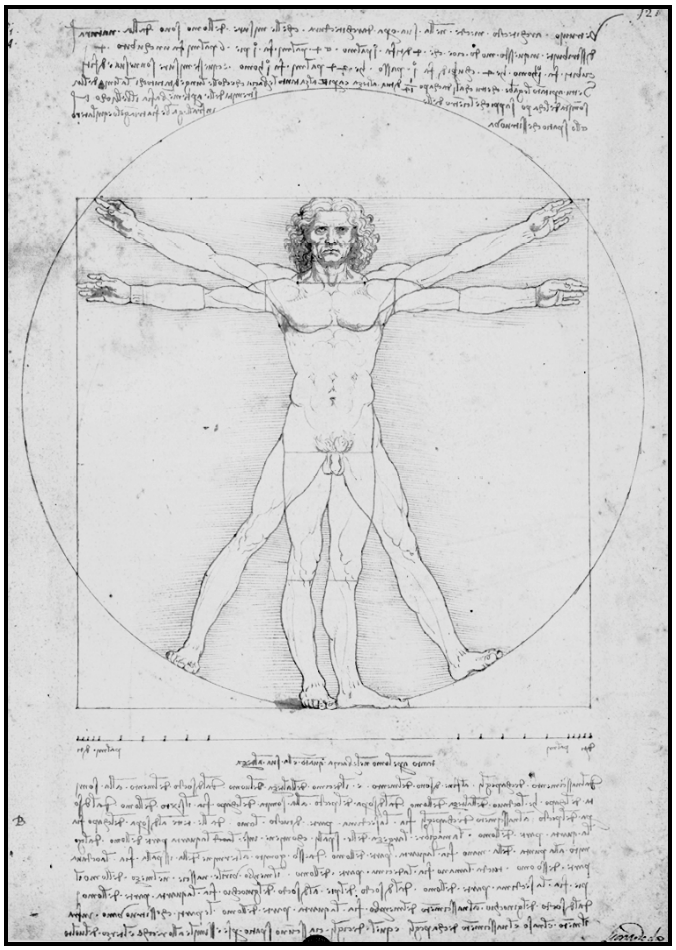
OPERATOR PERFORMANCE-ENHANCING TECHNOLOGIES TO IMPROVE SAFETY



A US DOT Safety Initiative for
Meeting the Human-Centered Systems Challenge

November 1999

OPERATOR PERFORMANCE-ENHANCING TECHNOLOGIES TO IMPROVE SAFETY

A US DOT Safety Initiative for Meeting the Human-Centered Systems Challenge

Contents

SUMMARY OF THE INITIATIVE

The program implements DOT Human Factors Coordinating Committee (HFCC) recommendations for a coordinated Departmental Human Factors Research Program to advance the human-centered systems approach for enhancing transportation safety.

Human error is a leading contributing factor in the majority of transportation crashes. This DOT initiative will develop technologies, methods and systems to mitigate human error and improve operator performance for both the noncommercial and commercial operators of transportation vehicles, equipment and systems. The goal of the program is to achieve a systematic implementation of results in transportation practice and produce a one third reduction in transportation incidents that result in fatalities, injuries, and property damage within 10 years after full implementation. The initiative will focus on the following two critical and synergistic safety components related to human factors research, technology development and implementation:

1) Operator Fatigue Management (OFM) research program for developing and implementing methods and technologies to detect fatigue and to ensure alertness; and

2) Advanced Instructional Technology (AIT) research program for developing and implementing advanced technologies to improve operator knowledge, skills, and attitudes with a special focus on recognizing and responding to imminent safety threats.

This integrated "ONEDOT" program will apply modern advances in sensing, simulation, computer communication and control systems and learning technologies to develop products designed both for commercial and non commercial operators. A two-phase, five-year partnership program is planned. The first Phase is a one year $1.5 Million program (Phase I) funded by DOT, followed by a four year $24 Million public-private partnership phase (Phase II) with 50 % of the funding from DOT. The first one-year phase of the DOT program will investigate and select methodologies and tools to address the two major human factor issues. The second four-year phase will perform operational trials and implementation of results and products selected from the first phase of research through public-private partnerships cost shared with at least $12 Million by private stakeholders from industries and the user community. Conservative estimates show that implementing products from this initiative would have a potential for an annual saving of over 10,000 lives, preventing 750,000 injuries and property and significant environmental damages.

The proposed initiative complements existing modal programs and capitalizes on the existing knowledge base and research results from the DOT modal agency programs, other Federal agencies and the private sector. The program meets the human-centered system requirements recommended by the National Science and Technology Council and DOT's Human Factors Coordinating Committee. The program will be coordinated by RSPA with oversight and guidance from DOT Human Factors Coordinating Committee.

FOCUSING ON HUMAN PERFORMANCE

Human performance-related problems play a significant role in the safety of U.S. transportation systems. Approximately 60 to 90 percent of transportation accidents involve human error and, in some transportation sectors, especially those involving night operations or irregular work schedule, fatigue may be a factor in one third of these errors. The risks (and subsequently, the costs) of motor vehicle crashes are not distributed equally. For example, per million miles traveled, the youngest drivers have the highest rate of involvement in police-reported crashes. Older motor vehicle operators have the highest rate of fatal crashes per mile driven. Mitigating human error in driving would have a direct impact to reduce the human and financial costs associated with crashes.

The impacts of human performance-related transportation crashes and incidents go well beyond fatality and injury to include major environmental disasters. No case is more reflective of the dangers of impaired human performance than the grounding of the U.S. tank ship EXXON VALDEZ in Prince William Sound, in which an estimated 1,000 miles of shoreline was affected. The cost of cleaning up the spilled oil was almost $2 billion during 1989 alone.

Awareness of the contribution of human performance and behavior in transportation is increasing at a time when new technologies, and innovative approaches to conducting operations, are being introduced to improve transportation system safety, reliability, and productivity. However, the capabilities of these technologies often are compromised because the full range of human performance issues is not considered. The use of a “human-centered” systems approach to the design, development, and implementation of technologies is necessary to ensure that the desired gains in safety, reliability, and productivity, as well as a high degree of public support for and acceptance of these systems, can be realized.

The DOT program will focus on two critical synergistic components:

- Managing operator fatigue to ensure alertness; and
- Enhancing operator knowledge skills and attitudes with a special focus on recognizing and responding to imminent safety threats.

<u>Operator Fatigue Management (OFM)</u>: “Fatigue” can result in sleepiness, drowsiness, and/or low alertness – all of which decrease the ability of the transportation equipment operators to safely function. Fatigue is significantly underestimated as a contributing factor in conventional accident reporting because it is difficult to accurately detect. Studies show that about 55 percent of the general public including commercial operators function while drowsy and about one half of Americans have difficulty sleeping. The scientific knowledge on human alertness has improved significantly in recent years but has not been applied to managing operator fatigue. This initiative will develop the knowledge base, strategies, tools and technologies to forecast and detect fatigue-compromised operators and to proactively manage fatigue to restore a safe level of operator alertness.

