Risk Management in Coal-Mines – Methodical Proposal for Polish and Czech Hard Coal Mining Industry

Piotr Tworek[1], ***Seweryn Tchórzewski***[2] *and* ***Petr Valouch***[3]

Effective risk management in coal mining companies may be achieved by adopting an integrated approach, i.e. IERM, which allows them to manage their risk exposure in a complete and complementary way. Risk needs to be properly identified, before it may be estimated, and later responded to adequately. This is a prerequisite for effective risk management in coal mining companies conducting their activities in Poland and the Czech Republic, as well as other countries all over the world. In both countries, i.e. Poland and the Czech Republic, coal mines operate within the Upper Silesian Coal Basin, which means that their operating conditions are almost identical. It may then be possible to standardise risk management procedures and implement them in companies' operations. This may be ensured by using the integrated risk management formula, outlined in this paper. Therefore, the paper aims to give an overview of the risk management problems experienced by coal mines, with the focus on the integrated enterprise risk management (IERM) concept, as well as proposing that the concept should be implemented in coal mines operating in Poland and the Czech Republic. In particular, it proposes that the traditional approach to the risk management process, i.e. Enterprise Risk Management (ERM) should be modified and transformed into an integrated process. The paper uses the method of synthesis. It also contains a review of scientific literature on the subject.

Keywords: *hard coal mining industry, risk management, financial risk, measurement and risk evaluation, enterprise risk management*

Introduction

Risk management in the coal mining sector is an area of a wide range of scholarly discussions (Schneider and Spinel, 2002; Karbownik and Tchórzewski, 2004; Wodarski, 2009; Tchórzewski and Tworek, 2011; Badri et al., 2011; Vaněk et al., 2013; Galvin, 2017; Shuwei et al., 2017). At the same time, it shows high practical applicability, as adverse risk consequences may be successfully reduced in coal mine operations, although the specific character of the risks faced in this sector makes it impossible to predict all the hazards fully and thus manage the risks in their entire range. In particular, this refers to force majeure events, also known as acts of god, as it is not possible to predict all rock bursts or methane outflows, etc. In addition, coal mining is perceived as one of the most dangerous and most risky industries all over the world. A coal miner's profession (vocational risk) involves continuing hazards and safety threats, which are common not only in Poland and the Czech Republic, where the accident rates, including the number of fatal accidents, are still relatively low when compared to such countries as China (Wang et al., 2008). Irrespective of the types of hazards in coal mining activities, however, risks should always be managed effectively and efficiently. This will allow coal mining companies to limit potential losses, which tend to be enormous in case of such occurrences.

Risk in the hard coal industry in Poland and the Czech Republic is managed in a very similar manner. The industries in the two countries are largely comparable; due to the geographical proximity of the coal mine deposits they exploit (the Upper Silesian Coal Basin). In both countries, coal mining enterprises operate in almost identical industrial and macroeconomic conditions (Maruszewska et al., 2014), as the profitability of the mining sector is highly affected by coal prices on the global markets. These are macroeconomic risk factors, which remain beyond the control of coal mines. Apart from these factors, there are also microeconomic risk factors and the literature on the subject also refers to the division into endogenous and exogenous risk factors, as well as the ones which are case-specific (Tchórzewski and Tworek, 2011). The identification of risk sources for a given coal mining company is, therefore, a necessity for effective and efficient risk management. It should also be noted that if risk is to be appropriately managed, i.e. well defined first and then accurately estimated, providing the basis for appropriate risk responses, adequate knowledge of risk management process and methods as well as an ability to put this knowledge into practice, are necessary.

Currently, Polish and Czech coal mines are striving to manage their risks but they are not using any integrated formula for this purpose. Therefore, the paper aims to present the problems of risk management in coal mines, with the focus on the concept of integrated risk management (IERM), proposing, at the same time, that the formula should be implemented in business activities of coal mines operating in the two countries. This proposal may also be considered by coal mining enterprises in other counties worldwide, due to the universal

[1] *Piotr Tworek*, University of Economics in Katowice, 1 Maja 50 Street, 40-287 Katowice, Poland, piotr.tworek@ue.katowice.pl
[2] *Seweryn Tchórzewski,* Silesian University of Technology in Gliwice, Roosevelta 26 Street, 41-800 Zabrze, Poland, seweryn.tchorzewski@polsl.pl
[3] *Petr Valouch*, Masaryk University in Brno, Lipová 507/41a, 602 00 Brno, The Czech Republic, Petr.Valouch@econ.muni.cz

character of the recommended formula. In particular, the concept refers to the modification of the traditional risk management formula – Enterprise Risk Management (ERM) (Tworek, 2013) – and its transformation into Integrated Enterprise Risk Management (IERM), taking into account the specific nature of the coal mining sector. The authors' objectives also include the identification of risk categories, and the description of specific risks coal mines are exposed to in their operations. The nature of risk in the coal mining sector necessitates a different approach to risk management, when compared to companies operating in other industries. The paper, apart from theoretical and conceptual deliberations, presents the findings of the empirical research conducted in this respect in some Polish coal mining enterprises. In addition to induction, deduction and synthesis, the paper also provides a review of the literature on the subject and contains a comparative analysis. The authors draw on the knowledge and the experience they have gained from the scientific research – spanning over a number of years – into financial challenges faced by companies, including coal mines, as well as risk management processes and methods in finance, economics, management and technical sciences. They also use the expertise acquired in course of their professional careers, including the assignments they have worked on for mining enterprises. Some source materials (specialised reports) on the companies surveyed come from online resources. Risk is a cross-disciplinary category and risk management can be examined across many dimensions and in various areas, therefore the paper is written by an interdisciplinary team of authors.

