



Chair of Mining Engineering and Mineral Economics

Master's Thesis

Evaluation and optimization of a 24/7-mine  
from the safety, operational and  
organizational point of view

Nikita Libman

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**MONTANUNIVERSITÄT LEOBEN**

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**AFFIDAVIT**

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I declare that I have read, understood, and complied with the guidelines of the senate of the Montanuniversität Leoben for "Good Scientific Practice".

Furthermore, I declare that the electronic and printed version of the submitted thesis are identical, both, formally and with regard to content.

Date 07.02.2023

Signature Author  
Nikita Libman

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## Declaration of Authorship

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„I declare in lieu of oath that this thesis is entirely my own work except where otherwise indicated. The presence of quoted or paraphrased material has been clearly signaled and all sources have been referred. The thesis has not been submitted for a degree at any other institution and has not been published yet.”

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## Abstract

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This master thesis is performed in a collaboration with VA Erzberg mining company – the largest open pit hard rock mine in central Europe. According to this fact the extraction processes are being performed 24 hours and 7 days a week. Thus, a fatigue monitoring system is planning to be implemented in order to mitigate dangerous situations during night shifts. In order to do so an investigation of possible systems on market and their comprehensive evaluation has been conducted. This paper work provides a suggestion of one company (producer or provider of a technology) that better fits in terms of quality, costs and efficiency.

Another task is the optimization of a traffic flow control in the mine. A solution on how to improve the current truck dispatch system has been developed. The improvement of the current system is performed with a Python script. The program conducts an analysis of every dump truck's movements during the whole day and creates a report. It includes several graphs with the crucial metrics and a brief overview of every machine performance. Based on this information the mine management can check the results of every truck's work and make necessary optimizations.

The study involves a comprehensive review of the literature on data analysis and fatigue monitoring systems in the mining industry, as well as case studies of companies that have successfully applied these technologies to their operations. The findings of the study suggest that data analysis has the potential to improve production planning and optimize resource utilization. Meanwhile fatigue control systems can enhance safety and environmental management in the mining industry. In conclusion, this study demonstrates that data analysis can play a vital role in improving the competitiveness and sustainability of the mining industry.

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## Zusammenfassung

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Diese Masterarbeit wird in Zusammenarbeit mit der Bergbaugesellschaft VA Erzberg – dem größten Hartgesteintagebau Mitteleuropas – durchgeführt. Dementsprechend werden die Extraktionsprozesse 24 Stunden und 7 Tage die Woche durchgeführt. So soll ein Ermüdungsüberwachungssystem implementiert werden, um Gefahrensituationen während der Nachtschichten zu entschärfen. Dazu wurde eine Untersuchung möglicher Systeme auf dem Markt und deren umfassende Bewertung durchgeführt. Diese Arbeit bietet einen Vorschlag für ein Unternehmen (Hersteller oder Anbieter einer Technologie), das in Bezug auf Qualität, Kosten und Effizienz besser passt.

Eine weitere Aufgabe ist die Optimierung einer Verkehrsflusssteuerung im Bergwerk. Es wurde eine Lösung zur Verbesserung des aktuellen LKW-Dispatch-Systems entwickelt. Die Verbesserung des aktuellen Systems wird mit einem Python-Skript durchgeführt. Das Programm führt den ganzen Tag über eine Analyse der Bewegungen jedes Muldenkippers durch und erstellt einen Bericht. Es enthält mehrere Grafiken mit den entscheidenden Metriken und einen kurzen Überblick über jede Maschinenleistung. Anhand dieser Informationen kann die Minenleitung die Ergebnisse der Arbeit jedes Lkws überprüfen und notwendige Optimierungen vornehmen.

Die Studie umfasst eine umfassende Überprüfung der Literatur zu Datenanalyse- und Ermüdungsüberwachungssystemen in der Bergbauindustrie sowie Fallstudien von Unternehmen, die diese Technologien erfolgreich in ihren Betrieben eingesetzt haben. Die Ergebnisse der Studie deuten darauf hin, dass die Datenanalyse das Potenzial hat, die Produktionsplanung zu verbessern und die Ressourcennutzung zu optimieren. Unterdessen können Ermüdungskontrollsysteme das Sicherheits- und Umweltmanagement in der Bergbauindustrie verbessern. Zusammenfassend zeigt diese Studie, dass die Datenanalyse eine entscheidende Rolle bei der Verbesserung der Wettbewerbsfähigkeit und Nachhaltigkeit der Bergbauindustrie spielen kann.

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## Table of Contents

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Declaration of Authorship .....	II
Abstract .....	III
Zusammenfassung .....	IV
Table of Contents .....	V
1 Introduction .....	1
2 Chapter I. Fatigue monitoring systems .....	3
2.1 Aim of the subtopic №1 .....	4
2.2 What is a fatigue? .....	5
2.3 Overview of the fatigue monitoring systems .....	5
2.4 Hexagon company .....	6
2.5 Optalert company .....	8
2.6 Ramjack company .....	11
2.7 Komatsu system .....	16
2.8 Comparison of the systems .....	18
2.9 Conclusion .....	20
3 Chapter II. Traffic Flow Control .....	21
3.1 Aim of the subtopic №2 .....	23
3.2 Data overview .....	24
3.3 Framework determination .....	25
3.4 Data familiarization and preprocessing .....	26
3.5 Data Analysis .....	28
3.6 Analysis of the movements .....	28
3.7 Idling locations .....	33
3.8 Idling time .....	36
3.9 Validation of the results .....	46
4 Conclusion .....	49
4.1 Conclusion overview of the Subtopic №1 .....	49
4.2 Conclusion overview of the Subtopic №2 .....	50
5 Bibliography .....	53
6 List of Figures .....	55
7 List of Tables .....	56
8 Annex .....	57
8.1 List of fatigue monitoring companies .....	57
8.2 Commercial offer from Hexagon .....	59
8.3 Commercial offer from Optalert .....	60
8.4 Commercial offer from Ramjack .....	61
8.5 Commercial offer from Komatsu .....	64
8.6 Output files as a result of the program's work .....	65

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# 1 Introduction

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Located 190 kilometers south-west of Vienna and 80 kilometers north-west of Graz, the Erzberg mine is one of the biggest open pit mines in central Europe. The greatest iron ore deposits in Austria are located in Erzberg, where there are thought to be 235 million tons of ore reserves. The graywacke zone encompasses Erzberg. It is regarded as having the greatest siderite ( $\text{FeCO}_3$ ) deposit in the whole globe. The mined material also contains dolomite, which is rich in iron, and ankerite in addition to siderite. The iron concentration ranges from 22% to 40%, with an average of around 33.5% due to the combination with less iron-rich rocks (Erzberg, Article about Erzberg on Wikipedia, 2022). The extracted raw minerals are sent by rail to the nearby steel plants in Leoben and Linz. They belong to a large international steel company Voestalpine.

Erzberg mountain is 1466-meter-high and has a total of 24 terraced levels. Mining is currently only operated up to the 21st level. These levels are named after saints or deserving miners (VA Erzberg, Information from the official website of the VA Erzberg company, 2022). On the figure 1 there is a view on the mine site and surrounding landscapes of the Alpine region.



Figure 1. Erzberg mine (Gerald Senarclens de Grancy, 2007)

The mine site is a crucial economic center in the Styria region. The mining operations are carried out 24 hours and 7 days per week. In order to keep the production flow without interruptions and on a decent level a precise work of all the units and departments is required. This would not be able but with a help of modern dispatch and communication systems. Around 230 employees are involved in various mining operations day and night. Some of the processes could be really dangerous and some things cannot fully depend on a human being despite the skills and experience. Luckily there are now quite a lot digital and technological solutions that help mining engineers and workers.

This master thesis will cover some of the most modern and effective digital solutions on the improvement of the mining processes. The whole project is divided into 2 main chapters that reflect each subtopic. Every subtopic describes a certain business case and proposes a solution based on evaluation and comparison of different metrics. Thus, the first subtopic is dedicated to a fatigue monitoring system and the second one – to an improvement of the current truck dispatch system.



## 2 Chapter I. Fatigue monitoring systems

As the Erzberg mine is being operated around the clock it is necessary to always keep all the processes in safe conditions and with high efficiency. This means that employees who work especially during the night shifts have to stay concentrated in tough conditions.

At the moment there are 3 shifts during a day. Each shift is about 8 hours long. A shift change lasts for approximately 15 minutes. This principle is called a 'hot seat change'. It means that an engine of a dump truck is never switched off except maintenance or breaks. A time table is shown on the figure 2.

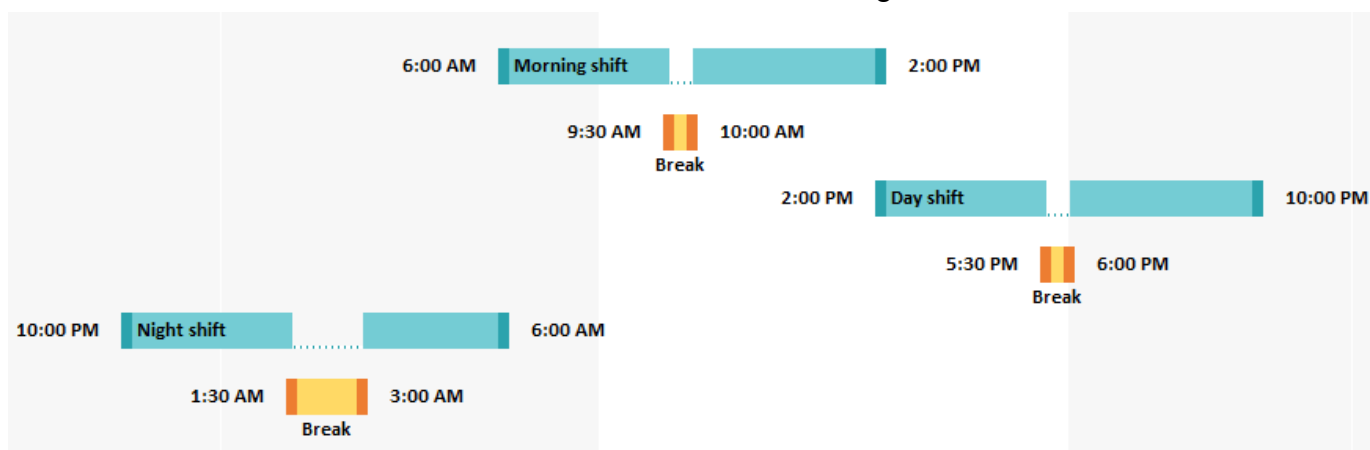


Figure 2. Time table

The fleet consists of 9 Komatsu and 7 Liebherr dump trucks. There are 11 dump trucks which always work at the same time in the mine. It means that at least 11 truck drivers operate simultaneously during every shift. In addition, there are always 10 additional stand-by drivers.

Every dump truck performs a repeated sequence of actions: loading of ore → transportation → unloading of ore. It is called a cycle (figure №3). Every cycle can last from 10 minutes up to 60 minutes. There are a lot of things which influence the whole cycle: loading of ore by an excavator, skills of operators, locations of loading and unloading points, path in the mine, obstacles and other vehicles that can appear on the way, breaks and weather conditions. The shorter the cycle the more ore is transported which means more production ratio and revenue in the end.

Capacity of each dump truck is 120 tons. The total weight of a fully loaded vehicle can reach 200 tons. Usually there are from 7 to 20 cycles per shift which means that a dump truck covers from 20 to 50 km of distance during 8 hours. In other words, by the end of a shift there should be 840 – 2400 tons of transported ore. This means,

that each cycle is essential for the overall production and there is a lot of responsibility on every driver.

The most potentially dangerous time period is during the night shift. It has already been proven by scientist and doctors that the best time to go to sleep is before midnight. After 12 am a person tends to feel tired more with each hour of being active. It is a potential risk for everyone in the mine.

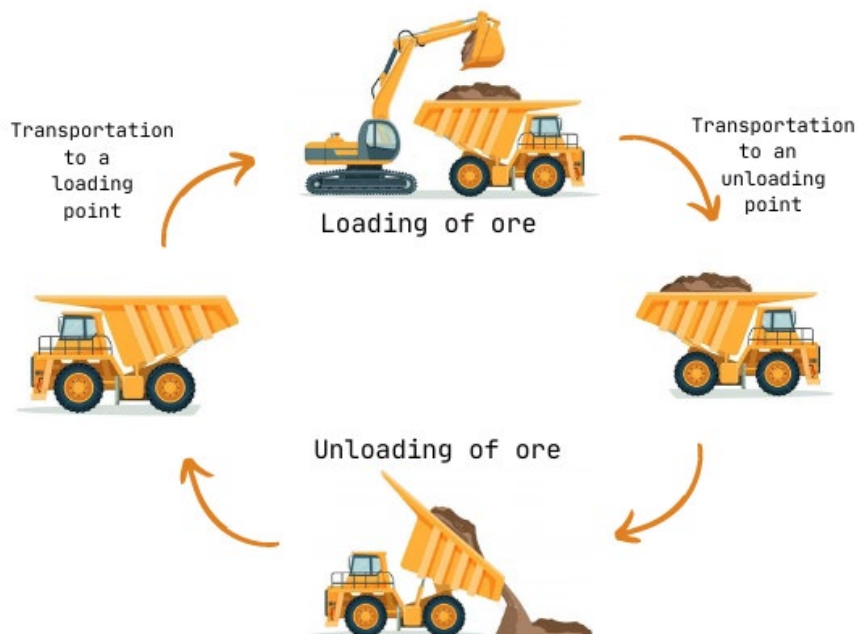


Figure 3. Cycle of a dump truck

In order to avoid any accidents a night rest between 1.30 am and 3.00 am was introduced to the miners. All the operations are stopped during this time. Workers are allowed to take a nap, relax and overcome the first signs of fatigue. At the moment this measure is crucial to keep drivers safe and sound. In addition, toxic fumes, dust and noise pollution are also reduced during this break. However, there is a sufficient drawback – downtime in production.

## 2.1 Aim of the subtopic №1

In order to be able to eliminate this non-productive time during the nightshift a proper solution has to be implemented. The most perspective one is a fatigue monitoring system.

There are loads of different variations on the market nowadays but all of them have one feature in common – detect and warn in advance about the first symptoms of drowsiness.

The aim of the master thesis is the investigation of possible systems on the market, the evaluation of the systems in use in other mines and finally a proposal, which system should be implemented at the Erzberg mine.

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## 2.2 What is a fatigue?

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A person is thought to need at least 7 hours of sleep per day. The best time for this is between 23:00 and 06:00 (1 hour). This pattern corresponds to our inherent impulses to align our sleeping patterns with those of the sun. The word "circadian rhythm" refers to the natural sleep-wake cycle of the human brain. It's similar to an internal clock. The better the quality of sleep, the less likely a person will be sleepy during the day. People are most likely to be sleeping between the hours of 2 and 4 a.m. (Kristeen Cherney, Frank Crooks, Kevin Martinez, 2019).

This fact has been known since the ancient times. Thanks to this knowledge Alexander the Great used to attack his enemies exactly during these time period. The opponent warriors were least active and it was rather easy to conquer them.

Drowsiness is a lethal and costly combination in the mining sector. Microsleep becomes far more likely when there is a lack of sleep or activities during the night. This behavior is commonly caused by exhaustion and fatigue. Fatigue is one of the leading causes of accidents on the job or on the road nowadays. Its level frequently does not correspond to weariness. Drowsiness is a distinct condition that exists between sleep and waking. The level of tiredness in a person can change quite quickly.

However, this state can be detected by modern technologies in advance and an accident can be prevented. Systems that now exist on the market provide different approaches on tracing and monitoring the human activity during driving.

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## 2.3 Overview of the fatigue monitoring systems

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The demand on such systems has increased in the recent past due to the developing mining technologies and high safety standards. In order to find the best system in terms of quality, reliability and price a broad research has been conducted. As a result, a list of 8 different and most attractive companies has been formed. The list is attached in the annex section. The evaluation criteria consist of the following parameters:

- Total price for all the units of a system during the pilot period;
- Technological solution;
- Sophistication of the system;

- Way of installation (implementation of a new software into an existing computer or necessity of a separate device);
- Efficiency of the usage based on other mines' experience.

Unfortunately, not all of this required information can be found in open sources or even on the companies' websites. Such systems are usually manufactured for a specific case as every mine has its own preferences. Thus, a personal request for every company was created. As the master degree project is limited in time, it was not possible to wait for all the companies' replies. However, offers from 4 manufacturers were received (Hexagon, Optalert, Ramjack and Komatsu).

In the following paragraphs within this chapter quotes from all these four companies will be studied and analyzed. In the end there will be a comparison table between the manufacturers that will provide a better overview.

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## 2.4 Hexagon company

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Hexagon, a global leader in sensor, software and autonomous solutions, is well aware of the risks its mining customers face. In order to reduce the risks involved, assistance in detecting fatigue levels is crucial because operators frequently are unaware of critical situations.

The HxGN MineProtect Operator Alertness System (OAS) helps operators maintain the degree of focus required for extended shifts by integrating distraction and tiredness monitoring, alerting, and reporting solutions.

OAS uses strong computer vision technology to provide operators with discrete, user-friendly displays with real-time information regarding their risk of distraction and fatigue as well as traffic awareness. OAS is linked with HxGN MineProtect Collision Avoidance System (CAS). OAS offers reliable, audible, and vibratory notifications about instances where people are tired or inattentive in order to stop accidents from happening. It has a cloud-based platform that continuously assesses in real time the risk of operator fatigue for each individual and the entire fleet, enabling action as necessary. Operators of medium-sized mobile equipment, including haul trucks, auxiliary vehicles, and other mobile equipment, receive real-

time notifications via computer vision Artificial Intelligence (AI) in response to alertness, fatigue, and microsleeps.

Remote monitoring centers conduct an unbiased analysis of each alarm before communicating any relevant events for prompt action to the mine via email or SMS. This helps to create a data-driven safety picture at the operator and fleet levels.

The in-cab gadget is simple to install, functional with masks, prescription lenses, and/or glasses, and operates in both bright and dark environments (figure 4). Full heavy- and light-vehicle fleet monitoring is possible thanks to the OAS-LV device's smooth integration and communication with the OAS Analytics server (Hexagon AB, information from the official website of the Hexagon company, 2023).



Figure 4. Human behavior tracking camera (Hexagon, 2022).

During the COVID-19 pandemic, when mines are requiring drivers to wear face masks, OAS allows operators to wear face masks while still being monitored for signs of fatigue and distraction.

In order to get a more detailed information about costs for the system a request was sent to a business development manager Mr. Reece Hanning in South Africa. A commercial offer was received.

<b>No</b>	<b>Name of a unit</b>	<b>Price</b>
1.	On-board hardware for the trucks	12 500 USD capital per truck once off
2.	Maintenance per year per truck.	1 875 USD
3.	Analytics and reporting platform	45 000 USD per year per site
4.	Remote Monitoring	2 600 USD per truck per year.

Table 1. Quote from Hexagon

In total it is 146 000 USD for the first year and thereafter over 71 000 USD per year plus escalation. The final price is calculated for the fleet of 5 dump trucks as a trial version.

Devices overview:

1. Camera with sensor that is installed in a cabin and tracks movements of a head, eyes and mimics;
2. Additional display that shows alert messages and current status of a driver which is installed in a cabin.

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## 2.5 Optalert company

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Optalert is a predictive sleepiness safety system that continuously provides drivers and supervisors with objective, scientifically verified alertness information in real-time. Two lines of defense against the effects of fatigue are provided by the constant flow of information, enabling all parties to monitor the risk and take preventive action before dangerous levels are reached. Both mining and transportation uses depend on this.

Optalert's technology identifies:

- Operators with the highest risk of drowsiness
- Route areas with the greatest likelihood of risk occurrences
- The period or time when activities are most vulnerable relative to a certain driver
- Most productive periods
- Measures done to mitigate immediate dangers

Optalert is being used by mining companies to measure the impact of drowsiness on operations. This factual information is used to support operational choices including task changes, shift rotations, break periods, and the timing of pertinent countermeasures.

Data can be used to describe the total risk of exhaustion in an operation. An objective assessment of the effectiveness of a company's fatigue risk management, OHS policies, and procedures over months or years can be made by quantifying risk changes.

