

JÓZEF DUBIŃSKI*[#], STANISŁAW PRUSEK*, MARIAN TUREK***KEY TASKS OF SCIENCE IN IMPROVING EFFECTIVENESS OF HARD COAL PRODUCTION
IN POLAND****KLUCZOWE ZADANIA NAUKI W ZAKRESIE POPRAWY EFEKTYWNOŚCI WYDOBYCIA
WĘGLA KAMIENNEGO W POLSCE**

The article presents an array of specific issues regarding the employed technology and operational efficiency of mining activities, which could and should become the subject of conducted scientific research. Given the circumstances of strong market competition and increasing requirements concerning environmental conditions, both in terms of conducted mining activities and produced coal quality parameters, it is imperative to develop and implement innovative solutions regarding the employed production technology, the safety of work conducted under the conditions of increasing natural hazards, as well as the mining enterprise management systems that enable its effective functioning. The article content pertains to the last group of issues in the most detailed way, particularly in terms of the possibility for rational conducted operation cost reduction.

Keywords: science, mining enterprises, efficiency, production costs

W artykule przedstawiono szereg wybranych zagadnień dotyczących technologii oraz efektywności prowadzenia działalności górniczej, które mogą i powinny stać się przedmiotem prowadzonych badań naukowych. W warunkach silnej konkurencji rynkowej oraz zwiększających się wymogów, dotyczących uwarunkowań środowiskowych, zarówno w zakresie prowadzenia działalności górniczej, jak i parametrów jakościowych produkowanego węgla, niezbędne jest opracowywanie i wdrażanie innowacyjnych rozwiązań dotyczących stosowanych technologii wydobywania, bezpieczeństwa robót prowadzonych w warunkach zwiększających się zagrożeń naturalnych, a także systemów zarządzania przedsiębiorstwem górniczym, pozwalających na jego efektywne funkcjonowanie. W treści artykułu do tej ostatniej grupy zagadnień odniesiono się najbardziej szczegółowo, zwłaszcza w zakresie możliwości racjonalnego obniżania kosztów prowadzonej eksploatacji.

Słowa kluczowe: nauka, przedsiębiorstwo górnicze, efektywność, koszty produkcji

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1. Introduction

In the conditions of strong competition, both in Poland and abroad, mining companies, if they want to maintain and stabilize their market position, have to adjust their strategies to the market requirements. They can take various actions in many areas, yet particularly important are efforts aimed at:

- maintaining high standards of work- and production-related safety,
- innovative technical and technological solutions of extraction, which include developing a model of modern coal mining,
- providing coal of proper quality,
- environmental protection.

Realisation of the aims is an indispensable condition of management, and in turn, of functioning of an enterprise. However, it is possible and justified to implement them only if profitability of mining production is maintained. The process of mining production means, first of all, selection of the right mining technology while maintaining work-related safety. However, if the mining activities are to make sense, it ought to be effective – the cost of production of coal has to be lower than its sales price (Fig. 1). Certainly, it can be decided to subsidize production, yet the presented considerations concern the current financial and legal conditions, which disallow such actions.

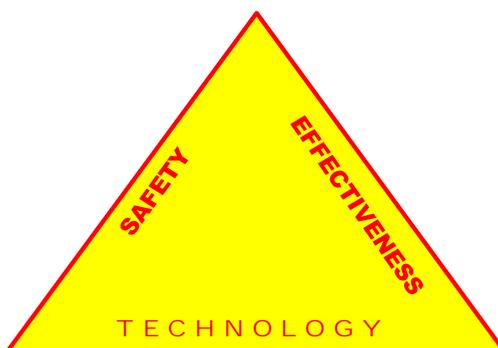


Fig. 1. Features of a model mining process

Actions aimed at ensuring competitiveness of a mining enterprise ought to be taken with support of the scientific community, as it is the only way to rationalise its activities associated with hard coal production in the complex and demanding environment. Hence, it is worth asking what the essential conditions of effective conduct of such activities are.

The process of coal mining requires constant modernisation of equipment and introducing innovative technologies determined by the conditions of deposits. In hard coal mining the changes occur both in the business environment, and in constantly deteriorating geological conditions. Mining operations are conducted in deeper and deeper deposits which, in turn, means an increase in the scale of natural hazards. Sole modernisation of equipment in mining enterprises and production lines is not enough. What is necessary are innovative mining technologies, modern warning

systems against hazards, and a system of managing an enterprise based on solid technical and economic knowledge.