<u>Advanced Instructional Technology (AIT)</u>: The advanced instructional technology initiative will increase operator skills to improve performance by applying modern advances in advanced instructional technologies methodologies and techniques such as interactive and computer-based training, modeling, and simulation. AIT products will be developed with inherent adaptability to provide individual operators with tools for correcting and improving crash avoidance operational

skills. Products initially will be focused on novice, younger and older age drivers, who have been shown statistically to be more prone to crashes. Follow-on efforts will target other classes of operators.

HUMAN-CENTERED SYSTEMS CHALLENGE

Transportation accounts for roughly half of the accidental deaths in the United States and has done so for at least the past 25 years. In the last 30 years, more Americans have died in transportation crashes than in all the wars fought in American history. Transportation accidents are also the major source of work-related fatalities. Highway transportation provides the most dramatic example of the transportation-related safety challenges. Each day, millions of days of life and functionality are lost to highway crashes. The NHTSA estimates that the economic costs over the lifetime of those injured and killed in highway crashes each year is about $150 billion.

Currently, there is one highway death every 13 minutes and an average of 115 deaths each day. In 1996 alone, approximately 6.8 million motor vehicle crashes were reported to police. This represents only a portion of the 15 million highway crashes, involving 26 million vehicles, which are estimated to have occurred. These crashes killed 41,907 people; an additional 3.5 million people were injured, of which more than 430,000 were incapacitated. Many types of crashes and vehicles are involved. In addition to crashes involving passenger and light trucks, which represent the majority of deaths and injuries, 621 occupants of heavy trucks were killed and 30,000 were injured. There were 2,260 deaths involving motorcycles and 5,412 pedestrian deaths.

Fatal accidents and injuries also occur in other modes of transportation. For example, there were 1,088 fatalities in all forms of aviation in 1996 and 359 serious injuries in general aviation alone. In 1996, there were 1,045 rail-related fatalities and more than 12,000 injuries (including highway-rail grade crossing accidents and railroad operations). There were 50 fatalities involving waterborne transport and 709 fatalities in recreational boating, for a total of 759 maritime-related fatalities in 1996.

The "human-centered systems" approach respects human capabilities and limitations and recognizes that systems can be only as effective as the humans who must use them. The goal is to design transportation systems that facilitate task completion, so that people can focus on task performance and not be distracted by characteristics of the system. Properly employed, “human-centered” systems can dramatically improve transportation safety, reliability, and productivity. Also, public acceptance of new systems depends on their ease of use, their simplicity of design, and the quality of their human-system interface. Success comes from putting people first and recognizing that the human contribution is a critical part of technology and system development, implementation, and operation.

Human performance and behavior, like most crosscutting transportation research topics, is interdisciplinary and complex. By working together as "ONE DOT," the agencies of the U.S. Department of Transportation (USDOT) employ synergy and economies of scale to answer the nation's most pressing transportation safety problems. The USDOT has adopted a "human-centered" approach to ensure that the full potential of transportation systems can be realized.

PROGRAM OPPORTUNITIES

The two complementing components of the program will be designed to focus on the goal of achieving a one third reduction in transportation fatalities, injuries, and property damage by 2020.

Operator Fatigue Management (OFM) Program

Plans for the program will focus on improving transportation safety by developing tools and technologies to forecast and detect compromised operators and implementing these tools and technologies to proactively maintain and/or restore operator alertness. The scientific knowledge of human fatigue and alertness has improved greatly in recent years but has not been applied efficiently and systematically to manage fatigue in transportation systems. A "human-centered approach" that considers the task being performed, the operational environment, and worker characteristics is proposed to deliver fatigue management solutions to transportation system operators and managers. The OFM Program will compile and synthesize what is known about human alertness and develop a comprehensive fatigue management reference resource to enable transportation operators, managers, and schedulers to manage fatigue proactively and to apply fatigue and alertness knowledge to practice. In addition, emerging technologies on fatigue management and analytical systems to forecast, detect and mediate decrements in alertness will be evaluated, selected and implemented.

An implementation plan will be designed to achieve a one third reduction of fatigue-related transportation injuries, fatalities, and property and environmental damage or loss within 10 years of applying OFM Program findings, products, practices, and systems in conjunction with implementation of the Advanced Instructional Technologies (AIT) program. These efforts require cross-modal research and technology applications to complement existing modal programs. A cross-modal team will execute the OFM Program and facilitate the transfer of research results, technical products, and lessons learned. The OFM Program will promote partnerships with state and federal agencies, the private sector, and academia that are pursuing, or interested in, developing fatigue management products.

In Phase I of the OFM Program, the USDOT will convene a Forum of national experts on Fatigue Management to ascertain the status of fatigue management approaches, and analytical systems to forecast, detect and mediate decrements in alertness. The consensus findings on proven safe and effective approaches will be analyzed and compiled into the 1st Edition of the Fatigue Management Reference (FMR). Other promising approaches will undergo further testing and validation.

In Phase II, the USDOT will initiate partnership research on promising fatigue management approaches and begin assessment of Fatigue Management Analytical Systems (FMAS) and FMAS based technologies. A prototype FMAS will be developed, tested, and demonstrated in the field and evaluated for its mode-specific capabilities. Those fatigue management technologies and approaches that proved successful will be implemented. The results will be incorporated into the 2nd Edition of the FMR.

Advanced Instructional Technologies (AIT) Program

Well-trained operators can overcome common human errors, such as inattention, operating inappropriately for conditions, and impairment. The AIT Program will create new uses of interactive, computer-based systems and simulation technologies for training applications. Continuing improvements in the capabilities of relatively inexpensive AIT systems are expected to make them more cost-effective and thus, more readily available for self-paced and instructor-based training. AIT systems also are inherently adaptable making them suitable for training novice operators and operators who face temporary, or permanent, physical or cognitive challenges. Because training can be tailored to address individual needs and the delivery system can adapt, the opportunities for training and maintaining the skills of novice and experienced operators are numerous.

The AIT Program will develop educational approaches to engage and teach appropriate attitudes, reactive skills, and preventative behaviors. It will evaluate and demonstrate the effectiveness of information technologies in preparing operators to identify, avoid, and manage potentially hazardous situations such as imminent crashes. Continuing improvements in the capabilities of relatively inexpensive AIT systems will make them cost-effective for training commercial and non-commercial motor vehicle operators.

