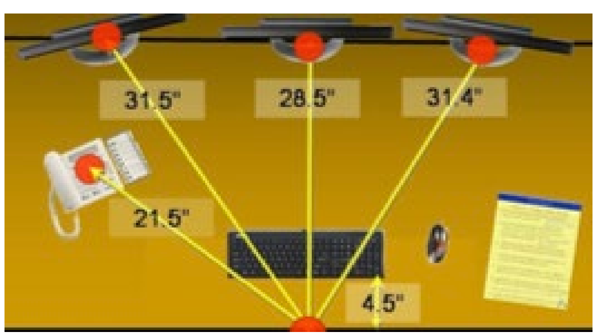
Workstation displays should have an adjustable tilt and rotation to allow operators to adjust their viewing distance. Additionally, workstation displays should be configured to meet the following criteria:

- Monitors should be 19.7 to 39.4 inches (50 to 100 cm) from the operator.
- The center of each monitor should be 15 to 20 degrees below eye level.
- The entire viewing area should be 0 to 60 degrees below horizontal eye height.
- The angular view height should be ±40 degrees horizontally and 30 to −20 degrees vertically.

Rationale

The suggested viewing distances have been shown to reduce visual strain and eye fatigue.(67) Viewing distances that are too close cause eye strain because the eyes are actively converging for the lenses to be able to focus. In addition, operators older than 40 yr should be encouraged to get their vision tested regularly and to wear corrective lenses that are appropriate for the monitor viewing distance, if applicable. Throughout the day, the eyes become fatigued, causing decreases in visual acuity and more difficulty focusing. These same effects occur when monitors are too far and instead result from eye divergence (appendix D).

Ergonomically, monitors should be placed directly in front of the operator within 19.7 to 39.4 inches (50 to 100 cm). Many TMC workstations now have multiple monitors, usually stacked or side by side. If this is the case, the guidelines can be easily adapted by changing the distance from the center of the monitor to the center of all of the monitors as a whole. For example, if there are four monitors per workstation, then the center should be between the second and third monitors. It is important for operators to be aware of the proper viewing distances and be able to make adjustments when necessary. Figure 18 provides an example of viewing distances for a workstation with three side-by-side monitors.



Source: 2009 Federal Aviation Administration.
1 inch = 25.4 mm.

Figure 18. Illustration. Example of viewing distances from three monitors that fall within the suggested range.(72)

OTHER CLOSELY RELATED GUIDELINES
Chapter 4 (guideline 50) and chapter 5 (guidelines 56, 59, and 60).

SPECIAL CONSIDERATIONS
Optimal viewing distance depends on individual differences (e.g., visual acuity, height, and corrective lenses) of the operator in addition to the workspace.

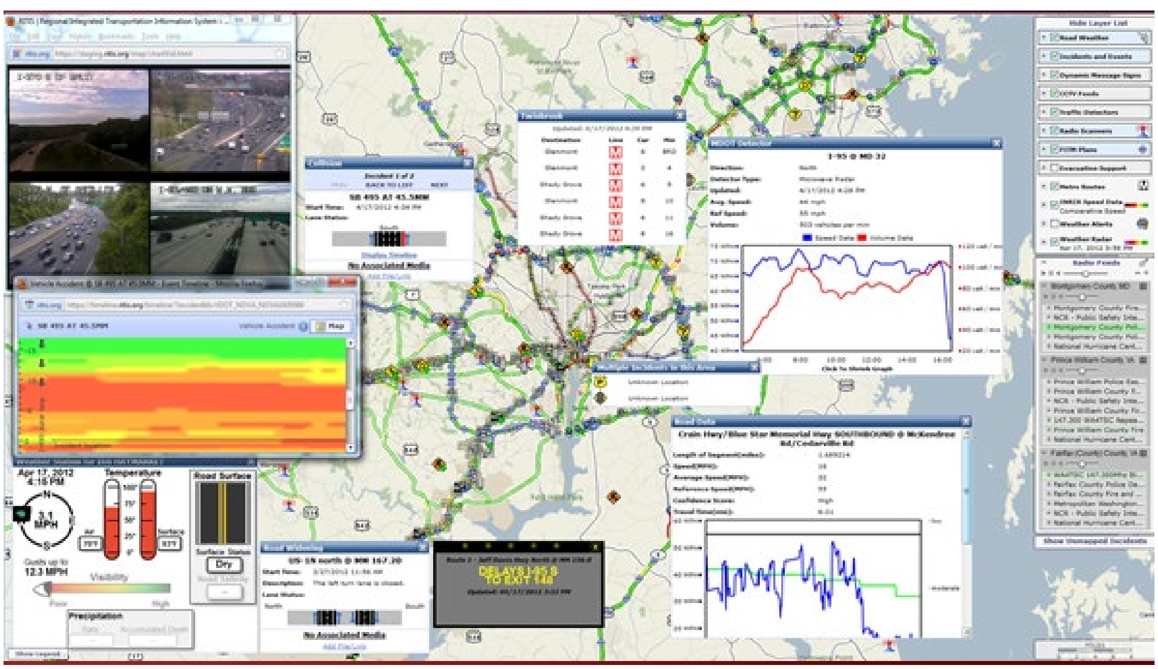
Guideline 58. Displaying Content in Workstations

Content displayed on workstations should adhere to the following guidelines:

- Avoid homonyms and words that may be misinterpreted.
- Avoid abbreviations.
- Label location, directional view, and what is being measured.
- Configure maps with north on top.

Rationale

It is generally best to keep complexity of content to a minimum.(62) It is unlikely that operators will have the time to read sentences of text displayed on monitors. Therefore, content should be easy to understand and concise while providing operators with all relevant information needed. Visual map displays are difficult to interpret when not properly labeled. Textual content on maps should follow the previously described guidelines and maintain consistency across all displays.(1) Figure 19 shows a workstation display with a variety of graphical and text-based layers. Note that it is not suggested to display all of these layers at once.



Reproduced with permission from CATT Lab © (2013) Regional Integrated Transportation Information System (RITIS).

Figure 19. Screenshot. Workstation display using RITIS software.(73)

OTHER CLOSELY RELATED GUIDELINES
Chapter 5 (guidelines 56, 57, 59, and 60).

SPECIAL CONSIDERATIONS
Simple content and information presentation will help with processing and efficiency.

Guideline 59. Selecting Font for Workstation Displays

Workstation display fonts should be selected based on following:

- Labels should be all uppercase.
- Content should be uppercase and lowercase.
- Avoid serif fonts (e.g., Times New Roman, Garamond, Book Antiqua).

Rationale

The font selected for the workstation display should facilitate legibility and readability of text.[62] Research suggests that 12-point font size is read quicker on a monitor than 10- and 14-point fonts.[74] Additionally, Arial, Verdana, and Courier are perceived as the most legible and readable. Note that with higher-resolution screens, the advantage of these fonts is not as strong anymore. A second study found that using bolding significantly reduces reading speed than nonbolding for both periphery (i.e., as measured as 10 degrees from central display) and central displays.[75] Additionally, reading speed is much slower when reading bolded text from a periphery display than from a central display. It is suggested that a thinner font should be used on peripheral displays for quicker and more accurate reading. Once the font and size are selected, operators should examine the readability and legibility from the suggested viewing distances presented in guideline 57.

OTHER CLOSELY RELATED GUIDELINES
Chapter 4 (guideline 53) and chapter 5 (guidelines 56–58).

SPECIAL CONSIDERATIONS
Operator feedback should be collected regarding the legibility and readability of text.

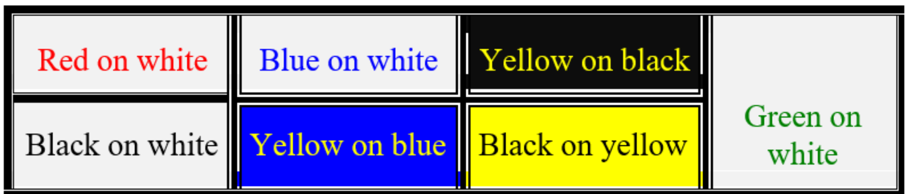
Guideline 60. Selecting Visual Display Colors

Color on workstation displays should be used to assist operators in easy and quick detection of displayed information by incorporating the following techniques:

- Use color-coding techniques.
- Use no more than seven colors per display.
- Limit the number of colors on maps, target symbols, and alphanumeric headings.

Rationale

Color-coding techniques help operators differentiate between operational or system statuses and should be consistent across all interfaces.(67,15) Also, color coding should conform to preestablished stereotypes (e.g., red means stop or danger and green means go or safety). This conforming helps to eliminate confusion that may result from unconventional color coding.(22) Figure 20 shows a set of suggested color contrast options for workstation displays. However, supervisors/managers need to be aware of any employees with red–green colorblindness and make adjustments as needed.



Adapted from © 2002 U.S. Nuclear Regulatory Commission.

Figure 20. Illustration. Suggested color contrast on workstation displays.(62)

Varying color saturation allows operators to determine the severity of an event (figure 21). It is usually insinuated that low saturation means less severe and high or dark saturation means more severe. In addition, color saturation can allow operators to easily make quantitative comparisons. Although less effective than color coding and color saturation, a brightness scale may be used to indicate severity.(22)

Source: FHWA.

Figure 21. Illustration. Example of orange hue saturation for varying intensities.

OTHER CLOSELY RELATED GUIDELINES
Chapter 5 (guidelines 57–59).

