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SOME ASPECTS OF USE OF THE SCENARIO METHOD FOR THE CONSTRUCTION OF A STRATEGIC PLAN OF THE HARD COAL SECTOR

Основна задача кожного підприємства – підвищення ефективності його діяльності. Цей принцип повністю можливо застосувати до вугільних підприємств, не дивлячись на те, що не завжди на це зорієнтовані державні органи і менеджмент цих підприємств. Вартість вугільного підприємства залежить від багатьох чинників, особливо від гірничо-геологічних і екологічних умов розробки, від вживаних технологій і економічних аспектів. Для пристосовування підприємств до оточуючих умов необхідна розробка стратегій ефективної роботи, для створення яких та їх оновлення вважаємо за доцільне використання методу сценаріїв.

Основная задача каждого предприятия – рост эффективности его деятельности. Этот принцип полностью применим к угольным предприятиям, несмотря на то, что не всегда на это сориентированы государственные органы и менеджмент этих предприятий. Стоимость угольного предприятия зависит от многих факторов, особенно от горно-геологических и экологических условий разработки, от применяемых технологий и экономических аспектов. Для адаптации предприятий к окружающим условиям необходима разработка стратегий эффективной работ, для создания которых и их обновления считаем целесообразным использование метод сценариев.

The primary goal of each enterprise - growth of efficiency of its activity. This principle is completely applicable to the coal enterprises in spite of the fact that not always the state bodies and management of these enterprises are focused on it. Cost of the coal enterprise depends on many factors, is especial from mining-geological and ecological conditions of development, from used technologies and economic aspects. Development of strategy is necessary for adaptation of the enterprises to surrounding conditions effective works for which creation and their updating the method of scripts is counted expedient use.

Introduction. There is no doubt that the basic objective of each enterprise is the growth of its value, especially from the viewpoint of the owner. This principle concerns also mining enterprises, in spite of the fact that not always this rule is perceived both by the “state treasury” and their managements. However, the functioning of mining enterprises should be assessed from the viewpoint of creation of their values, independently if we intend to sell them immediately or in the further future, if the subject of selling will be the entirety or part of the enterprise. The value of a mining enterprise depends on many factors, especially on occurrence conditions of deposits, in which extraction is conducted, on applied technologies or sensibility of economic factors on domestic and foreign markets. For the adaptation of enterprises to the surroundings conditions it is necessary to possess a strategy for the entire group of enterprises. For its construction and updating seems useful the scenario method.

The essence of such approach is the determination of a considered and compact series of events in dynamic changes of mining enterprises in the adopted time horizon (e.g. until 2020). The effect of this work should be the verbal description by help of qualitative features of the investigated system in the assumed time perspective. This description should be supplemented with numerical data, determined on the basis of prognostic models. Thus legitimate seems the assumption of the following procedure of investigation objective realisation:

1. completing, if it is possible, of a list of a event set in the initial state and events being possible in the assumed time horizon,
2. determination of probabilities of events and probabilities of the time of their occurrence, from the aspect of the adopted time horizon,
3. determination of interaction between the elements and system and the surroundings, i.e. changes of probabilities and time of occurrence of the given event in consequence of appearance of any of these events,
4. selection of the leading scenario, the so-called turning-point,
5. construction of the basic scenario,
6. construction of alternative scenarios,
7. assessment of scenarios on account of the possibility of their occurrence.

The realisation of the task, i.e. the construction of development scenarios of such complicated system, requires a great interdisciplinary research team and large group of experts, which will cooperate with the research team. Necessary is always a wide initial base of quantitative and qualitative data relating to the structure of the mining production process and conditions, in which mining enterprises are functioning.

Scope and way of scenario construction. The set of investigated information should contain data regarding the past and current situation of the entire branch and its components, as well as multi-variant predictions, constructed in the course of application of at least classic prediction methods.