The program will accomplish the strategic goal of reducing the rate of vehicle crashes, deaths, injuries, and property damage among operators by one third within 10 years of full implementation. This is to be achieved in conjunction with the OFM program through multi-agency planning and management teams, and through cost-sharing partnerships with industry and other non-federal organizations. Initially the program will develop, demonstrate and validate AIT systems to improve the operational skills of novice, younger and older age drivers, who have been shown statistically to be more prone to crashes. However, the research results, technologies, and procedures will be applicable to other classes of operators.

In Phase I, USDOT will plan and initiate assessments of current operator requirements, training programs and technologies and begin to establish public-private partnerships to direct and execute further technology development and testing.

In Phase II, the AIT partnership will closely involve stakeholders to develop performance guidelines, system functional requirements and specifications, and training procedures for novice operators. The partnership(s) will conduct field operational tests and will evaluate the most promising technologies and systems configurations and will facilitate their deployment and operation. USDOT will ensure that independent evaluations of the field test experiments are conducted and that objective cost-benefit assessments are performed.

PROGRAM PLANS

OPERATOR FATIGUE MANAGEMENT

Transportation operators working in occupational environments requiring shiftwork rotations from daytime to nighttime schedules, extension of work hours beyond 8 hours per day, and high physical and/or mental stress experience fatigue and decrements in alertness that adversely affect performance and safety. Studies show that the overwhelming majority of shift workers experience sleepiness in connection with night shift work (Akerstedt and Landstrom, 1996), and the pattern is consistent across all modes of shift work (Anderson, 1970; Gold et al. 1992; Menzel, 1962; Paley and Tepas, 1994; Thiis-Evensen, 1957; Verhaegen et al., 1981; Wyatt and Mariott, 1953; Akerstedt and Torsvall, 1978.) In one costly and highly publicized incident, the NTSB attributed the Exxon Valdez grounding to fatigue due to reduced sleep and extended work hours (NTSB, 1990).

With respect to transportation interests, while an apparently small percentage of trucking mishaps (crashes) have been attributed to operator fatigue, the National Transportation Safety Board (NTSB) feels that many of the US truck accidents are fatigue related. Research studies based on analyses of crash cases often consider driver loss-of-alertness to be a factor in more crashes than the national statistics indicate. A NTSB study (NTSB, 1990), completed in 1990, drew data from 182 fatal-to-the-driver large truck and bus crashes in 8 States. Driver fatigue was implicated as a causal factor in 31 percent of these crashes. While fatal-to-the-driver crashes are a small sub-sample of all truck crashes, fatigue is 30 times more prevalent in these crashes than in general truck crashes. The relationship of other types of truck crashes to fatigue varies widely. A recent Coast Guard analysis of 179 commercial marine casualties showed that fatigue contributed to 16% of vessel casualties (e.g., groundings) and 33% of personnel injuries (McCallum, Raby, Rothblum, 1996).

Although fatigue has been implicated in numerous transportation accidents and crashes, the NTSB also indicated that fatigue, as a causal agent, is grossly underestimated in conventional accident reports (Akerstedt and Landstrom, 1996). The gross underestimation of the role of fatigue in accidents is probably due to the difficulty of accurately detecting evidence of fatigue as a factor in an accident or crash. Therefore, it is likely that fatigue, and its associated deleterious effect on operator performance, is a bigger contributor to incidents, accidents, and fatalities than heretofore realized.

Furthermore, The New England Journal of Medicine (NEJM, 1997) has stated that drowsiness is a pervasive problem with all drivers. They cite polls that have found that up to 56 percent of the general public drives while drowsy – with a cost to society of more than $12 billion a year from related crashes. Other researchers say that nearly one-half of Americans (which includes transportation operators in all modalities) have difficulty sleeping (National Center on Sleep Disorders Research, 1993). The role of fatigue in crashes is difficult to determine based on crash investigations, but we know that alertness plays a role in all human performance. Improving alertness will improve operator performance and transportation safety across the board.

Research Approach

The term "fatigue" is shorthand for the various complex states of sleepiness, drowsiness, and low-alertness. One definition of "fatigue" is the decreased capability of doing physical or mental work, or the subjective state in which one can no longer perform a task effectively. But, while we cannot measure "fatigue" per se, we can measure indirect indicators like how alert people are, how they perform tasks that require sustained attention, hand-eye coordination, and their responses to changes in their environment. Scientists also can measure changes in how the body functions – changes in brain wave patterns, changes in eyelid position, changes in head position – that reflect how alert or how drowsy a person is. Research in this area continues. There is also an existing and still growing, large body of information and continuing research on the effectiveness and safety of fatigue management (Thomas and Raslear, 1997).

Our present technological capability to collect, compile, interpret, and apply this information provides us the scientific knowledge to effectively reduce the incidence and severity of fatigue and decreased alertness related accidents and casualties in transportation systems. The information enables us to forecast and detect periods of reduced alertness, develop countermeasures to enhance and maintain alertness at appropriate levels, and proactively intervene to restore required levels of alertness.

At this time, the level of science and technology knowledge make it possible to synthesize all that is known about human alertness and to develop a comprehensive reference of fatigue management and an analytical system, similar to medical diagnostic analytical systems. It is intended for transportation operators, managers, and schedulers to use to manage fatigue effectively. Such a system would enable application of fatigue and alertness research results to practice. There is also the potential for such a system to provide real-time monitoring of operators.

With respect to fatigue countermeasures, research has produced numerous recommendations and strategies to prevent degradation in alertness and performance. These countermeasures range from simple recommendations (e.g., napping) to more science-based product applications such as using pharmacological interventions (e.g., stimulants and sleep aids). Usually, the selection and implementation of countermeasures is left up to the individual. If countermeasures are implemented improperly, the use of such countermeasures may result in a false sense of security and complacency, and may compromise safety and performance. A comprehensive reference comprised of up-to-date knowledge of fatigue countermeasures will facilitate safe, effective fatigue management for transportation operators. Electronic access can make the knowledge readily available and a real-time analytical system could be the delivery mechanism.

DOT research will utilize current advances and develop technologies, methods and tools for OFM. The OFM Program will identify methods, technologies and tools to reliably detect the onset of fatigue and reduced alertness in DOT operators in all modalities and identify safe and effective countermeasures to fatigue that can enhance and maintain alertness at appropriate levels. Based on this work, the OFM Program will develop technology-based methodologies and tools for OFM by utilizing existing knowledge base and applying results to develop methods, tools and systems for monitoring and mitigating fatigue. The OFM program development and implementation will be accomplished through the following major steps:

- Developing technology capable of forecasting and detecting periods of reduced alertness for fatigue countermeasures to enhance and maintain alertness at appropriate levels,

- Assessing the effectiveness of fatigue management methods and technologies within the context of each transportation mode and developing a reference resource for managers and operators to select and implement effective fatigue management,
- Demonstrating, and validating a deployable technology based system to detect and forecast loss of alertness and to provide mode specific fatigue management recommendations, and
- Focusing initial OFM research on DOT transportation modalities and their key problems by Identifying and ranking potential solutions to operator fatigue and reduced alertness situations and selecting situations where training could be an effective (and cost-effective) solution.