In such shifting and dynamic conditions of the surrounding, identifying and assessing economic risk, as well as taking actions to minimise it, ought to be one of priorities of a mining enterprise. At present, in mining enterprises the risk is perceived, first of all, in the context of natural and technical hazards typical for hard coal mining industry (Jonek-Kowalska & Nawrocki, 2016). Such an approach is insufficient as the systems of risk management ought to consider sources of internal risk together with the factors of risk in near or far surrounding of an enterprise. Hence it is necessary to take actions aimed at changing the perception of the risk in Polish mining enterprises and implementing professionally prepared, advanced early warning and risk management systems like *Enterprise Risk Management* (ERM). It requires tight cooperation of researchers and management which will guarantee realisation of all the planned concepts and implementations.

Another group of changes occurring in the surrounding of the mining sector concerns more and more restrictive environmental protection requirements which follow the European Union's directives. The process of extraction has to be in line with strict legal mining regulations, and output processing technologies have to meet current ecological standards. In this context, proper planning and implementing actions associated with halting mining activities in unprofitable mining enterprises, together with reclaiming post-industrial areas (Jonek-Kowalska, 2014), is particularly important. The problem, as well as ongoing restructuring of hard coal mining industry, are still valid, from environmental, social and economic point of view.

Up till now the developed methods of eco-efficiency and sustainable development assessment of coal mines can be used by decision makers to assess coal mines from the perspective of those planning the strategy of development for the mining industry (Burchart-Korol et al., 2014; Czaplicka-Kolarz et al., 2015). To increase the environmental performance of coal mining processes, emissions of methane and consumption of electricity, heat and steel should be decreased. Reduction of methane emissions in coal mines can contribute to decreased greenhouse gas emissions. Apart from the three direct environmental aspects considered in environmental assessment in coal mines (drainage water, processing waste and methane emissions), the most important environmental aspects associated with coal mining operations are the indirect influence of electricity from the grid and the use of steel and heat (Burchart-Korol et al., 2016).

On one hand, the management strategy ought to guarantee an increase in effectiveness of production and a rational level of return on the invested capital (Michalak, 2014); on the other hand, it has to consider assumptions of sustainable development and maintain work-related safety indices (Michalak & Turek, 2011). The very specific nature of how mining enterprises function is a vast area for many branches of research. Without tight cooperation between the mining sector and experts and specialists in e.g. social sciences, law, mining, geodesy and transport, Earth sciences, chemistry, chemical technology, as well as process engineering and environmental protection, maintaining a competitive position on the hard coal market may turn out to be impossible (Dubiński & Turek, 2013).

With such a vast spectrum of issues, where research may play an important role, the presentation will focus on selected problems which concern improving effectiveness of mining enterprises and it is exactly what the publication is aimed at.

It has to be emphasised that, in the current situation of mining industry, proposals of introducing any changes resulting from research have to be subjected to economic evaluation.

2. Specific conditions and limitations to functioning of mining enterprises

Conditions in which mining enterprises function determine specific limitations – presented in a diagram in Figure 2 (Turek, 2014).

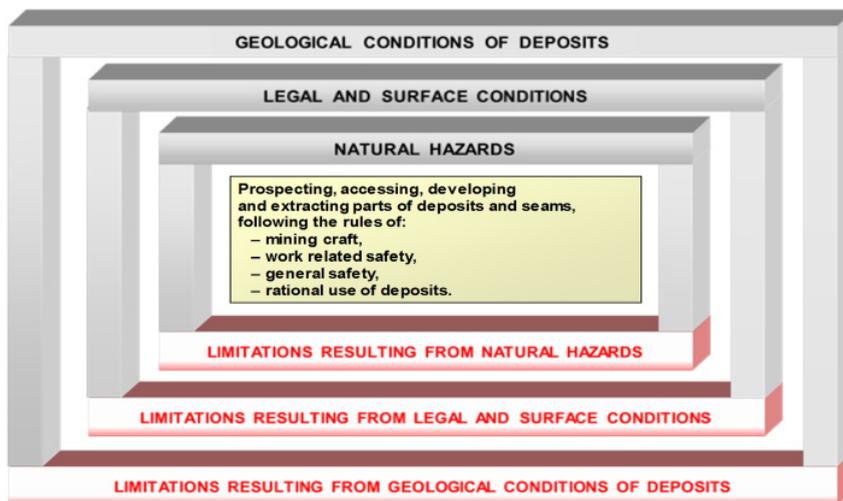


Fig. 2. Specific conditions and limitations to functioning of mining enterprise

Characteristics of functioning of mining enterprises is significantly different than a typical model of other enterprises operating on the market. It is a result of a few aspects inseparably associated with mining industry.

