# Evolution of Fatigue Risk Management Systems:

## *The "Tipping Point" of employee fatigue mitigation*

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Over the past five years, a broad international consensus has emerged across many 24/7 industries that the optimal way to manage and reduce employee fatigue risk is through a systematic process called a Fatigue Risk Management System (FRMS). Government regulatory agencies, industry associations, and many corporations with 24/7 operations have recently incorporated a FRMS into their regulations, industry standards, and corporate policies.

The pace of adoption of FRMS has accelerated so fast that it has taken some by surprise. Just in the last two years (2008-2010):

- The European Aviation Safety Agency (EASA) has made having an FRMS a requirement for airlines operating in Europe.
- The American Petroleum Institute published an ANSI standard (RP-755) that makes FRMS the operating requirement for managing employee fatigue in the petrochemical industry.
- The Federal Rail Safety Act mandated that US railroads have fatigue risk management plans.
- The US pipeline safety agency PHMSA proposed rule changes for natural gas pipeline control rooms that will include fatigue risk management.

How can a seemingly new concept have spread so far so fast? The answer lies in Malcolm Gladwell's thought-provoking book 'The Tipping Point".[1] Just like other ideas that suddenly enter public consciousness, FRMS is not actually a new concept but instead has been in development and operational use for more than 20 years. However, FRMS has only recently reached the "tipping point," gaining the attention of a sufficient critical mass of industry, government, and academic "influencers" to burst through into general international acceptance.

One reason FRMS remained hidden from public awareness is that until recently this system did not have a commonly-accepted name. During the past 20 years, various terms have been used to describe a systematic approach to managing employee fatigue risk in 24/7 operations, including Alertness Assurance, Alertness Management, Human-Centered Management, and Fatigue Management, and also specifically Fatigue Risk Management. However, during the past five years a consensus emerged, and governments and other organizations worldwide now have adopted the term "Fatigue Risk Management Systems."

This CIRCADIAN® white paper looks at the evolution of FRMS, its scientific basis, and the reasons it has remained under the radar for more than 20 years. It traces the story of the scientific research and operational experience leading to the development of the key concepts listed in Figure 1 that are essential to the success of FRMS:

**FIGURE 1:**
**Key characteristics of a successful Fatigue Risk Management System**

| | |
|---|---|
| **Science based** | Supported by established peer-reviewed science |
| **Data driven** | Decisions based on collection and objective analysis of data |
| **Cooperative** | Designed together by all stakeholders |
| **Fully Implemented** | System-wide use of tools, systems, policies, procedures |
| **Integrated** | Built into the corporate safety & health management systems |
| **Continuously improved** | Progressively reduces risk using feedback, evaluation & modification |
| **Budgeted** | Justified by an accurate ROI business case |
| **Owned** | Responsibility accepted by senior corporate leadership |

## 1. The rise and limits of Hours of Service regulations

As the practice of operating at night with extended hours and 24/7 work schedules spread across multiple industries following Edison's commercialization of electric light in 1882, the fatigue caused by working long hours around-the-clock became a major social issue. The emerging labor movement in the early 1900s eventually influenced work hour regulations and laws, and the concept of hours of service regulation emerged. As a result, the issue of workplace fatigue became intertwined with labor pay and rights issues and led to regulatory limits on work/duty duration and minimums of off-duty time duration in all transportation modes by the middle of the 20th century.[2]

In Europe, influential research on both the risk of accidents and the sociological and medical impacts of shiftwork by researchers, including Joseph Rutenfranz and Peter Knauth[3] in Germany, accelerated the momentum. The EU Working Time Directives eventually placed limits on work and rest hours in most industries and occupations.

In essence, the concept of Hours of Service regulation resulted in a prescriptive model that assumed that most of the risk of fatigue could be addressed by simply placing limits on the number of hours worked in a specified time period and providing for a minimum number of hours of rest between work shifts and between blocks of work shifts. The time of day or night of work, or the 24-hour clock timing of work and rest patterns over a period of days, were not part of the equation. As a result, the measurement of "successful" fatigue management too often became simply seen as the business' compliance with the input variables (e.g. number of work/rest hour regulatory violations) rather than the evaluation of any output variables (e.g. actual fatigue levels, fatigue-related accidents).

## 2. Development of the Scientific Concepts underlying FRMS

In the late 1970s, two fast-growing areas of scientific research--the electrophysiology of sleep and biological clock research--merged into a dynamic new discipline because they proved to be so interrelated. Sleep researchers such as William Dement[4] of Stanford University and Alan Rechshafften[5] of the University of Chicago had defined the systematic patterns of nocturnal sleep stages using the EEG (electroencephalogram), and had started to define clinical sleep disorders and how they could be diagnosed and treated. At the same time, biological clock researchers such as Jurgen Aschoff[6] and Rutger Wever[7] at the Max Planck Institute in Germany had demonstrated the intrinsic properties of the human circadian (approximately 24-hour) biological clocks and their "free-running" patterns. They and the French speleologist Michel Siffre[8] showed that when people lived in underground caves or bunkers without clocks or knowledge of time, the timing of their sleep drifted progressively later because the human biological clock has an intrinsic rhythm that is longer than 24 hours.

