U.S. Department
of Transportation
National Highway
Traffic Safety
Administration

NHTSA

DOT HS 813 390 December 2022

Developing a Webtool for Fatigue in Emergency Medical Services Scheduling

Suggested APA Format Citation:

Devine, J. K., Hursh, S. R., & Brown, B. (2022, December). *Developing a webtool for fatigue in emergency medical services scheduling* (Report No. DOT HS 813 390). National Highway Traffic Safety Administration.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT HS 813 390		

4. Title and Subtitle	5. Report Date
Developing a Webtool for Fatigue in Emergency Medical Services Scheduling	December 2022
	6. Performing Organization Code
7. Authors	8. Performing Organization Report No.
Jaime K. Devine, PhD.; Steven R. Hursh, PhD.; Ben Brown	
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
National Association of State EMS Officials 201 Park Washington Ct Falls Church, VA 22046-4527	11. Contract or Grant No. DTNH2215C00029
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
National Highway Traffic Safety Administration 1200 New Jersey Avenue SE Washington, DC 20590	Final Report
	14. Sponsoring Agency Code NPD-320

15. Supplementary Notes

Jaime K. Devine, Steven R. Hursh, and Ben Brown are affiliated with Institutes for Behavior Resources, Inc. The contracting officer's representatives for this project were Jordan A. Blenner, PhD, JD, and Mary Byrd.

16. Abstract

On behalf of NHTSA, the National Association of State EMS Officials had the Institutes for Behavior Resources, Inc. develop a publicly and freely available website tool based on a biomathematical model of fatigue that applies to typical shift configurations/lengths among EMS personnel. The purpose of this webtool is to help agencies create and evaluate work schedules that minimize fatigue.

17. Key Words	18. Distribution Statement
webtool, biomathematical model, fatigue, work scheduling, fatigue risk management, emergency medical services	Document is available to the public from the National Transportation Library, https://rosap.ntl.bts.gov/.

19 Security Classif. (of this report)	20. Security Classif. (of this page)	21 No. of Pages	22. Price
Unclassified	Unclassified	39	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

Table of Contents

List of Figures

List of Tables

List of Acronyms

API	applications programming interface
EMS	emergency medical services
FAST	Fatigue Avoidance Scheduling Tool
FRMS	Fatigue Risk Management System
IBR	Institutes for Behavior Resources, Inc.
SAFTE	sleep, activity, fatigue, and task effectiveness

Executive Summary

This report presents a webtool developed for the National Highway Traffic Safety Administration by the National Association of State EMS Officials (NASEMSO) through its work with the Institutes for Behavior Resources, Inc. (IBR). NHTSA is concerned with addressing the impact of fatigue within the EMS community as focusing on fatigue mitigation improves post-crash care by increasing the likelihood that EMS professionals safely arrive on the scenes of crashes and are able to provide better medical care. In 2021 some 12,000 EMS agencies responded to 1,436,763 motor vehicle crashes, underlining the importance of fatigue mitigation for EMS response to crashes (NHTSA, 2022). In addition, mitigating fatigue is particularly important for emergency vehicle drivers because fatigue associated with long shift hours negatively affects driving performance (Hsiao et al., 2018). The goal of this project was to develop a freely available tool to estimate fatigue risk in emergency medical services (EMS) based on work schedules with the goal of helping EMS clinicians make decisions about the potential safety impact of shift scheduling.

This tool is designed to inform users about fatigue risk associated with certain work schedule characteristics to let them make decisions about work scheduling for EMS. The tool then provides an overall risk level and effectiveness scores for the entire shift period as well as for each time the shift repeats (i.e., the work week or shift-appropriate equivalent). The SAFTE-FAST software system, a two-step, three-process model that estimates sleep patterns around work duties and then estimates performance levels, provides the outputs for the risk levels and effectiveness scores. The intended users for this webtool are EMS clinicians who are involved in designing schedules or assigning work shifts within their agencies, EMS clinicians in management roles, and EMS clinicians with roles in safety or crash prevention for their agencies. Four members of the intended user population beta-tested the webtool. In response to feedback, programmers added longer hour shift duration options to the input toolbar, hid the additional analysis results, shortened the text for the instructions, and added a “print” function. This webtool is now freely available for anyone who wishes to predict fatigue risk during EMS work schedules.

Background

Fatigue Risk in Emergency Medical Services

Fatigue is a well-documented threat to safety in the transportation and medical industries, as seen in the number of EMS clinicians reporting poor sleep quality and mental and physical fatigue (Patterson, Suffoletto, et al., 2010; Patterson, Weaver et al., 2012; Patterson, Buysse, et al., 2015). Fatigue poses a compounded risk in emergency medical services (EMS), since EMS clinicians deliver time-sensitive emergency medical care and operate vehicles and transport patients. Similar to other first responders, fatigue-related risks to safety in EMS are further complicated by the need to provide services on a continuous basis, which means that EMS clinicians are likely to work night shifts, rotating shifts, extended shift hours, and may have limited time to recover between shifts. EMS clinicians, therefore, experience fatigue due to sleep loss as well as circadian misalignment with respect to biological processes that promote wakefulness and alertness during the day and sleep at night.

Fatigue in EMS is related to increased safety risks for patients and EMS personnel. Work schedules seen in EMS have been associated with an increased risk of fatigue-related impairment (Barger, Lockley, et al., 2009; Patterson, Weaver et al., 2012; Ramey et al., 2019). Fatigue risk management systems (FRMS) apply a variety of procedures and tools to mitigate fatigue in work schedules, including instituting schedule changes (such as having less than 24-hour scheduled work days) or recommending strategic napping to reduce potential fatigue. While there are currently no regulatory guidelines for managing fatigue risk in an EMS setting, it has been suggested that biomathematical modeling could serve as a helpful fatigue-mitigating tool in the institution of an EMS-specific FRMS (Barger, Lockley, et al., 2009; James et al., 2018).

Biomathematical Modeling of Fatigue with SAFTE-FAST

Biomathematical models consider factors related to fatigue such as sleep, time of day, and work schedule to produce an estimate of performance and alertness that can be useful when making decisions about shift scheduling (Mallis et al., 2004). The patented sleep, activity, fatigue, and task effectiveness (SAFTE) model is a computerized biomathematical model that predicts changes in performance and alertness based on the sleep/wake schedule and the body's internal clock. The model evolved from research conducted by the U.S. Army on sleep deprivation and performance at the Walter Reed Army Institute of Research (Hursh, Redmond, et al., 2004).

FAST is a computer application derived from the SAFTE model that permits the processing of individual schedules (Hursh, Balkin, et al., 2004). FAST can be used to examine specific schedules to determine vulnerabilities, i.e., whether they are problematic, and it allows entry of proposed schedules and generates graphical predictions of performance along with tables of estimated effectiveness scores for objective comparison. Optimal schedules may be selected based on average effectiveness for proposed work periods or critical events and recovery sleep strategies within the constraints of transportation delivery schedules.

SAFTE-FAST is a two-step, three-process model that estimates sleep patterns around work duties and then estimates performance levels. The three processes involved are circadian function, homeostatic sleep reservoir, and sleep inertia. SAFTE-FAST solutions include desktop and web applications and an applications programming interface for integration with third-party scheduling systems.

The model is validated for use in shift-working populations and is used across a number of safety-sensitive industries (Hursh, Raslear, et al., 2006; Hursh, Redmond, et al., 2004; Mallis et al., 2004; Roma et al., 2012). SAFTE-FAST has been calibrated for fatigue risk estimation in a range of operational industries, including the military, transportation, and healthcare (Dean et al., 2007; Hursh, Raslear, et al., 2006; Hursh, Gertler, et al., 2011; Roma et al., 2012; Schwartz et al., 2021). SAFTE-FAST was further calibrated using sleep and work data from EMS clinicians for the purposes of developing fatigue risk levels and effectiveness predictions for this project.

Estimation of Risk

Dataset

For this project, a SAFTE-FAST scenario was developed using objective sleep and work data collected from EMS technicians by the University of Pittsburgh's Department of Emergency Medicine. Clinical EMS personnel working predominantly ground-based services were recruited to participate in a pilot study to capture EMS clinician schedules commonly associated with fatigue-related impairment. Thirty-seven EMS clinicians reported the duration of their previous night's sleep and wore wrist-worn actigraphy devices to track sleep and activity over the course of one work shift. The model did not differentiate between male and female EMS clinicians.

Sleep Patterns of EMS Clinicians on Typical Duty Schedules

Participants put on the actigraph and began tracking activity on average 5 hours (±5 hours, range: 0-19 hours) before their shift began and removed the actigraph on average 4 hours (±4 hours, range: 0-12 hours) after the end of their shift. Shifts lasted between 8 and 28 hours; shift specifics are summarized in Figure 1. Day shifts were defined as shifts within the dataset starting within the range of 06:00-12:00 (average start time: 07:18 ± 01:23) and night shifts were defined as shifts starting within the range of 15:00-00:00 (average: 20:27 ± 03:09). No shifts in this dataset began between the hours of 12:01-14:59 or between 00:01-05:59.

