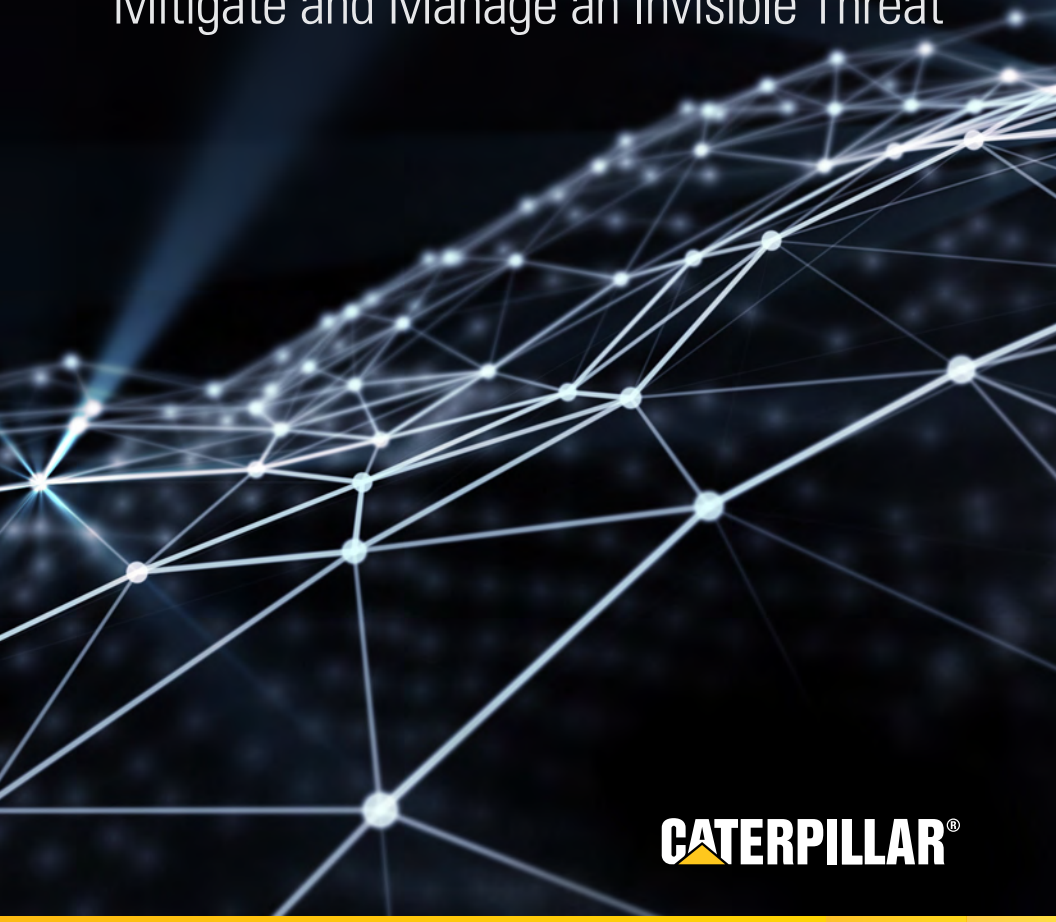
CATERPILLAR SAFETY SERVICES

Reducing Fatigue Risk

Optimize Technology and Culture to See, Mitigate and Manage an Invisible Threat



CATERPILLAR®

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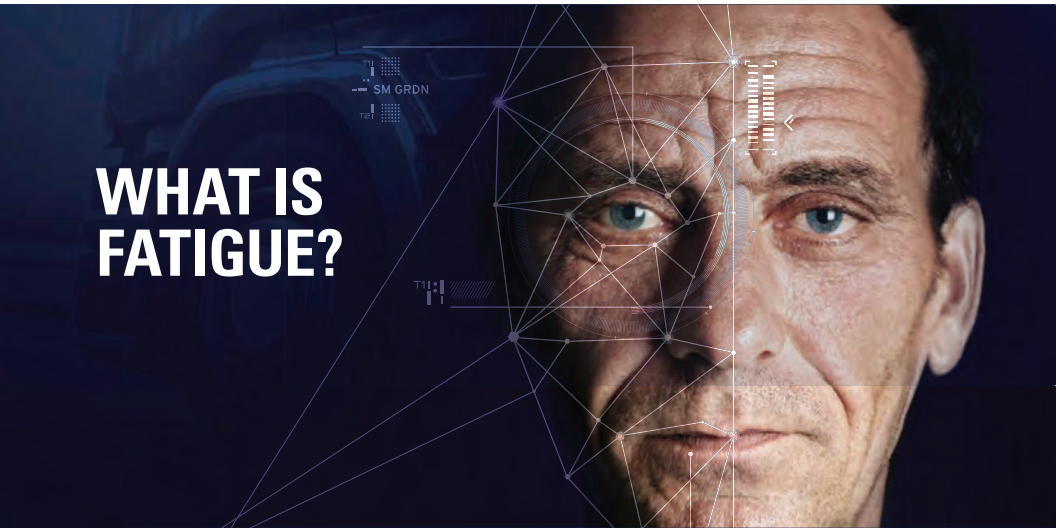
THE ROLE OF TECHNOLOGY IN FATIGUE MANAGEMENT

