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THEORETICAL AND PRACTICAL ASPECTS OF MATERIAL REQUIREMENTS PLANNING IN A MINING ENTERPRISE

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Abstract: The research problem raised in the paper concerns materials management of mining enterprises. It is an important area of activity in these enterprises, mainly due to the fact that the cost of materials consumption is, after the personnel cost, the second position in the cost structure in terms of value. In order to conduct the mining works planned in an efficient way, it is necessary to provide materials supply as well as to prepare them and transfer to production. It can only be achieved in the way of appropriate planning, which includes the division into product range and time periods. The way of planning should be adjusted to the specific conditions and the character of consumption, as well as link those with an operational production plan. Although a great number of publications on planning methods can be found, not many of them refer to the specificity of mining production processes, especially material requirements planning.
The objective of this paper is to present the theoretical assumptions of the material requirements planning process and the practical aspects of this process in the operating activity of mining enterprises. The paper is of theoretical and cognitive study character. The research was based on a systematic review method – systematic literature review, supplemented with the analysis of internal documents and programs used in materials management of mining enterprises.

Keywords: materials management, material requirements planning, mining enterprise

1. INTRODUCTION

For the efficient execution of the planned mining works it is necessary to provide materials supply, their preparation and handover for production. Rational, regular supply of a different type of materials for production may only be achieved in the way of appropriate planning, which includes a division into the product range and time intervals, months at best. Materials handover and supply should be planned in greater details, that is dividing into decades, weeks or even days. The way of planning should be adjusted to the concrete conditions and consumption character (Koh and Saad, 2003). All of this ensures the link between the supply plan with the operational production plan. As the mining enterprise functions in a relatively unpredictable mining and geological conditions, that is why in the process of materials supply planning it is necessary to include a random disturbance characterizing the course of the mining production process (Trenczek, 2016). The objective of this paper is to present the theoretical assumptions of the material requirements planning process and the practical aspects of this process in the operating activity of mining enterprises. The paper is of theoretical and cognitive study character. The research was based on a systematic review method – systematic literature review supplemented with the analysis of internal documents and programs used in materials management in a mining enterprise.

2. OBJECTIVES OF MATERIAL REQUIREMENTS PLANNING

A mining enterprise, if it wants to achieve its objectives, must use some amount of materials. The cost of materials shapes on the level of about 15% of the total cost value, and it is the second position, after the cost of personnel, that burdens the financial result the most in the mining enterprise. The cost of materials in a yearly scale amounts to PLN 100 million per mine, and in the scale of a mining plant consisting of a few mines it is the amount of PLN 1.5 billion (Kałuski, 2013).

The specificity of mining production results in the fact that most of the materials used does not come into the content of the product manufactured, that is commercial coal (Michalak, 2016). The materials are necessary to conduct the process of mining production, and also for the maintenance of the machines and appliance and for keeping them running (Drebenstedt and Singhal, 2014). Despite this character of materials, they play a very important role in the process of mining production. Their lack may cause a disturbance in the course of mining works and continuation of the production process. The mining plant, or the mines included in the plant to be precise, use a variety of materials. Their type depends on the character of the works conducted. The significance of the particular types of materials used in the mines is not the same, though. Some of them have a decisive impact on the course of production process, and their lack may lead to production halt. The significance of some materials is not as great, however, their shortage results in the impediment in conducting the mining works and may cause a disturbance in a regular production. In order to provide the continuance of mining works, in particular the adequate mining conditions, it is necessary to develop the material and technical supply plan. The purpose of this plan is to grant access for every mine department to the proper material quantity so that all the work posts may receive the materials in a required amount and type. Nevertheless, one must not forget about the rule of inventory minimization, because excessive inventory is, on one hand, a comfort for the people responsible for supply guarantee and on the other hand, is and additional, redundant cost increase (Dolgui and Prodhon, 2007; Jonek-Kowalska and Turek, 2013). In practice, as the results of direct interviews show, it happens that the reserves of some materials are too large and at the same time it happens that the materials shortage causes disturbance in the course of production, what is more, this forces an inadequate substitution.