The co-authors of the scenario must have at their disposal suitable calculation instruments in order to carry out manifold simulations, using prognostic models. The research team fulfils the role of cooperation coordinator with appointed expert groups for many partial research plots. In the course of many time organised sessions the team should univocally obtain the opinions of expert groups regarding the following problems:

- creation of the system's element list,
- determination of probability of events and time of their occurrence,
- determination of interaction between the elements and the system, and the surroundings,
- selection of the leading event.

The created expert groups have access to the package of programmes with different prediction techniques, collected by the data base team. The contacts of the research team with the group of experts take place in the course of conferences using the electronic post according to determined rules and defining of the way of opinion quantification. The agreed expert opinions are treated as the base to create scenarios through the research team. The initial version of the scenario constitutes the modified by expert opinions, initial scheme of quantitative connections of system elements in the period covered by the prediction. In the next step should originate the quantitatively presented scenarios grouping the conventional events as most probable and several versions of alternative scenarios. They should be assessed through a specially appointed group of experts, specialists of functioning of the whole branch. Their opinions about the presented future variants constitute some construction stage (describing) of verbal qualitative scenarios. At this stage the research team widens its composition by specialists from the sociology branch and specialists in the field of human behaviours. The question is to present the future state and such a manner, in which the human teams participating in the realisation will experience it in their present. The systems describe also the future of elements in a manner partially isolated in relation to other elements, i.e. illustrate the systems' future only partially. Thus it is necessary to join them in scenarios, in a logical chain of events that occur in the future. It is worth to bear in mind that not all problems of the present or past can be predicted and described in a numerical way. When constructing the scenario one should incorporate qualitative problems into quantitative predictions in order to obtain a full complete description of the investigated system in the future. We should not forget that the simple algebraic sum of elements is not the described system entity. All phenomena including technical and social ones create comprehensive systems subject to characteristic regularities, which cannot be concluded exclusively on the basis of knowledge about regularities ruled by their components. Each to day's partial prediction is the present in the future and is treated in the scenario as a decision, which the decision-maker takes in the future and which implies the course of subsequent decisions. These decisions, regarding for instance the production quantity or modernisation of technology, will require valuation through people who will take them. In order to correctly construct the scenario, a determined technique of its writing should be used, obeying the following rules:

- to obey the deduction principle, i.e. to formulate in turn the value system,
- aims, strategies and tactics. The detailed analysis of lower levels of the decision process in the microscale can be conducted after the accurate explanation of all elements and connections of the upper layers of the decision process,
- decidedly should dominate the verbal description of structural-dynamic system transformations and qualitative seizures. Into the text should be incorporated possibly only simple numerical specifications, as well as readable tables, diagrams or schemes,
- in the initial and alternative scenarios also the same sequence of topics and way of their presentation should be maintained,
- to use only one tense and mood, i.e. the scenario projection should be written in the future tense and indicative mood, and the scenario presenting the current state should be written in the indicative mood, but in the present tense,
- list of sources of numerical data, applied prognostic techniques and full set of calculation, obviously within the limits of the common sense, should constitute an annex to the scenario.

It should be stressed that the scenarios constructed in such a way must be additionally essentially assessed by experts. One should also formulate opinions on mutual implications between the state of the investigated system in the future and external conditions.

Unfortunately, the prognostic method of scenario construction is characterised by:

- high labour consumption, long realisation time, what is connected with considerable costs, a great, enormous research team, and continuously cooperating, necessary modern technical means,

- necessary, simultaneous application of many classic and non-classic prediction methods,
- high minuteness of detail in prognostic investigations, because the omission of some details can lead to their cumulation in the future, and their resultant to incorrect prognosis.