The power of merging these two streams of academic research became evident when a Harvard-Cornell team led by Elliot Weitzman, Martin Moore-Ede, Charles Czeisler, and Richard Kronauer created the first integrated human circadian sleep laboratory at the Montefiore Hospital in New York. One of their most influential early studies demonstrated that the brain's circadian clock exerted a strong control over the timing, duration, and stages of sleep.[9] In fact, as Alexander Borbely of the University of Zurich, Switzerland, and Serge Daan of the University of Groningen, Holland clarified, there were two major interacting determinants of sleep: a homeostatic component related to the time spent awake and accumulated sleep deprivation, and a circadian component related to the time of day of the individual's biological clock.[10]

Because of this circadian regulation of sleep, there was an important difference between a sleep opportunity and the amount of actual sleep it was possible to obtain during that opportunity. Torbjörn Åkerstedt of Sweden's Karolinska Institute showed that even under ideal sleeping conditions, people who slept eight hours when they went to bed at 11 PM would only sleep six hours if they went to bed at 3AM, and only four hours when they went to bed at 11 AM even though they had been kept awake all night.[11]

By the early 1980s, it became apparent that the underlying assumptions of hours of service regulations were severely flawed.[12] The emerging research on the circadian regulation of sleep and fatigue inevitably led to the conclusion that an employee could be fully compliant with hours of service but highly fatigued, or conversely could be non-complaint and fully alert and safe. The most significant factors influencing employee fatigue were determined to be the circadian times of work and sleep opportunity, and the consecutive number of hours awake, and neither of these were addressed by Hours of Service regulations.[13,14]

## 3. The first industrial applications of circadian sleep science

By some quirk of fate, in 1980 an Ogden, Utah newspaper picked up and published on its business page a story about the new research on the circadian timing of human sleep. This publicity generated a pink telephone-message slip in the Harvard office of Moore-Ede and Czeisler that read "I have a hundred shift workers who cannot sleep, can you help?"

The message came from Preston Richey. As production manager for the Great Salt Lake Minerals and Chemical Company in Ogden, Richey was responsible for the around-the-clock operations that harvested the salts from solar evaporation ponds juxtaposed to the Great Salt Lake. Day and night, huge front-end loaders scooped up the crystallized salt and dumped it into trucks lined up in non-stop progression.

From discussions with Richey, Moore-Ede and Czeisler learned that Richey's workforce was battling the problems of chronic fatigue, sleep deprivation, and sleepiness on the job. And no wonder: the employees worked on a weekly counterclockwise rotating schedule equivalent to spending a week in Utah, a week in Paris, and a week in Tokyo, in an endless jet-lag-inducing rotation.

Richey invited Moore-Ede and Czeisler to examine his operation. After arriving, they were briefed on how the operation ran and the problems the plant faced. As they sat around the conference table, the management team asked if they could help. Moore-Ede and Czeisler devised a new scientific approach to scheduling shifts around the clock that incorporated circadian sleep science, thus pioneering the concept of "biocompatible" shift-scheduling. Together with Richard Coleman, a psychologist from the Stanford University sleep center, Moore-Ede and Czeisler also developed the first training programs on sleep and alertness management for shiftwork crews.

The results were dramatic. Productivity rose by an unheard-of 22 percent as a tired work force was converted into a relatively energetic one. This productivity gain was measured in truckloads of potash leaving the plant: The alert operators became more efficient at operating the front-end loaders, fewer loads missed the trucks for which they were intended, and the pace of operations hummed forward at record speed. At the same time, employee turnover markedly dropped because the work force much preferred the new schedule. Health surveys showed that medical complaints, such as gastrointestinal symptoms, subsided and morale improved greatly.[15]

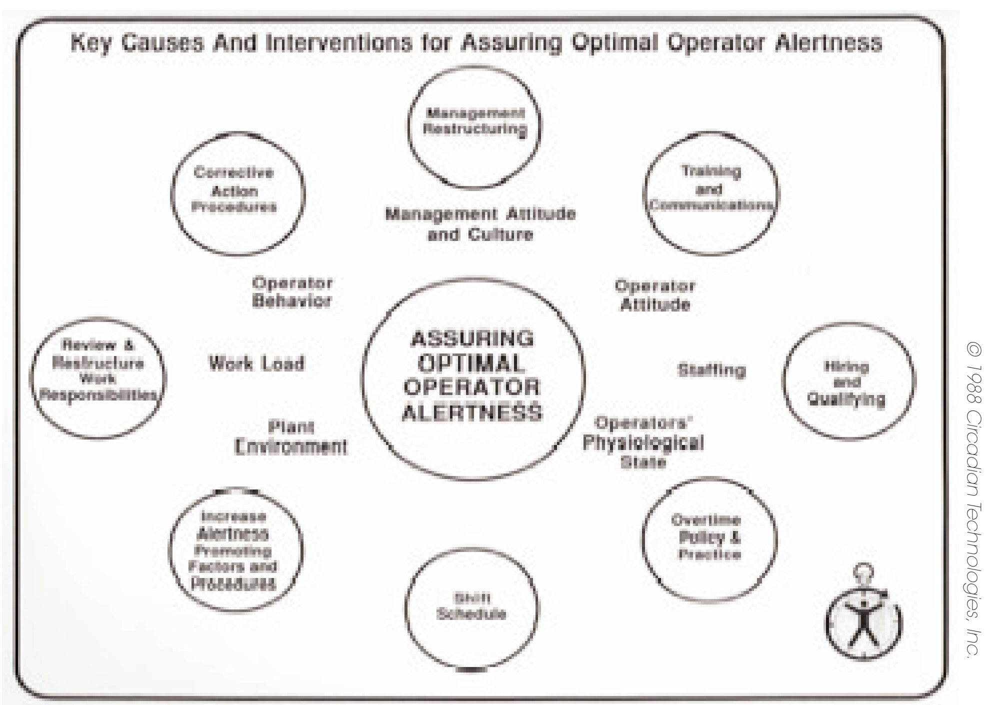
The productivity gains added $800,000 to the plant's bottom line in the first year alone, without the purchase of additional capital equipment or the hiring of any additional employees. The increase in productivity was sustained year after year following the completion of the research project, thereby verifying that it was not a "Hawthorne effect" (i.e., it was not caused simply by the increased attention paid to workforce during the study).[2]