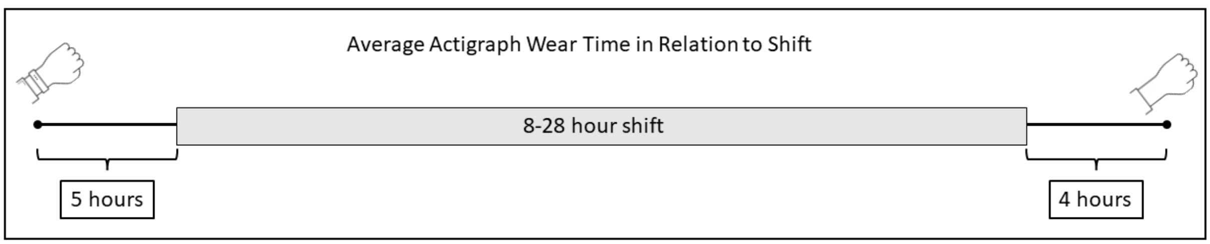

Figure 1. EMS Participant Schedules and Actigraphy Wear Times

EMS actigraphy data were analyzed to characterize attributes of work-sleep, namely, number of work-sleep events, sleep duration, and sleep onset relative to the start of the shift. The short actigraphy wear time outside of work hours limited the analysis of habitual EMS sleep behaviors. Results are summarized in Table 1. Thirty-three out of 37 participants (89%) slept between one to three times during their observed shift. The average work-sleep event was nearly three hours long (153 ± 98 minutes), but it differed by shift length. Probability of a work-sleep event occurring during a given hour of the work shift is summarized in Figure 2A. Work-sleep was more likely to occur overnight. Longer shifts were positively correlated with longer work-sleep duration ($r = 0.51$, $p \leq 0.001$), as shown in Figure 2B, as well as more work-sleep events/shift (Table 1).

Table 1. EMS Sleep Patterns Across Shifts

Shift Length	Day or Night Shift	Total Shifts	Total Work-Sleep Events	Work-Sleep Events/Shift	Average Work-Sleep Duration (minutes)	Average Time Between Shift Start and Work-Sleep (minutes)
8 hours	Day	0	--	--	--	--
	Night	7	7	1	115±57	272±108
12 hours	Day	0	--	--	--	--
	Night	5	6	1	150±67	446±93
14 hours	Day	0	--	--	--	--
	Night	2	2	1	55±35	631±93
16 hours	Day	0	--	--	--	--
	Night	4	3	1	262±58	568±60
18 hours	Day	2	1	1	96	1,055
	Night	0	--	--	--	--
24 hours	Day	14	30	2	173±118	902±196
	Night	1	1	1	76	473

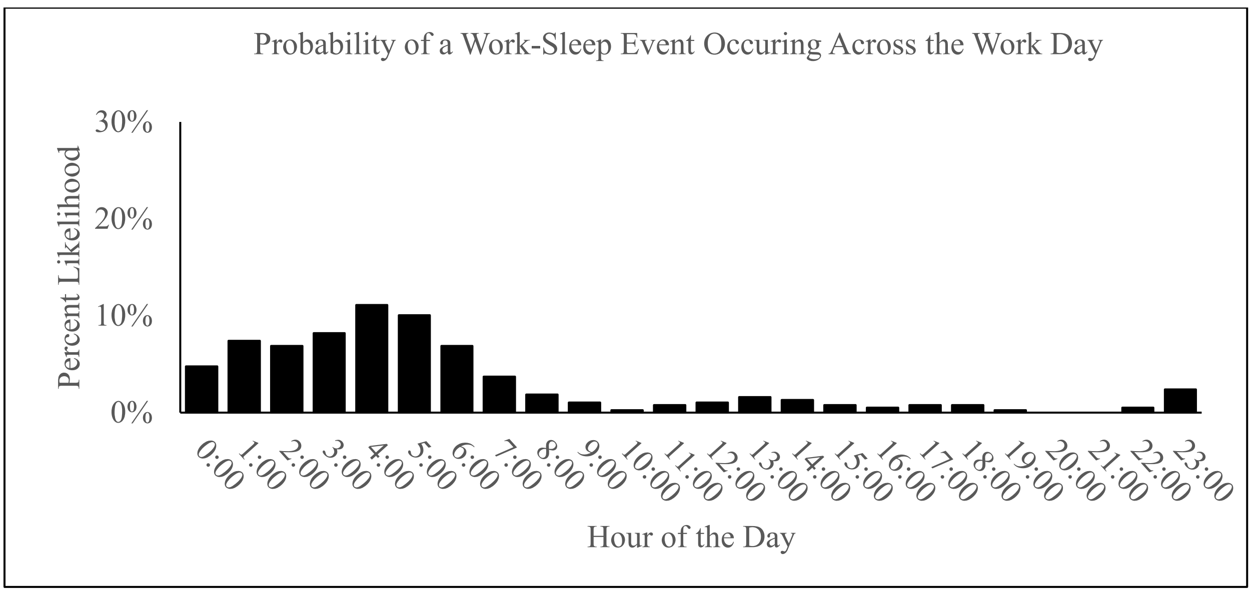

Figure 2A. Work-Sleep in Relation to Shift Hour

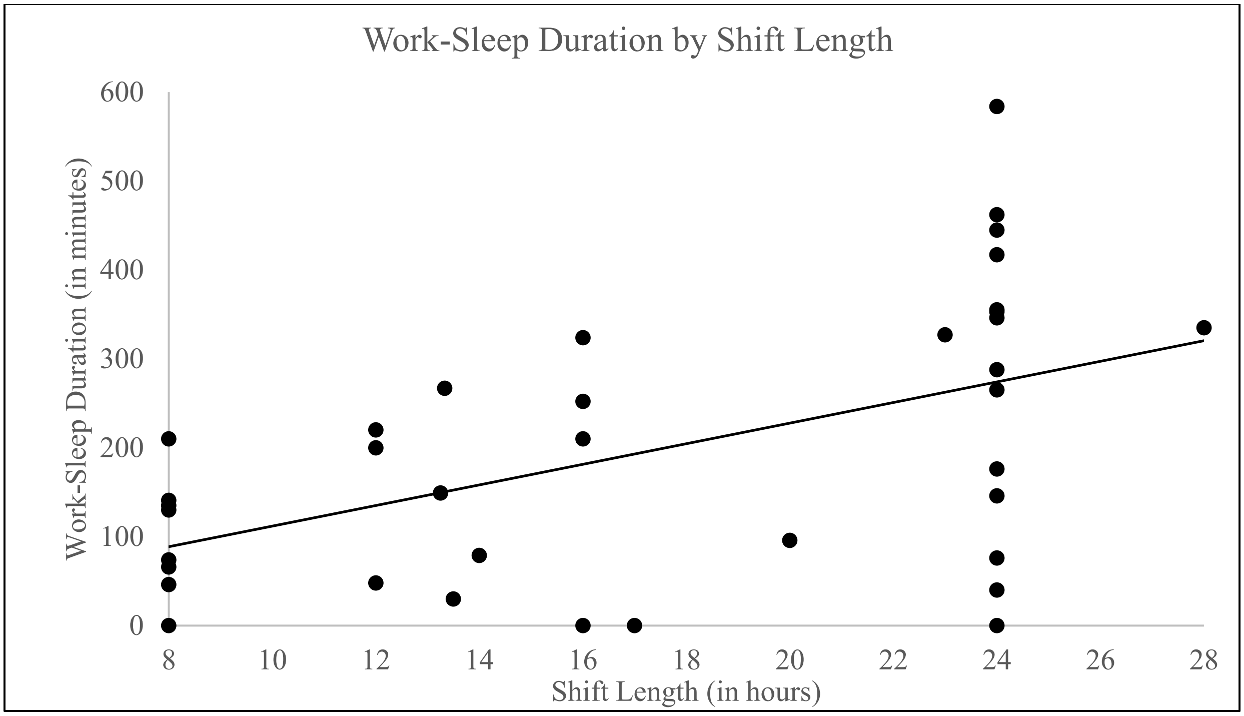

Figure 2B. Work-Sleep in Relation to Shift Hours

Modeling Sleep and Effectiveness in EMS

Effectiveness and fatigue during work schedules were modeled in SAFTE-FAST using the shift work template. Estimates of sleep were created using a combination of actigraphy-measured sleep, self-reported estimates of sleep, and the Auto-Sleep module (Roma et al., 2012), as depicted in Figure 3. Auto-Sleep is a sleep estimation algorithm within SAFTE-FAST. In the absence of objective sleep data, the Auto-Sleep module can be used to estimate timing and duration of sleep events based on work schedule and time-of-day data. A marker was used to highlight the actigraphy wear period (see Figure 3). Explicit sleep events were measured by actigraphy for an average of 22 hours per participant (1,342 ± 368 minutes; range: 613-2,039 minutes) during workdays. Auto-Sleep events were not permitted during the period of actigraphy wear. Because the study did not collect data on EMS sleep outside the study period, Auto-Sleep was added automatically prior to the work shift and after the work shift ended to avoid long periods of wakefulness, which would otherwise impact effectiveness predictions. Participants supplied a self-report of their sleep duration the night before their work shift; this information was used to modify the duration of Auto-Sleep event directly prior to the actigraphy wear period. A model of predicted effectiveness was developed for each participant. Effectiveness is an estimate of performance based on reaction time speed, wherein 100% effectiveness corresponds to a fully rested person's normal best performance. Lower percent effectiveness is related to greater fatigue risk. An effectiveness score of 77% is equivalent to 18.5 hours of continued wakefulness and is associated with a 30% increase (delay or worsening) in reaction time. An effectiveness score of 70% is equivalent to 21 hours of continued wakefulness (Hursh, Raslear, et al., 2006).

