illuMINEation
THE FUTURE OF MINING

D9.4 TRAINING ACTIVITIES FOR MINE PERSONNEL

This project Deliverable describes a course program dedicated to transfer illuMINEation knowledge to mine personnel.

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Abstract:	This deliverable explains approaches of how the developments of illuMINEation can be transferred into training activities for mine personnel. The deliverable shows the diversity of the skill-set brought in by the stakeholders in the mining industry and how this is complemented by the diversity of the technological developments. In summary, it can be concluded that a flexible and individual approach towards training is perceived the best option to tackle these challenges.

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Document author(s):

Entity	Contributor
MUL	Philipp Hartlieb, Michel Varelija
UPM	Alberto Fernandez
CUP	Pawel Stefaniak
GEO	Bartolomej Bursa

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Executive Summary

This deliverable addresses potential training activities for mine personnel within the framework of the illuMINEation project. It begins by mapping the potential stakeholders / trainees. These range from the workforce on the ground (e.g. machine operators), to foremen, local and global management of a mine and the mining company.

Secondly, the potential course content is discussed. It also relates course content to the stakeholders identified above. It is demonstrated that the technological developments as well as the stakeholders are very diverse.

Lastly, it is discussed that it is difficult, nearly impossible, and unreasonable to create a single "illuMINEation course" that covers all the factors and persons, depending on stakeholders and prospective course content. There are examples provided of how specific, bespoke courses can be tailored to target the right demographic.

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1 Introduction

1.1 Purpose of this Document

This document provides a description of a course programme, dedicated to transferring the knowledge generated in the illuMINEation project to the mine personnel.

1.2 Scope of this document

This deliverable provides a description of a potential training programme for all people engaged in mining, with a special focus on the mine personnel. Personnel can be anybody working in the mining environment, i.e. workers on the ground and machine operators, foremen, shift managers and company managers. In addition, the focus of the project is also on machine parts and maintenance. Hence, an attempt will be made to include these stakeholders as well. However, the target audience of the training course does not go beyond this limited group of people.

1.3 Related Documents

There are no related documents.

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2 The Training programme and course activity

The stakeholders within the mining environment are defined and described in this chapter. These are also the individuals for whom a specially designed training curriculum is required. The chapter offers a summary of the knowledge and technologies created throughout the illuMINEation project. This will assist in determining the ideal course design for the appropriate audience, along with delivery strategies that are committed to effectively transferring the necessary knowledge.

2.1 Stakeholder mapping

Mapping the training-related stakeholders and the target audience in mining companies needs to involve consideration of the organisational structure of the companies. Similar to the organisational structure proposed for the IIoT platform of this project which is based on edge-fog-cloud layers (Minon et al. 2022; Zeiner et al. 2021), also a mining company is structured in a multi-layer fashion. Every layer brings and requires a specific skill set, and fulfils a specific purpose.
Figure 1 exemplarily shows this layer structure. It needs to be noted here that all mines and organisations are different and that this sketch is only dedicated to underpinning the general concept. It is however evident, that a mine can in general be divided into the management and the mine operation part, where the first mainly has executive roles and the latter is much more technology driven. Additionally, i.e. in the operations part the process realisation and the process management play an equally important role. Figure 2 shows the structure of the mining company Minera de Orgiva (MDO) as one of the use case partners of the project. One can see that even a comparably small operation like MDO has a high diversity of roles and responsibilities.

