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Concept of technology assessment in coal mining

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Abstract. An increased competition in the economic market forces to develop more and more modern technological. However, these solutions are not always user-friendly and therefore in many cases they cause problems with operating them. Mining is one of the industries where the new technological solutions have been dynamically introduced recently. The effective mining exploitation requires using newer operation, mechanization and automation technologies as well as advanced security systems limiting the risk of negative events occurrence. The implementation of new organizational solutions and innovative devices is strongly connected with the necessity of employees' proper preparation for these changes. As a consequence, the demand for increasingly qualified and aware employees is increasing. The article refers to this problem in the field of developing the assessment concept of technologies implemented in mining. In particular, it concerns the assessment of employees' knowledge and awareness of the implemented solutions. The concepts of the Technology Assessment (TA) were used as the proposed estimation. In this respect, it is important to determine how new technologies are adopted by employees and what opportunities they can be fully utilized. The article should be treated as a voice in a broader discussion on the assessment and the impact of technology.

1. Introduction

In the current times of the technological and IT revolution, the technology grows and develops very quickly. The implementation of modern technologies to the industry in the area of services and as well as production is shaped by the indicator the industry structure modernity of a given country. Moreover, the implementation of high technologies generates significant economic benefits. This indicator determines the level of economic growth and at the same time competitiveness in the international arena. The highest modernity rate is possessed by the most developed countries, such as the USA, Japan or the countries of Western Europe. The countries, where innovative solutions are not endeavored, increase the technological gap between them and leading countries [1].

The expansion of technological innovations has a significant impact on the modernization of the economy. One of many examples is the reduction of labor costs because modern solutions allow achieving high results at low expenditures. The implementation of innovations is the basis for taking further actions in field of development, searching for more and more advanced processes and products. The use of modern technologies affects the efficiency of work, eliminates mistakes, increases precision, and therefore reduces the unit costs. This, in turn, has an influence on the competitiveness of the economy and the given industry. In addition, physical labor expenditures are limited but on the other hand, the demand for specialists increases. Therefore, it seems reasonable to state that the development of technology is an indispensable element of the development of every modern country, economy and individual societies [1].



In Poland, the growth of importance of high technologies and thus, the changes within enterprises using innovative solutions have been observed for last years. These changes concern in particular the organizational structure. The main changes affect work processes, information flow, employees training, document circulation, and above all, the improvement of work culture. Most often, the changes – even the small ones – are evaluated in the perspective of successes and losses.

These changes include also the area of technological equipment to a greater extent. The new systems and technical objects, which require very advanced knowledge to operate and maintain them, are used in the enterprises. One of the threats of the expansion of modern technologies is the barrier associated with the lack of skills in operating these innovative devices and technologies. Many users, and in the case of the industry – employees, can not follow the essence of operation and using advanced technical solutions. Therefore, the attempt to initiate changes in workplaces most often faces great resistance of the staff. A great example in this respect are mining companies [1, 2].

Despite the numerous restructuring changes in the mines, production and expenditures reduction, the mining is one of the fundamental industries in the Polish economy. Currently, the Polish coal mining employs nearly 120,000 people performing their duties in very difficult and unpredictable conditions from the security point of view. Working in underground mining plants is extremely difficult and dangerous due to natural unpredictable environment. The coal exploitation process is inseparably connected with both natural and technical hazards. The accumulation of negative factors, such as: methane, noise, the risk of rock throws, etc., forces to take measures to improve the conditions and comfort of work. Therefore, nowadays more and more modern technologies, reliable technological means, and in particular advanced machines and devices are being used [3]. An example of an innovative solution supporting the work of mining machines using virtual reality technology is the System of Interactive Manuals (pl. INSTO). This solution contains interactive procedures showing the following steps that have to be taken as a part of maintenance, utilization and conservation of the machine [4]. In addition, an innovative solution is an IT platform that enables data registration to detect and analyze the causes of failures and unplanned downtime during the mining machines' work [5, 6]. The main task of implementing these, often very advanced, IT tools is to increase the effectiveness of the mining production [7, 5].