Methods applied in scenario construction. Qualitative prediction methods are based on the opinion of experts, i.e. persons invited to participation in investigations because of the possessed knowledge. For predictions constructed in the enterprise, experts can be either the employed workers, or persons cooperating with them or persons from the outside. The predictions constructed by experts usually have the form of point-related predictions, which are expressed in the form of one value of the predicted variable. They can also have the form of interval predictions, expressed in the form of a numerical interval, or variant predictions, expressed in the form of different values of the predicted variable. It takes place, that predictions are formulated by one expert, but more often by a group of experts, but then the prediction proceeding is based usually on the Delphi method, or brainstorming.

The Delphi method serves the prediction of the economic development technique of other areas of human activity. It is assessed as a very good one, some people affirm that this method is irreplaceable when constructing long-term plans. It should give very good results in the case of determination of the moment of anticipated event appearance. It is a method of inquiry based on closed questions, which require replies of numerical meaning. The arguments and counterarguments are limited only to quantification. The method refers to the opinion of experts, who work independently from the remaining ones. Inquiry tests are carried out several times. The results of each stage should be elaborated statistically. Aiming at the creation of a majority group, we reject extreme opinions, in order to obtain at the final stage the conformability falling on the distribution centre. Before starting the tests, the assumption should be adopted that:

- the given problem cannot be solved by help of other methods,
- the research team and experts have the full awareness and deep knowledge relating to the aim of use of the Delphi method.

It should be stressed that we use this method for better recognition of the future and improvement of decision taking conditions. When preparing the questionnaire, the following questions should be taken into consideration, which undoubtedly are connected with the basic problem:

- which substitute decision could be taken,
- which substitute problem could be introduced,
- what obstacles can appear,
- what reactions can come into being at the moment of questionnaire result announcement?

Among others replies to these questions have impact on the receipt of the group of experts, as well as preparation of questions for the subsequent stages of investigation conducting. The term expert is not univocally interpreted in the literature. I think that for the use of our investigations it should be understood in the most widest meaning. In our investigations as expert we will consider a person, who has been invited to participate in inquiry tests. The team conducting investigations performed the selection and applied to the person on account of his/her individuality, competences, wide contacts as well as scientific and professional achievements. About the effectiveness of investigations using this method can decide persons with an open relation to problems and turned towards the future. The questions in the questionnaire should be compact and lead to replies, which can be expressed numerically and independent on each other. The realisation of contents of one question should not influence the realisation of the contents of remaining questions. In many questions necessary is to introduce the parameter of time. The question and, as a matter of fact, their collection in the questionnaire, should be thoroughly considered and discussed in order to eliminate interferences between questions and to receive replies, which are really concentrated on the adopted objective. Therefore we assume to introduce tentative questionnaires, which will serve to check the correctness of the question set and detailed formulation of individual questions. The so-called tentative questionnaires will be realised by a small group of experts. The obtained results will facilitate the analysis of connections between questions and will verify the ways, which will lead to the determined aims. In the tests we assume the application of common and fragmentary questionnaires.

A common questionnaire serves the determination of for example the future in the field of coal preparation for energy purposes from the aspect of new technological solutions of energy generation. The aim will be rather the determination of the problem's panorama. The prepared questions should be fairly varied and differentiated. The phenomenon of mutual interference of questions in principle is not troublesome. An important problem in questionnaire construction is the impact of current scientific tendencies, technical knowledge on limitations or distortions that sometimes can appear, resulting from not identical in meaning formulations or specialist nomenclature. The fragmentary questionnaire will

serve to investigate the prediction in the part of the tested sphere. The questions are subject to mutual penetrations and resulting hence connections. Inconveniences and faults must be removed in the tentative questionnaire or at the latest in basic investigations.

Description of scenario construction. The statistical elaboration of results does not afford greater difficulties, however, it may require fairly high labour expenditures. This concerns both the group of experts and the organisational team. The investigation method is expensive and fairly long-lasting.

The Delphi method comprises the following research stages: (Fig. 1).