Optalert has aided in the identification of underlying health issues in operators that may have an impact on their degree of alertness or tiredness throughout their shift. Drivers who consistently display high alertness levels have been examined by



medical professionals to rule out sleep disorders such as sleep apnea, insomnia, and shift worker disorder.

Devices overview:

1. Goggles with a special micro camera that tracks movements of an eye;
2. A tablet with software which is installed in a cabin.

Principle of working.

An LED sensor that is integrated into the glasses is used to measure eyelid movements at a rate of 500 times per second. (figure 6). The tablet then receives logged data from every blink through Bluetooth or cable connection (figure 7). Multiple glasses can be connected to one tablet but only ONE connection at the time.

Data from the glasses is objectively evaluated, and the driver's drowsiness is presented on the screen (scale 1-10). The tablet's encrypted data is subsequently delivered to Optalert's cloud-based server over 3G or Wi-Fi. It means that each driver's personal information is saved in the company's database, and they have access to it.

Secure remote access by customer to real-time drowsiness levels of all users via Optalert Individual Risk Indicator System (IRIS™) software (figure 8).



Figure 6. Glasses with micro camera (Optalert, 2022)



Figure 5. Optalert tablet (Optalert, 2022)

The Optalert Wireless Glasses are made up of a glasses frame with an infrared sensor array that rests beneath the user's left eye. A very low power infrared LED illuminates the eye and eyelids, and a photodiode measures eye and eyelid movements using the reflected infrared light. A PCB in the left arm of the glasses converts the eye and eyelid motions into a digital signal that is wirelessly transferred to the Optalert processing unit via Bluetooth 5.0. (Low Energy). The Optalert processing unit computes and displays a sleepiness score based on the Johns Drowsiness Scale to the user.

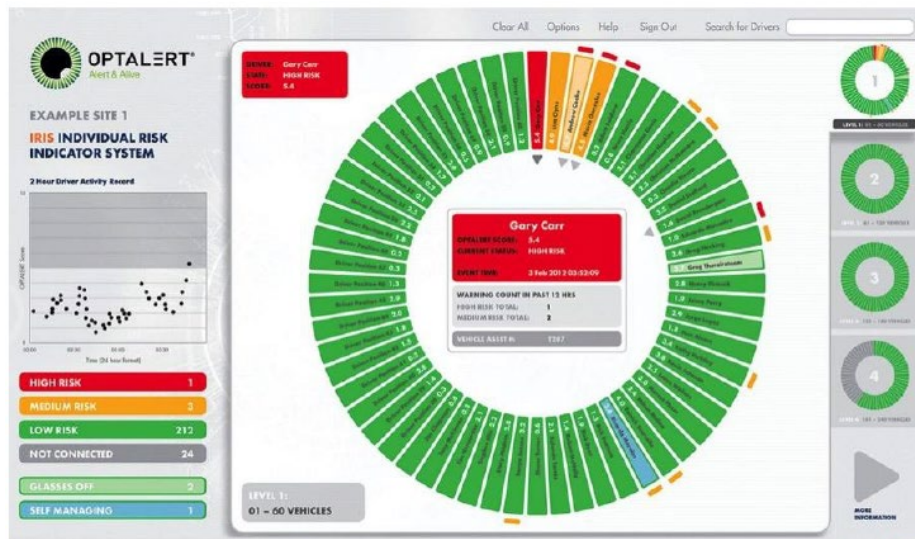


Figure 7. Optalert Individual Risk Indicator System (Optalert, 2022)

All of the glasses are one-of-a-kind and tailored to each driver. When the system senses a threat, it displays an alert message on the screen and emits a warning sound. A mine manager can monitor the status of all operators using the IRIS software (figure 7) and check if anyone has removed their glasses.

#### Experience of usage by mining companies.

In 2020 one of the Brazilian mines encountered in 1 year of usage Optalert system a decrease of accidents by 72%. The reason is that operators did not pay enough attention to the road. There were a lot of idling time due to fatigue before the implementation of the system (Optalert, Digital Agency. Information from the official website of the Optalert company, 2022).

Figure 8 illustrates Optalert data from a mining site in 2018, demonstrating a rapid decrease in sleepy drivers and the frequency of alert messages.

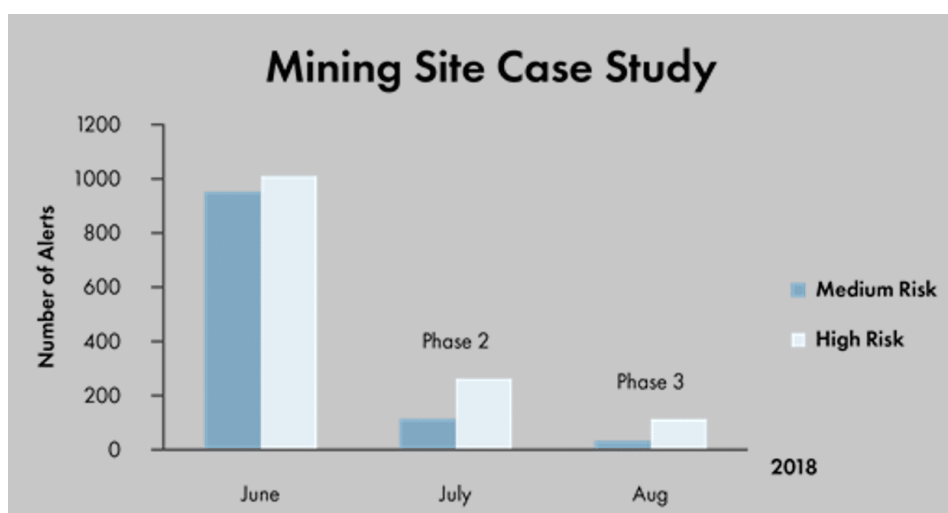


Figure 8. Results of using Optalert system (Optalert, 2022)



The graph on the figure 8 shows:

- During June the visual feedback of alertness / drowsiness scores and in-cab drowsiness warnings were switched **off**.
- In July visual feedback of alertness / drowsiness scores and in-cab drowsiness warnings (visual and sound) were switched **on** (active). As a result, operator self-management and a significant reduction in risks was achieved.
- In August a control room for monitoring and notifications was added when operators receive medium and high-risk alerts

The information about costs for the system was received by a global business development manager – Mr. Renato Lopez in Australia (table 2). The agreement below is intended to provide VA Erzberg GmbH with the opportunity to conduct a 60-day trial of Optalert's early-warning drowsiness detection products in their own environment in one location in Austria (Erzberg). The more detailed information from the commercial offer is presented in the annex section.

<b>Product</b>	<b>Quantity</b>	<b>Cost</b>
Eagle™ Industrial Mining Kits	5	
Wireless V8 glasses	12	
Glasses calibration tablet	1	
Professional services: Training and onsite implementation via assigned Optalert site champion	1	
<b>Total</b>		<b>USD \$ 47,500</b>

Table 2. Quote from Optalert

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## 2.6 Ramjack company

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Ramjack Technology Solutions is a professional systems integrator and technology advising firm focused on mining operations technology in difficult geographical areas. The company was founded in 2013 on the back of over 50 years of experience in the "real-time" mining technology area, and it bridges the gap between original technology producers and mine operations. Ramjack provides localized services to their mining customers through collaborations with multinational technology manufacturers and unique service packages that

guarantee increases in safety, productivity, and effectiveness using real-time technology and harsh mining environment experience.

Ramjack is a pragmatic Group of Companies focusing on maximizing the value of real-time technology that may boost mine production while also improving health and safety performance. A solution that fits best to the requirements of Erzberg is 'Life' by SmartCap because the system:

- reduces operational downtime due to accidents;
- minimizes damage to equipment;
- improves the safety of equipment (vehicle) operators and pedestrians.

Life by SmartCap continually monitors the tiredness level of equipment operators and alerts them when they are drowsy and more likely to cause an accident. It is a system that encourages self-regulation; but, if tiredness levels approach intolerable levels, warnings and triggers may be designed to allow for external intervention.

Life by SmartCap is the world's leading provider of Fatigue Management due to the following key aspects.

1. Predictive Capabilities – Life deploys unique algorithms built over many years of study to anticipate the danger of microsleeps before they occur. Life delivers real-time, actionable feedback to operators and managers, including tiredness alarms when the danger of microsleep is discovered, by integrating EEG (electroencephalogram) measurements of brain activity with SmartCap's patented fatigue prediction algorithms. In this regard, Life can completely remove any fatigue-related accidents from operation.
2. Advanced Science – To measure the alertness and awareness levels of equipment users, Life utilizes the gold standard in sleep research - Electroencephalography (EEG) technology. Numerous independent studies have shown that it is the safest and most efficient approach for monitoring tiredness levels. For almost 70 years, EEG has been used to detect and predict weariness. Its precision ensures the lowest possible false alarm rate, and it is unaffected by glare, lack of light, dampness, head rotations, or operator behavior, all of which are issues with camera-based fatigue monitoring systems.
3. Non-Intrusiveness – Life does not require cameras and is convenient to wear, making it the world's most adaptable fatigue monitoring device to current processes, procedures, and systems. The SmartCap Lifeband may be worn alone or with any

hat. It communicates with the SmartCap in-vehicle software through Bluetooth 4.0, delivering input and warnings to operators and central controllers. Lifeband readings are sent back to a central location for storage and analysis through 3G/4G, Wi-Fi, or satellite connections.

Technological principle.

Electroencephalography (EEG) is a technique for recording electrical activity in the brain that is used in electrophysiological monitoring. It allows for the rapid recognition of weariness. A driver must wear a specific band with an EEG device linked to it. It may be attached to a hat or helmet. The program may be integrated into current cabin displays or tablets. As a result, a motorist can monitor his or her own degree of weariness. The information gathered from each driver is saved on the mining company's server. It means that no one else has access to the confidential information.

Devices overview:

1. A band over a head with built-in EEG technology (figure 9);
2. Software that can be integrated into existing devices in a cabin.



Figure 9. Lifeband integrated into a helmet (Ramjack, 2022)

Life by SmartCap provides real-time feedback, helping drivers proactively manage their own alertness - anywhere, anytime. Figure 10 illustrates stages of fatigue that is displayed for driver on a screen in a cabin.



Figure 10. Stages of fatigue (Ramjack, 2022)

At Level 3+ and Level 4 Audible warning tone and screen turns to full brightness. These alerts make a driver aware that he/she is now at a higher risk of having a Microsleep. It is time to have a rest (RAMJACK, Johannesburg. Information from the official website of the Ramjack company, 2023).

#### Experience of usage by mining companies.

In one of the Australian mines' drivers had to take 30 minutes break every 2 hours. After SmartCap system was implemented drivers were allowed to take breaks when they wanted according to the alerts of the system. Efficiency has increased by 30%. The bar chart below (figure 11) shows an improvement in safety in one of the mines in South Africa in 2020. Red bars represent previous statistics whereas green – after system implementation.

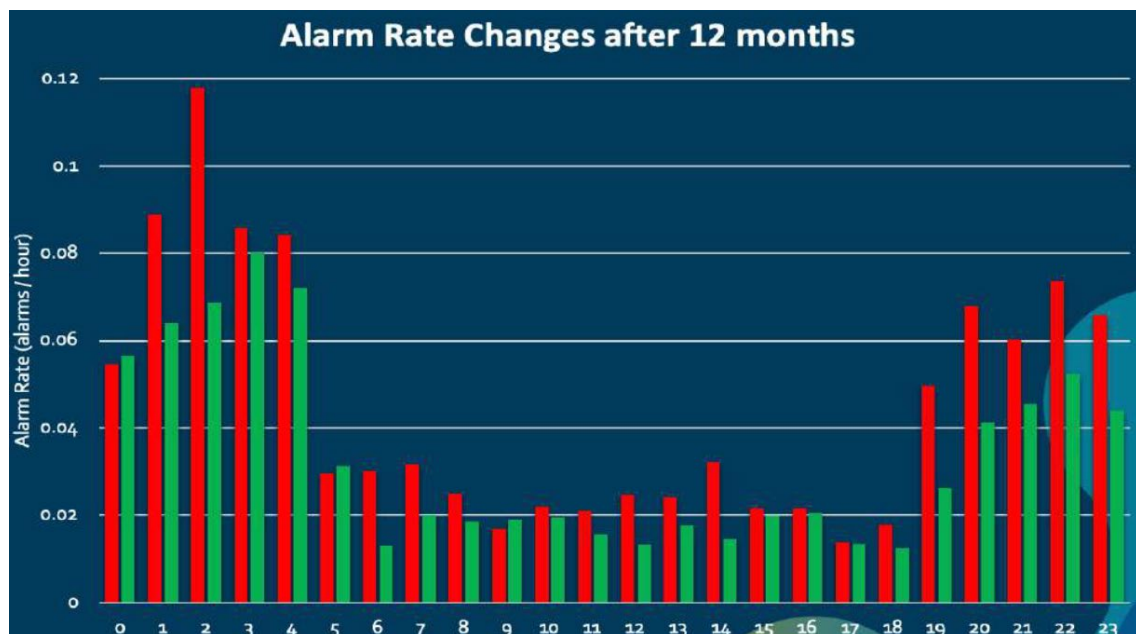


Figure 11. Results after implementing SmartCap system (Ramjack, 2022)

According to the figure 11 it can be seen that:

- number of alarms decreased by 25% within 12 months;

- the most significant improvements are during the night shift;
- risks on-site have reduced;
- workload for supervisors has decreased.

The information about costs for the system was received by a vice president – Rupert Birch from London, UK (table 3). This proposal provides a full deployment cost estimate based on the following information: 2 trucks, 3 operators per piece of equipment, 1 site to utilize SmartCap, 3-month trial period (including deployment time). For the pilot version it is not possible to integrate software into an existing device in a cabin. Thus, an additional display has to be installed into every truck. In addition, there will be 3 Lifebands for every operator. The more detailed information about the commercial offer is in the annex section.

<b>Total Scope Estimate</b>	<b>Price [USD]</b>
Software Licenses	4,200.00
Hardware - Vehicle Devices	2,790.00
Hardware - Miner Devices	2,005.26
Hardware - Infrastructure Devices	125.00
Deployment Services	14,540.00
Support and its pre-requisites	1,068.00
<b>Total:</b>	<b>24,728.26</b>

Table 3. Quote from Ramjack

## 2.7 Komatsu system

The Komatsu Drowsiness Detection System (DDS) is a system that assist in the safe operation of the machine. It recognizes the driver's face and detects the driver's eye lid behavior and face direction. If it determines that the driver is sleeping, looking away, operating the machine in an inappropriate driving posture, or is drowsy, it activates the drowsiness alarm buzzer and notification sound. In spite of these cases, the system does not always recognize them as errors. As a result, it is not advised to rely too heavily on this system. Drivers must always operate the machine safely and responsibly.

### Devices overview:

- 1) Drowsiness detection camera
- 2) Drowsiness detection system ready lamp
- 3) Drowsiness alarm buzzer
- 4) Driver status monitor
- 5) Voice alarm speaker

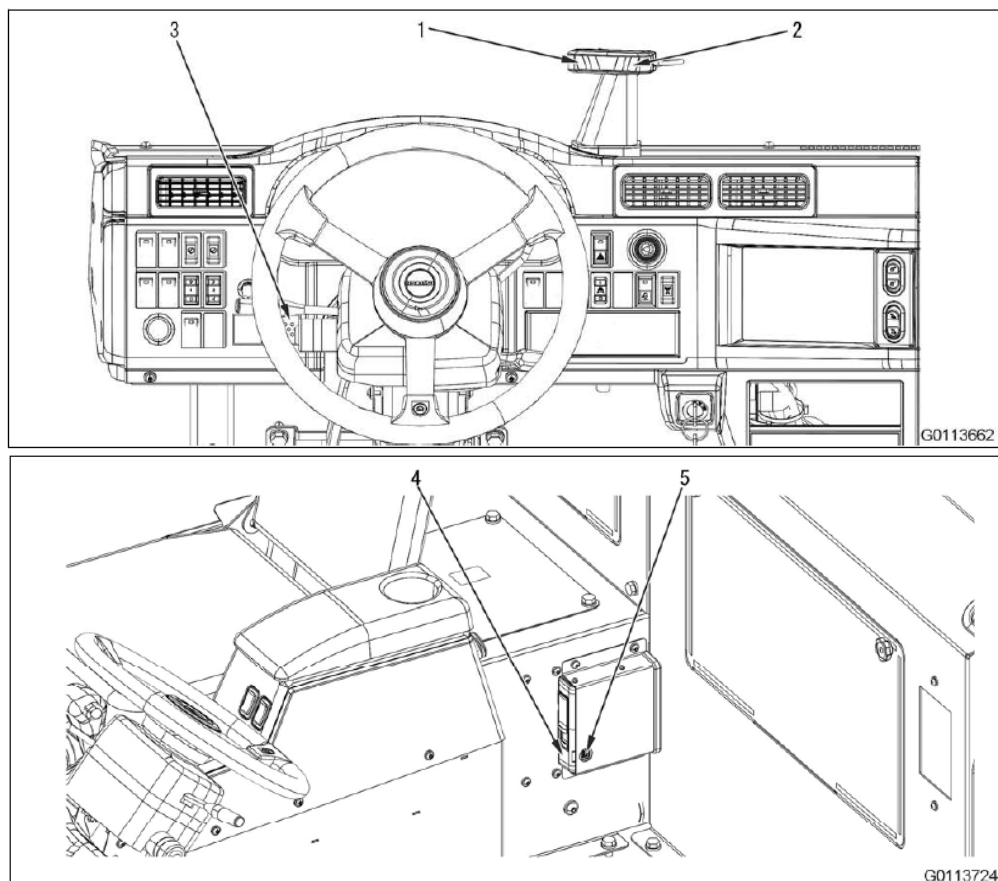


Figure 12. Komatsu DDS components (Komatsu, 2022)



## Principle of work

The driver's eye behavior (open or closed), face orientation, and driving posture are all detected by the drowsiness detection camera. The ready lamp indicates that the sleepiness detection system is active. The system recognizes the driver's face when it is highlighted. When it flashes, the system detects an unsafe condition. When the driver falls asleep for a brief period of time, or the driver's eye behavior or tiredness is detected, the drowsiness alert buzzer emits an intermittent sound. The sleepiness alert buzzer ends when the drowsiness detection system determines that the operator is not drowsy. The drowsiness alert buzzer does not always react to the notification sound. In response to the value set on the operation settings file, the driver *status monitor* activates the alarm and saves the detected data and machine status throughout travel in the SD memory card.

In the main unit, the images captured by the drowsiness detection camera are edited, and the driver's face direction, leaning, and eye activity (open or closed) are detected. The driver is alerted by the system's notification sound. When the system detects a driver performing a specified action, it sounds an alarm. Here is the list of alarm types:

- *Sleep Alarm*  
Driver closes eyes during travel.
- *Inattentive Driving Alarm*  
Driver looks aside during travel.
- *Poor Driving Posture Alarm*  
Driving posture is inappropriate during travel.
- *Drowsiness Alarm*  
Driver feels drowsy during travel.

The SD memory card stores all alarm types and machine information. Simultaneously, the images captured for each alarm are preserved. If the SD memory card's capacity surpasses the upper limit (for approximately one month), the driver status monitor overwrites the new data with the oldest data. The system has some constraints. To ensure that the camera works properly, the following situations must be avoided:

- A part of the driver's face is hidden by the steering wheel, mask, hairs, hat, sunglasses, mustache, eyeglass frame, or light or scenery reflected on a spectacle lens;
- Specialized eyeglasses or sunglasses with a powerful near-infrared ray cut filter are utilized;
- An oncoming vehicle's headlight or the sun reflects the face or sleepiness detection camera;
- Because of changes in facial expression or make-up, the system cannot easily distinguish eyes.

(Komatsu. Information from the official website of the Komatsu company, 2023)

The information about costs for the system was received by Erzberg Assistant Ore Production - Peter Schimek from a sales manager of KUHN Baumaschinen GmbH – Christian Moser (Eugendorf, Austria). The fatigue monitoring system tend

to have the best compatibility with dump trucks as long as it is produced by the same brand – Komatsu.

The price for one complete unit is 5500€.