The very foundation of any mining activity are the mineral deposits. A mine or, in a broader context, a mining enterprises can function only in the places where there are deposits, i.e. such a natural mass of minerals and rocks as well as other substances; in solid, gaseous or liquid state (in form of seams or other agglomerations), which are the object of mining activities, which may generate economic profits. The assumption leads to other specific features associated with the deposit itself. They are:

- determined location – resulting from the place where a deposit occurs,
- non-renewability – associated with depleting a deposit,
- uncertainty concerning abundance, structure and conditions of a deposit.

Apart from the abovementioned specific qualities of activities associated with a deposit, it is possible to determine further ones, concerning investments and operations (Turek & Michalak, 2009). They are:

- very long investment period,
- very long period of operating (deposit extraction),
- differentiated conditions of conducting mining operations, resulting from changing geological and mining conditions of a deposit,

- low flexibility of the production process associated with lack of alternative production,
- constant migration of works,
- significant differentiation of extraction sub-processes associated with their concurrence,
- high capital intensity of investments and operations, of extra high level of fixed costs.

In Poland's conditions, referring particularly to hard coal mining, two additional factors ought to be taken into consideration. The first one results from the strategic role of mining industry in securing the Poland's energy safety. Activities of mining enterprises have to be correlated with the requirements specified by the government's programs concerning the State's broader energy policy. The other one is associated with economic performance of mining enterprises, most of which have low profitability and liquidity. Combined with the aforementioned high capital intensity, it makes it very difficult and expensive to obtain financing for investments and operations (Michalak & Nawrocki, 2015).

In the process aspect, where the structure of the process of hard coal production is defined as a system of sub-processes, activities and technological operations, realized in specified time and space, aimed at obtaining a product of proper quality parameters (Turek, 2013); another factor concerning specific qualities referring to conducting mining activities can be presented – concurrence (of realization) which does not only refer to given sub-processes, but also to various actions associated with:

- exploring a deposit,
- accessing and developing a deposit for mining,
- extracting minerals – throughout the lifecycle: equipping, exploiting, and closing workings,
- reclaiming land after mining operations, and environmental protection.

As the deposit is systematically depleted, the abovementioned actions are conducted throughout the lifecycle of a mine. To secure continuous production, it is necessary to explore, access and extract new deposits and seams. For the reasons associated with safety of operations in a mining enterprise it is necessary to conduct works aimed at closing mined-out workings (disassembling roadway support, backfilling, damming). They ought to be closed for economic reasons too – to avoid incurring costs associated with maintaining unnecessary workings.

Another specific condition of conducting mining operations, subject to various regulations, is the duty to follow so-called mining craft i.e. requirements associated with: personnel safety in underground workings (e.g. concerning works conducted under natural hazards), common safety (e.g. concerning prevention of catastrophic influence of mining activities on the surface infrastructure), and rational deposit management (e.g. concerning the order and method of mining operations in given seams).

The scope of implementation of the actions, which ought to be taken to maintain the competitive position of a mining enterprises, and surrounding conditions, in which they function, have the biggest influence on the obtained indices of its effectiveness (Fig. 3).

3. Rational management – result of business activities

One of the terms which belongs to the group of issues employed to describe management processes is effectiveness. Properly managed enterprises have high effectiveness which is evaluated with indices (relative values). The indices determine a ratio between costs and revenues which

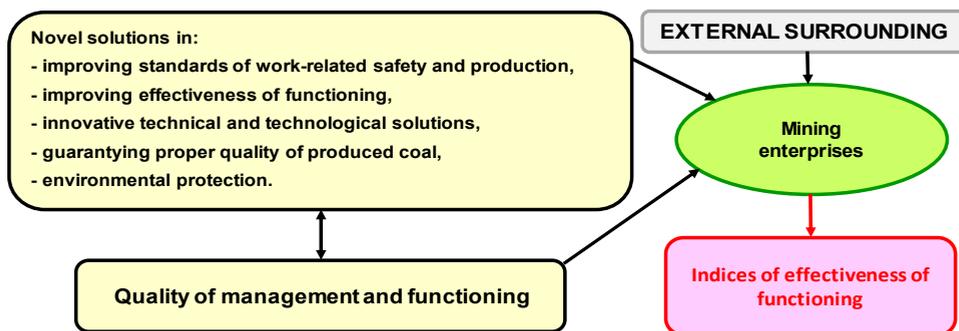


Fig. 3. Factors influencing effectiveness of mining enterprises

shows what result incurred expenditures generate. The obtained result is the effectiveness index also referred to as an efficiency ratio.