3. ELEMENTS OF MATERIAL REQUIREMENTS PLANNING

The material requirements planning in a yearly depiction has a form of material balance developed for a period of a calendar year. In this balance the following elements can be distinguished:

- disposal planned, R (consumption, sales),
- planned level of reserves at the end of year, Z_k (inventory at the end of period),
- planned level of reserves at the beginning of year, Z_p (inventory at the end of period),
- requirements planned, P
- surplus, N (excess)

Requirements (P) are the result of calculations made according to the formula:

$$P = (R + Z_k) - Z_p$$

Surplus, possible to liquidate at best, is calculated according to the formula:

$$N = Z_p - (R + Z_k)$$

In the mining enterprises, five basic ranges of activity may be distinguished in the process of material requirements planning: production, employee benefits, materials marked for the process at investment objects (investment), mines liquidation, own processing.

The development of material balance should always start from determining the disposal planned and the final level of reserves planned because these are the elements determining the requirements. The process of material requirements planning in the mining enterprises,

as it was mentioned before, consists of planning cycles including a calendar year and months, in connection with the technical and economic plan, but not only. From the planning point of view, the problem of material security should be analyzed in the contexts: strategic, tactical, operational.

As the plans have a strictly defined structure, that should correspond to the organizational structure of the mining enterprise, and an objective arrangement based on the distinguished spheres of the main activity, their content should refer to all these levels. Then the question arises, to what extent the material requirements planning is strategic planning, to what extent is tactical and to what extent is it operational planning? The individual levels of planning are described by several attributes, in which the aforementioned stock is included. These are:

- time horizon, which encompasses the supply plan, the longest for the strategic plan, medium-term for the tactical plan and the shortest for the operational one,
- range of material requirements planning, which involves the whole enterprise, the individual mines,
- participation, competence extent, including the responsibility of the particular management levels in the mining enterprise, both during plan development and execution,
- plan range in the mining enterprise, whether the whole plant or distinguished areas, or individual undertakings,
- type of measures included in the supply plan, that is, synthetic, indirect and analytical.

Material requirements planning, from the executional point of view, covers the particular management levels in the mining enterprise, with the adequate participation of proper staff and operational units.

When improving the process of material requirements planning, the notion of logistics of materials is very important. It has many meanings in both, subject literature and in practice (Lyssons, 2004). However, in relation with the problem of materials management it is worth using a definition that describes logistics as a process of planning, realization and control of the efficient, cost effective flowing and storage of raw materials, semi-finished goods, finished goods and the information related to that, from the point of delivery to the destination point in order to satisfy the customer requirements (Pfohl, 2001).

Material requirements planning in the mining enterprise includes cyclical activities. When developing the plan many different methods are used, taking diagnostic, prognostic activities using analysis, synthesis, simulation and assessment. On one hand, the specificity of the methods used in planning, on the other hand, the random course of mining works, mostly resulting from the perseverance of rock mass, cause that the plans are of probabilistic character. In turn, the particular operations of the planning process mainly have the course specific for the iterative cycle, with the inclusion of feedback loop.

4. ROLE OF MATERIAL REQUIREMENTS PLANNING

In the functioning of the mining enterprise the materials management is an important subsystem. It constitutes a set of activities providing supply, enabling a regular process execution in mining production.

One of the more important elements of supply plan is materials consumption. It defines the amount of materials quantity that should be disposed in the planning period from the storehouses of the mining enterprise in a way that secures the needs resulting from the actual economic activity. Material requirements have their source in a diversified range of mining production process. Thus, when developing the plan it is necessary to divide the materials into the consumption area. For example, the production can be particularized into: maintenance works, preparation works, reinforcement, longwall liquidation, ore haulage, other underground works, mechanical processing, other works on the surface.