## 2.8 Comparison of the systems

In the above paragraphs there was detailed overview about every company that is specialized in fatigue monitoring systems. Each manufacturer has its own approach for the solution of managing operators' drowsiness at work. In order to choose the best technology a comparison analysis will be conducted. Advantages as well as disadvantages of every company will be evaluated in a table 4.

№	Metric	Company			
		<i>Hexagon</i>	<i>Optalert</i>	<i>Ramjack</i>	<i>Komatsu</i>
1	Solution	Camera in a cabin	Glasses with micro camera	Band over a head	Camera in a cabin
2	Technology	Camera observes human behavior (mimics, gestures, eyes)	Camera tracks micro movements of eyes and eyelids	Electrophysiological monitoring method to record electrical activity of the brain.	Camera recognizes the driver's face, senses the behavior of driver's eye lid and the face direction.
3	Devices	Special camera and a separate display in a cabin, software	High-tech glasses with a mounted camera, separate display in a cabin, software	Headband that can be set into a helmet or cap, software can be integrated into an existing display in a cabin.	Camera with a lamp, buzzer, voice speaker, monitoring gadget.
4	Data storage	No data	On Optalert's cloud server. They have access to all the collected data	Data is stored on a mining company's cloud server. Nobody else has access to the data.	SD memory card



5	Efficiency	No data	In Brazil in 1-year number of accidents decreased by 72%.	In South Africa number of alarms decreased by 25% within 12 months.	No data
6	Number of vehicles for trial version	6	5	2	8
7	Price per vehicle [USD]	16 975	9 500	5 137,63	5 360
8	Total price [USD]	146 000	47 500	24 728,26	42 880

Table 4. Comparison analysis

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## 2.9 Conclusion

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According to the comparison table 4 it can be claimed that the most attractive fatigue monitoring company is Ramjack with the technology powered by SmartCap. Main advantages are that data is stored inside a mining company and software can be integrated into existing tablets or screens in a cabin. Moreover, price per vehicle is the lowest comparing to the other. The headband is rather easy to wear and install into a cap or helmet.

Unfortunately, Hexagon did not provide any information on data storage and experience cases from other clients. So, it is difficult to rely on its efficiency. Moreover, the proposed price is the highest one comparing to the other companies.

Efficiency of Optalert looks a bit unrealistic because of 72% decrease of accidents in 1 year. An additional microcamera in glasses that tracks eye movements can disturb drivers. On top of that these glasses are have to be charged which can be easily forgotten.

Despite of the good compatibility of Komatsu drowsiness system with the same brand dump trucks it still has a lot of limitations of usage (too strict positions of driver's body and face, no possibility to wear sunglasses and mustache). Another drawback of the system is that all data is stored on SD memory card. It limits the amount of recorded data and it also has to be transferred to a computer manually once a month. If not done so the data will be overwritten by fresh one.

However, the real performance and any improvements can be seen only after a pilot period which lasts at least 3 months. The report of the first subtopic tends to provide a detailed overview of possible fatigue monitoring systems on the market. The proposed solution presented by Ramjack is a recommendation. The final decision on purchasing and implementing a certain system should be made by the VA Erzberg mining company.

### 3 Chapter II. Traffic Flow Control

Erzberg is a modern open pit mine that seeks to improve every operation step by means of digitalization where it is possible. Without high-tech approaches it would be impossible to keep the production pace of 12 million tons annually (VA Erzberg, Information from the official website of the VA Erzberg company, 2022). One of the main contributions belong to dump trucks that operate all day long and every day. Thus, in order to distribute dump trucks and their hauling routes in an optimal way, shift supervisors use a truck dispatch system, which is self-developed by VA Erzberg (fig. 13). The system delivers real-time data from loading and hauling machinery (based on GPS and CAN-Bus). These data are processed and analyzed to create production KPIs.

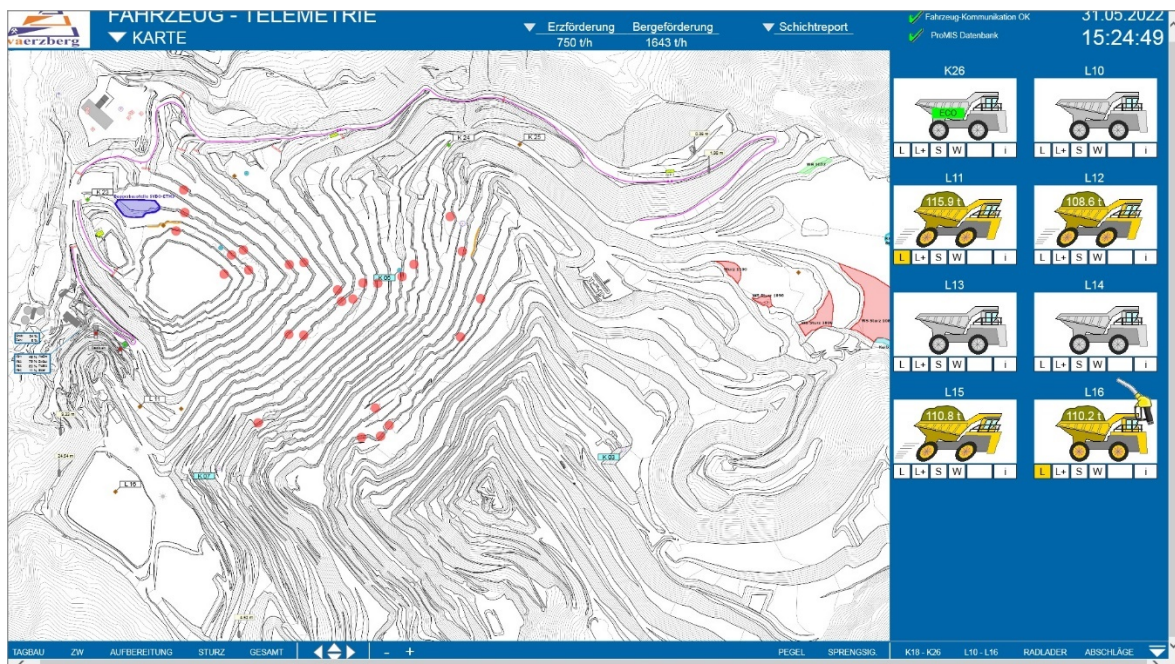


Figure 13. Truck dispatch system (VA Erzberg, 2022)

On the figure 13 is presented an interface of the dispatch system which provides an informative overview of every heavy machinery in the mine online. This dashboard consists of a main window, a toolbar and a table of vehicles' cards. The main window shows an interactive map of the Erzberg mine. Benches, main ramp and civil constructions can be easily distinguished. Red dots represent every vehicle which is currently in action. A vehicle's card provides information of a current status:

- Vehicle is greyed out – inactive/engine is switched off;
- Vehicle is leaned forward – in action/driving;
- There is a refueling gun near by a vehicle – machine is being tanked;

Additionally, to all these statues a dump truck can be loaded with ore (a pile is visible in the back) or empty. By clicking on a card, a separate window pops up (fig. 14). In

this window a detailed information can be found about a chosen vehicle: a covered distance and elevation, current speed (if it is driving), weight of transported ore (in case of driving full), fuel left, pressure in tires, timestamps of the latest events and many other. Information is well structured thanks to tabs. Navigation between the tabs is user friendly and intuitively understandable.

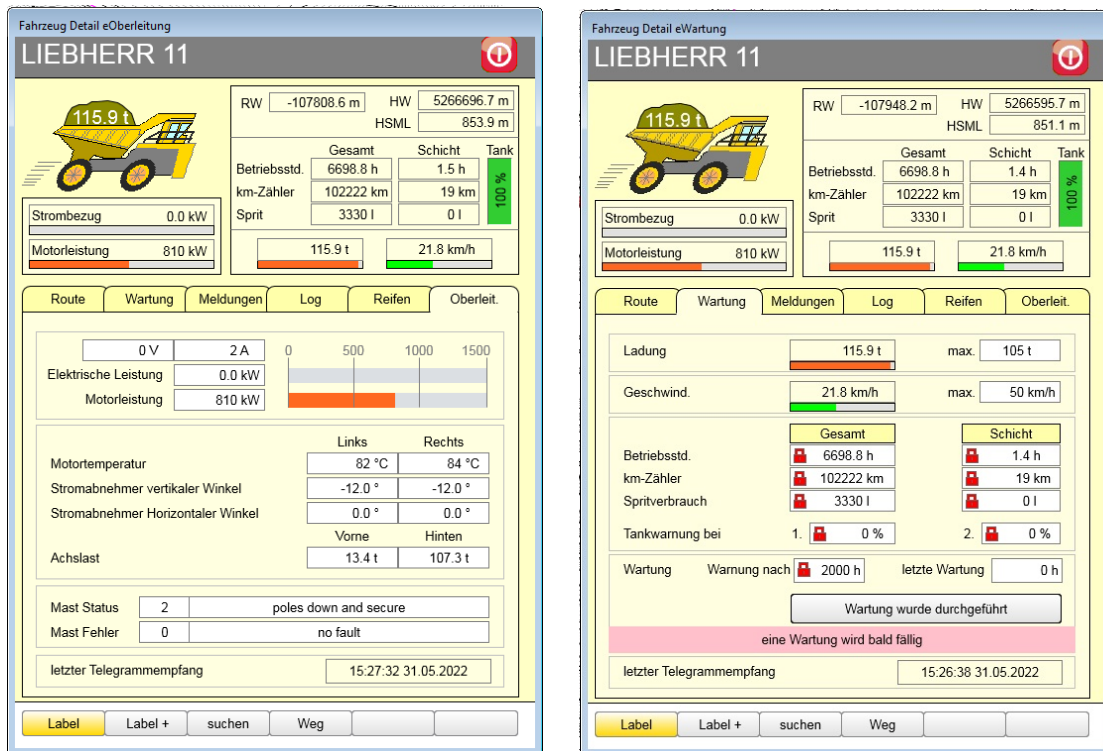


Figure 14. Vehicle's information card (VA Erzberg, 2022)

Every dump truck has an on-board computer which generates a package of data every 2 seconds. This data consist of a timestamp, name of the vehicle, longitude and latitude coordinates, status of the machine, elevation coordinate, speed and other details. All these data are sent to a central server where it is formed afterwards into a text file. Time frames can be determined once creating a file. The most convenient time frames for analysis are from shift's start to a shift's end and the whole day. Figure 15 gives an example of such dataset generated in a text file.

```

K18_05 - Notepad
File Edit Format View Help
2022-04-05;00:00:00.0;KOMATSU_18.STATUS_0;15.0;SPONT T_INTERN
2022-04-05;00:00:00.0;KOMATSU_18.STATUS_1;4.0;SPONT T_INTERN
2022-04-05;00:00:00.0;KOMATSU_18.HW;5267505.7;SPONT T_INTERN
2022-04-05;00:00:00.0;KOMATSU_18.RW;-108402.8;SPONT T_INTERN
2022-04-05;00:00:00.0;KOMATSU_18.HSML;836.6;SPONT T_INTERN
2022-04-05;00:00:00.0;KOMATSU_18.LOAD;1638.3;SPONT T_INTERN
2022-04-05;00:00:00.0;KOMATSU_18.SPEED;0.2;SPONT T_INTERN
2022-04-05;00:00:02.0;KOMATSU_18.STATUS_0;15.0;SPONT T_INTERN
2022-04-05;00:00:04.0;KOMATSU_18.STATUS_0;15.0;SPONT T_INTERN
2022-04-05;00:00:06.0;KOMATSU_18.STATUS_0;15.0;SPONT T_INTERN
2022-04-05;00:00:08.0;KOMATSU_18.STATUS_0;15.0;SPONT T_INTERN
2022-04-05;00:00:10.0;KOMATSU_18.STATUS_0;15.0;SPONT T_INTERN
2022-04-05;00:00:12.0;KOMATSU_18.STATUS_0;15.0;SPONT T_INTERN
2022-04-05;00:00:14.0;KOMATSU_18.STATUS_0;15.0;SPONT T_INTERN
2022-04-05;00:00:16.0;KOMATSU_18.STATUS_0;15.0;SPONT T_INTERN

```

Figure 15. Formed dataset in a txt file

In order to proceed further in this subtopic, steps of the project pipeline have to be determined. A pipeline is a progress toward a long-term goal that involves a series of discrete stages. Every next stage is a logical continuation of the previous one and cannot be dropped from the entire process. For a better overview the pipeline of the master project is presented on the diagram 16.

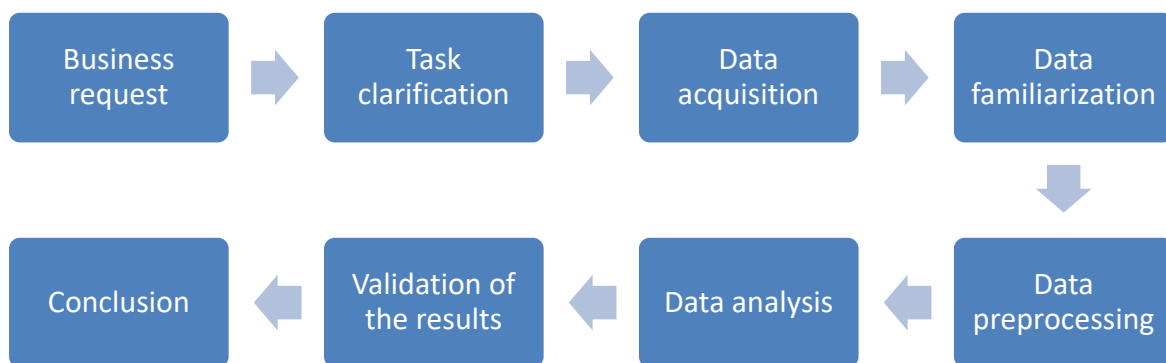


Figure 16. Project Pipeline

### 3.1 Aim of the subtopic №2

The current dispatch system provides a good overview about the operations in the mine. Despite the constant and detailed information from every dump truck there are still some issues that cannot be solved but with an additional analysis tools. The main problem is the optimization of the routes of dump trucks. Based on observations and experience of mine managers it was found out that all vehicles idle during the day. However, there is no certain time and exact locations of idling regarding every dump truck. Moreover, there is no information about circumstances of this idling time.



Thus, several aims of the 2<sup>nd</sup> subtopic can be formulated:

- review data acquisition and data processing
- evaluation and optimization of output-figures
- documentation of the truck dispatch system
- implementation of traffic flow control

The generalised task is to calculate the total idling time for every dump truck, found out exact locations of idling and determine their reasons.

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## 3.2 Data overview

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As it was mentioned above the data from every dump truck is generated by a form of a text file (fig.15). Unfortunately, the structure of this document is very poor what makes it difficult for any further analysis. At the moment the data is formed into blocks. Every block contains information about certain parameters within a specific timeframe. All the blocks have the following common features as timestamp and name of the dump truck plus a unique parameter:

- Velocity;
- Current status;
- X coordinate;
- Y coordinate;
- Elevation;
- Tire pressure;
- Tire temperature;
- And some other parameters.

Timeframe starts from a certain date at 00:00:00. Every block with specific parameters has a timeframe of 1 hour. Within this timeframe each new entry of information is stored in a row every 2 seconds. Once the last entry at 00:59:58 with information about the common parameters and one unique (velocity) is added to the first block a new block takes place right after it. The new block starts with the same date and time as the previous one but with a different unique parameter instead of the used one.

In other words, every new unique parameter is stored into a row rather than into a column. Such approach creates a lot of duplicates of the common parameters in every new block. Moreover, a size of a document incredibly increases. In addition, an excel table has a limited number of rows which equals to 1,048,576. It causes a potential problem in storing the data. A dump truck can generate too much data so there will be no free rows to write it in the same document. As a result, some data can be lost.

Due to the data privacy reasons an access to the internal server is limited in VA Erzberg. Taking this into account the mine managers have created a cloud server for sharing documents within a few seconds. All data on the cloud is synchronized which means that every user will see if there are made any corrections to a document.

### 3.3 Framework determination

The main aim requires to determine idling locations and their reasons in the whole open pit mine. It can be defined by analyzing movements of vehicles in the mine. Such data has been collecting for several years every day and every 2 seconds. It means that by date it has been formed an enormous amount of data. It is called a general population. Working with such a big data causes a lot of difficulties in terms of time, money and technology. However, there is a way how to ease the process without losing the efficiency a lot. A general population can be presented by a smaller chosen part of data – sample. The crucial thing about the sample is representativeness. It can be reached by a random selection of a sample out of the general population. It means that every part of the general population has the same probability of being in a sample.

However, Erzberg is a constantly developing mine which means that almost every half a year the shapes of the pit changes. New benches and paths for dump trucks appear as well. This cause new potential locations of idling. In order to analyze their reasons and exact coordinates some limitations have to be set. At first it was determined which part of the mine remains stable most of all for a decent period of time (at least a year and more). Such a place is the main ramp. On the figure 17 it is presented as a green solid line. Grey lines present benches and terrain.

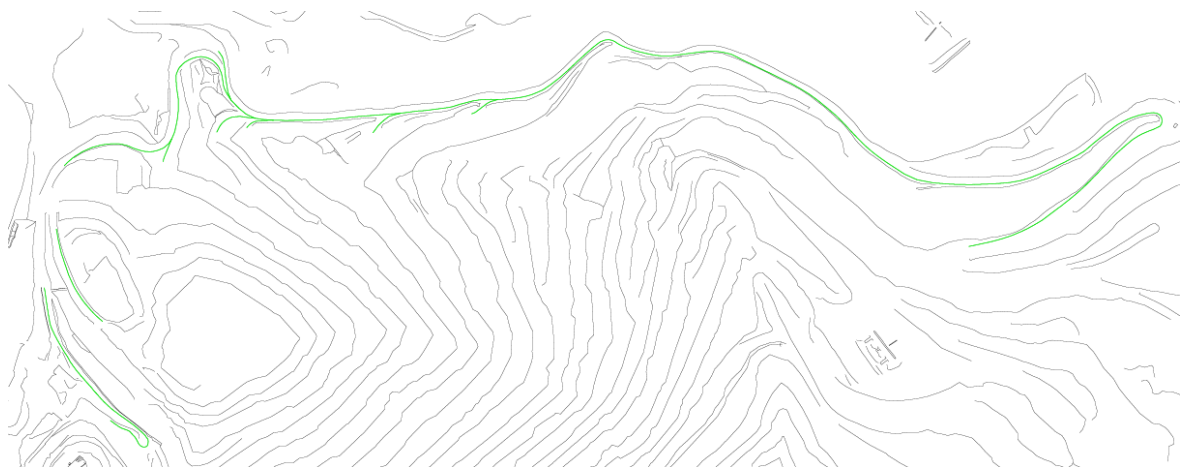


Figure 17. Main ramp

During one of the first meetings it was mentioned that the traffic flow was not always constant on the main ramp though the road itself remained the same. There were several reasons but the main is the construction works. So, it was agreed to consider a period after these works are done – April 2022. As the master thesis started in June 2022 it was decided to choose a sample from 04.04.2022 till 07.04.2022. Such timeframe provides a good sample of data, relatively equally represents other periods of operations in the mine and is suitable for efficient analysis. The Assistant Ore Production Mr. Schimek has uploaded several dozens of datasets to the cloud. Thus, there are 4 datasets for every dump truck according to each day. In total there are 64 datasets.

Data analysis can be performed in different ways. The most common is working directly in MS Office environment and operating with Excel features. This method

has a lot of advantages: plain and accessible interface, simple and fast plotting of graphs and diagrams, no need of specialized knowledge. However, there are big disadvantages: limited functionality with data processing, filtering, confined information size, absence of automation and data transformation. As it can be seen Excel is more suitable for daily routine and relatively easy tasks.

In order to proceed with more sophisticated tasks a more advanced tool for analysis is necessary – Python. It is one of the most popular nowadays programming languages that can be applied in various of cases. Python environment has several tools for data analysis and visualization – so called libraries – pandas, numpy, matplotlib, seaborn and some others.

The data analysis of this master thesis project is performed in 2 software programs: Jupyter Notebook and PyCharm. Both of them work perfectly with Python and has powerful features that can speed up coding process and help with debugging. A synergy of these tools will be beneficial in detailed analysis.