SPECIAL CONSIDERATIONS
The illuminance surrounding the workstations directly affects the visibility and usefulness of color-coding techniques.

WORKSTATION CONTROLS

This section covers a wide range of topics related to workstation controls. How information is input into a workstation (e.g., with a mouse and keyboard) can be a large determinant of its accuracy, speed, and overall efficiency. Although technology is rapidly evolving, this section strives to provide general guidance and principles that can stay current even as the technology develops. People often assume these ergonomic and hardware topics are self explanatory, but that is not the case. For example, not all computer mouses are created equal—recent research (guideline 63) discussed in these guidelines shows advantages of roller-style mouses over traditional inputs.(76,77) In addition, keyboard selection and feedback are discussed, especially as in relation to new operators. Furthermore, touchscreens are becoming more prevalent and should be incorporated into design considerations in future TMC workstations. General guidance principles are given that should remain useful even as touchscreens evolve. Finally, several guidelines are presented that address information system controls, labels, and buttons. This section includes the following guidelines:

- **Guideline 61**: Selecting a Keyboard.
- **Guideline 62**: Designing Keyboard Feedback.
- **Guideline 63**: Selecting a Mouse.
- **Guideline 64**: Selecting a Touchscreen.
- **Guideline 65**: Selecting Information Control Systems.
- **Guideline 66**: Determining Placement of Control Buttons.
- **Guideline 67**: Using Labels and Coding Techniques.

Guideline 61. Selecting a Keyboard

An ergonomically designed keyboard that includes the following features should be used:

- A QWERTY design.
- Keyboard height of 1.38 inch (3.5 cm) or less.
- Adjustment angle between 0 and 15 degrees.
- Toggle keys (Caps Lock, Num Lock, and Scroll Lock), which must display status.
- Concaved keys, which should have a height of at least 0.10 inch (0.26 cm) and an illuminance of at least 0.05 ft-c (0.5 lux).

Rationale

The guidelines listed are based on the standards from *Human Factors Engineering of Computer Workstations*.[67] It is important that toggle keys display status so that operators are able to enter information quickly and with minimal errors. The purpose of concaved keys is to allow the fingertips to fit precisely within the grooves, which sustains speed and accuracy. Figure 22 and figure 23 illustrate two optimal numerical configurations. These designs are optimal because users are most familiar with the layout of a telephone and of a calculator. Additionally, the cursor arrows on a keyboard should follow one of the four designs displayed in figure 24 through figure 27.[68] Note that touchscreen inputs are covered in guideline 64.

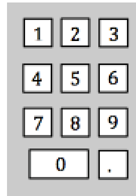


Figure 22. Illustration. Telephone numerical keypad configuration.(67)

Figure 23. Illustration. Calculator numerical keypad configuration.(67)

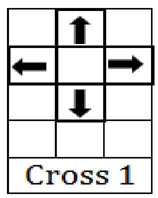


Figure 24. Illustration. Cross 1 cursor arrow configuration for a keyboard.(67)

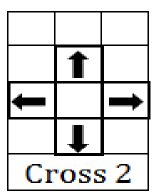


Figure 25. Illustration. Cross 2 cursor arrow configuration for a keyboard.(67)

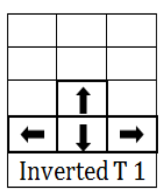


Figure 26. Illustration. Inverted T 1 cursor arrow configuration for a keyboard.(67)

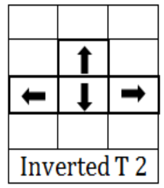


Figure 27. Illustration. Inverted T 2 cursor arrow configuration for a keyboard.[67]

OTHER CLOSELY RELATED GUIDELINES
Chapter 4 (guideline 51) and chapter 5 (guidelines 62 and 64).

SPECIAL CONSIDERATIONS
Review OSHA's purchasing guide checklist (appendix C).

Guideline 62. Designing Keyboard Feedback

Keyboard feedback should be designed to keep the operator in the loop by incorporating the following:

- All keyboard presses should have auditory and/or tactile feedback.
- Feedback should occur at the same time for every keyboard press.
- Auditory feedback must be adjustable and able to be turned off.

Rationale

Keyboards, or keying feedback, help facilitate learning. Feedback is especially important for new or entry-level operators. Feedback lets the operator know if the entry was successful or if there were errors. There are primarily two types of keying feedback: auditory and tactile. Tactile feedback is most suitable for frequent and continuous keying. Tactile feedback should be clear to distinguish and should occur in a consistent manner such as the force required to actuate the key (also known as the keying breakaway). Auditory feedback should be adjustable in volume, and operators should be able to disable it when desired. Auditory feedback should follow the same manner as tactile feedback, except activation should be in sync with key presses. The combination of both types of feedback has been shown to be the most effective.[67]

OTHER CLOSELY RELATED GUIDELINES
Chapter 5 (guidelines 61 and 65).

SPECIAL CONSIDERATIONS
Operators should become familiar with the types of keyboard feedback and how to disable these notifications.

Guideline 63. Selecting a Mouse

Prior to selecting workstation mice, the location of the input device and the space capacity and restraints should be determined.

Rationale

A recent study found that a roller-style mouse was superior to a standard mouse, a touchpad, and a trackball.(76) The benefits of a roller-style mouse include the following:

- Proper hand and shoulder posture.
- Lower activity for forearm extensor muscles.
- Comfortable and easy to use.
- Better cursor and clicking control.
- Ability to use both hands.
- Easy to learn.

A study found that the use of a roller-style mouse in call centers reduced wrist, shoulder, and forearm pain as compared to a conventional mouse.(77) It is also suggested that the best mouse placement is in the central region in line with the keyboard (figure 28).(78) This position is feasible with a roller-style mouse and maybe a touchpad but not with a standard mouse. A second option to the roller-style mouse is a touchpad. The benefits of using touchpads include good cursor and clicking control, good shoulder posture, and lower forearm muscle activity.(76)

Figure 28. Photo. Suggested workstation placement of a roller-style mouse.(79)

OTHER CLOSELY RELATED GUIDELINES
Chapter 4 (guideline 51) and chapter 5 (guideline 56).

SPECIAL CONSIDERATIONS
It is important to measure usability or collect operator feedback regarding their preference of input device.

Guideline 64. Selecting a Touchscreen

Touchscreens should provide real-time tracking of operators' movements and have highly effective entry rates with limited errors.

Rationale

Recently, TMCs are beginning to use touchscreens to control workstation and central wall displays. Touchscreens are primarily used for key presses, object detection, and drag and drop tasks. A real-time tracking feature provides operators with status feedback, which helps reduce errors.

It is important that touchscreens have a high effective entry rate.(80) To help ensure this, the touchscreen design should include the following:

- Word predictions and/or a stylus. If a stylus is used, the keyboard on the touchscreen should not follow a QWERTY format. Instead, the keyboard should have less distance between keys that are commonly used together. Another solution would be to increase the touch area.(67,80)
- An autocorrect function.
- Touchscreen buttons should have a width and height of at least 0.37 inch (0.95 cm). Operators are increasingly likely to miss taps with smaller button sizes, especially below 0.20 inch (0.5 cm).
- The area between buttons should be at least 1.30 inch (3.2 cm). The purpose of having space between buttons is to mitigate errors and unwanted button presses (figure 29).

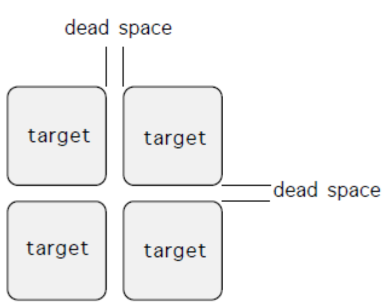


Figure 29. Illustration. Example of dead space between touchscreen buttons.(67)

It may be useful to explore speech-recognition systems. Such a system can decrease time to complete a task and error rates. However, speech-to-text and speech-recognition systems may elicit errors that will actually increase operator workload and time to complete a task. For example, errors with these systems include misinterpreting words or phrases and an inability to detect and account for accents. Additionally, such systems may distract operators with increased noise in the TMC. Unless the speech-recognition algorithm has strong reliability and validity, it may be appropriate to wait until there are further advances in technology.

OTHER CLOSELY RELATED GUIDELINES
Chapter 5 (guidelines 65 and 66).

SPECIAL CONSIDERATIONS
Touchscreen buttons greater than 0.87 inch (2.2 cm) have null effects on performance.

Guideline 65. Selecting Information Control Systems

Prior to purchasing information control systems or input devices, it is necessary to determine the intended use and appropriateness of the desired device(s), grouping requirements, and spacing and relationship of controls to corresponding displays.

Rationale

Groupings of input devices should be determined by frequency, importance, and sequence of use. Spacing requirements include proximity, obstruction, and orientation. Controls that are frequently used should be located within the operator's focal line of sight. Controls that are used sequentially should be in close proximity. Proximity is the distance between a control and other controls or displays. It is important that near controls look dissimilar and do not block or obstruct other controls.[67,81] There are three types of primary control display relationships: (1) one display and one control system, (2) one display and several control systems, and (3) several displays and one control system. It is important that the use of the control matches the intended use. Table 13 provides suggestions for determining the appropriate control.

Table 13. Suggested use of input control devices under specified scenarios.[62]

Input Control Devices	Appropriate Use
Touchscreen	• Moving/holding arm to screen for long periods of time is not required, and hand(s) temporarily blocking screen will not disrupt tasks. • Screen does not have small buttons, and low-level resolution is required for positioning.
Mouse	• Adequate space is available. • Low- to medium-level resolution is required for positioning.
Trackball	• Rapid cursor positioning is desirable. • Limited space available.

