INSIGHT INTO TRANSFERABILITY OF KNOWLEDGE AND TECHNOLOGY IN MINING INDUSTRY

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Abstract: *Geographical transferability of technology has the potential to make a more efficient use of resources. However, inappropriate transferability of data can provide misleading results. Use of automation, IT and communication techniques depend on the size of mine. As far as small mines are concerned, the main limitations are costs and lack of sufficient knowledge and know how. Due to these limitations small mines have to take over already developed mining and ICT technologies. Throughout Europe there are more than 120 small mines, which are not able to do specific research and technical development departments, as RTD is not intended to yield immediate profit and generally carries greater risk of uncertain return on investment. This is why smaller mines have to take over mining techniques and technology already developed in different projects. This paper presents some specific insights into problem of knowledge and technology transferability in mining industry.*

Key words: results transferability, underground coal mine, ICT technology, OPTI-MINE

1. Introduction

A commonly used definition of transferability describes the process of transferring knowledge and good practices between partners. Transfer studies emphasise the specific character and content of transferred data and their modifications throughout transferring process. Moreover, transfer allocates attention to the behaviour and role of institutions or companies and individuals during the implementation process. Transferability thus heavily depends on the interplay between all of the partners. It must be noted that transfer does not only include simply copying successful solutions, but also allows for the possibility to make substantial changes. Transferability of a solution and technology is understood as the ability or feasibility of transfer.

In this paper transferability analysis is a process of assessing the possible feasibility of transferring a successfully implemented innovative solution from one mine to another (in similar or lower stage of development). It is important to remember that what is best for one mine it is not necessarily best for the other one. The process analyses the context conditions that influence potential implementation in the "take-up" coal mine and learning from the experience of the leading mines. Transferability analysis provides an opportunity to learn from the previous experience of implementation and allows to exploit opportunities and avoid mistakes.

There is a lot of advantages of using the transferability analysis:

- Do not have to reinvent the wheel
- Clear definition of innovative solution
- Comparability between different innovative solutions
- Systematic approach to innovation
- Focuses on the essence and reduces the complexity of the solution
- Reduces the risk of bad decision making
- Feasibility check at an early stage
- Learn from the mistakes and problems of others
- Process itself leads to stakeholders and expert involvement

It is important to remember that transferability is not an all-or-nothing process and we can distinguish three different degrees of knowledge or technology transfer (Table 1).

Table 1 *Different degrees of transferability*

Copying	Direct and complete transfer of current solution
Emulation	Transfer of the ideas behind the project
Inspiration	Final outcome does not actually draw upon the original idea

The underlying process of transferability should include answers to a list of questions concerning transfer, which will help to pinpoint attention on various aspects of this complicated process:

- What is transferred?
- From where are lessons drawn?
- What are different degrees of transfer?
- What are the key steps in transfer process?
- What restricts or facilitates transfer process?
- What are the initial conditions and initial requirements?

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The idea of transferability was a part of OPTI-MINE demonstration project funded by the European Commissions' Research Fund for Coal and Steel (Grant Agreement RFCP-CT-2011-00001), which was aimed at integration and installation of newest ICT mining solutions in industrial-scale and bringing together all the technical and economic data in order to make a European wide implementation in the mining industry possible at minimum risk. Not only the new ICT applications itself were demonstrated, but also integration of ICT systems, into one common based open network platform of high bandwidth and standardised configuration (TCP/IP). Possible applications of network based ICT are presented in Figure 1. Thus the processes as a whole are optimised, what considerably increased mines safety and efficiency [4].

