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COPEC

CASE STUDY

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Fatigue safety standards at the leading company in fuel distribution in Chile. Implementation of Gauss Control and a FRMS.

Written by José Rafael Campino, October 2018.

In the first semester of 2018, incidents rate (severe accidents divided by miles traveled) in heavy duty vehicles from COPEC at Mejillones' division, went down by 68 percent compared to the same period in 2017. This was possible because of the implementation of Artificial Intelligence (IA) algorithms that identify the most fatigued drivers and management software that recommends strategies to intervene these drivers, both tools were developed by Gauss Control. This methodology was based in different studies of the Circadian Rhythm, including studies and best practices delivered by CIRCADIAN (the world leading company in human fatigue management).

COPEC is the leader in fuel distribution in Chile, with a market share of around 60%, and with 85% of the market supplying fuel to mining; Chile's main economic activity and an industry with very high safety standards.

For this company, safety is the most important value of its operation. That’s why it has been leading safety standards in Chile for years. During years of work it had achieved significant reductions in incidentability. However, the company faced a problem: efforts to improve safety were growing substantially but the results were practically the same. In the search for new horizons in road safety, they decided to implement Gauss Control technology because it had

a different approach to the conventional and realized that there was an opportunity to apply innovative and high impact methodologies.

Fatigue involves an extreme feeling of tiredness and a reduction of the body's abilities. It affects our behavior and decisions, putting us in risk. Basically, fatigue is generated in our body because of a sleep deficit. Is not only about "how much we sleep" but also "when". Alertness varies during night and day and practically, our body is designed to sleep during night. That explains why drivers that work between 3 and 5 in the morning, have 15 times more chances to suffer a severe or tragic accident.

A study we realized with COPEC, began with the data processing of more than 24 thousands trips of Transcom, Transportes Casablanca and Linsa companies through a 4 years historical database. With this information and the industry benchmark, Gauss Control implemented the CAS, fatigue bio-mathematical model developed by CIRCADIAN, being able to estimate drivers' risk based on the knowledge and behavior. This study, elaborated with PUC professors and CIRCADIAN's CAS model, was the inspiration for Gauss Control. From that moment, our mission has been saving humans lives through safety and fatigue solutions based on predictable models.
By 2015, Gauss Control did a consulting job which included a fatigue assessment using the biocompatibility of shifts, historical accidents database and a survey of the company's drivers considering demographic, sleep disorders, knowledge and risk factors. One of the biggest discoveries was that drivers' perception showed that fatigue is the riskiest factor at work.

Gauss Control introduced the electronic hours of service data (HOS) in one of our predictive models to identify which was the most dangerous operation so they could elaborate measures to mitigate the risk. We included a Fatigue Risk Management System (FRMS) to attack fatigue in a strategic way: bio-compatibility of shifts, alertness monitoring during shift and fatigue training.

MATHEMATICAL MODELS

For this case study, 2 mathematical models were used: Circadian Alertness Simulator (CAS) and Cumulative Fatigue Level (CFL). The CAS model, developed by CIRCADIAN Technologies, allows to estimate the biological compatibility of shifts structure of a company, detecting the operations exposed to greater risk due to human fatigue and the causes of this risk. The CFL artificial intelligence algorithm, developed by Gauss Control, predicts the fatigue risk for the next work day for each driver, so the Gauss Control software can recommend mitigation strategies.

HOW DO THESE MODELS WORK?

1. CIRCADIAN ALERTNESS SIMULATOR (CAS)

The CAS model predicts the risk by analyzing the biocompatibility of a driver within a shift using the last 14 days of duty and rest logbook data for each driver, returning an Fatigue Index that ranges from 0 (not fatigued) to 100 (extremely fatigued).
This model is basically composed by 2 processes that simulate the daily alertness (the homoestatic process -or sleep pressure- and the circadian rhythm) and a sleep prediction in a window of opportunity. The parameters of the model functions for circadian and homeostatic components were determined through an optimization algorithm for data fitting, using 10,000 days of sleep-wake-work data from transportation employees working their normal duties.

Circadian Rhythm

All human beings have an internal clock (SCN) that regulates a large number of physiological processes with a 24-hour pattern. We can see patterns of brain wave activity, cell regeneration, hormone production and other biological activities. Also, it correlates with our alertness levels, reaction times, and consequently the likelihood of suffering a severe accident.

