

STANISŁAW PRUSEK**, MARIAN TUREK**,
JÓZEF DUBIŃSKI**, IZABELA JONEK-KOWALSKA**

INCREASING PRODUCTIVITY – A WAY TO IMPROVE EFFICIENCY OF OPERATIONAL MANAGEMENT IN HARD COAL MINES

WZROST PRODUKTYWNOŚCI – SPOSÓB NA POPRAWĘ SKUTECZNOŚCI ZARZĄDZANIA OPERATYWNEGO

The article contains considerations on possible actions directed at increasing productivity of hard coal mining industry. It is necessary to improve the state of the industry, and ensure its survival. Basic definitions and measures concerning productivity and management were presented to illustrate examples referring to a mining enterprise. Then, basing on organizing, one of the management functions, the issue of productivity in a mining enterprise and its influence on improving effectiveness of operational management, was analysed. An assumption was presented that solutions concerning identification of sources and volume of costs, hitherto existing in mining enterprises, ought to be complemented with the planning function following process approach. It can be the starting point for decisions of economic feasibility of given deposits, seams or parts of them, before mining operations start, and to control incurred costs in process approach. The article is summed up with a process algorithm of cost management.

Keywords: mining industry, costs, mining operations, productivity, operational management

Artykuł zawiera rozważania dotyczące możliwych działań ukierunkowanych na zwiększenie wydajności górnictwa węgla kamiennego. Aktualnie konieczne jest bowiem poprawienie stanu przemysłu górniczego i zapewnienie jego przetrwania. W artykule zaprezentowano zatem podstawowe metody i narzędzia umożliwiające zwiększenie wydajności i poprawę efektywności zarządzania operacyjnego w przedsiębiorstwie górniczym. Następnie, skoncentrowano się na organizacji jako jednej z kluczowych funkcji zarządzania i w tym kontekście rozpatrywano możliwości poprawy wydajności i efektywności. Przyjęto przy tym założenie, że istniejące rozwiązania dotyczące identyfikacji źródeł i wysokości kosztów produkcji górniczej, należy uzupełnić o narzędzia umożliwiające planowanie i rozliczanie kosztów w ujęciu procesowym. To z kolei powinno umożliwić podejmowanie decyzji o uruchomieniu kolejnych pokładów i wyrobisk przed rozpoczęciem wydobywania na podstawie racjonalnie prowadzonego rachunku

* SILESIAN UNIVERSITY OF TECHNOLOGY, FACULTY OF ORGANIZATION AND MANAGEMENT, 26 ROOSVELTA STR.,
41-800 ZABRZE, POLAND

** CENTRAL MINING INSTITUTE, 1 GWARKÓW SQ. 40-166 KATOWICE, POLAND

Corresponding author: izabela.jonek-kowalska@polsl.pl

ekonomicznego. W podsumowaniu artykułu zawarto algorytm postępowania dotyczący planowania kosztów produkcji górniczej.

Słowa kluczowe: przemysł górniczy, koszty, proces produkcji górniczej, produktywność, zarządzanie operacyjne

1. Introduction

For many years Poland's hard coal mining industry has been undergoing restructuring processes whose main aim remains increasing effectiveness of mining enterprises and coal mines. There are many reasons (geological and mining, technical, infrastructural, social and political) why the efforts have failed. Yet productivity improvement, while maintaining high work-related safety, is a top priority, as it is an indispensable condition if the industry is to survive and develop. The priority is even greater, considering postulates of decarbonising economy and intensively changing conditions of hard coal world markets, which we are experiencing nowadays.

In coal mining industry there is a buzz phrase "*Today it is not hard to excavate, but to sell what you excavated*". These simple words perfectly characterise the most important problem which mining enterprises are facing now, because you can sell, with profit, only what has a competitive cost [8]. The fundamental condition is effective functioning of a mining enterprise. One of the measures of effectiveness is productivity. The article deals with the issues of productivity and its links with the new approach to management processes, realized in a mining enterprise.

The article mainly contains theoretical considerations of a model nature. They are focused on improving productivity in terms of work efficiency and economic effectiveness. Therefore, the main objective of the conducted considerations is to identify and characterize management-mechanisms that enable the improvement of productivity in the Polish hard coal mining, while the research problem comes down to the following question: How to improve the productivity of Polish mining companies by using operational management tools in the natural conditions of underground hard coal mines? In order to solve a problem formulated this way, the article successively answers the following partial research problems:

- What is productivity and how is productivity expressed?
- How can effective management support productivity growth from a process and resource perspective?
- What specific boundary conditions should be taken into account by a mining company in the process of improving productivity?
- How do productivity changes affect total and unit costs in a mining company?
- How in practice did productivity in terms of efficiency and effectiveness change over time in Polish hard coal mining in market economy conditions?
- Are changes in operational management necessary in the context of changes in productivity in Polish hard coal mining?

2. Productivity

In market economy conditions there is no room for an enterprise, also a mining one, which functions "at all cost", ignoring the balance of revenue and expenditure associated with its operations. It has to be effective. Effectiveness of operations, as a universal category, which is not always

precisely and unambiguously defined, is assessed with indices (relative values), determining the ratio of costs to revenue and vice versa: effectiveness is the ratio of effects to expenditure in form of a number which shows what results are generated by expenditure incurred. The obtained result is the efficiency index. Depending on the purpose, efficiency indices can be used by enterprises in various areas. The key index is productivity (Bijańska, 2011).