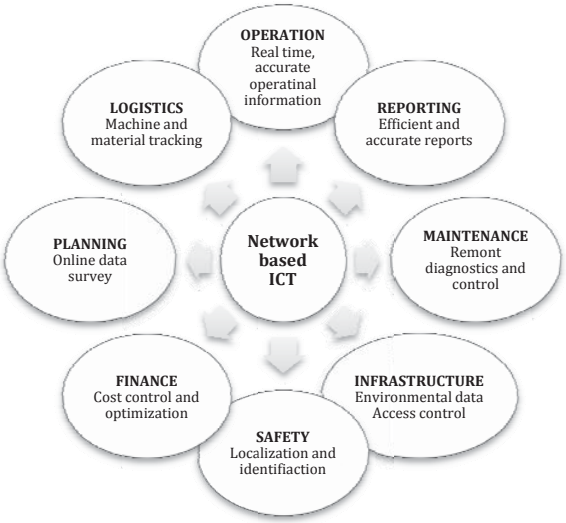

Fig. 1 *Possible applications of network based ICT in coalmines. (www.opti-mine.eu)*

2. Methodology

Use of mechanization, automation, information and communication techniques depends on mine size. Main limitations concerning small mines are costs and lack of sufficient knowledge and know how, due to these limitations small mines have to take over already developed mining and IT technologies [1]. Throughout Europe there are more than 120 small mines (approximately 40 within the European Union). By small mine we consider a mine with production rates about 0.5 million tons per year or lower. Due to limited competitiveness and capabilities such small mines generally are not able to do specific research and technical development department being either staffed by engineers and tasked with directly developing new products or staffed with industrial scientists and tasked with applied research in technological fields which may facilitate the future product development. RTD is not intended to yield immediate profit, and generally carries greater risk and uncertain return on investment. This is why small mines have to take over and adopt mining techniques and technology developed for bigger mines in different projects such as, for example OPTI-MINE.

It is important to remember that bigger mines often have other needs than the small ones. Nevertheless, different projects results allow smaller mines to adapt the low cost IT solutions based on open underground communication platform, which promises low costs of adaptation (for limited needs). Many real life transferability cases prove how easy innovative technologies can be transferred to other (similar or smaller and less technologically advanced) mines. Transferability also offers knowledge that ensure smaller mines participation in the technological and economic progress driven by newest IT and ICT technologies.

Essential basis for any transferability is the experience gained within projects, especially implementations concerning industrial demonstration and applications of newest technologies. As OPTI-MINE was a demonstration project aiming at integrating, installing and operating of new ICT applications on industrial-scale, and it was carried out at five different European underground coalmines, allowing collection of large amounts of heterogeneous data. The demonstration covers the leading edge ICT for underground mining processes logistics, transport, personnel and machine communication and staff localization. The benefits of this comprehensive optimization of mining process are related to considerable improvements in efficiency, mine safety, environmental impacts, occupational safety and health [3].

Generalization and transferability of knowledge should be a key result in all projects, especially those concerning applications of new technologies. Dissemination of results to a wide audience associated with mining industry should allow transferability. Applied transfers of both knowledge and technical solutions should be initialized by interested parties (readers of the demonstration projects results), who need to connect elements from specific projects and it results to their own experiences and needs. Transferability studies show that the general comparative analysis has to be done and transfer of exact solution or technology strongly depends on local conditions. Each time talking about transferability of project results in mining industry, the general comparative analysis has to be done in all five fields:

- Geological and mining conditions
- Material resources
    - Equipment
    - Technologies
    - Infrastructure
- Human resources
    - Amount of workers
    - Number of specialists
- Health and safety
- Economics and finances

3. Transferability analysis

In this paper the following terminology is used in case of possible transfer of innovative technology and ideas between two or more mines:

- Prototype mine – mine, where an innovative solution was successfully implemented
- Follower mine – mine, which wish to implement an innovative solution
- Expert – organization/company/person that will coordinate the transferability process
- Components – factors that can contribute to the transfer success or failure
- Sub-components – components relevant to transferability
- Down/up scaling – decreasing/increasing the size and range of the implementation

Methodology to analyze the transferability and enhance the policy to transfer of innovative solutions to another coalmine should be designed to maximize the usability (as presented in Figure 2). This is a qualitative methodology based on systematic steps, where the management in cooperation with experts comes to conclusions on introducing innovations.

