Assessing occupational health and safety management quality by means of multi-criteria assessment: A case study

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Abstract. Audit inquiries used as a controlling tool are an important element of the structure of each management system. Such inquiries allow us to determine whether the undertaken actions are consistent with the adopted decisions, whether they have been properly implemented and are efficient. With respect to occupational health and safety management systems (SZBiHP), which is being implemented in the mining industry in Poland since the 1990s, one of the first solutions of that type were audit inquiries based on the MERIT survey (Management Evaluation Regarding Itemized Tendencies). As part of the method developed by the National Institute for Occupational Safety and Health (NIOSH), the WOP assessment indexes (so-called partial indexes) are determined separately for each assessed problem area, and then, basing on them, the final assessment of the OHS management (WZBP) is calculated. In the article, the results of audit surveys (partial indexes of WOP assessments) were used to determine the final assessment of the quality of occupational health and safety management using one of the multicriteria assessment methods in the computational layer - the ideal point method.

1. Introduction

The concept of occupational health and safety was for many years associated merely with the provision of technical equipment, and the preventive measures undertaken in particular problem areas were primarily associated with the determination of the causes and circumstances of accidents. It was not until the 1980s that more attention was paid to the socio-organizational aspect: the place and role of people in the cause-and-effect chain, the behavior and attitude of employees in production processes, etc. [1, 2, 3, 4]. At that period the concept of error of the human factor (human error) was coined, understood as an action deviating from the required standards and requirements of the situation (these derogations appear when any of such elements as: information, work tools, knowledge and skills, physical capabilities or incentives necessary to implement work tasks is defective or does not occur at all [5, 6, 7, 8]).

More and more frequently, the level of safety is treated as a resultant combing the attitude of the employees and their behavior as well as that of the environment. The concept of behavior-based system (BBS) has been coined, addressing employees’ involvement in the issues aimed at improving the level of work safety through the creation of joint responsibility for the level of occupational health and safety (OHS) and the development of occupational health and safety management systems. According to the creator of safety management – D. Petersen, dangerous activities, dangerous conditions and accidents are phenomena or events which are the manifestations of disturbances in the management system [9], which confirms the legitimacy of one of the fundamental principles of safety management, according to
which there is no absolute secure (i.e. safe) area of human activity, and hence always potential disturbances should be anticipated.

The need to implement the principles of the occupational health and safety management system in Polish companies has been enforced by limited effectiveness of the so far applied methods of safety analysis, based mainly on grouping and balancing the number of accidents and on retrospective models for the assessment of their causes and circumstances, as well as by organizational, legal and economic requirements - the more developed country, the more attention is paid to the issues of work safety and prevention in particular [10]. Therefore, as part of each newly-developed or improved occupational health and safety management system, it is essential to ensure first of all adequate resources and measures facilitating the implementation of health and safety policy, the improvement of employees’ qualifications and a wide participation of employees involving the actions undertaken in particular problem areas.

The function of an executive instrument enabling the implementation (improvement) of every occupational health and safety management system which can ensure its monitoring and evaluation of the effectiveness of undertaken actions is carried out by an audit of occupational health and safety management system. The MERIT survey (Management Evaluation Regarding Itemized Tendencies) was used as the first tool of this type in the hard coal mining industry in Poland. The said survey, which is an element of Total Safety Management (TSM), was developed by the National Institute for Occupational Safety and Health (NIOSH) [11, 12] and was adapted to Polish conditions as part of the program Partners in Economic Reform (PIER) - pilot studies were carried out in 1996 at coal mines ‘KWK Rydultowy’, ‘KWK Chwałowice’ and ‘KWK Niwka-Modrzejów’.

The MERIT survey contains 29 questions grouped into nine problem areas:
A. "Planning actions in the field of occupational safety management".
B. "Accident investigation".
C. "OHS control and inspection".
D. "Observation and analysis of the work task realization".
E. "Personal protection".
F. "OHS regulations in the company".
G. "Information provided on the condition of OHS".
H. "Promotion of OHS".
I. "Personal evaluation of OHS".

The survey has formalized character and uses two scales: verbal and digital. The respondents participating in the survey answer each question by choosing (underlying) one of the 5 possible alternatives scored on a scale from 0 to 4, where the rating 0 corresponds to a failing grade, and the assessment 4 - the ideal grade (the selected answers should in the best way describe the implementation of actions undertaken in the above-mentioned problem areas at parent companies/objects).