## 4. The first development of a Fatigue Risk Management System

The 1982 report of this Great Salt Lake Study in the scientific journal *Science*[15] triggered a wave of publicity. By the end of the year, more than 300 major corporations with shiftwork operations contacted Moore-Ede and Czeisler wanting to benefit from the application of circadian sleep science to their shift-scheduling and employee-training programs. Moore-Ede subsequently launched the consulting firm CIRCADIAN® in 1983 to address this demand. As multiple industries implemented the applications of circadian sleep science, it quickly became apparent that multiple workplace, social, and environmental factors caused employee fatigue.

The first opportunity to develop a comprehensive approach to manage fatigue, termed "Alertness Assurance," arose in 1987. Less than a year after the Chernobyl disaster, the U.S. Nuclear Regulatory Commission (NRC) sent a shockwave through the U.S. nuclear power industry by closing PECO's* Peach Bottom nuclear power plant in western Pennsylvania. NRC took this action on March 31, 1987 because the control room operators had been discovered sleeping in their comfortable, high-backed chairs during the night shift. Never before had a nuclear power plant been closed because of human fatigue unrelated to a nuclear accident. As the late Republican senator John Heinz from Pennsylvania put it, the Peach Bottom closure was "a wake-up call for the nuclear industry."

**FIGURE 2:**
**The Alertness Assurance program designed and implemented by CIRCADIAN® at the Peach Bottom Nuclear Power Plant in 1987-1988.**



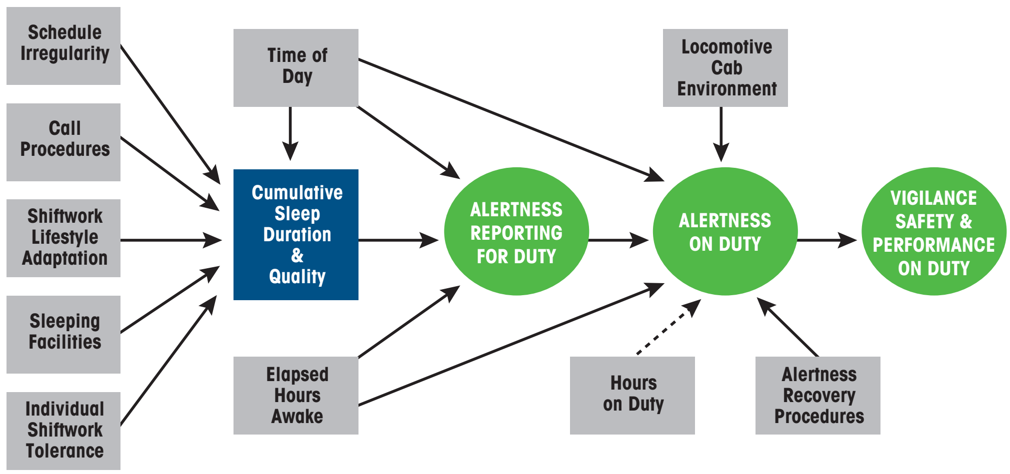

* *PECO = Philadelphia Electric Company. The Peach Bottom power plant is currently owned by Exelon.*

The NRC did not allow the Peach Bottom plant to reopen for another two years, resulting in enormous costs and consequences for PECO and its management team. Peach Bottom reactors 2 and 3 had been supplying enough power to light the city of Philadelphia, and thus the city had to purchase $14 million per month of replacement power from other utilities. The NRC fined PECO $1.25 million, the largest fine assessed to that date against a nuclear power plant, and also fined the sleeping control room operators $500 to $1,000 each. The company board fired all members of the management chain responsible for PECO's nuclear power operations, including the company president and the chairman and chief executive officer. Even after the Peach Bottom plant reopened following an extensive retraining of the crews assisted by CIRCADIAN®, a $150 million shareholders' suit against the chairman/CEO and the president of PECO remained. Two insurance companies finally agreed to pay $34 million to settle the shareholders' derivative suit.

PECO hired CIRCADIAN® to develop the comprehensive operator fatigue management program illustrated in Figure 2. This program systematically addressed a wide range of factors that can contribute to fatigue risk and then set up systems to manage the risk.

This process of comprehensive fatigue risk management using the term "Alertness Assurance" was subsequently applied over the next several years to address fatigue risk in a broad range of other industries. For example, a train accident with multiple fatalities between a passenger train and a freight train in Alberta, Canada brought attention to the issue of train crew fatigue when accident investigators found that the freight train had passed a red signal after the crew had worked long hours. So when Transport Canada inspectors in 1993 boarded a train in British Columbia and then saw the same crew at the controls they saw when they got off the train in Ontario, Transport Canada issued an emergency order to tightly restrict train crew hours. Faced with a $300 million cost of implementing this new rule, the major Canadian railways, Canadian National (CN), Canadian Pacific and VIA passenger rail came to CIRCADIAN® to seek an alternative, less-restrictive solution.