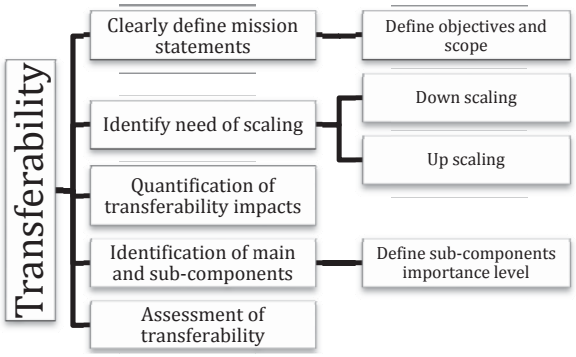

Fig. 2 *Transferability analysis methodology [2]*

Gathering information – key to successful transferability

Gathering enough of the required information concerning the possible future transfer is the most important step, so information required for transferability assessment should be collected from various sources. The choice of information sources and their quantities strongly depends on type of transfer; best sources include [2]:

- Field visit in prototype mine – site visits are very useful and allow gathering first-hand experience concerning implementation and its direct impacts
- Literature –available documents and literature related to the innovative solution is a very good source of information, and can be obtained from prototype mine that has successfully implemented innovative solution and also from independent experts in specific field
- Interviews – interviews with prototype mine and experts allow receiving information that is not readily available form published literature
- Projects workshops, forums and international conferences are an ideal opportunity to address transferability issues.

Clearly defined mission statement

Transferring innovative technology or idea requires a clearly defined mission statement (clear objectives) and a realistic scope, which is the first step of a transferability assessment. This allows avoidance of any misunderstandings during the subsequent transferability and implementation. Generally, this is the most important step in the whole transfer process, and any further steps regarding transferability should only be carried out if and after the follower mine fully understands and agrees with the specific transfer objectives and its scope.

Identification of down/up scaling needs

Determining whether scaling of the transferred technology is required is the second most important task on transferability case. This depends on the context condition, mainly the implementation size in the follower mine in comparison to the prototype mine. It is extremely important to scale the project size to the actual conditions and consider all the differences and difficulties that might arise from this scaling.

Identification and quantification of the impacts of transferability

Identification and quantification or qualitative description of the transferability impacts is essential justification and supporting evidence for consideration of transfer assessment for the future implementation by the potential follower mine. These impacts vary according to different innovative technologies and solutions being analyzed for further transferability. These impacts can include changes in: efficiency, safety, environment or accessibility and economic aspects. In OPTI-MINE project thanks to use of Key

Performance Indicators (KPI) a multi-criteria analysis takes into account a wide rang of impacts and provides an effective quantitative way of justifying the implementation of innovative ICT solution [5]. If it is possible all impacts should be quantified and supported by qualitative information.

Identification of main-components and sub-components

The main-components (factors) that can contribute to the success or failure of the transferability must be identified, so that their relevance to the future transfer of innovative solution can be assessed. These main-components should be further broken down into sub-components relevant to transferability process. The identification of main-components and sub-components in the context of transferability strongly depends on the experience of the prototype mine and committed independent experts. The list of components and sub-components which can influence the transferability needs to be created, revised and finalized on the basis of available materials and information gathered from both prototype mine and experts.

Identify level of importance of sub-components

The relative level of importance needs to be defined for each sub-component (i.e. high/medium/low). Of course, the chosen level of importance should be supported and justified by proper comments. Identifying levels of importance should be judged from the follower mine's point of view, but of course experiences of the prototype mine and advice from experts are very valuable in this process.

Assessment of the transferability

This part is a subjective assessment of the ease of problems and difficulties experienced during implementing solution in the prototype mine. The discussion between mines as well as with the experts is one of the key factors in this step. The assessment should be made in a quantitative way and if assessment is carried out in a group, an anonymous scoring approach can be effective.

Transferability conclusions

The final step of transferability assessment is drawing conclusions regarding the potential of new technology transferability through consideration of all the factors identified and all assessment values ascribed to each component. This step should discuss all the key factors and barriers for transferring the innovative solution. Concluding remarks about the chances of successful transferability should be made.

If there are no strong or modest constraints, it is very likely that the transfer will be successful, particularly when any supporting factors can be put in place.

If there are no strong constrains, but few modest constrains, it is likely that the successful transfer will be difficult unless the constraining conditions can be adequately addressed.

If there is one or more strong constraints, it is likely that the transfer of innovative solution will not be possible unless the constraining conditions can be overcome.