Based on the completed survey sheets, the \( WOP_i \) rating index is determined separately for each problem area [11, 13, 14]:

\[
WOP_i = \frac{\sum_{j=0}^4 c_j}{pn}
\]

where:
- \( i \) - number of area subjected to assessment;
- \( j \) - granted assessment grade;
- \( c_j \) - number of answers with the assessment grade \( j \);
- \( p \) - number of questions within the problem area;
- \( n \) - number of respondents taking part in the research.

These indexes allow us to determine strengths and weaknesses in the field of occupational health and safety management, and thus to determine the directions of necessary changes.
2. Discussing the results of the audit of the occupational health and safety management system

The MERIT survey, which comprised two hard coal mining companies and two mining-oriented service companies providing mining works for the mining companies was carried out in 2016. The summary of the values of $WOP_i$ and $WZBP$ indexes for particular objects subjected to assessment is presented in Table 1.

| Object | $WOP_A$ | $WOP_B$ | $WOP_C$ | $WOP_D$ | $WOP_E$ | $WOP_F$ | $WOP_G$ | $WOP_H$ | $WOP_I$ | $WZBP$ |
|--------|---------|---------|---------|---------|---------|---------|---------|---------|---------|--------|
| I      | 2.500   | 1.833   | 2.333   | 2.000   | 4.000   | 2.000   | 3.000   | 2.333   | 2.667   | 2.519  |
| II     | 2.750   | 2.167   | 2.333   | 1.750   | 3.000   | 3.000   | 3.000   | 2.333   | 2.333   | 2.519  |
| III    | 2.250   | 2.500   | 1.667   | 1.500   | 3.000   | 1.000   | 1.333   | 2.000   | 2.000   | 1.917  |
| IV     | 3.000   | 2.833   | 2.667   | 2.500   | 3.000   | 2.500   | 2.333   | 2.667   | 3.000   | 2.722  |

With respect to as many as six problem areas (A, B, C, D, H and I), the object IV scored the highest values of $WOP_i$ indexes:

- with respect to the problem area A. "Planning actions in the field of occupational safety management" the steps undertaken by the management of the mining company in view of occupational health and safety management are accepted by most employees. The campaign launched to promote the need to implement OHS management system, presentation and explanation of basic organizational and structural assumptions connected with the above problem was acknowledged by the employees, which resulted in the value of $WOP_A = 3.000$;
- in the case of problem area B. "Accident investigation" the respondents positively assessed the professionalism of actions in the field of occupational accident investigations ($WOP_B = 2.833$). These studies are characterized by a careful analysis of each accident, concluded with the preparation and implementation of appropriate preventive measures. Approx. 25% of the respondents reported the need to pay more attention to the investigation of potential accidents, which is one of the most effective methods of improving the condition of occupational health and safety;
- in the area C. "OHS control and inspection", the value of the $WOP_C$ index was only 2.667. Although the control and inspections carried out by external bodies and the management of the mining company are positively perceived, their quality often leaves much to be desired. In the opinion principally of the employees of the preparatory works departments, liquidation units, ventilation departments, electrical and machinery departments, the reasons for this state of affairs should be attributed to a large number of workplaces often located in excavations far from each other, which often makes it difficult or even impossible to carry out a thorough check;
- only 2.500 was the index $WOP_D$ for the problem area D. "Observation and analysis of the work task realization". The actions undertaken by the mining company to develop appropriate instructions and technologies for each workplace are perceived positively, but this is often done without the participation of the most experienced employees. In the first place, the method of analyzing the performance of works in terms of safety was assessed negatively (such an analysis should be carried out by the supervising staff during daily inspections of workplaces), which corresponds with the conclusions concerning the area C. "OHS control and inspection";
- in the opinion of the respondents, the actions undertaken to promote health and safety issues and observance of OHS regulations were assessed as poor ($WOP_H = 2.677$). Despite fairly high prizes, the employees are rather reluctant and unenthusiastic about organized competitions promoting knowledge on health and safety issues, and they do not acknowledge the effectiveness of the disciplinary system in force in the mining company (the system of rewards
and penalties). Also the form and quality of the knowledge transfer promoting the issues of occupational health and safety is at a very low level;

- with respect to the problem area I. "Personal evaluation of OSH in the company" (the value of the $WOP_I$ index amounted to 3.000) the employees acknowledge the efforts of the mining company management undertaken to create appropriate (safe and ergonomic) working conditions. In the opinion of some of the surveyed employees (about 30%), the critical remarks concerned mainly the quality and manner of assigning work tasks to be carried out, execution of workstation instruction, instructions on health and safety, or providing the employees with knowledge on technologies or technical projects and change sheets in these projects. Often the need to change the way of informing the staff about the state of OHS was raised (transfer of information from the briefings of supervisors with the management of the mining company).