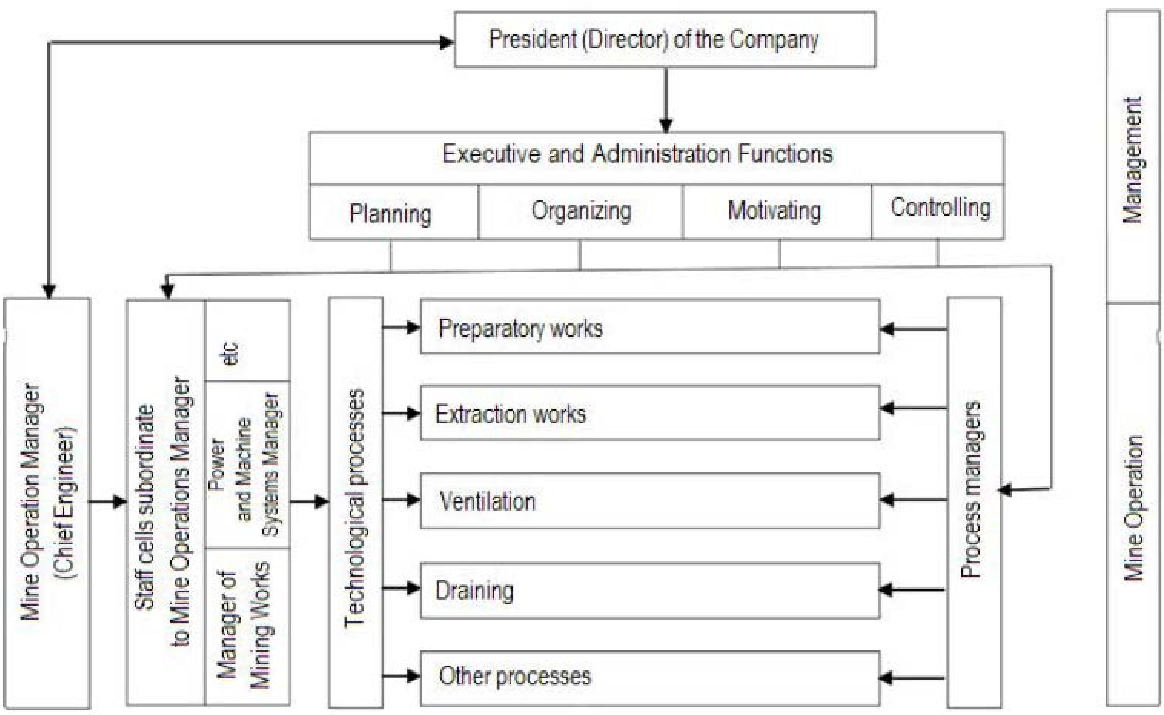

Figure 1: Schematic diagram of the functional-processing structure of a mining company (from Kudełko 2016).

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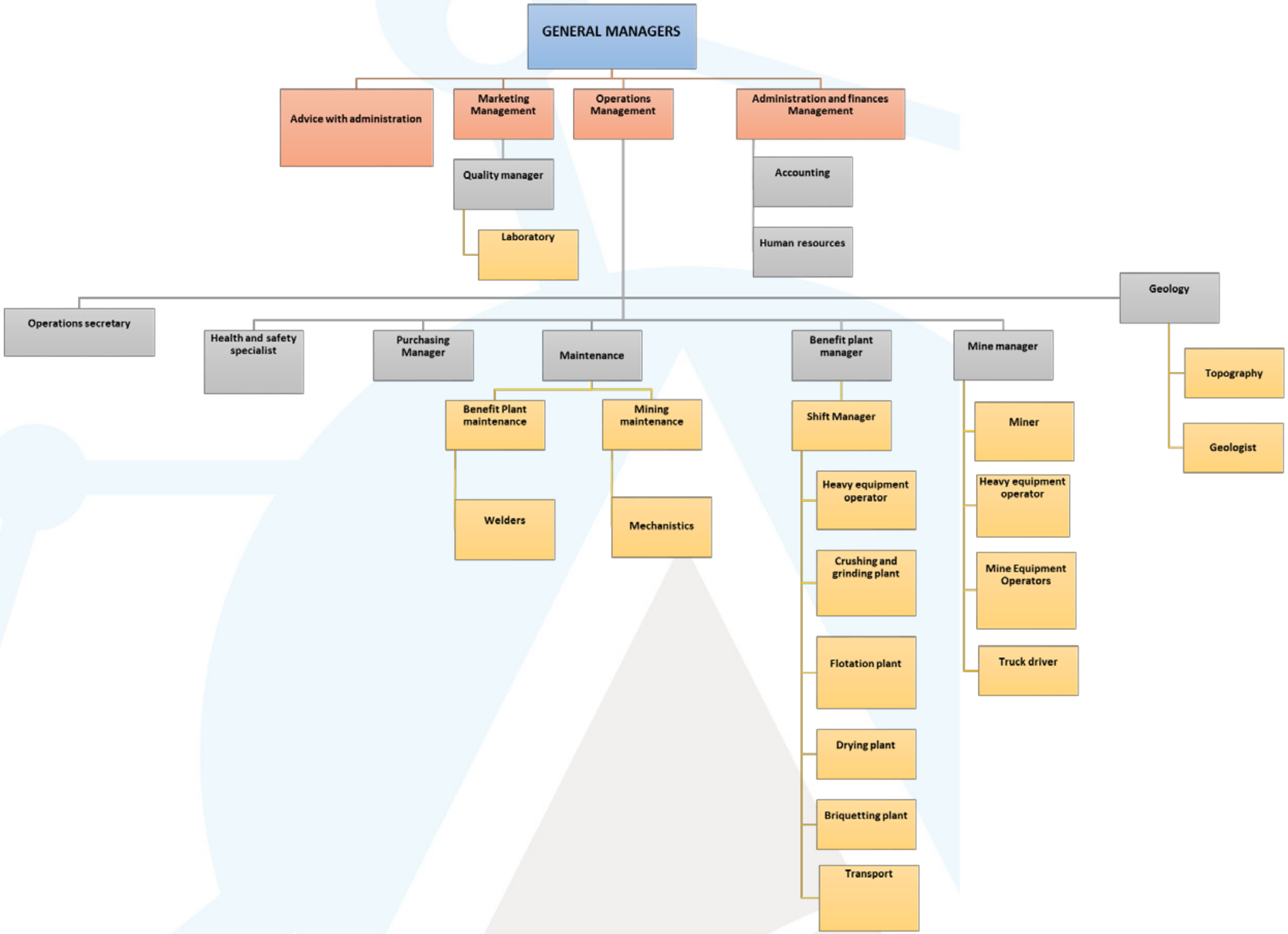