Guideline 66. Determining Placement of Control Buttons

It is important to consider the type, size, and placement of control buttons while adhering to the following:

- Button activation forces under 0.06 lb (0.25 N) should be avoided.
- Displacement should be between 0.04 and 0.24 inch (0.1 and 0.6 cm).
- Maximum force of 0.06 to 0.34 lb (0.25 to 1.5 N) should be used for frequently used buttons.
- A button lock function should be available for tasks involving prolonged or continuous use.

Rationale

There are several ways to safeguard against unintended button presses, such as using barriers between buttons as well as taking into account button labels, shape, location, and activation force.(62) These guidelines are useful in helping to prevent errors and operator confusion.

OTHER CLOSELY RELATED GUIDELINES
Chapter 5 (guidelines 56, 61, 63, and 64).

SPECIAL CONSIDERATIONS
Compare prices of control button options in the market and collect operator feedback on quality.

Guideline 67. Using Labels and Coding Techniques

Labels and coding techniques should be used to assist operators in identifying specific controls. Techniques include the following:

- Labels should not be placed on top of buttons.
- Labels placement should be consistent.
- Content and abbreviations should be concise, easy to identify, and universally understood across operators.

Rationale

Labels help operators in identifying specific controls, which provides operators with the benefit of a quick identification tool. When worded properly, labels help reduce operator workload because operators rely less on memory and more on environmental cues. Also, labels are relatively seamless to learn and aid to novice operators.(1) While using labels is beneficial, one potential setback is that relying on them may increase visual search times as operators try to search for a control based on its label.

In addition to labels, applying proper coding techniques is a useful method to assist operators in easily identifying controls. Table 14 and table 15 provide the advantages and disadvantages of a variety of coding techniques.

Table 14. Advantages of specified coding techniques.[82]

Advantages	Location	Shape	Size	Labeling	Color
Improves visual identification	X	X	X	X	X
Improves nonvisual identification (tactile)	X	X	X		
Helps standardization	X	X	X	X	X
Aids identification under low levels of illumination	X	X	X	—	—
May aid in identifying control position or settings	—	X	—	X	—
Requires little training and is not subject to forgetting	—	—	—	X	—

—The coding technique does not possess the advantage.

Table 15. Disadvantages of specified coding techniques.[82]

Disadvantages	Location	Shape	Size	Labeling	Color
May require extra space	X	X	X	X	—
Affects manipulation of control (ease of use)	X	X	X	—	—
Has limits in number of available coding categories	X	X	X	—	X
Requires control within viewing distance and adequate illumination	—	—	—	X	X

—The coding technique does not possess the disadvantage.

OTHER CLOSELY RELATED GUIDELINES
Chapter 2 (guideline 9) and chapter 5 (guidelines 58 and 69).

SPECIAL CONSIDERATIONS
TMCs should consider using labels with symbols rather than text to help operators identify specific controls.

CENTRAL WALL DISPLAYS

The purpose of a central wall display is to provide operators with an overview of common information, such as traffic flow and status updates. Evolving technology and styles have supported a recent shift away from traditional TMC central wall displays that are flat and instead encourage curved displays, which have several benefits described in the following guidelines. This section addresses overall central wall configuration, including recent trends. It also provides recommendations for viewing distance, color contrast, font, and size selection. The role of central wall displays is changing, but they are still a primary focus point in TMCs and should be designed accordingly. This section includes the following guidelines:

- **Guideline 68**: Configuring a Central Wall.
- **Guideline 69**: Determining Viewing Distances for Central Wall Displays.
- **Guideline 70**: Selecting Color Contrast.
- **Guideline 71**: Selecting Font and Size.

Guideline 68. Configuring a Central Wall

The following should be considered when designing central wall displays:

- Type and number of displays.
- Layout of TMC, including space and equipment constraints.
- Visual content.

Rationale

The purpose of a central wall display is to provide operators with an overview of common information, such as traffic flow and status updates. A recent trend in TMCs is to move from one large screen to multiple video displays.[15] This design permits flexibility in content display and can quickly be changed to a different visual display. This configuration allows much more information to be displayed from various outputs such as live camera feeds, regional and local maps, local news, weather stations, and system reports.[15]

Flat central wall displays may cause strain on operators' necks by requiring them to continually change head positions to view all of the monitors. A curved central wall display is more efficient and can help alleviate this problem. It permits monitors to be placed close together while still leaving a small gap in between monitors for easy maintenance. The small gap is especially important, given that monitors may need maintenance or may need to be replaced. The gap allows staff to quickly fix individual monitors without shutting down all of the monitors. Figure 30 presents an example of a curved central wall display.

Source: FHWA.

Figure 30. Photo. Curved central wall display at Arizona traffic operations center.

OTHER CLOSELY RELATED GUIDELINES
Chapter 4 (guideline 50) and chapter 5 (guidelines 69–71).

SPECIAL CONSIDERATIONS
TMCs should minimize the use of static information and should focus on providing dynamic information on a central wall display.

Guideline 69. Determining Viewing Distances for Central Wall Displays

Central wall viewing distances should be determined by considering the following:

- Whether all operators need to be able to view all details.
- Whether information can also be viewed on workstation monitors.
- Whether there are visual obstructions for operators whose workstations are off center.

Rationale

A general rule in sizing video walls is to determine the maximum viewing distance and divide it by six. For example, if the maximum viewing distance is 30 ft (10 m) from the farthest operator, then the height of the video wall should be at least 5 ft (1.6 m).[(83)]

Some large displays have lower resolution and brightness, which make them more susceptible to glare. The center wall display(s) should be configured in a way to reduce glare.[(1,15)] Off-centered viewing degrades color and brightness and increases reflectance. All operator workstations should be positioned so that operators are less than 30 to 45 degrees from the center on a large display or from the center of each individual monitor.

OTHER CLOSELY RELATED GUIDELINES
Chapter 4 (guideline 50) and chapter 5 (guidelines 68, 70, and 71)

SPECIAL CONSIDERATIONS
TMCs should minimize the use of static information and should focus on providing dynamic information on a central wall display.

Guideline 70. Selecting Color Contrast

Color-related characteristics should be determined for central wall displays that accommodate rapid visual search and change detection. Key features include the following:

- Saliency of most important information.
- Color contrast.
- Uniform and standardized brightness throughout entire central wall display.

Rationale

Visual search is when an operator scans the central wall display to find the desired information. Change detection occurs when an operator monitors the central wall display and notices or becomes aware of any changes. Thus, there should be a high degree of saliency for important information. Incorporating the appropriate color contrast allows for easier and faster recognition of information displayed and reduces eye strain. The overall system contrast ratio should account for ambient lighting within the room as well as the imaging from the central wall display (there is no standard minimum values due to the differences in each environment when screens are viewed). White backgrounds are discouraged because they appear brighter than other information. Black or dark background colors are preferred for central wall display technology (table 16).[84]

Table 16. Preferred color contrast combinations from most to least readable.

Most Readable	Moderately Readable	Least Readable
Black on yellow	Yellow on black	Green on white
Blue on yellow	White on green	Brown on yellow
Yellow on brown	Red on white	White on red

Manufacturers have made rapid advancements in ultra-high definition products, and many will make their way into the TMC marketplace. Color brightness should be standardized across the entire central wall display. If the central wall display consists of several monitors, the brightness and color contrast should be matched for all displays. Ambient light falling on the monitors should be minimized for better contrast.

Flat panel displays typically accommodate higher brightness requirements when compared to projection cube alternatives. A higher brightness may be necessary to improve overall contrast in environments where ambient light is very high. However, video displays that are too bright negatively affect operators who work directly in front of the central display and may cause operators to suffer from headaches or eyestrain. If the wall is not bright enough, contrast will likely be too low, making it difficult to quickly and accurately discern information as required.

OTHER CLOSELY RELATED GUIDELINES
Chapter 5 (guidelines 68, 69, and 71).

SPECIAL CONSIDERATIONS
It is beneficial to use color mode in cameras to improve night vision and assign an individual to constantly monitor displays and make corrections.

Guideline 71. Selecting Font and Size

The following should be considered when selecting font and font sizes for central wall displays:

- Avoid font effects such as shadowing or embossing.
- Use only sans serif style fonts.
- Ensure font size is readable by all TMC operators.

Rationale

As the resolution of commercially available displays rapidly increases, the opportunities to include complex image and video content to a central wall display are nearly unlimited. Some suggestions from video wall experts for selecting fonts include the following:

- **Font**: It is optimal to use sans serif fonts (Arial, Gothic, Tahoma, etc.) only. Serif fonts (Times New Roman, Book Antiqua, Garamond, etc.) add excess noise and are more difficult to read.

- **Shade**: It is best to avoid applying shades or other effects on text. These effects typically do not translate well on central wall displays.

- **Size**: There is a linear relation between viewing distance and character size. For example, if the distance to the central wall display is four times the distance to the workstation monitor, then the size of the characters also needs to be four times the size of the desktop character size.[85] In cases when the font is too small, operators may strain trying to view the information or avoid using the wall as a tool.

OTHER CLOSELY RELATED GUIDELINES
Chapter 5 (guidelines 68 and 69).

SPECIAL CONSIDERATIONS
It is beneficial to determine the maximum viewing distance before selecting font size and color.