**FIGURE 3:**
**Factors contributing to train crew fatigue risk that were managed by the CANALERT Alertness Assurance program.**






CIRCADIAN® first analyzed the multiple causal factors contributing to train crew fatigue and fatigue-related errors and accidents and developed the flow chart seen in Figure 3. They then designed an Alertness Assurance program to address each of these fatigue risk factors, and undertook a scientific study measuring train crew sleep and microsleeps on the job and other performance and alertness measures before and after the application of fatigue countermeasures, a study published as the CANALERT 1995 report.[16] Subsequently, the railways systematically implemented the Alertness Assurance process across their operations. For example at CN, CIRCADIAN® built and helped CN implement a crew-scheduling software system to ensure crew assignments that minimized fatigue risk across their entire coast-to-coast rail system.

## 5. The development of fatigue risk models

As alertness assurance/fatigue risk management programs began to move from research projects into industrial implementation, it became essential to develop methods to measure fatigue risk that were both practical for day-to-day operations and did not require the costly and cumbersome measurement of sleep-wake patterns in employees.

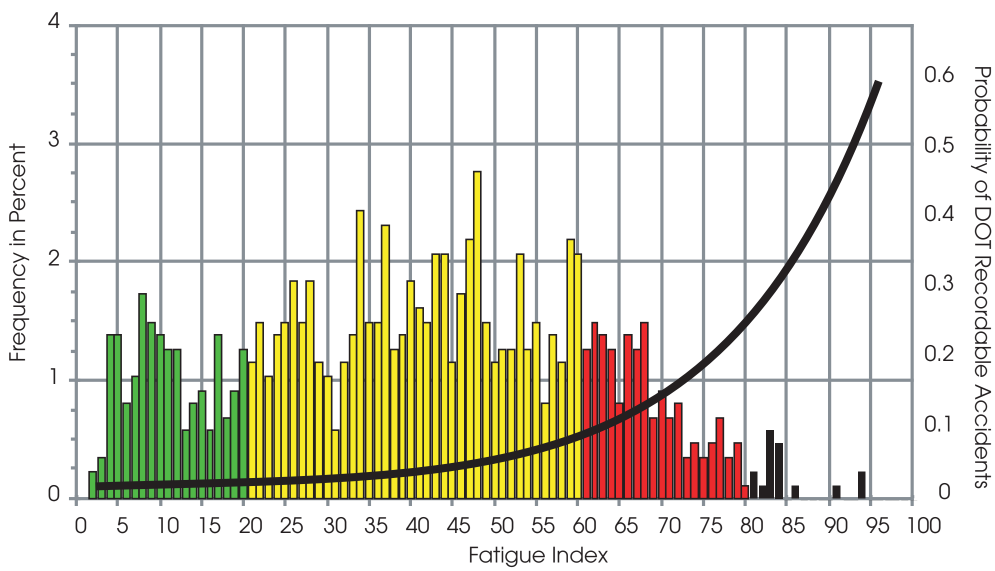
To address this need, several teams of researchers independently developed mathematical fatigue risk models that sought to predict fatigue risk based on the well-established science of the circadian and homeostatic regulation of sleep. These researchers included Torbjörn Åkerstedt who collaborated with Simon Folkard of the University of Swansea, Wales to develop the Three-Process Model;[17] Martin Moore-Ede of CIRCADIAN® who developed CAS;[18] Drew Dawson of the University of South

Australia who developed FAID;[19] and Steve Hursch of John Hopkins University who developed SAFTE-FAST.[20] To make these fatigue risk models practical for operational use when employees' actual sleep is unknown, sleep prediction algorithms were added based on work-rest cycles so that employers could enter readily available data from timesheets, duty-rest logs, or shift schedules.

For example, CIRCADIAN® created the Circadian Alertness Simulator (CAS) using more than 10,000 days of sleep and alertness data collected from transportation employees working a wide variety of duty-rest patterns. CIRCADIAN® then optimized the system to predict accident risk, validating it against a database of DOT recordable truck accidents (fatal, serious injury, disabled vehicle).

As one of its outputs, CAS can calculate a Fatigue Risk Score, which assesses acute and chronic sleep deprivation scaled from 0 (minimal fatigue risk) to 100 (very high fatigue risk). As Figure 4 shows, the average (i.e., mean) US over-the-road truck driver has a Fatigue Score of 40; as the score rises, accident risk exponentially increases.

**FIGURE 4:**
**The distribution of CAS fatigue risk scores (1 = low, 100 = high) in truck drivers, and the probability of a DOT-recordable truck accident per driver in the next year.**




*1 = lowest risk, 100 = highest risk*
*The percent of truck drivers is shown with each fatigue score. The black line shows that the relatively few drivers with high risk scores (red and black) have a much higher rate of DOT recordable accidents. (Data replotted from Moore-Ede et al21).*