Risk Categories in the Coal Mining Sector – an Attempt at a Synthetic Presentation of the Problem

Risk in the coal mining industry has its own unique profile, determined, first of all, by the type of operations carried out directly in coal that is located deep beneath the earth surface, which in turn leads to extraordinary hazards, such as rock bursts, coal dust explosions, methane outflows, life-threatening cave-ins, flooding of excavations etc. These are environmental risks and, as such, are not always possible to foresee. In particular, specific coal mining conditions are caused, first of all, by a limitation of the excavation environment, secondly, the prevailing geo-mechanical impact of rock mass on the environment and, thirdly, the intensification of technical equipment in the excavation area and, fourthly, limited forced ventilation of coal mines (Kapiesz, 2004). These are the basic determinants of risks which are specific to coal mining operations. Nevertheless, when identifying the risks facing the coal mining industry, one should not forget about a mechanism of risk, which is universal. Every coal mining risk has its own cause, i.e. a source of risk, leading to the occurrence of risk and, as a result, risk consequences. Negligence in relation to methane concentration measurement in coal mines, for example, and human errors are frequent causes of methane explosions, which may lead to fatalities. Therefore, management of safety hazards has become a priority, not only in Poland and the Czech Republic (Kapiesz, 2004), but also in the coal mining industries worldwide (Saleh and Cummings, 2011). Addressing this priority, OKD a. s. – the only coal mining company in the Czech Republic – has implemented a number of technical safeguards, such as continuous modernisation of communication devices, motion detection systems in excavations which are vulnerable to rock burst damage, state-of-the-art methane concentration measuring systems etc. (Czechy, 2017). Similar measures have been implemented by Polish coal mining enterprises, such as Jastrzębska Spółka Węglowa S.A. (JSW S.A.), Polska Grupa Górnicza z o.o. (PGG Sp. z o.o.), Kompania Węglowa S.A. (currently PGG Sp. z o.o.) and Katowicki Holding Węglowy S.A. (currently PGG Sp. z o.o.), and contributed to a significant improvement in accident rates. For instance, looking at the statistics as of 18 May 2015, the number of fatal accidents in the Polish coal mining industry was as low as 6 (Polska, 2017). Nevertheless, this industry is still perceived as a particularly hazardous sector, when it comes to a risk of accidents and resulting disabilities, and is often referred to as a risky industry. Therefore, the environmental risks combined with the safety hazards should be seen as the key risk categories in the coal mining industry. Apart from the two categories, which show the overall picture of industry risks (coal mining risks), attention should also be drawn to the risks related to mining processes, i.e. operational risks. The risks are connected with engineering and coal mining technologies (technical risk) deployed under the ground. These are the three key components of global risk in the coal mining industry. In their publications numerous authors share this idea, adding an investment risk, which should not be neglected as every new excavation site requires a significant amount of funds to be spent by a coal mine, and such investment always carries the risk of failure. The exploitation of a new deposit has to be economically effective. That is why, as a rule, investment processes in the coal mining sector involve the calculation of return on investment, on one hand, and an investment risk, on the other hand. A wide range of methods may be used to this end, such as return on investment accounting and risk management techniques, including risk simulation and real options (Hall and Nicholls, 2007). A particularly important method, which should be used in coal mining, is the method that takes into account the Risk-Adjusted Discount Rate (RADR), where a discount rate is adopted as a calculation rate in the Net Present Value (NPV) approach (Marcinek et al., 2010). The advantage it offers is the fact that project risk is also covered. The estimation is based on the general concept of a risk premium expected by an investor (in this case, a coal mining company) and a risk-free rate. When modified to be tailored it to the needs of investment activities carried out by coal mining companies, it may be assumed that – apart from a risk-free rate which expresses

the value of money over time and a rate which indicates an average premium for a risk of operations (assets involved) conducted by a coal mining undertaking the project – the calculation of the RADR needs to take into account another rate which represents an additional risk factor, which may be positive, negative or zero-value, and which expresses the difference between the risk taken up by the coal mining company in their business activities and the risk of the investment project in question (Marcinek et al., 2010). As a result, the RADR may be widely applicable in coal mining industries in Poland, the Czech Republic and other countries, as investment projects are inherently risky and the traditional formula of NPV clearly needs to be modified, i.e. by replacing the traditional discount rate calculated according to the Weighted Average Cost of Capital (WACC) method or the Capital Asset Pricing Model (CAPM), in form of NPV_{RADR}. Such an approach takes into account the dependency between the risk the coal mining company experiences in its operations as a whole and the risk of the given investment project. It can then be assumed that the RADR stands for the discount rate for which the NPV of the project undertaken by the coal mining enterprise equals 0, which should be seen as another dependency in this respect. Under this concept, the more risky the project, the higher value of the calculation (discount) rate should be accepted in calculations and vice versa. In general, the project should help the company to maximise its value. In Poland, such an approach is followed by, for example, Kombinat Górniczo-Hutniczy Miedzi (KGHM Polska Miedź S.A.) (KGHM, 2017). However, no matter how risk is adopted in investment activities and, further on, in operational or financial activities conducted by coal mining enterprises, risk is a common and dynamic phenomenon in the coal mining sector, which is likely to bring about losses and tends to cause pervasive and wide-ranging effects over time (Tworek, 2013). Besides, this definition of risk in the coal mining sector may also be completed by adding a political risk. The Polish coal mining industry is a very demanding sector in this respect. For illustrative purposes – at the turn of 2014/2015 in Poland a wave of protests swept through Upper Silesia die to a decision made by management boards of former KW S.A. (currently PGG Sp. z o.o.) and JSW S.A on restructuring processes to be launched in these companies (e.g. a closure of 4 coal mines belonging to KW S.A. 4 was planned, which would lead to around 20,000 workers being made redundant) (Polska, 2017). However, due to these social protests and the political pressure the decision was abandoned. Similar problems were encountered in 2016 and may be predicted to recur in the future. The situation in the Czech Republic is slightly different as trade unions in the Czech coal mining sector are much less privileged.

