Experiences and best practices from the pilot case at Callio Lab, Finland

Baltic Sea Underground Innovation Network (BSUIN)

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Abstract	Underground laboratories provide a unique environment for various industries. They are the perfect place for developing new technologies for mining, geophysical surveys, radiation detection, and many other studies and measurements. In this pilot, the underground laboratory Callio Lab, Finland, was used as a pilot site for the Well-being with intelligent and adaptive lighting in the underground mine project. One of the aims was to gather experiences and feedback from the users and gather valuable scientific data on the possibilities of intelligent, adaptive lighting for the underground workers.

Contents

1. Content of present document

1.1 Document justification

The present document is part of the BSUIN project's WP4 outputs related to the use of underground facilities as a pilot environment for research and industrial testing. In the following report, the pilot case with adaptive and intelligent lighting and the experiences within the underground laboratory Callio Lab, Pyhäjärvi, Finland, are described.

1.2 Content description

Underground laboratories for piloting and testing services and technologies is not an everyday possibility or even an idea to aim at. The BSUIN project created a possibility for out of the original scope of Underground Laboraotires to initiate new research projects. The intelligent and adaptive lighting has been studied in the context of households, public and office buildings and underground garages, the latter mostly from the energy-saving and guiding perspective, but not in actual underground working environments. The pilot project on intelligent and adaptive lighting in underground spaces was initiated, and a separate project funding for the actual project was applied and received. As such, similar research had not been conducted before in any of the BSUIN partner laboratories.

2. The BSUIN project

The BSUIN project aims to make the underground laboratories (UL) in the Baltic Sea Region more accessible for innovation, business development and science by improving the information about the underground facilities, the operation, user experiences, the underground working environment and safety. Based on the improved characteristic information, business models and service portfolios are updated to help the underground laboratories the established network to understand the full potential of the facilities.

Baltic Sea Underground Innovation Network (BSUIN) is a collaboration project between 13 partners from eight Baltic Sea Region (BSR) countries.

PARTNER LABORATORIES:

- Callio Lab, Pyhäsalmi (Finland),
- Äspö Hard Rock Laboratory, Oskarshamn (Sweden),
- TU-Freiberg's Research and Education Mine "Reiche Zeche" (Germany),
- Conceptual Lab development coordinated by KGHM Cuprum R&D centre (Poland),
- Ruskeala, Karelia (Russia),
- Underground Laboratory of Khlopin Institute in St Petersburg (Russia).

Figure 1 Map of the Baltic Sea region with the underground laboratories involved in the project.

ASSOCIATED ORGANISATION LABORATORIES:

- Experimental mine Barbara (Poland),
- Hagerbach Test Gallery (Switzerland).

Besides project partners, 17 associated partners contribute to achieving project goals. In the project participate five existing underground laboratories around BSR. Moreover, one UL prototype will be developed within BSUIN activities. During the project, the ULs will be characterised both from an infrastructural and operational perspective. As a result, the UL within the network will be more attractive and known to potential customers. The ULs are looking for customers to develop innovative activities and to increase the usage of laboratories.

The project's main outcome is a sustainable network organisation, which will collect, describe and distribute the information projecting, building and maintaining this kind of facility.

The project is funded by Interreg Baltic Sea funding cooperation. Its duration is 36 months with a total budget of 3.4 M€.

3. The pilot site

3.1 Callio Lab, Pyhäjärvi, Finland

Callio Lab is a University of Oulu, Kerttu Saalasti institute led underground research infrastructure and a network of underground researchers and research organisations. Callio Lab is an underground laboratory located in the Pyhäsalmi mine in Central Finland, 160 km south of Oulu and 350 km north of Helsinki.