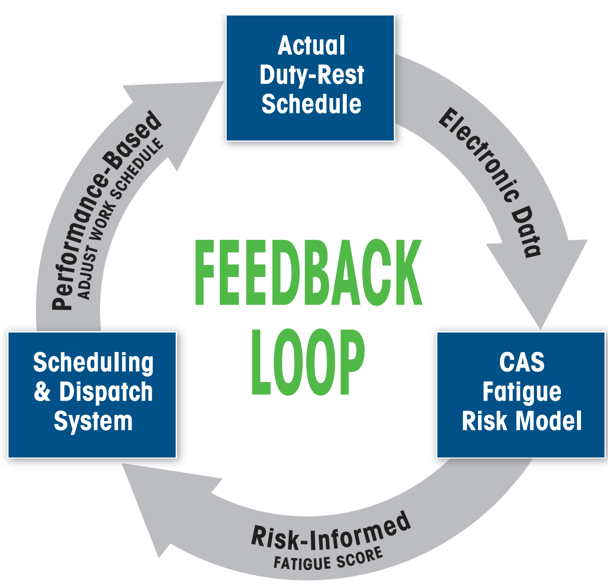
These fatigue risk models now have been used in work schedule optimization, fatigue-related accident investigations, and shiftworker lifestyle education and training. For example, the transportation industry has used CAS in numerous fatigue risk management systems and found it to be an effective tool in employee fatigue reduction programs.

## 6. Continuous improvement using risk-informed performance-based fatigue management

Sustaining an organization's use of fatigue risk programs proved to be another challenge. Too often the experience of implementing the early alertness assurance/fatigue risk management systems showed that once the crisis that led to its implementation had passed, management moved on to address other business problems, often unintentionally allowing  the effort to peter out and loose its effectiveness. For example, it is noteworthy that some years after the initial Peach Bottom incident, the NRC again disciplined the nuclear plant after safety-critical employees were videotaped sleeping on the job.

The lesson is that FRMS must be designed and maintained as a continuous improvement system, not merely as a reaction to a crisis. The only reliable way to implement such a system is to measure fatigue risk on an ongoing basis (using a validated fatigue risk model in combination with other outcome measures, such as accidents and injuries), regularly review the results, and then take actions to reduce the risk. It is also important to ensure that the incentive systems for managers and employees are designed to reward the progressive improvement of results over time. This process is called Risk-Informed Performance-Based (RIPB) safety management and is illustrated in Figure 5.

**FIGURE 5:**
**The feedback loop used to continuously assess fatigue risk using the CAS fatigue risk model, and to provide feedback to managers and employees who adjust their duty-rest pattern in order to reduce the fatigue score**



One of the longest continuous experiences with an RIPB continuous improvement FRMS system has been the CAS-based dispatching of truck drivers at Dupre' Transport, a 500-unit trucking carrier based in Lafayette, LA. During the eight years that Dupre' has been using the CAS Fatigue Risk Software, its accident and injury rates have significantly declined. A video clip from the National Geographic TV documentary "Dead Tired," telling the story of Dupre's continuous-improvement FRMS, is found at: *http://www.circadian.com/pages/969_dead_tired_fatigue_training_dvd.cfm*

In 2000, despite diligently applying a traditional safety program, Dupre' Transport had an elevated rate of highway accidents involving their gasoline delivery trucks. After a dozen of their gasoline delivery trucks had overturned on the highway in 2000-2001, their insurance carrier, XL Capital, asked CIRCADIAN® to conduct an emergency assessment of the Dupre' Transport operation. This assessment found that a disproportionate number of accidents involved drivers who had had elevated CAS fatigue scores in the month prior to their accidents. With this information in hand, CIRCADIAN® designed and Dupre' Transport introduced a FRMS with Risk-Informed Performance-Based safety management program in the last few months of the FY00/01 fiscal year. The FRMS-RIPB program included manager and driver sleep management and alertness training, monthly analysis of CAS Fatigue Scores for each driver, and a safety management process in which drivers and managers were held accountable for the reduction of their CAS fatigue scores. The drivers were each individually provided with their own CAS Fatigue Scores on a monthly basis and were coached by the safety department on how to reduce CAS fatigue scores by altering the timing of their duty and rest hours.

During the next three fiscal years (FY 01/02, FY 02/03 and FY 03/04), while Dupre' Transport maintained the RIPB program described above, accident, personal injury, and driver turnover data was collected from the truckload driver population. As a result, Dupre' experienced a 69% a reduction in its rate of highway accidents.[21] Today Dupre' has day-to-day operational experience for more than 400 million miles using this CAS-based Risk-Informed Performance-Based fatigue risk management system. Other major trucking fleets have since then seen similar results by applying this CAS fatigue modeling technology. For example, CR England, a Utah based carrier with 3,300 drivers, has experienced a 53% reduction in severe accidents per million miles.[22]

## 7. Integration with Safety Management Systems

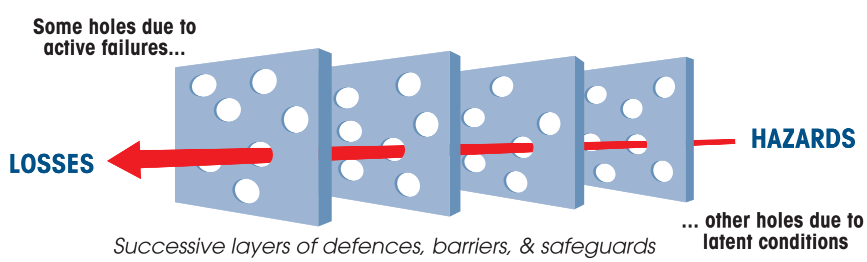
A key step precipitating the "Tipping Point" of widespread FRMS acceptance was Drew Dawson's integration of fatigue risk management with the concept of Safety Management Systems (SMS).[23]

