ABC ANALYSIS IN SPARE PARTS WAREHOUSE

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Abstract: The goal of this study was to carry out single- and multi-aspect ABC analyses in spare parts warehouse. Two cases were considered within the investigations. First case concerned stock with the required safety stock, whereas in the second case, safety stock was neglected. Comparison of the results for both analyses was to show how the level of safety stock impacts on selection of more profitable and most often replenished areas and for which groups of product range warehousing brings highest financial profits. Pointing to key areas of warehouse parts will allow for further development of the company oriented towards profits and improved customer service. It will allow for investing in more cost-effective areas and exclusion of those which freeze the capital.

Keywords: ABC analysis, data normalization, utility function.

1. Essence of ABC Analysis

Maintaining of particular inventory level is one of the major goals in warehouse management [1.]. Spare parts warehouse management provides a problematic aspects for planning. On the one hand, advance purchase and storage is connected with bearing inventory costs, causes freezing of financial resources and, moreover, the chances are the stock will never be used. On the other hand, lack of stock is associated with the risk of costs of machine stoppage time in the case of sudden breakdown. In order to avoid such situations, a list of spare parts i.e. safety stock, critical for inventory, is prepared. It allows for elimination of costs of machinery stoppage.

Except for safety stock, other spare parts being an essential element of determination of future warehouse needs are kept in warehouses. Difficulties connected with planning their level are associated with unpredictability of the frequency of replacement of parts, thus this stock should be analysed in a statistical and economical way [2.].

One of the methods used for analysis of material demand is ABC analysis, which is based on Pareto principles. It assumes that 20% of products covers 80% of share in general demand for goods [3.].

This method *provides focus on the materials whose supply takes higher positions in total value of material consumption and total value of turnover in companies* [4.]. It divides warehouse product range into three categories. First category is a group of 20% of goods marked A, including items of highest (80%) share in general supply. Second group is formed by the goods whose share in total supply amounts to more than 80%, marked B. Third group, marked C, encompasses the rest of goods, whose share in total supply amounts more than 90% [3.].

ABC method of categorization of inventory items allows to focus on most expensive items (or other items strategic to the enterprise) [5.]. The obtained results aim to indicate items whose purchase and storage in the warehouse is the most or the least beneficial for companies. The results of analysis might help identify these machines and equipment which are most prone to failure.
Use of ABC method allows for planning of material demand towards most profit-generating goods with higher stock rotation rates. Detailed description of ABC method will be provided in the form of case study for warehouse in certain enterprise.

2. Case study

The investigated warehouse is used for storage of spare parts and for maintaining flow i.e. continuity of production through securing parts for machines and tooling which are used throughout production cycle. The time period from which source data originate encompassed the time from January to September 2009.

Case I

The warehouse comprises several thousand inventory items for ABC analysis which were divided according to the areas they are used. These areas include:

- automation,
- hydraulics,
- electricity,
- electronics,
- mechanics,
- pneumatics,
- others.

The analysis focused only on safety stock.
The goal of the investigations was to localize the areas of spare parts which generate highest profits and are the most often replenished during the investigated period of time. The obtained results are supposed to constitute starting point for planning of the level and structure of spare parts stock. In order to realize the assumptions, the criteria were determined to allow for finding right solution.
These criteria include:

- sales figures,
- rotation rate,
- value of the generated profit on sales.

Selection of goals and criteria is closely related to managers' demand for particular results (the goal could equally be to point to goods with highest inventory levels or highest costs of storage; then, criteria would also change). After determination of criteria, next stage is to assess them on the basis of source data.
Sales figures is given by a total of product of unit price and quantity for each item within range of products.
The total of sales figures for these items comprises sales figures for the determined groups of products: [6.]

$$S = \sum S_i , \tag{1}$$

where

S - sales figures for individual groups of products determined on the basis of material consumption documents.

Profits on sales is a difference between the sales figures and the costs: [6.]

$$ZS = \sum S_i - \sum K_z \tag{2}$$

where

K_z - total cost of purchase of a group of items calculated on the basis of material consumption documents.