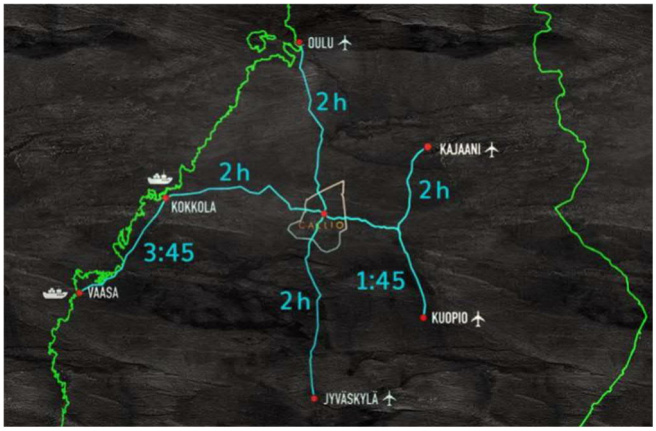

Figure 2. Travel time to the underground laboratory from the main urban centres.

The well-developed network of underground tunnels is suitable for engineering, geoscience, physics, agriculture, working environment studies, and business cases (figure 3.). The mine has more than 100 km kilometres of tunnels and a vertical depth of 1.4 km. The main level of the mine is at a depth of 1410 m, and current mining activities take place between 1000 – 1400 m..

Figure 3. Callio Lab research fields

The Callio Lab research infrastructure has a wide range of activities ranging from education and life-long learning to future space-era closed environment food production and Earth observations to developing an analogue space research environment. Examples of underground space usage in Callio Lab is presented in figure 3.