Figure 2: Schematic overview of the structure of Minera de Orgiva, depicting the many different roles even in a small mining company.

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Considering that the use case partners are actually operating a mine in this project (excluding project partner Epiroc as mining equipment and systems manufacturer), the following numbers distinguish briefly between the different roles of the people involved in mining (Table 1). One can see the huge diversity in terms of company size, operating sites and people working in the different levels.

Table 1: Overview of workforce in the pilot sites' companies;

Company	**Engineers**	**Workers**	**Management**	**Total**
Boliden [1]	339	889		1226
Minera de Orgiva	7	47	3	57
RHI Magnesita	5,827[2]	7,741	1160	14,728
KGHM Polska Miedz	158	302		460
Total	**6331**	**8979**	**1163**	**16471**

Language plays an important role in all teaching and training-related aspects, as language is of course the major transmitter of information. Language barriers are not easy to overcome and can make knowledge transfer difficult. Any training programme will therefore need to consider the language skills of the trainers and trainees, as well as the availability of respective training material in suitable languages. In the use case sites of the project we have four prevailing mother languages (German, Polish, Spanish and Swedish) as well as English as general project language. It will depend on the basic (language) education of the workforce which language needs to be applied in which circumstances. As a rule of thumb, it might be fair to say that any basic training for the "people on the ground" (machine operators, etc) should be done in their respective mother language, whereas the language skills of the management are usually much more diverse and that any training for management and executives could be performed in English. Please bear in mind that this is just a general assessment and that actual skills might change from use case to use case, mine to mine and country to country!

2.2 Delivery methods and workload

In a university context, classes are mostly sub-divided by the nature of their delivery method and/or the kind of commitment to be expected both by the lecturer and the students. This can range from lectures, and practicals, to seminars, excursion or labs.

- Lectures are courses in which the transfer of knowledge takes place through lectures by the instructors.
- Integrated courses are combinations of lectures with courses which are closely interlinked didactically and jointly assessed.
- Seminars are courses in which students elaborate on own subjects/topics and finally present and discuss the findings.
- Labs are courses in which students practically apply the previously gained knowledge to a certain task.
- Excursions are classes in which students are exposed to a site / mine / operation of interest and are guided by the responsible person(s).
- Practicals are hands-on training sessions, in which the students learn how to handle certain technologies.

[1] The Boliden numbers are for the Garpenberg Operation and the Boliden Area Operation, i.e., all Swedish underground operations including the mills. "Engineers" refer to all white-collar employees.
[2] The numbers for RHI Magnesita are officially divided into Management, general blue-collar and white-collar. In this table "engineers" refers to all white-collar employees, except management.

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The delivery methods will depend on the type of course and audience. Whereas lectures and seminars offer the potential to host them either in presence or online / hybrid, practical, labs and excursions are dedicated to in-presence teaching and interaction. The implementation of AR/VR for these purposes (e.g. for remote training of hands-on activities) may be possible but is not part of this document.