Productivity, as one of measures of efficiency, is a commonly used concept, which can be expressed with various measures (Rybak, 2016). Most often it is the ratio of the amount of made / sold product, or the value of product sold within a given period (so-called product stream), to the amount of used tangible input resources of the production system:

- physical – e.g. amount and / or value of used materials, energy, fixed assets,
- financial – e.g. value of fixed or working capital involved in production (Bąk, 2007), and intangible (human) resources – e.g. number of employees, time of work (number of worked days / hours), costs of labour (so-called expenditure stream of production factors) (Rodríguez & Arias, 2008). Measures defined in such a way specify so-called partial productivity – materials, energy, fixed assets, capital, labour. In general (Durlik, 1993):

$$\text{Productivity "P"} = \frac{\text{Effects "E1"}}{\text{Expenditure "E2"}}$$

When the whole volume of product made / sold within a given period and the whole amount of used resources are considered, we can talk about total productivity. For such an approach factors in given streams have to be measured in the same units. Most often total productivity is expressed (Jonek-Kowalska, 2013):

- in monetary units – as the ratio of revenue to expenditure incurred on assets used,
- as the ratio of the amount of made / sold product to expenditure incurred on assets used.

Any index expressed in form of a quotient, where obtained production output is referred to the amount of used input resources of the production system, can become a partial productivity measure. For a coal mining enterprise, the effect is the amount of produced coal (Stoker et al., 2005). The applied mining systems, which consider deposit conditions within given mining areas and the need to provide work-related safety (first of all preventing natural hazards) and protecting the surface, ought to ensure (Fig. 1):

- possibly maximal surface protection,
- minimal losses of deposit,
- maximal profitability.

Examples of partial productivity measures with reference to a mining enterprise are presented in Table 1.

It has to be emphasised that total productivity most often considers all factors of production of an expenditure stream – technological level, skills of personnel, organization of an enterprise, changes in capital expenditure (Bijańska & Wodarski, 2017; Diana et al., 2015), relations in planning and organising a production process – thus providing a fuller picture of an enterprise. Partial productivity focuses on fragmentary scope, which may result in unfavourable consequences for an enterprise itself (Jonek-Kowalska, 2013). For instance, focusing on improving general or underground productivity may lower total productivity, e.g. by wasting effective time of work of expensive equipment in extraction workings.

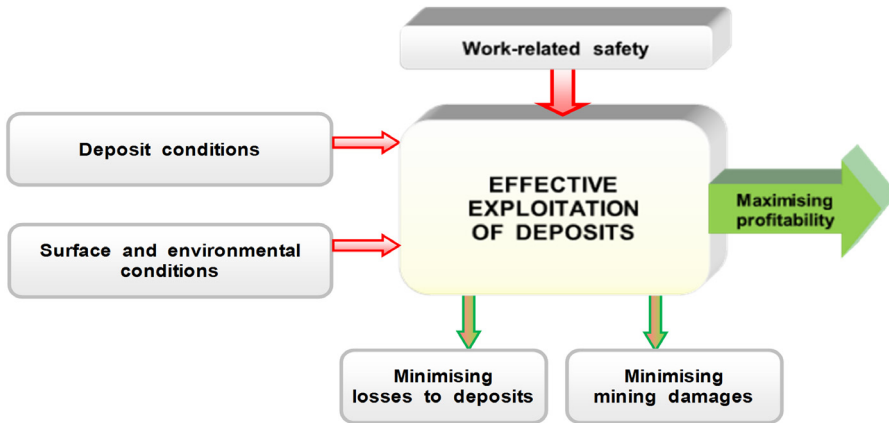


Fig. 1. Conditions and effects of productivity of a mining enterprise (Source: own study)

TABLE 1

Examples of partial productivity measures in a mining enterprise

Partial productivity measures	Example
Workforce productivity	Number of kilograms of coal to the number of worked working days of all the personnel (so-called general productivity, expressed in coal). Number of kilograms of run-of-mine coal to the number of worked working days of the underground personnel (so-called underground productivity, expressed in run-of-mine coal). Number of produced tons of coal to the number of all the personnel (so-called productivity per an employee). Value of sold coal (revenue) to the costs of remuneration with overheads of all the personnel. Value of sold coal (revenue) to the number of personnel / underground personnel.
Machine and equipment effectiveness	Number of tons of run-of-mine coal to the number of worked hours – most often referred to a given type of equipment, e.g. shearers, conveyors – so-called equipment effectiveness. Number of worked minutes per shift – so-called effective time of work in a working. Number of minutes of downtime due to a failure to the number of ton of run-of-mine coal – so-called failure index.
Energy productivity	Number of ton of run-of-mine coal / coal to the installed / used power – so-called energy productivity index.
Capital productivity	Number of produced / sold coal to the costs of used or employed resources. Revenue from the sales of coal to the costs of used or employed resources. Value of produced coal to the value of “frozen” materials and stock or fixed assets (buildings, structures, machines, equipment, installations, networks).
Mining face productivity	Number of produced tons of coal – in one longwall, per shift, day, month. Length of driven roadways – per one shearer, per shift, day, month.

Source: own study, based on [9].

Total productivity index is not used in hard coal mining. Instead, cost of production of one ton of coal or of one GJ of energy which can be produced from one ton of coal is determined. Due to significant differences in geological and mining conditions in given coal mines, there is no point in creating a “universal” index, which certainly would have to be “modified” in each mine to adjust it to its specific conditions. In mining enterprises and coal mines, productivity is usually considered partially, in the following aspects:

- effectiveness of current production to the amount of used resources of different categories, e.g. human resources, materials, energy,
- determination of current state, referred to what could be achieved as far as production and used resources are concerned,
- comparability of indices calculated to analyse a given coal mine with other ones,
- trends determining changes in productivity indices and their tendencies over time.