One of the most overlooked influencers in human error and accident causation is the effect of fatigue. It is often regarded as a contributing factor with no real solution, rather than a primary causal factor that can be prevented. This paradigm exists because fatigue is often believed to occur almost exclusively as a result of personal choice, when in reality, fatigue is inherent in human nature. The human body was designed to require certain levels of maintenance in the form of sleep at regular intervals and in specific amounts. For this reason, fatigue cannot be eliminated in the workplace however, it can be measured, mitigated and managed.

In the workplace, we often consider fatigue (or a lack of energy) the result of poor personal choices, such as unhealthy diet, lack of exercise or placing low priority on sleep; or as a result of poor character, like laziness, lack of motivation or apathy. However, the most common causes of worker fatigue are more closely associated with individuals' physiology, rather than their choices. This whitepaper will explain the causes of fatigue, the impacts that it has on the workplace and the role fatigue mitigating technologies and change management play in the broader fatigue risk management system



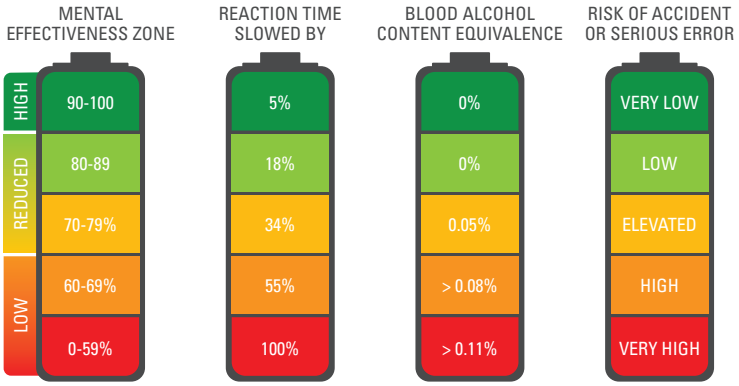
WHAT IS FATIGUE?

Fatigue is both a physical and mental impairment affecting one's alertness, attentiveness, mental and physical performance. The sources of fatigue for most shift-workers come from several key factors that include circadian physiology, choices about sleep, diet and exercise, shifts and rosters, physical or mental exertion and overall workload. The effects of fatigue include slower reaction times, reduced motor skills and decreased coordination as well as an increase in risky behavior, decrease in motivation and an overall reduction in performance.

In many ways, these symptoms are similar to that of intoxication. Dawson and Reid support this assertion, "… there is now scientific evidence that suggests when we're tired (or mentally fatigued) our ability to perform the simplest of tasks is impaired to the same level as if we were legally intoxicated!" (Dawson and Reid, 1997).

Using the latest in wearable technology, fatigue can be formally scored and measured against Blood Alcohol Content (BAC) impairment. A score of 100% indicates no fatigue and aligns with a 0.00 BAC. Once a person begins to lose hours, quality or regularity of sleep, his/her fatigue score decreases in conjunction with reaction times, motor skills and performance. At 70%, a score regularly seen

by shift-workers, miners and night-shift employees, the fatigue score correlates to 0.08 BAC; indicating the person is legally too drunk to drive in the USA and Australian road safety standards.



With the introduction of technology that can measure fatigue, it's not surprising many people thought the fatigue problem was solved.

At one point in the evolution of fatigue mitigation, fatigue-detecting technology was viewed as the "silver bullet". The science behind most of the technologies was solid and field studies showed positive results. However, after a flurry of installations of various technologies and millions of dollars spent on hardware and labor, fatigue remains one of the top five areas of concern for managers across multiple industries.

The science and psychology of fatigue management reveals that the implementation of a single technology forms only part of a much bigger solution; a solution that must incorporate multiple touch points and cultural change to be effective.