With respect to the problem areas E "Personal protection" and G "Information provided on the condition of OHS", the actions undertaken by the management of the object I were rated the highest (in the case of the area G ex aequo with the object II). The respondents highly rated the actions undertaken to ensure access to personal protective equipment ($WOP_E = 4.000$). The efforts of the mining company management to provide maximum protection for the employees through the use of a wide range of personal protective equipment can be considered model-like. They were optimally selected to match working conditions, ensuring at the same time comfort for the employees to carry out their work tasks.

In the case of the problem area G. "Information provided on the condition of OHS" ($WOP_G = 3.000$), very high rating given by the respondents confirms the legitimacy and effectiveness of health and safety briefings conducted by the staff supervising and managing the mining company, where statistical analysis of accidents and current health and safety matters are discussed.

In the case of problem area F " OHS regulations in the company ($WOP_F = 3.000$), which had the highest rating given by the respondents of the object II, the respondents declare good knowledge of the regulations and technologies applicable for a given workstation as well as other provisions contained in the Safety Document.

The values of the final index $WZBP$ indicate explicitly that the quality of actions undertaken in the area of OHS regulations had the lowest assessment score in the case of object III ($WZBP = 1.917$). In that case, as many as seven times (areas: A, C, D, F, G, H and I) the mentioned areas had the last places in partial rankings (within particular problem areas), and as many as four areas: C, D, F and G the values of partial indices $WOP_i$ were lower than 2.000.

3. Multicriteria assessment with the application of the ideal point method - the essence and assumptions of the method

The ideal point method belongs to the group of multicriteria optimization methods. It has a multi-stage character (figure 1) and it allows us to organize the examined objects on the basis of the distances separating them from the so-called ideal solution and from the so-called anti-ideal solution [15].
**Figure 1.** Stages to follow in the ideal point method [15].
4. Exemplary application of the ideal point method in the assessment process of the quality of the occupational health and safety management

Based on the results of the audit of the occupational health and safety management system (table 1), the assessment input matrix was developed (table 2), whereof elements are the quotients of the obtained WOPi values and the maximum obtainable value WOPi (WOPi = 4)

Table 2. Assessment of the quality of the occupational health and safety management using the ideal point method - input matrix.

| Criterion (problem area) | Object | A   | B   | C   | D   | E   | F   | G   | H   | I   |
|-------------------------|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| I                       |        | 0.625 | 0.458 | 0.583 | 0.500 | 1.000 | 0.500 | 0.750 | 0.583 | 0.667 |
| II                      |        | 0.688 | 0.542 | 0.583 | 0.438 | 0.750 | 0.750 | 0.750 | 0.583 | 0.583 |
| III                     |        | 0.563 | 0.625 | 0.417 | 0.375 | 0.750 | 0.250 | 0.333 | 0.500 | 0.500 |
| IV                      |        | 0.750 | 0.708 | 0.667 | 0.625 | 0.750 | 0.625 | 0.583 | 0.667 | 0.750 |

The normalized matrix is presented in table 3.

Table 3. Assessment of the quality of occupational health and safety management using the ideal point method - normalized matrix.

| Criterion (problem area) | Object | A   | B   | C   | D   | E   | F   | G   | H   | I   |
|-------------------------|--------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| I                       |        | 0.474 | 0.388 | 0.512 | 0.507 | 0.610 | 0.444 | 0.597 | 0.497 | 0.528 |
| II                      |        | 0.521 | 0.458 | 0.512 | 0.444 | 0.457 | 0.667 | 0.597 | 0.497 | 0.462 |
| III                     |        | 0.426 | 0.529 | 0.366 | 0.380 | 0.457 | 0.222 | 0.265 | 0.426 | 0.396 |
| IV                      |        | 0.568 | 0.600 | 0.585 | 0.634 | 0.457 | 0.556 | 0.465 | 0.569 | 0.593 |