The scientific research plays a significant role in the process of modernization and increasing the work safety in mining. In particular, they concern providing the mining excavations safety [8, 9, 10, 11, 12], ventilation and dust safety [12, 13, 14, 15] which have fundamental meaning for the continuity and effectiveness of the mining production process. The main objective of these activities is to achieve a state in which it will be possible to effectively and safely conduct mining production. The safety issue in mining has always been a priority.

The analysis of statistical data of the Polish mining statistical office, called Wyższy Urząd Górniczy (WUG) [16], showed that the accident rate within mining was between 1600 and 1700 accidents per year in recent years. Fatal accidents account for 0.97% and heavy accidents for 0.78% of all accidents in mining. The average of all accidents in mining in the last 10 years was 2236. The majority of them (70%) is caused by the mistakes made by employees (accidents due to the human reasons). These reasons include improper employee behavior, improper operation of the material factor and arbitrary behavior of the employee. It means that in the whole system related to the mining exploitation, it is a man that is the weakest link [3]. Figure 1 shows the number of accidents occurring in the coal mining in the last 10 years.

Analyzing the presented data, it can be concluded that the absolute accident rate in mining is decreasing. The reason of this fact may be the improvement of security due to the implementation of the advanced technologies, as well as the fact that employment in mining has significantly decreased. Nevertheless, the average accident rate is 2236 events per year in the last 10 years. 1566 of them are caused by human factor.

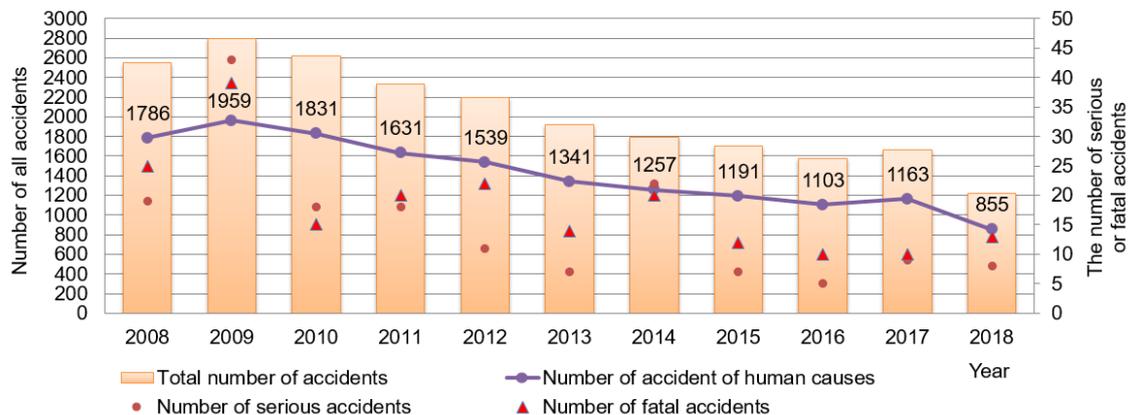


Figure 1. Occurrence of accidents in mining in 2008-2018 (source: authors' own study based on WUG data [16]).

Therefore, it seems reasonable to state that the human factor is a very important in terms of safety. There is also a question about the reasons for the employees' behavior that generates accidents. It is not subject to discussion that with the growing demands of the industry, employees should also have increasing technological awareness, knowledge and commitment to work. In order to determine the level of employees' awareness, surveys, the results of which are presented in this paper, were conducted. They concern the assessment of organizational and technological changes introduced in the mines. Based on the obtained results, it was decided to use the TA assumptions to develop the concept of assessment of technologies introduced in mining. This is a new approach to the problem of identification and assessment of technological barriers in the mining industry. In current reality, this approach seems to be justified. It is not subject to discussion that a quite conservative mining industry must adapt to changes occurring in the economic environment in order to meet market requirements. In particular, it applies to the changes in terms of industry revolution called Industry 4.0.