The research program will collect data and conduct research to identify and better understand the maintenance and restoration of operator alertness in the following areas:

- Monitoring of operator alertness,
- Effectiveness of preventive fatigue countermeasures by transportation modality, and
- Effectiveness of operational fatigue countermeasures by transportation modality.

The OFM Program will focus on transportation operators. However, many of the research results, technologies, and procedures will be applicable to the performance of other classes of operators and modes.

In particular the emphases of specific applications will include interaction of circadian processes, sleep loss, and work/activity schedules and prediction of operator performance decrements. The effects of operator education on factors impacting fatigue will also be addressed. The OFM Program will develop analytically-based technology systems to aid managers in selection and implementation of fatigue management methods. The sources for data on OFM Research technology effectiveness will come from various transportation modes, military operations, and other fields. The OFM Program will also employ simulator technologies for research data collection and validation.

The program will apply analytically based systems that are currently available to OFM. For example, computer models exist that can forecast fluctuations in alertness as a function of previous sleep, time since last sleep (period of wakefulness), and circadian rhythms. The deficiency in these models is that they do not account for the effects of work-related or environmental factors or the restorative benefit of countermeasures nor do they accurately predict performance measures. Another element is the ongoing research in fatigue is validating, various tools that can detect the onset of reduced alertness.

An approach for measuring accomplishments by implementing the program objectives will be developed as follows:

Reduce the economic impact from fatigue-related transportation injuries, fatalities, and property and environmental damage or loss by one third within 10 years of full implementation.

Success in achieving this goal will be measured by steps implemented and direct measures of the impact resulting from its implementation in terms of reducing incidents of fatalities, injuries and associated losses each year, compared with the previous year.

Provide outreach and education and training to enhance operator self-awareness and knowledge of fatigue countermeasures, strategies, tools, and technologies to forecast and detect compromised operators and to maintain or restore operator alertness in a proactive manner.

Progress will be measured by improvements in operators' self-awareness and knowledge on fatigue and on the extent of operator familiarity with available options and countermeasures to reduce fatigue.

Improve effectiveness of analytical and technology based systems to detect and forecast loss of alertness and to provide mode specific countermeasure recommendations.

The impact of applying results of field tests and evaluations of fatigue/alertness will be measured in terms of the number and extent of fatigue countermeasures implemented in practice

Project Planning and Partnerships

The OFM is a cross-modal research and technology initiative that complements existing modal programs and develops a synergistic program that can produce results for use by each of the modes. A cross-modal team will be established to execute the OFM initiative and facilitate the transfer of research results, technical products and lessons learned to the individual modes.

DOT will strongly pursue partnerships with industries, states and other government organizations, associations, academic institutions, and other parties interested in the development and deployment of the OFM Initiative systems and products. These partnership organizations would develop performance guidelines, specifications, and procedures, and would test and evaluate the most promising findings, practices, products, and systems to facilitate their deployment and operation. This Partnership will develop and adapt research systems and procedures for reducing operator errors and enhancing operator safety skills, cognitive abilities, and behaviors.

OFM Phase I

Fatigue Management Reference

A national "experts forum" and demonstration event will be organized to bring together technical experts and practitioners in fatigue management, developers of emerging technologies, and vendors to present their views and reach a consensus on priority areas for the program at the conference. Based on the current state of fatigue knowledge and technologies, research required to advance fatigue management will be identified. Those approaches and technologies that prove successful will be complied into a Fatigue Management Reference (FMR) resource of best practices on effective fatigue management.

Phase 1 of the OFM Program will produce the following products and results:

1) consensus findings from national experts and demonstrations on Fatigue Management approaches,
2) compilation and release of the 1st edition of the FMR guidelines, and
3) initial assessment of "promising" Fatigue Management approaches.

The estimated funding for the first year of the Program is $1,000,000.

Countermeasures Assessment and Fatigue Management Guidelines The FMR compendium will specify ranking of fatigue countermeasures for an operator's sleep and work schedule. This reference will be tailored to the attributes of each transportation modality. It will focus on both preventive and operational fatigue countermeasures and bring together the best practices for their use in all transportation modalities. The assessment of countermeasures will provide guidelines and ensure that only safe, effective ones are included for developing guidelines.

Baseline Assessment of Fatigue Countermeasures and Indirect Fatigue Indicators The safety and effectiveness of two classes of fatigue countermeasures, preventive and operational, will be assessed. The assessment of indirect fatigue indicators will provide input to the development of the FMAS.

Assess Preventive Fatigue Countermeasures Preventive countermeasures for fatigue and the subsequent loss of alertness are those interventions that may be employed in the work environment. The countermeasures will be ranked in effectiveness.

An overview list of preventive countermeasures is presented in Table 1.

Table 1. Preliminary Summary of Planned Preventive Countermeasures

Class	Countermeasure
Behavioral	
	Trip planning
	Hours of service
Biological/biochemical	
	Adequate sleep
	Napping
	Phased circadian rhythms
	Melatonin
Technological	
Environmental	Bright light/specific wavelength of light
Detection for preventive action	Fitness-for duty measures
	Psychomotor vigilance testing
	Performance test batteries
Math models/algorithms	Two-Process Model
	Three-Process Model
	Workload model

An overview list of operational countermeasures is presented in Table 2.

Table 2. Preliminary Summary of Planned Operational Countermeasures

Class	**Countermeasure**
Behavioral	
	Exercise
Biological/biochemical	
	Napping
	Anchor Sleep
	Diet
	Caffeine
	Tobacco
	Amphetamines and other stimulants
	Benzodiazepines and other sedatives
Technological	
Environmental	Bright light/specific wavelength of light
	Portable light behind knee
	Sleeping quarters design
	Sound
	Odor
	Lowered temperature
	Ventilation
Detection for alerting stimulus	Psychomotor vigilance testing
	Activity-based alertness maintenance monitoring
	Vehicle-based operational alertness/ vigilance monitoring
	Vehicle-based performance measures
Math models/algorithms	Algorithms for operator alertness
	Real-time analytical systems
Interface and system design	Improved displays and enunciators

The Program will assess the countermeasures focusing on their validity and usability in an operational environment to aid the potentially fatigue-comprised operator and to maintain an adequate level of alertness. The countermeasures will be ranked in effectiveness.

The results will provide quantitative data on operational countermeasures and deficiencies which impact operator performance and ranked assessment of data and priorities for implementation.

