THE IMPORTANCE OF LOGISTICS IN METALLURGICAL PROCESSES

[1]Petr BESTA, [1]Zdeněk MARTÍNEK, [1]Adam DRASTICH

[1]*VSB - Technical University of Ostrava, Ostrava, Czech Republic, EU, petr.besta@vsb.cz*

https://doi.org/10.37904/clc.2022.4549

Abstract

Manufacturing companies are under great pressure in the current highly competitive environment. High customer demands as well as pressure from the competition are forcing companies to streamline all their processes. In this situation, it is increasingly important to optimize the company's logistics processes. The production of iron in a blast furnace is extremely demanding in terms of the large volumes of raw materials that must be continuously available. At the same time, some technological processing of these raw materials is necessary before using them. There are also other stock items that have fundamentally different consumption and volume. Iron production is also specific in terms of the continuous operation of the blast furnace itself. Therefore, it is necessary to constantly provide the required quantity of feedstock. The bulkiest raw materials in terms of quantity are iron ore, alkaline additives and blast furnace coke. Three types of material used were analyzed in the research carried out. Two types were related to the most voluminous stock items listed above. The third type of stock item is one of those that is expensive but is consumed rather irregularly - spare parts. The aim of this paper is to assess the variability in consumption for the stock items in question. Standard logistics tools from the field of stock classification methods were used for the evaluation. The research was conducted in a selected metallurgical company in the Czech Republic.

Keywords: Logistics, metallurgical production, costs, process

1. INTRODUCTION

Industrial production is currently one of the most challenging areas of business. Manufacturers in all industries are confronted with major changes in technology, but also with changes in customer requirements. Customers are placing increased emphasis on quality, speed and, above all, flexibility in delivery. The highly competitive business environment forces companies to continuously look for potential opportunities to reduce costs. Increasing the efficiency of your processes, eliminating sources of waste and reducing costs can also be referred to by the term - manufacturing mastery [1,2].

An important business segment that is gaining more and more importance is logistics. Especially in the area of inventory management, which can have a major impact on a company's competitiveness. Inventory management can be understood as the efficient handling and effective management of stock items, the use of all reserves that exist in this area, and respect for all factors that affect the effectiveness of inventory management [2,3,4].

The existence of stock items at a time when they have no use, when there is no demand for them, is a waste of resources. The absence of stock items at a time when the customer's order needs to be fulfilled leads to lost sales and consequently to a loss of both customers and the company’s reputation [5,6,7]. In the area of continuous production processes, it is naturally necessary to maintain adequate quantities of stock items, given the need for their technological adjustment. An example is the agglomeration processes that the ore concentrate undergoes before entering the blast furnace operation. Therefore, it is necessary to maintain an adequate amount of stock items within these production processes, due to the time required for their modification [8,9,10].

In general, metallurgical production processes are very specific in terms of optimization and inventory management [11]. The material flows taking place in metallurgical companies represent a huge amount of material. In the case of major feedstocks such as ore, coke and alkaline additives, this is in the order of millions of tones in a single year. At the same time, some raw materials need to be processed before they can be used. For example, iron ore undergoes a process of homogenisation and subsequent sintering. All of these aspects affect inventory management in a metallurgical plant.

This paper deals with the results of the research conducted on inventory optimization in a metallurgical organization. The aim of this paper is to conduct an analysis of the variability of consumption for selected groups of stock items. The method of assessing consumption variability, also sometimes referred to by the acronym XYZ, was applied for the evaluation. The research was carried out as part of a long-term study carried out in a selected metallurgical company.

2. PROBLEM FORMULATION

Variability analysis is also often referred to as XYZ analysis and is one of the basic statistical tools used in inventory management. Unlike the Pareto analysis, this method assesses the regularity of consumption. It is logical that the approach chosen for materials whose consumption is regular will be different than for those materials that are used more sporadically. Items are classified into three or more groups. Group X contains items with highly regular consumption that do not have significant fluctuations in consumption. Group Y contains items that show strong seasonal fluctuations or trends. Group Z contains items whose consumption is particularly irregular and the possibilities of forecasting consumption are limited. Items are classified into groups X, Y, Z according to the value of the coefficient of variation (**Equation 1**).

$$Vx = \frac{S_x}{\bar{x}} \times 100 \qquad (1)$$

where:

S_x - standard deviation

$\bar{x}$ - arithmetic mean

The principle of grouping is shown in **Table 1**. The coefficient of variation essentially determines the very heterogeneity of the statistical population. The greater dispersion and remoteness of individual values from the measure of the mean position will imply a higher degree of variability in consumption [12,13]. The coefficient of variation is determined as the ratio of the standard deviation and the simple arithmetic mean. The procedure for preparing the XYZ analysis can be summarized as follows: preparation of a record of inventory consumption for a certain period, determination of the average and standard deviation, determination of the coefficient of variation, classification of items into individual groups. It is then appropriate to use data for a longer period of time to measure the variability of consumption [2].