2. Preliminary research

The competitiveness of the market forces to implement the modern and innovative solutions in the form of advanced technologies. The aim of these activities is to improve work effectiveness, economic profit and work safety. However, the sudden pace of new technologies implementation limits the possibility of using the full potential of machines and devices due to the barriers of understanding their operation and service. This barrier has a negative impact on the enterprise functioning and posts a social threat.

Due to the significant importance of hard coal mining for the Polish economy and the scientific interest of the authors, preliminary surveys concerning the technical barriers [20] among mine employees were carried out. Respondents were asked, what they think about the implementation of modern technologies into the mining industry and whether there is a need to implement modern technologies in hard coal mines. The obtained results indicate that 68% of respondents negatively assessed the introduction of modern technological equipment in mining. Only 27% of them supported such activities and 5% did not have an opinion on this topic. Figure 2 presents the obtained results in a graphic way. It also shows the reasons for the negative attitude of employees towards the introduced changes.

The obtained results are very interesting. Particularly worrying is the large group of opponents of the technological progress. It turns out that, contrary to the predictions and logical thinking, employees are not interested in introducing new technological solutions in mines. Therefore, it was natural to identify the reasons for their strange attitude in this topic.

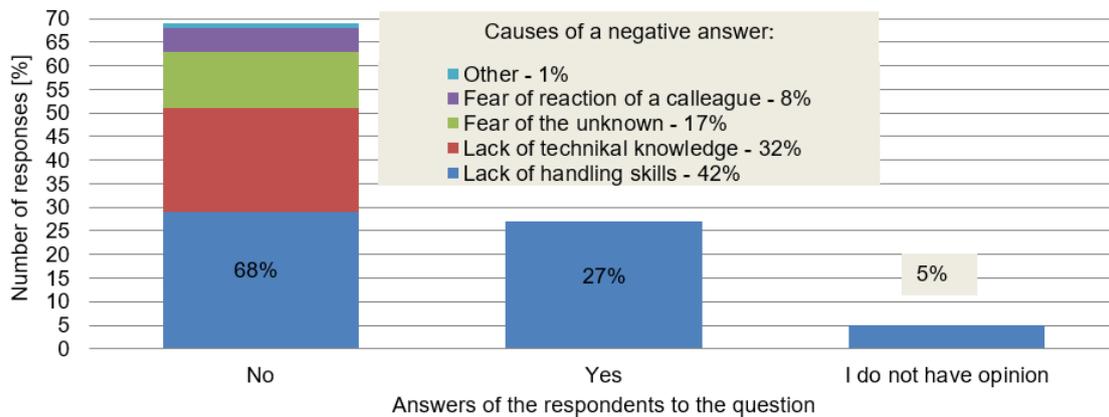


Figure 2. The results of survey research regarding the implementation of new technologies in mining. (source: authors' own study based on [3]).

The obtained results from this part of the survey explain to a large extent the reasons for the previous responses. The most frequently given reason for the lack of interest in new technological solutions was the lack of skills in using modern machines and devices. This is the reason given by 42% of respondents. Lack of technical knowledge about the operation and functionality of these devices was indicated by 32% of respondents. Employees also presented their concerns about the risk of losing their jobs due to introducing the new solutions as well as and the negative reaction of colleagues on the situation when they reveal the inability of using the modern machines and devices. The answers indicate lack of information on the operation, advantages and purpose of implementing the new technological solutions. In this respect, it seems to be necessary to introduce a comprehensive training program for the employees. Its goal should be to improve the competences of the employees, as well as their awareness and work culture.

The adequate trainings improve the effectiveness and safety of employees and this, in turn, has a significant impact on the company's development. Within the mining companies, there are many trainings, so it was decided to check their quality and the importance of the discussed topics. For this reason, the research on the quality of mining training was conducted [3, 19]. The results of the surveys and discussion panels showed that employees can see big mistakes in the organization of trainings. It applies both to the way they are conducted and the topics which are discussed. Primarily, the trainings concern security aspects and are acceptable by the employees. However, there are no properly prepared and carried on trainings in the field of implemented techniques and technologies. Generally speaking, it often happens that the poorly grounded knowledge in this area make employees feel fear of the implemented changes. The employees very negatively referred to the organization of trainings. Many of the trainings are conducted in a very monotonous way, and the with practical classes are very limited.