Sleep Pressure

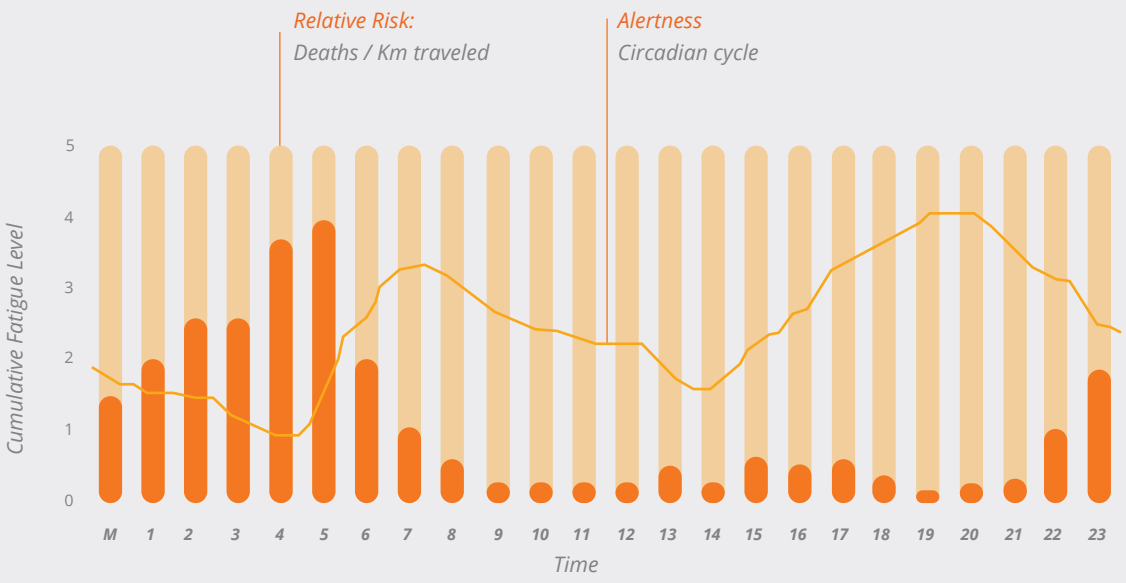
Fatigue increases in our body when we stay awake for several hours. Our brain accumulates adenosin -a chemical which make us feel tired- and drives us to sleep. Studies show that the performance of a person

who has been awake for 20 hours is equally impaired than having more than 0.08 degrees of alcohol in the blood (over the legal limit.

Currently this model has been shown to present significant correlations with severity and frequency of truck accidents worldwide, and a 98% correlation with the percentage of time driving while drowsy.

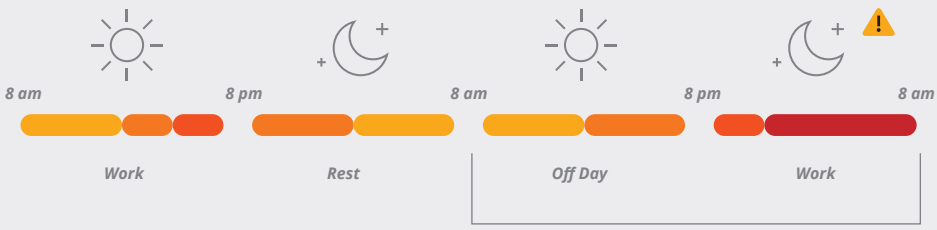
CIRCADIAN RHYTHM

Fig. 1



SLEEP PRESSURE

Fig. 2



Driver awaken for 22 hours = 0,8 grs of alcohol in the body.

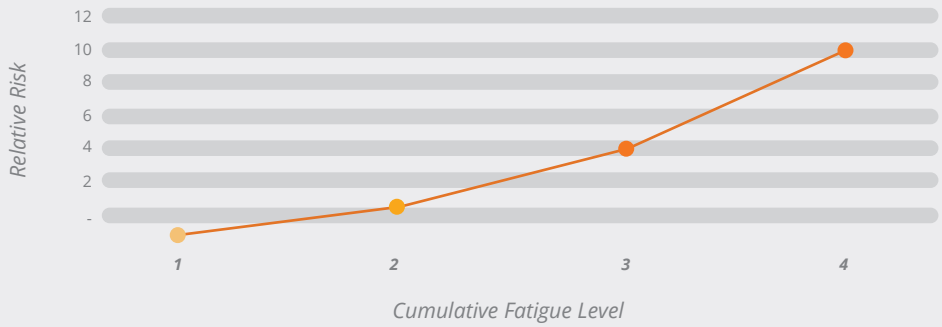
2. CUMULATIVE FATIGUE LEVEL (CFL)

This AI algorithm predicts the probability of occurrence of at least one micro sleep event (MSE) for the next work-day of a driver (next 24 hours). To make these predictions, the model considers certain information available of the driver, such as KPIs of the last 14 days of duty and rest logbook data (duration of the workdays, consecutive days worked, time of day, breaks duration, rotation of start/end times, among others) and driver profile (fatigue knowledge, health, chronotype, demographics); but it can also consider the micro sleep events of the last 14 days of the driver in case of having computational vision cameras that detect the occurrence of these events while driving, and real quantity and quality of sleep in case that the driver is using sleep wearables (such as Fitbit). The CFL delivers a value that ranges from 1 (little fatigued) to 4 (very fatigued).

