

## APPLICATION OF THE TCO METHOD FOR DETERMINING THE TOTAL COST OF SMG IN AN UNDERGROUND COPPER MINE

Mirośław LEWICKI

Jan Wyżykowski University, KGHM Polska Miedź S.A. Oddział Zakłady Górnicze Lubin,  
Miroslaw.Lewicki@kgm.com

**Abstract:** *Self-propelled mining machines used in underground copper mine KGHM Polska Miedź S.A. show a great variety of types. This is mainly due to the specifics of the mining method based on pillar-chamber technology with ceiling deflection with possible modifications or with filling. Linking the cost of using particular machines produced by differential manufacturers has provided a justifiable and effective selection of those machines that perform best in the technological process of extracting copper ores. The total cost method of TCO, which brings the surveyed objects to comparable conditions, makes it possible to compare machines on the basis of efficiency and effectiveness in the work performed while simultaneously determining the costs incurred. Using the Data Warehouses and co-working software of SAP Business Objects, allows relatively quickly and easily to obtain comparative cost sheets in scope of bearing cost by type with a reference to their technical efficiency. Linking the above-mentioned activities allows higher mechanical supervision to effectively manage a machine park.*

**Key words:** total costs; technical and economic analysis.

**JEL Classification Codes:** AA, BB, C1.

### 1. INTRODUCTION

The management of SMG self-propelled mining machines in the conditions of an underground copper mine requires ensuring high efficiency of machines involved in the process of mineral extraction. Linking the efficient operation of machines with the relatively accepted costs incurred for their operation and maintenance is one of the main management issues.

The TCO total cost method has not previously been used to study the effectiveness of investment projects related to self-propelled SMG mining machines. You can see references to the use of this method in the analysis of the costs of using IT products or other repetitive objects that are relatively easy to describe in terms of the entire operation process. The adaptation of this method to the cost-technical analysis in the conditions of underground mining constituted a major logistic and IT challenge. Measures taken to use this method by KGHM Polska Miedź S.A. they were consulted by a consulting company. This allowed for the construction of a model process of exploitation for the purposes of the TCO method (Radoń et al., 2015).

The TCO total cost method reflects the actual operating conditions of the machines and the costs incurred for individual objects during their operation.



This is an open-access article distributed under the Creative Commons Attribution-NonCommercial 4.0 International License (<http://creativecommons.org/licenses/by-nc/4.0/>).

## 2. TERMS FOR THE INTRODUCTION OF THE TCO METHOD IN THE MINE

Running a mining robot using pillar-chamber technology with roof deflection forces the use of a dispersed system of self-propelled mining machines. This is due to the need to conduct different phases of the mining process using different types of SMG (Lewicki, 2005). For example, after the process of drilling the shooting holes using self-propelled drilling vehicles and shooting the ancestor, the loading and dropping of spoil on the departmental transshipment point follows. The use of LK2, LK3 and LK4 loaders with diversified bucket capacity allows you to load spoil on self-propelled haulers or direct haulage. The nature of the exploited field and the adopted project of mining robot mining forces the use of mining machines with given operational parameters. In addition, the dimensions of the sidewalks and the chambers limit the range of applied SMGs due to their overall dimensions. The diversity of machines used in the process of minerals extraction associated with changing geological conditions enforces the use of rational management of the machine park aimed at efficient and failure-free operation of individual units (Lewicki, 2015). Means:

- the need to have effective technical and financial instruments allowing to evaluate and compare used machines in terms of their production characteristics and costs incurred,
- the need to allocate costs incurred to generic cost groups responsible for maintaining machines in efficiency and responsible for production,
- the need to isolate the impact of the environment on costs and technical efficiency,
- having historical data that allows a representative comparison of different types of machines.

The interest of management services in the scope of cost optimization and ensuring proper relationship between SMG availability and costs incurred for individual machines focused on the search for various financial and technical instruments to perform the assumed tasks (Kopacz, 2012). It seems important to pay attention to SMG monitoring and use of the total cost method. Monitoring ensures effective diagnosing of machines during the extraction process and the TCO method allowing to assess the costs incurred on SMG including production parameters.

## 3. CHARACTERISTICS OF MODEL TCO CONDITIONS

Based on the SAP BW data warehouses, an application was developed to compare the SMG in terms of type, manufacturer, generated costs and achieved production rates. It is useful to base on the company's accounting plan for all cost items. Costs were used to:

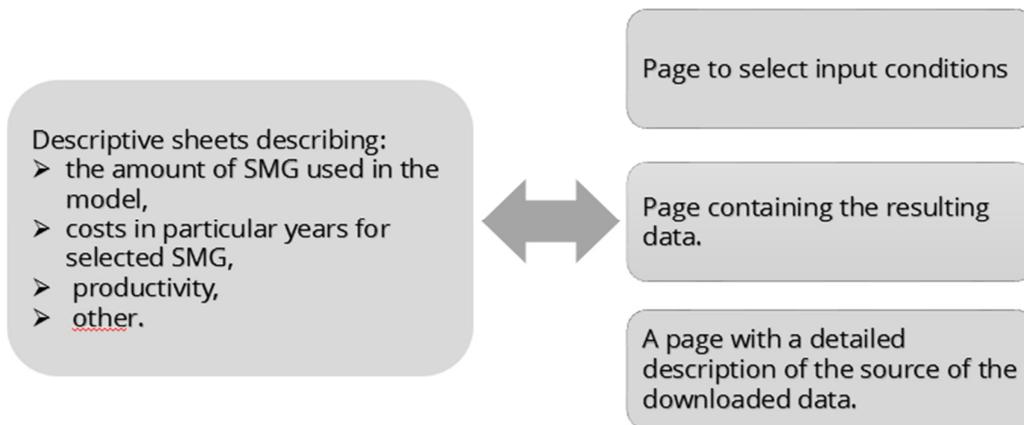
- purchase costs of the machine including the purchase price of the basic version and the price of additional equipment options;
- operating costs that group SMG operators' labor costs, fuel costs, tires, operating oils, electricity and other materials;
- maintenance costs including the cost of own service of SMG servicing, cost of spare parts, costs of external maintenance services, external and own repairs, balance depreciation, costs of maintenance services and services of auxiliary departments;
- indirect costs that group storage costs, service purchases and common costs.

The TCO model should represent the completeness of the costs incurred within the field of the estimated or relatively separate technological process. The TCO method has been successfully adapted to the conditions of the underground copper mine. Applied mechanisms and procedures have allowed for:

- description of the analyzed infrastructure in the mine within a given period of time;
- highlighting the aspect of accurate cost analysis for individual machines involved in each technological process.

The measurement of the achieved values within the scope of appropriate groups of costs depends strictly on:

- importing the tested objects to comparable states;
- having comparable cost data available for adequate quantitative tests.

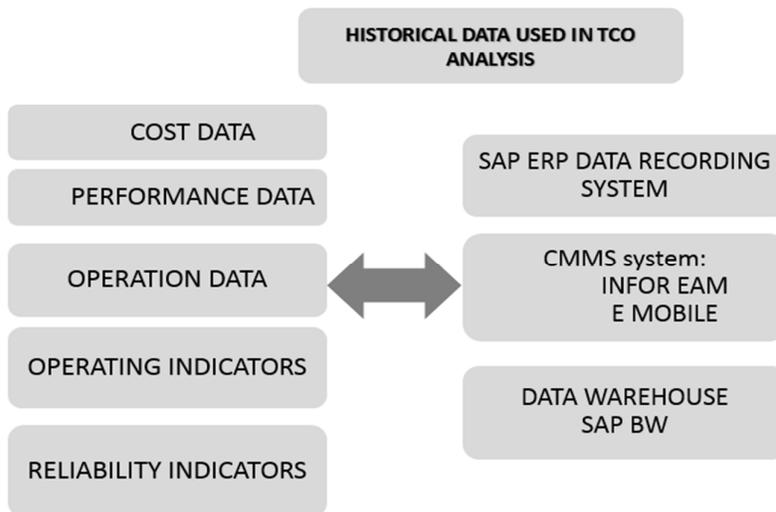


**Figure 1. General form of TCO**

#### 4. DATA SENSITIVITY

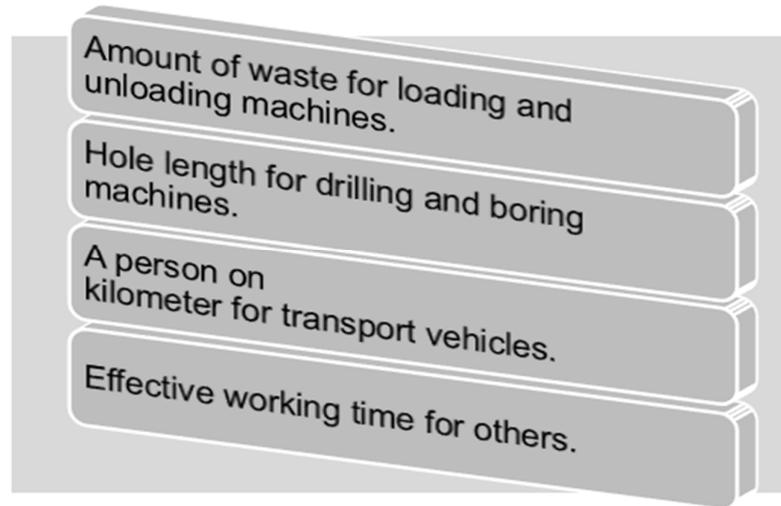
The sensitivity of the TCO method to the accuracy of the description of the characteristics of individual SMG forces the users of data entry systems to control the input data entered after the purchase of new machines. In addition, it is necessary to maintain the accuracy of accounting for individual cost items for machine orders and control orders assigned to each machine individually. It is necessary to build intermediate checkpoints to verify the credibility of the data entered. Employee liability as well as adequate training in related archival and historical data processing systems are important. The built-in model based on the SAP BW data warehouse allows efficient and accurate observation of individual cost items for each type of SMG.