Depending on the objective, effectiveness indices are employed by enterprises in various areas. One of the key effectiveness indices is productivity, which can be expressed with various measures. Most often it is the ratio of produced / sold product, or the value of product sold over a given period of time (so-called product stream); and the amount of input resources used by the production system, as well as the amount of material, financial and immaterial resources (personnel) – e.g. number of employees, time of work (number of shifts / hours worked), costs of work (so-called stream of input of production resources).

Effectiveness is a universal category, yet its definition is not always precise and clear-cut. The term of effectiveness is tightly associated with the concept of rational management. The theory of rational management defines effectiveness of an enterprise through comparing outputs and inputs, as a result of business activity of an enterprise. Rational management considers in its theory both performance formula and savings formula (Fig. 4). Performance formula assumes obtaining maximum effects with determined fixed expenditures. Savings formula assumes obtaining given effects while minimizing incurred expenditures.

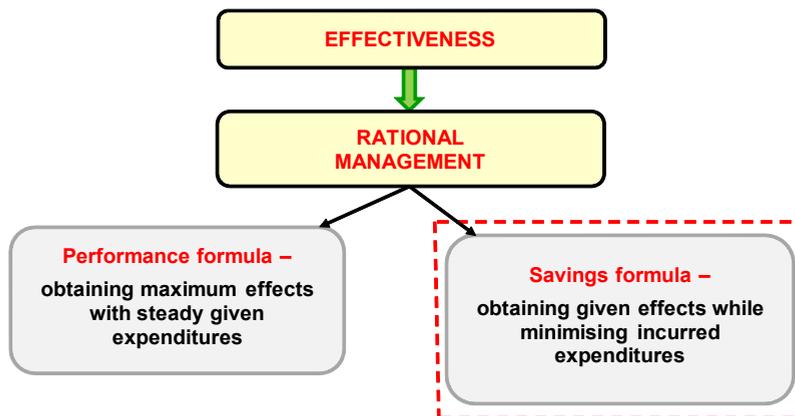


Fig. 4. Formulas determining rational management

Coal is a product (effect of functioning) of mining enterprises. It is possible to increase its volume (production), yet, following rational management, only as much of coal as can be sold ought to be produced. If the demand drops (as it is happening now), increasing the volume of produced coal may increase productivity with a certain level of financial input (costs), but has disastrous consequences if there are no customers for the product. To increase productivity, it is necessary to lower incurred expenditures. Hence, applying methods of operations management, it is necessary to find the right way to use own resources, which enables reaching the target profit.

4. Production costs in hard coal mining industry – tasks of science relating to possibility of lowering them

Figure 5 shows average structure of production costs by type in hard coal mining industry.

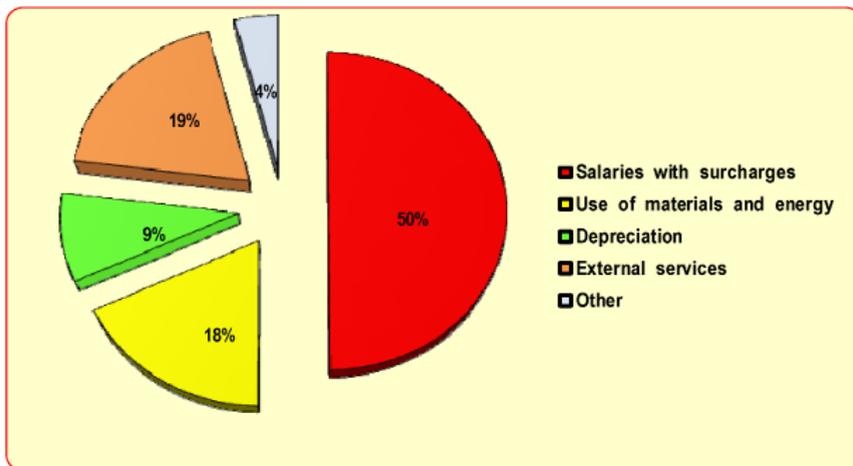


Fig. 5. Average structure of production costs by type in hard coal mining

Unfortunately, it has to be concluded, that analyses of values of production costs in the last ten years show a constant increase, even though the volume of production and employment are decreasing. As Figure 5 shows, costs of salaries with surcharges have the highest share and constitute approximately half of the production costs, often even 52-53%. Systematically increasing costs of salaries have the biggest influence on the increase in production costs. Moreover, there is another unfavourable aspect of such a situation – it is assumed that approximately 90% of the costs are fixed costs. It makes it significantly harder to manage costs and means that lowering the volume of production does not result in lowering unit cost of production. It has to be emphasised that, despite aforementioned characteristics of mining activities, 90% share of fixed costs in the production costs is not economically justified and results mainly from making a pro-social assumption of rigid salaries and a rigid level of employment (Jonek-Kowalska, 2015). In free-market economy conditions such an approach has no rational justification, as

costs of salaries are by nature variable costs, dependant on the volume of production, even in hard coal mining industry.