The major sources of risks in coal mining projects are presented in Fig. 1.

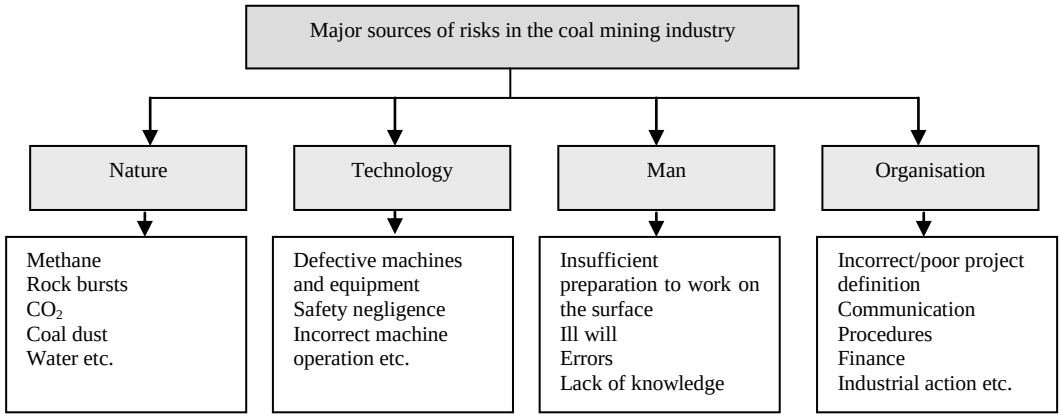

Fig. 1. Sources of risks in projects carried out in the hard coal industry (Karbownik and Tchórzewski, 2004; Wodarski, 2009).

Fig. 1 summarises and gives an overview of the key issues related to the specific character of risks in the hard coal industry. As can be seen in Fig. 1, there are a number of fractional reasons which may cause risks in the operations carried out by a coal mining enterprise. In particular, the organisational risk may be related to the workers' resistance against a decision about the coal mine closure, on one hand, and the social resistance against a radical restructuring programme, to be implemented in the coal mining sector, on the other hand (Karbownik, 2005). The risk factors listed in Fig. 1 can be divided into endogenous and exogenous ones, where an unpredictable exogenous risk means a lack of political will to carry out the consistent restructuring of coal mines (Poland), while a predictable exogenous risk means insufficient government funds for the coal mining restructuring programme, on one hand, and a fall in revenues generated by the coal mining companies, on the other hand (Karbownik, 2005). The general economic situation of the Polish coal mining industry is best reflected by the current financial standing of PGG Sp. z o.o., i.e. the largest mining group in Europe and, at the same time, the leading producer of hard coal in the European Union, which replaced troubled KW S.A. (insolvency risk) in 2016 (PGG, 2017). In the Czech coal mining sector, the situation looks much less disadvantageous due to higher effectiveness of management in OKD, a. s. and, generally, better developed organisational culture. The years 2017 and 2018 are expected to see similar trends both in the Polish and in

the Czech hard coal industries. The key reasons behind this are low coal prices at the world commodity exchanges, which reflect the unfavourable developments in the ARA (Amsterdam-Rotterdam-Antwerp) coal price index. Unlike Poland, the Czech Republic harnesses some other sources of energy (nuclear energy). In Poland, due to the political reasons, as well as some social resistance (the memories of the Chernobyl nuclear plant disaster in 1986 are still vivid), a nuclear plant has not been constructed yet. Coal mining is the main source of energy in Poland for the needs of heavy industry (iron and steel industry, metallurgy, electricity generation etc.).