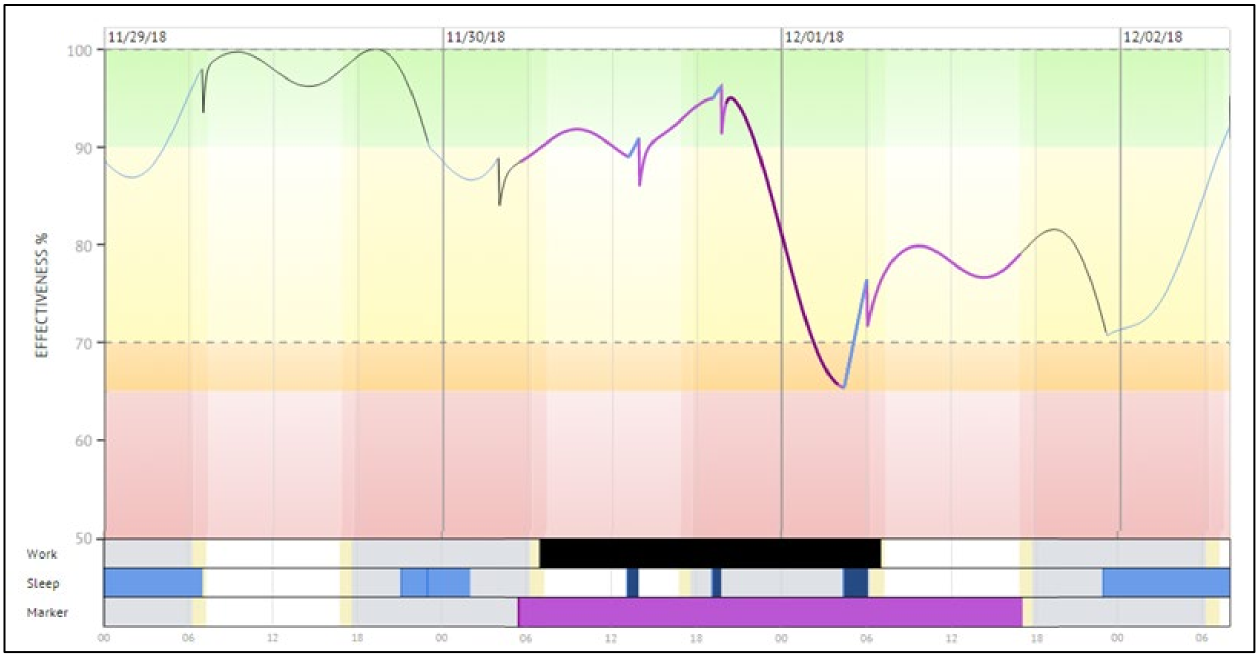

Figure 3. Model of Sleep and Work to Predict Effectiveness During EMS Work Schedules

Figure 3 above is a participant example of modeled work, sleep, and effectiveness. Effectiveness, an estimate of performance scaled as a percent of a fully rested person's normal best performance that ranges from 0-100%, is displayed as a line along the y-axis. Time in hours across multiple days is depicted on the x-axis. Predicted effectiveness during the study period is highlighted in purple. Below the effectiveness graph on the y-axis, the participant's work shift (24 hours) is indicated by the black bar on the row labeled "work." In the row labeled "sleep," AutoSleep (indicated by light blue bars) was used to estimate sleep occurring before and after the actigraphy wear period while sleep events measured by actigraphy are indicated by dark blue bars. On the bottom row, a marker (in purple) was added to delineate the actigraphy wear period.

Auto-Sleep and EMS-Specific Work-Sleep Rules

The observed work-sleep patterns described above in Table 1 were used to develop Auto-Sleep rules pertaining to work-sleep for EMS schedules, which permit napping. Observed EMS sleep patterns and expert consultation with Dr. Daniel Patterson, a sleep expert from the University of Pittsburgh, were used to develop rules for the modeling of work-sleep events (i.e., naps taken during work hours). The timing and duration of work-sleep events were determined based on shift length, shift start time, and shift type as outlined in Table 2.

Table 2. Work-Sleep Rules

			First Work-Sleep Event		Second Work-Sleep Event	
Shift Length (hours)	**Shift Start Window (hh:mm)**	**Number of Work-Sleep Events**	**Work-Sleep Duration (min)**	**Time Between Shift Start and Work-Sleep Onset (min)**	**Work-Sleep Duration (min)**	**Time Between Shift Start and Work-Sleep Onset (min)**
8	06:00-17:59	0	0	0	--	--
	18:00-05:59	1	120	300	--	--
12	06:00-17:59	0	0	0	--	--
	18:00-05:59	1	160	400	--	--
14	06:00-17:59	0	0	0	--	--
	18:00-05:59	1	160	600	--	--
16	06:00-17:59	1	120	600	--	--
	18:00-05:59	1	200	600	--	--
18	06:00-17:59	1	160	600	--	--
	18:00-05:59	1	200	600	--	--
24	06:00-17:59	2	160	600	160	1,000
	18:00-05:59	2	200	600	200	1,000

Comparison of Webtool Work-Sleep Rules Against Independent Study Findings

The work-sleep rules were compared against objective sleep data collected from EMS technicians in collaboration with the University of Pittsburgh's Department of Emergency Medicine. These data were collected separately from the dataset used to develop work-sleep rules and were part of an ongoing study to evaluate the impact of sleep health education and training on EMS clinician sleep quality and fatigue. As of April 2021, 595 volunteers from across 35 agencies provided information about their sleep during shifts across 8,233 total shifts. Due to complications related to the COVID-19 global pandemic, actigraphy data was not collected in this study and could not be compared against work-sleep rules for the webtool calibration. Work-sleep rules were analyzed against volunteers' self-report of sleep behavior. Volunteers reported the hours of sleep obtained per 24-hour period during EMS shifts between 8-72 hours in length, as shown in Figure 4.

Sleep duration units for work-sleep rules were converted from minutes to hours. Work-sleep rules for 24-hour shifts extend to 48- and 72-hour shifts as well since all sleep duration is quantified by a 24-hour period. Mean reported number of hours slept during shifts (intra-shift sleep) were then compared against number of hours as determined by work-sleep rules by shift length duration and shift start time (day or night). Reported means from 36- and 48-hour shifts and from 60- and 72-hour shifts were averaged to compare against 48-hour and 72-hour shifts, respectively. Work-sleep rules for 18-hour shifts starting at day or night or 72-hour shifts starting at night could not be compared due to a lack of self-report data for shifts of these lengths and start times. Statistical significance could not be determined due to the lack of variance in work-sleep rules, but an exploratory paired-samples t-test was conducted to evaluate differences between mean reported hours slept and work-sleep rules. Exploratory t-tests did not indicate significant differences between reported sleep and work-sleep rules for daytime shifts ($t = 0.07$, $p = 0.95$) or nighttime shifts ($t = 1.90$, $p = 0.13$), indicating that sleep duration was comparable between the two measures. Comparisons of work-sleep rules and self-report sleep hours by shift length are summarized in Figure 5 for daytime shifts (5A) and nighttime shifts (5B). Means and standard deviations from the self-report data are compared against work-sleep rules in Table 3.