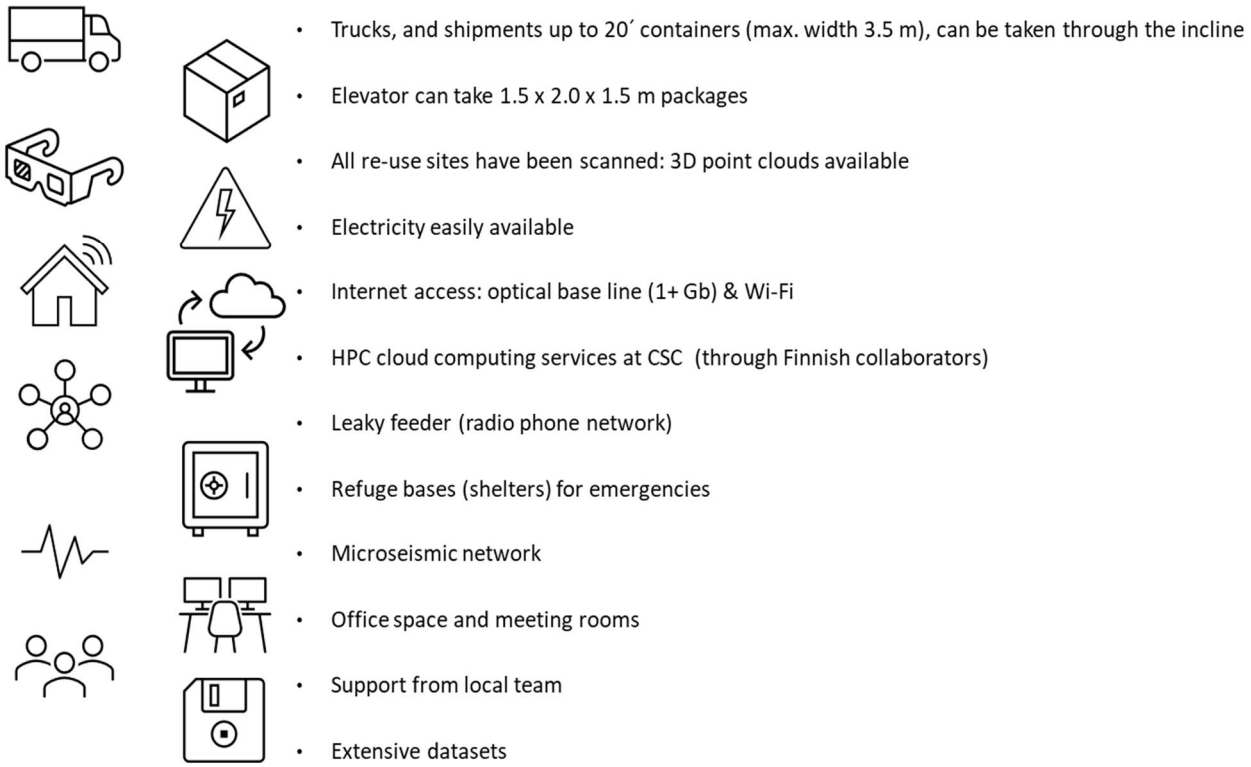

Figure 4 Callio Lab possibilities and support services currently available.

The underground tunnels of Callio Lab are sizable and are accessible even with trucks. Even 20'sea containers can be transported through the 11 km long incline, "the main road" with a unique platform". The incline grants access from the surface to the bottom of the mine, down to 1.4km depth. For personnel logistics between the surface and the bottom of the mine, a 1.4 km long elevator takes the personnel down in less than three minutes. The maximum speed of the elevator in personnel transport is 12 m/s, and the person count is limited to 20 people. The fast internet access throughout the reuse facilities makes the Callio Lab an option for any research with a need for reliable and secure internet or remote connection.

4. Experiences from the underground pilot site

4.1 Why pilot with intelligent and adaptive lighting?

According to a literature survey done in the BSUIN project preparation phase, intelligent and adaptive lighting has been tested or used in schools, offices/warehouses, commercial buildings and above and underground parking halls. The main emphasis has been on reducing the energy costs, especially in schools and office work, to increase residents' ability to work. However, studies and applications related to underground environments, i.e. mines and tunnels, were not found. Additionally, studies of the impact of intelligent and adaptive health and well-being were found in surface buildings, i.e. hospitals, households etc.), but not in underground environments. These findings led us to the proposal to have an intelligent lighting pilot at the Callio Lab, Finland.

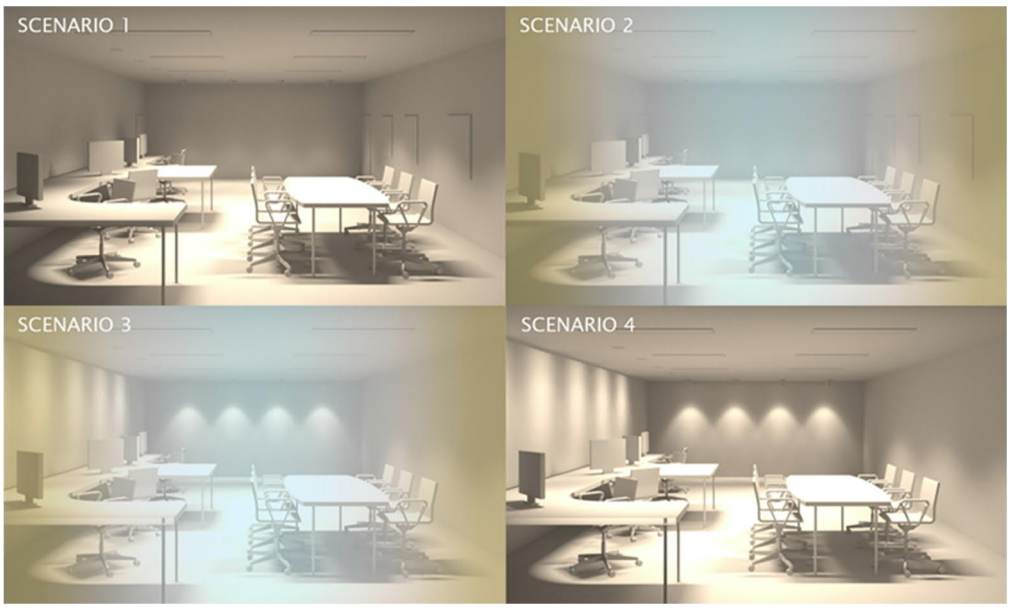

Figure 5. Different lighting scenarios developed for the project. Illustrations by Mia Pujol and Henrika Pihlajaniemi.