2. Management – definition and realization

There are many definitions of “management”, most often formulated by numerous researchers dealing with the problems of management. All of them, depending on their research area, emphasise different aspects. Yet all of the definitions derive from the most general one describing management as **art or practical and rational application of specific means, which enable reaching appointed aims with available resources.**

A more detailed definition was formulated by an American researcher R.W.Griffin: **management is a set of activities (organizing, planning, motivating, controlling), directed at an organization’s resources (human, financial, physical, informational), employed to realize its specified aims** (Turek, 2013). Within each of the sets of activities, called management functions, organization’s managers can employ specific methods and means to realize them. The functions cover the whole area of an organisation’s activities, which are interlinked and interdependent (Fig. 2).

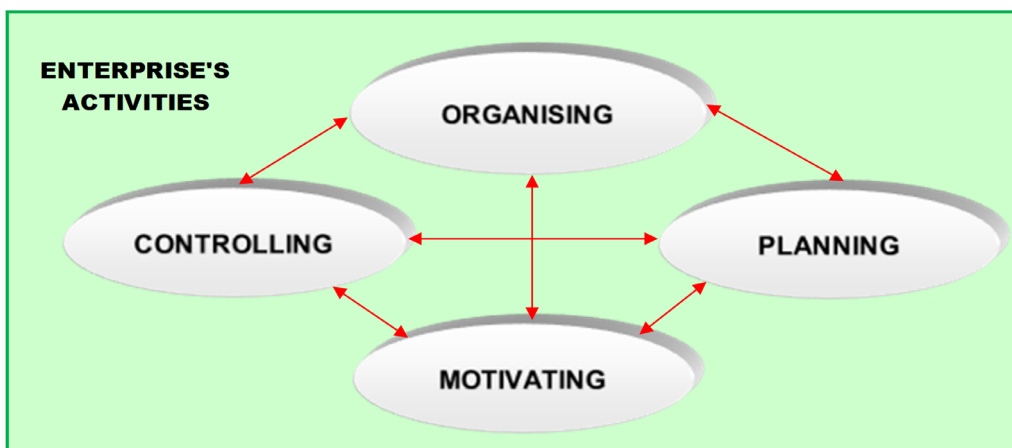


Fig. 2. Functions of management (Source: own study (Jonek-Kowalska, 2013))

An organization's sense of purpose is arranging participants' actions in such a way that it realizes its mission, obtaining desired results or realises its tasks with optimal use of its resources. Knowing that:

- any system capable of creating purposeful behaviour of a person or a group of people is an organisation,
- any component of an organisation capable of action is an organizational unit,

a mining enterprise (a coal mine or a group of coal mines) can be treated as an organization, and an incorporated individual coal mine as an organisational unit.

Development and effective functioning of an enterprise depend mainly on the quality of management (Jonek-Kowalska, 2013). A well-managed mining enterprise, even in rather unfavourable geological and mining parameters of deposits and rather unfavourable market conditions (sales possibility, price of coal), can function effectively. There are known various approaches to the issue of management. The most common ones are:

- general – an organization (enterprise) is considered as a whole, managed strategically through proper shaping of organizational structures and managing human and tangible resources,
- functional – deals with operations (production) realized by autonomous parts of an organization (enterprise), i.e. groups of people realising the same tasks (functions),
- process – all continuous and systematic actions which concern planning and monitoring realisation of a given process in an organization (enterprise) in such a way that its aims are realised. Process approach means identifying all the processes realized in an enterprise, determining mutual relations between the processes and managing them. Process management means constant monitoring and streamlining the processes through adjustments when the assumed results differ from the actual results.

In process management, a mining enterprise is no longer perceived through the prism of an organigram and its cells, but through the aims it realises.

Managing an enterprise can be considered a process itself – all the decision makers take actions which are interrelated and are directed at meeting desired aims. To enable process approach to the issue of enterprise management, the first step must be drawing a type of a map of partial processes realized in it – primary ones i.e. making the main product, and auxiliary ones.

In management, there is a concept of “operational management”. Without specialist definitions and descriptions, the easiest way to present the concept is to compare aims of “management” and “operational management”. Generally, management is directed at survival and development of an enterprise, through determining if, in the conditions it functions in, with specific resources of various types (which perhaps ought to be increased or decreased), it makes a proper amount of “proper” commercial product, which is sold and yields specific profits (doing the right things). Operational management deals with the issues of determining such a use of owned resources, so that it was possible to obtain assumed profit while making “proper” product (doing things in the right way) (Kosieradzka, 2004) (Fig. 3).

Another feature characterising operational management is the time horizon of problems it deals with. Operational problems concerning difficulties in generating expected profit (using owned resources), must be solved on the fly. Hence it should be realised at least once a year, and preferably even more often.