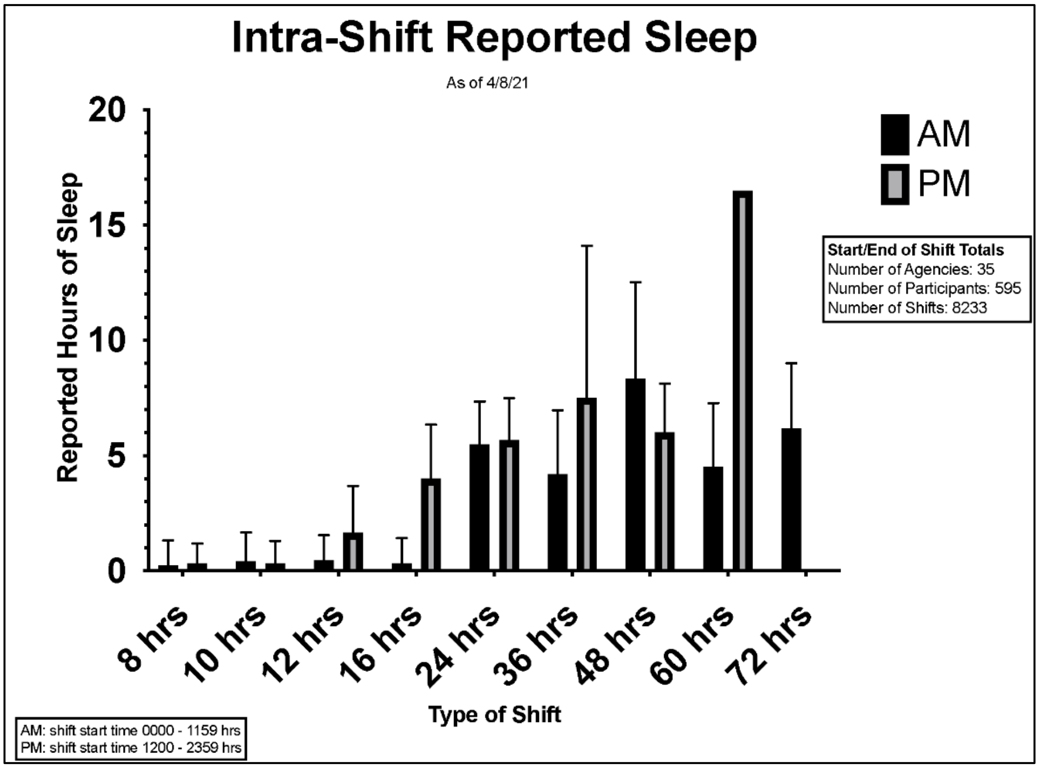

Figure 4. Intra-Shift Reported Sleep by Shift Length and Shift Start Time. Reprinted With Permissions From Patterson et al., 2021 (unpublished)

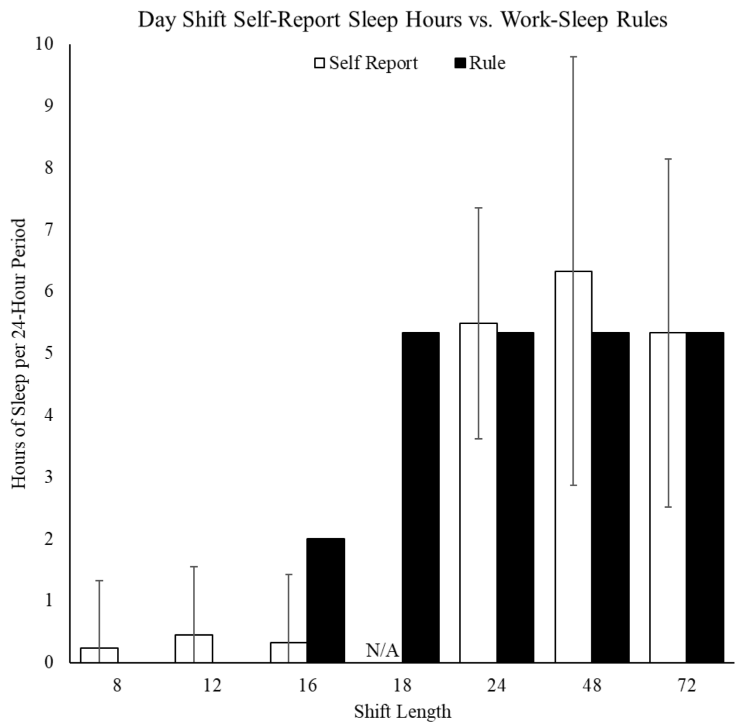

Figure 5A. Intra-Shift Self-Reported Sleep Hours Compared to Work-Sleep Rules

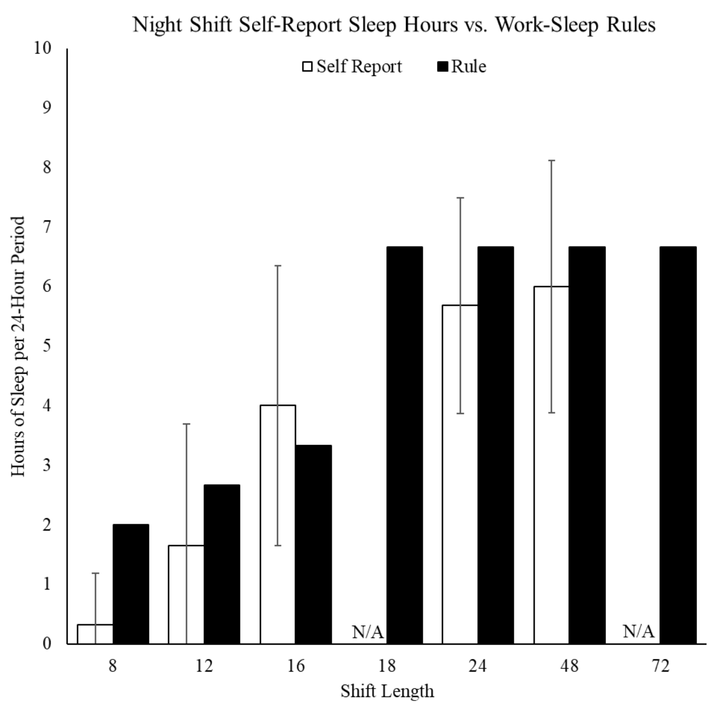

Figure 5B. Intra-Shift Self-Reported Sleep Hours Compared to Work-Sleep Rules

Table 3. Work-Sleep Rules Compared to Self-Report Sleep Means and Standard Deviations

Self-Report Sleep			**Work Sleep Rule**		
Webtool Shift Length Option (hrs)	**Shift Type**	**Reported Sleep Hours (M±SD)**	**Webtool Shift Length Option (hrs)**	**Shift Type**	**Work-Sleep Hours**
8	Day	0.2±1.1	8	Day	0
	Night	0.3±0.9		Night	2
10	Day	0.4±1.3	NA	*Work-sleep rules for 10-hour shifts were not constructed due to their infrequency for EMS clinicians*	
	Night	0.3±1.0			
12	Day	0.4±1.1	12	Day	0
	Night	1.7±2.0		Night	2.5
14	Day	NA	14	Day	0
	Night	NA		Night	2.5
16	Day	0.3±1.1	16	Day	2
	Night	4.0±2.3		Night	3.7
18	Day	NA	18	Day	2
	Night	NA		Night	3.7
24	Day	5.5±1.9	24	Day	5.3
	Night	5.7±1.8		Night	6.7
36	Day	4.2±2.8	NA	*Work-sleep rules for 36-hour shifts were not constructed due to their infrequency for EMS clinicians*	
	Night	7.5±6.6			
48	Day	8.3±4.2	48	Day	5.3
	Night	6.0±2.1		Night	6.7
60	Day	4.5±2.8	NA	*Work-sleep rules for 60-hour shifts were not constructed due to their infrequency for EMS clinicians*	
	Night	16.5			
72	Day	6.2±2.8	72	Day	5.3
	Night	NA		Night	6.7

Permutation Database for Risk Assessment

SAFTE-FAST scenarios were used to develop a database that stores all possible permutations for the shift effectiveness results based on user input from the webtool, Auto-Sleep with EMS-specific work-sleep rules (Table 2), and a set of scheduling parameters. The tool's scheduling parameters were held constant as outlined in Table 4 for all permutations. The constants were determined in consultation with project team members to reflect normal operations at a central North American location without significant seasonal circadian variation.

Table 4. Scheduling Parameter Constants

Location	Time Zone	Time of Year	Prep Time (min)	Unwind Time (min)	Assumed Awake Zone	Industry
Kansas City	Central Time	Equinox (March 20)	30	30	1600-1900	Shift work

Webtool Development

The webtool is a single-page application that captures user input and fetches results from a single-page relational database server into the same page. The webtool also features additional pages for the Frequently Asked Questions (see Appendix A) and definitions (see Appendix B). IBR designed the page to work on Internet Explorer 11 browsers since end users might have outdated capabilities.

User Interface

This section describes how users are expected to interact with the tool as they enter or select information in each required field. Based on the user's inputs, a corresponding risk level and effectiveness output are automatically generated. The final user interface is shown in Figure 6A. Changes that were made to the user interface following beta testing are discussed below and shown in Figure 6B.