TECHNOLOGY FOR MEASURING AND MANAGING FATIGUE

There are many different types of technology available to measure fatigue levels and/or intervene when fatigue is detected. These include validated surveys like the Safety Perception Survey, fatigue modeling software such as a Fatigue Avoidance Scheduling Tool (FAST), sleep/alertness wearables like the Cat® Smartband – which provides a fatigue score – and in-cab fatigue detection solutions like the Driver Safety System (DSS). When these technologies are utilized together and supported by a culture of fatigue intervention and employee assistance, they form a comprehensive solution, typically referred to as a Fatigue Risk Management System (FRMS). The improper or ineffective introduction of technology can derail efforts toward the development and implementation of a FRMS. Similarly, when utilizing technology in a fatigue risk assessment, where baseline metrics around fatigue are determined, it is crucial to manage its introduction and use.

TECHNOLOGY

However, technology alone will not change some of the inherent problems and sources of fatigue within an operation, or the lifestyles of individuals. It may capture and mitigate the symptom of fatigue, namely falling asleep, but it will not necessarily impact the decisions that are made about behaviors related to sleep, fatigue and alertness outside of work. When used as a tool to train and educate a workforce on the impact of behaviors on and off the job, technology can have incredibly powerful positive results. Further, when technology is embedded in a comprehensive FRMS, the fatigue mitigation culture can develop further.

Too often, technology is installed or implemented without proper change management processes to ensure its success. This often creates significant hurdles for organizations who are faced with resolving tampering events, destruction of property and disengagement after implementation. It is far easier to spend time prior to installation, engaging with the workforce and creating dialogue to ease the introduction of new technology, rather than managing resistance once the technology is installed.

Supporting the introduction and installation of fatigue technology with proper change management processes forms the biggest single opportunity to ensure implementation success.

TECHNOLOGY

The three key steps to ensure the greatest value is obtained from any technology installation are:

1. **Have a process for identifying the problem.**
   A few of the questions that must be answered before selecting the technology solution include: What is the scale of fatigue risk we currently have? What is the cause of our fatigue problem? Does the technology solution fit the fatigue problem? Can we measure the scale of risk as well as the impact of the technology on operator fatigue?

2. **Fit the solution to the problem.**
   Ensure that the fatigue solution truly fits and addresses the core problem. Is the source related to the schedule? The policies for overtime? Limits on hours of work? Long, monotonous hours of work? Are multiple technologies required? Is there a need to assess or change policies, practices and procedures? The answers to these questions determine which technology may best be suited to identify, intervene or measure the situation creating the fatigue.

3. **Manage the change.**
   Regardless of the technology, this is by far the most important step in ensuring a successful implementation. In the absence of change management, complete failure or severely reduced results will be the outcome. Key tasks to this change management include:

   a. Educating all involved parties

   b. Develop clear procedures for outcomes

   c. Follow up and improve

Supporting the introduction and installation of fatigue technology with proper change management processes forms the biggest single opportunity to ensure implementation success.

A Tale of Two Implementations

A case study comparing two mine sites clearly shows the reduced performance of technology when the change management process is not followed. **Mine A** effectively managed the change using the key tasks listed above as well as incorporating the technology and a holistic FRMS. **Mine B** simply installed the technology without any consideration of the reaction it may cause and without the layers of protection in an FRMS; such as training and education on fatigue, policies, schedules and procedures that minimize fatigue risk and a culture that supports actively managing personal and operational fatigue.

Site no. 1
Holistic Fatigue Management Solution

Worked openly with employees
Educated on fatigue mitigation
Established consistent guidelines
Management out in open
Events as coaching opportunity

Tampering Events: 13
Fatigue Event Reduction: 82%

Site no. 2
Technology Only / "Silver Bullet Approach"

Employees told nothing, rumor mill
No training, no understanding
Management response varies by supervisor/shift
Management unseen
Events meant automatic discipline

Tampering Events: 375
Fatigue Event Reduction: 44%

The results are drastic: Not only is the outcome less than desirable in terms of fatigue reduction, but additional time, resources and money were lost through the need to repair and replace portions of the in-cab technology. These costs came from the technology mysteriously "falling off" or accidentally being adjusted with hammers, hands or boots. Further, some became very expensive hat and coat hooks in the cab. These situations invariably increase significantly when proper steps are not taken prior to, during and following the installation of the technology. Many, if not all, of these negative outcomes can be avoided by taking the time and allocating resources to educate the workforce on the technology and develop clear procedures for its use.

REAL WORLD RESULTS

Following are sample results gathered from several fatigue risk assessments conducted at mines from across the globe. These include fly in – fly out operations, mixes of "camp" and "town" employees, and different safety cultures and maturity levels around fatigue.