The problem of risk in the operations of the Polish coal mining enterprises may be illustrated by the results of the empirical research conducted in the coal mines belonging to such groups as JSW S.A., PGG Sp. z o.o. (former KW S.A. and KHW S.A.). The key aim of the research was to identify the most frequent risk factors which occur in projects carried out in the coal mining sector. In course of the research, twenty-eight projects implemented in the coal mines of the companies listed above were thoroughly analysed. The projects surveyed were broken down into four groups: firstly, underground coal mining projects (infrastructure), which comprise the activities related to the components of infrastructure and are aimed at ensuring the smooth operation of the underground part of a coal mine, for example, construction or removal of a mining level, drainage, methane extraction, etc.; secondly, underground coal mining projects (production), which comprise the activities directly related to the mining capacity of the coal mine, such as wall reinforcement or closure; thirdly, on-the-surface projects (infrastructure), which comprise the activities related to the components of infrastructure and are aimed at ensuring the smooth operation of the on-the-surface part of the coal mine, for example, construction of a coalbed methane extraction station; and fourthly, on-the-surface projects (other), which comprise the activities related to the operation of the coal mine, focusing on supporting processes such as information sharing, sales network development etc. (Tchórzewski and Tworek, 2011). The research shows that the biggest group among all the projects surveyed and conducted by coal mines are underground coal mining ones (infrastructure) – 39 %, followed by underground coal mining projects (production) – 29 % (Tchórzewski and Tworek, 2011). This may come as no surprise as this is typical for the coal mining industry and geology, i.e. coal mining operations are linked to underground engineering projects (Badri et al., 2011). The projects are likely to be exposed to environmental risks (acts of god), which are mostly due to changeable geological conditions, insufficient investigation of the structure and load-bearing properties of rocks and soils (Schneider and Spinel, 2002). In as many as 14 projects, the coal mining environment (natural hazards) was indicated as a key risk factor in the operations of the coal mines under research, and this risk was experienced in case of every project under review (Tchórzewski and Tworek, 2011). Therefore, in the light of these results, it may be concluded that an unfavourable natural environment is a major risk factor in projects carried out by coal mines in Poland. As this risk is inherent in all coal mining projects, which has to be clearly emphasised, it can be presumed that it occurs in the Czech Republic in a similar way. In addition, the key risk factors include delays in project completion stages, a lack of appropriate project management experience, errors in technical documentation, as well as problems with the funding for the project. A detailed analysis shows that over 250 various risks were identified for the 28 projects surveyed and 35 of these risks could be classified as having at least significant impact on the project (Tchórzewski and Tworek, 2011). In particular, the most important observations made when reviewing the research findings include the following: first of all, the group of risk factors having at least significant impact on the project comprises 10 elements, which are indicated more than 5 times (such factors can be regarded as commonly present in projects); secondly, at the same time, it can be noticed that the factors placed under the umbrella term of „delays" are the most popular ones – 33 occurrences (the most frequently indicated reaction (risk response) to these risks is making allowances, when designing a project schedule, for possible delays; this means being aware that the schedule is too tight but also forced by external conditions not too leave much space for any adjustments in the action plan); thirdly, the risk factor number five is a lack of project management experience and competence on the part of Project Manager and the Project Team' (such a high position in the ranking means that managers working for coal mines are increasingly aware of project requirements and needs as well as the necessity to continue the development of their competence as well as the competence of their co-workers); fourthly, since coal mines work on a number of projects at the same time, they seem to be concerned about their access to funds for the projects, even the ones which can be regarded as strategic from the point of view of the company's operations (Tchórzewski and Tworek, 2011). It was also observed that there was a clear lack of any homogeneous system for risk analysis and evaluation, for the needs of similar projects implemented in the various coal mines surveyed. This has led to the fundamental conclusion that coal mines in Poland lack an integrated risk management system. An analysis of the operations and the organisational structure of the Czech company of OKD a.s. has led to the same conclusion.

The Concept of Integrated Risk Management in a Coal Mining Enterprise – Proposed Methodology

The implementation of the integrated risk management concept in Polish and Czech coal mining enterprises is bound to bring a number of advantages. Contrary to the traditional risk management concept of ERM

(Tworek, 2013), the integrated approach to risk management (IERM) – will enable coal mining companies to manage their risks in a comprehensive way and standardise risk management policies in all coal mines belonging to the coal mining groups. The ERM formula is applied in many industries all over the world, including Poland. The example given above, i.e. KGHM Polska Miedź S.A., one of the leading world producers of copper and refined silver, could be referred to again, where a common framework was implemented for risk management across the organisation, with the related principles outlined, in particular, in a document approved by the company's management board in 2013 – Corporate Risk Management Policy at KGHM Polska Miedź S.A. Capital Group (KGHM, 2017). It sets out the guidelines for risk management in the company and the goals defined in this area, such as: first of all, to ensure that shareholder value is created and protected by establishing a coherent approach to risk identification, evaluation and analysis and by implementing responses to key risks; secondly, to protect employees' lives and health, the natural environment and the reputation of the company's brand; thirdly, to support the achievement of business objectives by introducing tools for early warning of opportunities and threats; fourthly, to ensure strong support for decision-making at all levels across the organisation; fifthly, to build an organisation which is aware of risk to be taken and aims at continuous improvement (KGHM, 2017). However, the detailed analysis of the risk management policy and activities of KGHM Polska Miedź S.A. may lead to a critical opinion about the manner in which risks are handled by this company. First of all, risk management is not carried out as an integrated process. The company also fails to employ all the accessible risk management methods completely.

Due to the specific character of operations, the company size, the multitude of processes which are carried out in the coal mining sector and, first of all, the risks which such companies as JSW S.A., PGG Sp. z o.o., (former KW S.A. and KHW S.A.) and OKD a. s. face in their operations, an integrated risk management system (IERM) should be introduced at the central level in all these enterprises, based on an independent managerial function – a risk manager. The concept is presented in Fig. 2.