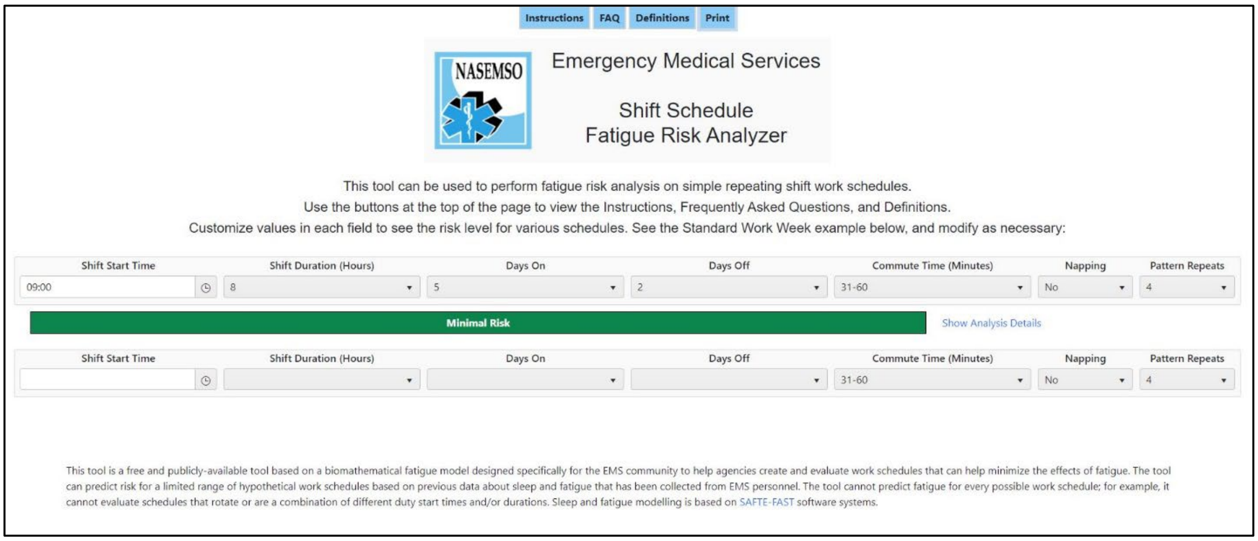

Figure 6A. Webtool User Interface

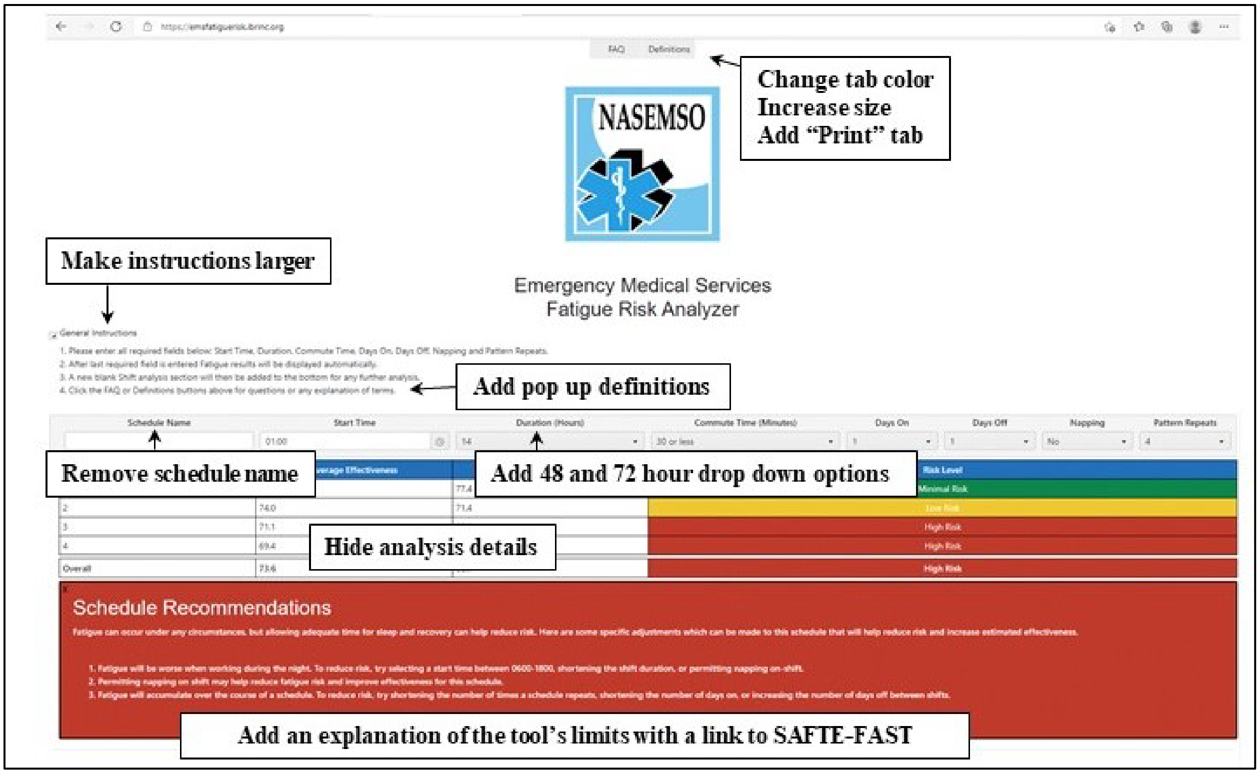

Figure 6B. Webtool User Interface

Instructions

Instructions for use are available at the top of the webtool (see Figure 6A).

Inputs

Users select information for each required field in a toolbar on the home screen of the webtool. Once all fields have been entered, a risk level with options to see analysis details will auto-populate along with another empty toolbar in case users wish to enter another schedule. As shown in Figure 6A, the top toolbar has been auto-populated with a typical work schedule to provide guidance to the user. These fields can be changed in the first toolbar. A list of input fields and their definitions are included in Table 5.

Table 5. Input Fields and Definitions[1]

Field Name	Definition	Number of Options	Input Options
Shift Start Time	Allows the user to enter a start time at which workers begin their shift. This tool cannot be used for rotating schedules or schedules that are a mixture of more than one shift start time.	23	0000-2300
Shift Duration	Allows the user to enter continuous hours spent on shift.	8	8, 12, 14, 16, 18, 24, 48, or 72 hours
Commute Time	Allows the user to enter their best estimate of the average employee commute time. Options refer to commute times for one direction (e.g., from home to work) rather than round-trip time	4	30 minutes or less 31-60 minutes 61-90 minutes 91 minutes or greater
Days On	Allows the user to enter the consecutive working days per schedule. If a user selects the 24-hour shift duration, the maximum number of consecutive days on will be limited to 3. If the user selects 48- or 72-hour long shifts, the number of consecutive days on will automatically set to 2 or 3, respectively.	7	7 - 1 days on
Days Off	Allows the user to enter the consecutive non-working days per schedule.	7	1- 7 days off
Number of Shift Repeats	Allows the user to enter the number of times that workers will be repeating the same schedule. This value will dictate the number of output rows with effectiveness calculations for each cycle.	4	1- 4 repeats
Napping Permitted	Allows the user to enter whether workers are allowed to take a nap while on shift. If you select "Yes", then the model will assume one nap between 120-160 minutes long for night shifts between 12 and 14 hours, one nap between 120-200 minutes long for any shift (day or night) between 16-18 hours long, and two naps between 160-200 minutes each for shifts equal to or longer than 24 hrs.	2	Yes No

[1] Note: The variables in this model were set prior to the current application; thus, no additional variables were added to the model for the EMS community.

Outputs

An overall risk level associated with an entered schedule will auto-populate below the input toolbar. As shown in Figure 6A, a clickable hyperlink also allows the user to expand this section to see more analysis details. When expanded, the output includes a breakdown of risk levels across all schedule repeats as risk may change over time. The breakdown also includes the average effectiveness and minimum effectiveness for a schedule repeat and the overall schedule. For schedules with a moderate or high overall risk level, a set of recommendations related to the schedule input populates below the additional analysis. These recommendations are based on the specific features of the schedule that may be contributing to fatigue. Users will see different recommendations based on the parameters they selected for each entered schedule. An explanation of output terms is summarized in Table 6.

Table 6. Output Fields and Definitions

Field Name	Definition	Number of Options	Output Options
Risk Level	Level of risk for the entire shift. Levels of risk were determined using thresholds established by the Federal Aviation Administration and Federal Rail Administration fatigue regulations.	4	Minimal Risk: Minimum effectiveness > 77. Low Risk: Minimum effectiveness is between 70-77. Moderate Risk: Minimum effectiveness is < 70 for less than 20% of the entire shift. High Risk: Minimum effectiveness is < 70 for 20% or more of the entire shift.
Average Effectiveness	The average level of effectiveness for the entire shift's work events	Range	0-100
Minimum Effectiveness	The lowest estimated effectiveness score for the entire shift's work events	Range	0-100

Frequently Asked Questions

Users can click on the tab marked "FAQ" at the top of the webtool to see a list of frequently asked questions. The FAQs will appear in a pop-up box. Users can exit the box by clicking an "X" in the upper right-hand corner, clicking the hyperlink labeled "Close" in the lower left-hand corner, or by clicking the screen outside the box. FAQs also are included in the print function described below. The FAQs are included in Appendix A.

Definitions

Users can click on the tab marked “Definitions” at the top of the webtool to see definitions of terms related to the use of the webtool. The definitions will appear in a pop-up box. Users can exit the box by clicking the hyperlink labeled “Close” in the lower left-hand corner, by clicking an “X” in the upper right-hand corner or by clicking the screen outside the box. The definitions are included in Appendix B.

Print Function

Users can click on the tab marked “Print” at the top of the webtool to either print or save a pdf version of any schedules they may have created on the webtool home page during a single visit to the website. The printout or pdf will also include the list of FAQs for the user to reference if needed.

Beta Testing

A beta test of the webtool user interface was done during the final stages of development of the webtool. The goal of the beta test was to evaluate how well the webtool worked technically and to get feedback from a sample of intended users. Persons who were considered eligible to be beta testers were EMS clinicians in an administrative or safety-related role. Five beta testers were asked to provide anonymous online feedback about how useful or intuitive they found the webtool to be. Four of the testers provided input. Questions included the following.