Stock rotation rate means how many times a year the stock can be replenished: [7.]

$$RZ = \frac{S_i}{\overline{Z}} \tag{3}$$

where

$\overline{Z}$ - mean level of stock for the investigated period of time.

Highest value of this index involves lower value of capital frozen in inventory. The type of stock is also essential since in the case of safety stock warehouse the value of rotation can be very low or even at zero level. This might mainly concern those items which are outdated. However, not all the stocks with lower rotation rate will be redundant. Maintaining stock, despite low rotation, can be justified by the need for safety stock which is supposed to ensure immediate customer service [8.].
The values for criteria for each group from product range are presented in Table 1.

Table 1. Values of individual criteria for each group of products. [10.]

Groups of items	Quantity (pcs)	Sales (PLN)	Profit (PLN)	Rotation (times)	Mean inventory (PLN)
Automation	875	385237.89	66385.65	0.220	1753998.23
Electronics	2633	50907.99	7320.14	0.029	1753998.23
Electricity	7484	224540.60	34293.20	0.128	1753998.23
Hydraulics	12254	341286.24	55423.29	0.195	1753998.23
Mechanics	27517	901586.45	113208.00	0.514	1753998.23
Pneumatics	846	131476.09	18823.74	0.075	1753998.23
Others	9097	234387.18	53422.35	0.134	1753998.23

For each criterion, single-criterion analysis was consecutively carried out i.e. categorization of areas of products into groups A, B and C (Table 2.). Order of modifying actions was consistent with appearance of each column in the Table.

Table 2. Categorization of the areas of spare parts according to the criterion of sales. [10.]

Group of items	Sales	% share in total sales	Cumulated share	Group
Automation	385237.89	16.98	57	A
Plumber	341286.24	15.04	72	A
Other	234387.18	10.33	82	B
Electrician	224540.60	9.89	92	B
Pneumatics	131476.09	5.79	98	C
Electronics	50907.99	2.24	100	C
TOTAL	**2269422.44**	**100.00**		

Division of areas of spare parts according to the criterion of profit on sales and rotation criterion was made in the same manner as in the case of criterion of sales figures. The results for each analysis are presented in Fig. 1.

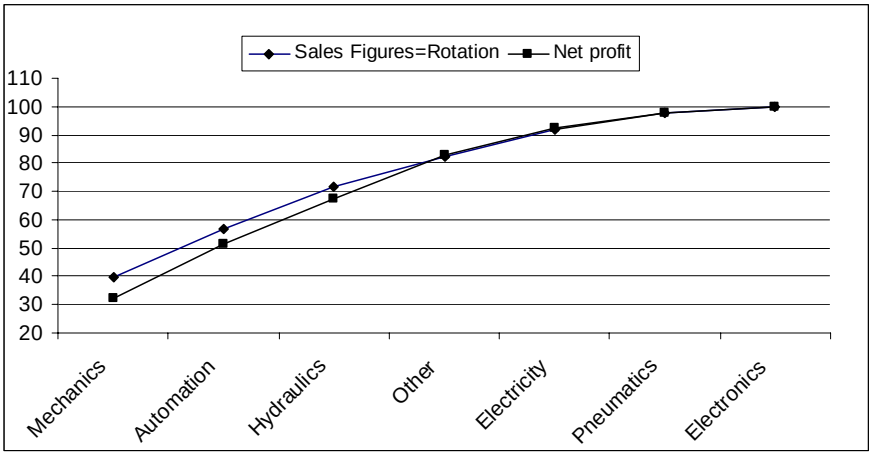

Figure 1. Graphical representation of the result of analysis. [10.]