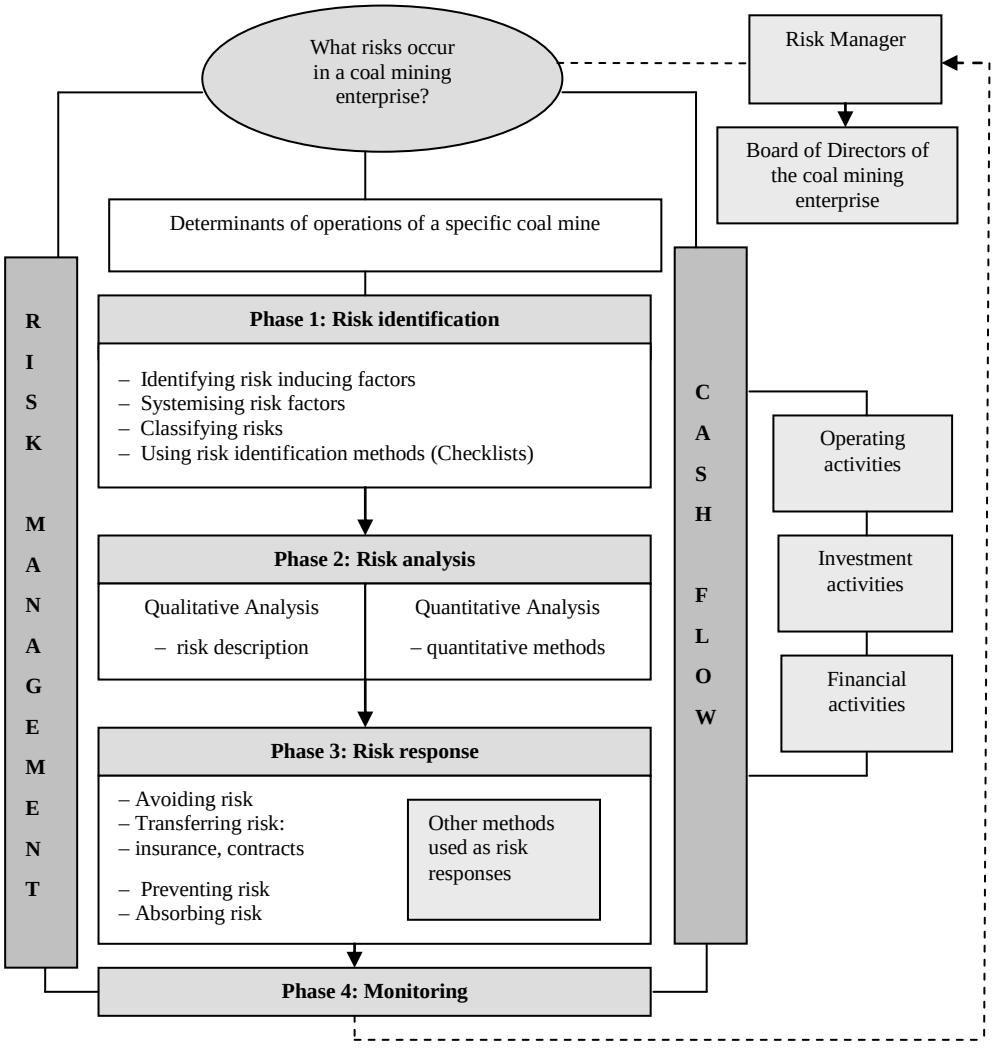

Fig. 2. An idea diagram of an integrated risk management system in a coal mining enterprise (Tworek, 2013).