CHAPTER 6. COMMUNICATION AND COORDINATION WITH THE PUBLIC, COLLEAGUES, AND AGENCIES

Timely and effective communication within a TMC environment is critical for successful operations but can be complex and difficult to maintain. First, operators need to communicate with one another regarding incidents and responses, while managers and supervisors need to communicate with operators about action plans and personnel matters. Additionally, operators who work in the TMC may need to communicate with remote staff. TMCs may directly or indirectly communicate with customers and drivers through public media streams and DMSs. A critical component of TMC communications involves emergency and incident management. This chapter presents guidelines that define the communication landscapes for TMCs and includes descriptions of potential interactions within and outside of the agency, the content required for different types of messages, the most effective format for these messages, and different mediums of communication.

OPERATOR COMMUNICATION AND COORDINATION

The following section addresses the various means of communication from a human factors perspective (including instant messaging, which is becoming ubiquitous). Effective communication is vital to a successfully operating a TMC. In addition, while much of the work of a TMC occurs within a central operations center, some staff may work remotely. Many TMCs have multiple operations centers and will need to coordinate and communicate various operations. Consequently, communication coordination among these staff is discussed. This section includes the following guidelines:

- **Guideline 72**: Communicating via Instant Messaging.
- **Guideline 73**: Using Additional Means of Communication.
- **Guideline 74**: Coordinating Interactions Among Distributed Workers.

Guideline 72. Communicating via Instant Messaging

> Operator-to-operator communication tools, such as instant messaging, should be selected by examining the following:
>
> - Identify scenarios that could benefit from messaging tools.
> - Consider the advantages and disadvantages of changing communication approaches.
> - Involve operators in the decision by collecting feedback on utility and desirability.

Rationale

With increasing frequency, TMCs are using tools, such as instant messaging, to support communication tasks.[14] Agencies must carefully consider when these tools are appropriate by examining the type of information being shared, the memory load associated with the information, the time sensitivity of the information, and the frequency of exchange.

An advantage of instant messaging is a decrease in audible noise that may serve as a distractor or interruption. This form of communication provides automatic documentation, allowing clarity of information to be preserved as opposed to errors in remembering. However, instant messages may be ignored or overshadowed by other tasks and may not support a rich dialog or a verbal conversation.

OTHER CLOSELY RELATED GUIDELINES
Chapter 2 (guideline 12), chapter 4 (guideline 55), and chapter 6 (guidelines 73 and 75).

SPECIAL CONSIDERATIONS
It is helpful to consider whether tasks that permit communication via instant messaging would be required or optional.

Guideline 73. Using Additional Means of Communication

The pros and cons associated with different communication tools should be evaluated within the TMC, including the following:

- Noise level.
- Frequency of exchange.
- Location of individuals.
- Documentation.

Rationale

Agencies need to identify which tools are best suited for their staff based on the type, speed, and frequency of information exchanged. For example, instant messaging is fast and immediate but may not be appropriate if verbal conversation is needed. Remote staff cannot participate in in-person verbal dialogs and may have physical limits (e.g., working on scene or a noisy road environment that limits the quality of phone or radio communications). Table 17 provides a comparison of some of these issues.

Table 17. Modes of communication and associated issues.

Issue	Verbal	Telephone	Radio	Instant Messaging	Email
Delayed response	—	—	—	X	X
Can fail to perceive	—	—	—	X	X
Complicated dialog	X	X	X	—	X
Documentation	—	—	—	X	X
Effective in noisy environment	—	—	—	X	X
Limits noise exchange	—	—	—	X	X
Requires shared equipment	—	—	X	X	—
Requires colocation	X	—	—	—	—
Error prone	—	—	X	X	X
Creates distraction	X	X	X	—	—

—The mode of communication does not have the associated issue.

OTHER CLOSELY RELATED GUIDELINES
Chapter 4 (guideline 55) and chapter 6 (guidelines 72, 74, and 75).

SPECIAL CONSIDERATIONS
Instant messaging can reduce noise in the TMC.

Guideline 74. Coordinating Interactions Among Distributed Workers

Tools and procedures should be created to optimize communication between the TMC and remote staff.

Rationale

While much of the work of a TMC occurs within a central operations center, some staff may work remotely full or part time. Additionally, many TMCs have multiple operations centers and need to coordinate and communicate various operations. Communication strategies must be reliable and efficient.[86]

It is important to understand who will be communicating and under what context to better determine the appropriate communication tools. Remote staff should be able to enter and update incident information into the TMC software tool, which can help improve efficiency and accuracy of event reporting and reduce radio traffic.

The following are suggested procedures to ensure stable interactions among distributed workers:

- Identify communication links that need to be maintained.
- Determine task types and frequency of communication.
- Develop protocols for efficient and consistent language.
- Reduce redundancies and minimize memory load (when possible).
- Identify tools to support timely communication and prevent misunderstandings or missed messages.

OTHER CLOSELY RELATED GUIDELINES
Chapter 6 (guidelines 72 and 73).

SPECIAL CONSIDERATIONS
It is beneficial to try to understand who will be communicating remotely and in what context.

PUBLIC MESSAGES

One of the most important goals of a TMC is to maintain credibility. If travelers distrust the information from a TMC, they may ignore messages or take nonsuggested routes. In order to maintain credibility, TMCs must ensure that motorists have the most up-to-date and accurate information on which to base travel decisions. The following section provides guidance on effective communication across a variety of media, especially as it relates to the message content. Each medium has its own human factors issues related to perception and understanding of the information, and TMC staff should be aware of these issues so that messages can be optimized. In addition, there is a discussion of user testing for public messages, which provides the TMC staff with a list of appropriate tools and sources for conducting testing or choosing a firm to conduct quality usability testing. This section includes the following guidelines:

- **Guideline 75**: Creating Effective Public Communication.
- **Guideline 76**: Effectively Using and Displaying Content on DMSs.
- **Guideline 77**: Communicating with the Public via Text Messages and Email.
- **Guideline 78**: Creating General 511 Content.
- **Guideline 79**: Creating 511 Telephone Content.
- **Guideline 80**: Creating 511 Website Content.
- **Guideline 81**: Performing User Testing.

Guideline 75. Creating Effective Public Communication

Content must be accurate, current, and valuable to motorists. The following guidelines should be implemented:

- Do not display information until it has been verified.
- Only display current information.
- Do not display obvious or trivial information.
- Do not display information that is irrelevant to most drivers.

Rationale

One of the most important goals of a TMC is to maintain credibility. If travelers distrust the information from a TMC, they may ignore messages or take nonsuggested routes. Thus, operators must be educated on their responsibility for ensuring that motorists have confidence in the disseminated information.[50] There should be a single point of review that approves each message prior to broadcasting it to the public. The public information representative should always be involved in determining and disseminating information. When multiple agencies are providing information, all information should be coordinated and consistent.

In order to maintain credibility, TMCs must ensure that motorists have the most up-to-date and accurate information on which to base travel decisions. Thus, when updating content, the TMC must consider the audience and the intended impact on driver behavior to determine the delivery mechanism (DMS, HAR, email, etc.) that can most directly reach the correct audience. Table 18 shows characteristics of messages by technique.

Table 18. Characteristics of messages by technique.

Characteristics of Messages	DMS	HAR	511	Website	Press Release	Text Message	Social Media
Long, detailed messages	—	X	—	X	X	—	—
Major events	X	X	X	X	X	—	X
Automated messages	X	X	X	X	—	X	X
Flexible messages	X	—	—	X	X	—	X
Access large population	X	X	X	X	X	X	X

—The technique does not have the specific message characteristic.

OTHER CLOSELY RELATED GUIDELINES
Chapter 6 (guidelines 76–80).

SPECIAL CONSIDERATIONS
A single point of review should be responsible for approving communications with the public.

Guideline 76. Effectively Using and Displaying Content on DMSs

The following information should be included when posting travel times and incident information on DMSs:

- Brief description of situation (including reason to comply with suggested action).
- Location of situation.
- Effect on travel (e.g., lanes blocked).
- Action to take (e.g., where to exit).
- Identifiers before number (e.g., Route 1).

Rationale

Motorists can benefit from a number of different types of information, including the location of the problem, lanes affected, location of lane closure, effect on travel, appropriate driving response, and the reason to follow recommendations.[87] Operators must construct messages to account for human sensation, perception, and cognitive limitations that keep drivers from being able to handle a large amount of message information.[50,88] The communications channel, the specifics of the incident, and the policies of the TMC will determine which parts of content are delivered and how they are integrated.

Travel Times

Findings from previous research provide suggestions of both content and format for travel times displayed on DMSs that account for human limitations (figure 31).[88]

Source: FHWA.

Figure 31. Illustration. DMS travel time template showing destination and time.

Figure 31 adheres to the following suggestions:(89)

- Indicate the time units (e.g., minutes) for travel times to destinations.
- Left justify the destinations and right justify the travel times.
- List destinations as street names or towns (exit numbers are not recommended). It is not necessary to include distance to destinations, time stamps, trend indicators, or color coding of text.
- Employ a maximum of three destinations and no more than six information units (e.g., destination is one unit and travel time is one unit).

Incidents, Congestion, and Construction

To maximize route diversion in response to an incident or congestion, the following display features should be considered:

- Specifically recommend using an alternate route (e.g., USE ALT RTE).
- Indicate a specific alternate route (e.g., VIA RT 355).
- Indicate major delay or incident (e.g., MAJOR DELAY).
- Provide an open-ended travel time estimate (e.g., 30+ MIN).
- Show travel times for both current and alternate routes.