Approximately how many schedules did you enter into the webtool?

How useful did you find the EMS Fatigue Risk Analyzer webtool? Was it simple to understand how to enter a schedule into the webtool?

Was it simple to understand the webtool-generated output (i.e., the effectiveness and level of risk)?

How easy was it for you to modify a proposed schedule to reduce the level of risk?

Was it simple to understand the webtool-generated recommendations for how to reduce risk?

How relevant do you think the webtool is to your work/EMS work schedules?

Would you use this webtool or a similar webtool to estimate fatigue risk when designing work schedules for EMS? If so, how often do you think that you would use this webtool or a similar webtool to estimate fatigue risk when designing EMS schedules?

What did you like about the webtool?

What did you dislike about the webtool?

What do you think could be fixed to make the webtool better for estimating fatigue risk in EMS work schedules?

Do you think you would make any changes to scheduling after using this webtool?

Results

Four out of the five beta testers provided feedback about the webtool with two testers completing the feedback anonymously online and two testers providing feedback via email directly to the project manager. The testers found the webtool easy to understand, but they were impatient with the number of steps required to get results. The testers wanted more flexibility in schedule input options and less instructions or text in the results. Testers also indicated that they wanted to be able to save their results.

Changes to Webtool in Response to Tester Feedback

A picture of the webtool user interface before beta testing is compared against the webtool interface after beta testing in Figure 6B. In response to feedback, programmers added 48-hour and 72-hour shift duration options to the input toolbar, hid the additional analysis results (namely, the effectiveness scores and breakdown across schedule repeats), and shortened the text for the instructions. The "print" function was also added in response to beta testers' requests. In addition, the top toolbar was auto-populated with a typical work schedule to provide greater clarity without requiring beta testers to check the definitions page.

Website Hosting and Deployment

The website and database have been deployed by an IBR developer. The webtool is currently hosted and maintained by IBR on an AWS EC2 server, which is a simple HTTP server (nginx) that hosts a set of static files. The webtool in this format can be hosted anywhere on a simple HTTPS server. If IBR continues to host the webtool, it may be moved to a simpler AWS hosting solution (S3). If IBR continues to maintain the tool, then the webtool will either need to be hosted by IBR or an IBR developer would need to have access to the host.

Discussion

The EMS fatigue risk webtool is a freely available tool to help EMS clinicians make decisions about the potential impact of shift scheduling on safety. The tool allows users to input potential schedules based on start time, shift length, days on, days off, number of times the schedule repeats, and whether napping on shift is allowed. Users can also adjust schedules to reflect the average amount of time it takes EMS clinicians to commute to work. Users can then change these input parameters to see how changing the schedule impacts overall risk level and effectiveness scores. Users may also enter multiple potential schedules to compare risk level and effectiveness between schedules. This tool is not designed as a replacement for an effective Fatigue Risk Management System (FRMS), but it may help users visualize the relationship between shift scheduling and fatigue.

At the time of publication, the webtool is freely available for anyone who wishes to predict fatigue risk in EMS work schedules and may be used for exploratory or educational purposes. Education about fatigue and sleep health is an important component of a successful FRMS. Fatigue training has been shown to improve worker sleep quality, perceived workplace safety, feelings of fatigue, and personnel performance in shift-working populations (Barger, Runyon, et al., 2018) and has been recommended as a tool to mitigate fatigue risk in EMS operations (Patterson, Higgins, et al., 2018; Patterson & Robinson, 2019).

The webtool may also serve as an aid for EMS personnel attempting to develop an FRMS for their organization. The webtool allows users to proactively evaluate fatigue risk for proposed schedules, like how biomathematical modeling software is used for the aviation and rail industries (Huerta, 2012; Szabo, 2011). While at the time of publication, there is no requirement for fatigue risk assessment in EMS, biomathematical modeling has been suggested as a tool to improve on-the-job safety in EMS and other healthcare industries (James et al., 2018; Schwartz, Devine, Hursh, Davis, et al., 2021; Schwartz, Devine, Hursh, Mosher, et al., 2021). The EMS fatigue risk webtool uses output data from the SAFTE-FAST model to predict fatigue risk, and it may serve as prospective modeling of fatigue for agencies that would otherwise not have access to such a tool.

Conclusion

The EMS Shift Schedule Fatigue Risk Analyzer webtool models fatigue risk using output from a validated biomathematical model of fatigue (SAFTE-FAST) and data collected from EMS personnel. The webtool has undergone limited beta-testing with members of the intended audience, and the work-sleep parameters have been compared against independent study findings. The webtool serves as a freely available educational and prospective scheduling tool with the goal of mitigating fatigue risk associated with shift work in EMS.

References

14 CFR Parts 117, 119, and 121 Flightcrew Member Duty and Rest Requirements, 14 CFR Parts 117, 119, and 121 C.F.R. (2012). www.ecfr.gov/current/title-14

49 CFR Part 228 Hours of Service of Railroad Employees; Substantive Regulations for Train Employees Providing Commuter and Intercity Rail Passenger Transportation; Conforming Amendments to Recordkeeping Requirements, (2011). www.ecfr.gov/current/title-49/subtitle-B/chapter-II/part-228.5

Aemmi, S. Z., Mohammadi, E., Heidarian-Miri, H., Fereidooni-Moghadam, M., Boostani, H., & Zarea, K. (2020). The effectiveness of bright light exposure in shift-worker nurses: A systematic review and meta-analysis. *Sleep Science, 13*(2), 145-151.

Barger, L. K., Lockley, S. W., Rajaratnam, S. M., & Landrigan, C. P. (2009). Neurobehavioral, health, and safety consequences associated with shift work in safety-sensitive professions. *Current Neurology and Neuroscience Reports, 9*(2), 155-164. doi.org/10.1007/s11910-009-0024-7

Barger, L. K., Runyon, M. S., Renn, M. L., Moore, C. G., Weiss, P. M., Condle, J. P., . . . Patterson, P. D. (2018). Effect of fatigue training on safety, fatigue, and sleep in Emergency Medical Services personnel and other shift workers: A systematic review and meta-analysis. *Prehospital Emergency Care, 22*(Suppl 1), 58-68. https://doi.org/10.1080/10903127.2017.1362087

Boivin, D. B., & James, F. O. (2002). Circadian adaptation to night-shift work by judicious light and darkness exposure. *Journal of Biological Rhythms, 17*(6), 556-567. doi.org/10.1177/0748730402238238

Dean, D. A., 2nd, Fletcher, A., Hursh, S. R., & Klerman, E. B. (2007). Developing mathematical models of neurobehavioral performance for the "real world". *Journal of Biological Rhythms, 22*(3), 246-258. doi.org/10.1177/0748730407301376

Folkard, S. (2008). Do permanent night workers show circadian adjustment? A review based on the endogenous melatonin rhythm. *Chronobiology International, 25*(2), 215-224. doi.org/10.1080/07420520802106835

Gertler, J., Hursh, S., Fanzone, J., Raslear, T., & America, Q. N. (2012). *Validation of FAST model sleep estimates with actigraph measured sleep in locomotive engineers* (Report No. DOT/FRA/ORD-12/05). Federal Railroad Administration. https://railroads.dot.gov/-elibrary/validation-fast-model-sleep-estimates-actigraph-measured-sleep-locomotive-engineers

Gumenyuk, V., Roth, T., & Drake, C. L. (2012). Circadian phase, sleepiness, and light exposure assessment in night workers with and without shift work disorder. *Chronobiology International, 29*(7), 928-936. doi.org/10.3109/07420528.2012.699356

Hsiao, H., Chang, J., & Simeonov, P. (2018). Preventing emergency vehicle crashes: Status and challenges of human factors issues. *Human Factors, 60*(7), 1048–1072. doi.org/10.1177/0018720818786132

Hursh, S., Gertler, J., & Raslear, T. (2011). Measurement and estimation of sleep in railroad worker employees (RR11-02). *Research Results*.