When a driver has CFL equal to 1 it means that he has less than a 2% chance of having an MSE during the next workday (see graph table nº 3); but if the driver has a CFL equal to 4 it means that he has more than a 20% chance of having a MSE during his next workday. In case the driver presents CFL greater than or equal

CUMULATIVE FATIGUE LEVEL

Fig. 3



DRIVER FATIGUE AND MICRO SLEEP EVENTS

Fig. 4

Cumulative Fatigue Level	Probability Range (Model)		Experimental rate	% Total days of works	% Total MSE	Relative risk to CFL = 1
	Min Range	Max Range				
11	0%	2%	,7%	20%	6%	1x
24	2%	10%	,1%	58%	38%	2x
3	10%	20%	10,6%	11%	19%	6x
4	20%	100%	20,3%	11%	37%	12x

to 3 (over 10% likely to have an MSE) the Gauss Control software immediately recommends implementing mitigation strategies, such as scheduling a more bio-compatible trip and planning countermeasures to maximize the alertness while driving.

This algorithm is regularly calibrated using thousands of MSEs that Gauss Control receives from its clients every month. This is why currently the algorithm is highly predictive and capable of finding new risk patterns that for an expert consultant would be practically impossible to recognize. One of the advantages of using artificial intelligence is that computers (machines) are capable of learning faster than any expert (machine learning).

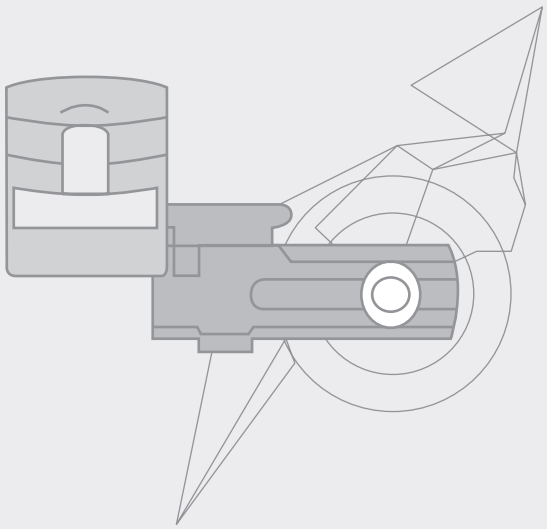
The output label selected was MSE because it is available in a large number of trucking companies that have computational vision cameras that detect the occurrence of MSE (Gauss Control clients) and when they happen it is probable that it ends in a fatal accident.

Driver fatigue and Micro Sleep Events

In general, driver fatigue can be characterized by many characteristics, such as a decrease in mental and physical performance, reduced alertness, loss of cognitive and logical reasoning skills, impaired judgment, reduced motor coordination, slower reaction time, distraction, mental lapses, erratic behavior, and ultimately the occurrence of Micro Sleep Events.

Fatigued drivers are often unaware of their condition, often driving repetitive episodes of 1.5 –12 seconds with their eyes totally closed, where they are mentally incapable of evading potential accidents and unable to respond to external events. In this case, the brain was disconnected for a few moments. The most frightening thing about MSE is that they happen mostly without knowledge or forewarning; if something changes in the trajectory, like another vehicle or a curve, the driver will not be able to react to minimize the impact and the consequences are usually terrifying.

MICROSLEEP SENSOR *Fig. 5*



BIOCOMPATIBILITY

The first two questions that we had to answer were: Where is the highest risk? What can we do to reduce it? To understand the biocompatibility of shifts we followed a 4 steps methodology:

- Assessment:
  Drawing a base line of fatigue risk for every driver by using the historical data and CAS model.
- Shifts simulation:
  Analyzing multiple choices of shifts structures and their biocompatibility levels.
- Optimization:
  Choosing the most convenient shift structure in terms of cost and efficiency. We understand that clients must create a balance safety between productivity.
- Implementation and monitoring:
  By using Gauss Control software, the client can monitor and manage the risk in the operation by creating specific tasks for supervisors.