Table 1 Principle of group classification

Group	Coefficient of variation (%)
X	0-50 %
Y	50-90 %
Z	over 90 %

The classification into groups as shown in **Table 1** is not the only option. In the case of stock items with smaller fluctuations in consumption, the individual groups can be divided by up to 25 %. The XYZ classification then determines the appropriate strategy for each group corresponding to that level of variability. For Group X, the principles of safety stock can generally be used. For items with extreme variability, other inventory parameters must also be evaluated. In the framework of the conducted research, variability analysis was applied to selected groups of stock items.

3. EXPERIMENTAL WORK

In the framework of the conducted research, selected stock items within the metallurgical production were experimentally assessed. Consumption was analyzed for three categorically different types of stock items. The consumption of ore, basic raw materials (limestone) and two types of selected spare parts was assessed. In the case of ore, the monitored metallurgical enterprise currently uses mainly ore from Ukraine (Ore I.) and Russia (Ore II.). Before heat treatment, the ore undergoes a homogenisation process, where its chemical properties are averaged out. **Table 2** also shows data on the consumption of basic raw materials (limestone $CaCO_3$). Again, two types of basic raw materials used were evaluated. Basic raw materials are used in pig iron production mainly for alkalinity adjustment reasons. Their use is increased when the metallurgical company utilities mainly ore which is acidic in nature. The third group of stock items analyzed is spare parts that are used in production. Iron production in the blast furnace is characterized by its continuous process. Any interruption in the production process can have quite disastrous consequences. Given these facts, the availability of all stock items, including spare parts, is a key factor.

Table 2 Data for the types of stock items assessed

Month	**Consumption of stock items**					
	Ore I. (thousands of tones)	**Ore II. (thousands of tones)**	**Limestone I. (thousands of tones)**	**Limestone II. (thousands of tones)**	**Part I. (pieces)**	**Part II. (pieces)**
January	101	70	23	40	2	0
February	99	68	20	11	0	0
March	102	71	22	34	0	0
April	105	69	19	22	6	4
May	99	50	38	31	1	0
June	100	51	21	20	12	10
July	104	69	23	22	0	0
August	110	72	21	26	4	2
September	99	71	20	24	6	0
October	101	68	29	21	0	0
November	104	65	22	19	0	2
December	102	69	24	8	1	0
Average	102.2	66.1	23.5	23.2	2.7	1.5
S_x	3.1	7.2	5.0	8.6	3.6	2.8
V_x	3.0 %:	10.9 %:	21.4 %:	37.0 %:	133.8 %:	189.5 %:
Group	X	X	X	X	Z	Z

Consumption data for the stock items evaluated are presented in **Table 1** for a period of one year. In the case of ore and limestone, the consumption figures are in the order of thousands of tones, while in the case of spare parts they are in units. The consumption of all types of stock items was analyzed using the method of analysis of variance (XYZ). **Table 1** shows the calculated values required to determine the key parameter, which is the coefficient of variation (V_x). Within Table 1, the calculated mean and standard deviations are given for the data.

Based on these sub-parameters, the value of the coefficient of variation (V_x) was determined through **Equation 1**. On the basis of its value, the individual items are classified into their respective groups. The groupings were made on the basis of the ratings shown within **Table 1**.

4. RESULTS AND DISCUSSION

The analysis of variance that was performed classified the observed types of stock items into their respective groups. The lowest variance value was found for the utilized ore materials (3.0 % and 10.9 %). These items have been classified in Group X. These are raw materials that are used evenly throughout the year. This is due to the essentially constant output of the blast furnace. Regularity in consumption allows for superior planning. In the context of feedstocks, the need to treat and process them before use must also be taken into account in the planning. The evolution of the consumption of the ore I. stock item and its average value is shown in **Figure 1**.