1. Preparation for survey conducting. After the initial elaboration of the questionnaire the tentative questionnaire should be carried out, which is designed to correct the set of questions and to check the real possibility of realisation and investigation aim.
2. Questionnaire I sending. The questionnaire I we send by electronic post to all experts being in the list. Also information should be attached regarding the aims and prognostic character of the

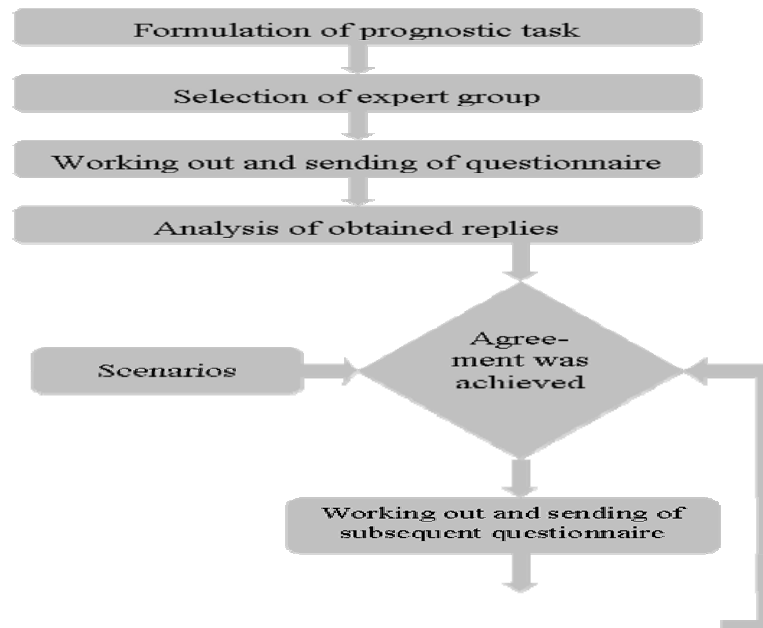


Figure 1 – Process of scenario construction when using the Delphi method

questionnaire, requiring a time-limit of 7 – 10 days for reply elaboration. The questionnaire can contain the experts' self-assessment. It is necessary to give the scale of assessments:

- 1 – very complete,
- 2 – complete,
- 3 – subject-oriented,
- 4 – poorly subject-oriented,
- 5 – incompetent.

It could seem that the experts' self-assessment is somewhat infantile, but practically it is difficult to imagine another way of proceeding. Moreover, it is difficult to imagine to put them through an examination, since they were acknowledged as experts and placed in the list.

1. Questionnaire I analysis. After receiving replies concerning the questionnaire I, they are verbally and statistically elaborated. After the elimination of extreme replies the distributions are constructed according to the statistical requirements.
2. Questionnaire II sending. We send the questionnaire to experts, attaching the statistical elaboration of questionnaire I and expert's replies included in this questionnaire.

The following possibilities should be taken into consideration:

- the first expert's reply is contained in the interquartile range and then we can expect that further expert's replies will be the confirmation of the first one, because it is improbable that he/she suddenly would like to change the mind.
- the first expert's reply lies beyond the interquartile range, if the expert maintains the reply he/she should be requested for explanation and justification. This results hence that from an expert

representing another opinion than the majority, not only the explanation, but also justification of his/her standpoint is demanded. The aim is to induce less courageous experts and those that have no strong arguments to join the group. The objective of this procedure is to separate extremists.

3. Analysis of questionnaire II. The data contained in the questionnaire II usually differ from results in questionnaire I with respect to reply dispersion.
4. Sending of questionnaire III. The basic task of this questionnaire (III) is the reduction of the number of extremists through the confrontation of their argumentation. When sending the questionnaire III we attach to it the results of questionnaire II analysis. The experts are obliged to refer to the opposed arguments or join the majority or justify their standpoint. Irrespectively of their decisions we demand from them to refer to different views and quoted counterarguments, which result from questionnaire II. In this procedure phase, what is characteristic for the Delphi method, very distinctly occurs the privilege of the majority of the expert group in relation to the extremists. The majority attacks, but must not justify its views, while the extremists fight for their position against each other or against the majority, and they must constantly argue and justify their opinions.
5. Analysis of questionnaire III. Investigations into the questionnaire III results and specification of results.
6. Sending of questionnaire IV. The sending of questionnaire IV and results of questionnaire III still more strengthens the standpoint of the group, and moreover it is aimed at the crystallisation of divergent views – decisions.
7. Final elaboration of results. The final results are presented in tables, which contain the averaging of specialists' assessment.