The next two positions with the biggest share in the production costs are costs of external services and costs of used energy and materials. It is noticeable that their shares are similar, of approximately 18-19% of total extraction costs.

Costs of depreciation are mostly about 9% of total costs.

Other costs by type, like taxes, fees and other costs, have the lowest share in the structure of production costs – about 4%. In recent years the costs have been significantly increasing, but due to their small share in the structure of total costs, they did not have a huge influence on resultant value. Nevertheless, it can be identified another possibility of scientific support for the mining sector, which can be the results of work in the field of economic sciences related to the financing of activities of the sector. For example, they could concern to the structure and method of financing, especially in the case of adverse conditions that result from changes in the external environment of the mining industry, including in particular, decrease in coal demand (Bąk, 2007; Bąk & Sierpińska-Sawicz, 2016; Sierpińska-Sawicz & Bąk, 2016).

The aforementioned pro-social approach to shaping costs in mining enterprises results in a systematic increase in the unit cost of production, which has been showing a systematically rising trend since 1990 (Fig. 6), despite substantially limited production (Fig. 7) and reduced employment (Fig. 8).

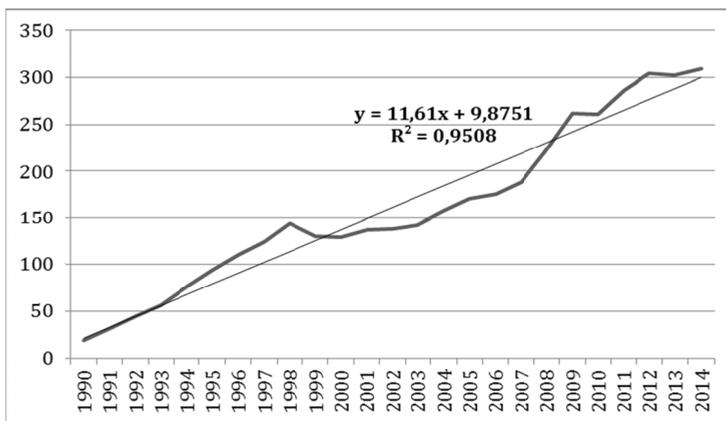


Fig. 6. Unit cost of mining, 1990-2014 [PLN/Mg]

Trends presented in Figures 6-8 are not economically justified and cannot be still maintained as they will deepen the crisis in the industry. Hence, it is necessary to take an immediate and effective action aimed at limiting the rate of how unit production costs grow and increasing price competitiveness of Polish coal both on the domestic and the foreign markets. Idle waiting for an increase in prices on the internal market and the world market, which could improve effectiveness on the revenue side, is a serious negligence and it only prolongs the period of continuous loss of profitability in most of the operating mining enterprises.

The scope of possible actions, supported with research, to lower costs of production, is presented in a diagram (Fig. 9).

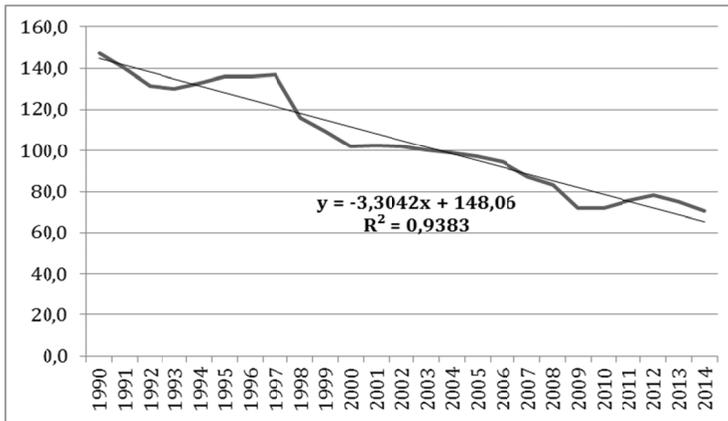


Fig. 7. Hard coal production in Poland, 1990-2014 [million Mg]