Hursh, S. R., Balkin, T. J., Miller, J. C., & Eddy, D. R. (2004). The fatigue avoidance scheduling tool: Modeling to minimize the effects of fatigue on cognitive performance. *SAE transactions*, 111-119. doi.org/10.4271/2004-01-2151

Hursh, S. R., Raslear, T. G., Kaye, A. S., & Fanzone Jr, J. F. (2006). Validation and calibration of a fatigue assessment tool for railroad work schedules, summary report (Report No. DOT/FRA/ORD-06/21). Federal Railroad Administration. https://railroads.dot.gov/elibrary/validation-and-calibration-fatigue-assessment-tool-railroad-work-schedules-summary-report

Hursh, S. R., Redmond, D. P., Johnson, M. L., Thorne, D. R., Belenky, G., Balkin, T. J., . . . Eddy, D. R. (2004). Fatigue models for applied research in warfighting. *Aviation, Space, and Environmental Medicine, 75*(3), A44-A53. www.academia.edu/62461336/Fatigue_models_for_applied_research_in_warfighting

James, F. O., Waggoner, L. B., Weiss, P. M., Patterson, P. D., Higgins, J. S., Lang, E. S., & Van Dongen, H. P. A. (2018). Does implementation of biomathematical models mitigate fatigue and fatigue-related risks in emergency medical services operations? A systematic review. *Prehospital Emergency Care, 22* (Suppl 1), 69-80. doi.org/10.1080/10903127.2017.1384875

Mallis, M. M., Mejdal, S., Nguyen, T. T., & Dinges, D. F. (2004). Summary of the key features of seven biomathematical models of human fatigue and performance. *Aviation Space Environmental Medicine, 75*(3 Suppl), A4-14. www.ncbi.nlm.nih.gov/pubmed/15018262

National Highway Traffic Safety Administration. (2022, September). *Post-crash care: EMS response to MVC injuries* [Web page with embedded PowerPoint]. https://nemsis.org/post-crash-care-ems-response-to-mvc-injuries/

National Library of Medicine (2020, January 6 - 2021, November 19) The EMS Sleep Health Study: A randomized controlled trial. Identifer NCT04218279. https://clinicaltrials.gov/ct2/show/study/NCT04218279

Patterson, P. D., Buysse, D. J., Weaver, M. D., Doman, J. M., Moore, C. G., Suffoletto, B. P., McManigle, K. L., Callaway, C. W., & Yealy, D. M. (2015). Real-time fatigue reduction in emergency care clinicians: The SleepTrackTXT randomized trial. *American Journal of Industrial Medicine*, *58*(10), 1098-1113. doi: 10.1002/ajim.22503

Patterson, P. D., Higgins, J. S., Van Dongen, H. P. A., Buysse, D. J., Thackery, R. W., Kupas, D. F., Becker, D. S., Dean, B. E., Lindbeck, G. H., Guyette, F.X., Penner, J.H., Violanti, J.M., Lang, E.S., & Martin-Gill, C. (2018). Evidence-based guidelines for fatigue risk management in emergency medical services. *Prehospital Emergency Care*, *22*(Suppl 1), 89-101. doi: 10.1080/10903127.2017.1376137

Patterson, P. D., Mountz, K. A., Agostinelli, M. G., Weaver, M. D., Yu, Y. C., Herbert, B. M., Markosyan, M. A., Hopkins, D. R., Alameida, A. C., Maloney, J. A., III, Martin, S. E., Brassil, B. N., Martin-Gill, C., Guyette, F. X., Callaway, C. W., & Buysse, D. J. (2021). Ambulatory blood pressure monitoring among emergency medical services night shift workers. *Occup Environ Med, 78*(1), 29-35. doi.org/10.1136/oemed-2020-106459

Patterson, P. D., & Robinson, K. (2019, August). *Fatigue in emergency medical services systems* (Report No. DOT HS 812 767). National Highway Traffic Safety Administration. https://rosap.ntl.bts.gov/view/dot/42185

Patterson, P. D., Suffoletto, B. P., Kupas, D. F., Weaver, M. D., & Hostler, D. (2010). Sleep quality and fatigue among prehospital providers. *Prehospital Emergency Care, 14*(2), 187-193.

Patterson, P. D., Weaver, M. D., Frank, R. C., Warner, C. W., Martin-Gill, C., Guyette, F. X., Fairbanks, R. J., Hubble, M. W., Songer, T. J., Callaway, C. W., Kelsey, S. F., & Hostler, D. (2012). Association between poor sleep, fatigue, and safety outcomes in emergency medical services providers. *Prehospital Emergency Care*, *16*(1), 86-97. doi: 10.3109/10903127.2011.616261

Ramey, S., MacQuarrie, A., Cochrane, A., McCann, I., Johnston, C. W., & Batt, A. M. (2019).

Drowsy and dangerous? Fatigue in paramedics: an overview. *Irish Journal of Paramedicine, 4*(1). doi.org/10.32378/ijp.v4i1.175

Raslear, T. (2009). Criteria and procedures for validating biomathematical models of human performance and fatigue: Procedures for analysis of work schedules (Report No. FRA-2009-0043-0003). Federal Railroad Administration. www.regulations.gov/document/FRA-2009-0043-0003

Roma, P. G., Hursh, S. R., Mead, A. M., & Nesthus, T. E. (2012, September 1). *Flight attendant work/rest patterns, alertness, and performance assessment: Field validation of biomathematical fatigue modeling* (Accession Number ADA571645). Federal Aviation Administration. https://apps.dtic.mil/sti/citations/ADA571645

Schwartz, L. P., Devine, J. K., Hursh, S. R., Mosher, E., Schumacher, S., Boyle, L., Davis, J. E., Smith, M., & Fitzgibbons, S. C. (2021). Biomathematical modeling predicts fatigue risk in general surgery residents. *Journal of Surgical Education*, *78*(6), 2094-2101. doi.org/10.1016/j.jsurg.2021.04.007

Temple, J. L., Hostler, D., Martin-Gill, C., Moore, C. G., Weiss, P. M., Sequeira, D. J., Condle, J. P., Lang, E. S., Higgins, J. S., & Patterson, P. D. (2018). Systematic review and meta-analysis of the effects of caffeine in fatigued shift workers: Implications for emergency medical services personnel. *Prehospital Emergency Care, 22*(Suppl 1), 37-46. doi.org/10.1080/10903127.2017.1382624

Appendix A: Frequently Asked Questions (FAQs)

FAQs could be accessed via webtool site as of March 30, 2022.

1. Who is the intended user for this tool?
    a. This webtool is designed to estimate fatigue risk to emergency medical services (EMS) personnel based on their work schedules with the goal of helping EMS administrators make decisions about the potential impact of shift scheduling on safety. This webtool is intended as a tool or guide for both individual EMS clinicians as well as agencies. For best results, the user should be someone in EMS who is responsible for, or involved in, the process of making schedules for EMS employees.
2. What is Effectiveness?
    a. Effectiveness is an estimate of performance, scaled as a percent of a fully rested person's normal best performance. The person's normal best performance would equate to an effectiveness level of 100%. Effectiveness drops as a person becomes more fatigued. For example, an effectiveness score of 77% is equivalent to being awake for 18.5 hours continuously while an effectiveness score of 70% is equivalent to 21 hours of continued wakefulness (Dean et al., 2007).
3. How is level of risk computed?
    a. Level of risk for an inputted shift schedule is determined based on whether the lowest estimated effectiveness score for the entire shift falls below standard thresholds. Minimal risk is any proposed schedule where effectiveness does not drop below 77%. The tool uses 77% effectiveness as the threshold for low risk based on Federal Aviation Administration (FAA) fatigue regulations (Huerta, 2012). The threshold for moderate risk is a schedule with less than 20% of the shift below 70% effectiveness, based on fatigue regulations used by the Federal Rail Administration (FRA) (Szabo, 2011). The threshold for high risk is a proposed schedule that would result in effectiveness below 70% for more than 20% of the entire shift. Effectiveness scores and level of risk have been tested and validated in a shift-working population and reflect safety criteria from safety-sensitive industries. The criteria for level of risk described above have been established specifically for use in this webtool. This webtool does not reflect federal or State safety regulations on EMS working hours.
4. Why are the risk thresholds in the webtool based on FAA and FRA regulations?
    a. Research that helped benchmark safety regulations among transportation workers closely resemble shift activities of EMS workers as an occupation that requires multiple episodes of intense concentration and attention to detail per shift, with serious adverse consequences potentially resulting from a lapse in concentration. FAA and FRA regulations were used as a reference in the webtool because Federal or State safety regulations on EMS working hours do not currently exist (Huerta, 2012; Raslear, 2009; Szabo, 2011).

5. How is this tool specific to EMS technicians?
    a. This webtool has been informed by biomathematical modeling of EMS sleep and fatigue through the Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE) model Fatigue Avoidance Scheduling Tool (FAST) software application. Data regarding EMS sleep and fatigue has been collected in collaboration with the University of Pittsburgh Department of Emergency Medicine EMS Shift Work Project ("The EMS Sleep Health Study: A Randomized Controlled Trial," Patterson et al., 2021). Please visit www.emergencymedicine.pitt.edu/research/ems-shift-work-project for more information.
6. What is commute time? How does commute time affect level of risk?
    a. Commute time refers to the average amount of time it takes employees to travel from home to work. The webtool allows the user to select a range of average commute times; 0-30 minutes, 31-60 minutes, 61-90 minutes, or greater than 90 minutes. These options refer to one-way travel times. Commute time options cannot reflect every worker's schedule, but they can provide a more accurate estimate depending on conditions specific to the user's agency. Commute time can impact fatigue by limiting the amount of time between shifts that a worker would be able to sleep. For example, if a worker works a 12-hour shift multiple days in a row with a 30-minute one-way commute, they would have 11 hours of free time between shifts to sleep each night (24 hours - 12 hours - (30 minutes*2 trips) = 11 hours). However, if the average worker has a 90-minute, one-way commute, free time between shifts would be 8 hours (24 hours - 12 hours - (90 minutes*2 trips) = 8 hours). The amount of time off between shifts will dictate how many hours a worker would be able to sleep.
7. How does the webtool estimate the amount of time a person sleeps? How are these estimates different during work (i.e., napping) compared to free time?
    a. Prediction of sleep in this webtool is based on biological need for sleep. The average human requires 8 hours of sleep to recover from daily wakefulness. While a given individual may require more or less than 8 hours of sleep or may not take advantage of opportunities for sleep, this variability cannot reasonably be accounted for within the parameters of this tool. The webtool, therefore, estimates that a worker will sleep a full 8 hours in the absence of any time restrictions. In other words, the tool assumes that if an individual has an 8-hour period of free time, they will take advantage of that opportunity to sleep as much as possible. Time limitations due to the proposed work schedule will shorten the amount of sleep that a worker can get off-shift, but the tool will not account for individual sleep behavior. The duration of sleep during work (i.e., napping) has been determined based on EMS personnel self-report of time slept on work as well as objective data from sleep tracking wrist-worn actigraphy devices (Patterson et al., 2021). Nap duration increases with time on shift and differs between day and night shifts.