4.2 The pilot project

The Intelligent lighting pilot in Pyhäsalmi mine is part of occupational well-being with intelligent lighting project. The project was led by the Oulu School of Architecture, University of Oulu, and the project duration was 1.1.2019 – 31.10.2021. Collaborators for the project

included CERF, Kerttu Saalasti Institute, BSUIN project, Pyhäsalmi mine and Pyhäjärven Callio. The project was funded by the Finnish Work Environment Fund, University of Oulu and Fagerhult Oy.

The shift managers office, "Pomola" at the Pyhäsalmi mine, was chosen as a pilot location. The office space was refurbished with adaptive and intelligent lighting solutions, thus creating a living lab environment for testing the effects of lighting for well-being. The site was chosen based on the results of a pre-survey: that was the location where there were, most of the time, people present in this 1.5 km deep mine.

In the pilot area, four test scenarios were developed to test the utilisation of circadian lighting principles relating to human physiology and factors of architectural lighting relating to visual and spatial experience. See figure 4. for the different lighting scenarios.

The evaluation of the pilot project employs a mixed-methods approach: measurements of workers' activity, stress levels and sleep patterns, questionnaires and interviews, evaluation probes, and lighting control log data analysis.

Figure 6. One of the lighting scenarios from the Pomola. The pilot site was presented to BSUIN members in December 2019 during the BSUIN Steering Committee meeting.

4.3 Experiences

Experiences and feedback from the pilot case were studied using an online questionnaire. Only the project manager of the pilot answered. The questionnaire was sent at the end phase of the BSUIN project and the mid-way of the pilot case project.

Question 1. How would you describe the Underground Laboratory Callio Lab?

From the perspective of our research needs, Callio Lab is a real-world testing/living lab area with several types of underground facilities and personnel working with different types of tasks related to mining, management, maintenance, installations, research and business. It allows piloting new solutions and studying work processes, the well-being of the personnel, environmental conditions, and relations. Our special focus in the research has been intelligent lighting solutions in underground environments and their influence on workers' well-being.

Question 2. What kind and type of facilities did Callio Lab have for the pilot environment and more specifically for the project itself?

There would have been available several environments for our pilot study, starting from Retka restaurant and office rooms to maintenance and research laboratory spaces. We chose for our intelligent lighting pilot the office space for management personnel on the Main level - "Pomola".

Question 3. Could you provide a brief description of the project, the created pilot environment, and the objectives of the project?

The project studies the problematics of designing lighting for underground environments through a case study pilot lighting project in the Pyhäsalmi mine. As a case study, an underground working environment in the mine was refurbished with adaptive and intelligent lighting solutions, thus creating a living lab environment for testing the effects of lighting on well-being. The intelligent lighting pilot study is related to two research and development

projects at the University of Oulu: Occupational Well-Being and Safety with Intelligent Lighting and BSUIN – Baltic Sea Underground Innovation Network. The research was carried out by the research group of the Oulu School of Architecture in collaboration with CERF and KSI.
In the research, several scenarios and concepts for using adaptive and intelligent lighting were created and studied. These utilised both the principles of circadian or biodynamic lighting related to human physiology and factors of architectural lighting related to visual and spatial experience, functionality, aesthetics and meaning. The research approaches well-being holistically, encompassing both the physiological effects of lighting and the influences on psychological, such as mood, sense of security, and job satisfaction. The evaluation of the pilot project employed a mixed-methods approach: measurements of workers' activity, stress levels and sleep patterns, questionnaires and interviews, evaluation probes, and lighting control log data analysis.