The workload of courses may vary. It would not be realistic to assign certain credits / hours to specific tasks. Some trainings may be possible within just 1 or 2 hours (e.g. training on handling a certain piece of equipment like intelligent rock bolts), whereas others would need longer commitment (e.g. training on data evaluation for tailings dam stability and associated AI tools).

2.3 Qualification profile and goals

This chapter provides a very brief overview of the major objectives of the training programme.

The training activities from the illuMINEation project offer a sound practical and scientific education in the fields associated to the project (i.e. sensors, IoT, mining, rock mechanics, maintenance, environmental monitoring) at different levels (see chapter 2.1).

The training activities are aiming at mine personnel of all levels of the mining industry, i.e. the use case partners involved in the project. Other relevant stakeholders as e.g. mining engineers, public authorities, employees of institutions and educational institutions from the mining and tunnelling industry at large are not explicitly excluded but are not the focus of this deliverable. Generally, the receivers should be accustomed to mining operations at large, and have specific knowledge about mining systems, machines and auxiliary processes. General computer literacy, basic programming and a desire to dig into complex relationship is beneficiary but not mandatory given that the qualification for the different jobs might differ significantly.

The training activities combine a selection of specialised courses and activities which are tailor-made for the respective audience and might hence not directly relate to one another.

2.4 Course content

Firstly, this chapter provides an overview of the technologies developed in the illuMINEation project. This information will be complemented by the expected target audience. Finally, the chapter also provides an insight into possible teaching and training activities for the different stakeholders based on the initial assessment.

Table 2 shows an overview of the major technologies developed during the illuMINEation project. Furthermore, it depicts the major technology developers ("tech partners") and how we assume that the technologies might be used by the different groups of stakeholders identified in chapter 2.1.

As a general rule of thumb, it can be assessed that the workforce "on the ground" is more likely to receive training on the physical handling of the technologies, sometimes amended by basics in data read-out and evaluation. This includes not only the installation process, but everything that can be associated with the "cloud layer" in the digital equivalent. Engineers are more likely to work with the research component of the technology and with readout and interpretation of basic data on a mine and process level. This can also include data visualisation, analysis,

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handling of equipment and many more. It is probably fair to say that the engineers are the ones who, in many cases, will spend most time with technologies developed and deployed. The managers frequently need aggregated data and statistics, and the KPIs they seek may be very different from what the workers and engineers require. This structure will also be reflected by their needs for training and education, as every group of stakeholders will have their special requirements.

If positioning and tracking with the “Retenua System” can be taken as an example, it can be assumed that the maintenance engineers in the workshop would need to know how to install the equipment and the mobile fleet and get it working, whereas those who are operating the machines would need to know how to handle the digital component (the interface) and how to react in case the system is actually triggered. Engineers would receive the same information on a different level. They would probably be interested in identifying the reasons for the stop(s), identifying hazardous zones and/or behaviours. Finally, the management might be interested in identifying the amount of stops in a given operation.

All of this will need to be reflected in a course programme / in course programmes presenting the contents of illuMINEation.

Table 2 shows the huge variety in potential course content, ranging from basic handling of technology to readout, data analysis and deriving aggregated information. Any courses stemming from the illuMINEation project will therefore need to be individualised for the respective audience. The design of a general “illuMINEation Course” can be regarded as unrealistic.

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Table 2: Overview of the major technologies developed in illuMINEation, with a reference to the technology partners, as well as an assessment on which type of employee might use it in which fashion.

WP	***Technology***	***Tech-partners***	***Stakeholders***		
			Engineers	***Workers***	***Management***
3	*Micro Raman*	*AMS, IMA*	*In-situ analysis, mine planning*		
3	*IoT devices, sensors and multi-hop LORA communication*	*WSENS*	*Set-up, readout*	*Installation, handling*	
4	*Rock bolts*	*MUL, DSI*	*Readout, analysis*	*Installation, handling*	*Aggregated data*
4	*Environmental sensors*	*CUP*	*Readout, analysis*	*Installation, handling*	*Aggregated data*
4	*Positioning and tracking*	*EPI, RET*	*Installation*	*Handling, usage*	*Aggregated data*
4	*Tailing dams*	*KGHM*	*Analysis, usage of platform and algorithms*		*Aggregated data, decision making*
4/6	*Drones*	*LTU*	*Route planning, handling, usage*		
5	*MWD*[3]	*UPM, LTU*	*Readout, analysis, mine planning*	*Handling, usage*	*Aggregated data, mine planning*
5	*AWD*[4]	*IMA*	*Readout, analysis, mine planning*	*Handling, usage*	*Aggregated data, mine planning*
5	*Combined data (MWD+AWD)*	*UPM, LTU*	*Readout, performing evaluations*		*Aggregated data, mine planning*
6	*Additive manufacturing*	*EPI*	*Analysis, identification of parts*	*Identification of parts, manufacturing*	
6	*Battery monitoring*	*JRS, EPI*	*Analysis*		*Aggregated data*
6	*Pred. Maintenance*	*TEC, EPI*	*Analysis, maintenance planning*		*Aggregated data*
7	*IIoT Platform (edge, fog, cloud setup)*	*JRS*	*Installation, handling, design of dashboards, usage*	*Installation*	*Handling, design of dashboards, usage*
8	*Visualisations*	*DMT*	*Design of dashboards and usage*		*Aggregated data and decision making*