Public Safety Announcements

From a human factors stance, it is important to determine the usefulness of public safety announcements (PSAs) displayed on DMSs and to eliminate any unnecessary and ineffective messages. Displaying PSAs too often may be distracting, and urgent messages displayed on DMSs will be less effective. Table 19 provides an evaluation of various PSAs displayed on DMSs and recommendations to improve the content displayed.(90)

Table 19. Evaluation and recommendations to improve PSA content displayed on DMSs.[28]

Finding	Recommendation/Guidance
Assertive PSAs are taken seriously.	Assertive PSAs need to be examined more carefully to identify the impact on driver behavior.
PSAs that show a monetary fine impact driving.	It is uncertain whether including monetary fines have a positive or negative impact on driving. Hence, PSAs that show monetary fines need to be examined on the road before further implementation.
PSAs that include data on crash statistics impact driving.	It is uncertain whether including crash statistics will have a positive or negative impact on driving. Hence, PSAs that show crash statistics need to be examined on the road before further implementation.
There is an association between the frequency of observation of PSAs on DMSs and the perceived usefulness.	More studies need to be done to pinpoint the appropriate number and frequency of PSAs on DMSs to avoid the introduction of an unnecessary number of messages.
Younger drivers (younger than 30 yr old) are less likely to consider PSAs on DMSs effective.	Awareness on (and familiarity with) PSAs should be promoted among the younger groups of the population.

OTHER CLOSELY RELATED GUIDELINES
Chapter 3 (guidelines 32 and 33) and chapter 6 (guideline 75).

SPECIAL CONSIDERATIONS
DMS characteristics may affect legibility and message length, including the type of sign (light-emitting diode, fiber optic, etc.) and the number of lines and characters per line.

Guideline 77. Communicating with the Public via Text Messages and Email

Motorists should be presented with short, direct, and easy-to-understand messages with opt-in and opt-out features. Motorists should have the ability to control information preferences, and the messages should reach motorists in real time.

Rationale

Public communication via email and text messages can provide interested motorists with concise, geographically relevant information. Motorists can opt-in to receive text or email alerts about roadway conditions and travel advisories. Sometimes, this can include specifying the level of detail or type of information that they want to receive (such as information about a particular county or commuting corridor). By choosing to receive these messages, the TMC will have an audience that is receptive and interested in timely alerts. However, message quality and frequency must be considered to avoid antagonizing users with overly frequent alerts or out-of-date information.

Guideline 78. Creating General 511 Content

511 systems should be used to offer a clear and easy way for customers to receive travel information, including major incidents, weather advisories, and details for construction zones and special events.

Rationale

Traditionally, 511 systems offer a clear and easy way for any customer to get travel information. Some segments of the population prefer this method of getting information. This system is best aligned with certain types of information, generally more regimented with clearly delineated incidents. Additionally, 511 communications can be tailored to be an effective source of major event information.[91,50]

At a minimum, 511 systems should communicate information on any events that could significantly impact traffic, including major incidents, construction, weather, and special events. Depending on the region, agencies may include congestion, speed, and travel times.[91] In addition, 511 systems can provide a method for customers to relay incident information to the TMC. The system may seem antiquated in light of the vast digital data available to customers; however, it remains a well-liked method of interaction for many motorists.

OTHER CLOSELY RELATED GUIDELINES
Chapter 6 (guidelines 75, 80, and 81).

SPECIAL CONSIDERATIONS
Drivers on the road should not receive information via text or email. It is necessary to explore alternate options.

Guideline 79. Creating 511 Telephone Content

511 telephone menus should be created that are easy to use with clear and precise content. Content should include the following:

- Minimum top-level options should be traffic, transit, weather, and help.
- It would be useful to include other important regional options explicitly or under "Other Information."
- Voice recognition may be useful to some users as long as a back-out option exists.

Rationale

Seeing information visually is a much different experience than listening to the same information over the telephone. Agencies should try to eliminate free-form text and rely on consistently formatted text fields that are appropriate for concatenated speech or text-to-speech technologies.

Alternatively, professional voice talent is used for the similar quality in voice as a radio voice in the system.[91]

Users will not receive the desired information if they are confused or frustrated with the 511 system. If they leave the system due to an unsatisfactory experience, they will likely not return and will not adjust their travel behavior in a desirable way. Telephone menus and voice recognition should be intuitive and easy to understand to promote efficient use.[91]

Guideline 80. Creating 511 Website Content

511 websites should be utilized to provide more content and details to website users such as the following:

- Traveler pretrip planning opportunities.
- Current road conditions.
- Visual regional information.

Rationale

The 511 system serves as a brand for traffic information and, thus, is used to denote traffic information websites. The information must be the same as the telephone content but may be presented in a different format. Websites can include color-coded map data showing speed conditions, incidents, construction zones, weather, planned events, travel times point-to-point or to common destinations, camera images, and more.[91,50]

OTHER CLOSELY RELATED GUIDELINES
Chapter 3 (guideline 36) and chapter 6 (guidelines 75, 78, and 81).

SPECIAL CONSIDERATIONS
There should be consistency between telephone and website content.

Guideline 81. Performing User Testing

In communicating with the public, user testing should be performed early and often.

Rationale

The usability of communication techniques (DMS, 511, website, social media, etc.) is important to ensure use of systems, attention to messages, and desired actions and behavior. Systems that are not usable and messages that are unclear or poorly understood will reduce the credibility of the agency and negatively affect driving behavior. User testing is part of the iterative process for developing and properly designing communication tools. As technology continues developing and new communication tools arise, user testing will still play an active role in the iterative process.

User testing is important for several reasons, including the following:

- The designer of the system is not the intended user.
- Users of the system may have difficulty interpreting or locating information that the designer believed to be intuitive.
- Users do not interact with the technology in the same way as the designer.

The quality of content and information dissemination via social media, DMSs, 511 communication, and websites can be evaluated along several key dimensions, including accuracy, reliability, timeliness, consistency, and relevancy.[91] This may initially be achieved through performing pilot testing and collecting operator and staff feedback. Additionally, it is important to address the following questions prior to implementing a new system as well during user testing:

- What is the user's purpose of using the communication system?
- What information are they looking for?
- How often will they use the system?
- What experiences do they have with this or similar systems?
- How do they want to use the information (e.g., read on a mobile phone or desktop)?

User testing techniques should vary for each type of communication tool, including DMS, 511, websites, and other social media. There are numerous techniques for user testing; some are more valuable than others but, nevertheless, all are pertinent to designing effective public messages. It may be necessary to consult with a usability expert before performing such techniques.

For further literature on user testing, readers can visit references 92 and 93:

OTHER CLOSELY RELATED GUIDELINES
Chapter 3 (guideline 37) and chapter 6 (guidelines 72 and 76–80).

SPECIAL CONSIDERATIONS
Feedback should be collected from a variety of sources (e.g., feedback can be obtained through voicemail, via 511 prompts, or email forms).

EMERGENCY OPERATIONS, MANAGEMENT, AND COORDINATION

Emergency operations and incident management are important parts of TMC operations, especially with the increasingly prevalent trend to co-locate emergency operations within a TMC. Although emergency and incident management operations are not the most frequent activity in a TMC, they are extremely important and have the potential for catastrophic consequences if not performed properly. The following section gives a brief overview of emergency operations and coordination across agencies when dealing with incidents. The purpose is not to provide an exhaustive account but rather a high-level introduction to raise awareness and provide references to further indepth sources for personnel who have a particular interest. While the topics are not traditionally considered human factors, human factors is a broad area that incorporates issues of communication, stress, shiftwork, and decisionmaking, which have been addressed in earlier guidelines. This topic area incorporates those earlier guidelines into an emergency or incident operations framework. This section includes following guidelines:

- **Guideline 82**: Preparing for Emergency Response.
- **Guideline 83**: Evaluating TMC Emergency Response.
- **Guideline 84**: Developing Coordination Protocol for Emergency Operations.

Guideline 82. Preparing for Emergency Response

> For successful emergency management, TMC operators need to partake in preparatory activities and understand existing protocols and procedures.

Rationale

The role of the TMC in emergency management is often quite encapsulating and may increase operator stress. An abrupt increase in stress is detrimental on operator performance and causes operators to commit more errors, which in turn, decreases vigilance and increases workload. Preparation activities provide operators with exposure, allowing them to create strategies. It is important that operators complete activities and training for various scenarios, including winter storms, special events, hazardous material spills, detour and evacuation routes, power outages, flooding, etc.[94]

Figure 32 can be used as a preparation activity as well as a checklist during an emergency response. As a preparation activity, this will allow operators to better understand their role during an emergency and provide them with expected procedures.[94]

- ✓ Detects events and issues notifications to appropriate agencies.
- ✓ Monitors and relays TMC camera and sensor information (e.g., weather information, traffic queues, etc.).
- ✓ Provides emergency response resources, including personnel and equipment, as requested.
- ✓ Refocuses, to the extent possible, camera and sensor information on an event and monitors and relays to first responders as requested.
- ✓ Provides communication support using TMC systems and capabilities as requested.
- ✓ Assists with coordination involving specialized agencies (e.g., hazardous materials spill, fire evacuations, and transportation closures).
- ✓ Transitions from providing support for a planned event to providing response to an unplanned incident occurring at the event.
- ✓ Facilitates evacuations by suspending highway work or projects on evacuation routes and provides equipment and personnel resources to assist in the staffing and implementation of evacuation traffic control points.