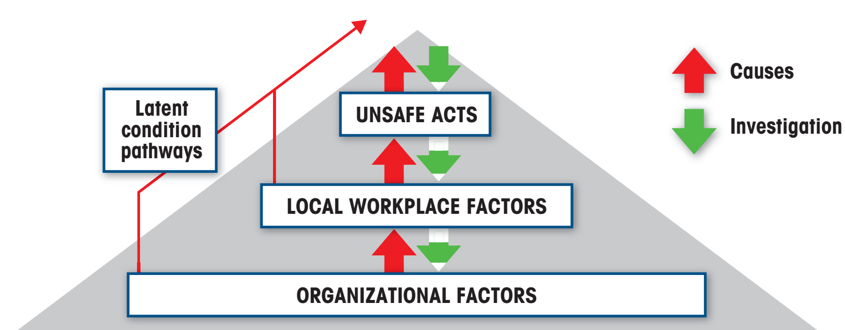
SMS had emerged as a systematic business model for managing safety risks in industries such as aviation, maritime, and oil.[24] A series of major industrial accidents between 1970-1990, including Flixborough where a chemical plant explosion destroyed an English village in 1974 and Piper Alpha where a North Sea oil platform exploded and killed 167 people in 1988, led to government inquiries. Two UK government reports from the Robbens (1974) and Cullen (1992) commissions led to the regulatory requirement that safety-critical industries implement formal safety management systems. These commissions' findings soon led to the adoption of similar regulatory requirements in Europe, Canada, Australia, and elsewhere.

The evolution of the systematic analytical concepts of SMS has been strongly influenced by the work of James Reason at the University of Manchester, England. As described in Reason's 1990 book "Human Error",[25] most major industrial and transportation accidents are the result of multiple latent points of system failure and not just the immediately obvious active error of the human at the controls.

Reason introduced the imagery of a series of Swiss cheese slices (Figure 6, top) to explain that every level of organizational defense against potential hazards has holes in it. It is when the holes line up that a pathway for accidents to occur emerges. These slices of cheese, which Reason calls "defenses in depth," operate at different levels of control, (Figure 6, bottom) which Reason summarized as Organizational Factors, Local Workplace Factors and Unsafe Acts .

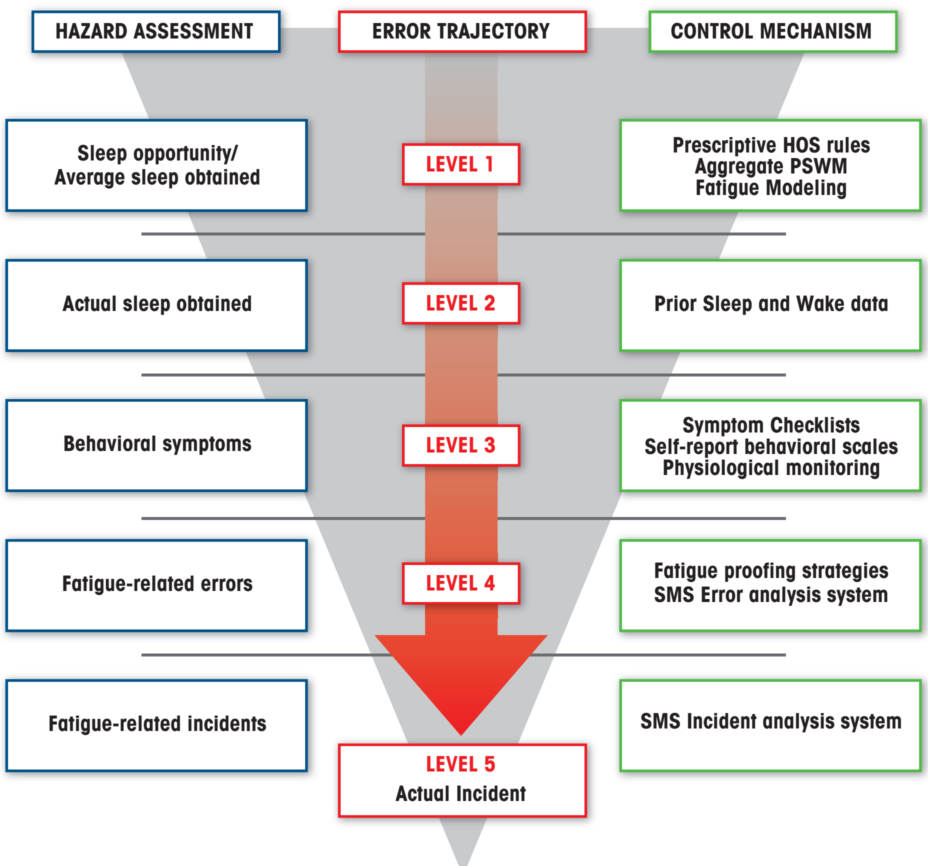
**FIGURE 6:**
**Reason's concept of the organizational protection against hazards which consists as a series of defenses. Top: Like holes in slices of Swiss cheese, these lines of defense ("defenses in depth') each have gaps or failure points in them. Bottom: Losses occur when hazards penetrate through the holes in each line of defense which are found at different levels of control in an organization. (From James Reason 1997[26] and Reason 2009[27])**



Dawson applied these concepts to Fatigue Risk Management by pointing out that the degree of fatigue likely to be associated with a particular duty-rest or shift schedule could be analyzed using Reason's concept of levels of latent and active errors. Dawson and McCullogh[23] developed a Fatigue Risk Trajectory diagram illustrated in Figure 7 where Reason's triangle from Figure 6, bottom is flipped so that the sequence of hazards flows down the page.