The results from single-criterion ABC analysis show that profit, rotation rate and sales figures were highest for mechanics, automation and hydraulics areas. 40% of goods on the average generate ca. 80% of profit, sales figures and rotation.
As results from the comparison of current results, for which all the criteria are treated equally, the company should invest in spare parts from mechanics, automation and hydraulics areas since, firstly, they generate the most of financial profits and, secondly, they are the most often replenished i.e. they do not freeze financial means for too long and do not cause rise in inventory costs.
On the basis of the same data one can carry out multi-criterion analysis, whose task is to indicate the products which show best values for the criterion depending on managers need. This means that a weighted average is calculated for each criterion. This causes distinguishing of those spare parts which are not necessarily of high sales figures but should generate lowest inventory cost i.e. high rotation rate.
Therefore, another stage in the analysis is to calculate total value of criteria and their weights i.e. to conduct multi-criteria analysis. In the investigated warehouse, the goal is to search for those products which generated highest profits and were most often replenished. Adequately to the goal, weights which have subjective nature were determined, which means that their level depends on the level of importance, to the enterprise, of individual criteria during general evaluation. The values of weights are, respectively, 20%, 40% and 40%.
Before total values are calculated, they must be normalized (Table 4.). Normalization is carried out according to the formula: [9.]

$$k = \frac{k - k_{min}}{k_{max} - k_{min}} \tag{4}$$

where

k – value of criterion before normalization,
max – maximal value of criterion,
min – minimal value of criterion.

The normalized values should match the range of [0,1].

Table 4. Normalized values of criteria. [10.]

Group of items	Sales figures	Profit on sales	Rotation
Mechanics	1.00	1.00	1.00
Automation	0.39	0.56	0.39
Hydraulics	0.34	0.45	0.34
Others	0.22	0.44	0.22
Electricity	0.20	0.25	0.20
Pneumatics	0.09	0.11	0.09
Electronics	0.00	0.00	0.00

On the basis of normalized data, utility function should be determined for each area of products, given by the formula: [9.]

$$F = \sum_{i} (w_i \cdot k_i) \tag{5}$$

where

w_i – weights of individual criteria,
k_i – values of criteria.

This function allows for totalling up of the values of individual criteria for each group of items and for making decision on the most beneficial group of products (Fig. 2.).

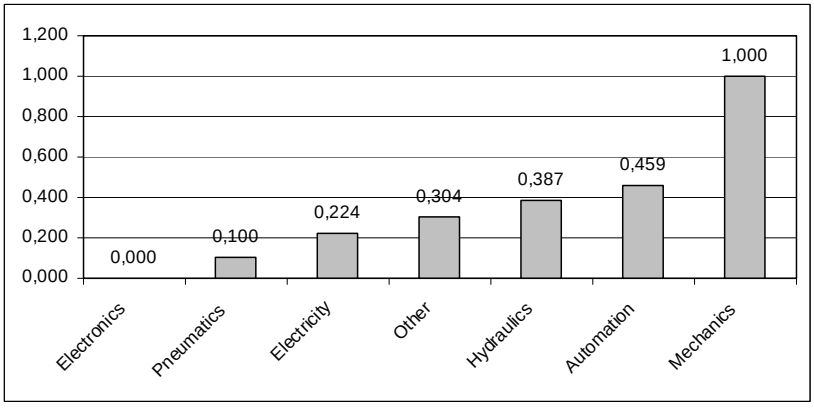

Figure 2. Graphical representation of aggregated utility function.[10]

The results of multi-criteria analysis converge with previous results of single-criterion analysis, which proves accuracy of the decision concerning selection of the most profitable groups of items which are also characterized with highest demand. At this level of investigations, sales figures were the least significant criterion of choice. In consideration of the numerical data obtained for utility function, one can observe that the area of mechanics clearly dominates over other areas of items.
It should be remembered that the results of analysis concern the inventory levels including safety stock. Therefore, the amount of safety stock in general stock in the warehouse can impact on the assessment of groups of items. The decisions made at this stage can be

inaccurate since the level of safety stock in required on the basis of the contract. This causes that the demand for parts resulting from the requirement of storage might be higher than for the remaining part of non-obligatory stock. Therefore, company does not have to make choice which spare parts to buy additionally in order for them to generate fast profits and high level of service.
In order to assess how the level of safety stock impacts on generating profits and on rotation, ABC analysis should be carried out exclusively for the stock devoid of safety stock i.e. current stock (case II).

Case II

From previous source data the items should be excluded which have to be stored obligatory in the warehouse and then, on the basis of this level another calculation should be made.
The goal of another analysis is to obtain answers to the following questions:

- how does safety stock impact on profitability or rotation in individual areas?
- do the results of both analysis converge?
- are the results from case I determined by the level of safety stock?