Materials consumption for operational objectives, namely production, constitutes one of the most important elements as it directly conditions the possibility of the production plan execution and has a significant share in the structure of total materials consumption in the mines. It amounts to about 75% of total consumption for all the objectives. The consumption quantity for production objectives is determined on the basis of the production planned and the plan of preparation and reinforcement works. The so called consumption standards should also be taken into account. In the hard coal mines most of consumption standards relates to the mining output quantity calculated per 1000 t, or to a length unit of a pit calculated per meter.

In practice, material requirements planning is strictly connected with the production amount planned and with data regarding consumption in the previous periods. On these grounds the limits of materials order and spare parts plans are determined, or of other goods for the individual mines and other organizational units. This process is performed using the program SZYK2/KLM/LMP – plans and requirements.

5. MATERIAL REQUIREMENTS PLANNING AND THE ENVIRONMENT OF MINING ENTERPRISE

The system of materials connections in a mining enterprise with its environment is changing, in terms of materials flow intensity, is multi-source and very diversified from the point of view of supply source. The factors determining changes are: conditions: geological and mining, technical and technological, organizational and economic, innovative activity, material substitution, and external conditions, that is purchase possibilities, supply provisions change, price change etc.

In general, on one hand changes in the conditions of reserves deposition, on the other hand, technological changes stemming from technological advancement and science development, improvement of the forms of work organization cause that the arrangement of materials connection in the mining enterprise with its environment and the whole sphere of materials management become more and more complex and variable. Therefore, these processes should be followed by changes in the process of material requirements planning. The key directions of changes include:

- plan structure rebuilding for the compliance with the current requirements, and at the same time, supply tasks,
- implementation of the ways of adequate requirements planning faced by materials management in the mining enterprise,
- improvement of information processing techniques, appropriate for practical utilization in the process of material requirements planning,
- development of adequate IT systems enabling a timely information flow in the proper range and also proper quality for the correct planning and control of supply processes.

Supply plans, or materials management plans to be precise, are the basic tool of regulating the actual materials flow, providing a regular course of mining works. Thus, system approach was linked with the use of computer-aided algorithms. It constitutes a condition of effective problem solving of materials management in the mining enterprise.

6. MATERIAL REQUIREMENTS PLANNING AND INNOVATION INITIATIVES

In the recent years, a significant form of planning in the mining enterprises are so called innovative initiatives that are a some kind of element of technical and economic plan, both in a yearly approach and the one for many years too (Oshokoya and Tetteh, 2018). Within the frames of these initiatives, the sphere of technical and organizational activities should be included concerning the rationalization of materials consumption. The prognoses of materials management improvement are its reflection. They should be developed for the period of many years and include a complexity of mining and technical as well as organizational and

economic undertakings. It constitutes a result of materials management improvement on all the levels, organizational units of mines and the board. Updating the particular tasks, along with their particularizing, should be performed in yearly periods. Such program should include:

- detailed arrangement of tasks, along with describing the way and deadline of completion, for the organizational units and people responsible for executing the concrete tasks, supervision over the execution,
- amount of outlays and predicted effects,
- automatic effects listing and determination of the cost materials decrease,
- monitoring and corrective measures.

In this approach the program of materials management improvement is basically a part of specialized innovation plan.

7. INFORMATION SYSTEM OF MATERIAL REQUIREMENTS PLANNING

A proper execution of the planning function for material and technical assurance grounds on a lot of information of geological and mining as well as technical and economic character (Jonek-Kowalska, 2017). From the operational point of view, several information groups may be distinguished.

The first information group is all kinds of standards, which include, among others:

a) materials consumption standards per unit and group
b) analytical-statistical indicators, materials consumption rates, financial limits
c) information (directive) indicators, material limits, stock increment indicators per production increment unit.

This information should be developed by the staff from the mining and energy-mechanic department as well as by the economic department, and also gathered from the external sources.