Every analysis of data starts with a determination of aims, tasks and steps of the process. The main aims have already been defined in the previous chapter. Task is an auxiliary stage that helps in better understanding of the aim and its achievement. Here are the following tasks:

- 1) Get familiar with the provided data;
- 2) Check if all datasets have the same structure and content;
- 3) Determine steps of analysis;
- 4) Set intermediate check-ups and deadlines;
- 5) Agree on the type of output (which metrics have to be shown);
- 6) Perform the analysis;
- 7) Make a conclusion.

During the analysis it can happen that some of the tasks will be corrected, cancelled or some new tasks will be added. During intermediate meetings iterations of analysis process will be presented and tasks will be checked. It will help to keep the project on the right way and meet expectations of the project owner – VA Erzberg.

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### 3.4 Data familiarization and preprocessing

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As it has been mentioned before there are 64 datasets in total. The first insight about the data can be made by checking the size of files. The information is presented on the picture 18. This table was created by means of Tableau as an informative dashboard. The size of a square represents the size of a file in megabytes. It can be seen that datasets with the information about all Komatsu dump trucks except 24 and 25 have the smallest size. It means that these vehicles probably covered the least distances during the whole timeframe. Meanwhile all Liebherr machines created most of the data. However, as it is known that Liebherr are hybrid dump trucks which mean that they also generate additional information about electrical features. This first familiarization gives a good first insight of the data



and understanding of further filtering and preprocessing. It should be mentioned that the size of 110 Mb is pretty large for a dataset. We will try to optimize this number in the further steps.

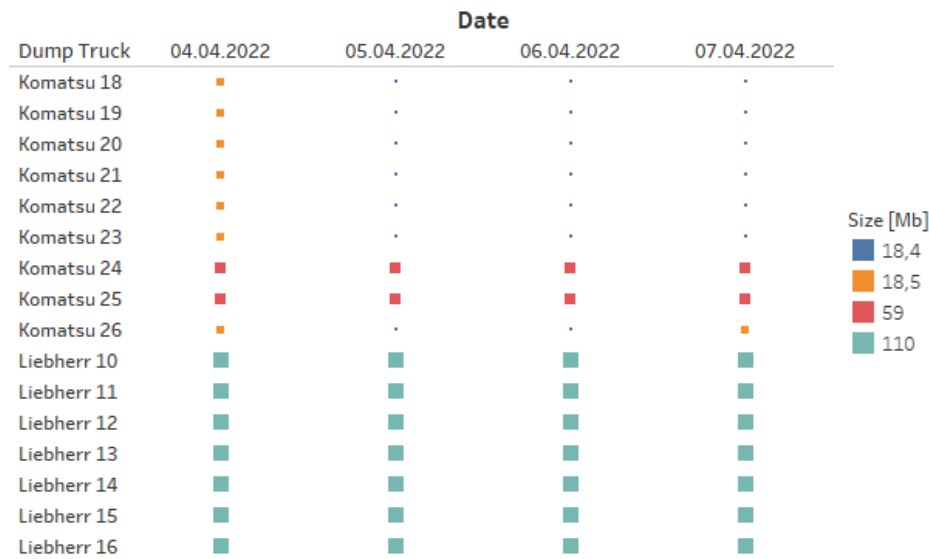


Figure 18. Information about the dataset's size

As it was mentioned above, the structure of every dataset is not convenient for an analysis – too many duplicates, information about each parameter is written in a row rather than in a column, there is probably some additional information which is irrelevant for the analysis. A preprocessing of data is required in order to optimize the structure. However, after the initial check of the datasets it can be stated that all of them have the same structure. It means that the analysis procedure will be the same for each dataset.

In preprocessing step information about unique parameters will be transposed from rows into columns. The following columns will be dropped as they are not useful for the analysis: 'SPONT T\_INTERN', 'unit', 'STATUS\_1', 'LOAD'. Some columns will be renamed for better understanding. Thus, 'hw' stands for 'y coordinate' and 'rw' – for 'x coordinate'.

The analysis will be started with the first sample from Komatsu 18 on 04.04.2022. After the initial preprocessing of data with Python we got a table that has only 43200 rows comparing to the raw dataset that has 302400 rows (fig. 20). The size of the document has also decreased from 18,5 Mb to 2,3 Mb. The results are shown on the picture 19. The raw dataset is called 'K18\_04', the updated one is 'K18\_04\_sample'. Thus, by simply optimizing the initial dataset it is able to save at least 8 times less space on the server per file. This step can be performed by rearranging SQL requests. Moreover, the total calculation time can be decreased as well. In addition, a raw dataset will be easy to read and clear for understanding.



 K18_04	27-Jun-22 13:34	Microsoft Excel Comma Separated Values File	18,522 KB
 K18_04_sample	15-Oct-22 17:10	Microsoft Excel Comma Separated Values File	2,322 KB

Figure 19. Size of raw dataset and preprocessed

	datum	y_coor	x_coor	speed	height	status_0
0	2022-04-04 00:00:02	5267461	-108430	0.0	837	15
1	2022-04-04 00:00:04	5267461	-108430	0.0	837	15
2	2022-04-04 00:00:06	5267461	-108430	0.0	837	15
3	2022-04-04 00:00:08	5267461	-108430	0.0	837	15
4	2022-04-04 00:00:10	5267461	-108430	0.0	837	15
...	...	...	...	...	...	...
43194	2022-04-04 23:59:50	5267505	-108402	0.2	836	15
43195	2022-04-04 23:59:52	5267505	-108402	0.2	836	15
43196	2022-04-04 23:59:54	5267505	-108402	0.2	836	15
43197	2022-04-04 23:59:56	5267505	-108402	0.2	836	15
43198	2022-04-04 23:59:58	5267505	-108402	0.2	836	15

43199 rows × 7 columns

Figure 20. Preprocessed dataset

The most important data for the analysis has been saved to new columns: 'datum' (timestamp), 'y\_coor' (y coordinate), 'x\_coor' (x coordinate), 'speed' (velocity of a dump truck), 'height' (elevation above the sea level) and 'status\_0' (status of a dump truck). The table on figure 19 will be similar for other dump trucks' datasets.

### 3.5 Data Analysis

This chapter will explain in details the behavior of all the dump trucks in the mine. The analysis will be followed by tables, graphs and diagrams. As it is performed by means of Python some code examples will be presented to describe the most sophisticated and crucial parts of the script. In addition, some hypotheses will be stated that have to be proved or refuted. This is necessary in order to derive statistics and make conclusions. First of all, steps of analysis have to be determined:

1. Analysis of the movements;
2. Finding the most frequent idling locations;
3. Calculating the total idling time;
4. Plot idling locations on the mine map.

### 3.6 Analysis of the movements

During the provided timeframe from 04.04.2022 till 07.04.2022 all of the 16 dump trucks were operating in the mine. However, some of them were not working entire days. There are several reasons for that: maintenance service, absence of necessity for the production purposes or others. As it was mentioned in the Fatigue

Monitoring Systems chapter there are usually 11 dump trucks that work simultaneously in the mine. This fleet is currently enough for daily activities during a shift.

Based on the gathered and preprocessed data it is able to get trajectories of movements of every dump truck during a day. On the figure 21 there is a plot of the movements of one of the vehicles. The darker the line the more often a machine was driving this path.

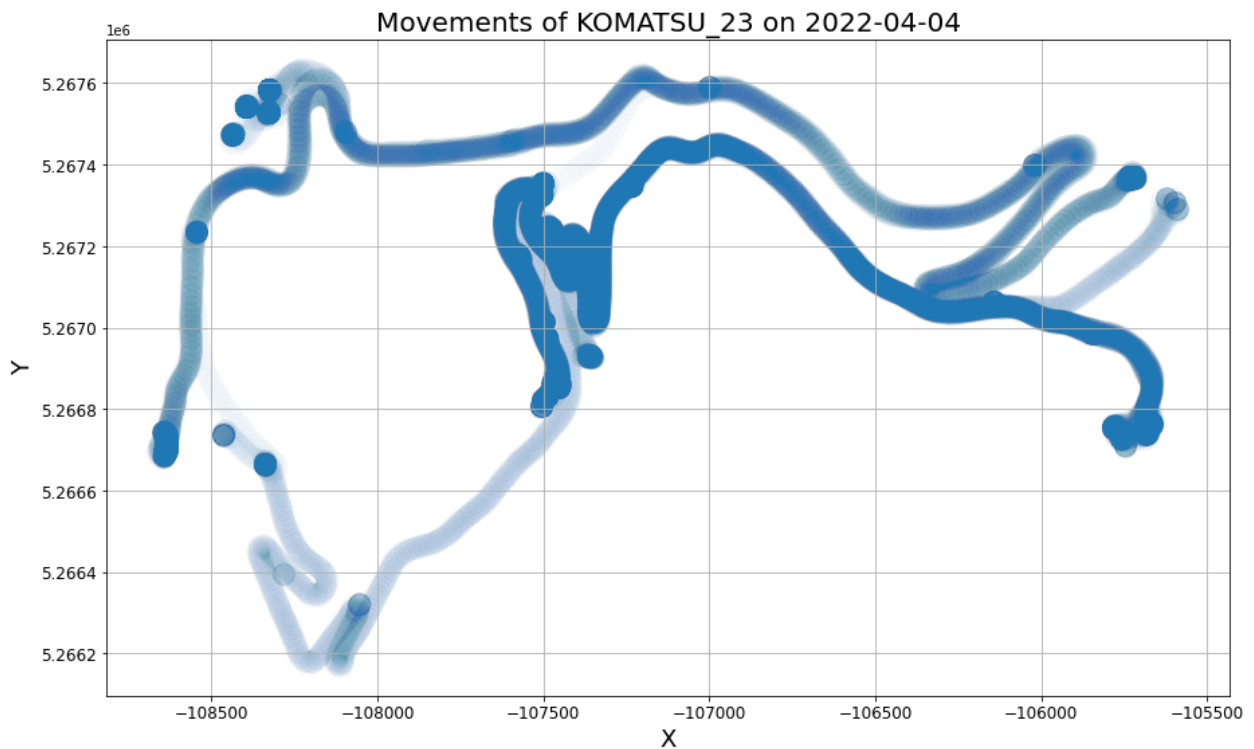


Figure 21. Movements of Komatsu 23 on 04.04.2022

In the Framework Determination chapter, it was proposed to consider only the main ramp as the main place for finding idling locations. This statement can be assumed as the first hypothesis. As we can see on the picture 21 Komatsu 23 indeed was driving pretty often down the main ramp during 04.04.22. This is obvious as this road provides access to the majority of the benches and tailings site in the mine. In order to prove this hypothesis, we should check trajectories of other dump trucks. To ease this process, we should first find out which vehicles did not move at all on certain days. This information will be structured in a table. The table is presented on the picture 22. A green square means that a dump truck was operating on a specific day, a red square means the opposite.

#### Hypothesis № 1

*The main ramp is the place with the greatest number of idling locations.*

Dump Truck	Date				Moved
	04.04.2022	05.04.2022	06.04.2022	07.04.2022	yes no
Komatsu 18	■	■	■	■	
Komatsu 19	■	■	■	■	
Komatsu 20	■	■	■	■	
Komatsu 21	■	■	■	■	
Komatsu 22	■	■	■	■	
Komatsu 23	■	■	■	■	
Komatsu 24	■	■	■	■	
Komatsu 25	■	■	■	■	
Komatsu 26	■	■	■	■	
Liebherr 10	■	■	■	■	
Liebherr 11	■	■	■	■	
Liebherr 12	■	■	■	■	
Liebherr 13	■	■	■	■	
Liebherr 14	■	■	■	■	
Liebherr 15	■	■	■	■	
Liebherr 16	■	■	■	■	

Figure 22. Table of dump trucks' movements

As we can see on the figure 22 none of the dump trucks were operating on 05.04.22. Moreover, Liebherr 10 didn't work during the entire period of the analysis. It can be stated that all of the rest Liebherr machines were working on 04, 06 and 07 of April. Some of the Komatsu vehicles were partly in operation during the considered time period. If they didn't work on a specific day then they work on a different day. 04.04 is the day with the least number of involved dump trucks – 12. On the other days there were 13 machines operating in the mine. It is known that during one shift there are only 11 dump trucks that can operate simultaneously. It means that some of the trucks don't operate 3 shifts in a row.

As long as we determined days of operations and specific dump trucks to be considered we can plot trajectories of their movements. This approach should provide information about the most common paths in the open pit mine. The graph is plotted on the data from all the dump trucks that were moving in the mine on 04.04.2022. The graph is presented on the picture 23. Greyed out lines represent the least common ways, whereas blue lines stand for the most frequent ones. This is determined by the number of common coordinates in the generated datasets from the vehicles.

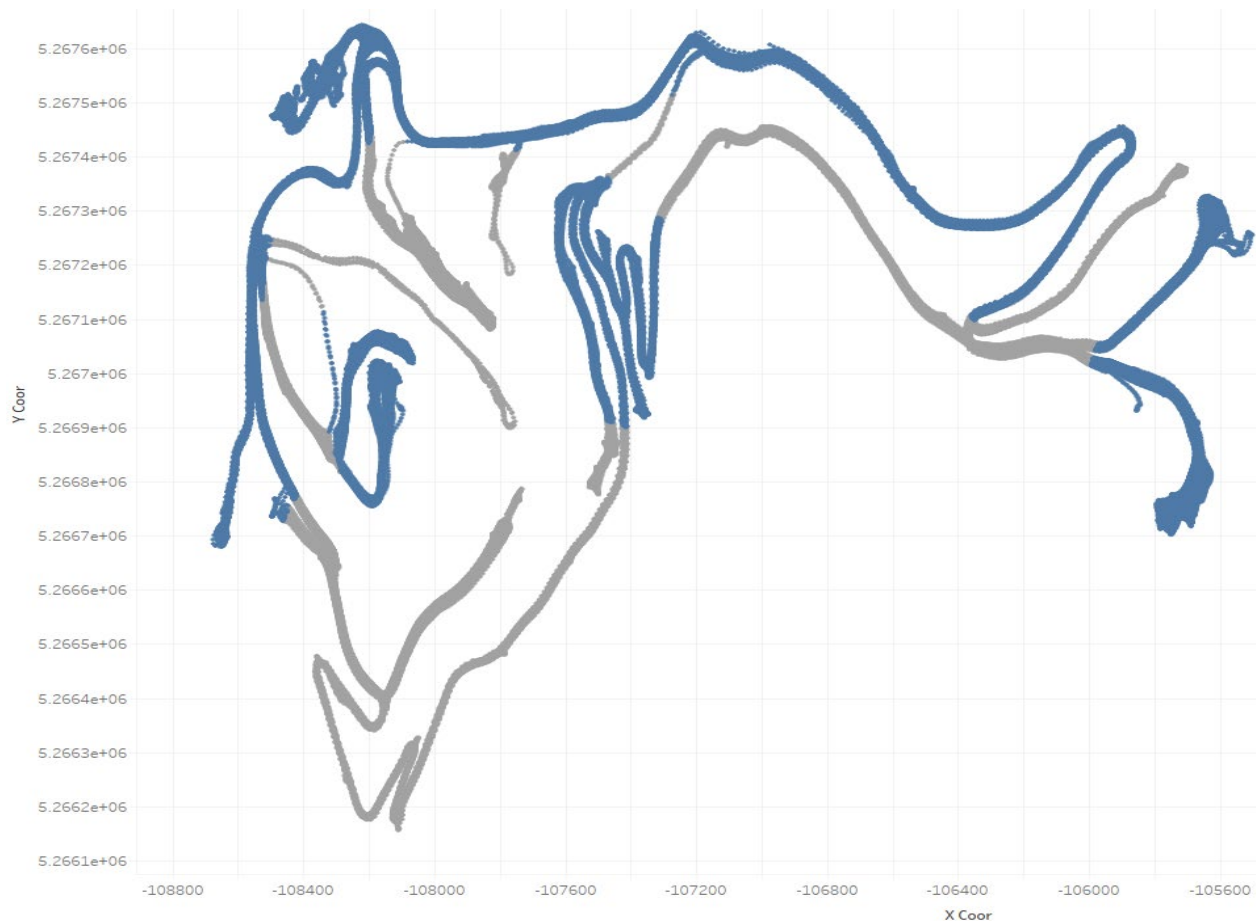


Figure 23. Trajectories of all the machines' movements on 04.04.22

The graph on the figure 23 shows that the most popular paths are lining along the main ramp and also on the tailing sites. The last are obvious as every dump truck has to come to such places in order to unload the overburden or loose rock. The idling time on these sites depend only on the maneuvers of the other machines that have to unload. Besides that, there are some benches in the center of the mine where the majority of the trucks spent a lot of time. These places have to be considered as bottlenecks due to several reasons:

- The width of the benches in blue paths might be too narrow and dangerous, so drivers have to slow down;
- It is quite difficult to move for two dump trucks in opposite directions on these benches because the benches are not wide enough;
- There might be often obstacles on the ground on these places such as rocks or stones.

Besides the mentioned above locations the main ramp is still of the main interest. The plotted graph shows that all the dump trucks use this path most of all. However, the hypothesis №1 cannot be completely proved yet as graph 23 only shows information about the most frequent movement paths. In order to prove the first hypothesis, we need to find the most common idle locations. In order to do so we



have to filter the data and leave only that information where the speed equals to zero. This will provide us the coordinates where a vehicle was standing still.

During one of the intermediate meetings it was proposed by the managers of VA Erzberg to exclude some locations and periods from calculating idling time. Moreover, only two specific statuses of dump trucks have to be considered. As mining vehicle is a sophisticated machine there is a list of different statuses that are recorded and tracked during its exploitation by an on-board computer (fig. 24).

Status	German	English
0	unbekannt	unknown
1	leer/steht	empty/standing
2	leer/faehrt	empty/driving
3	beladen aktiv	loading active
4	beladen/faehrt	loaded/driving
5	beladen/steht	loaded/standing
6	abladen aktiv	unloading active
7	beladen/faehrt/elektro	loaded/drives/electro
8	leer/faehrt/elektro	empty/drives/electric
15	zuendung aus / Fehler	ignition off/error

Figure 24. Table of statuses

As it can be seen from the picture 24 there are 10 different vehicle statuses. However, the crucial for the analysis are statuses 1 and 5 which mean empty and loaded standing respectively. It is necessary to know where exactly trucks were standing with an empty and full back because it effects on KPI.

According to the company's preferences workshop areas have to be excluded from the analysis. There is one main location in the mine where dump trucks staying because of maintenance or repairing. This place is located on the north part of the main near the main ramp. The area of this workshop place is approximately 31 000 m<sup>2</sup>. It is presented on the figure 25.

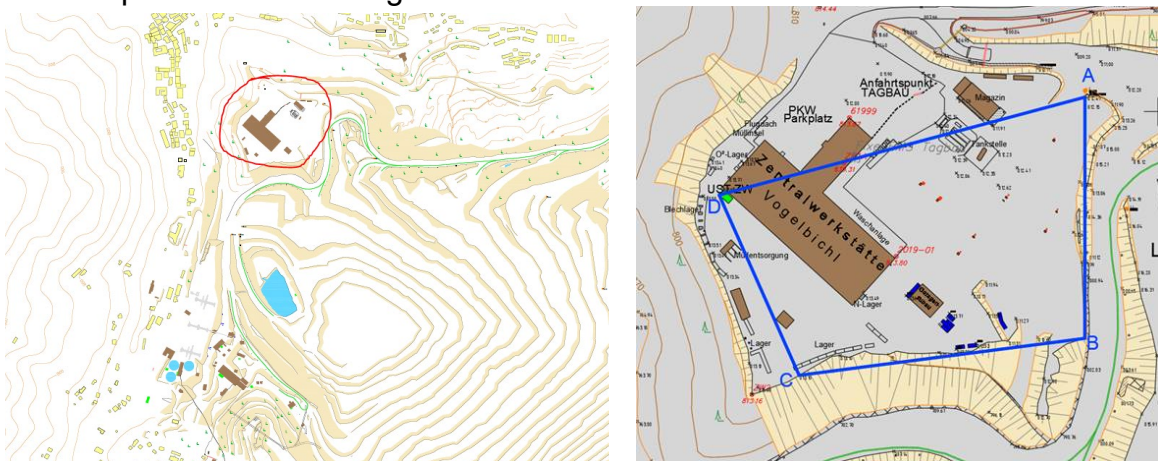


Figure 25. Workshop area (VA Erzberg)



Here are the coordinates of this area:

- A( X,Y,Z) : -108251.75, 5267610.14, 812.15
- B( X,Y,Z) : -108251.86, 5267439.41, 812.71
- C( X,Y,Z) : -108454.28, 5267413.26, 813.10
- D( X,Y,Z) : -108510.95, 5267540.88, 813.53

On top of that idling time should not be considered during shift changes and lunch breaks:

Lunch break:

9.30 – 10.00 am (morning shift)

5.30 – 6.00 pm (afternoon shift)

1.30 – 3.00 am (night shift including sleeping time)

Shift change:

5.45 – 6.00 am

1.45 – 2.00 pm

9.45 – 10.00 pm

### 3.7 Idling locations

In this chapter we will try to prove the Hypothesis №1 telling that the most idling locations are concentrated along the main ramp. Some limitations will be considered such as ignoring the workshop area, records during lunch breaks and shift changes. Idle is assumed when a vehicle stands still, in other words the velocity has to be 0 km/h. In addition, only two statuses will be taken into account: empty and loaded standing.