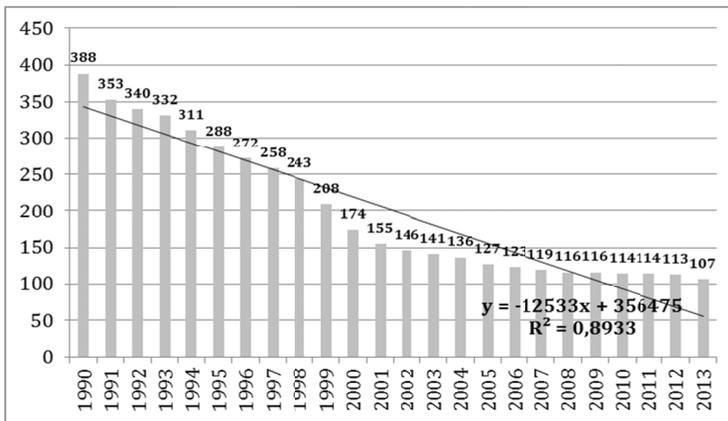


Fig. 8. Employment in hard coal mining in Poland, 1990-2014 [thousands of people]

The first task to solve with the use of scientific research ought to be lowering labour intensity of given technological operations, i.e. increasing productivity. In the best mining enterprises in the world, the share of labour cost in the production costs is 30%. In our conditions, in this very aspect, the key issue is to find ways to increase concentration of production with the use of the longwall system. Certainly, alternative methods of extraction are also an important challenge, provided they guarantee high productivity.

Another group of actions aimed at lowering production costs may be associated with lowering costs of use of materials. For example, if roof bolting was successfully implemented for use in roadways, it would lead to a significant reduction in the costs. Additionally, it would be associated with lowering labour intensity of development works. Then, the whole package of actions aimed at lowering material costs, both in the aspect of quantity and the costs of producing them, is available. Thus, it would be necessary to seek solutions within technology of conducting works, and new alternative materials which can be applied in underground workings.

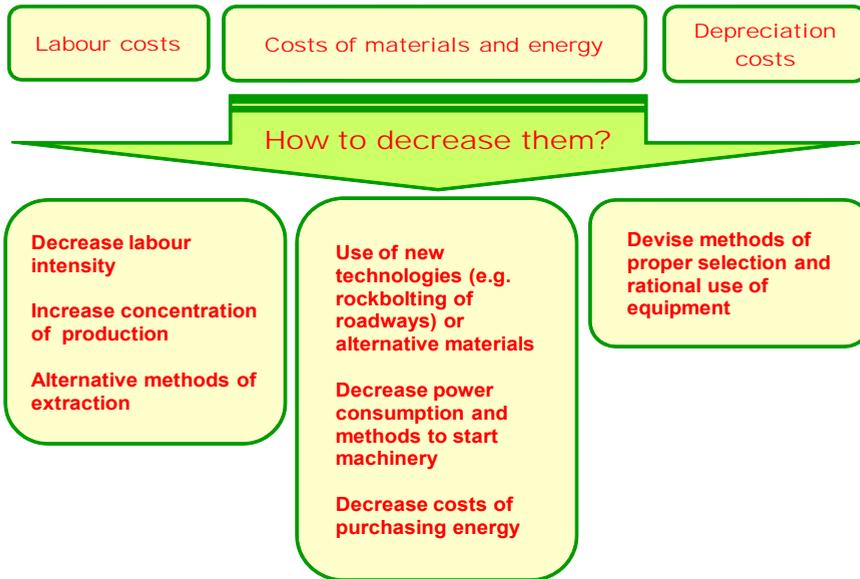


Fig. 9. Proposed actions lowering coal production costs which can employ results of research

The issue of costs of use of energy – there are possibilities to seek innovative solutions concerning both the amount of used energy, and the cost of purchasing energy. In many cases the solutions ought to concern lower power consumption, the methods to start various machinery, and possibilities of lowering costs of purchasing energy.

Finally, the issues associated with depreciation costs. Wrong selection, inappropriate use, irregularity of the production process, are the main causes of losses in spite of often very high expenditures on new machinery and equipment. Then, conducting research into proper selection and rational use of equipment is a serious challenge relating to rationalization and improving effectiveness of mining processes.

5. Effective functioning of mining enterprises – tasks of science relating to possibility of improving it

Tasks of science relating to improving effectiveness of functioning of a mining enterprise can be illustrated by the problem concerning the issues of devising a method to evaluate costs of their mining projects (Fig. 10).

Planning mining operations which are not aimed at the volume of production but on meticulously calculated economic effect has to play a significant role in the way how a mining enterprises' use own resources, which enables effective functioning of a mining enterprise. In a mine, and in a broader context, a mining enterprise, such a procedure can be conducted basing on the process system of cost management.