The addition of the CMMS system, which allows for the management of work time and maintenance costs, as well as the SAP ERP data recorder system, gives the operator the convenience, precision and speed of the technically-economical analysis of the SMG. The data records associated with the result sheets are shown in figure 2.



**Figure 2. Data record system**

The basic parameters of productivity are presented in figure 3.



**Figure 3. Observed production parameters**

## **5. RESULT REPORT**

The final report generated for the specified machine type and the specific manufacturer allows you to observe cost and production parameters in annual time periods. In order to ensure proper observation of the results, the results reports contain a set of control sheets that allow them to comment on the number of machines considered for analysis.

The ability to analyze individual types of machinery in different areas or with respect to the whole mine enables to isolate the specifics of the environmental conditions and their impact on the production parameters and if it ceases to be related to repairs.

A summary of the resulting control sheet associated with the supplementary sheets is shown in Fig. 4. Accurate result analysis allows you to specify a period of analysis that includes the most representative time period in the representative sample of comparable objects.

The figure displays three tables related to TCO control. The largest table on the left is a detailed breakdown of costs, categorized by 'Typ wg DTR' (CB4PCK) and 'składnik modelu TCO'. It lists various cost components such as 'Koszty eksploatacji', 'Koszty utrzymania', and 'Koszty odtworzenia' with their respective units and currencies. Two smaller summary tables on the right provide a consolidated view of these costs for two consecutive years (1 rok and 2 rok), including metrics like 'Ilość m-cy użytkowania w roku' and 'Czy maszyna ujęta w kalkulacji TCO'.

Figure 4. Summary of sample results sheets that control the TCO

## 6. INTRODUCTION OF THE TCO METHOD TO THE SMG MANAGEMENT PROCESS

Machines used in the copper ore mining process must achieve planned availability. High technical requirements of individual units mean the need to ensure proper organization of work. This means timely implementation of technical reviews aimed at catching the smallest failures according to the tabulated lists of control activities. It also means the current observation of SMG during the implementation of production processes through their on-going monitoring. In addition, the machine park is built on known purchases from well-known manufacturers. It is important to specify the purchase conditions that allow you to refer the purchase price to the maintenance costs incurred in a given period of operation. The use of historical data on the use of various machines from different manufacturers allows for effective forecasting of the resulting costs and selection during the purchase of those types of machines that will meet the best production goals.

Availability of historical data on the work of machines referring to a particular mine area allows the dedication of purchasing solutions to the specific working conditions that exist in a particular mining field. The TCO method allows determining the costs of operation and maintenance in particular periods of machine life. Simultaneous derivation of technical parameters, i.e., for example, availability or consumption of a unitary fuel, allows determining the most effective machine life periods. By introducing real periods of use to the balance sheet depreciation tables, the use of machines outside their effective area is avoided. It is possible to carry out the process of liquidation of the exploited unit against the hyperbolic increase of the costs of qualifying the machine to often unprofitable overhaul.

## 7. CONCLUSIONS

The TCO method of cost elements with SMG performance parameters allows for:

- correct and cost-effective selection of SMG types and directly related picking,
- observing performance indicators for different types and types of SMG under the conditions of underground copper mine,
- observing directions of development in the field of SMG economy and their maintenance in the state of technical and organizational efficiency,
- an appropriate choice of suppliers to minimize the costs incurred while ensuring technical efficiency within the framework of ongoing tendering procedures.

Machine operation in underground copper mine means heavy changing conditions depending on the location of mining work. The rocky overgrowth, the varying degrees of rock failure, the geological differentiation of the exploitation fields are among the examples of conditions that affect the work of the SMG. Any failure at the front indicates an interruption of the production cycle due to the need to tow the inoperative machine. It is necessary to build a machine park on the basis of known manufacturers. Increasing purchase costs is justified and compensated by minimizing service repairs. Proper selection of the machine park enables effective management by the technical staff. It also allows you to obtain performance indicators at the planned level, which means that you maintain a certain level of production costs.

Stopping the increase in costs is the main task in terms of improving the efficiency of operations and is included in the strategic objectives of KGHM Polska Miedź SA. The use of the TCO methodology allowing to compare the costs of various types of machines in given annual time segments turned out to be a legitimate and effective solution meeting the assumed goals.

## REFERENCES

1. Kopacz, M. (2012), Economic assessment of implementation of mining machines monitoring in KGHM PM SA, Lubin: Materials of the II International Copper Ore Congress.
2. Lewicki, M. (2005), Evaluation of effectiveness in the process of reconstruction of machinery in conditions of KGHM PM S.A., Kraków: School of underground exploitation.
3. Lewicki, M. (2015), The analyze of sensitivity of TCO indicators to a selection of producers and to typology of purchased mobile mining machines, Lubin: Materials of the International Copper Ore Congress
4. Radoń, T., Czaplak, M., Nalepa, G., Lewicki, M., Sztuk, P., Rus, M., Ławrzyniak, B. (2015), Report of the Team for the development of the principles of using the TCO method in KGHM Polska Miedź S.A. in the area of mining machines, Lubin: Materials by KGHM Polska Miedź S.A.