Idle locations can be found by grouping 'x' and 'y' coordinates and considering the mentioned above filters. A dump truck can visit a place with the same coordinates several times a shift and during the day as well. Thus, if a machine is spotted multiple times with 0 speed on the same location this behavior can be treated as 'idling'.

However, after a precise study of the filtered data it was noticed that information about a machine's characteristics is generated at very close positions which leads to decrease of finding exact downtime location. A sample of the dataset from Komatsu 23 on 04.04.22 is taken as an example and shown on the figure 26.

	x_coor	status0_1	status0_5	total
y_coor				
5267369	[-105733, -105719]	97	14	111
5267370	[-105733, -105723]	113	1	114
5267371	[-105731]	19	0	19
5267372	[-105728]	0	12	12

Figure 26. Adjacent idling coordinates of Komatsu 23 on 04.04.22

As it can be seen on the figure 26 there are first 5 rows of a dataset with coordinates of downtime ('y\_coor' and 'x\_coor') and number of stops with different statuses (columns 'status0\_1' and 'status0\_5') and a total sum of them (column 'total'). As it has been already mentioned a vehicle can visit the same location with different statuses. This assumption is proved in the table. Komatsu 23 visited the location in the first row 97 times with an empty back and 14 times with loaded during 04.04.22.

In the dataset it is seen that one Y coordinate has several X coordinates where a dump truck was spotted. Moreover, there are quite a lot of adjacent Y coordinates. As a result, it is difficult to define a certain idle location because there is too much noise of numerous dots on a map. This issue is presented on the picture 27. Movements of all dump trucks on 07.04.22 are taken as an example. Red color markers stand for loaded back and green – for empty back. On the right left corner there is a legend of all vehicles abbreviations where first letter stands for the name of the dump truck and digit for its serial number. For instance, 'K' is Komatsu and 'L' is Liebherr. Blue solid curve represents the main ramp in the mine. The map on the figure 27 is plotted based on the information from datasets of each vehicle. One of them was presented on the figure 26.

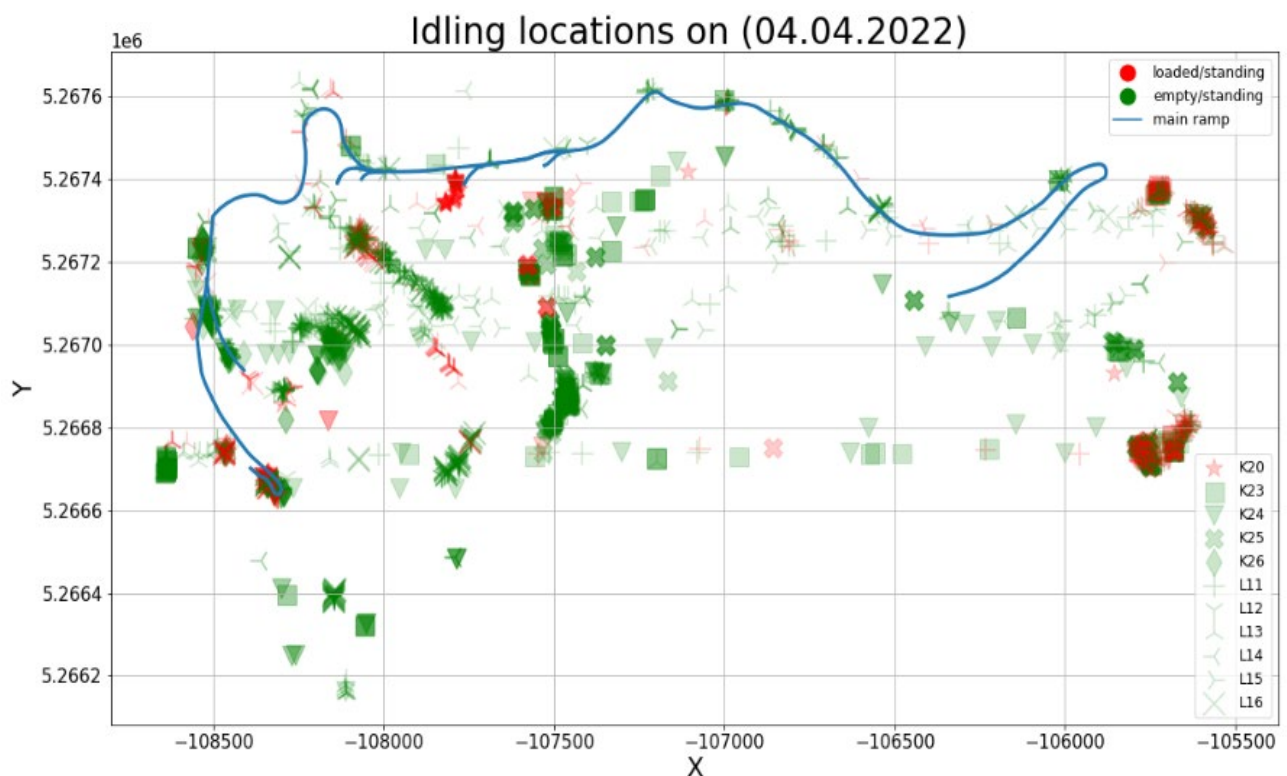


Figure 27. Map of idling locations of all dump trucks

The map on the picture 27 shows an enormously big number of dots with downtime locations. However, it is able to notice that the majority of the stops were followed with an empty back. Preliminarily, it can be asserted that the hypothesis №1 is partially justified – a lot of dots are concentrated near the main ramp and in the tailing sites. All Komatsu dump trucks are presented by thick markers, whereas Liebherr by thin.

The map above gives us an overview of all the downtime locations where all the dump trucks were on 04.04.22. However, this graph does not say anything about the number of stops on these locations. Another graph has to be plotted for better understanding of the approximate number of the stops. This information is shown on the picture 28.

On the following bar chart 20 most frequent locations are presented. Each bar corresponds to a certain pair of coordinates where all the dump trucks stopped most often. Bars have different colors according to a status: blue stands for 'empty standing' and orange for 'loaded standing'. The location with coordinates (5266396;-108147) has the greatest number of stops – 280 which were all followed by status 'empty standing'. It has to be mentioned that on some locations dump trucks were making stops with both statuses. For example, a place with coordinates (5266666;-108337) has bars with two different colors.

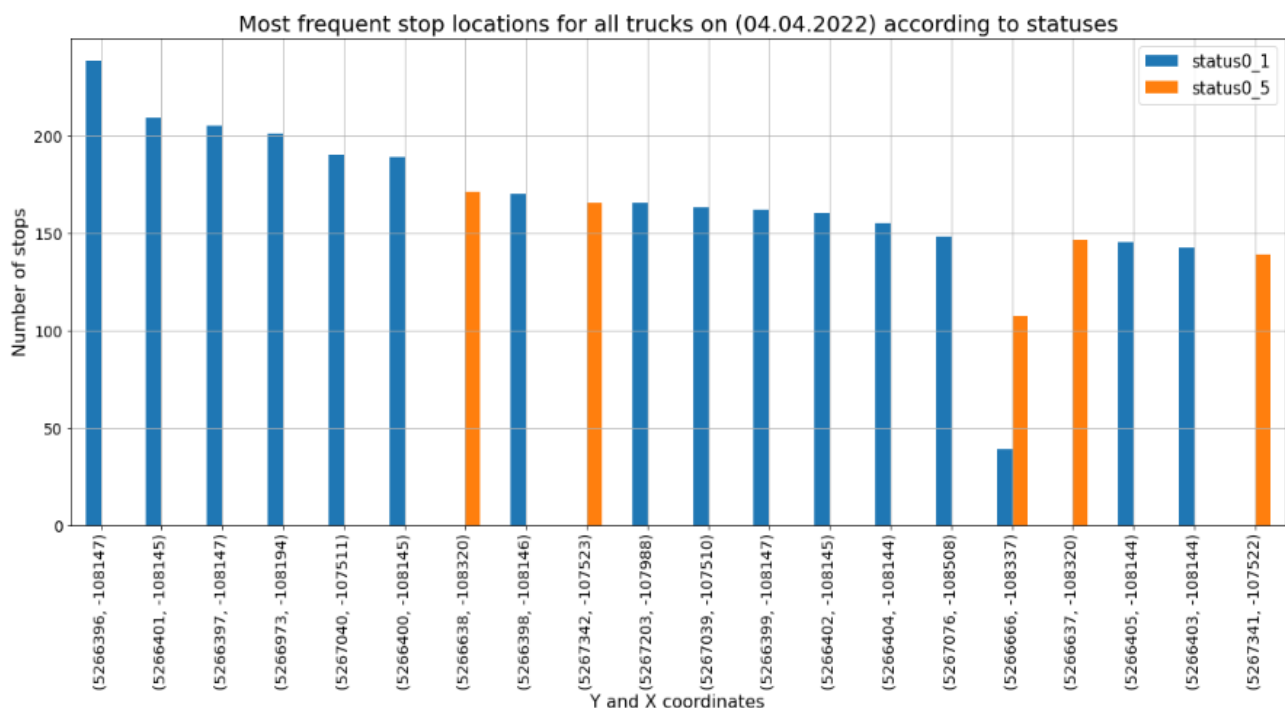


Figure 28. Number and coordinates of idling locations

The map with idling locations on the figure 27 and the bar chart with the total number and coordinates of them on figure 28 describe all the data of every stop. Despite it provides a good overview of the situation in the mine on 04.04.22, still there is too much noise in the results.

The best solution to increase the accuracy of idle places is to aggregate the adjacent locations. It was agreed to take a mean value of the coordinates in the range of  $\pm 5$  meters. A mean value is better than a median in this case as all the data from a chosen range will be taken into account. Thus, a unique pair of coordinates will be formed which will provide a better understanding of downtime locations in the mine. Technically we group data in every dataset by coordinate Y, take a mean X coordinate regarding Y coordinate and make a total sum of all entries stops (with status 1 and 5). A code example is presented on the picture 29.

```

def total_stops_counter(df):
    stops_counter = df.drop(['time'], axis=1)
    stops_counter = stops_counter.groupby('y_coor').agg(
        {'x_coor': 'mean', 'status0_1': 'sum', 'status0_5': 'sum', 'total': 'sum'})
    stops_counter['x_coor'] = stops_counter['x_coor'].astype(int)
    stops_counter = stops_counter.reset_index()
    return stops_counter

stops_counter = total_stops_counter(joined_df)
stops_counter.sort_values(by='total', ascending=False).head()

```

Figure 29. Code example of coordinates grouping

### 3.8 Idling time

In this chapter a final result with precise idling locations will be derived. As long as every row in each dataset contains information about a timestamp, idling location relatively to each unique pair of coordinates will be calculated. This approach saves calculation time and provides all the benefits from the aggregation function.

During the work on finding a solution how to create such a code in Python two different iterations were made. In the first iteration it is used an enumeration method. There are two main blocks of code which are performed by functions. The description of the code will be made in cursive font. The first block of code is presented on figures until 30.

#### First iteration

*The first function starts with creation of two lists with unique 'X' and 'Y' coordinates.*

```

3 def enum(df):
4     df_zero_speed_filtered = df.reset_index(drop=True)
5     y_list_df = df_zero_speed_filtered['y_coor'].unique().tolist()
6     x_list_df = df_zero_speed_filtered['x_coor'].unique().tolist()
7

```

*Once the lists are created a dictionary of unique pair of coordinates shall be created. This is achieved by sorting out every Y coordinate and matching it with every X coordinate. Once a match is made such a unique pair of coordinates is saved into a row of the new dictionary. This dictionary will not contain any duplicated pairs of coordinates. Next to the coordinates the rest information of vehicle's information is saved into the row. All the rows with the same unique pairs of coordinate and additional information are formed into a separate small dataset inside a general dictionary. In the end a general dictionary with multiple datasets will be generated.*

```

15 dict_df = {}
16 for i in range(len(y_list_df)):
17     for j in range(len(x_list_df)):
18         if df_zero_speed_filtered.query(f'y_coor == @y_list_df[{i}] and x_coor == @x_list_df[{j}']).shape[
19             0] != 0:
20             dict_df[i, j] = pd.DataFrame(
21                 df_zero_speed_filtered.query(f'y_coor == @y_list_df[{i}] and x_coor == @x_list_df[{j}']))
22

```

On this step it is checked whether there are any empty datasets inside the general dictionary.

```

25 clean_dict_df = {k: v for (k, v) in dict_df.items() if not v.empty}
26 for name, df in clean_dict_df.items():
27     df.reset_index(drop=True, inplace=True)
28 clean_dict_df

```

On this step small datasets inside the great dictionary are filtered regarding the status. In the end 2 new dictionaries will be created. One dictionary will contain small datasets with only status 1 - 'empty standing' and the second dictionary will contain small datasets with only status 5 - 'loaded standing'.

```

34 idle_status1_df = {}
35 idle_status5_df = {}
36 for name, df in clean_dict_df.items():
37     status1 = df.query('status_0 == 1')
38     status5 = df.query('status_0 == 5')
39     idle_status1_df[name] = pd.DataFrame(status1)
40     idle_status5_df[name] = pd.DataFrame(status5)

```

On this step it is checked whether the new 2 dictionaries have any empty small datasets. If so, such datasets are dropped.

```

44 clean_idle_status1_df = {k: v for (k, v) in idle_status1_df.items() if not v.empty}
45 for name, df in clean_idle_status1_df.items():
46     df.reset_index(drop=True, inplace=True)
47
48 clean_idle_status5_df = {k: v for (k, v) in idle_status5_df.items() if not v.empty}
49 for name, df in clean_idle_status5_df.items():
50     df.reset_index(drop=True, inplace=True)

```

On this step an idling time relatively each unique pair of coordinates is calculated inside every small dataset. Only those timestamps are concerned where the difference in time between two adjacent rows is not greater than 2 seconds. In other ways such rows are dropped. This procedure is done first for the dictionary with the status 'empty standing'. A result is updated in the dictionary.

```

57 timedelta_status1_df = {}
58 for name, df in clean_idle_status1_df.items():
59     pure_idle = df['datum'].diff()
60     total_sum = pure_idle.loc[pure_idle.loc[:] == "0 days 00:00:02"].sum()
61     df['Y,X'] = df['y_coor'].apply(str) + ', ' + df['x_coor'].apply(str)
62     df.drop(['y_coor', 'x_coor'], inplace=True, axis=1)
63     df = df.loc[[0]]
64     df['idling'] = total_sum
65     df = df[['Y,X', 'idling', 'status_0']]
66     timedelta_status1_df[name] = pd.DataFrame(df)

```

The previous step is repeated again but now with the dictionary with the status 'loaded standing'.



```

70 timedelta_status5_df = {}
71 for name, df in clean_idle_status5_df.items():
72     pure_idle = df['datum'].diff()
73     total_sum = pure_idle.loc[pure_idle.loc[:] == "0 days 00:00:02"].sum()
74     df['Y,X'] = df['y_coor'].apply(str) + ', ' + df['x_coor'].apply(str)
75     df.drop(['y_coor', 'x_coor'], inplace=True, axis=1)
76     df = df.loc[[0]]
77     df['idling'] = total_sum
78     df = df[['Y,X', 'idling', 'status_0']]
79     timedelta_status5_df[name] = pd.DataFrame(df)
80
81     return timedelta_status1_df, timedelta_status5_df
82
83
84 delta1, delta5 = enum(km24_04_zero_speed_filtered)

```

As a result of the first function we receive two dictionaries which consist of small unique datasets of coordinates and calculated idling time.

In the second function we concatenate all the small and separate datasets from the previous function into one solid dataframe. In the final dataset we group all the data by unique pair of coordinates and aggregate a maximum value of the idling time.

```

5 def conc(dt1, dt5):
6     if len(dt1) > 0 and len(dt5) > 0:
7         stat1_df = pd.concat(dt1.values(), ignore_index=True)
8         stat5_df = pd.concat(dt5.values(), ignore_index=True)
9         final_df = pd.concat([stat1_df, stat5_df])
10        final_df = final_df.reset_index(drop=True)
11        final_df.drop(final_df[final_df['idling'] == "00:00:00"].index, inplace=True)
12        final_df = final_df.groupby(['Y,X', 'idling']).max()
13        final_df = final_df.reset_index()
14        final_df = final_df.sort_values(by='idling', ascending=False)
15        final_df = final_df.reset_index(drop=True)
16    elif len(dt1) > 0 and len(dt5) == 0:
17        stat1_df = pd.concat(dt1.values(), ignore_index=True)
18        final_df = stat1_df.reset_index(drop=True)
19        final_df.drop(final_df[final_df['idling'] == "00:00:00"].index, inplace=True)
20        final_df = final_df.groupby(['Y,X', 'idling']).max()
21        final_df = final_df.reset_index()
22        final_df = final_df.sort_values(by='idling', ascending=False)
23        final_df = final_df.reset_index(drop=True)
24    elif len(dt1) == 0 and len(dt5) > 0:
25        stat5_df = pd.concat(dt5.values(), ignore_index=True)
26        final_df = stat5_df.reset_index(drop=True)
27        final_df.drop(final_df[final_df['idling'] == "00:00:00"].index, inplace=True)
28        final_df = final_df.groupby(['Y,X', 'idling']).max()
29        final_df = final_df.reset_index()
30        final_df = final_df.sort_values(by='idling', ascending=False)
31        final_df = final_df.reset_index(drop=True)
32
33    return final_df
34
35
36 final_km24_04 = conc(delta1, delta5)
37 final_km24_04.head(10)

```

Figure 30. First iteration script



The result of the work of two functions is presented on figure 31 as table. Every row has a unique pair of coordinates and a total idling time on this location.

	Y,X	idling	status_0
0	5266973, -108195	0 days 00:03:10	1
1	5266974, -108195	0 days 00:02:56	1
2	5266975, -108195	0 days 00:02:08	1
3	5266973, -108194	0 days 00:02:06	1
4	5267342, -107524	0 days 00:01:56	5
5	5267341, -107523	0 days 00:01:52	5
6	5266666, -108339	0 days 00:01:48	5
7	5266638, -108321	0 days 00:01:46	5
8	5266634, -108321	0 days 00:01:46	5
9	5266665, -108339	0 days 00:01:38	5

Table 5. Final table with total idling time and locations of the 1st iteration

The mentioned above blocks of code are calculated for a dataset of Komatsu 24 on 04.04.22. As it can be seen from the final table 5 all data is sorted in the descending mode regarding the total downtime. This dump truck had the longest idling time (00:03:10) at the location with coordinates (5266973, -108195) with a status 'empty/standing'.

Though this approach gives important data about exact locations and a sum of idling time there are still some drawbacks:

- There are still quite a lot of adjacent locations;
- There is no information about a total sum of stops according to every location;
- The major problem is the code execution. It takes at least 5 hours for calculations to form the final table per each vehicle's dataset.

A problem of such a long running of code is that there are over 50 000 'x' coordinates as well 'y' in each dataset. The script has to sort out every entry of 'x' coordinate and match it with every entry of 'y' coordinate. To do so a loop inside a loop was created which enormously slowed down the calculation process.