Functions of management (organizing, planning, coordinating, motivating and controlling), realized with proper means and directed at an organization's resources, ought to serve realisation

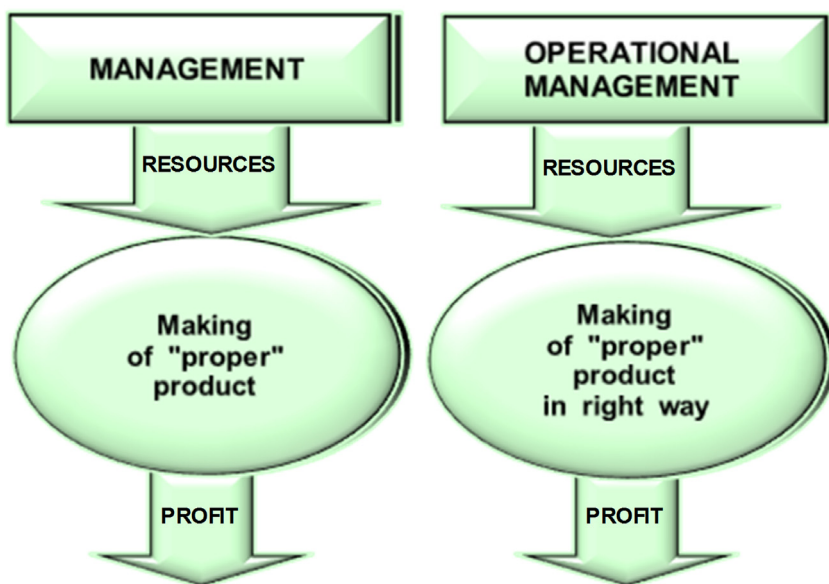


Fig. 3. Comparison of basic aims of management and operational management (Source: own study)

of the assumed aims (Michalak, 2014). Application of the general definition of management, referring to a mining enterprise, is presented schematically in Figure 4. However, it has to be remembered that for a mining enterprise, providing a satisfying level of work-related safety in underground workings is always a significant condition of its functioning.

Using as an example one of the functions of management, organizing, the issue of productivity in a mining enterprise and its influence on improving efficiency of operational management will be analysed.

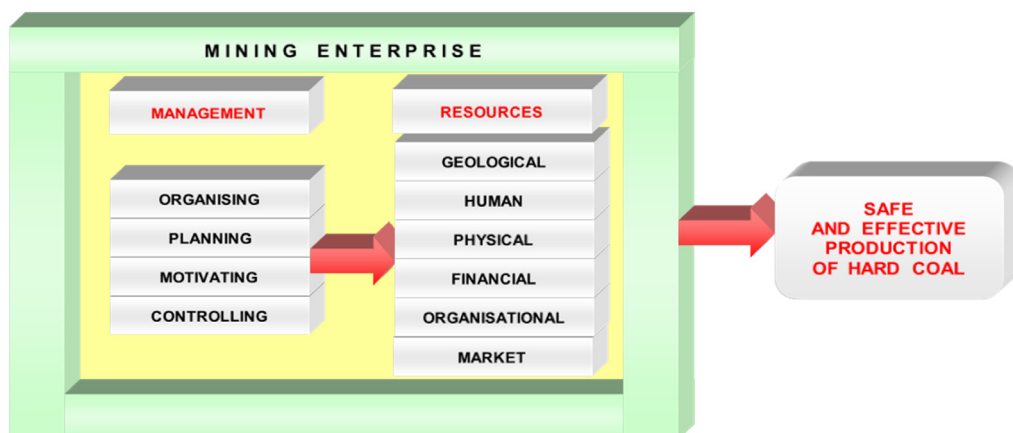


Fig. 4. Idea of managing a mining company (Source: own study)

3. Significance of organizing as one of the functions of management

Organizing is a set of various actions directed at reaching and keeping such a state of an enterprise that it could function following the assumed plans. It is optimal resource management, which will enable realization of specific plans (visions, missions, strategies), i.e. “making a proper product, in a proper way”.

The first step to do so is creating a certain type of “indispensable data base” characterising structures, resources and hitherto activities of an enterprise. In a coal mine (a mining enterprise), to organise and plan the volume of production properly, it is necessary to identify resources (geological, human, physical, financial, organisational, market) associated with productivity (Betz et al., 2015). The issue is important in two aspects (Bał, 2007, 2008).

The first one concerns geological resources, in conjunction with market conditions. Data concerning geological resources, together with “standard” information about a deposit (e.g. the volume of resources in given categories, parameters and conditions of seams, existing natural hazards and their scale) has to contain, as detailed as it is possible, information about the type of coal and its quality parameters (calorific value; sulfur, ash and moisture content) in given seams or their sections (Turek & Michalak, 2012). The information, correlated with the data on market conditions such as scale of demand and possibility of selling coal of given assortments and quality parameters, ought to be the very foundation for planning and taking decisions about commencing exploitation in a given seam or its section, as well as the volume of production. Proper management **must unconditionally follow the rule that only the seams whose coal is sellable are exploited and only in such a quantity that can be all sold**. In hitherto practice of mining enterprises there were many examples showing that even coal produced at low cost, with high productivity indices, which cannot be sold, does not bring any economic effects (Turek & Michalak, 2012).

The second aspect concerns other factors, considered from the following points of view:

- technical – in which it is determined if an enterprise (a coal mine) has proper spatial structure and technical equipment (machines and equipment, facilities, networks, installations) and proper number of personnel of specified qualifications to have technical possibility to plan required scope of mining operations, realized in safe conditions,
- economic – in which it is determined if an enterprise (a coal mine), of given employment (own and external personnel), spatial structure (vertical and horizontal mine workings), organizational system and owned tangible assets (or which have to be purchased), is able to conduct effective production, without incurring unnecessary costs, e.g. due to excessive employment or possession (maintaining) of unnecessary tangible assets (Wodarski, 2009).

Then, bearing in mind that each component of resources **means incurring costs associated with maintaining it**, a detailed analysis whether to keep them ought to be prepared. E.g.:

- in the spatial structure there must be maintained only such a number of development workings from the surface (shafts, ramps), levels, capital and production workings and which is necessary for safe realisation of planned mining works, and all the unnecessary ones ought to be closed (Michalak, 2013),
- as for technical equipment, the aim is to keep only the machines, equipment, facilities, networks and installations which are used in the production process, and their technical state ought to enable possibly the most reliable performance (Sun & Anwar, 2015),

- as for the scope of planned works and installing proper technical equipment, it is necessary to determine the number of necessary personnel, considering their required qualifications, analysing also possibility of using external companies' employees.