The planned volume of production, transformed into value aspect, and assortment and quality aspect, is associated with expected revenues from the sales and, after deduction of incurred

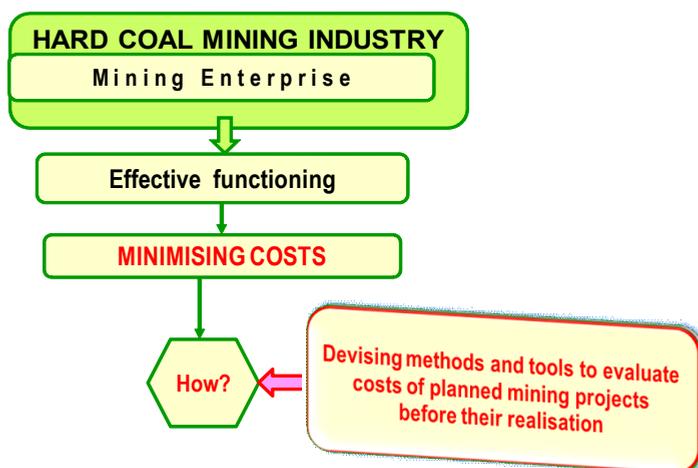


Fig. 10. Tasks of science relating to improving effectiveness of mining enterprise

costs, the profit is evaluated. The values are considered in economic plans of a mining enterprise, which, following the new approach to management ought to start playing a leading role. In the process approach to cost management, a situation that technical plans, which most often assume quantitative volume of production and sometimes qualitative aspect of coal, without paying attention to the issues of economic profitability of planned activities, is no longer acceptable.

The first stage would be including direct costs in the life cycle of an extraction working. Then, after adding indirect costs, following separately determined rules, it would be a starting point to determine unit costs of extraction and effectiveness (including productivity) of projects planned in a given deposit, seam or extraction working.

At present, in the systems filing costs which are used in mines there is a possibility of obtaining reports which group costs by type. It is then possible only to evaluate costs of extraction *ex post*, considering main stages of the life cycle of an extraction working. Following the concept of process cost management, a change in the approach is possible. Basing on technical projects, it is possible to determine costs with the calculation method, prior to taking a decision (*ex ante*), whether to start works to open a new extraction working. It will enable an individualized approach to every single working and processes associated with it.

In this very area it would be necessary to devise methods and tools to evaluate costs of planned mining projects prior to their realisation (*ex ante*), which would facilitate:

- automatic acquisition of value data concerning human resources and PP&E involved in mining production, basing on IT systems already used by hard coal mining industry,
- planning costs throughout the life cycle of an extraction working by teams preparing production, without unnecessary involvement of financial and accountancy personnel,
- providing consistent, transparent documentation of the production processes considering specifics and periodicity of mining production,
- approving cost accounting throughout the life cycle of an extraction working by the management and personnel of mining enterprises,
- as seamless as possible adapting the new solution and popularise its use among the personnel of hard coal mines.

6. Example of practical implementation of evaluating costs of planned mining projects

An example of implementing a method of evaluating costs of planned mining projects is presented in a diagram in Figure 11.

In the process approach to management it is necessary to ‘map’ processes, recognise their structure and elements. Following the rules of so-called mining craft and ‘indispensable data base’, created for a given enterprises (mine), each of them, especially the development processes (accessing a deposit, preparing a seam for mining operations), basic processes (mining seams, mechanical processing) and auxiliary ones (e.g. ventilation, fighting natural hazards, transport), ought to have specified conditions, in which it is realised, number of necessary operations