Assess Fatigue Detection and Monitoring Technologies

Fatigue can be measured via indirect indicators such as how alert people are, i.e., how well they perform tasks that require sustained attention, their hand-eye coordination, and their responses to changes in their environment. Scientists also can measure changes in body functions – changes in brain wave patterns, changes in eyelid position, changes in head position – that reflect how alert or how drowsy a person is.

The existing fatigue detection and monitoring technologies will be reviewed and their capabilities to detect fatigue and loss of operator alertness and to predict of performance decrements will be validated. The products of this review will make important contributions to the development of the FMAS.

The results will provide table(s) of monitoring approaches including methods/algorithms for predictive performance, quantified planning consequences and assessments o fatigue data and priorities in practice

Fatigue Management Applications and System Requirements

Inputs will be developed for OFM system requirements for the primary Fatigue Management Reference (FMR) and the subsequent evolutionary Fatigue Management Analytical System (FMAS). That is, the available and relevant specifications for math model/algorithm-based operator alertness detection and forecasting systems will be documented and assessed for how well the current specifications will meet the system requirements.

The results will provide system requirements for the Fatigue Management for Transportation Operators Program. System requirements for the Fatigue Management Reference (FMR) resource application will be designed to address operator fatigue within each transportation modality. The system requirements derived from the FMR compendium for the Fatigue Management Analytical System (FMAS) will be upgraded to serve operator monitoring and countermeasure management advice applied to changing operational conditions.

Fatigue Awareness and Education Programs

Information about the physiological mechanisms that underlie fatigue, the misconceptions about fatigue, and specific recommendations for countermeasures based on the current findings have great value. The state of fatigue education of operators in the different transportation modalities will be summarized, identifying (and assessing) the education and training tools being used.

OFM Phase II

Fatigue Management - Analytical Systems and Technology Development:

Lessons learned from Phase I and the development of the 1st edition of the FMR, as well as promising fatigue management approaches that were proven effective, will be compiled into the 2nd edition of the FMR. The document will be prescriptive for predicting alertness levels. To more accurately forecast and predict levels of alertness, the fatigue management system must consider individual characteristics, operational demands, and fatigue-inducing factors in a dynamic analytic fashion. The OFM program will identify, develop, field test, and demonstrate Fatigue Management Analytical Systems (FMAS) that show promise. Only the most promising approaches and technologies will undergo further research and testing. A prototype FMAS that detects and forecasts loss of alertness and provides mode-specific fatigue management recommendations will be demonstrated in an operational setting.

In the Program's follow on years, the OFM Program will focus on performing the following tasks:

1) test and demonstrate FMAS,
2) validate "promising" Fatigue Management Approaches, and
3) 3) deploy 2nd edition of the FMR.

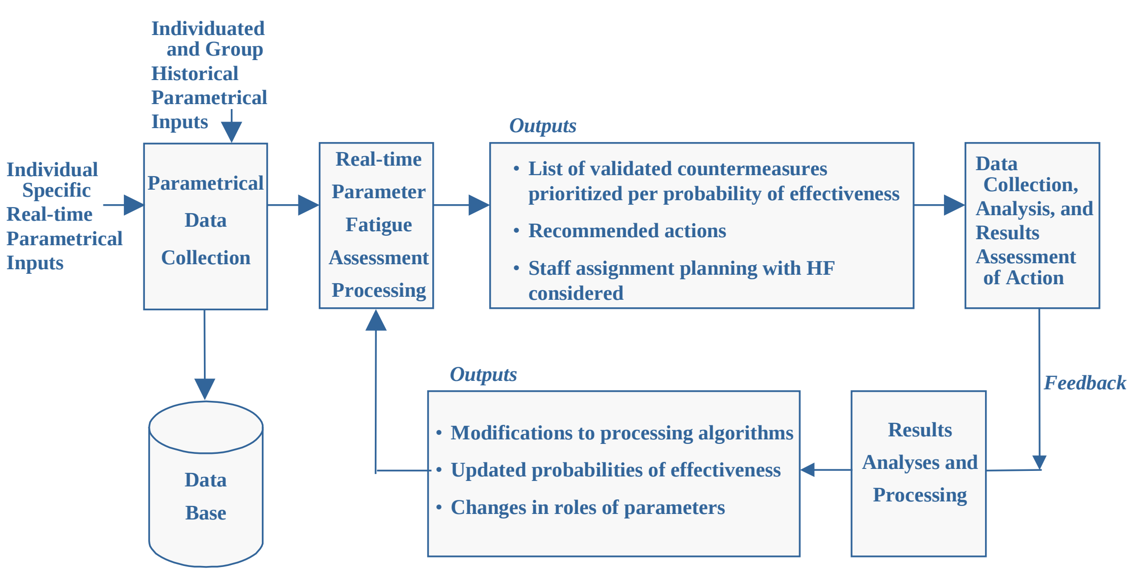
The estimated funding for the second phase of the Program is $5,000,000.

Fatigue Management Analytical System (FMAS) Development

The FMAS will accept, in real-time, parametrical inputs specific to individuals and parametrical inputs about the current conditions relevant to fatigue-related factors. It will also accept historical parametrical inputs specific to individuals and groups. These inputs are collected for processing and are also inputs to the System's Database.

A potential architecture for the FMAS development is depicted in Figure 1.

Figure 1. Fatigue Countermeasure Expert System



The real-time system processes parameter inputs and generates outputs for fatigue countermeasure selection, action recommendations, and staff assignment planing. These outputs go to users and also to analysis and assessment processes to provide feedback in the form of outputs to modify the processing of parametrical inputs, effectiveness tables, and changes in parameters. The feedback is essential for enhancing and updating (“training”) FMAS’s capabilities and performance.

Prototype FMAS

A prototype analytical system will be developed that will enable users to forecast and detect periods of fatigue and reduced alertness, identify safe, effective countermeasures, and proactively intervene to restore required levels of alertness for transportation operators, managers, and schedulers.