3. Technology Assessment

Technological progress is a source of social development and, at the same time, threats at many levels. Realizing that fact helps to minimize its negative impact. The scientific tools such as: Technology Assessment (TA), technology interview, technology acceptance model, technological forecasting and technology foresight are used for this purpose [2]. Taking into account the specificity of the mining industry and the essence of the study, the authors decided to use the concepts of Technology Assessment. It seems that in this area, there are the biggest problems concerning the mining industry.

Using the Systematic Literature Review, the issues within TA were examined. The collected research material presents a high degree of differentiation of the problem letting interpret TA in a fairly free way. In general, the literature shows that Technology Assessment is an interdisciplinary concept possible to be applied to both technical and social sciences. TA can be divided into three groups. The first interpretation defines the Technology Assessment as a generally obligatory system of science and

technology management system in the entire European Union. This system has a decisive influence on the shaping of the science and technology policy. According the second interpretation, TA is a methodology based on the specific stages of proceedings in terms of the assessment of technology. The third group considers TA as a technology assessment tool. This tool evaluates and estimates technology but also sets the directions for the further development. Applying this tool, it is possible to analyze the impact of technology on the social environment. The main objective of TA is the identification of the risk of implemented technologies. It should be done in advance to allow determining the effects of technology implementation and planning potential solutions to reduce the risk. TA is associated with preparing many alternative options of the used technological solutions and adapting the innovative products to the needs and capabilities of the selected groups of users [2]. Therefore, it seems that TA is the appropriate tool for assessing problems related to the implementation of the new solutions in mining.

It should be emphasized that the constant development of technology is necessary and, at the same time, unavoidable. Therefore, it is necessary to understand the essence of the accompanying changes. It is worth preparing for the changes and being aware of their negative consequences, threats and problems that will occur in the future. Knowledge about the potential threats is necessary to take correct actions to minimize their negative consequences. Technology Assessment is an area identifying the problems but also a tool evaluating the value of the very problem, as well as an indication of how to solve these problems.

4. Conception

The problems of underground mining can be considered in various aspects: economic, ecological and security of technology and staff. These issues have been the subject of authors’ as well as other scientists’ research for many years [3, 6, 7, 8, 9, 10, 17, 18, 20, 21]. The study focuses on the subject of occupational safety in mining in relation to the implemented modern technology as well as widely understood awareness and work culture. Based on the mentioned accident rates and research on training, it can be claimed that the awareness and knowledge of employees can be the foundation of the efficient implementation of the technical changes. It seems justified to state that in many aspects, the state and condition of underground mining depend on the awareness and competence of the people working there. The aim of the presented concept is to identify problems related to the barriers in mining and methods of their removal. Figure 3 shows the preliminary concept of the methodology for the assessment of the new technological solutions introduced in mining.

Stage 1	Stage 2	Stage 3		Stage 4	Stage 5
List of devices	Subjective assessment	Objective evaluation		The indicator of the technological advancement level	Comments*
		Parameters subject to evaluation	The average value of parameters		
Name	d1	p1, p2	$\sum(p1, p2)$	H1	---
Name	d2	p1, p2, p3	$\sum(p1, p2, p3)$	H2	---
Name	d3	p1, p2, p3, p4	$\sum(p1, p2, p3, p4)$	H3*	tips, recommendations
Name	d4	p1	$\sum(p1)$	H4*	tips, recommendations
Name	d5	p1, p2, p3	$\sum(p1, p2, p3)$	H5	---
Name	d6	p1, p2, p3	$\sum(p1, p2, p3)$	H6	---
Name	d7	p1, p2, p3, p4	$\sum(p1, p2, p3, p4)$	H7*	tips, recommendations

Figure 3. Concept of the methodology for the assessment of the new technological solutions introduced in mining (source: authors’ own study).