Every day the Gauss Control software calculates the biocompatibility risk for the operations of its clients. The methodology consists of periodically reviewing this risk and performing simulations to optimize it. It is a process of continuous improvement.

In the case of COPEC, a group of medium-high risk operations was identified where the methodology described above was applied. The following is the case of Operation "CODELCO Radomiro Tomic".

EXAMPLE OPERATION "CODELCO RADOMIRO TOMIC"

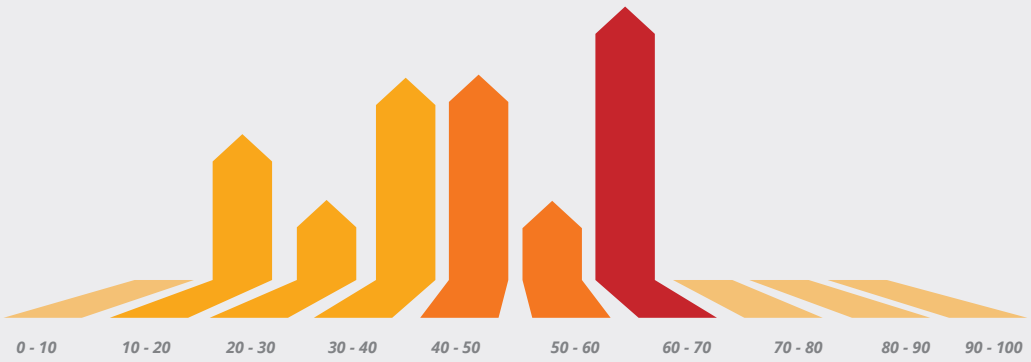
As a result of the process, we discovered that one of the riskiest operations in COPEC, in terms of biocompatibility, was the distribution of fuel from Mejillones Division to CODELCO Radomiro Tomic. There was a 6x1 shift structure with workdays lasting up to 14-16 hours (due to the distance of the mining site with respect to the plant where they load fuel). Because COPEC demands theirs drivers a 12 hours rest between workdays, next day workhours were supposed to start 4 hours later than the day before, which meant that in 6 days drivers could go around the clock (6x4 equal to 24 hours). This type of situation caused a desyncronization in the biological clock of these drivers, equivalent to having jet lag, for which the body did not know when it had to sleep or work.

With Gauss Control's recommendations, this operation changed their shift to a 2x2 format. This allowed to obtain 2 benefits: by having only 2 days

of consecutive work the driver minimized consecutive work rotations that de-synchronize the biological clock and are able to maintain more regular work schedules; the 2 days of rest allow recovering the debt of sleep to the driver. In the graphs illustrated below it is possible to observe that the risk of this operation was considerably reduced.

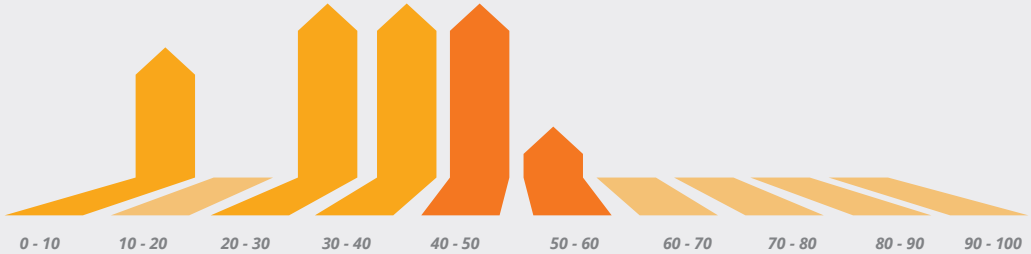
SHIFTS BIOCOMPATIBILITY - BEFORE MODIFICATION

Fig. 6



SHIFTS BIOCOMPATIBILITY - AFTER MODIFICATION

Fig. 7



ALERTNESS AND MONITORING

Although biocompatibility is very important, the unpredictable and chaotic nature of transport operations does not allow for very regular shift structures. Every logistic operation has demands that vary from day to day, for example one day a driver can make a trip to a mining company, but the next day to a service station. It is very difficult to program a driver in windows of several days because waiting times are highly variable, traffic on the routes is also relatively unpredictable and transport times are affected by weather conditions or road accidents. That is why, in addition to the biocompatibility module, Gauss Control developed the Cumulative Fatigue Level, an algorithm to help drivers, supervisors and dispatchers plan for "tomorrow".