Coal Mine, Australia

At a large coal mine in Australia, it was widely recognized that shift work inherently led to fatigue, particularly while working night shifts. To better understand the impact of the working hours and identify opportunities for individual shift workers to improve their sleep quality and quantity, the site conducted a Cat Smartband study. Twenty-five volunteers were invited to act as a test group for the study. The 25 volunteers wore the Cat Smartband continuously for four weeks to capture a set of night shifts, a set of day shifts and days off in between. At the conclusion of the data collection period, the Cat Smartbands were collected and returned to Caterpillar Safety Services' fatigue risk experts for download and analysis. Group statistics were then presented to site managers and volunteers. Volunteers also received personal and confidential one-on-one reviews of their data with the experts.

REAL WORLD RESULTS

The benefits of inviting subject matter experts to conduct the initial change management sessions were seen very quickly. There is typically some difficulty securing volunteers prior to the expert's arrival on site. However, over the course of an hour-long information and Q & A session with the crew, there were more volunteers than available Smartbands. Once people understand the technology, what will be done with the data and how it can benefit them, most are very agreeable to participating.

One of the key benefits individuals received was the individual counselling about their results. Through these individual sessions, participants found that there were differences in the quality of sleep as well as the impact of reduced sleep on their alertness. Further, several individuals held suspicions that they may suffer from a sleep disorder. The results supported these "hunches" and enabled a more specific discussion around next steps to begin medical diagnosis and treatment. This is incredibly powerful as certain sleep disorders such as sleep apnea are well known to significantly increase the risk of incidents at work.

The simple act of making employees aware of their sleep habits and resulting alertness also makes enormous changes to the organization's culture. A common break room conversation often revolves around how little sleep one got before work. The less sleep, the more prestige someone has. You can imagine the site supervisor's pleasant surprise at hearing the conversation turned around into a competition about who got more sleep the night before and who had the higher alertness and effectiveness score on their Cat Smartband.

The results of the sleep study supported several notions held by the site including reduced alertness during night shift. One of the key discoveries, however, was the drop in alertness from the first to the second day shift after days off. This was the result of individuals going from days off to a much earlier than desired wake time to start shifts. By the third day, individual circadian rhythms and routines adjust to the early wake time. Another key discovery was the significantly improved sleep quality achieved whilst sleeping in camp, as compared to sleeping at home. Site-based operators achieved more consistency in wake and sleep times, improving their fatigue score considerably from those who drove to and from the site.

Gold Mine, Western United States

A large open pit gold mine in the western United States was contemplating what level of fatigue may exist in its operation and what technology and countermeasures may be able to address it. To achieve this, Caterpillar deployed the Cat Smartband, DSS, FAST and undertook an extensive analysis of machine data throughout a 90-day site assessment. During this time, 40 volunteers from various job tasks wore the Cat Smartband for 60 days whilst the DSS was installed on five haul trucks for 90 days. Using the data from the Cat Smartband, a FAST analysis was performed on the work schedules and machine data was collected on the five trucks that were installed with the DSS. During the 90-day assessment, change management meetings were held with all production employees to deploy the Cat Smartbands to volunteers, provide information about the project, answer questions and clearly define expectations.

REAL WORLD RESULTS

There were several key findings from the analysis of the various sources of data. First, there were more than 140 fatigue events (eye closures greater than 1.5 seconds while driving) captured during the initial phase of the DSS monitoring. In the initial phase, the in-cab alarm which would alert the driver to fatigue or distraction events is not activated; this enables a clear baseline of events to be identified. In the final phase of the DSS study alarms initiate immediately when a fatigue event is detected. With the introduction of the DSS alarms, the site saw a 56% reduction in fatigue events. After each event a follow-up process and intervention plan are enacted to manage the safety of the driver.

Following the drop in fatigue events, there were also changes in operator driving behavior visible in the machine data. Event codes related to operator driving were screened out, including hard breaking, hard shift and driving with body raised. Over the course of the DSS assessment, the occurrence of these events decreased by 13% in trucks running the DSS. Numerous studies demonstrate that fatigue impacts how operators perform while driving or operating equipment. The results of this assessment further support those findings.

An assessment of the shift roster indicated some inherent challenges resulting from early shift start times that were increasing the number of fatigue events experienced by the site. Both the Cat Smartband and the FAST analysis showed lower than expected sleep quantities and poor quality sleep compared to other shiftwork/mining environments. This translated into nearly double the number of fatigue events captured by the DSS when normalized and compared to other similar sites. "What-if" modeling of minor changes indicated some "low hanging fruit" that would immediately improve the ability of operators to achieve more sufficient rest. This has proven a valuable resource for site managers as they continue to improve the safety and effectiveness of their operators.