Fig. 2 presents a four-phase process of risk management in a coal mining enterprise. In particular, phase 1 of the risk management process involves risk identification, with the use of appropriate methods, techniques and tools, in order to define the factors, which may lead to risks in a coal mine, and their division into specific risk categories (Fig. 1). It is recommended here that checklists should be widely used, as they are a fairly common tool in activities conducted by companies with different business profiles (Tworek, 2013). In practical terms, checklists are based on answers given to pre-agreed questions, i.e. specific types of risks are assigned to previously identified risk areas in a given coal mine, and then checklist questions are formulated, to be responded to by a risk manager (Tworek, 2013). This method is best suited for risk identification due to its strengths, and, first of all, the fact that – unlike probabilistic methods – it does not require any complicated computer software and, consequently, tends to be quite affordable. Its main advantage is high simplicity and ease of application in practice. The use of the method is recommended in international risk management standards, such as ERM standards, with ISO 31000:2009 (AS/NZS ISO, 2009) as the standard with the highest applicability (Tworek, 2010). In addition, ISO/IEC 31010:2009 standard shows the methods which should be employed in a risk estimation process (ISO/IEC, 2009). Taking into account the specific character of coal mining operations, the application of some methods indicated in the ISO standard, especially simulation ones, may prove to be particularly useful. The ISO/IEC 31010 standard makes reference to as many as 31 methods (ISO/IEC, 2009), among which special attention should be drawn to a stochastic simulation method of Monte Carlo, where risk is described by the distribution of probability (Rogowski, 2016), in line with the general definition of risk in science. However, this does not mean that other methods, indicated in the standard, cannot be used in coal mining enterprises. This refers, in particular, to other risk identification methods (phase 1), such as brainstorming, which is very popular and should be used in a complementary way, remembering, though, that industry-specific conditions tend to play an important role when identifying risk (Tworek and Valouch, 2011). When looking at the entire risk management process in a coal mining enterprise, risk identification appears to be of key importance as it provides the basis for risk analysis and evaluation (phase 2), utilising appropriate quantitative and qualitative methods (Fig. 2). Risk quantification is the most challenging stage in the risk management process, and this is particularly true when it comes to probabilistic methods. Currently, however, coal mining enterprises all over the world have a wide array of options here. The Monte Carlo method, for instance, when applied in the practical business context, can prevent numerous companies from making wrong investment decisions. This method has some advantages, which are highlighted by many authors in their publications on the topic including its applicability to the coal mining sector (Marcinek et al., 2010). This method may prove to be markedly useful when evaluating risk of projects conducted by coal mining enterprises, as the analysis of target variable distribution (investment profitability level) generated in the simulation allows us to look at specific parameters of the distribution in a detailed way and calculate the probability of an investment project being unfeasible, i.e. NPV < 0, meaning that the investment under consideration is bound to bear high risk (Rogowski, 2016). In order for the Monte Carlo simulation method to be used to analyse risk of a specific project, selected input data needs to be defined in a deterministic financial model, the aim of which is to calculate the NPV for the project, as referred to above (Rogowski, 2016). The literature points out to the fact that computer programs (Crystal Ball or @RISK) designed for Monte Carlo analysis enable the generation of thousands of cash flow alternatives (i.e. thousands of scenarios) and, as a result, thousands of project NPVs (Marcinek et al., 2010). Monte Carlo simulation provides data on numerous attributes, i.e. maximum loss, maximum and expected profit, although the distributions of possible NPVs as such do not show which project should be chosen, i.e. the investor has to know how to interpret the results (Marcinek et al., 2010). Every type of distribution which is adjusted to the given data may be used in probabilistic simulation, for example, preliminary metallurgical tests in a potential coal mine may show that the processing output could be expressed as normal distribution with the average value of 85 % and a standard deviation of 5 % (Marcinek et al., 2010). Also, a wide range of other probabilistic and statistical measurements proposed by science may be taken advantage of in risk simulation carried out for coal mining companies (Hall and Nicholls, 2007), which is referred to indirectly in ISO/IEC 31010 standard. At the same time, the standard focuses on quality analysis methods such as risk matrix, where specific types of risk are assigned specific likelihood of occurrence and, in addition to that, risk may be graded, ranging from very low, through low, moderate, high and very high (PMBOK, 2009). This may lead to better understanding of risk mechanism in the coal mining sector and, first of all, help to complete quantitative methods to make the results more reliable. The strengths offered by the method include, first of all, the fact that it enables a company to prioritise different project-related risks for further analysis or for coming up with adequate risk responses (phase 3) and secondly, it reflects the level of risk tolerance accepted by the coal mining company (ISO/IEC, 2009). Other methods indicated in ISO/IEC 31010 standard, such as sensitivity analysis, decision trees, HAZOP, FMEA etc., also demonstrate their applicability, although they can only be labelled as simple methods here (compared to simulation methods), with inflexibility being the main argument raised against their suitability. This deficiency, which may also be attributed to the discount method of NPV, is making

them increasingly unpopular in the coal mining sector, to the advantage of dynamic methods (risk simulation, real options), though they continue to be applied in business practice.

As presented in Fig. 2, the risk, once estimated, needs to be evaluated and responded to in the right way (phase 3). The most effective method in this respect seems to be insurance, which may be perceived as a separate method of risk financing in coal mining operations (Wang et al., 2008; Galvin, 2017). This method allows risk consequences to be transferred to an insurer. This is highlighted by ISO 31000 standard (AS/NZS ISO, 2009). In practical terms, Polish and Czech coal mines, as well as coal mining companies located in other countries all over the world, should opt for all risks insurance, to ensure comprehensive protection for their business, which is particularly relevant when dealing with investment processes in the coal mining sector. Currently, this appears to be the most effective financial instrument (Valouch et al., 2009) for preventing a coal mining company and a project undertaken by it from negative risk effects. The only downside here seems to be the high cost of insurance policies. All these actions, tasks and efforts, related to management, are subject to control and monitoring (phase 4) by a risk manager, who is then expected to report the status of risk management in their coal mining enterprise to the board of directors. This manager is required, in particular, to manage risks at the corporate level. It does not mean, however, that a risk management team – consisting of various subject matter experts and specialists, including engineers, lawyers, economists etc. – may not be appointed. In line with this concept, the appointed risk management team would have a separate scope of tasks and responsibilities, and would be responsible, first of all, for defining the scope of tasks and responsibilities related to their activities, in cooperation with the director/top level management of the coal mine; and secondly, for simplifying and reviewing risk management initiatives at the operational and strategic levels; thirdly, for reporting risk management initiatives and activities and their results; fourthly, for communicating the risk management issues; and fifthly, for reviewing the company's risk management policies on an annual basis, against the types of risks that need to be addressed (Ministry of RP, 2004). This team could be led by one person – the risk manager, who would bear overall responsibility for risk management in the enterprise, in front of the board of directors (Fig. 2).