Source: FHWA.

Figure 32. Illustration. TMC operator task checklist for use during emergency operations.[94]

During emergencies, TMC operators are often tasked with selecting the correct CCTV and locating the incident or emergency to relay to other corroborating agencies. This task can be difficult because operators must be able to quickly identify the exact location being viewed on a CCTV, including the cardinal location. Fortunately, previous research has developed three techniques to improve operators' confidence in correctly identifying the location.[95] These techniques include the following:

1. Rely on topographies initially (landmarks, mountains, water, etc.).
2. Look for shadows to evaluate direction orientation.
3. Determine the cardinal direction, using prior knowledge, based on the location of rush hour traffic. (This may be less reliable when traffic appearing to be rush hour traffic is actually caused by an incident or emergency.)

OTHER CLOSELY RELATED GUIDELINES
Chapter 2 (guidelines 15 and 16) and chapter 6 (guidelines 83 and 84).

SPECIAL CONSIDERATIONS
For detailed training and response activities, visit the I-95 Coalition website.[96]

Guideline 83. Evaluating TMC Emergency Response

During the TMC's response to an emergency operation, it is important to plan for increased coordination requirements with law enforcement, possibly requiring a liaison officer being sent to or received from the lead law enforcement agency.

Rationale

The role of TMC operators during an emergency response consists of four overarching stages: (1) risk/threat assessment, (2) response, (3) recovery, and (4) mitigation. The mitigation stage provides TMC operators and management an opportunity to evaluate the successes and failures during the emergency response. Table 20 provides detailed information on each stage.

Table 20. Four-stage evaluation of TMC emergency response.

Stage	Actions Performed
1. Risk/threat assessment	Monitor and detect incidents and events through sensors and real-time camera feeds.
2. Response	Notify appropriate agencies, update public communication channels (DMS, HAR, 511 telephone and website services, etc.), continue to monitor sensors and cameras, and initiate the response.
3. Recovery	Update public communication channels, debrief operators, return to normal operations, and input incident information into tracking logs.
4. Mitigation	Evaluate TMC response by qualitatively noting both positive and negative performance, quantitatively evaluate TMC performance by creating data outputs (tables, figures, pie charts, flowcharts, etc.), and determine whether further training is needed.

OTHER CLOSELY RELATED GUIDELINES
Chapter 6 (guidelines 82 and 84)

SPECIAL CONSIDERATIONS
The TMC should see little difference between activities for either a security operation or emergency response to a natural event.

Guideline 84. Developing Coordination Protocol for Emergency Operations

It is essential that coordination protocols for emergency operations are well understood for emergency operations and include the following:

- How protocols are coordinated internally.
- Who releases information.
- Who receives information.

Rationale

When a regional or State emergency operations center (EOC) is established in response to a major disaster or incident, the emergency support function representative will seek information, such as the damage to major transportation corridors, status of roads and bridges, and best alternate routing if main routes are degraded. After the initial emergency response to a major disaster, a forward operational office may be established, and there will be requests from that entity for transportation-related information or tasking requirements.

There will likely be other distractions in the case of a State-managed TMC, including the governor, or in the case of an urban regional TMC, the mayor, who may be seeking information. Politicians have been known to bypass EOCs, going directly to the source—in this case, the TMC. The media may also find its way to the TMC. While a joint information center is normally established to manage the release of information, the TMC should develop its own protocols delineating how these requests for information will be handled.

It may be appropriate to dispatch a liaison officer to external partners during emergency operations to provide an immediate information link. The protocol for this should be formally established, with communications channels mapped out.

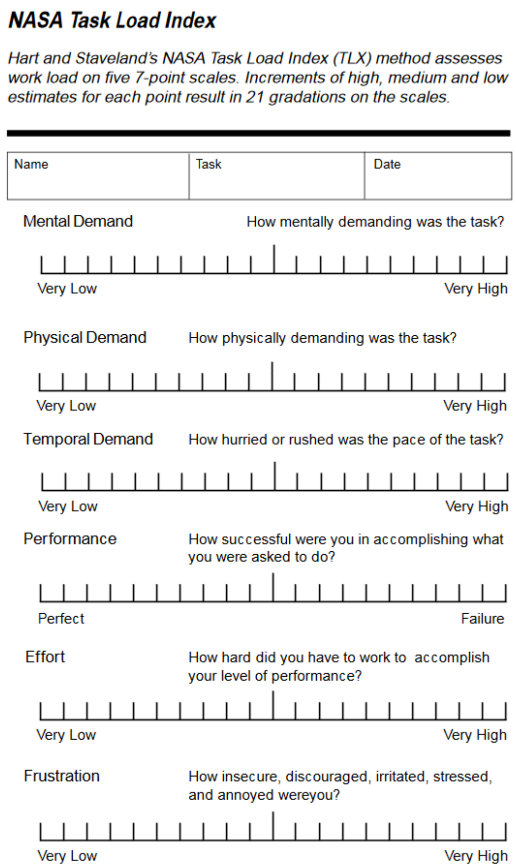
Because the TMC has a robust communications capability, there may be instances when the TMC is required to absorb additional personnel when the parent agency activates its own EOC. In this case, there should be procedures established as to how that will happen (i.e., who does what and in what order).

OTHER CLOSELY RELATED GUIDELINES
Chapter 6 (guidelines 82 and 83)

SPECIAL CONSIDERATIONS
When developing protocol, the process itself should be coordinated with external partners.

APPENDIX A. NASA-TLX

Appendix A presents a screenshot of the NASA-TLX, which assesses workload on six seven-point scales: mental demand, physical demand, temporal demand, performance, effort, and frustration.



NASA Task Load Index

Hart and Staveland's NASA Task Load Index (TLX) method assesses work load on five 7-point scales. Increments of high, medium and low estimates for each point result in 21 gradations on the scales.

Name	Task	Date

Mental Demand — How mentally demanding was the task?

Very Low — Very High

Physical Demand — How physically demanding was the task?

Very Low — Very High

Temporal Demand — How hurried or rushed was the pace of the task?

Very Low — Very High

Performance — How successful were you in accomplishing what you were asked to do?

Perfect — Failure

Effort — How hard did you have to work to accomplish your level of performance?

Very Low — Very High

Frustration — How insecure, discouraged, irritated, stressed, and annoyed wereyou?

Very Low — Very High

Source: NASA.

Figure 33. Screenshot. NASA-TLX.[10]

Further information, including supporting literature and how to score the NASA-TLX, as well as to receive a paper version of this assessment technique is available on the NASA-TLX website.[10]

APPENDIX B. OSHA ERGONOMICS SOLUTIONS: EVALUATION CHECKLISTS FOR COMPUTER WORKSTATIONS

Appendix B provides a series of checklists (figure 34 through figure 45) to evaluate a computer workstation and includes topics of consideration, such as working postures, seating issues, keyboards and other input devices, monitors, work areas, and accessories.

WORKING POSTURES–The workstation is designed or arranged for doing computer tasks so it allows your	**Y**	**N**
1. Head and **neck** to be upright, or in-line with the torso (not bent down/back). If "no" refer to Monitors, Chairs and Work Surfaces.		
2. Head, neck, and **trunk to** face forward (not twisted). If "no" refer to Monitors or Chairs.		
3. Trunk to be perpendicular to floor (may lean back into backrest but not forward). If "no" refer to Chairs or Monitors.		
4. Shoulders and **upper arms** to be in-line with the torso, generally about perpendicular to the floor and relaxed (not elevated or stretched forward). If "no" refer to Chairs.		
5. Upper arms and **elbows** to be close to the body (not extended outward). If "no" refer to Chairs, Work Surfaces, Keyboards, and Pointers.		
6. Forearms, wrists, and **hands** to be straight and in-line (forearm at about 90 degrees to the upper arm). If "no" refer to Chairs, Keyboards, Pointers.		
7. Wrists and **hands** to be straight (not bent up/down or sideways toward the little finger). If "no" refer to Keyboards, or Pointers		
8. Thighs to be parallel to the floor and the **lower legs** to be perpendicular to floor (thighs may be slightly elevated above knees). If "no" refer to Chairs or Work Surfaces.		
9. Feet rest flat on the floor or are supported by a stable footrest. If "no" refer to Chairs, Work Surfaces.		

Figure 34. Screenshot. Working postures evaluation checklist.[(69)]

SEATING–Consider these points when evaluating the chair:	**Y**	**N**
10. Backrest provides support for your lower back (lumbar area).		
11. Seat width and **depth** accommodate the specific user (seat pan not too big/small).		
12. Seat front does not press against the back of your knees and lower legs (seat pan not too long).		
13. Seat has cushioning and is rounded with a "waterfall" front (no sharp edge).		
14. Armrests, if used, support both forearms while you perform computer tasks and they do not interfere with movement.		
"No" answers to any of these questions should prompt a review of Chairs.		

Figure 35. Screenshot. Seating evaluation checklist.[(69)]

KEYBOARD/INPUT DEVICE–Consider these points when evaluating the keyboard or pointing device. The keyboard/input device is designed or arranged for doing computer tasks so the	**Y**	**N**
15. Keyboard/input device platform(s) is stable and large enough to hold a keyboard and an input device.		
16. Input device (mouse or trackball) is located right next to your keyboard so it can be operated without reaching.		
17. Input device is easy to activate and the shape/size fits your hand (not too big/small).		
18. Wrists and **hands** do not rest on sharp or hard edges.		
"No" answers to any of these questions should prompt a review of Keyboards, Pointers, or Wrist Rests.		