As explained before, the platform processes millions of data points to identify the most fatigued drivers and apply a mitigation plan. This plan has 2 stages: a programming of a biocompatible trip and the application of measures to maximize the alertness.
The first stage is carried out every day by the dispatchers. They receive tasks for each fatigued driver and simulate a trip where the chances of having an MSE are considerably lower (or a 24-hour break). The tasks have to be executed in a period of less than 24 hours.

The second stage is generated exclusively for drivers who were scheduled on work days that present a medium-high risk. For them a trip is planned where the supervisor must support the driver to implement countermeasures to maximize his alertness; such as breaks to take naps (particularly before dawn), administer caffeine responsibly, detentions every 90 minutes to perform active pauses or walking, among others. These countermeasures are very well detailed in the Gauss Control platform and were taught to drivers and supervisors in the Gauss Control training program.

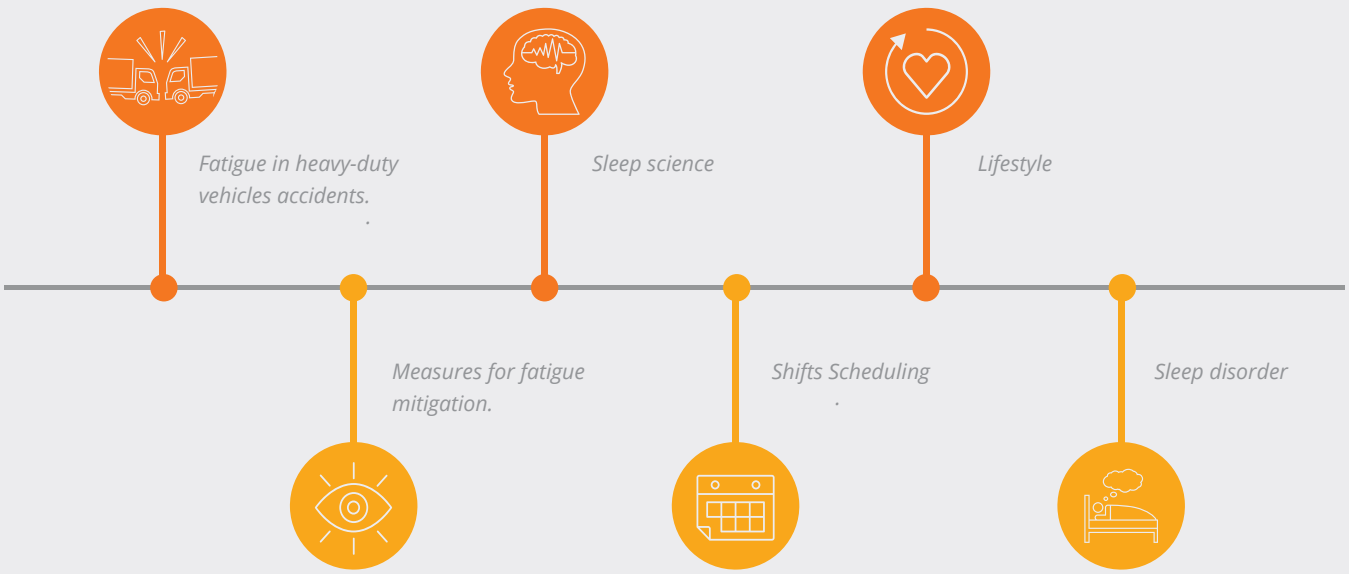
With all these measures COPEC's risk at the Mejillones division was considerably reduced, but the predictive models detected that there were still certain operations that were exposed to a certain level of fatigue risk. For these operations (15% of the fleet) it was recommended that they install computer vision cameras that detected MSE while driving and wake the driver. These cameras not only served to incorporate a last barrier of defense, but also every time an MSE happened it was used to train the CFL algorithm, identifying new risk patterns.

FATIGUE TRAINING

COPEC already demanded a fatigue and somnolence training program to their drivers. We started a project to introduce an eLearning program for each drivers which includes all necessary topics. The positive thing is that drivers may study and do tests from their computers. The platform allows managers to supervise who is failing on tests and why, creating specific tasks to help them to 'catch up' easily.

Training is also important to every person in the company, so just add a list of users and will be doing the right thing.

E-LEARNING TOPICS



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KEEP DRIVERS SAFE

Gauss Control is a top solution in human fatigue administration in Chile, implemented in the most important mining holdings and dangerous materials contractors.

It is a cloud based solution built on a Fatigue Risk Management System (FRMS) which allows users to identify and manage risk in a strategic way.

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