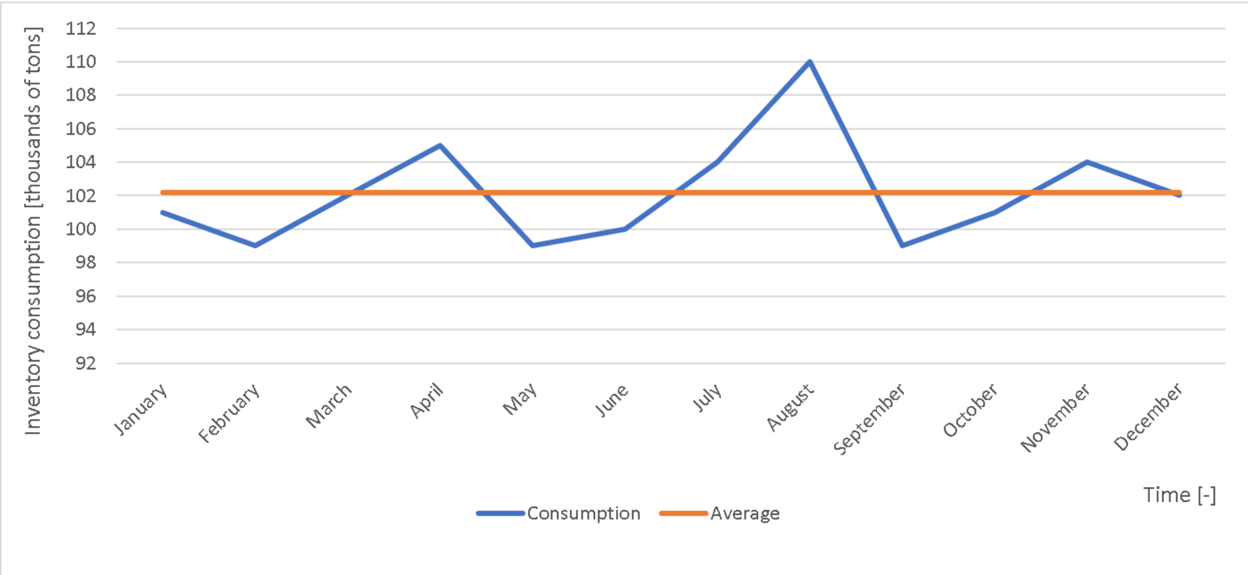

Figure 1 Consumption trend for the stock item - ore I.

In the case of Limestone I and II, the analysis revealed a significantly higher level of variability (21.4 % and 37 %, respectively). Although the items are again classified in group X, the value of the coefficient of variation shows a more pronounced fluctuation in consumption than is the case for ore. This may be related to the ore materials used. Their higher acidity will require the use of more limestone as the alkaline component. At the same time, limestone can also be fed into the blast furnace independently in case of a change in technological parameters. A slightly higher value of consumption variability can therefore be expected for this stock item. The trend in consumption of limestone II is shown in **Figure 2**.

The third type of stock item analyzed was spare parts. In their case, a high variability in consumption was identified for both items under study. This is due to the nature of this group of stock items, which are not used regularly but mainly in the event of unforeseen breakdowns. The coefficient of variation for those items was 133.8 % and 189.5 %. On the basis of these values, the items were assigned to group Z (high variability). In the case of these items with high variability in consumption, the potential consequences of their shortage need to be accurately assessed. In the event that their unavailability should threaten the continuity of production, it is necessary to have an adequate amount of these items in stock. This is even more crucial in metallurgical production due to the continuous nature of the production process. **Figure 3** shows the variability in consumption for a given segment of stock items. In the case of spare parts, it is also possible to use selected methods to predict their future consumption.