Test and Validation

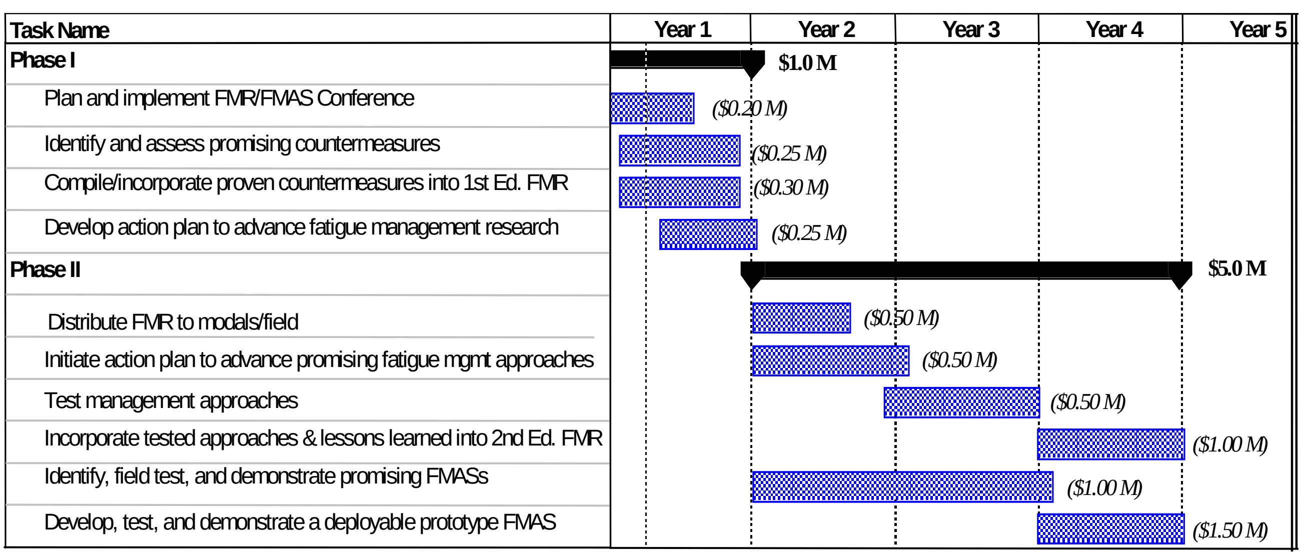
Collaborative partners will be identified and selected following the acquisition and implementation of the OFM systems. The data collected from the tests will be assessed for the effectiveness for deploying fatigue management systems. The actual and potential costs and benefits of “tested” FMR and FMAS will be documented and outreach mechanisms will be established to disseminate OFM Program results.

Summary of Budget and Schedule:

The estimated budget requirement for the proposed two phased OFM Research Program is $1,000,000 for the Phase I and $5,000,000 for Phase II as shown in Figure 2.

Figure 2. OFM Program Budget and Schedule

Note: Federal budget dollars only



ADVANCED INSTRUCTIONAL TECHNOLOGY

Poor operator performance is a major factor in transportation crashes. DOT estimates that 60 to 90 percent of transportation incidents involve human errors. These errors include inattention, operating inappropriately for conditions, and impairment (e.g., alcohol, drugs, and fatigue). An added dimension to this problem is the increased use of various advanced engineering and systems technologies which are not always fully understood by the operators.

The transportation industry is a significant part of the American economy contributing 11.1% of the G.D.P in 1996. Transportation employs as many as one out of every seven workers in the United States. For example, in 1996, there were more than 9 million truck drivers transporting cargo interstate, 8 million of whom held Commercial Driver' Licenses (CDL). In 1998, there were 147,000 people employed as operators of Class 1 Line haul railroads. The FAA reported 615,000 pilots with active certificates and 541,000 people holding non-pilot certificates in 1997. There are a large number of operators who can benefit from AIT.

A skilled operator must be educated and trained to be safe. Safe operators take personal responsibility for performing carefully as well as interacting properly with others. One approach to the goal of increasing the number of safe operators is to develop and implement a set of procedures that provides a lifetime of learning opportunities. Such an initiative will require the development of a variety of educational and informational tools and procedures, and will use many different types of technologies.

Certain transport modes have minimum age requirements, and a few also have maximum age ceilings. Operators are novices when they are learning to perform a job, a task, to operate new equipment, or to understand new or changed information or procedures. Experienced operators must refresh their knowledge and practice to maintain their performance. Complex skills must be practiced, and will naturally degrade if they are not practiced. Many commercial operations use a variety of procedures to refresh and enhance operators' knowledge and skills. AIT systems will produce technologies to facilitate refresher training and skilled maintenance. Finally, training procedures and programs that can develop operator skills also can be used to influence the design of those operational systems and equipment.

One major component of such an effort would draw from the many new advanced instructional technologies available for transportation operator education, training, and evaluation. Among the most promising technologies are interactive, computer-based systems. These systems range from relatively simple and inexpensive desk-top computers and interactive TV to elaborate full mission simulators, many of which employ motion. The commercial transportation industry and the military currently use a variety of AIT systems and procedures for operator training. The AIT initiative will enhance and create new uses of these systems. In addition, continuing improvements in the capabilities of relatively inexpensive AIT systems are expected to make them more cost-effective and thus more readily available for training.

Research Approach

The scope of the AIT Program includes the research, development, testing and evaluation needed for deploying advanced instructional training technologies and related procedures that could help reduce human error. The specific human performance and behavior problems that this Program will address depend strongly on the particular transportation modes and operator categories emphasized. The AIT Program will include focus on younger and older novice drivers.

The research results, technologies, and procedures will be applicable to all operators. The content and emphasis of the training products will change depending on modal and operator characteristics, but the fundamental elements, techniques, and technologies will be transferable.

The AIT Program will collect data and conduct research to identify and understand operator needs and deficiencies, and the role of human error in the following areas:

- Psychomotor – physical and perceptual skills necessary for safe operations;
- Cognitive – judgment, decision making, and risk management; and
- Knowledge and attitudes – understanding laws, regulations, and operational practices.

The AIT systems may range from inexpensive, personal computers, to interactive TV, to more complicated applications. An important constraint for the potential training systems to be successful is that they must be affordable and practical for wide-scale deployment. This constraint favors simpler, widespread technologies over more complex, limited production systems such as full mission simulators. Moreover, technologies that effectively leverage instructors – that is, the number of students receiving high quality training per instructor – by speeding the training process or serving many students in parallel are desirable.

Computer-based training and learning systems have many benefits. For example, such systems allow for multiple rehearsals under controlled and safe environments, and with many different situations using varying climatic conditions. Specific skills or skill components can be trained. Training can be self-paced with appropriate feedback and related tutorials which can create a very positive learning environment. Failures have minimal consequences but the training program can still provide structured punishment. Lastly, various forms of motivation can be used to create and enhance the potential for positive learning experiences.

An early task of the AIT Program will be to assess the state-of-the-art of AIT systems potentially applicable to training commercial operators. Sources for these data on AIT system effectiveness will come from various transportation modes, military operations, and other fields. The technology categories expected to be assessed, and consequently candidates for adaptation, development, and testing in the AIT Program will include but be not limited to the following tools and technologies:

- Distance learning systems (e.g., interactive TV, PC-Internet);
- Stand-alone interactive systems such as desktop PC instruction;
- Simulations that range from simple CBI PCs to complex dynamic systems; and
- Virtual reality devices that provide “high fidelity” simulation performance -- graphics, sound, and optic feedback -- potentially for a lower cost than for a complex, high fidelity simulator.