8. Why can't I enter a 24-hour shift that has more than 3 consecutive days on?
    a. The webtool is calibrated to allow for up to a 72-hour (3 consecutive days of 24-hour) shift. Shifts longer than 72 hours are not frequently utilized in EMS, which has prevented in-depth research into fatigue risk occurring during shift lengths longer than 72 hours. Therefore, only shifts up to 72 hours without a break can currently be predicted by the webtool. This webtool does not reflect Federal or State safety regulations on EMS working hours.
9. Why is level of risk greater when working at night? How can workers avoid fatigue during night shifts?
    a. The circadian rhythm is a natural, biological process that regulates sleep and activity cycles across the day in humans. Humans are biologically inclined to be active during the day and sleep at night. Even when fully rested, it is more difficult to perform at 100% effectiveness during the night. Getting a full 8 hours of sleep before working a night shift, exposure to bright light, and caffeine may help improve alertness during night shifts. The circadian rhythm takes a few days to adapt to a new schedule, so working more nights in succession, rather than working a rotating schedule, will help a worker develop a stable routine which will promote effectiveness and reduce risk (Aemmi et al., 2020; Boivin & James, 2002; Folkard, 2008; Gumenyuk, Roth, & Drake, 2012; Temple et al., 2018).
10. How can I reduce risk for a schedule?
    a. A list of recommendations for reducing risk can be found by clicking on the information icon ⓘ, or by following this link. A list of recommendations specific to schedules with moderate or high risk will populate below the overall schedule row in the tool. Fatigue risk can be most effectively reduced by getting enough sleep, either at night, during days off, or through napping.
11. What if I want to check the level of risk on a rotating shift schedule?
    a. The webtool cannot model fatigue risk for a rotating schedule. Individual shifts within a rotating schedule can be independently modeled, but users should expect that fatigue risk would be elevated with schedules that change more frequently. The webtool does not reflect any additional risk associated with frequent rotation between shifts with different start times or durations.
12. What if none of the schedule input options reflect the schedule I am trying to check?
    a. The input options for this webtool are limited to schedule parameters, which are commonly used by EMS agencies. Prediction of risk in this webtool has been informed by data collected from actual EMS personnel and comparable safety-sensitive industries. The level of risk for working schedules, which have not been observed in EMS, cannot reliably be calculated. This webtool does not reflect federal or State safety regulations on EMS working hours.

13. How can I save my results?
    a. The webtool is designed to help users understand fatigue risk based on work schedules with the goal of helping EMS administrators make decisions about the potential impact of shift scheduling on safety. This tool can serve as a guide for scheduling, but it should not be treated as objective data. The tool does not allow the user to export results as a CSV or Excel table. The user can print a copy of the webtool results or save as a PDF using the Print function.
14. Why does the tool show a breakdown of risk by number of schedule repeats? Why does the level of risk change across schedule repeats?
    a. The webtool allows a user to repeat a shift schedule up to 4 times. This allows the user to see the predicted level of risk for up to a month of shifts. (For example, the level of risk for a month of working the typical 9-5 work week can be estimated by inputting an 8-hour shift, starting at 0900, 5 days on, 2 days off, repeated 4 times). Fatigue can accumulate over the course of a schedule that does not allow for sufficient recovery time between shifts, but also, the level of risk can decrease after a worker adapts to a new schedule, like a night shift. The webtool provides a breakdown of each repeat of the schedule so that the user can identify how risk changes over time, and when during a schedule risk may be the worst.
15. Where can I find more information about fatigue in EMS?
    a. Learn more about fatigue risk in EMS by going to www.emergencymedicine.pitt.edu/research/ems-shift-work-project, www.ems.gov/projects/fatigue-in-ems.html, or https://nasemso.org/projects/fatigue-in-ems/.
16. What is IBR? What is SAFTE-FAST?
    a. IBR stands for the Institutes for Behavior Resources, Inc. IBR is an independent nonprofit research, services, and educational organization based in Baltimore, MD. IBR provides fatigue risk management research and consulting services to operational environments including: aviation, trucking, rail, military, and energy, among others. More information about IBR can be found at www.ibrinc.org. One of the tools that IBR uses to predict fatigue is SAFTE-FAST. SAFTE-FAST refers to the Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE) model Fatigue Avoidance Scheduling Tool (FAST) software. The SAFTE model is a biomathematical model that predicts cognitive performance effectiveness as a function of several interacting variables such as hours of continuous wakefulness and amount of prior sleep. The SAFTE-FAST software application is used to analyze, predict, and prevent fatigue-induced risk. The SAFTE model and SAFTE-FAST software application have been evaluated as fatigue risk management tools in a variety of operational settings (Gertler et al., 2012; Hursh, Balkin, et al., 2004; Hursh, Redmond, et al., 2004; Hursh, Raslear, et al., 2006; Roma et al., 2012; Schwartz et al., 2021). More information about SAFTE-FAST can be found at https://www.saftefast.com.

17. How is this webtool different from the SAFTE-FAST software?
    a. This webtool is a free and publicly available tool based on a biomathematical fatigue model designed specifically for the EMS community to help agencies create and evaluate work schedules that can help minimize the effects of fatigue. The webtool is limited in its ability to predict risk based on previous data about sleep and fatigue that has been collected from EMS personnel. SAFTE-FAST is a licensed software application. More information about SAFTE-FAST can be found in FAQ #16 or at www.saftefast.com.
18. Why isn't the webtool working when I access it from a Mac device using the Safari browser?
    a. The EMS fatigue risk analyzer webtool is not supported by all browsers on all platforms. If you are trying to access the webtool using a Mac or iOS device, please try Chrome, Firefox, Microsoft Edge, or Internet Explorer browsers for best results.

Appendix B: Terms and Definitions

Shift: The start time and duration for one work period.

Days on: The number of consecutive days that a given shift will be worked without a day off.

Days off: The number of consecutive days when a worker will not be working between working days.

Shift pattern: The pattern of days on and days off associated with a given shift.

Schedule: The overall pattern of shift days on and off over all repeats.

Commute time: The amount of time per direction before beginning a shift or after ending a shift that is dedicated to traveling to and from the work site.

Napping: Sleep occurring during work hours.

Effectiveness: Estimated performance, scaled as a percent of a fully rested person's normal best performance and ranges from 0-100%. The average person's normal best performance would equate to an effectiveness level of 100%. Effectiveness corresponds to the speed of a person's response to a reaction time test. Reaction time speed is highly sensitive to fatigue, and it is correlated with many other cognitive performance metrics. Lower percent effectiveness is related to greater fatigue risk. Effectiveness will deteriorate over the course of any shift, though some shift schedules will be more fatiguing than others. The effectiveness scores shown in this tool reflect the average estimated effectiveness based on the shift schedule settings entered into the tool and reflect anticipated fatigue risk to an average worker adhering to the proposed schedule. Effectiveness scores provided by this tool are estimates based on the features of the shift schedule; actual workers may perform better or worse than predicted.

Risk Level: Level of risk for an inputted shift schedule is determined based on whether the lowest estimated effectiveness score for the entire shift falls below standard thresholds. The tool uses 77% effectiveness as the lower threshold for low risk associated with fatigue based on Federal Aviation Administration (FAA) fatigue regulations. An effectiveness score of 77% is equivalent to 18.5 hours of continued wakefulness and is associated with a 30% increase (delay or worsening) in reaction time. The lower threshold for moderate risk is 70% effectiveness, based on fatigue regulations used by the Federal Rail Administration (FRA). An effectiveness score of 70% is equivalent to 21 hours of continued wakefulness. Proposed schedules that would result in predicted effectiveness scores lower than 70% for more than 20% of the entire shift are set as the thresholds for high risk due to fatigue in this tool. The tool will show the level of risk as a color, with minimal risk indicated by green, low risk indicated by yellow, moderate risk indicated by orange, and high risk indicated by red. The color code corresponds to a range of estimated effectiveness scores over the hours of one shift of the proposed schedule that has been entered into the tool.

DOT HS 813 390
December 2022

U.S. Department
of Transportation

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Traffic Safety
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15795-120922-v4