Here it ought to be mentioned that nowadays such analyses are already often conducted. True, they certainly are, but what has to change is the hitherto philosophy of the approach: only the components which are obviously unnecessary are made redundant, while keeping many which "may come in handy one day". It is forgotten that anything "left just in case" means certain, often significant, costs of overhauls, maintenance, power supply, depreciation allowances, taxes, employing extra personnel – which increase necessary expenditure, and as a consequence lower productivity (Michalak, 2016).

Next step of the function of organizing in management ought to be identification of sources and the volume of costs, dividing them into fixed and variable costs. Nowadays, in mining enterprises and coal mines, costs are considered basing on technical and economic plans (PT-E), applying various forms whose aim is to include and present costs by type. In cost accounting, total costs of production are divided into fixed ones and variable ones. They are separated by cost accounting of historical performance, basing on detailed, many-year-long theoretical studies and practical tests conducted by experts (Modak et al., 2017). Basing on statistical measures and available publications concerning relations between fixed and variable costs in the structure of costs by type, including remuneration with overheads, use of materials, depreciation, use of energy, external services, taxes and fees, and other costs, proportions between them are determined.

Such cost management in a mining enterprises means that information on incurred costs of production is useful mainly for the needs of bookkeeping and financial systems – as they use systematic cost accounts which enable, most of all, recording and allocating costs for tax and financial reporting purposes (Kosieradzka, 2004). Yet they are not very suitable for management accounting – it is impossible to plan costs with "zero based budgeting", which, due to the character of mining operations, ought to be applied. Budgeting costs is conducted basing on *ex post* cost analysis. The starting point for planning monthly costs is a yearly technical and economic plan, a result of historical analyses, sometimes with minimal adjustments, most often arbitrary, linked with current production targets and economic indices. With the system, it is impossible to assess cost-effectiveness of production *ex ante*. It also does not fulfil the controlling function as the control is conducted with reference to the plan, i.e. again by type, which does not give any ground to assess effectiveness of basic mining processes as costs of production in given extraction workings are not determined. Keys which enable planning and allocating indirect costs of underground and surface accompanying processes are not applied. As a result, the calculated unit cost of production is an ordinary quotient of total costs and the volume of production, and apart from benchmarking has no significant value for management processes in a mining enterprise or a coal mine.

The existing solutions concerning identification of sources and volume of costs ought to be complemented with functions of planning, following the process approach, basing on "zero based budgeting". It will be the starting point for decisions about commercial viability of given deposits, seams or sections of them, for controlling costs in process approach and e.g. preparing pro-effectiveness system of remuneration (Betz et al., 2015).

Process approach to cost management also provides base to assess effectiveness of given plans, and the whole mining enterprise. It is undoubtedly useful e.g. to determine the volume of:

- costs incurred to maintain the existing infrastructure of a coal mine (depreciation allowances, costs of maintenance and servicing),

- costs of materials, energy and overhauls incurred during production – which is important while determining the volume of expenditure that has to be incurred when economic viability of “creating” a new extraction working is assessed,
- costs of services provided by external companies – which is important while determining volume of expenditure associated with employing own and external personnel.

And finally, step three i.e. identification of process sources of productivity from the operational point of view (length, sequencing, continuity, systematicity, seasonality of production) and strategic (realization of replacement and development investments as well as use of organisational changes) (Mishra et al., 2013). To manage an enterprise properly, its actions must be well-planned – it is necessary to specify the program and sequence of tasks, works and actions, which are to be realised. It can be done well only if a detailed analysis is conducted of the course of actions making up given processes in the operational aspect of current production, which ought to be a task of operational management, and strategic aspect associated with investments i.e. future-oriented (Turek & Michalak, 2012).

4. Lowering costs of functioning of an enterprise – key condition to increase productivity

Hitherto considerations focused mainly on the issues of costs of functioning of a mining enterprise. A properly managed enterprise has high effectiveness of its operations, assessed with indices (relative values) determining the ratio of costs to revenue. The received numerical result shows the result generated by incurred expenditure. The obtained result is known as efficiency index. As it has been mentioned, one of them is productivity, i.e. a quotient of effects and expenditure incurred to obtain them. It leads to a simple conclusion: **the greater the obtained effect and/or lower the incurred expenditure, the greater productivity indices.**

Coal is the product (effect of operations) of a mining enterprise. It is possible to increase its volume (production), yet, proper management ought to mean that only the volume of coal which can be sold is planned for production. When demand decreases (as it is now) increasing the volume of coal production may improve productivity, of course at a given level of expenditure (costs), but could have disastrous consequences if it is impossible to sell it. If we want to increase productivity, **it is necessary to follow another possibility – lowering incurred expenditure.** It means finding “proper” way to use owned resources with operational management methods, which enables reaching the assumed profits.

Process approach to managing costs has a great potential. In the process approach to the issue of management it is necessary to draw “a map” of processes, recognise their structure and elements. Basing on the knowledge of rules of so-called “mining practice” and “indispensable data base” created for a given coal mine, each of processes, especially the primary and auxiliary ones, ought to have specific conditions in which it is realised, number of necessary operations and partial operations, their sequence of occurrence. Only basing on such information it is possible to plan properly their length and necessary personnel, i.e. the two factors, which have critical influence on indices of reached productivity and costs of coal production, ought to be determined with utmost diligence (Bijańska & Wodarski, 2017).