### Second iteration

In order to optimize the previous code another script iteration has been made. This time there is a completely different approach. At first, every dataset will be sorted in ascending mode regarding 'y' coordinate. The main idea is to divide a filtered dataset into blocks where the difference in coordinates between adjacent rows not greater than 5 meters. As soon as blocks will be formed it will be easy to take median values of 'y' and 'x' coordinates within each block. A median value is better in this case because it will help to avoid an influence of anomalies (too big or too small coordinate values regarding the rest in the same block). However, the idling time of all other adjacent coordinates within the same block will be summed up as well as the number of stops. In theory such approach should speed up the calculation execution and increase the accuracy. The reason is that script runs down every row and divides an initial dataset into smaller blocks and then makes an aggregation. There is no enumeration as loop inside a loop which requires lots of

memory storage. As in the previous iteration code examples will be followed with comments in cursive font. The blocks of code are presented on the figures till 32.

*At first, we have to collect all the same pair of coordinates with timestamps regarding status 1 (empty standing).*

```

1 def group_stat1(df):
2     status0_1 = df.query('status_0 == 1')
3     status0_1 = status0_1.groupby('y_coor').agg(lambda x: list(x))
4     status0_1 = status0_1.drop(['date', 'speed', 'height', 'status_1'], axis=1)
5     status0_1.reset_index(inplace = True)
6     status0_1 = status0_1[['y_coor', 'x_coor', 'time', 'status_0']]
7     status0_1['x_coor'] = status0_1['x_coor'].apply(np.mean).astype(int)
8     return status0_1
9
10 status0_1 = group_stat1(km23_04_pure)
11 status0_1

```

*Here we make a sum of all stop entries with status\_0 = 1*

```

3 def stops_counter1(row):
4     ones = 0
5     for value in row:
6         if value == 1:
7             ones += 1
8     return ones
9
10 status0_1['status0_1'] = status0_1['status_0'].apply(stops_counter1)
11 status0_1 = status0_1.drop(['status_0'], axis=1)

```

*We will make the same two previous steps but now regarding status 5 (loaded standing). Afterwards we concatenate two tables with status 1 and 5 into one.*

```

3 def concat (df1,df5):
4     joined_df = df1.append(df5)
5     joined_df = joined_df.fillna(0)
6     joined_df['status0_1'] = joined_df['status0_1'].astype(int)
7     joined_df['status0_5'] = joined_df['status0_5'].astype(int)
8     joined_df['total'] = joined_df['status0_1'] + joined_df['status0_5']
9     return joined_df
10
11 joined_df = concat(status0_1, status0_5)

```

*Now we calculate a sum of all idling entries regarding every unique pair of coordinates. The following function checks only those timedelta idling entries which equal to 2 seconds in a value list regarding every unique pair of coordinates. Then it saves all found idling entries into a new list to a column ['idling'] regarding every unique pair of coordinates.*

```

7 def total_idle (row):
8     idle = []
9     d1 = timedelta(days=0, hours=0, minutes=0, seconds=2)
10    for value in row:
11        if value == d1:
12            idle.append(value)
13    return idle
14
15    joined_df['idling'] = joined_df['time'].apply(total_idle)
16    joined_df['idling'] = joined_df['idling'].apply(np.sum)
17    joined_df = joined_df.drop(['time'], axis=1)
18    joined_df = joined_df[['y_coor', 'x_coor', 'idling', 'status0_1', 'status0_5', 'total']]
19    joined_df.drop(joined_df[joined_df['idling'] == 0].index, inplace=True)

```

Now we sort our dataframe regarding 'y' coordinate in ascending.

```

23 joined_df = joined_df.sort_values(by='y_coor')
24 joined_df.reset_index(drop=True, inplace=True)

```

Here we divide current dataset into 2, regarding status\_0 in order to properly calculate idling time for locations with status0\_1 and status0\_5.  
status\_0 = 1

```

6 idle_stat1 = joined_df.query('status0_5 == 0')
7 idle_stat1 = idle_stat1.drop(['status0_5', 'total'], axis=1)
8 idle_stat1.reset_index(drop=True, inplace=True)

```

Now we create a dictionary of several datasets. These datasets consist of adjacent coordinates. Difference between them is not greater than 5.

```

6 def dict_idle(df):
7
8     dict_stat_raw = {}
9     k = 0
10    while k <= len(df):
11        i = 0
12        while i <= len(df):
13            try:
14                if df.loc[i + 1, 'y_coor'] - df.loc[i, 'y_coor'] <= 5:
15                    dict_stat_raw[k] = pd.DataFrame(df.loc[:i + 1])
16                    i += 1
17                else:
18                    dict_stat_raw[k] = pd.DataFrame(df.loc[:i])
19                    break
20            except:
21                dict_stat_raw[k] = pd.DataFrame(df.loc[:i])
22                break
23
24        k += 1
25        df = df.loc[i + 1:]
26        df = df.reset_index(drop=True)
27
28    return dict_stat_raw
29
30 dict_stat1_raw = dict_idle(idle_stat1)

```

Here we divide dataframes from the previous dictionary into blocks of 5 rows, where it is necessary.

```

5 def coor_blocks(df, status):
6     new_y_coor_df = {}
7     for name, df in df.items():
8         if df.shape[0] > 5:
9             i = 4
10            while i <= len(df):
11                row_df = df.loc[i - 4:i]
12                new_y_coor_df[i] = pd.DataFrame(row_df)
13                i += 5
14        else:
15            new_y_coor_df[name] = pd.DataFrame(df)

```

Here we reset index numeration, so every block starts with 0 index and ends with 4. Also, we take 1 median X and Y coordinates from every block, but take a sum of all idling entries and stops.

```

20 final_y_df = {}
21 for name, df in new_y_coor_df.items():
22     df.reset_index(drop=True, inplace=True)
23     df['y_coor'] = df['y_coor'].median().astype(int)
24     df['x_coor'] = df['x_coor'].median().astype(int)
25     df['idling'] = df['idling'].sum()
26     df[status] = df[status].sum()
27     df = df.loc[[0]]
28     final_y_df[name] = pd.DataFrame(df)
29     conc_df = pd.concat(final_y_df.values(), ignore_index=True)
30
31 return conc_df
32
33
34 check_stat1 = coor_blocks(dict_stat1_raw, 'status0_1')
35 check_stat1 = check_stat1.sort_values(by='idling', ascending=False)
36 check_stat1.reset_index(drop=True, inplace=True)
37 check_stat1.head()

```

Figure 31. Second iteration script

We will repeat the same 4 previous steps but now regarding the status 5 (loaded standing). Afterwards we have to concatenate two tables into one. The result for the dump truck Komatsu 25 on 04.04.22 is shown in the table 6.

	y_coor	x_coor	idling	status0_1	status0_5	total
0	5267042	-107510	0 days 00:10:30	340	0	340
1	5267332	-107505	0 days 00:06:52	0	220	220
2	5267327	-107506	0 days 00:03:34	0	121	121
3	5267055	-107511	0 days 00:03:12	102	0	102
4	5266987	-105796	0 days 00:03:02	98	0	98

Table 6. Final table with total idling time and locations of the 2nd iteration

As we can see the table 6 was generated as a result of the second script work. Here are presented the first 5 rows as an example. This table has aggregated unique pair of idle coordinates, total downtime and sum of stops with different

statuses. The information in the table is more accurate as the coordinates do not intersect. Another advantage of the new script is that the execution time decreased up to 12 seconds.

Now it is possible to create a final map with all the idling locations. This time every location will also show a number of stops by the color density (fig. 34).

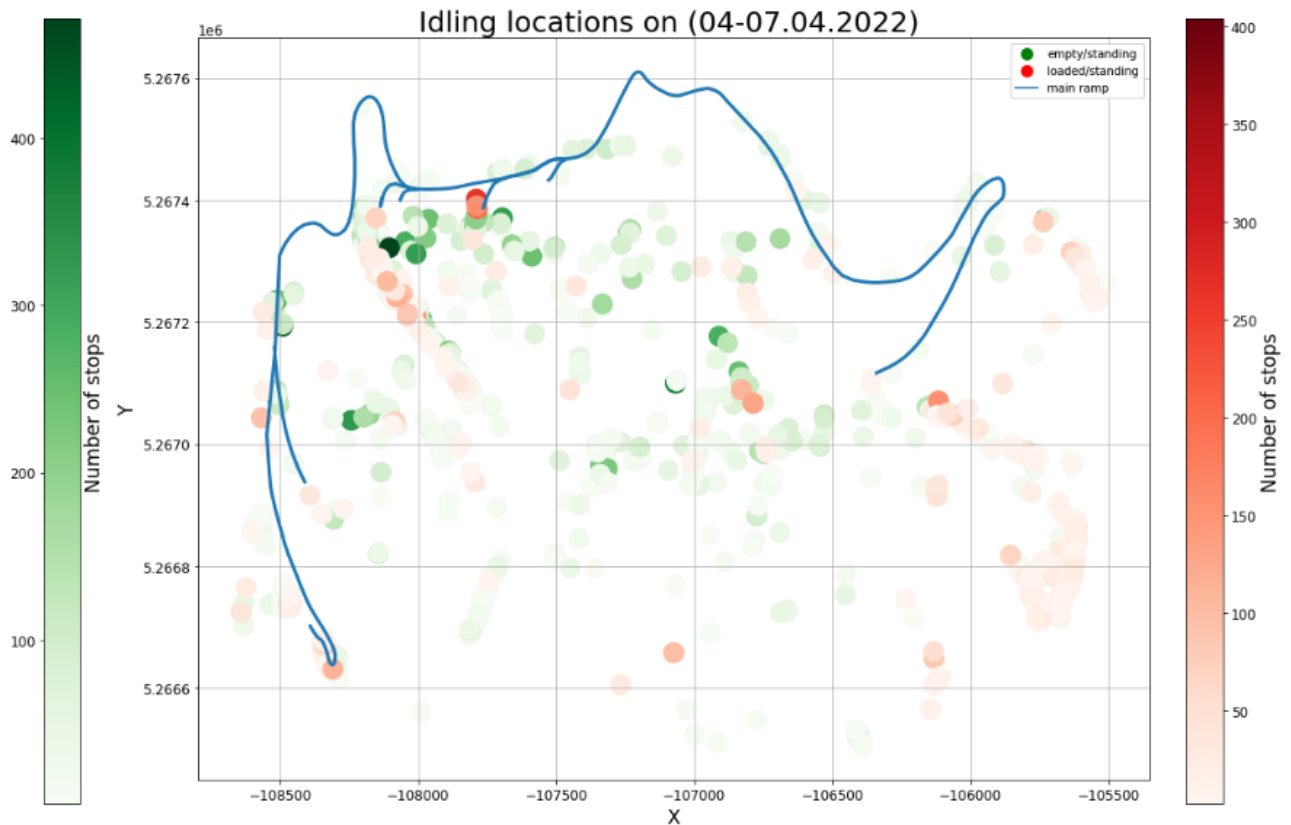


Figure 32. Final map with idle locations

The map on the figure 32 shows idling locations of all the dump trucks that were operating in the mine from 04 till 07 April 2022. Red color stands for loaded standing status and green color – for empty standing. The darker the color the more stops were made on the location. Color bars on the sides of the map show the dependence between color density and number of stops. The maximum number of stops that was made around a location is 450 with an empty status. It means that the majority of the vehicles idle with an empty back. We can see that the greatest number of dots are concentrated on the bench that leads to the main ramp in the north-west of the mine. Looks like the main reason of such situation is because of traffic lights. Another big concentration of stops is located on the tailing site in the south-east part of the mine. There are also quite a lot of idle locations in the center of the mine. It is difficult to state a certain reason of this behavior as there are several benches in this place. Perhaps the benches are too narrow for two dump trucks to travel at once in opposite directions. The real circumstances of the situation have to

be witnessed in situ. In addition, there are plenty of dots that are spread along the main ramp. However, the majority of the downtime positions are situated in the intersections between the main ramp and auxiliary benches.

Thus, the hypothesis №1, saying that the main ramp is the place with the greatest number of idling locations, is partly proved.

Thanks to the final table on the figure 33 we can also calculate a total idle time for every dump truck. An example from Komatsu 25 on 04.04.22 is presented on a bar chart 35.

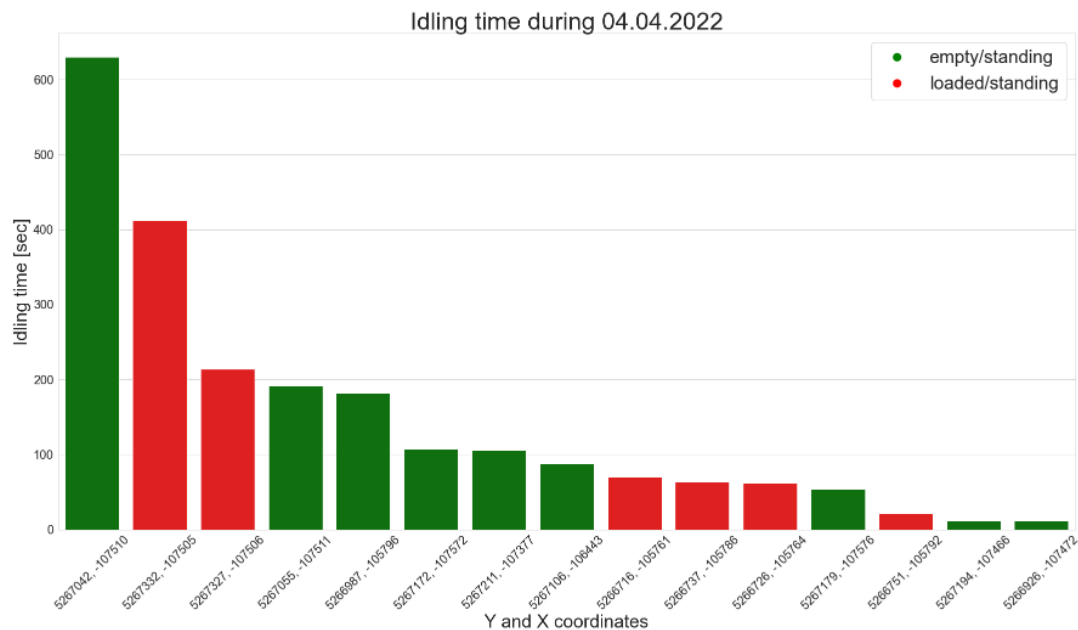


Figure 33. Idling time according to coordinates

The figure 33 shows a total downtime by the end of the day on 04.04.22. Each bar relates to a certain location in the mine. Green color stands for idle with an empty back and red with a loaded one. So, the longest downtime with 10 minutes was on the position with coordinates 5267042; -107510 with an empty back. As we can see this dump truck was idling on 04.04 more often with an empty back than with a loaded one. A script also makes a report for a dump truck with idling details:

- Overall idling time - 0 days 00:38:12
- Total idling time with status "empty/standing" - 0 days 00:23:32
- Total idling time with status "loaded/standing" - 0 days 00:14:40

Based on this it is able to collect all downtime information about every machine during the considered timeframe. The generated information is presented in the table 7.



	04.04.22	06.04.22	07.04.22	total
<b>dump_truck</b>				
K26	43	82	43	168
L12	54	64	50	168
K23	34	36	68	138
L16	28	29	57	114
L11	20	52	37	109
K25	29	50	29	108
K24	28	40	28	96
L14	41	12	40	93
L15	17	45	28	90
L13	20	18	40	78
K20	28	0	0	28
K22	0	18	9	27
K19	0	0	24	24
K21	0	12	9	21
K18	0	0	0	0
<b>Total</b>	<b>342</b>	<b>458</b>	<b>462</b>	<b>1262</b>

Table 7. Total idling information about every truck

Data in the table 7 is sorted by the column 'total' in descending mode. This column makes a sum of all downtime by the end of the entire period for each dump truck. All figures are presented in minutes. The last row 'Total' shows a summarized downtime of all dump trucks regarding each day. The calculated idling time includes information about both statuses 'empty' and 'loaded' standing. As we can see the longest idle in total by the end of the whole considered timeframe belongs to Komatsu 26 and Liebherr 12 and equals to 168 minutes (~ 3 hours). The longest downtime in total of all dump trucks was on 07.04.22 and was 462 minutes (~8 hours). The shortest total idling was on 04.04.22 and equals to 342 minutes (~6 hours). On 06.04.22 the total downtime is 458 minutes (~7,5 hours). The overall idle is 1262 minutes (~ 21 hours) in 3 days. The gathered data can be presented in more informative way as a graph (figure 34).

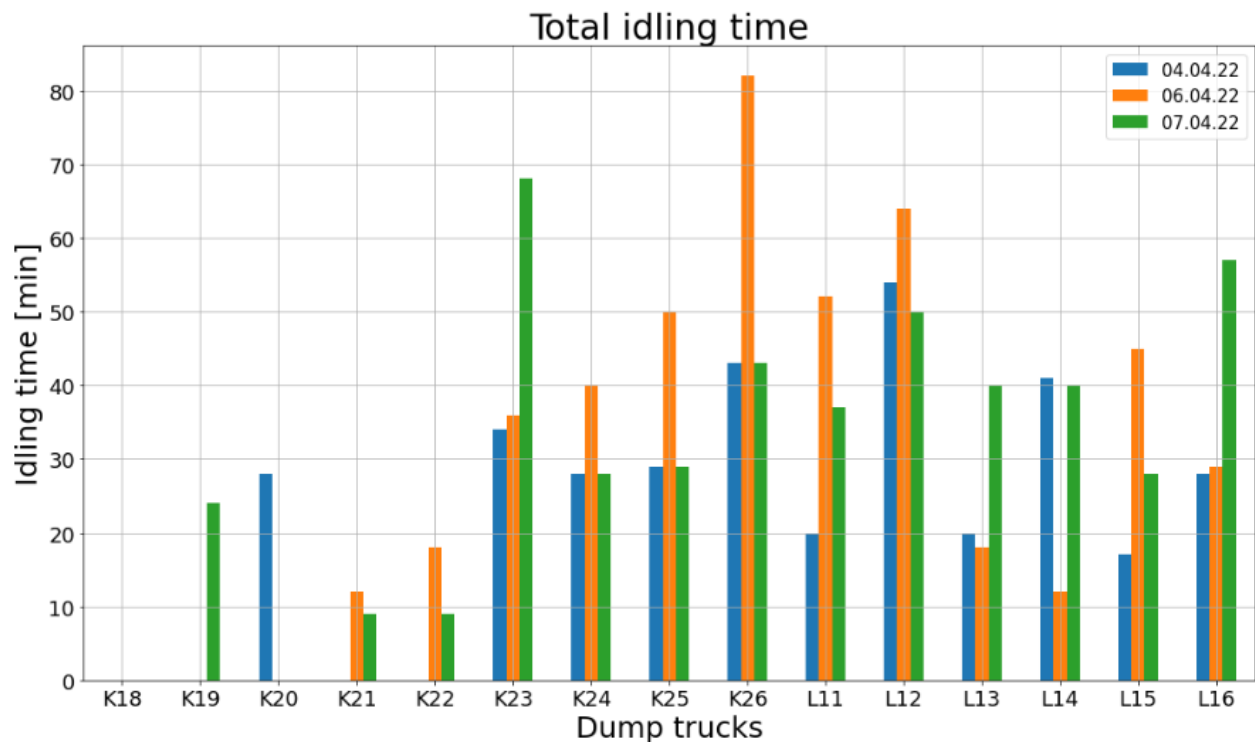


Figure 34. Total idling time of all machines

The graph 34 illustrates aggregated idling time for every machine as colored bars which represent a specific day. This bar chart provides us a bit more detailed information. For example, Komatsu 26 had the longest downtime of 80 minutes on 06.04.22 than any other vehicles. Mostly all of the vehicles were idling every day. Looks like Komatsu 18 did not operate that much during the considered period. Komatsu 19, 20, 21 and 22 were idling only during some specific days. Most probably they were on maintenance on the other days or were out of service. The average downtime off all the rest is between 20 and 40 minutes a day. Overall, as it can be seen every vehicle that was operating in the mine during a specific day had some idling time by the end. Otherwise it did not move at all or only a very limited amount of time.