Figure 36. Screenshot. Keyboard/input device evaluation checklist.[(69)]

MONITOR–Consider these points when evaluating the monitor. The monitor is designed or arranged for computer tasks so the	Y	N
19. Top of the screen is at or below eye level so you can read it without bending your head or neck down/back.		
20. User with bifocals/trifocals can read the screen without bending the head or neck backward.		
21. Monitor distance allows you to read the screen without leaning your head, neck or trunk forward/backward.		
22. Monitor position is directly in front of you so you don't have to twist your head or neck.		
23. Glare (for example, from windows, lights) is not reflected on your screen which can cause you to assume an awkward posture to clearly see information on your screen.		
"No" answers to any of these questions should prompt a review of Monitors or Workstation Environment.		

Figure 37. Screenshot. Monitor evaluation checklist.[(69)]

WORK AREA–Consider these points when evaluating the desk and workstation. The work area is designed or arranged for doing computer tasks so the	Y	N
24. Thighs have sufficient clearance space between the top of the thighs and your computer table/keyboard platform (thighs are not trapped).		
25. Legs and **feet** have sufficient clearance space under the work surface so you are able to get close enough to the keyboard/input device.		

Figure 38. Screenshot. Work area evaluation checklist.[(69)]

ACCESSORIES–Check to see if the	Y	N
26. Document holder, if provided, is stable and large enough to hold documents.		
27. Document holder, if provided, is placed at about the same height and distance as the monitor screen so there is little head movement, or need to re-focus, when you look from the document to the screen.		
28. Wrist/palm rest, if provided, is padded and free of sharp or square edges that push on your wrists.		
29. Wrist/palm rest, if provided, allows you to keep your forearms, wrists, and hands straight and in-line when using the keyboard/input device.		
30. Telephone can be used with your head upright (not bent) and your shoulders relaxed (not elevated) if you do computer tasks at the same time.		
"No" answers to any of these questions should prompt a review of Work Surfaces, Document Holders, Wrist Rests or Telephones.		

Figure 39. Screenshot. Accessories evaluation checklist.[(69)]

GENERAL	Y	N
31. Workstation and equipment have sufficient adjustability so you are in a safe working posture and can make occasional changes in posture while performing computer tasks.		
32. Computer workstation, components and accessories are maintained in serviceable condition and function properly.		
33. Computer tasks are organized in a way that allows you to vary tasks with other work activities, or to take micro-breaks or recovery pauses while at the computer workstation.		
"No" answers to any of these questions should prompt a review of Chairs, Work Surfaces, or Work Processes.		

Figure 40. Screenshot. General evaluation checklist.[(69)]

APPENDIX C. OSHA ERGONOMICS SOLUTIONS: PURCHASING CHECKLISTS FOR COMPUTER WORKSTATIONS

Figure 41 through figure 45 provide a series of checklists for purchasing a computer workstation and include topics of consideration, such as monitors, keyboards and other input devices, wrist rests, and telephones.

Monitors	✓
1. Make sure the screen is large enough for adequate visibility. Usually a 15 to 20-inch monitor is sufficient. Smaller units will make it difficult to read characters and larger units may require excessive space.	
2. The angle and tilt should be easily adjustable.	
3. Flat panel displays take less room on the desk and may be more suitable for locations with limited space.	

1 inch = 25.4 mm.

Figure 41. Screenshot. Monitor purchasing checklist.[69]

Keyboards	✓
1. Split keyboard designs will allow you to maintain neutral wrist postures.	
2. Keyboards with adjustable feet will accommodate a wider range of keyboard positions and angles. Adjustable feet on the front as well as the back will further aid adjustments. Increased adjustability will facilitate neutral wrist postures.	
3. The cord that plugs into the CPU should be long enough to allow the user to place the keyboard and the CPU in a variety of positions. At least six feet of cord length is desirable.	
4. Consider a keyboard without a 10-key keypad if the task does not require one. If the task does require one occasionally, a keyboard with a separate 10-key keypad may be appropriate. Keyboards without keypads allow the user to place the mouse closer to the keyboard.	
5. Consider the shape and size of the keyboard if a keyboard tray is used. The keyboard should fit comfortably on the tray.	
6. Consider keyboards without built-in wrist rest, because separate wrist rests are usually better.	
7. Keyboards should be detached from the display screen if they are used for a long duration keying task. Laptop keyboards are generally not suitable for prolonged typing tasks.	

Figure 42. Screenshot. Keyboard purchasing checklist.[69]

Keyboard Trays	✓
1. Keyboard trays should be wide enough and deep enough to accommodate the keyboard and any peripheral devices, such as a mouse.	
2. If a keyboard tray is used, the minimum vertical adjustment range (for a sitting position) should be 22 inches to 28 inches from the floor.	
3. Keyboard trays should have adjustment mechanisms that lock into position without turning knobs. These are frequently over tightened, which can lead to stripped threads, or they may be difficult for some users to loosen.	

1 inch = 25.4 mm.

Figure 43. Screenshot. Keyboard tray purchasing checklist.[69]

Wrist Rests	
1. Wrist rest should match the front edge of the keyboard in width, height, slope, and contour.	
2. Pad should be soft but firm. Gel type materials are recommended.	
3. Wrist rest should be at least 1.5 inches deep (depth away from the keyboard) to minimize contact pressure on the wrists and forearm.	

© OSHA.
1 inch = 25.4 mm.

Figure 44. Screenshot. Wrist rest purchasing checklist.[(69)]

Telephones	
1. If task requirements mandate extended periods of use or other manual tasks such as typing while using the phone, use a telephone with a "hands-free" headset.	
2. The telephone should have a speaker feature for "hands-free" usage.	
3. "Hands-free" headsets should have volume adjustments and volume limits.	

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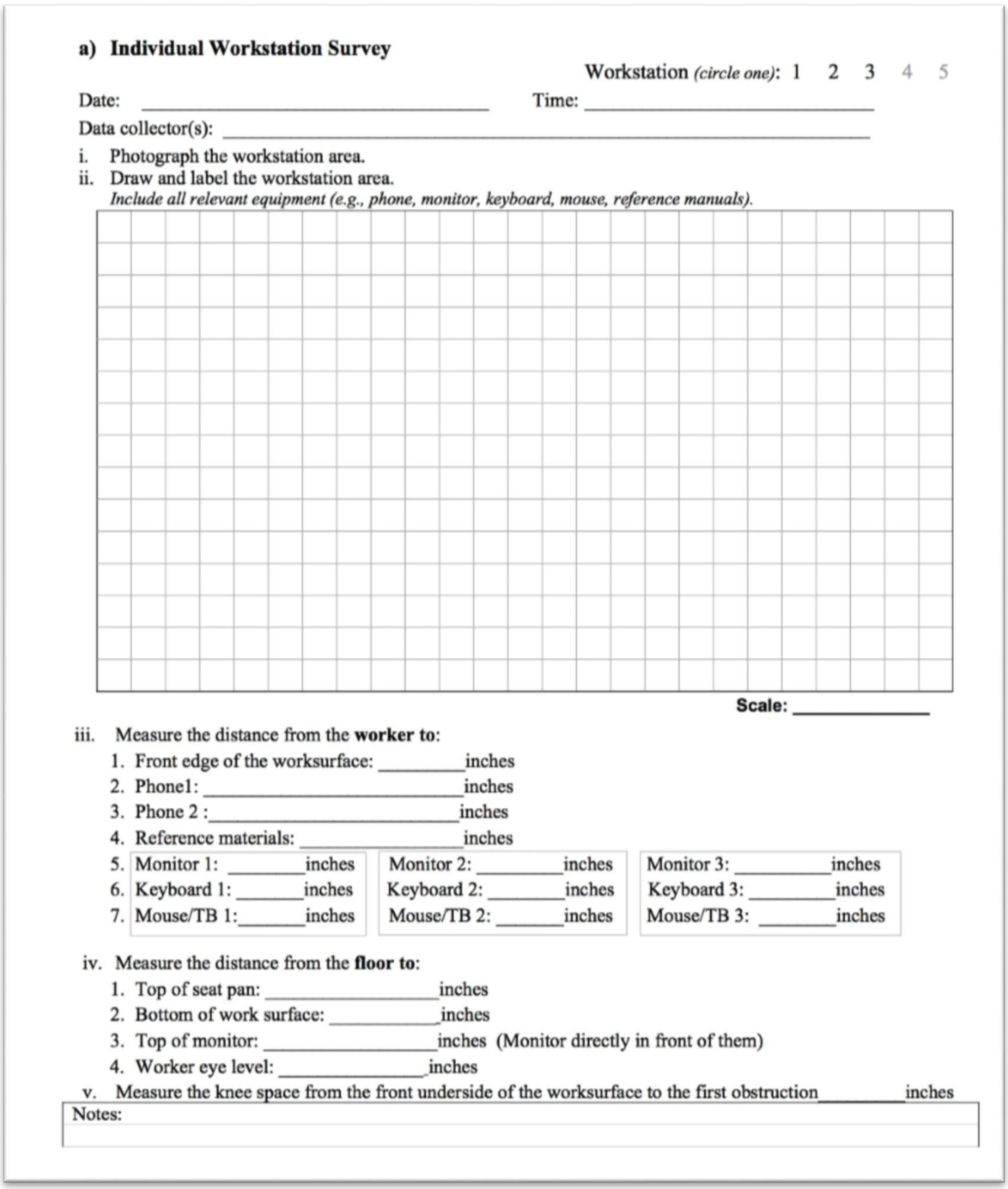
Figure 45. Screenshot. Telephone purchasing checklist.[(69)]

APPENDIX D. WORKSTATION EVALUATION QUESTIONNAIRE

Appendix D provides an example of a workstation evaluation questionnaire (figure 46 through figure 51), which allows for an organized repository of information about measurements that can impact workstation design (including distances from the worker to several tools needed for performing tasks) as well as notes about task performance observations and visual documentation.



a) Individual Workstation Survey

Workstation *(circle one)*: 1 2 3 4 5

Date: ______________________________ Time: ________________________

Data collector(s): ____

i. Photograph the workstation area.
ii. Draw and label the workstation area.
Include all relevant equipment (e.g., phone, monitor, keyboard, mouse, reference manuals).