After obtaining the replies, we carry out the statistical analysis of experts' agreement (Dittman, 2003).

1. If experts' replies are expressed in the interval scale or quotient scale, then for conformability assessment the interquartile range can be used:

$$\Delta = Q_3 - Q_1 \quad (1)$$

where: Q_1 – bottom quartile (first),

Q_3 – top quartile (third)

The conformability of experts' opinions is considered as sufficient, when the interquartile of their replies does not exceed the previously determined threshold value Δ' ($\Delta \leq \Delta'$).

2. If the experts' replies are expressed in the nominal scale, then for conformability assessment the coefficient of dispersion of relative classification can be used:

$$h = \frac{k}{k-1} \left(1 - \sum_{j=1}^k f_j^2 \right) \quad 0 \leq h \leq 1 \quad (2)$$

where: h – number of categories of replies to questions,

f_j – frequency of j^{th} category occurrence as reply in the total number of replies.

The conformability of experts' opinions is considered as sufficient, when the value of the coefficient of dispersion of relative classification h is close to zero.

3. If the experts' replies are expressed in the ordinal scale, then for conformability assessment the coefficient of concordance can be used:

$$W = \frac{12S}{n^2(k^3 - k)} \quad 0 \leq W \leq 1 \quad (3)$$

where: $S = \sum_{j=1}^k \left(\sum_{i=1}^n x_{ij} - \bar{x} \right)^2$

$$\bar{x} = \frac{1}{k} \sum_{i=1}^n \sum_{j=1}^k x_{ij}$$

n – number of experts

k – number of reply categories in the question

x_{ij} – rank given to the j^{th} category of reply through the i^{th} expert

The conformity of experts' opinions is considered as sufficient, when the value of the coefficient of concordance is close to the unit.

The case of technological development of hard coal extraction technology. In the process of hard coal output and preparation many different technologies are used, which mutually penetrate, become complete or are functioning independently. For the identification of each technology and their description it was necessary to work out their systematics. The complexity of the production process in underground mining forces the introduction of a determined technology systematics resulting either from their spatial location in the mine's structure or inferiority in the framework of sequence (importance) of partial technologies. Otherwise, we can divide the technologies for example into technologies connected with underground operations or those on the surface. However, we should take into consideration that a number of technologies possess many applications in both areas of mining activity, thus it was legitimate to divide them into groups according to the criterion of importance in order to achieve the aim in the form of the final product, i.e. commercial coal. Such approach to the problems of mining technologies division to some extent in a natural way separates homogenous groups of mining technologies.

The adopted in investigations (Turek, 2008) systematics takes into consideration two principal aspects: the character of the technology itself or the sphere of its functioning. From this viewpoint the analysed technologies in the first approach were divided into:

- extraction technologies, from among of which were distinguished
 - mining technologies,
 - auxiliary mining technologies
- technologies of extraction mechanisation processes,
- technologies of system infrastructure, comprising
 - systems of automatics,
 - systems of informatics,
 - supply systems,
 - teletransmission systems
- coal mechanical preparation technologies.

In the second stage in the mining technology group technology sets comprising homogenous ranges of application were separated. These are:

- opening (first working) technologies,
- development technologies,
- extraction technologies.

In the group of auxiliary mining technologies were separated:

- transport technologies,
- ventilation technologies,
- water drainage technologies.

It has been also acknowledged that mechanisation technologies are functioning in the framework of mining technologies and there is no need for their more detailed systematics.