4. Information and communication technologies

The use of mechanization, automation, information and communication techniques strongly depends on mine size and its technological advance. Automated mining involves and allows reduction of human labour from the mining process. Automation in mining deals with applying both robotic and IT technology to mining vehicles or equipment but also deals with process automation. In order to gain more control over the mining operations the mine automation hardware and software are implemented in order to help mine administrators organize, control and monitor mining event throughout the whole site in real time, this allows to identify productivity bottlenecks and increases accountability.

OPTI-MINE demonstrational project results show that network communication and ICT are a basis for safety and efficiency of optimized underground operations. Process optimization is only possible by fully transparent processes, which are achieved by the use of newest communication and IT technologies. Different mines implemented Ethernet based underground networks for multiple purposes [3]:

- Reducing cost and improving production due to optimizing material logistics
- Reducing cost by remote controlled longwall operations
- Improving personnel communication and tracking (increased safety)

A single, unified and multi-purpose networking system was deployed to keep total cost at lowest possible level, what is a very important factor regarding possibility of transferability to smaller and less technically advanced mines, witch often need to build a whole new network infrastructure, which sometimes can be expensive but for sure very profitable, as communication is regarded as a strategic investment. General advantages of implementing new ICT are quite oblivious:

- Helps to analyse logistic processes
- Improves communication
- Increase safety
- Reduces maintenance times
- Allows to grow with future demands

The range of the possible OPTI-MINE project results transferability is as follows [2]:

- Definition of the prerequisites in terms of mining equipment and staff knowledge
- Definition of the minimal level of Information and Communication Technology (ICT) for the basic implementation (both hardware and software)
- Definition of ICT modules for further growth
- Maintenance of the ICT system
- Advice for an ICT introduction strategy
- Estimation of cost and benefits in terms of economics.

5. Conclusion

Nowadays almost whole mining industry is in the process of transition towards automation and application of ICT technologies – it refers also to small mines, obviously on a proportionally smaller scale, as they still require a large amount of human capital.

Generalizability and transferability of the result to a wide audience associated with the mining industry bring progress. Approaches, which have been used for transferability of project OPTI-MINE results regarding innovative ICT technologies to other mines, suggest that, at a minimum there is a need for mine-specific substitution of practice pattern data as well as extensive analysis of the installation and maintenance costs. Introducing state of the art ICT into a smaller and not as advanced mines is possible but each time detailed individual comparative analysis of all aspects is required – the pros and cons of each individual case.

Nowadays predominantly the excavation of hard coal occurs in complicated geological conditions. Such conditions are results of highly folded layers; numerous big faults with drops reaching even 200 meters and more. Main natural hazards in hard coal mines embrace hazards connected with gas emission, fire, coal dust, seismicity and rock bursts, water and radioactive phenomena. These hazards should be regarded as dominating. Reduction or liquidation of hazards is performed with usage of adequate techniques that are designed either for each hazard individually or for a group of hazards that occur together in the area of the carried out exploitation. It is important to compare the geological mining conditions and adjust the transferred technology to local conditions, as it will influence the safety of work; in some cases, the use of the solutions presented in specific project simply may be impossible due to different conditions. Each time we are talking about transferability of specific solution form one to another coalmine, the general comparative analysis has to be done in all five fields (geological & mining conditions, material resources, human resources, health & safety, economics & finances).

References

1. **R.P.H. Willis, S.G.E. Ashworth**
   Technology and knowledge transfer – good practice guidelines, The Journal of The South African Institute of Mining and Metallurgy, 2002
2. **P. Kolodziejczyk**
   Study on transferability to small mines of lower technical status, www.opti-mine.eu, 2015
3. **Evonik Industries AG**
   OPTI-MINE Handbook, www.opti-mine.eu, 2014
4. **C. Mueller**
   Network communication and ICT as basis for safety and efficiency of optimized underground operations, Proceedings CIM Vancouver, 2014
5. **M. Bendrat, C. Dauber**
   Key Performance Indicators – A Tool to Assess ICT-Applications in Underground Coal Mines, Proceedings Aachen International Mining Symposia AIMS Vol. 13, 2014