The first stage of the proposed method consists of creating a list of devices involved in the coal exploitation or coal transport. It is worth taking into account the types of the used machines, upgrades and systems' software of these devices. Each of devices is individually evaluated by the employees. These assessments are collected through questionnaires / surveys completed during periodic trainings. Respondents are asked to assess the advancement of a given device on a scale from 1 to 10, as well as indicate the reasons for their opinion. These evaluations are calculated using the average value and subsequently, attributed to the individual weights of the machines. Due to the possibility of evaluation differentiation, the second stage is called subjective assessment of the employees. The next stage consists of objective evaluation, i.e., evaluation based on the examination of the technological parameters of the device (px). In the beginning, the parameters deciding about the advancement in terms of the device's operation, maintenance or level of understanding are determined. Subsequently, these parameters are being estimated, i.e., a specific numerical value is being attributed to them. These values are necessary to determine the level of the device advancement (Hx) in the fourth stage of the method. At present, it is proposed to calculate the indicator based on two components: subjective and objective opinion; however, the authors conduct research aimed at developing a more objective and precise indicator (Hx).

The indicator of the technological advancement level of the devices used in mining is aimed at classifying devices in terms of their technological advancement and problems with operating them. In the next stage, it will be possible to properly select the employees for the operating device. The higher the indicator is, the more difficult the operation of the device is. In the figure 3, there is an asterisk placed in the superscript of the H3, H4, H7 indicators. This solution is proposed to use in the case of placing additional information about the device or the required qualifications of the employee to operate it.

The concept of the method for assessing the technological advancement of mining equipment requires developing the parameters estimation and determining the final indicator. However, trying to assess this state forces the employees to indicate the difficult or incomprehensible elements, as well as issues which should be discussed during the trainings. It seems reasonable to conduct further study in this area. The preliminary expert interviews confirm the need to develop such a method. Further rapid implementation of the new technological solutions is now expected. It refers mainly to the concept of the Industry 4.0. In this respect, there is lack of knowledge among many employees, which may result in their reluctance and lack of interest in the carried out changes.

5. Conclusions

In considerations presented in the study, several problems, of which solutions have not been applied yet, are discussed. The first one concerns the increasing pace of the technological progress, which, due to the increased competition of the economic market, strongly refers to the industry. The rapid pace of progress and the changes within enterprises is the cause of the growing technological barrier. The employees often do not keep pace with understanding the operation of modern devices and the way which they are used. As a consequence, the demand for more and more qualified staff and a higher number of specialists increases. For the employees, it means that they need to raise their qualifications or else they can lose their jobs. A good example of a company struggling with the mentioned problem are hard coal mines. The mining industry is characterized by particularly difficult and dangerous working conditions. Due to the numerous threats in underground mining excavations, the accident rate is constantly high. The article presents the issue of the weakest link within the mining enterprise which is crew – not well-prepared to work. Despite taking a number of actions in this area, it is clear that the level of competence of many employees requires significant improvement. This is evidenced by, among others, data on accident rates in mines. Human resources, including employee awareness, are the basis for the development of every enterprise, including mining. The conducted research and the obtained results clearly indicate that the selection of properly qualified employees is a growing problem in mining. The lack of such qualifications causes resistance to the necessary changes.

The analysis of the reasons for such a behavior indicated that the lack of technological knowledge and the incorrect training system within the company are a significant problem. Based on the analysis of the literature, the Technology Assessment area, which is used to indicate the stages of proceedings to solve the problem, was examined. Based on the source texts, carried out study and own observations, the authors made an attempt to create a method for assessing the advancement of the mining machines. This assessment concerns the quantitative and qualitative evaluation of the implemented technological devices. It seems that this direction of research is justified, necessary and perspective. It should sensitize and show the directions of activities the managers of mines and capital groups. The significant changes in the industry, related to implementation of the cyber-physical systems can deepen the frustrations of employees. A well-educated, prepared, motivated and, above all, aware and committed employee is the basis for the development and success of every company.

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