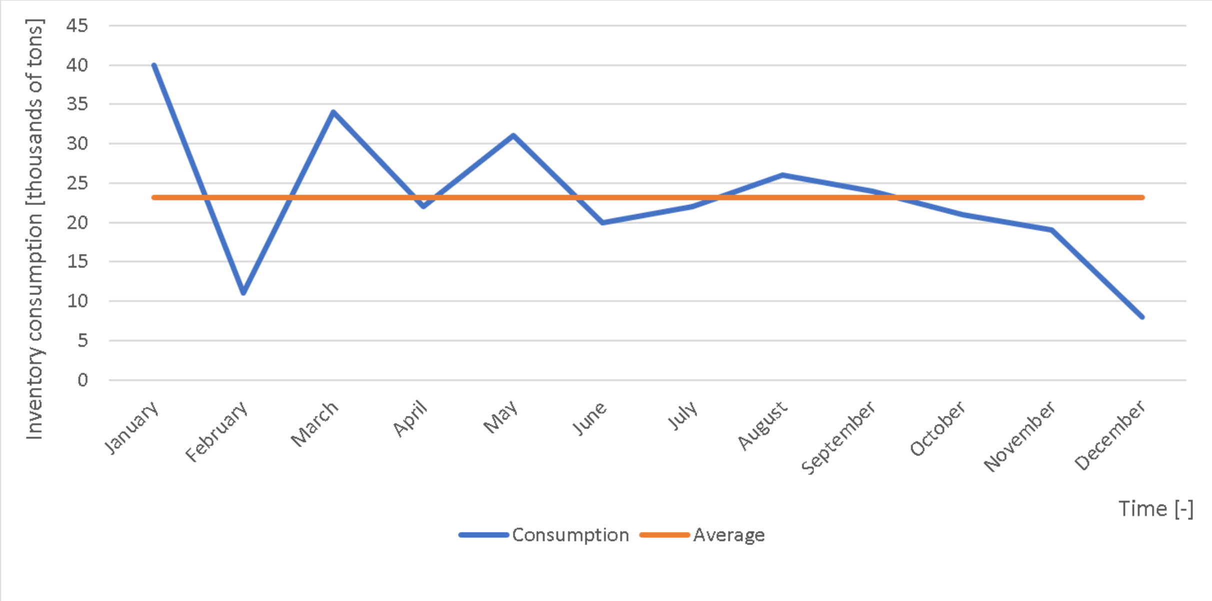

Figure 2 Consumption trend for the stock item - limestone II.

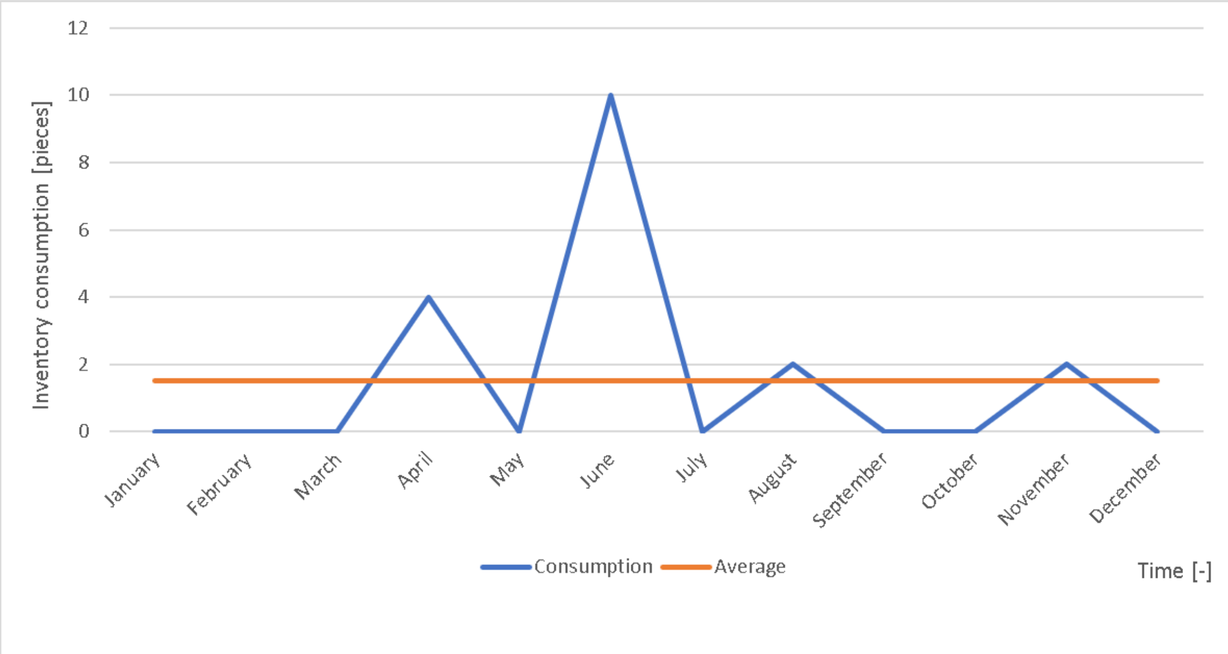

Figure 3 Consumption trend for the stock item - spare part II.