Potash Mine in Southern United States

A mine in the southern United States, similar to the one in the western United States, believed it had some challenges with fatigue but was unable to determine the extent or true risk to its operations. Caterpillar deployed the Cat Smartband, DSS, Operational Analysis and FAST to identify the risk and find potential improvements. One of the key findings is in the strong correlation between the Cat Smartband scores and the number of DSS fatigue events captured.

REAL WORLD RESULTS

A simple alignment of the data showed a very strong correlation between operators who had the lowest effectiveness scores and the highest number of DSS fatigue events. This speaks to both the predictive value of the Cat Smartband as well as the ability of the DSS to capture events related to fatigue.

Another key event at this site shows the personal and individual benefits that result from the change management, technology and ongoing monitoring of the technology. A particular individual was consistently and regularly experiencing fatigue events. A safety advisor in the Caterpillar DSS Monitoring center noticed that the person was also constantly squinting during the video clips captured by the DSS when an event was detected. The advisor flagged one of the fatigue events and during a follow up visit to the site, was able to meet privately with the operator. Through a conversation and discussion, they determined that the operator's eyesight was partially responsible for the fatigue result and was causing the squinting. They were able to put the operator on a path to correcting his vision.

All of these examples highlight some of the powerful benefits that can be achieved through the implementation of technology into a culture that is prepared to accept it. While the technology alone can provide some benefits to reducing fatigue, the optimal benefit is derived when not only the operators, but also the supervisors and managers understand it, believe it is beneficial and support it. One particular site in western Canada implemented cultural change management by opening the information/education sessions to all employees, including administration, maintenance, and processing. A production manager on this site questioned the site fatigue champion about why some of the "fatigue meetings" were going over by 5 or 10 minutes. Later, after attending one of the presentations given to a production crew, the manager retracted his earlier skepticism and told the fatigue champion the information shared was "too important to cut short". That particular site consistently has among the lowest fatigue events per mobile hour across all sites currently utilizing the DSS.

ADDITIONAL INFORMATION

Cat Smartband – A wrist-worn sleep device that helps you understand the connection between operator sleep, fatigue and accident risk. The Cat Smartband monitors quantity and quality of sleep, using this information to calculate an effectiveness score that is viewable by the wearer at any time. Caterpillar fatigue experts download the sleep data to generate detailed reports for further analysis, fatigue management and wearer education.

Driver Safety System (DSS) – A non-intrusive, instant, in-cab fatigue and detection system for operators. The DSS monitors eye-closure duration and head pose; the moment an event is detected an in-cab alarm and seat vibration system instantly alert the operator. At the same time, monitoring experts classify and confirm each event to provide customized reporting, site-level recommendations and educational support.

The DSS integrates seamlessly into mixed truck fleets, providing 24/7 operator protection.

APPENDIX

Fatigue Avoidance Scheduling Tool (FAST) – Data analysis software that identifies fatigue vulnerabilities and models optimal work schedules and roster designs. FAST utilizes individual and group sleep data to generate detailed performance predictions and site wide shift solutions.

Fatigue Risk Assessment (FRA) – A 90 day assessment empowering leaders with knowledge about fatigue and distraction, whilst revealing the scale of risk on site. Combining the DSS, Cat Smartband and FAST tools, the FRA culminates in a detailed analytic report that clearly depicts operational risk and can overlay VIMS™, Cat EMSolutions™ and other machine data for intensive review.

Fatigue Risk Management System (FRMS) – A solution that leverages your people, processes, technology and environment to create a highly customised and sustainable fatigue risk management plan that utilises continuous improvement and change management principles. The FRMS process is a holistic solution providing you and your leadership team with the knowledge and tools to deploy the layers of risk protection you need to mitigate and manage fatigue.

Safety Perception Survey (SPS): A tool used to determine the current risk profile of your organization and understand the cultural drivers within your business. Create a strategic improvement plan aligned to your specific business needs and, use the SPS to benchmark your results against world-class safety organisations.

No matter what industry you work in or what equipment you use, your first priority is the safety of your employees. Keeping your people safe is more important than anything else. Caterpillar agrees, and we're committed to helping you make sure everyone who works in, on or around Cat equipment comes home safe every day.

LEARN MORE?

For more information on any of the fatigue technolgies discussed in this paper, email: safetyservices@cat.com or visit CAT.COM/SAFETY

To book a fatigue and distraction technology assessment on your site, call: **1800 000 288**

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