### 3.9 Validation of the results

The conducted above analysis was performed by means of a script developed on Python. A script is a program or sequence of instructions that is interpreted or carried out by another program rather than by the computer processor (as a compiled program is). In other words, all the analysis instruments that are necessary to describe a dump truck's behavior on a specific time period are integrated into one program – script. This program is easy to run as it functions automatically. The

biggest advantage of the program is that it does not require any specific programming knowledge. Below will be described steps on how to use the script. In order to perform an analysis of any dataset a user have to place a csv document into a folder where the program exists. Besides the program there are 4 additional files with the main ramp coordinates. They should always stay in the same folder with the main program file. The initial view of the folder is presented on the figure 35.






Name	Date modified	Type	Size
 erzberg_app	04-Sep-22 22:54	Application	95,661 KB
 main_ramp.pkl	29-Aug-22 16:27	PKL File	13 KB
 small_ramp.pkl	29-Aug-22 16:27	PKL File	2 KB
 small_road1.pkl	29-Aug-22 16:27	PKL File	2 KB
 small_road2.pkl	29-Aug-22 16:27	PKL File	2 KB

Figure 35. Initial view of program's folder

Once a raw dataset has been placed to the folder, an application 'erzberg\_app' has to be double clicked. It will start the script. Nothing is required to do further just wait a bit. Usually it takes from 10 to 15 seconds to let the program perform an analysis. The execution time depends on the size of the data.

As a result of running the program 4 png and 1 txt file will appear in the same folder. The images contain graphs and bar charts about a dump truck's behavior meanwhile a txt file contains a short report about idling details.

1. 'K23\_movements\_plot' – an image that illustrates a map with movements trajectory of Komatsu 23 on a specific day. The abbreviation in the file's name stands for the model of a dump truck ('K' – Komatsu, 'L' – Liebherr);
2. 'K23\_stops\_plot' – an image that illustrates a bar chart with the most frequent idling locations and their number according to statuses;
3. 'K23\_idling\_time' – an image that illustrates a bar chart with a downtime sum on certain locations according to statuses;
4. 'K23\_idling\_map' – an image that illustrates a map of the mine with the main ramp and most frequent idling locations. The frequency of stops depends on a color density of a dot.
5. 'K23\_idling\_result' – a txt file with a brief overview about the idle during a specific day. It contains information about an overall idle, total idle times with a status 'empty standing' and with a status 'loaded standing'.

The output files are presented in the Anex section. It can happen that after the execution of the program there will be generated only 2 files in the folder. It means that either a dump truck did not make any move (a corresponding txt file will contain this message) or data in the 'csv' file is not in an applicable format. A detailed instruction on how to install and use the application is written in a 'readme' file. This

file comes together with an installation app and will appear in a chosen directory once the program will be installed on a computer.

The script allows to conduct independently an analysis of any dataset obtained from a dump truck. To date there are some limitations. All the generated datasets must have the same structure and data types as those that have been used during working on the project. A timeframe in one dataset should not be greater than one 1 day. The program can perform only one dataset at a time. It means that only one 'csv' file should be uploaded to the folder with the script. In case it is necessary to perform another analysis of a different dataset, an existing 'csv' document has to be deleted or replaced by a new one. The output documents from the previous analysis can be kept in the same folder. The names of the output files from the analysis program contain a short name of dump truck and a description of a plot. There is no information about the date. Thus, in order to avoid overwriting output files from the same vehicle but on different days, the previously generated files have to be moved to a different folder and renamed. The installation file has a size of 95 Mb. It can be easily transferred by USB flash memory cards or stored in a cloud. The program does not require any preinstalled special software as Python or any Integrated development environment (IDE) such as PyCharm. The program is compatible with Windows 7 and younger versions.

---

## 4 Conclusion

---

The master thesis was designed together with an Austrian mining company VA Erzberg in order to solve some of their current business cases. Thus, the project compiles of two main subtopics:

1. Proposal of the best fatigue monitoring system based on investigation and evaluation of the current situation on the market;
2. Development of a traffic flow control system in an open pit mine.

The project embraces both of the subtopics and provides a detailed solution for every issue following with numerous tables, figures and graphs. This chapter will describe in general a solution for each case with most crucial findings, facts and figures.

---

### 4.1 Conclusion overview of the Subtopic №1

---

Currently the management of VA Erzberg is highly concerned about their drivers' safety especially during the night shifts working. In order to mitigate any risk of accident in the mine a night rest of 1.5 hour is provided for everyone. However, such measure causes a production decrease and as a consequence – profit loss. A more efficient solution was proposed – implementation of a fatigue monitoring system. This system involves tracking the behavior of the drivers during the operations on dump trucks. Once a driver starts to feel sleepy or tired the system notifies him or her about it at once. Such approach should eliminate the inefficient night rest and allows drivers to interrupt an operation once they about to feel drowsiness.

At the moment there are dozens of different companies on the market that provide a fatigue monitoring system. In the master project only 4 the most potentially attractive companies were analyzed. Every producer has its own approach though the final idea is the same. In order to choose the best system a list of characteristics has been formed:

- A complexity of the technology;
- Necessary devices;
- Ways of the data storage;
- Efficiency;
- Number of vehicles for trial version;
- Price per vehicle [USD];
- Total price [USD]

After a thorough comparison analysis only one company was chosen which meets most of the requirements. The company is Ramjack with the technology powered by SmartCap. Main benefits are that data is stored inside a mining company and software can be integrated into existing tablets or screens in a cabin. Moreover, price per vehicle is the lowest comparing to the other – 5 137,63 USD. The technological solution is based on an electrophysiological monitoring method to record electrical activity of the brain. Special sensors are embedded into a band over a head. The headband is rather easy to wear and install into a cap or helmet. According to the efficiency, in South Africa number of alarms decreased by 25% within 12 months. Thus, this system is highly recommended for the needs of VA Erzberg.

---

## 4.2 Conclusion overview of the Subtopic №2

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VA Erzberg follows the modern trends in mining and actively implements digitalization in every day operations. An interactive dispatch system has been developed in the company that allows to track movements of dump trucks, monitor their statuses and collect information about vehicles' characteristics. However, there are some issues that require additional analysis:

- Traffic flow interruption, reasons and possible solutions;
- Data acquisition and processing.

As part of the master project an interruption of a driving flow can be treated as an idle. Thus, the task can be formulated as to calculate the total downtime for every dump truck, found out exact locations of idling and determine their reasons. The working process was based on an analysis of the data that was acquired from the mine managers.

After familiarisation with the data it can be stated that its structure and size are not in the best conditions. Main drawbacks are a big number of duplicates, information about each parameter is written in a row rather than in a column, there is probably some additional information which is irrelevant for the analysis. All these lead to increase of rows number. As a consequence, there are 3 main issues:

- An csv table has a limited number of rows which equals to 1,048,576. A dump truck can generate too much data so there will be no free rows to write it in the same document. As a result, some data can be lost;
- The more rows the larger the size of a document. It requires more space on a server;
- Data analysis requires thorough preprocessing which increase calculation time.

### Possible solutions:

- Optimise data storage by reorganisation of the database and generation of datasets;



- By arranging more accurate SQL requests, it can be possible to speed up the analysis.

The entire analysis process was performed by means of programming language Python, integrated development environment (IDE) such as PyCharm and Jupyter Notebook and visualization software Tableau. During the conduction of the analysis a hypothesis was formulated:

Hypothesis № 1

*The main ramp is the place with the greatest number of idling locations.*

By the end of working on the subtopic №2 a program was developed which allows to perform independently an analysis of any dataset generated by a dump truck. Here are the following findings that are made thanks to the analysis:

1. During the considered timeframe from 04.04.2022 till 07.04.2022 none of the dump trucks were operating on 05.04.2022;
2. Almost all of the 16 vehicles were working during the mentioned above period except Komatsu 18 and Liebherr 10;
3. Every vehicle that was operating in the mine during a specific day had some idling time by the end;
4. The majority of the downtime locations were followed by the status 'empty standing'. This number is greater than the locations with the status 'loaded standing' by 2.4 times;
5. The maximum number of stops that was made around one location is 450 with an empty status by all vehicles and by the end of the entire period;
6. The majority of the idling positions are situated in the intersections between the main ramp and auxiliary benches. Thus, the hypothesis №1, saying that the main ramp is the place with the greatest number of idling locations, is partly proved;
7. The longest idle in total by the end of the whole considered timeframe belongs to Komatsu 26 and Liebherr 12 and equals to 168 minutes (~ 3 hours);
8. The longest downtime in total of all dump trucks was on 07.04.22 and was 462 minutes (~8 hours);
9. The average downtime off all the operating machines is between 20 and 40 minutes a day;
10. Komatsu 26 had the longest downtime of 80 minutes on 06.04.22 than any other vehicles;
11. Those dump trucks that did not have any downtime most probably were on maintenance or out of service on that day.

According to the conducted analysis it is able to state certain locations and overall time of idle for every dump truck. The main reasons for downtime are traffic lights on the intersections between the main ramp and side benches. In some places in the mine there are benches that might be too narrow for two vehicles to pass at

once in opposite directions. So, drivers have to stop in order to let the other one to pass. As it can be seen machines with loaded back have more priority in the passage as number of the idling stops with such status is almost 2.5 times less than with an empty one.

Overall, in order to eliminate these unnecessary idling stops a precise supervision in the mine at the exact locations has to be conducted. In addition, the developed analysis program can help to monitor the situation in the mine by the end of each shift or day relatively to every dump truck.

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## 6 List of Figures

Figure 1. Erzberg mine (Gerald Senarclens de Grancy) .....	1
Figure 2. Time table .....	3
Figure 3. Cycle of a dump truck.....	4
Figure 4. Human behavior tracking camera (Hexagon, 2022).....	7
Figure 6. Optalert tablet (Optalert, 2022).....	9
Figure 5. Glasses with micro camera (Optalert, 2022) .....	9
Figure 7. Optalert Individual Risk Indicator System (Optalert, 2022).....	10
Figure 8. Results of using Optalert system (Optalert, 2022).....	10
Figure 9. Lifeband integrated into a helmet (Ramjack, 2022).....	13
Figure 10. Stages of fatigue (Ramjack, 2022) .....	14
Figure 11. Results after implementing SmartCap system (Ramjack, 2022) .....	14
Figure 12. Komatsu DDS components (Komatsu, 2022).....	16
Figure 13. Truck dispatch system (VA Erzberg, 2022) .....	21
Figure 14. Vehicle's information card (VA Erzberg, 2022).....	22
Figure 15. Formed dataset in a txt file .....	23
Figure 16. Project Pipeline .....	23
Figure 17. Main ramp .....	25
Figure 18. Information about the dataset's size .....	27
Figure 19. Size of raw dataset and preprocessed .....	27
Figure 20. Preprocessed dataset .....	28
Figure 21. Movements of Komatsu 23 on 04.04.2022 .....	29
Figure 22. Table of dump trucks' movements.....	30
Figure 23. Trajectories of all the machines' movements on 04.04.22.....	31
Figure 24. Table of statuses .....	32
Figure 25. Workshop area (VA Erzberg) .....	32
Figure 26. Adjacent idling coordinates of Komatsu 23 on 04.04.22.....	33
Figure 27. Map of idling locations of all dump trucks.....	34
Figure 28. Number and coordinates of idling locations.....	35
Figure 29. Code example of coordinates grouping .....	36
Figure 30. First iteration script.....	38
Figure 31. Second iteration script.....	42
Figure 32. Final map with idle locations .....	43
Figure 33. Idling time according to coordinates .....	44
Figure 34. Total idling time of all machines .....	46
Figure 35. Initial view of program's folder .....	47
Figure 36. 'K23_movements_plot' file.....	65
Figure 37. 'K23_stops_plot' file.....	65

Figure 38. 'K23_idling_time' file.....	66
Figure 39. 'K23_idling_map' file.....	66
Figure 40. 'K23_idling_result' file.....	66

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## 7 List of Tables

---

Table 1. Quote from Hexagon .....	7
Table 2. Quote from Optalert.....	11
Table 3. Quote from Ramjack.....	15
Table 4. Comparison analysis .....	19
Table 5. Final table with total idling time and locations of the 1st iteration .....	39
Table 6. Final table with total idling time and locations of the 2nd iteration .....	42
Table 7. Total idling information about every truck .....	45
Table 8. Fatigue monitoring companies .....	58



## 8 Annex

### 8.1 List of fatigue monitoring companies

№	Company name	Name of the system	Short description	Contacts	Website
1	<u>Hexagon</u>	HxGN MineProtect Operator Alertness System	An integrated fatigue and distraction management solution. The system helps operators of heavy and light vehicles to maintain the level of attention necessary for long hours and monotonous tasks.	<a href="mailto:info@hexagon.com">info@hexagon.com</a>	<a href="https://hexagonmining.com/solutions/safety-portfolio/hxgn-mineprotect-operator-alertness-system">https://hexagonmining.com/solutions/safety-portfolio/hxgn-mineprotect-operator-alertness-system</a>
2	<u>SmartCap</u>	Life by SmartCap	SmartCap was developed to overcome the limitations of other fatigue monitoring technologies.	<a href="mailto:info@smartcap.ch">info@smartcap.ch</a>  <a href="mailto:mike@ramjack.co.za">mike@ramjack.co.za</a>	<a href="http://www.smartcap.ch.com/life-smart-cap/">http://www.smartcap.ch.com/life-smart-cap/</a>
3	<u>CAT</u>	Driver Safety System	A non-intrusive, in-cab detection technology that instantly alerts operators the moment fatigue or distraction is identified. It works by monitoring eye-closure duration and head pose. If the system detects a fatigue or distraction event, the operator is immediately alerted through an in-vehicle seat vibration and audio alarm.	<a href="https://www.cat.com/en_US/products/new/technology/detect/detect/102341.html">https://www.cat.com/en_US/products/new/technology/detect/detect/102341.html</a>	<a href="https://www.cat.com/driversafety">https://www.cat.com/driversafety</a>
4	<u>WOMBATT-VOZ</u>		A fatigue prediction system based on voice analysis. It does not require specific devices for its operation		<a href="https://wombattvoz.net/">https://wombattvoz.net/</a>

			unlike the rest of the technologies that exist in the market (cameras, bands, caps, lenses, etc.)		
5	<u>OKO Mining</u>	Optical Fatigue Detection System	The OKO system is based on the non-contact technology of continuous tracking and recognition of the driver's eye and head movements.	<a href="mailto:info@oko-systems.ru">info@oko-systems.ru</a>	<a href="https://oko-systems.ru/en">https://oko-systems.ru/en</a>
6	<u>DotNetix</u>	Nexus	The Operator fatigue monitoring system monitors the operator using advanced sensors to determine if the operator is distracted or tired. Using advanced algorithms, the unit is able to detect the operators face and monitor his facial features.	<a href="mailto:info@dotnetix.co.za">info@dotnetix.co.za</a>	<a href="https://www.dotnetix.co.za/fatigue-monitoring">https://www.dotnetix.co.za/fatigue-monitoring</a>
7	Optalert		Optalert is the only predictive drowsiness safety system in the world that continuously provides scientifically-validated, objective alertness information to both drivers and supervisors in real-time.	<a href="mailto:info@optalert.com">info@optalert.com</a>	<a href="https://www.optalert.com/industries/mining-transport/mining/">https://www.optalert.com/industries/mining-transport/mining/</a>
8	MPI	MPI Fatigue Management	MPI's Driver Status / Fatigue Monitor is a driving auxiliary warning system that is based on machine vision technology to detect abnormal driving status. It can detect and alert the driver on various conditions, including fatigue, distraction, smoking and telephonic use while driving.	<a href="https://www.mpi.co.za/our-branches">https://www.mpi.co.za/our-branches</a>	<a href="https://www.mpi.co.za/fatigue-management">https://www.mpi.co.za/fatigue-management</a>

Table 8. Fatigue monitoring companies

## 8.2 Commercial offer from Hexagon



Nikita Libman &lt;libmannikita@gmail.com&gt;

### RE: Hexagon - fatigue and distraction technology

1 message

**HANNING Reece** <reece.hanning@hexagon.com>  
To: "nikita.libman@unileoben.ac.at" <nikita.libman@unileoben.ac.at>  
Cc: Nikita Libman <libmannikita@gmail.com>

Tue, Jul 19, 2022 at 10:22 AM

Dear Nikita

Good to hear from you.

To give you an idea on costs:

1. On-board HW for the trucks – 12500USD capital per truck once off plus 1875USD maintenance per year per truck.
2. Analytics and reporting platform – 45000USD per year per site.
3. Remote Monitoring – 2600USD per truck per year.
4. The above excludes installation and commissioning fees.

So just over 146000USD for year 1 and thereafter just over 71000USD per year plus escalation, Let me know if these numbers work for your budget, if so we can take it from there?

Kind regards

Reece

Business Development Manager

Mining division

**Hexagon**

T: +27 11 594 3911 M: +27 82 451 5436

E: [reece.hanning@hexagon.com](mailto:reece.hanning@hexagon.com) LI: [linkedin.com/in/reece-h-0535b35a/](https://www.linkedin.com/in/reece-h-0535b35a/)

Woodlands Office Park, Bldg 18

[20 Woodlands Drive](#)

Woodmead

South Africa

[hexagonmining.com](http://hexagonmining.com) | [LinkedIn](#) | [Facebook](#) | [Twitter](#)

## 8.3 Commercial offer from Optalert



### PILOT AGREEMENT

This agreement is intended to provide VA Erzberg GmbH with the opportunity to conduct a 60-day trial of Optalert's early-warning drowsiness detection products in their own environment in one location in Austria (Erzberg). In order for the Pilot to be evaluated objectively, customers are encouraged to identify a site champion to implement the solution and determine success criteria in consultation with their Optalert account manager prior to the Pilot/Trial start date.

Product	Qty	Cost
eagle™ Industrial Mining Kits	5	
Wireless V8 glasses	12	
Glasses calibration tablet	1	
Professional services: Training and onsite implementation via assigned Optalert site champion	1	
<b>Total</b>		<b>USD*\$ 47,500</b>

#### Inclusions

##### **Before 60-day PILOT**

- Optalert dispatches products to the customer.
- Optalert provides/delivers onsite training to site champion/s on the solution and glasses fitment and implementation.
- Establish – employee, roster, and bus details to set up in the online portal
- All systems fitted with a data-only SIM card or access to site WiFi and drivers assigned and calibrated with their unique pair of glasses by site champion/s. All users must not require prescription lenses. If required, Additional costs of US\$250 per lens if needed.
- Optalert and customer perform a live test. Weekly data and report/s to be provided as agreed with fatigue project stakeholders
- Go Live

##### **During 60-day PILOT**

- The initial 20-day period will be conducted "blind" i.e. the user will not see their score for a drowsiness baseline. The second 60-day period will have real-time scores shown to users, alerts (cabin/SMS/online platform) and depot engagement with the drivers.
- Weekly phone hook-up to review pilot and web-based support with VA Erzberg GmbH fatigue project stakeholders
- Remote site champion support
- Email, phone, and remote web-based support or further visits if required
- email daily or weekly reports as agreed with the customer.

##### **Post 60-day PILOT**

- End of the 60-day trial – Optalert to present a Scientific report of the pilot to VA Erzberg GmbH project fatigue stakeholders.

## 8.4 Commercial offer from Ramjack

VA ERZBERG

Ramjack Technology Solutions

Fatigue Management System

### ***Proposed Rollout Plan (Implementation)***

In addition to providing simple, purpose-built hardware and software, Ramjack is proud to have locally situated, experienced technical services team(s) able to manage projects professionally, including:

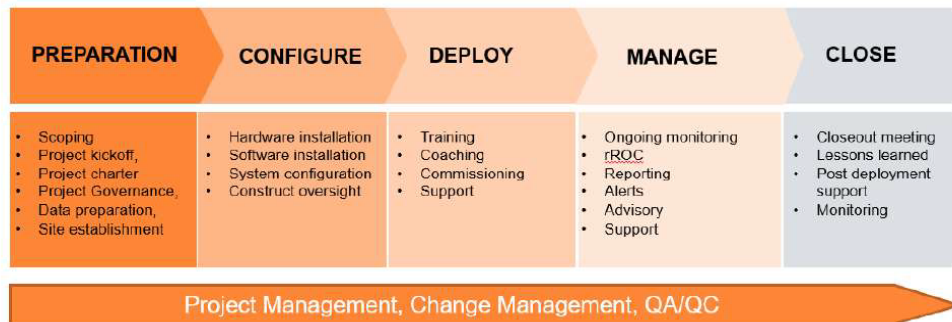
1. Project Charter
2. Change Management
3. Installation
4. Commissioning
5. Monitoring and Adoption

With every system rollout, Ramjack provides a project plan and the required personnel to support the complete deployment process. Ramjack follows a standard deployment methodology for the installation, configuration, commissioning and training of all its systems.