The planned volume of production, transformed into value approach and assortment and quality approach, is associated with expected sales revenue and, after deducting the incurred costs,

profit is assessed. The values are included in economic plans of a mining enterprise, which ought to start playing the leading role in the new approach to management. In the process approach to cost management, a situation when technical plans, which most often consider the volume of production and, alternatively, the quality of coal, without paying special attention to the issue of economic viability of planned activities, is not acceptable. When meeting the production targets is prioritised, which often determines personnel's salaries, the targets are often realised "at all costs", without considering economic consequences of such actions.

Planning mining operations which are not directed at the volume of production, but at its **carefully calculated economic effect**, must play a significant role. In a coal mine, and more broadly, in a mining enterprise, such a planning procedure can be conducted basing on the system of process cost management. Then, the first stage would be including direct costs in the life cycle of an extraction working. Then, after adding indirect costs, following separately established regulations, it would be the starting point to determine unit costs of production and effectiveness, including productivity, of mining operations planned in a given extraction working (Jonek-Kowalska, 2013).

As it has been already mentioned, currently, in cost accounting systems applied in coal mines, it is possible to get reports which group costs by type. Thus it is only possible to evaluate costs of production *ex post*, considering main stages of the life cycle of an extraction working. In the process concept of cost management, it is proposed to change such an approach basing on the developed technical projects, getting costs with the calculation method, **prior to making a decision** (*ex ante*) about commencing works aimed at opening a new extraction working. It enables a custom approach to each of mine working and processes associated with it (Fig. 5).

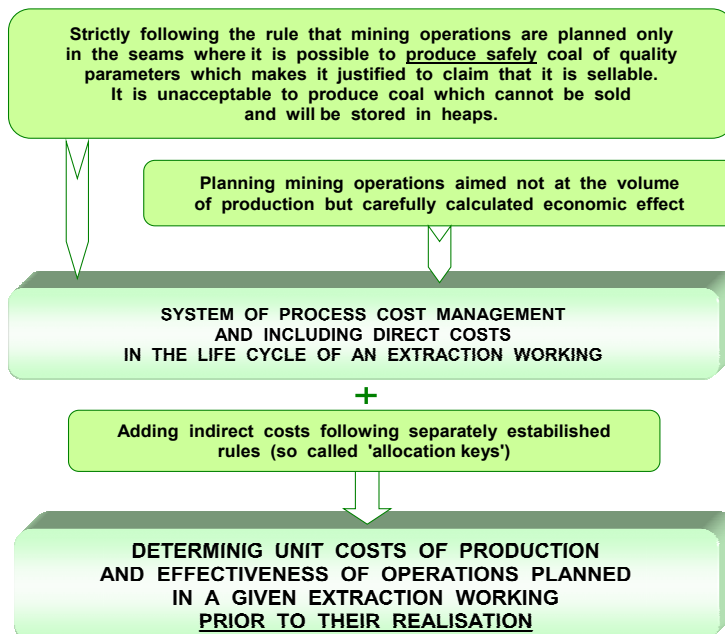


Fig. 5. Process algorithm of cost management (Source: own study)

5. Productivity in Polish hard coal mining – practical perspective

For many years Polish hard coal mining has been struggling with the problem of lack of economic effectiveness. In the initial period of the transformation, inefficiency resulted mainly from overgrowth of employment and low labour productivity. This is clearly confirmed by the data presented in diagram 1 and 2. In the years 1998-1999, 243 thousand and 207 thousand people were employed in Polish mines, respectively, with the lowest overall productivity in the analysed period and the lowest gross margin on sales. Between 2000 and 2007, during the restructuring process, employment was reduced by almost 89 thousand people, which allowed to significantly improve work efficiency and as a consequence to achieve positive financial results. It can therefore be concluded that in the years 1998-2007 the final efficiency of the sector was positively influenced by improvements in labour productivity (Turek, 2014; Wodarski et al., 2017).

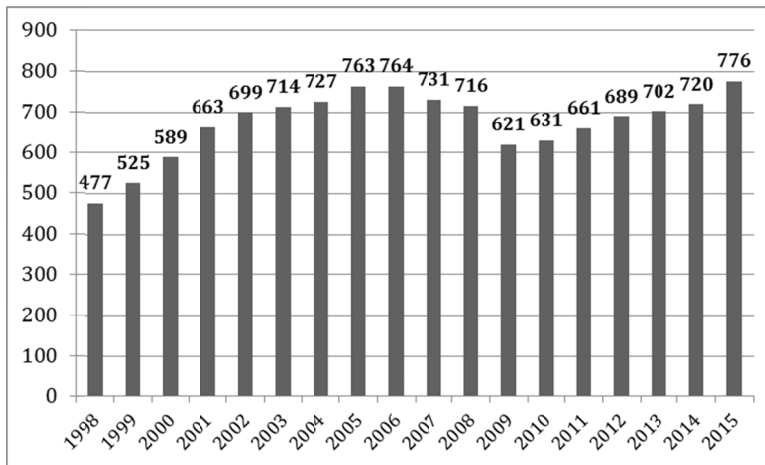


Diagram 1. General efficiency in Polish hard coal mining in the years 1998-2015 [in tonnes per 1 employee]
(Source: Own study based on data from the Ministry of Economy)

In 2008, the global economic crisis and the resulting reduction in electricity demand have a negative impact on the sharp drop in efficiency. This, in turn, reduces the demand for hard coal and causes the need to reduce output, which, with a stable and unreduced employment level, lowers labour productivity. Nevertheless, despite the decrease in labour productivity, in the years 2009-2012 the financial results of Polish hard coal mining are positive and the efficiency relatively high. This is a result of high prices of hard coal on the global market, which, despite decreasing efficiency and growing unit cost of extraction, allowed the sector to increase its financial profits. With prices plummeting and unit costs rising steadily, hard coal mining continues to generate losses again, which is reflected by a negative gross margin in the years 2012-2015. It can therefore be concluded that for the years 2008-2015, the financial results of hard coal mining are adversely affected not only by decreasing productivity but also by unfavourable and turbulent external conditions.