Scale: ____________

iii. Measure the distance from the **worker to**:
1. Front edge of the worksurface: ________inches
2. Phone1: ________________________inches
3. Phone 2 :________________________inches
4. Reference materials: ______________inches
5. Monitor 1: _______inches | Monitor 2: ________inches | Monitor 3: _________inches
6. Keyboard 1: ______inches | Keyboard 2: ________inches | Keyboard 3: ________inches
7. Mouse/TB 1:______inches | Mouse/TB 2: _______inches | Mouse/TB 3: _______inches

iv. Measure the distance from the **floor to**:
1. Top of seat pan: ________________inches
2. Bottom of work surface: ___________inches
3. Top of monitor: _________________inches (Monitor directly in front of them)
4. Worker eye level: ______________inches

v. Measure the knee space from the front underside of the worksurface to the first obstruction________inches

Notes:

Source: 2009 Federal Aviation Administration.

Figure 46. Screenshot. Page 1 of workstation evaluation questionnaire.[72]

Workstation *(circle one)*: 1 2 3 4 5

vi. Complete the following. Observe the employee while they are working.

1. Does the user adjust the workstation when beginning work?	❑No ❑Yes
2. Is the head/neck upright and in line with the torso? (head not bent up or back)	❑No ❑Yes
3. Do the head, neck, and trunk face forward (not twisted)?	❑No ❑Yes
4. Is the trunk perpendicular to the floor (may lean backward but not forward)?	❑No ❑Yes
5. Are the shoulders and upper arms in line with the torso, generally perpendicular to the floor and relaxes (not elevated or stretched forward)?	❑No ❑Yes
6. Are the upper arms and elbows close to the body (not extended outward)?	❑No ❑Yes
7. Are the forearms at about 90 degrees from upper arm?	❑No ❑Yes
8. Are the wrists and hands straight (not bent up/down/sideways)?	❑No ❑Yes
9. Do the wrists, arms, or hands rest on a hard surface?	❑No ❑Yes
10. Can the input device be used without reaching?	❑No ❑Yes
11. Are the thighs parallel to the floor and lower legs perpendicular to the floor?	❑No ❑Yes
12. Are the feet flat on the floor or supported by a stable footrest?	❑No ❑Yes
13. Are glare and reflections present on the monitor?	❑No ❑Yes
14. Does the monitor have brightness and contrast controls?	❑No ❑Yes
15. Is there sufficient space between the top of the user thighs and the bottom of the work surface so that the user can move the legs freely without scraping them on the work surface?	❑No ❑Yes
16. Is there sufficient space under the work surface for knees and feet with the user in a normal working position?	❑No ❑Yes
17. Can the workstation be used for either right- or left-handed activity?	❑No ❑Yes
18. Is the head upright (not bent) and shoulders relaxed (not elevated) when using the phone?	❑No ❑Yes
19. Do the users stretch, stand, or move while taking microbreaks?	❑No ❑Yes

Notes:

b) Employee Survey

Source: 2009 Federal Aviation Administration.

Figure 47. Screenshot. Page 2 of workstation evaluation questionnaire.[72]

Date: ___________ Time: __________ Workstation *(circle one)*: 1 2 3 4 5

Background

1. What is your job title?	______________________________
2. How long have you been employed at your current job?	______ years ______ months
3. On average how many hours per day do you type while **at work**?	______ hours
4. On average how many hours per day do you type while **at home**?	______ hours
5. On average, how many hours per day do you talk on the phone at work?	______ hours
6. At work, how often do you take breaks?	____ mins per ______ hours worked
7. Are you a touch typist?	❑ No ❑ Yes
8. What is your dominant hand?	❑ Left ❑ Right
9. What is your sex?	❑ Female ❑ Male
10. What is your age?	______ years
11. How tall are you?	______ feet ______ inches
12. Do you smoke?	❑ No ❑ Yes
13. Do you wear any of the following?	❑ Contact lenses ❑ Single Rx glasses ❑ Bifocals ❑ Trifocals

14. While at work do you use:

a. a footrest? ❑No ❑Yes	b. armrests? ❑No ❑Yes	c. back support? ❑No ❑Yes	d. a document holder? ❑No ❑Yes

15. Have you received training or brochures on ergonomics (chair adjustments, monitor placement, taking breaks, etc.)?	❑ No ❑ Yes

16. Are you experiencing any of the following? ❑ No
❑ Yes. *Check all that apply. Write down the affected area(e.g., left wrist)*

❑ Aching ____________	❑ Swelling ____________
❑ Burning ____________	❑ Stiffness ____________
❑ Cramping ____________	❑ Tingling ____________
❑ Numbness ____________	❑ Weakness ____________
❑ Pain ____________	❑ Other ____________

If you answered Yes:

a. What area bothers you the **MOST**? ____________

b. How much discomfort are you are experiencing **now**:	None	① ② ③ ④ ⑤ ⑥ ⑦	Unbearable
c. How much discomfort do experience when it is **at its worst:**	None	① ② ③ ④ ⑤ ⑥ ⑦	Unbearable

Comments:

Workstation

Source: 2009 Federal Aviation Administration.

Figure 48. Screenshot. Page 3 of workstation evaluation questionnaire.[72]

Rate the following: *Mark the circle to indicate your rating.*

17. Office temperature	Too cold	①②③④⑤⑥⑦	Too hot
Comments:			
18. Lighting	Too dark	①②③④⑤⑥⑦	Too bright
Comments:			
19. Noise levels	Too quiet	①②③④⑤⑥⑦	Too noisy
Comments:			
20. Workstation furniture (desk)	Completely unacceptable	①②③④⑤⑥⑦	Completely acceptable
Comments:			
21. Chair	Completely unacceptable	①②③④⑤⑥⑦	Completely acceptable
Comments:			
22. Computer monitor	Completely unacceptable	①②③④⑤⑥⑦	Completely acceptable
Comments:			
23. Keyboard	Completely unacceptable	①②③④⑤⑥⑦	Completely acceptable
Comments:			
24. Mouse or trackball	Completely unacceptable	①②③④⑤⑥⑦	Completely acceptable
Comments:			
25. Phone	Completely unacceptable	①②③④⑤⑥⑦	Completely acceptable
Comments:			
26. Number of breaks you receive	Completely unacceptable	①②③④⑤⑥⑦	Completely acceptable
Comments:			
27. Workload	Too low	①②③④⑤⑥⑦	Too high
Comments:			

Source: 2009 Federal Aviation Administration.

Figure 49. Screenshot. Page 4 of workstation evaluation questionnaire.[72]

28. Variety of tasks	Completely unacceptable	①②③④⑤⑥⑦	Completely acceptable

Comments:

29. Level of control over your work	Completely unacceptable	①②③④⑤⑥⑦	Completely acceptable

Comments:

30. Stress level at work	Completely unacceptable	①②③④⑤⑥⑦	Completely acceptable

Comments:

31. Satisfaction with your job?	Extremely unsatisfied	①②③④⑤⑥⑦	Extremely satisfied

Comments:

32. Amount of ergonomics training you receive?	Too little	①②③④⑤⑥⑦	Too much

Comments:

33. How often do you experience discomfort while working?	Never	①②③④⑤⑥⑦	Every day

Comments:

34. The layout of the control center is	Completely unacceptable	①②③④⑤⑥⑦	Completely acceptable

Comments:

35. How legible is the information on the large screen displays?	Completely legible	①②③④⑤⑥⑦	Completely illegible

Comments:

36. Information on the large screen display	Useless	①②③④⑤⑥⑦	Useful

Comments:

Source: 2009 Federal Aviation Administration.

Figure 50. Screenshot. Page 5 of workstation evaluation questionnaire.[(72)]

39. Please identify any ergonomic tools you have experience with using, including those that you tried and didn't like. If you tried it and don't use it, please explain why.

Ergonomic keyboard ☐ Use ☐ No experience ☐ Don't use

Why?____

i. Keyboard tray ☐ Use ☐ No experience ☐ Don't use

Why?____

ii. Document holder ☐ Use ☐ No experience ☐ Don't use

Why?____

v. Ergonomic Mouse/trackball ☐ Use ☐ No experience ☐ Don't use

Why?____

'. Footrest ☐ Use ☐ No experience ☐ Don't use

Why?____

'i. Wrist rest ☐ Use ☐ No experience ☐ Don't use

Why?____

'ii. Headset ☐ Use ☐ No experience ☐ Don't use

Why?____

'iii. Other__________________

40. Do you have any additional comments about the furniture or computer equipment?

Source: 2009 Federal Aviation Administration.

Figure 51. Screenshot. Page 6 of workstation evaluation questionnaire.[(72)]

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