Question 4. How well did Callio Lab meet your requirements on the realisation of your pilot environment? What kind of challenges did you meet and how these were solved? What kind of successes you had?
Callio Lab welcomed us warmly as a community to do real-world study in the underground mining environment and was very helpful in all phases of research. For example, they provided us transportation and guidance to the underground facilities, where we were not allowed to move around without guidance. All the safety matters were instructed with care, and there were no problems. While designing the project, Jari Joutsenvaara [research coordinator at Callio Lab] provided us with all the needed information and helped us with many contacts with the mining company. Our pilot environment was built into the office space on the main level, and the mining company collaborated with us well throughout the project. The company let their personnel to participate in our study during their working time, it purchased the intelligent lighting fixtures for the test environment according to our plans, and the electricians of the company made the installations. The main challenges in the project have been motivating enough workers of our test environment to participate in the study, as there was only a limited number of people

working in the chosen office. Our evaluation protocol, which combines physiological measurements, questionnaires and interviews, is quite time-consuming. As we are testing several scenarios of intelligent lighting solutions in the same room, the phases are repeated many times with the participants. However, using several methods has been a robust approach, as if some of the methods has failed, we have gained good research material with the other methods. At the moment, the biggest challenge has been coronavirus and the lock-down of the mine for visitors, so we could not carry out the early summer evaluation phase. We hope to be able to carry out that phase in August instead. All in all, the pilot has been a success, and technically the pilot installation has been working well, and the workers have been satisfied with the results. We have gained good research material for the analyses.

Question 5. Where was the pilot case disseminated (newspapers, journals, conferences)?
The pilot case has been disseminated so far in a conference presentation and conference proceedings article: Pihlajaniemi, Henrika (2019). Working in deep darkness – well-being through adaptive and intelligent lighting in underground spaces. in Proceedings of PLDC 8th Professional lighting Design Convention, Rotterdam 23. – 26. October 2019.

Question 6. How, the now created test environment could be further utilised? For what type of users, the pilot environment would be useful, e.g., academic, business, etc.?
As long as the pilot environment is used by the mining personnel, it can be used only for short periods for other purposes when the personnel is not using the room. It could be used now for short demonstrations and user experience testing. In the future, the room and intelligent lighting environment could be used for many kind of workers (business, academic, training) and visitors, and the ideas presented and tested in the study could be applied in other spaces of the Callio Lab facilities, as well. For example, Retka could be developed into a multi-purpose visitor centre.

Question 7. In your opinion, based on experiences and expert background, for what kind and types of projects Callio Lab underground laboratory would be suitable for?

Callio Lab is a unique environment, which is especially suited for studying underground environmental conditions and users' experiences in a living lab, real-world environment, where there is no contact to natural light and to the outdoor environment. This is a special opportunity concerning lighting research and the development of intelligent solutions.

Question 8. What would an ideal underground pilot and test environment be? What kind of prerequisites should be met for the success of planned projects and research, e.g., related to facilities, access, support, etc.?

Ideally, from our perspective, the test environment would have personnel spending regularly time in the pilot environments so that long-term studies of users' experiences would be possible. The access to the environment would be made flexible, and there would be facilities such as a restaurant, rest spaces, rooms to stay overnight etc. Booking system to facilities and support personnel. Good internet and electricity connections etc.

Question 9. Other comments?

Thank you for the opportunity to do a pilot project and for all the help during the process!

5. Summary

Underground laboratories provide unique possibilities for research, science and even business. The pilot case at Callio Lab, Pyhäjärvi, Finland, highlights the possibilities for fields outside the underground laboratories' normal user segments/fields. The project Occupational Well-Being and Safety with Intelligent Lighting was the first human-reflection related project at the site. The experiences will help create better service offerings to the new users and user segments of underground laboratories. Although the project was the first of its kind, the project outcomes bring new information about the importance of lighting in underground working conditions.