For each of the problem areas, the same criterion weight was adopted:

\[
Q = \begin{bmatrix}
q_{A1} & 0.111 \\
q_{B1} & 0.111 \\
q_{C1} & 0.111 \\
q_{D1} & 0.111 \\
q_{E1} & 0.111 \\
q_{F1} & 0.111 \\
q_{G1} & 0.111 \\
q_{H1} & 0.111 \\
q_{I1} & 0.111 \\
\end{bmatrix}
\]

Due to the fact that each of the problem areas (assessment criteria) was treated as a criterion of the "benefit" type, the ideal solution \( A^* \) has the following form:

0.063; 0.067; 0.065; 0.070; 0.068; 0.074; 0.066; 0.063; 0.066 and the anti-ideal solutions \( A^- \):

0.047; 0.043; 0.041; 0.042; 0.051; 0.025; 0.029; 0.047; 0.044.

The calculated relative distances of individual objects in relation to the ideal solution are presented in table 4.
Table 4. Relative distances of individual objects in relation to the ideal solution (for the same criteria weights).

| Relative distances of particular objects $K_i$ | Ranking |
|-----------------------------------------------|---------|
| $K_I$                                         | 0.575   | 3       |
| $K_{II}$                                      | 0.644   | 2       |
| $K_{III}$                                     | 0.163   | 4       |
| $K_{IV}$                                      | 0.730   | 1       |

5. Conclusions
The situation on the labor market, strong competition and concern about company image have brought about changes in the perception of occupational health and safety issues: these issues are an integral part of the production process, and the decision-makers are increasingly concerned not only with technical measures to improve OHS conditions at workstations, but also with the analyses of attitudes and behavior of employees in the work process and the research on the so-called threat potential. Such an approach to the issues of occupational safety is reflected in the philosophy of OHS management. Psycho-physical predispositions, qualifications, professional experience, behavior of employees and a priori actions constitute, in view of the assumptions of occupational health and safety management, a significant group of factors shaping the level of occupational health and safety. The audits of the occupational health and safety management system are commonly used as research tools in this field, and the method Management Evaluation Regarding Itemized Tendencies (MERIT) is the first of the above mentioned ones used in a hard coal mining sector in Poland. It enables both the assessment of the quality of actions undertaken in the area of occupational health and safety management "here and now", but it also allows tracking trends and directions of changes in the quality of undertaken actions over time (the calculations refer to the first of the mentioned cases). The obtained values of indexes give us an opportunity to compare the results involving the particular problem areas, but also to compare the objects themselves (in the paper these objects were 4 entities from the mining industry: 2 hard coal mining companies and two mining service subcontractors).

The article proposes a twofold interpretation of the $WOP_i$ assessment indexes based on the MERIT survey: as final assessments under single-criterion tasks and as partial assessments within one multicriteria task (the criteria are understood as the quality of actions undertaken in specific, defined problem areas, i.e. in the areas $A+I$). At the same time, for the purpose of generating the final assessment of the occupational health and safety management, an alternative method of determining the final assessment based on the ideal point method was proposed. This method is based on determining the relative distance of individual objects in relation to the so-called ideal object/solution. The determined synthetic measures $K_i$ allowed for grading the assessed objects. In the example above, the quality of actions undertaken in the object IV was rated the highest (0.730), and the lowest was in the object III (0.163). The order of objects in the ranking based on the ideal point method is very similar to that obtained based on the values of $WZBP$ indexes (the arithmetic mean of partial indexes $WOP_i$ - table 1). However, it should be noted that if the ideal point method is used, there is a possibility to differentiate the significance of individual criteria, e.g. due to the nature of the examined object, the preferences of the evaluator, etc., which can significantly enrich the assessment itself. For example, for different weights of the criterion:
the relative distances of individual objects in relation to the ideal solution are respectively (table 5):

Table 5. Relative distances of individual objects in relation to the ideal solution (for different criteria weights).

| Relative distances of individual objects $K_i$ | 0.583 |
|-----------------------------------------------|-------|
| $K_{II}$                                      | 0.714 |
| $K_{III}$                                     | 0.146 |
| $K_{IV}$                                      | 0.738 |

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