AIT Program investigations will focus on achieving the following major objectives:

Achieve a cross modal AIT program development and implementation through partnerships.

Public-private partnerships will be a key element of the AIT Program. The program will follow examples of partnerships such as NASA's Advanced General Aviation Transportation Experiments (AGATE) program, RSPA's Advanced Vehicles Technologies (AVP) program, MARAD's Ship Operations Cooperative Program (SOCP), and the R&D and deployment partnerships within the Intelligent Transportation Systems (ITS) program.

Identify, adapt and develop AIT systems designed to improve the safety training and education of younger and older novice operators and demonstrate its effectiveness.

Through laboratory experiments, field tests, and operational demonstrations involving potential and current commercial operators, the AIT program will measure the effectiveness of candidate prototype AIT systems. With the goal of significantly reducing the nature, rate and distribution of operator errors, increasing the level of operating knowledge attained and retained; and increasing duration of retention of attained operating knowledge.

Adapt and apply AIT systems to other operators and measure the safety effectiveness.

The AIT applications should be useful to the full spectrum of transportation operators--experienced professionals and non-commercial operators-- including the young and the more mature. Private sector and commercial operators require training or retraining to build or maintain their performance due to the introduction of new equipment, technology, changes in operational policies, changes in information, as well as to maintain the required skills and proficiencies. Skill performance and retention varies across the life span as well as between individuals. It is important to provide skill enhancements best suited to age-related skills and abilities. Activities to meet all aspects of this objective will build on findings specific to novice commercial operators and will be applied to all operators.

Support lifetime learning and training opportunities to enhance operator safety.

The AIT Program will support lifetime learning opportunities through outreach and public information and education (PI&E). These activities will bolster both implementation and continuing private sector participation in AIT programs. Measuring the success of achieving this objective shall be accomplished by increasing public education activities, publication of peer-reviewed papers, articles, media information and annual "readership" of program newsletters and summaries.

Establish a ONE DOT team for AIT and institute an AIT program administrative manager and point-of-contact.

The ONE DOT team will manage the implementation of the AIT Program, will represent USDOT in partnership activities, and will coordinate related operator training activities within USDOT. The team will assess public-private partnership options and, in consultation with stakeholders and other experts will develop appropriate partnership processes.

Promote AIT research and applications across transportation modes.

AIT outreach and public education activities will reach a wide range of transportation audiences, within the USDOT, the transportation community, and the public at large. The program will conduct technology demonstrations and workshops as a means for public information , education and for attracting private sector partners.

Project Planning and Partnerships

AIT is a public-private partnerships program. The partnerships leverage federal funds through private sector cost sharing and they ensure more effective program and investment decisions by directly addressing the needs of the stakeholder community. The Program will incorporate public and private stakeholder views to ensure that AIT systems are technically, socially, and economically viable. The Program will institute appropriate Advisory Committees and peer review mechanisms to provide program oversight. Successful AIT products would be made available beginning from the 12th month of program initiation. Phase I includes a set of activities that will demonstrate within the first year, the various concepts and technologies relative to the overall program.

AIT Phase I

Schedule: 12 months; Budget: $0.5M *(federal)*

The first phase of the AIT Program will demonstrate the feasibility of the technology and training concepts and establish administrative procedures for performing Phase II including an establishment of the AIT ONE DOT team, administrative management, AIT partnerships, and additional outreach organizations.

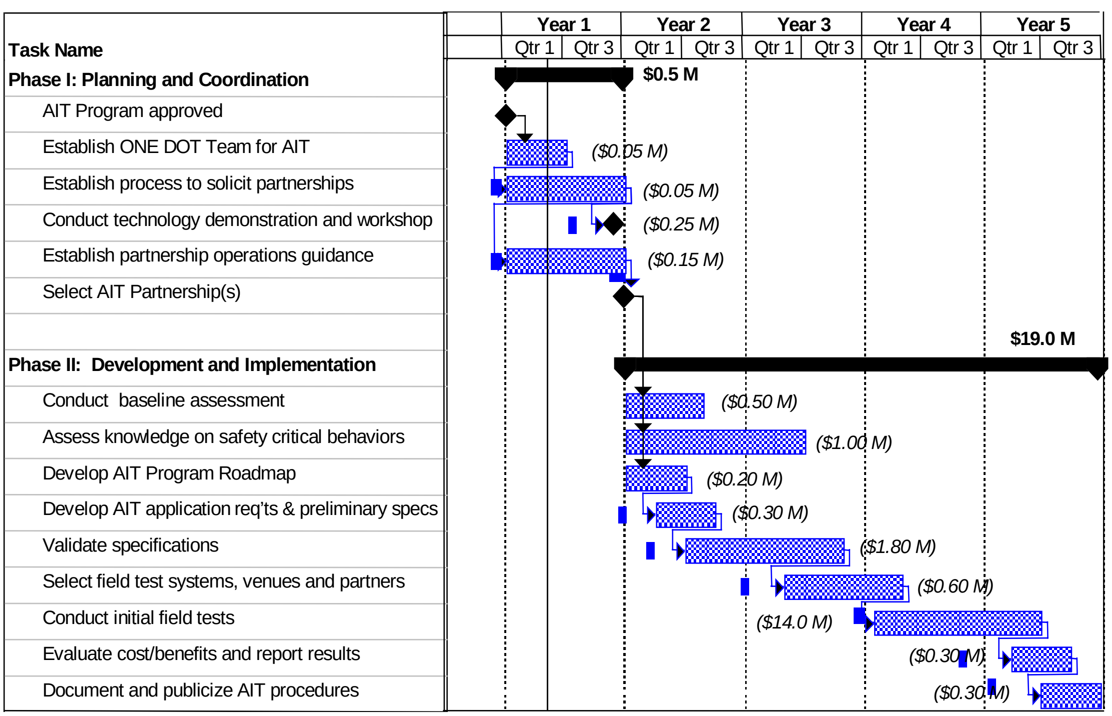


Figure 3. AIT Program Budget and Schedule

Note: Includes $7.5 M federal dollars and $12.0 M non-federal cost share.

The major tasks and milestones for Phase I are the creation of the USDOT program and the selection of the procedures needed to establish the AIT public-private partnership(s) to conduct Phase II of the program. Phase I tasks will include the following:

Establish a ONE DOT administrative contact and oversight Team for AIT planning, program management, and cross-modal coordination

USDOT will establish procedures for AIT Program direction and implementation and will initiate procedures needed to establish a public-private sector working group to assist the ONE DOT Team.