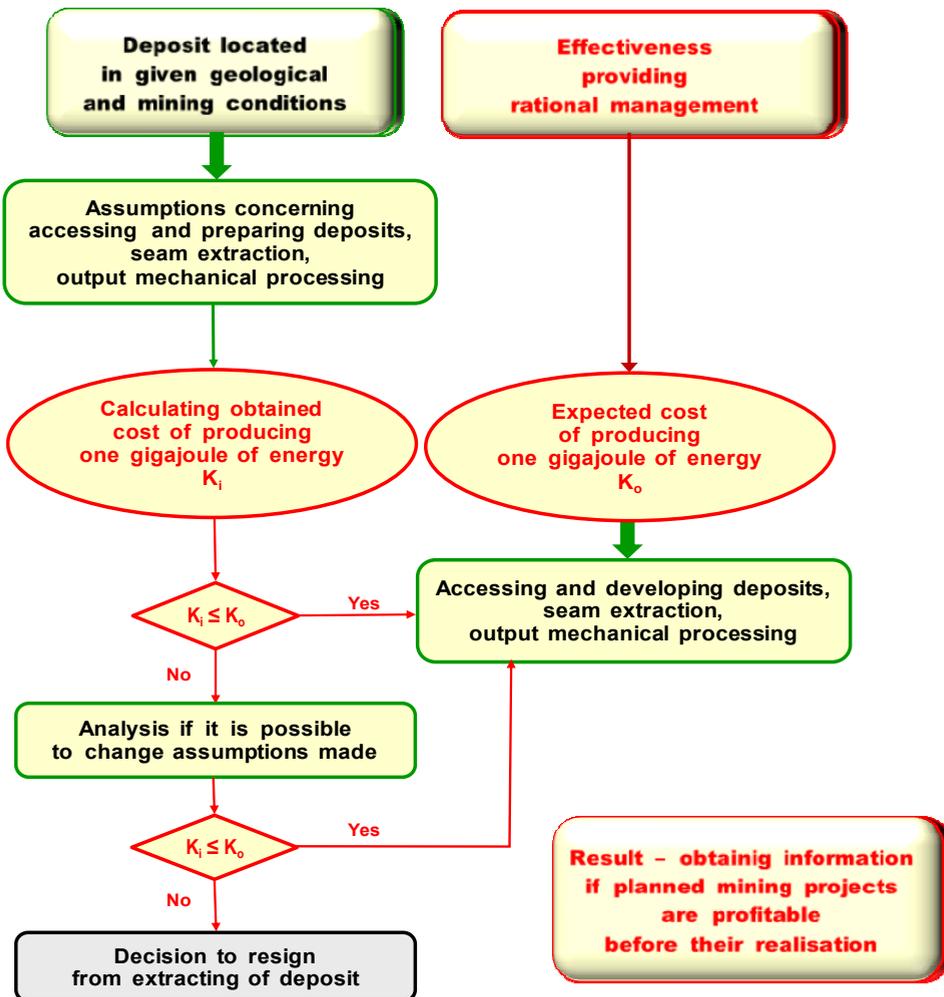


Fig. 11. Task of science relating to improving effectiveness of functioning of mining enterprise

and sub-operations, their sequences. Only on the basis of such data it is possible to plan how long they ought to last, the necessary number of personnel involved and the technical equipment, i.e. two values which mostly influence indices of obtained productivity and costs of producing coal.

As for direct costs, personnel responsible for preparing production processes in a mine, basing on their expertise, can easily prepare quantitative assumptions: necessary equipment, labour workload, use of supply media, which concern accessing a deposit, preparing a seam for mining, mining and mechanical processing of the mined output. The direct costs planning sheets can be filled in with the obtained values. Then, using proper IT tools, basing on data collected in financial and accountancy systems of enterprises and mines, they would be evaluated.

On the basis, also employing IT support, having considered indirect costs, the cost of production of one gigajoule of energy K_i can be easily determined. After comparing it with so-called expected cost of production of one gigajoule of energy K_o , which guarantees rationality of mining operations, effectiveness of planned mining projects can be assessed before any works start.

If the obtained result of the cost of planned production is not satisfactory, the software enables easy evaluation of changes in the cost through modifying assumptions made. If it turns out to be impossible to obtain satisfactory results which would secure profitability of the realised actions, then, on the very basis, without sustaining losses associated with failed mining projects, it will be possible to take a decision to withdraw from the project.

The presented concept of managing costs in mining, thanks to the ability to calculate effectiveness at each level of production, may be a starting point to develop a pro-effectiveness motivational system. Such a system is indispensable as it is necessary to lower the share of fixed costs in the total costs and adjust the level of salaries to the current economic situation and financial results of mining enterprises. Without radical changes in the area of the costs it will be impossible to lower unit production costs in hard coal mining.

7. Summary

Within the next few years there will not be any real alternative to coal as the main fuel. It means a serious chance of stability for hard coal mining. Yet, to use it properly it is necessary to take steps aimed at e.g. improving effectiveness of coal production and safety standards of work and production.

Basing on the presented proposals and examples, it may be concluded that all the actions; related to technical, technological and economic issues; ought to be taken in cooperation with the scientific community. They ought to concern the issues associated with possibilities to lower production costs. One of feasible solutions, which may bring significant results, is implementing the rules of process-oriented cost management. It ought to support developing proper methods and tools, including software, to evaluate costs of planned mining activities prior to their realisation.

It is the only way to optimize operations of a mining enterprises, in highly competitive conditions of the complex and demanding surrounding. Without tight cooperation of the mining industry with experts and specialists in various branches of science, maintaining the competitive position on the hard coal market, and even further functioning of the industry may turn out to be impossible.

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