Planning the consumption of spare parts is then crucial when it comes to high-cost stock items. In the metallurgy sector, this can be, for example, selected key parts for the continuous casting section. In some cases, these may be spare parts that are not immediately available or need to be individually manufactured. When it comes to parts that would mean stopping the production process in the event of a failure, it is essential to have these costly and unique parts in stock. The principles for determining safety stock levels can also be used for individual groups of stock items. This is suitable for stock items with a high regularity in consumption where consumption can be confidently predicted. However, it is also necessary to take into account the technological requirements for the preparation of raw materials before their use.

5. CONCLUSIONS

In today's dynamic environment, inventory management is a key aspect that affects a company's competitiveness. Metallurgical production is very specific because of its continuous nature. At the same time, it uses categorically different types of stock items. In the research conducted, analysis was carried out for three different types of stock items. The results confirmed major differences in the consumption patterns of individual stock items. In the case of regularity in consumption, standard logistic concepts can be used to determine safety stock levels. In the case of stock items where there is a high variability in consumption, it is also necessary to assess the potential risks arising from shortages. In general, it is crucial to classify stock items into groups according to their importance and the nature of their consumption, and then define a single strategy for these complex groups. Inventory management in metallurgical production must also take into account the specifics of the production process. The determination of the quantity of stock items required must also take into account the requirements of all production operations through which the raw material passes. Optimizing inventory management can then give the company a long-term competitive advantage.

ACKNOWLEDGEMENTS

The article was created thanks to the project No. CZ.02.1.01/0.0/0.0/17_049/0008399 from the EU and CR financial funds provided by the Operational Program Research, Development and Education, Call 02_17_049 Long-Term Intersectoral Cooperation for ITI, Managing Authority: Czech Republic - Ministry of Education, Youth and Sports.

The work was supported by the specific university research of the Ministry of Education, Youth and Sports of the Czech Republic No. SP2022/27.

REFERENCES

[1] WILLMOTT, P., MCCARTHY, D. *TPM - A Route to WorldClass Performance*. Oxford: Butterworth-Heinemann, 2000.

[2] BAZALA, J. a kol. *Logistika v praxi*. Praha: Verlag Dashöfer, 2004.

[3] HOBBS, D. P. *Lean Manufacturing Implementation: a Complete Execution Manual for any Size Manufacturer*. Boca Raton: J. Ross Publishing, 2004.

[4] WILLIAMS B., TOKAR, T. A review of inventory management research in major logistics journals Themes and future directions. *International journal of logistics management*. 2008, vol. 19, no. 2, pp. 212-232.

[5] LENORT, R., BESTA, P. Logistics of End of Life Electronics Equipment Disassembly. *Acta Montanistica Slovaca.* 2009, vol. 14, pp. 268-274.

[6] GHIANI, G., LAPORTE, G., MUSMANNO, R. *Introduction to Logistics Systems Planning and Control*. New Jersey: John Wiley and Sons, 2004.

[7] LENORT, R., BESTA, P. Hierarchical Sales Forecasting System for Apparel Companies and Supply Chains. *FIBRES & TEXTILES IN EASTERN EUROPE*. 2013, vol. 21, no. 6, pp. 7-11.

[8] FELD, W. M. *Lean manufacturing: tools, techniques, and how to use them*. Boca Raton: St. Lucie Press, 2000.

[9] STOUGHTON, B. *The Metallurgy of Iron and Steel*. London: Hard Press, 2012.

[10] LU, L. Important iron ore characteristics and their impacts on sinter quality – a review. *Mining, Metallurgy & Exploration*. 2017, vol. 32, pp. 88-96.

[11] KOŠTURIAK, J., FROLÍK, Z. *Štíhlý a inovativní podnik*. Praha: Alfa Publishing, s.r.o., 2006.

[12] TOŠENOVSKÝ, J. *Statistika v řízení jakosti*. Ostrava: DTO, s.r.o., 1995.

[13] FOTR, J., ŠVECOVÁ, L. *Manažerské rozhodování*. Praha: Ekopress, s.r.o., 2010.