In Polish hard coal mines deposit opening took place by means of vertical shafts using the deposit structure, rarely mixed structure and this will remain so. However, deposit opening directly from the surface or existing levels is anticipated. The opening technology under the assumption of the deposit structure is characterised by short realisation time and low execution costs.

As the basic mining system will remain the longwall system in different variations, with distinct superiority of longitudinal and diagonal systems with roof caving. The development of this getting system will result from the necessity to adapt detailed solutions to more and more difficult geological and mining conditions. Important tasks should be connected with the safety level rise and production effectiveness, particularly:

- reliability improvement of production systems, especially individual equipment elements,
- modification of execution and improvement of conditions of gate roads maintenance,
- adaptation to the conditions of associated hazards, including rockburst, fire and methane hazards,
- improvement of remote systems of steering and automatics.

It results from the investigations carried out that longwall systems with high daily output (> 6000 t/d) using cutter-loaders will be solutions with high innovativeness level. Thus in the case of mining of horizontal and slightly inclined seams widely the highly efficient longwall system will be applied.

The intensity increase in the extraction of thin and thick seams (with seam thickness above 4.5 m) is anticipated. It should be stressed, what anyway is not revealing that according to experts' anticipations the extraction conditions of seams with medium thickness will be subject to worsening, mainly on account of the decrease of opened-up resources. Hence the extraction of remainders should be anticipated, where the application of longwall systems is not possible. Extraction according to predictions (Turek, 2008) will take place by means of short-front systems, including open-end methods.

In the light of realised investigations it should be stated that in the nearest time the return to the plough technique should follow. The conviction prevails that its quick development will follow especially also in the area of steering and automatics.

In the extraction of seams with medium thickness and high promotion of the cutter-loader technique state the following activities should be anticipated:

- introduction of remote electro-hydraulic steering with respect to powered support sets,
- introduction into the power transmission system of the scraper chain conveyor of a system of automatic initial tension regulation of the scraper chain,
- development of an integrated steering system of longwall machines and devices,
- introduction of automatic steering of powered support sets,
- development and introduction of an advanced system of technical diagnostics,
- application of the computer geotomography system in order to monitor the state of the rock mass tremor hazard,
- introduction of an integrated system of set protection against the dynamic impact of the rock mass.

The extraction of thick seams follows currently either using full thickness extraction or division of seam into layers in the extraction field. In the first case should be anticipated:

- introduction into the power transmission system of the scraper chain conveyor of a system of automatic initial tension regulation of the scraper chain,
- introduction of remote electro-hydraulic steering of powered support sets,
- introduction of an integrated steering system of the production process on the longwall.

Extraction using layers will force the introduction of the following solutions:

- to the power transmission system of the scraper chain conveyor of a system of automatic initial tension regulation of the scraper chain,
- remote electro-hydraulic steering of powered support sets.

The seam extraction by means of the sublevel caving method will require:

- introduction into the power transmission system of the scraper chain conveyor of the system of automatic initial tension regulation of the scraper chain,
- introduction of remote electro-hydraulic steering of powered support sets,
- introduction of the integrated steering of the mechanisation system with reference to the technological process of mechanical getting of the solid,
- introduction of an automated steering system of the process of coal getting from the underworked layer.

It should be stressed that longwall systems are directly connected not only with deposit opening operations, but first of all with development operations. From among the operations carried out in the framework of longwall field preparation for extraction we distinguish both development technologies as well as technologies including roadway and open-end systems (inclines, diagonal ventilation, transport, and water roads etc.)

The remainder deposits, localised within pillars and seam parts with irregular forms will gradually force the use of short-front systems, especially open-end systems (pillar – open-end) and roadway systems.

In the course of driving of roadway workings, commonly used are and will be in the anticipated future two basic technologies of roadway workings driving: heading machine technology – based on the use of heading machines, and blasting technology – in which rock mining will be realised using explosives. The main factor deciding about the selection of the driving technology will be rock properties in the cross-section of the driven working (including: workability type of occurrence and structure).