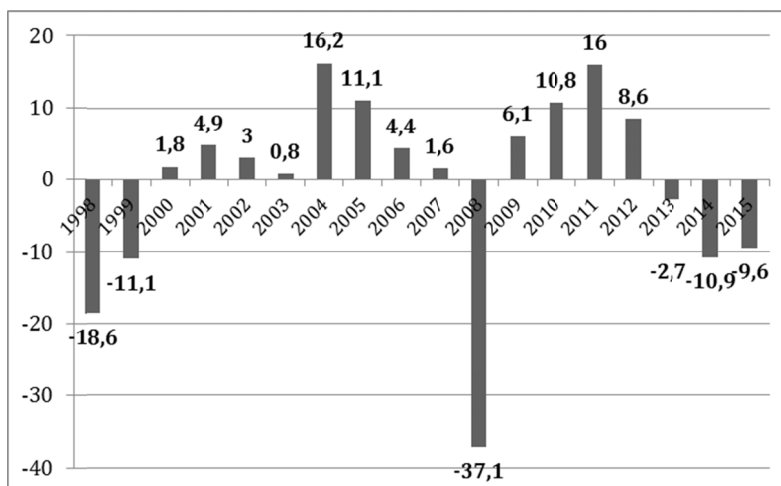


Diagram 2. Gross profit margin on sales in the Polish hard coal mining industry in the years 1998-2015 [in %]
 (Source: Own study based on data from the Ministry of Economy)

6. Summary

In the light of the considerations concerning the role of productivity in operational management of a mining enterprise, it is clear that in the current domestic and world coal market situation, to make it function effectively, lowering and rationalising costs must be a priority. Lowering costs, i.e. incurring expenditure, determines an increase in productivity – increasing production volume does not make any sense when the demand drops). Higher productivity gives more flexibility and improves efficiency of operational management, directed at determining conditions of coal production in a “proper” way.

Yet it should not come down to a statement like “*we don’t do something, we won’t incur costs*”. A new approach like process cost management enables formulating a conclusion that “*we don’t do something, because it isn’t cost-effective*”. And, most of all, it is possible to realise the fact prior to commencing works and incurring expenses associated with it. Well in advance, it is possible to assess economic viability of assumed technical enterprises, associated with opening an extraction working. By applying so-called calculation sheets and proper IT tools, it is easy to assess effectiveness of various variants of realization. Depending on current needs, it is possible to assess with a great degree of probability (Betz et al., 2015):

- basic indices of effectiveness, i.e. productivity, expressed with a quotient of revenue obtained from selling product stream (coal) and expenses – costs:
 - of used resources of expenditure stream of production factors (intangible – labour and tangible – materials, energy, fixed assets),
 - necessary to incur due to unfavourable influence on the surrounding, resulting from conducting mining operations (e.g. waste, mining damage),
- cost of production, expressed in PLN/GJ – in various variants of opening, exploiting and closing an extraction working – referred to the sales price and available revenue, it is then possible to determine if realization of planned enterprises is cost-effective.

The above summary, the conducted considerations and empirical data allow us to unequivocally respond to the main research problem presented at the beginning, i. e. the following: How to improve the productivity of Polish mining companies by using operational management tools in the natural conditions of underground hard coal mines? Referring to the partial problems we can conclude that:

- productivity in practice is most often expressed in terms of labour efficiency and economic effectiveness,
- effective operational management allows the level of resources to be adapted to existing production capacity and market demand,
- in operational management in the mining company, apart from universal conditions of productivity growth, consideration should also be given to the work safety of mining crews as well as geological and mining conditions describing the natural parameters of the deposit,
- in accordance with the results of the empirical analysis and theoretical considerations, lowering labour productivity adversely affects the unit production cost and consequently the efficiency of mining companies,
- in the Polish hard coal mining industry in the initial period of functioning in the market economy, the main reason for the deterioration of efficiency was low labour productivity, however in the years 2008-2015, apart from this factor, the negative situation of the sector was equally strongly influenced by the deteriorating economic situation on the global hard coal market and the drop in prices of this raw material.

In the light of the aforementioned facts, changes in operational management of mining companies with a view to improving productivity in terms of efficiency and effectiveness are still necessary. Further research in this area should be directed towards detailing the ways of productivity improvements and referencing them to particular resources and processes. It is also worthwhile in this respect to carry out in-depth practical analyses of cost-intensiveness in terms of resources and processes.