Identify and establish process for a public-private partnership and manage AIT activities

USDOT will convene a national experts Forum and technology demonstration to market partnerships, establish initial requirements for data collections and technology development, and to demonstrate the feasibility of the proposed effort. USDOT will follow up by issuing Federal Register notices for proposed AIT contract management and for proposed AIT partnerships.

AIT Phase II

Schedule: 48 months; Budget: $19.0M *($7.0M federal, $12.0M private sector)*

The core of the work in Phase II will be planned, directed, and performed through the AIT partnership(s). USDOT will review and concur with the plans for all projects that will use federal funds. AIT ONE DOT Team members and other federal staff will participate in partnership activities and provide technical oversight as necessary (e.g., they could serve as COTRs).

During this phase of the program, the AIT partnership will adapt and develop systems that can improve the safety of operators. Specifically, the partnership will develop performance guidelines, system functional requirements and specifications, and training procedures. The partnership will develop or acquire AIT systems to validate specifications. The AIT partnership(s) will test and evaluate the most promising configurations to facilitate their deployment and operation. The partnership(s) will demonstrate the effectiveness of AIT systems and procedures in reducing errors and in enhancing operator safety skills, cognitive abilities, knowledge and behaviors. Initial research results and technologies will be transferred to other transportation modes for analysis and testing during this phase of the Program as appropriate.

USDOT and its partner organizations will develop field test plans and objectives, select evaluation candidates and venues, acquire systems, and conduct tests. USDOT will ensure that independent evaluations of the field test experiments are conducted and that objective benefit-cost assessments are performed.

Clear measures of effectiveness, that are understandable and acceptable to stakeholders and policymakers alike, will be defined to substantiate the attainment of program objectives. Potential safety benefits are difficult to estimate and quantify precisely. Therefore, it may be necessary to establish, test, and validate surrogate measures to estimate safety advantages of AIT systems and related training procedures.

USDOT and its AIT partners will conduct outreach activities to inform the public and key stakeholders of the capabilities, benefits, and availability of AIT systems. These activities will be a continuation, and possibly expansion, of the outreach program begun in Phase I. Through these outreach activities, USDOT and/or the AIT Partnership will facilitate the deployment of AIT systems and training programs.

At this point in the Program, USDOT expects that individual AIT partners and other non-Federal entities will begin to implement AIT systems and training programs for transport operators..

Phase II will demonstrate quantitatively the effectiveness of AIT systems and training programs in improving the safety of operators. The types of evaluations and operational testing will be based on the individual AIT components. Primary Phase II tasks will include but not limited to the following:

Conduct baseline assessment of successful advanced training systems and procedures used by USDOT modes other Federal Agencies, industries, and the military.

The AIT Partnership will identify the nature and type of training systems to be assessed and will identify organizations that will develop and/or use AIT systems and support. A process for contacting relevant organizations to perform pilot tests will be developed and implemented for selected advanced training systems.

Assess the state of knowledge on safety critical behaviors shown by the various transport operators.

The AIT Partnership will review and assess previous operator task analysis, in-depth accident causation analysis, and other relevant operator behavior analyses by transportation mode. Procedures will be developed for updating and validating previous operator task assessments using research simulators, in-vehicle operator task data recording, and other promising measurements. An expert panel will review and approve procedures and will establish baseline data for various groups of operators (by experience and age) for different transportation mode.

Develop a prioritized roadmap of AIT development needs and opportunities.

The AIT Partnership will determine use of potential advanced technologies needed for training of critical operator behaviors and develop functional requirements for matching candidate technologies.

Develop requirements and preliminary functional specifications for AIT systems and training procedures.

The AIT Partnership will develop experimental designs for initial field studies relative to the various AIT systems to be tested and will establish data collection and analysis procedures.

Validate specifications and develop model AIT systems and procedures.

The AIT Partnership will develop field test objectives and evaluation criteria. It will conduct limited field testing of various AIT systems and design full scale field tests to begin the deployment process.

REFERENCES

Akerstedt, Torbjorn, Landstorm, Ulf, 1996. Work Place Countermeasures of night shift Fatigue. International Journal of Industrial Ergonomics 21, 167-178.

Akerstedt, Torrbjorn, Torsvall, L., 1978. Experimental changes in shift schedules-their Effects on well being. Ergonomics 21, 849-856.

Andersen, F.E., 1970. Three-shift Work. Socialforskningsinstitutet, Copenhagen.

Gold, D.R., Rogacz, S., bock, N., Tosteson, T.D., Baum, T.M., Speizer, F.E., Czeisler, C.A., 1992. Rotating shift work, sleep, and accidents related to sleepiness in hospital Nurses. American Journal of Public Health 82, 1011-1014.

McCallum, Marvin C., Raby, Mireille and Rothblum, Anita M., 1996. Procedures for Investigating and Reporting Human Factors and Fatigue Contributions to Marine Casualties. Coast Guard Technical Report. AD-A323392.

Menzel, W., 1962. Menschliche Tag-Nacht-Rhythmiik und Schichtarbelt. Schwabe, Basel.

National Center on Sleep Disorders Research, 1993. Wake Up America: A National Sleep Alert. Final Report of the National Commission on Sleep Disorders Research. National Center on Sleep Disorders Research, National Heart, Lung, and Blood Institute, Bethesda, MD.

New England Journal of Medicine. The Perils of Drowsy Driving Editorial September 11, 1997 Vol. 337, No. 11

NTSB, 1990a. Grounding of the US tankship Exxon Valdez on Bligh Reef, Prince William Sound near Valdez, Alaska, March 24, 1989. National Transportation Safety Board. Maritime Accident Report, NTSB/MAR-90/04.

NTSB, 1990b. Safety Study: Fatigue, Alcohol, Other Drugs, and Medical Factors in Fatalities-to-the-Driver Heavy Truck Crashes. PB90-917002, NTSB/SS-90/01, February, 1990.

NTSB, 1995. Factors that affect fatigue in heavy truck accidents. National Transportation Safety Board. Safety Study, NTSB/SS-95/01.

Paley, MJ., Tepas, D.I., 1994. Fatigue and the shiftworker: firefighters working on a Rotating shift schedule. Human Factors 36, 269-284.

Thiis-Evensen, E., 1957. Shift work and health. Proceedings of the XII International Congress of Occupational Health. (Helsinki) Helsinki, pp. 97-105.

Raslear, Thomas, G., Kuehn, G., 1997. The Effects of Work Schedule on Train Handling Performance and Sleep of Locomotive Engineers: A Simulator Study. DOT/FRA/ORD-97-09.

Verhaegen, P., Maasen, A., Meers, A., 1981. Health problem shift workers, In: Johnson, L.C. et al. (Ed.), Biology Rhythms and Shift Work. Spectrum, New York.

Wyatt, S., Mariott, R., 1953. Night and shift work changes. British Journal of Ind Med 10, 164-177.