For the needs of the optimistic scenario from among existing getting technologies the two most innovative technologies were presented: getting by help of arm heading machines by means of the milling method and special heading machines using non-conventional getting techniques.

It should be anticipated that in the nearest time a number of changes in the construction and work technology of arm heading machines will be introduced, breaking the rock solid through milling. The

number of applied arm heading machines, getting punctually, of medium and heavy type will increase. This will concern mainly systems of remote steering of heading machine work, remote machine operating from the surface and communication with the machine from an optional place for monitoring and control of its technical conditions, steering of the direction of working driving using a technology similar to GPS or an alternative one. The introduction of a system of monitoring and communication for the automatic control of power absorption of the getting organ, machine element vibration, temperature of the system for the control of the profile of the driven working and systems for the invasionless determination of the type and properties of rocks as well as gas and water outburst hazards at the working's life (in terms of distance) of georadar type should be anticipated.

In the case of arm heading machines getting punctually in order to increase their effectiveness will be worked out, executed and applied in the first sequence self-propelled working platforms for roadway support transport and assembly, and next temporary, powered hydraulic roadway supports.

The above mentioned scenario of the mechanisation development of roadway working driving through getting using arm heading machines by means of the milling method constitutes an optimistic development variant. It should be expected that the driving of roadways, using heading machines by means of the milling method within the period until 2020 will be the most commonly applied method. To a greater extent will find application medium heading machines with installed power up to 350 kW. Heading machines with very developed systems of automatic and remote steering control of the driven profile, control of driving direction with the use of a technology similar to GPS will be most often used in mines characterised by very high hazard. Owing to the lack of possibilities of automation of the process of face steel-frame support setting, inexpedient will be to remove the steering station to the surface. Thus aiming at the maximum use of the heading machine's possibilities it is necessary to create the possibilities of simultaneous getting and support setting in the working.

On account of:

- the necessity of driving in the nearest future of a number of roadway workings in compact and very compact rocks,
- competitiveness of solutions of special heading machines in relation to currently applied heading machines,
- to necessity to use in new solutions advanced solutions with respect to the materials and technology.

It should be expected that in the nearest time numerous changes in the construction and work technology of both special heading machines using active tools and heading machines getting by means of the back cut method will be introduced. After the application of these changes (using active tools), these technologies can be successfully used in the Polish mining industry when opening new deposit parts.

The above mentioned scenario of mechanisation development of roadway working driving through getting using special heading machines which apply non-conventional getting techniques constitutes an optimistic development variant.

Summary. Because the strategy consists in the distribution of resources in order to achieve the aims of enterprises in the competitive market system, these resources must be in suitable proportions to the main objective. The resources of each enterprise consist in reality of human, physical and financial resources. The technologies applied by enterprises constitute its essential resources. The technology development strategies in mines are connected with the application and elaboration of new solutions in order to achieve maximum economic successes. In order to achieve competitive superiority, the strategy of technology development should be included in the general enterprise strategy. A very important aspect of technology strategy is the continuous use of appearing technologies. Therefore necessary is a well organised system of technology assessment. In the case of construction of the strategic plan of the hard coal sector, comprising a number of separate enterprises, it seems necessary to:

- recognise the basic technologies which exert influence on a greater number of enterprises and to consolidate them, ensuring them knowledge and personnel, creating conditions for independent action,
- ensure coordination of research work conducted through individual enterprise,
- implement new technologies through their purchase or realisation of joint undertakings,
- ensure dissemination of these results in all enterprises of the sector.

An important component of such activities was the realisation of the project entitled "Scenarios of technological development of the hard coal extractive industry", co-financed by the European Regional

Development Fund (Turek, 2008). This project was realised in the period 2006-2008 through a scientific consortium; its co-ordinator was the Central Mining Institute (GIG) in Katowice.

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