References

- Bąk P., 2007. *Characteristic of the capital gaining sources and financing the activity of coal mine enterprises. Part 1: Sources of the own capital*. *Gospodarka Surowcami Mineralnymi – Mineral Resource Management* **23**, 1, 93-108.
- Bąk P., 2008. *Financing of the investment activity based on the example of coal mining industry*. *Gospodarka Surowcami Mineralnymi – Mineral Resources Management* **24**, 3, 11-17.
- Bąk P., 2007. *Characteristic of the capital gaining sources and financing the activity of coal mine enterprises. Part 2: Sources of the own capital*. *Gospodarka Surowcami Mineralnymi – Mineral Resource Management* **23**, 1, 109-121.
- Betz M.R., Partridge M. D., Farren M., Lobao L., 2015. *Coal mining, economic development, and the natural resources curse*. *Energy Economics* **50**, 105-116.
- Bijańska J., 2011. *Finance and risk*. [W:] *Finance and risk*. 13th International Scientific Conference, Bratysława 2011. Bratysława: Vydateľstvo ECONOM, 231-241.
- Bijańska J., Wodarski K., 2014. *Risk management in the planning of development projects in the industrial enterprises*. *Metalurgia* **53**, 2, 276-278.
- Bijańska J., Wodarski K., 2017. *Defining a strategy of coal enterprises in crisis situation*. [W:] 4th BE-ci. International Conference on Business & Economics 2017, 05-07 June, 2017, Brno, Czech Republic. Ed. by: Zafer Bekirogullari, Melis Y. Minas & Roslind X. Thambusamy. Brno: Future Academy, 91-105.

- Diana C., Sorin M., Iirela I., Laura M., Sabina I., 2015. *Creating Competitive Advantage in Coal Mining Industry in Romania: A New Challenge*. *Procedia Economics and Finance* **23**, 428-433.
- Durlik I. 1993. *Inżynieria zarządzania. Strategia i projektowanie systemów produkcyjnych. Część I*. Agencja Wydawnicza Placet, Gdańsk.
- Jonek-Kowalska I. 2013. *Różne spojrzenia na efektywności w przedsiębiorstwie*. [W:] *Analiza i ocena kosztów w górnictwie węgla kamiennego w Polsce, w aspekcie poprawy efektywności wydobywania*, praca zbiorowa pod red. M. Turka, Wydawnictwo Difin S.A., Warszawa.
- Kosieradzka A. 2004. *Metoda wielokryterialnej oceny produktywności*. „Zarządzanie Przedsiębiorstwem”, Nr 2.
- Michalak A. 2014. *Conceptualization of the cost of capital in the theory of economy and contemporary economic sciences*. [W:] *Political Sciences Law, Finance Economics and Tourism, International Multidisciplinary Scientific Conferences on Social Sciences and Arts SGEM 2014, Conference Proceedings* **2**, Albena, Bulgaria, 115-120.
- Michalak A., 2013. *Problems of capital categorization in economic sciences and economic practice*. [w:] *Aktualne Problemy Podnikowej Sfery 2013*, S. Majtan (Ed.), Ekonomiczna Universita v Bratislave, Bratislava, Slovakia, 380-384.
- Michalak A., 2016. *Specific risk in hard coal mining industry in Poland*. [W:] *International Conference on Management: Trends of management in the contemporary society*, Brno, June 9th-10th 2016. Peer-reviewed conference proceedings. Ed. by Sylvie Formankova. Brno: Mendelova univerzita v Brne, 41-44.
- Mishra D.P., Sugla M., Singha P., 2013. *Productivity Improvement in Underground Coal Mines - A Case Study*. *Journal of Sustainable Mining* **12**, 3, 48-53.
- Modak M., Pathak K., Kanti K., 2017. *Ghosh Performance evaluation of outsourcing decision using a BSC and Fuzzy AHP approach: A case of the Indian coal mining organization*. *Resources Policy* **52**, 181-191.
- Rodríguez X. A., Arias C., 2008. *The effects of resource depletion on coal mining productivity*. *Energy Economics* **30**, 2, 397-408.
- Rybak A., 2016. *Possible strategies for hard coal mining in Poland as a result of production function analysis*. *Resources Policy* **50**, 27-33.
- Stoker T. M., Berndt E. R., Ellerman A. D., Schennach S., M., 2005. *Panel data analysis of U.S. coal productivity*. *Journal of Econometrics* **127**, 2, pp. 131-164.
- Sun S., Anwar S., 2015. *R&D status and the performance of domestic firms in China's coal mining industry*. *Energy Policy* **79**, 99-103.
- Sierpińska-Sawicz A., Bąk P. 2016. *Costs of corporate bond issues in coal mining companies*. *Contemporary Economics* **10**, 2, 99-111.
- Sierpińska M., Bąk P., 2013. *The role of corporate bonds in financing mining sector companies during an economic downturn*. *Gospodarka Surowcami Mineralnymi – Mineral Resource Management* **29**, 1, 141-155.
- Turek M. 2013. *System zarządzania kosztami w kopalni węgla kamiennego w cyklu istnienia wyrobiska wybierkowego*. Wydawnictwo Difin S.A., Warszawa.
- Turek M. 2014. *Produktywność – kluczowy czynnik funkcjonowania przedsiębiorstwa górnictwa*. Referat wygłoszony na konferencji Mechanizacja, Automatyzacja i Robotyzacja w Górnictwie, Ustroń, 11-13 czerwca 2014 roku. Materiał niepublikowany.
- Turek M., Michalak A., 2012. *A method of pricing an asset lost in a mining catastrophe*. *Archive of Mining Sciences* **57**, 3, 799-814.
- Wodarski K., 2009. *Strategic planning in Polish hard coal industry*. [w:] *Menedżment i pidpriemnictvo v Ukraini. Etapi stanovlennâ i problemy rozvitku*. Lwów, Ukraina, 536-543.
- Wodarski K., Bijańska J., Gumiński A., 2017. *The method of validity evaluation of hard coal excavation in residual seam parts*. *Archive of Mining Sciences* **62**, 4, 675-687.