The main advantage of the integrated risk management concept, as illustrated in Fig. 2, is its applicability in operations of all coal mines belonging to a mining enterprise. This will allow integrating risk management in all coal mines separately and then creating one integrated risk management system at the central corporate level. An essential part of the concept, however, is finding one common denominator for the coal mining enterprise, i.e. the value around which risks could be estimated. Net cash flows may be regarded as such a value, as every economic event, including the ones which are risk consequences, is reflected in the financial reporting of a coal mining enterprise (Tworek, 2013). The financial reporting data enable the identification of all the risky events which have occurred in the company's activities. After that, in order to estimate risk, two methods can be used complementarily. The first and most important one is Cash-Flow-at-Risk (*CFaR*) method, which shows risky cash flows in the coal mining company. Its formula is following:

$$P(CF \leq CF_0 - CFaR) = \alpha \tag{1}$$

where *CF* is a cash flow in a specific period, which is a random variable, *CFaR* is a risky cash flow, CF_0 means the planned cash flow in the analysed period, and α is the tolerance level (Jajuga, 2007). The second method – Earnings-at-Risk (*EaR*) – shows profits at risk in a company and can be described with the following formula:

$$P(E \leq E_0 - EaR) = \alpha, \tag{2}$$

where E means a net profit in the analysed period, which is a random variable, *EaR* is a net profit at risk, E_0 is the planned net profit in the analysed period, and α is the tolerance level (Jajuga, 2007). The methods are simply the expansion and modification of the Value-at-Risk (*VaR*) concept and their choice in order to estimate risk, as suggested in the paper, seems reasonable from the point of view of the subject matter and the methodology. This is also due to the fact that in science risk is perceived as a strictly quantitative category, which should be emphasised again (Knight, 1921).

Conclusion

Risk management in coal mining companies requires a systemic approach. Risks which are taken in the coal mining sector, including risk factors (Fig. 1), justify such an approach. What seems particularly important here are risk consequences, which may be painfully disastrous in this sector. To give some examples, in 2006 in Poland a methane explosion in Halemba coal mine caused the deaths of 26 miners. Also, 20 miners were killed and 35 injured in Wujek coal mine in 2009. These accidents belong to the most tragic disasters in the history of the Polish coal mining industry in the last 10 years.

Risk management in coal mining enterprises should not, therefore, be limited to the general concept of ERM, but it needs an integrated formula (Fig. 2). Integrated risk management means a holistic approach to risk

management, with the risk manager taking advantage of a full range of methods available in this respect (AS/NZS ISO, 2009). The methods used to identify and quantify risks, as well as the ones designed for risk management processes, should be applied in a complete and complementary way. Besides, a coal mining enterprise needs to find the common denominator around which risk should be estimated. The paper recommends that net cash flows may be used as such value (Tworek, 2013), since – according to the general concept of risk in science – all risk consequences have their financial implications (Valouch et al., 2009), i.e. losses incurred by coal mining enterprises. Summing up, it may be concluded that integrated risk management in a big coal mining enterprise with a modern management style means the following:

1. the enterprise has clearly identified who is to handle and bear the responsibility for risk management;
2. the risk management is carried out in all the dimensions in which the enterprise operates and applies to all the coal mines included in this group;
3. a complete range of methods are used to manage risks, with the focus on the CFaR method proposed in the paper;
4. the risk management supports the overall risk management process in the coal mining enterprise;
5. the risk management carried out by risk managers also refers to competitors (other coal mining enterprises) and, in particular, takes into consideration the macroeconomic, systemic and industry-specific determinants;
6. the risk management is carried out in an on-going and reliable way, and it is analysed as a process;
7. an effective risk management process mitigates the risk experienced by the entity in its operational and strategic activities, i.e. contributes to the creation of its value (Tworek, 2013).

Only such a formula will allow the achievement of risk management goals, which include, on one hand, maximisation of the enterprise value and, on the other hand, mitigation of losses that are now incurred by Polish and Czech enterprises due to risks. This conclusion is equally pertinent to coal mining enterprises worldwide, keeping it in mind that methodical aspects are of key importance, since incorrect selection of risk identification methods, coupled with insufficient knowledge of their applications, may lead to wrong evaluation (quantification) of risk and the failure to take into account all the risk factors a given coal mining enterprise is exposed to. Consequently, inadequate risk responses may be chosen. Another vital issue is the knowledge of strengths and weaknesses presented by specific risk management methods. Here, the attention should be drawn to the relevance of some solutions offered in the risk management standards mentioned in the paper, such as, in particular, ISO/IEC 31010 standard, which is highly applicable and is especially recommended to production companies. When using the solutions outlined in the paper, note should be taken of the fact that the concept illustrated in Fig. 2, has a prominent advantage i.e. high flexibility of application. One has also to remember that every coal mining company all over the world is different in some respects and, as a result, risk management processes will naturally vary from case to case. Therefore, the method ought to be tailored to the needs of the coal mining company where it is going to be employed. The implementation of the solutions suggested in the paper is bound to bring tangible benefits to numerous coal mining enterprises in Poland, the Czech Republic and other countries, such as, for example, the generation of additional savings for a corporate group as insurers tend to reduce insurance premiums for production companies that have put in place an integrated risk management (IERM) system in their operations.

References

AS/NZS ISO, 2009: ISO 31000:2009: Risk Management – Principles and Guidelines, *Standards Australia and Council New Zealand, Sydney-Wellington.*

Badri A., Nadeau S., Gbodossou A. (2011) Integration of OHS into Risk Management in an Open-Pit Mining Project in Quebec (Canada), *Minerals, 1, pp. 3-29.*

Czechy, (2017) Bezpieczniej w kopalniach OKD, *[online], [cit. 2017-06-28].* http://www.nettg.pl/news/100482/czechy-bezpieczniej-w-kopalniach-okd

Galvin J. (2017) Critical role of risk management in ground engineering and opportunities for improvement, *International Journal of Mining Science and Technology, 19 May, 2017, pp. 1-7.* https://doi.org/10.1016/j.ijmst.2017.07.005