**FIGURE 7:**
**The stages in the Fatigue Risk Trajectory leading to a fatigue-related accident. (From Dawson & McCullogh, 2005[23] with permission)**




In Dawson's scheme, the first level is the sleep opportunity provided by the work-rest schedule, controlled by prescriptive Hours of Service, labor agreements, and/or corporate policies, and by the use of fatigue risk models. The second level is the actual amount of sleep obtained, which is determined by commuting time to and from work and the personal lifestyle decisions of the employee. The third level is the behavioral symptoms of fatigue resulting from the cumulative effect of shortages in the sleep obtained, which may or may not be detected by peers and managers or the self-awareness of the employee. The fourth level is the occurrence of fatigue-related errors and the fifth and final level is the number of actual incidents (accidents, injuries, production errors) caused by fatigue-related errors. These five levels make up the line of defenses, and when the holes in the "Swiss cheese slices" line up, fatigue related accidents and injuries occur.

What Dawson & McCullogh's Fatigue Risk Trajectory provided was a systematic process for analyzing fatigue risk that is readily understood by managers educated in SMS processes. As such, it represented an important conceptual step that helped to tip the balance of general acceptance of FRMS, including, importantly, the general acceptance of "Fatigue Risk Management Systems" as the preferred nomenclature.

One of the key features of FRMS is that the process seeks to identify the holes in the "Swiss cheese slices" from a fatigue perspective and should also identify the mitigation required to either close the holes or at least reduce their size. The outputs from these mitigations, together with the identified fatigue issues, will then feed into the SMS, e.g., in the form of additional policies, revised procedures, or assurance criteria, which will update and strengthen the management systems.

## 8. Best Practices in FRMS implementation

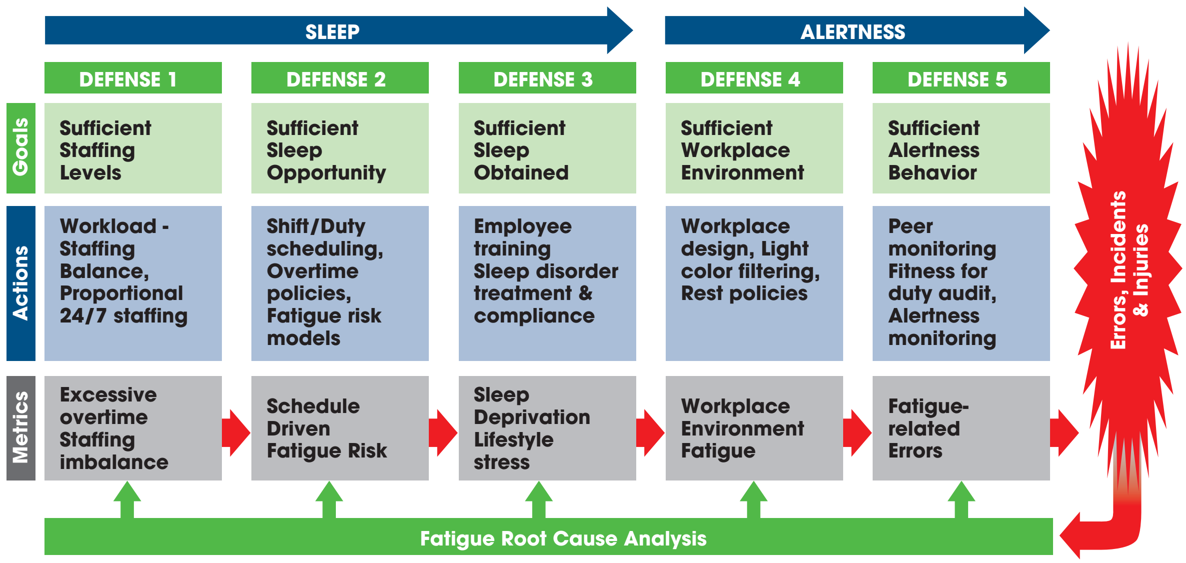
While Dawson's fatigue risk trajectory concept provides a valuable framework for the systematic analysis of fatigue risk, a limitation of this approach is that it is excessively sleep centric, as illustrated by the title of Dawson & McCulloch's *Sleep Medicine Reviews* article "Managing Fatigue: It's About Sleep."

Optimizing the amount of sleep employees obtain is obviously important, but there are other levels of defense necessary in order to assure alertness on the job. CIRCADIAN®'s experience in designing and implementing FRMS over the past twenty years has led to the appreciation of the critical path for assessing and managing fatigue risk. As illustrated in Figure 8, there are five key "defenses in depth" that must be managed by FRMS. The first three of these defenses impact sleep management, but the last two provide alertness management, which is a significantly different issue:

### 1. Workload-staffing balance

The staffing level, and not the shift schedule, is the primary determinant of overtime levels, average time off-duty, and other key factors related to employee fatigue. Therefore, it is vital to first address taskload/workflow issues, ensure adequate staffing levels, and to proportionally balance them to workload across the 24/7 schedule. Workload/staffing balancing strategies are discussed in more detail by Todd Dawson in the CIRCADIAN® white paper *Proportional Staffing and Flexible Workforce Management*.[28]

**FIGURE 8:**
**The five major lines of defense used in designing and implementing a Fatigue Risk Management System and the feedback loop which analyses fatigue-related errors & incidents and strengthens defenses to ensure the FRMS is risk-informed, performance-based, and continuously improved.**