[3] Measurement – While – Drilling
[4] Analyse – While – Drilling

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To date, the illuMINEation project has facilitated trainings that have been performed by all partner categories (universities, OEMs, mines and research organisation), delivering training for topics like:

- Periodic verification of analytical tools and the developed functionality of the demonstrator; determining further directions of work and preliminary development of a schedule for further work; site inspection of the dam.
- Tailings dams.
- Sensors, sensor printing and use for geotechnical applications; focus on safe zone concepts.
- Machine learning tools to applied mineral engineering.
- MWD calibration, procedure to correlate MWD and AWD data, operational integration of MWD data in underground mining.
- Drill rig use and MWD navigation.

Respective details can be found in Table 3. The table also shows the range of trained people (from students, to operators and management), reaching a total audience of 164 people. Further trainings are planned towards the end of the project, i.e. focussing on the latest project results.

Table 3: Overview of training activities held during the illuMINEation project

Audience	No. of people	Content
Management and operational staff	17	Discussion of the current results of the illuMINEation project; periodic verification of analytical tools and the developed functionality of the demonstrator; determining further directions of work and preliminary development of a schedule for further work; site inspection of the dam.
International student scientific organization of the University of Wroclaw	9	Latest results of illuMINEation, focus on tailings dam stability.
Students of Life Sciences	20	Focus on WP4 and tailings damns.
Geotech. Engineers	9	Focus on Sensors, sensor printing, use of geotechnical sensors for safe zone concepts.
Students of the Master Sustainable Mining, UPM	8	Machine learning tools applied to mineral engineering.
MUL, CUP, LTU, UPM, MDO, RHIM, IMA	10	MWD calibration, procedure to correlate MWD and AWD data, operational integration of MWD data in underground mining.
Drill rig operators, mine assistant manager, geologist, global mining support team	12	Drill rig use and MWD navigation.
Students of Mining Engineering Symposium, SIMIN 2023	60	Online technical session to present the results obtained during the illuMINEation project regarding: Predictive maintenance, Wireless IoT sensors applied in mining environments, operational integration of measurement-while-drilling technology.
Professionals and students from the Chilean mining industry which participate in SIMIN 2023 congress	19	Technical course dictated in the context of SIMIN 2023 named “Application of drilling monitoring technologies in mining using Artificial Intelligence” in which the methodologies and results obtained from the work in the Working Package 5 “Sustainable & intelligent mineral resource extraction” obtained during the illuMINEation project were presented. The course delivered theoretical, technical and operational knowledge regarding the measurement and use of massive data from the drilling operation seeking to improve the knowledge of the rock mass using artificial intelligence techniques.

Generally, the workshops and training activities need to (and have been) held in a flexible manner, so that adaption to topics and circumstances is easily possible.

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3 Conclusions

This deliverable has listed all the potential stakeholders in the mining industry with a special emphasis on the use case partners of the project. Furthermore, the report analyses the technologies developed and how they can be transferred into training activities for the mine personnel.

The illuMINEation project develops a wide range of technological solutions for a wide range of potential application cases. This ranges from sensors for rock mechanics, environmental monitoring and tailings dam stability assessment to battery monitoring, predictive maintenance and additive manufacturing. The use case partners are distributed all over Europe, speaking 4 different mother tongues, in addition to English.

A range of individual training activities already held during the project demonstrates that tailor-made trainings for the respective audience are best suited to transfer information about the project and knowledge about the technologies to the right people.

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4 Publication bibliography

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