Our five-stage methodology for implementation is followed throughout the duration of the project to ensure success at all stages of execution.

Of further importance is the supporting processes of, Project Management, Change Management and Quality Assurance, which continue throughout the implementation process and through to Ramjack's support model.

Upon agreement with VA Erzberg, Ramjack will prepare the necessary project planning documents, method statements and plans to support our implementation methodology, as illustrated in the image below:



VA ERZBERG

Ramjack Technology Solutions

## Fatigue Management System

The deployment tasks for the proposed Smartcap system will be as follows (with indicative pricing):

STAGE	Location	Task	Units / day	Total Units	Application Specialist	Project Manager	Install Technician	Cost (USD)
					1,040.00	1,100.00	920	
PREP	Remote	Kickoff and change management			1	1		2,140.00
CONFIG & DEPLOY	Site Visit 1	Vehicle install	2	2			1	920.00
		Lifehub Server Setup fee			1			1,000.00
		Training and best practices					4	3,680.00
		Travel					2	920.00
MANAGE	Site Visit 2	Follow up - adoption					2	1,840.00
		Travel					2	920.00
CLOSE	Remote	Post deployment support			3			3,120.00

2 site visits are proposed. The first to install the hardware and provide initial training to the operators on how to use the system as well as management to understand the data and how to report.

The second site visit will be scheduled a few weeks after Smartcap is live so Ramjack can assist with ensuring adoption of the system. This will run in accordance to the agreed change management protocols during the preparation stage which will be documented in the Project Charter.

Post deployment, up to 3 days (or 72 hours) of consulting time is made available to ensure the adoption continues over the coming months. The hours can be used any time and cover follow up meetings, progress reports and any other issues directly related to the deployment of the system.

The expectation is that at the end of the deployment period, the system is working well and delivering the insights to fatigue that the client requires. VA Erzberg can use the remaining time to full appreciate the benefits of the SmartCap solution.



VA ERZBERG

Ramjack Technology Solutions  
Fatigue Management System

## Indicative Trial Deployment Quote

Co. Reg # - VAT Reg #	Date
Directors: M. Jackson, R. Birch	Quote#
	Expiration Date

2022/07/20  
VAER20220720-01  
2022/08/20

Doruk Technology Solutions Ltd  
19 Heathmans Road  
London, SW64TJ  
United Kingdom

**CUSTOMER** Nikita Libman  
Email: libmannikita@gmail.com  
VA Erzberg, Erzberg  
Erzberg, Eisenerz  
Austria, A-8780  
Customer ID: VAER

Included: Trial Deployment - Fatigue Management Solution

Salesperson	Payment Terms	Shipping Terms (INCOTERMS 2020)	Delivery Date	RAMJACK Job	Project Location
R. Birch	60% Deposit on PO 40% on Delivery 10% Commissioning	EXW Brisbane, Australia	8-12 weeks after receipt of deposit payment.	VAER20220720-01	Eisenerz

Qty	Part Number	Name	Unit Price (USD)	Line Total (USD)
<b>Software Licenses</b>				<b>4,200.00</b>
1	RTS-SCT-560-00001	LifeHub Fatigue Map - Annual Fee	5,000.00	-
6	RTS-SCT-880900007	SmartCap Pilot End user Licence (3-months)	435.00	3,480.00
6	RTS-SCT-880900009	SmartCap Pilot SSA (3-months)	90.00	720.00
<b>Hardware - Vehicle Devices</b>				<b>2,790.00</b>
2	RTS-SCT-900-00085	LifeDisplay 5" Heavy Vehicle System	1,395.00	2,790.00
<b>Hardware - Miner Devices</b>				<b>2,005.26</b>
6	RTS-SCT-900-00047	LifeBand Kit	299.00	1,794.00
6	RTS-SCT-990000061	LifeBand branded Baseball Cap	10.85	65.10
6	RTS-SCT-400810001	LifeBand Sensor Spots (10 pack)	4.36	26.16
6	RTS-SCT-370810003	LifeBand Removable Sleeve - each	20.00	120.00
<b>Hardware - Instruments</b>				<b>-</b>
<b>Infrastructure - LTE Signal Generation</b>				<b>-</b>
<b>Infrastructure - LTE Signal Propagation</b>				<b>-</b>
<b>Hardware - Infrastructure Devices</b>				<b>125.00</b>
1	RTS-SCT-400810007	LifeBand Charging Station	125.00	125.00
<b>Shipping</b>				<b>-</b>
1	RTS-SHP-EXW	Shipping Ex Works (named place of delivery)	-	-
<b>Deployment Services</b>				<b>14,540.00</b>
1.0	RTS-SCT-SRV-SW-FX-PE	Central Server Trial Setup Fee	1,000.00	1,000.00
1.0	RTS-SRV-DY-L6	Project Manager	1,100.00	1,100.00
3.0	RTS-SRV-DY-L5	Application Specialist / Specialist Engineer	1,040.00	4,160.00
7.0	RTS-SRV-DY-L2	Installation / Support Technician	920.00	6,440.00
4.0	RTS-SRV-DY-L2-TR	Travel Rate: Installation / Support Technician	460.00	1,840.00
<b>Support and its pre-requisites</b>				<b>1,058.00</b>
10%	<various>	Spare Hardware to be kept on site	<N/A>	598.00
12	RTS-SRV-SUPRT	Monthly Cost Remote Support	156.70	470.00
<b>Total</b>				<b>24,728.26</b>

**Notes**  
 A) All hardware quoted on an EXW basis; client responsible for all logistics and customs, taxes and tariffs  
 B) Solution specification assumes WiFi or LTE coverage is available on-site. SIM cards and data charges have been excluded.  
 C) Travel charged at cost + 20%

## 8.5 Commercial offer from Komatsu

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Von: Moser Christian <[C.Moser@kuhn.at](mailto:C.Moser@kuhn.at)>  
 Gesendet: Mittwoch, 28. September 2022 16:18  
 An: Schimek Peter <[Peter.Schimek@vaerzberg.at](mailto:Peter.Schimek@vaerzberg.at)>  
 Cc: Afenzler Peter <[Peter.Afenzler@vaerzberg.at](mailto:Peter.Afenzler@vaerzberg.at)>; Wabra Florian <[Florian.Wabra@vaerzberg.at](mailto:Florian.Wabra@vaerzberg.at)>  
 Betreff: [External] DDS

**ACHTUNG:** Sie erhalten dieses E-Mail von außerhalb. Bitte klicken Sie auf keinen Link und öffnen Sie keine Attachments wenn Sie sich nicht über deren Herkunft sicher sind.

Gück Auf Herr Schimek,

anbel die Informationen betreffend der Müdigkeiterkennung für die Komatsu 785-7 Maschinen.

Preis bewegt sich bei ca. 5500€

Für die -8 Maschinen wird auf der BAUMA eine Version ausgestellt.

Schöne Grüße




Christian

Ing. Christian Moser  
 Verkaufsführung / Verkauf

KUHN Baumaschinen GmbH  
 Kuhn Straße 1, 5301 Eugendorf, Österreich  
 Tel: +43 6225 8206 130  
 Mobil: +43 664 8151162  
 E-Mail: [C.Moser@kuhn.at](mailto:C.Moser@kuhn.at) Web: [www.kuhn.at](http://www.kuhn.at)



3 attachments

-  **FAI DDS HD785-7 GEN00223-02.pdf**  
8965K
-  **OMM DDS HD785-7 PEN01552-00.pdf**  
467K
-  **MDPN-138 HD785-7 Drowsiness Detection System.pdf**  
589K

## 8.6 Output files as a result of the program's work

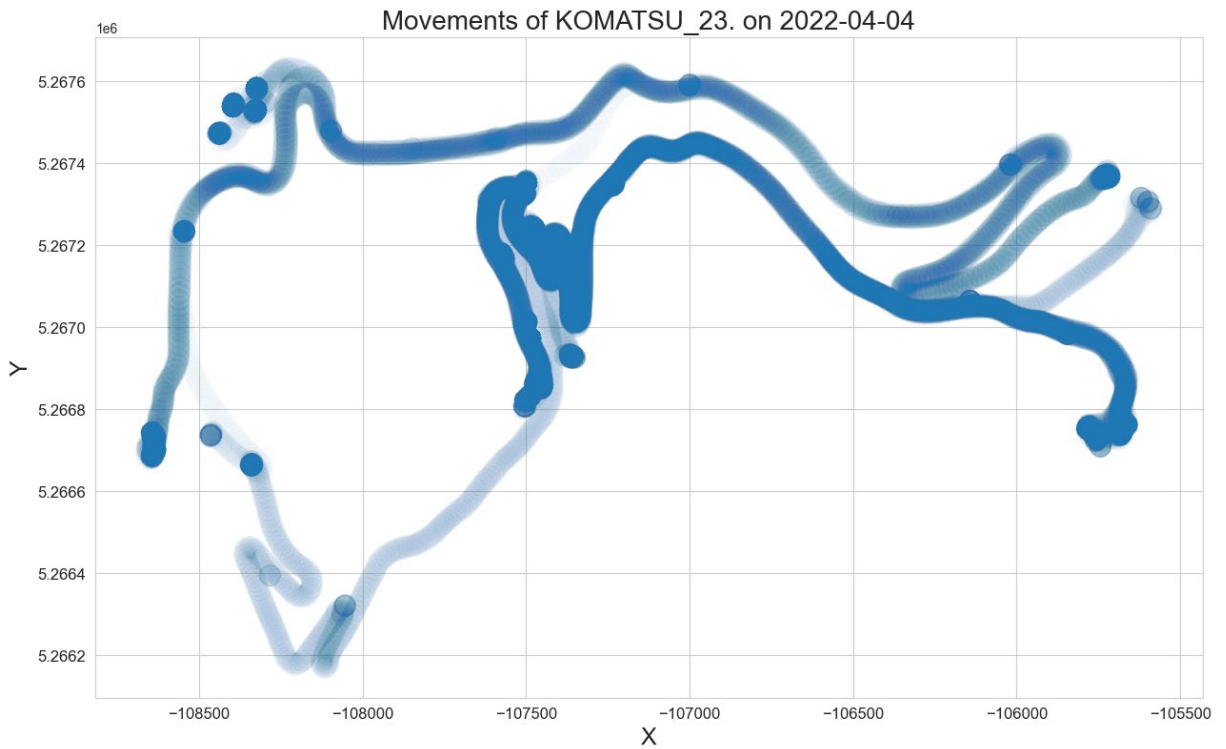


Figure 36. 'K23\_movements\_plot' file

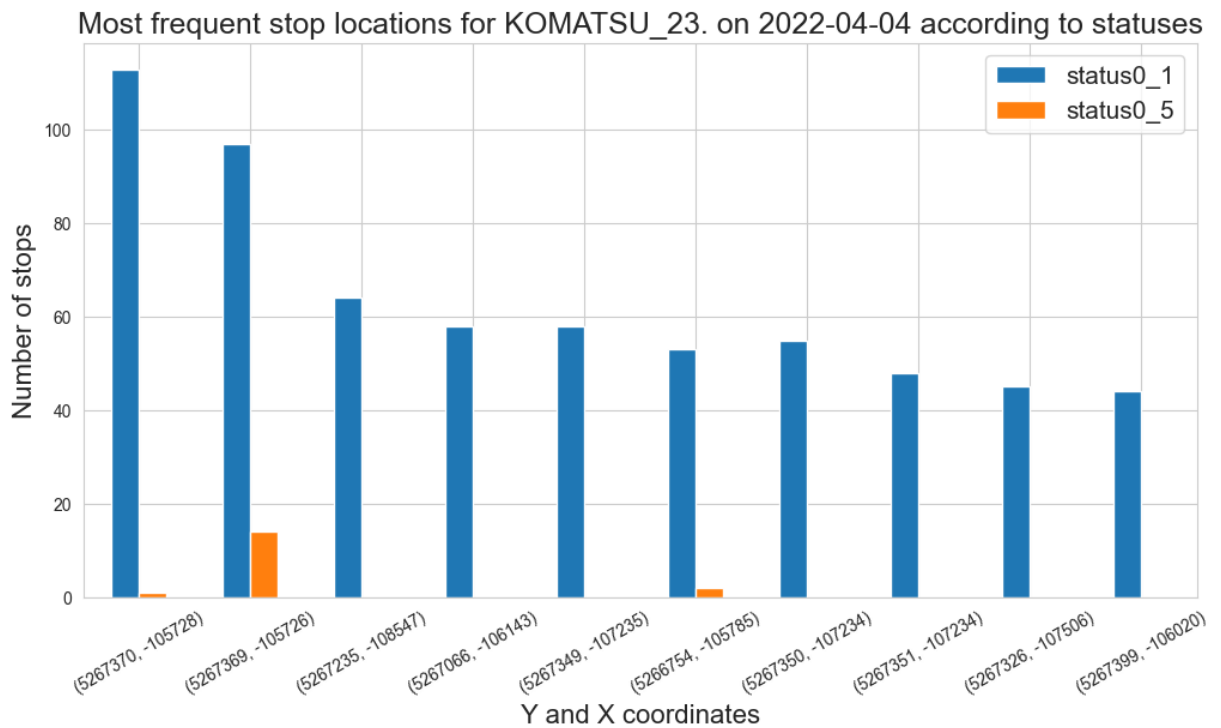


Figure 37. 'K23\_stops\_plot' file

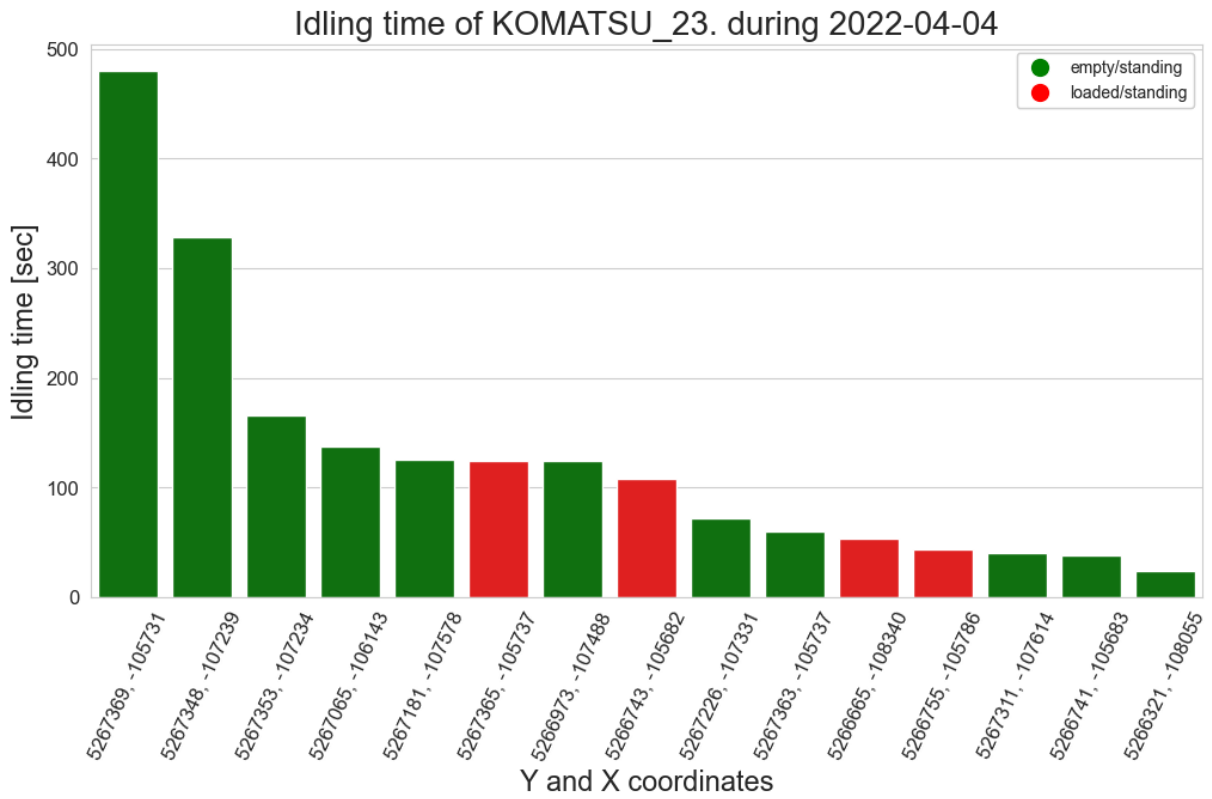


Figure 38. 'K23\_idling\_time' file

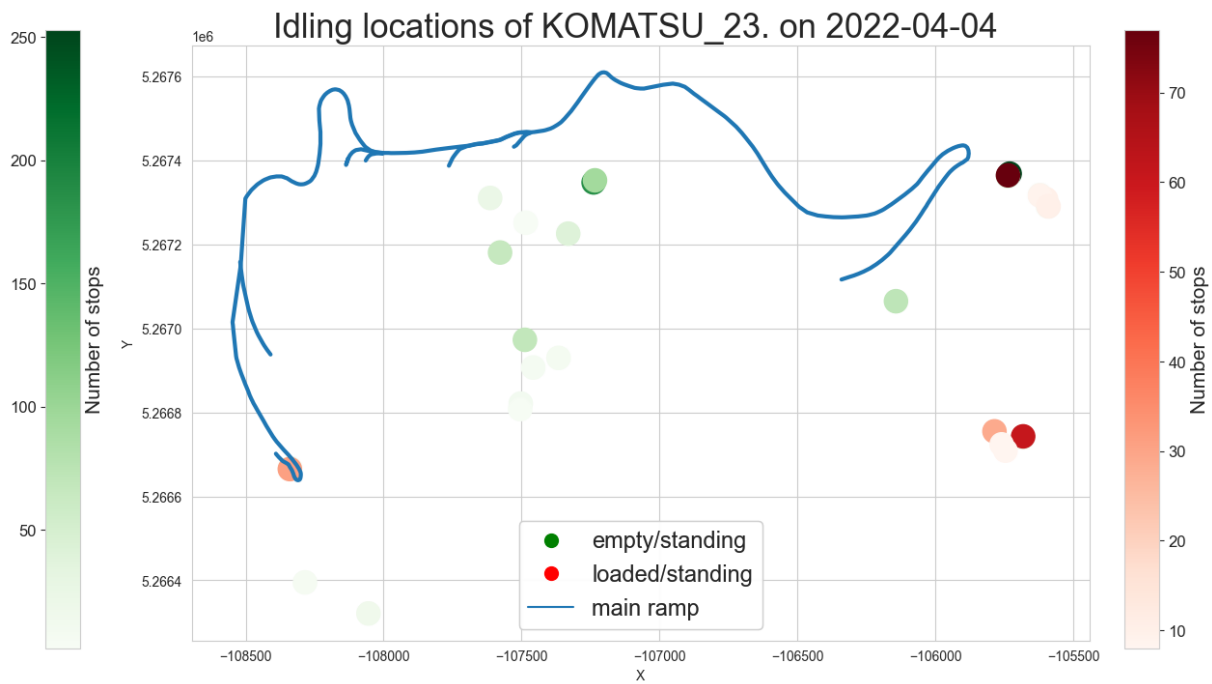


Figure 39. 'K23\_idling\_map' file

```

K23_idling_result - Notepad
File Edit Format View Help
Overall idling time on 2022-04-04 - 0 days 00:34:46
Total idling time with status "empty/standing" - 0 days 00:28:00
Total idling time with status "loaded/standing" - 0 days 00:06:46
    
```

Figure 40. 'K23\_idling\_result' file