## 2. Shift or duty-rest scheduling

Even in appropriately staffed operations, poorly designed shift schedules, duty-rest schedules that do not account for an employee's commuting time to and from work, or employees swapping shifts or overtime assignments may lead to excessive employee fatigue. Operations should address this issue by using fatigue risk models to assess actual (rather than just planned) work-rest patterns in order to measure and intervene to minimize the risk, as well as to provide a set of outer-boundary limits (e.g., limits on working beyond a certain number of consecutive hours or working more than a certain number of days in a row). The key factors in developing an optimal shift schedule are discussed further by Davis and Aguirre in the CIRCADIAN® white paper, *Employee Involvement in Shift Scheduling*.[29]

## 3. Employee fatigue training & sleep disorder management

Educating employees to better understand and manage their personal sleep and fatigue risk is a critical component of an FRMS. Factors such as inadequate shiftwork lifestyle coping skills, personal crises (such as a sick child at home), and undiagnosed and treated sleep disorders may prevent employees from obtaining adequate sleep even when they have work-rest schedules designed to provide adequate sleep opportunity. How to optimize the benefits of employee shiftwork lifestyle training is discussed in a CIRCADIAN® white paper, *Shiftworker Lifestyle Training: Employee and Employer Benefits*, by Todd Dawson[30] and the screening and management of sleep disorders in a white paper by Acacia Aguirre, *Reducing the Costs, Risks, and Liabilities of Obstructive Sleep Apnea*.[31]

**4. Workplace environment design**

However diligently they manage their sleep, employees still will be required to work in the early morning hours at the lowpoint in the circadian cycle or will report on occasion to the workplace in a sleep-deprived state. The next critical line of defense is the design of the workplace environment. Key factors such as the intensity and wavelength of lighting, sound levels, temperature and humidity should be designed to protect employees' levels of alertness and prevent employee impairment. A CIRCADIAN® management report, *The Practical Guide to Managing 24-Hour Operations*,[32] discusses these and other environmental factors.

**5. Alertness monitoring & fitness for duty**

Holes in the above four defenses (cheese slices) may still exist. Therefore, a fifth line of defense is critical. Reducing fatigue-related risk in the workplace requires that both the employees themselves and their supervisors and peers learn to recognize the signs and symptoms of fatigue through workplace training programs that have fatigue as their focal points. In addition, technologies such as alertness monitors and fitness for duty tests are becoming increasingly reliable and available to the shiftwork population and its managers. A review of the current state of alertness technologies is discussed in a white paper jointly developed by CIRCADIAN® and Caterpillar titled Operator Fatigue Detection: Technology Review.[33]

## Conclusion

The recent general acceptance of FRMS as the standard for managing and mitigating employee fatigue risk represents a significant maturation in the understanding of and response to this risk. There is much work to be done in moving from a dependence on the old and familiar prescriptive hours of service rules to a process that requires active management but also provides more flexibility. To accomplish this switch, organizations that implement FRMS must ensure that the system is firmly embedded in the health and safety management systems of the company and that it is rigorously maintained, carefully monitored and continuously improved upon. This process should all be part of the continuous cycle of managing the risk profile of any organization's management system. Provided it is properly designed, implemented and managed, FRMS offers a major step reduction in health and safety risks in 24/7 operations.

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# ABOUT THE AUTHOR

For 30 years, **Dr. Martin Moore-Ede** has been a leading expert on managing the risks of human fatigue in transportation and industrial businesses that operate 24/7. After experiencing the challenges of fatigue as a surgeon-in-training required to work 36-hour shifts, Dr. Moore-Ede was one of the first to define the challenges of living, working and sleeping in a 24 hour a day, 7-day a week world. As a professor at Harvard Medical School (1975 – 1998), he led the team that located the biological clock in the human brain that controls the timing of sleep and wake, and pioneered research on how the human body can safely adapt to working around the clock and sustain optimum physical and mental performance.

In 1983 Dr. Moore-Ede founded Circadian Technologies, Inc. (www.circadian.com), a research and consulting firm dedicated to reducing the costs and liabilities of managing a 24/7 workforce. As Chairman and CEO, he has guided the growth of the international network of Circadian companies "CIRCADIAN®" which now advises over half of the Fortune 500 companies on 24/7 work schedules and fatigue risk management. CIRCADIAN® also assists companies in obtaining regulatory waivers and exemptions, and provides expert services related to work-rest and Hours of Service regulations and fatigue impairment.

Dr. Moore-Ede graduated with a First Class Honors degree in Physiology from the University of London, and received his medical degrees from Guy's Hospital Medical School, and his Ph.D. in Physiology from Harvard University. He has published 10 books, and more than 145 scientific papers on human fatigue, errors and accidents and the physiology of sleep deprivation and circadian rhythms. Dr. Moore-Ede holds multiple patents on tools for assessing and mitigating fatigue risk including the Circadian Alertness Simulator (CAS) a scientifically validated fatigue risk model. He has served on multiple national and international committees, and has received numerous awards including the Bowditch Lectureship of the American Physiological Society. He is a frequent guest on television (CNN, Today Show, Good Morning America, 20:20, Dateline, Oprah Winfrey, Nova, BBC), radio (NPR Fresh Air, Connection), and print media (Wall Street Journal, New York Times, Washington Post, Time and Newsweek). He has testified before Congressional committees on multiple occasions, and advised government agencies on hours of service and working time regulations in the US, Canada and the U.K.

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