In the group of information for planning purposes, the basis data source is a long-term (strategic) plan, technical and economic plan, maintenance plan (supplements to maintenance plan), technical projects, schedules of preparation works, reinforcement, wall course and liquidation, wall equipment with basic machines and appliances. Information for planning is created when almost all the other segmental plans.

Supply plan is linked to a network of information relationship in the whole arrangement of plans in the mining enterprise. However, a dominant role is served by the technical and economic plan, which includes production plan. It determines supply planning into the following data set: information about the amount of yearly production divided into quarters with a product range structure, planned production quality improvement, basic assumptions for the plan for the next year, supplementing information concerning the undertakings from other segmental plans, causing production changes.

The plans of investment undertakings encompass the initiatives triggering both, materials consumption increase an decrease. The key information coming from this plan are:

- type and amount of materials savings planned due to the unit consumption decrease and materials substitution,
- research on changes in production technology and organization,
- requirements regarding materials and test apparatus.

The plan of investment and overhaul shapes the material requirements in two ways: direct and indirect. A direct influence comes from material requirements for overhaul and investment processes, rather rarely conducted by the mining staff. An indirect influence means material requirements for external companies in general, to conduct investment and repair works. Material requirements also stem from the activity concerning work safety and hygiene as well as from other auxiliary functions, e.g. auxiliary production, non-operational and administration/office works. The links between the segmental plans in the process of

material requirements planning are multi-directional. Especially intensive feedback functions occur between the production (excavation) plan and innovation development plan.
In practice of mining enterprises IT solutions are used, supporting inventory management processes. Both JSW S.A. and PGG S.A. use the solutions from Central Unit of IT in Mining – SZYK 2/KLM. This process is being conducted in four modules (Wroński, 2009): LMP Plans, LMU Stock replenishment, LMO Order, LMZ Stock analysis. In turn, in LW "Bogdanka" S.A. an IT system is functioning, that supports material requirements planning for the purpose of mining works in the hard coal mine called "MAINCOAL". This solution, in cooperation with LW "Bogdanka" S.A., was developed by IGSMiE PAN consortium in Crocow and PRGW in Sosnowiec. The main objective of this solution is, among others, increase of materials planning accuracy (Łoś, 2009).

8. CONCLUSIONS

Although the publications on mathematical planning methods are broadly accessible and there are many of them, but only a few of the works concern the specificity of mining production processes. Thus, it may be stated that despite a common utilization of advanced mathematical methods in many areas of mining sciences, in the sphere of material requirements planning such information is scarce. An exception here is a publication by Kałuski (2013).
Material requirements planning in the mining enterprise depends on the excavation planned. However, in order to achieve the production planned, it is necessary to conduct the preparation works and the ones allowing access at an appropriate time, and these in turn require a variety of materials in an appropriate quantity. For the adequate supply of a large mining enterprise, in the IT solution developed for that purpose (SZYK 2/KLM), over 520 unified groups of product range were formed, including almost 115 thousand product range items. Regardless of the groups distinguished, in this program 100 groups are functioning, encompassing almost 7 thousand product range items. Suppliers of the items are selected in the way of spot auction. The basic supplies are received in the way of bidding procedure, based on Public Procurement Law. It is a solution that should be given a positive evaluation, however, in the view of research conducted in the mines, the IT system SZYK 2 should be extended with, among others, the utilization of:

- multi-criteria models of material requirements support,
- artificial intelligence for material requirements support.

Irrespective of that, it may be stated that the access to some tools for material requirements planning is not a guarantee for success. Observation of the previous practice indicates that the mining enterprises are not able to implement many accessible solutions efficiently, that would enable proper material requirements planning. What is more, it should be emphasized that the decrease of the cost of materials by 1% provides savings in the mine up to PLN 1 million in a year. Therefore, it is necessary to introduce an efficient change, not only in terms of tools in a form of new or improved IT systems, but also to change the employee attitudes who play a key role in this process.

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