Hall J., Nicholls S. (2007) Valuation of mining project using option pricing techniques, *The Finsia Journal of Applied Finance, 4, pp. 22-25.*

ISO/IEC, 2009: 31010:2009: Risk Management – Risk Assessment Techniques, *International Organization for Standardization (ISO), IEC, Geneva.*

Jajuga K.(2007) Zarządzanie ryzykiem, *PWN, Warszawa, p. 383.*

Kapiesz J. (2004) Zagrożenia skojarzone a ocena ryzyka zawodowego, *Wiadomości Górnicze, 4, p. 183.*

Karbownik A. (2005) Zarządzanie ryzykiem w projekcie restrukturyzacji górnictwa węgla kamiennego, *Wiadomości Górnicze, 1, p. 4.*

Karbownik A., Tchórzewski S. (2004) System zarządzania projektami w przedsiębiorstwie, In: *Nowoczesność przemysłu i usług – nowe wyzwania, Tom I, Ed. J. Pyka, TNOiK, Katowice.*

KGHM (2017) Corporate Risk Management Policy at KGHM Polska Miedź S.A. Capital Group, *[online], [cit. 2017-08-19]*. *http://kghm.com/pl/inwestorzy/zarzadzanie-ryzykiem/proces-zarzadzania*

Knight H.F. (1921) Risk, Uncertainty, and Profit, *Hart, Schaffner & Marx, Boston.*

Marcinek K., Foltyn-Zarychta M., Pera K., Saługa P., Tworek P. (2010) Ryzyko w finansowej ocenie projektów inwestycyjnych – wybrane zagadnienia, *Akademia Ekonomiczna im. K. Adamieckiego, Katowice, p. 73, 74, 133, 137, 137, 131.*

Maruszewska W.E., Vaněk M., Vilamová Š. (2014) Economic situation of hard coal mining industry in Upper Silesian Coal Basin, *Acta Montanistica Slovaca, 19(2), pp. 70-116.*

Ministry of RP (2004) Zarządzanie ryzykiem w sektorze publicznym. Podręcznik wdrożenia systemu zarządzania ryzykiem w administracji publicznej w Polsce, *Ministerstwo Finansów RP, Warszawa.*

PGG (2017) Polska Grupa Górnicza, [online], *[cit. 2017-07-26]*, *https://www.pgg.pl/*

PMBOK (2009) A Guide to the Project Management Body of Knowledge (PMBOK® Guide), *Project Management Institute, Newtown.*

Polska (2017) Aktualna statystyka wypadków górniczych, *[online], [cit. 2017-07-14]*. *http://www.nettg.pl/news/100722/aktualna-statystyka-wypadkow-gorniczych*

Rogowski W. (2016) Rachunek efektywności inwestycji. Wyzwania teorii i potrzeby praktyki, *Wydawnictwo Nieoczywiste, Kraków, pp. 491, 491-498.*

Saleh J.H., Cummings A.M. (2011) Safety in the mining industry and the unfinished legacy of mining accidents: safety levers and defense-in-depth for addressing mining hazards, *Safety Sciences, 49, pp. 764-777.*

Schneider E., Spinel M. (2002) Rozkład ryzyka związanego z warunkami geologicznymi przy realizacji budowli podziemnych według systemu BOT, *Budownictwo Górnicze i Tunelowe, 3, p. 45.*

Shuwei J., Zhifang W., Junai Y. (2017) A Research on Risk Identification for Coal Mining Enterprises Based on FMEA and Fuzzy VIKOR, *Industrial Engineering Journal, 20(2), pp. 91-98.*

Tchórzewski S., Tworek P. (2011) Managing risk in projects in coal-mining industry: the example of Polish coal-mines, *Proceedings of the 13th International Scientific Conference on Finance and Risk, Ekonomická Univerzita v Bratislave, Vydavateľstvo EKONOM, Bratislava, pp. 418-427.*

Tworek P. (2013) Reakcja na ryzyko w działalności przedsiębiorstwa budowlano-montażowego, *Wydawnictwo Difin, Warszawa.*

Tworek P. (2010) Risk Management Standards – The Review of Approaches and Concepts, *Book of proceeding from 5th International Scientific Conference "Managing and Modeling of Financial Risks", VŠB – Technická Univerzita Ostrava, Ostrava, pp. 409-417.*

Tworek P., Valouch P. (2011) The Condition of Construction Industry in Poland and the Czech Republic under the Financial Crisis. Selected Issues. In: Inwestycje i nieruchomości. Wybrane zagadnienia, *Wydawnictwo Uniwersytetu Ekonomicznego, Katowice, pp. 27-44.*

Wang W., Zhao W., Hao J. (2008) Applied research on risk management in mining shaft construction projects, *Proceedings of the International Conference on Wireless Communications, Networking and Mobile Computing, WiCOM, 19-21 September, Dalian, pp. 1-5.*

Wodarski K. (2009) Zarządzanie ryzykiem w procesie planowania strategicznego w górnictwie węgla kamiennego, *Wydawnictwo Politechniki Śląskiej, Gliwice.*

Valouch P., Sedláček J., Mokrička P. (2009) Rezervy jako nástroj řízení rizik, *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, LVII (6), pp. 323-330.*

Vaněk M., Tomášková Y., Straková A., Špakovská K., Bora P. (2013) Risk Assessment in Mining-related project management, *GeoScience Engineering, LIX (3), pp. 47-53.*