Fig. 3. and 4. present percentage contribution of groups of parts in general stock in the warehouse and after elimination of safety stock according to the number of inventory items since it is impossible to exclude the impact of quantity in safety stock on change in the results of ABC analysis in Case II.

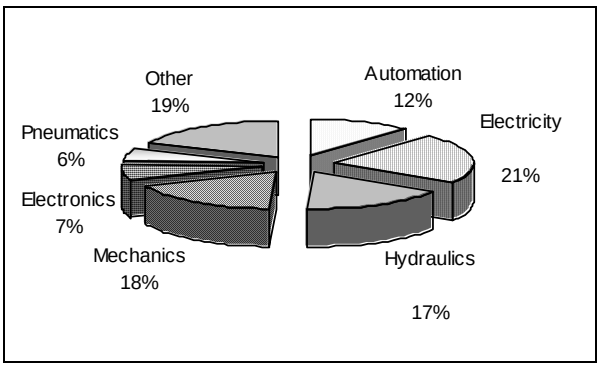

Figure 3. Percentage quantity of items in the groups for the whole stock. [10.]

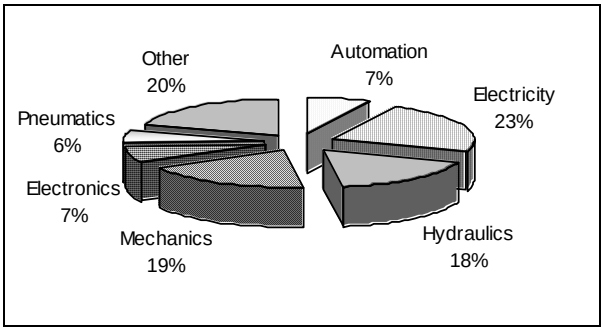

Figure 4. Percentage quantity of items in the groups for the rest of stock. [10.]

Comparison of Fig. 3. and 4. reveals that safety stock do not impact quantity in the area of pneumatics and electronics; their percentage is similar for both cases. In the area of mechanics, hydraulics and other parts, insignificant, one-percent change was observed, whereas in electronics, the share increased by 2%. The highest difference was observed for automation since its level decreased by as much as 5%, which means that the highest level of safety stock occurs for this group. The area of mechanics remained almost at the same level, the results of future ABC analysis should not change much.
ABC analysis for current stock was carried out analogically to analysis of stock containing safety stock. Final results of single-criterion analyses are presented in Fig. 5.

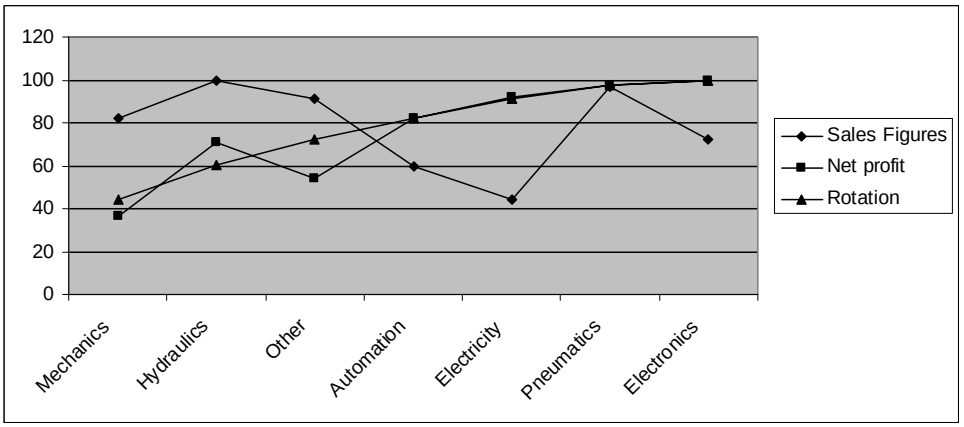

Figure 5. Graphical representation of the results for single-criterion analysis. [10.]

For the same data after their normalization, aggregated value containing weights for individual criteria were obtained and utility function was determined. The results are compared in Table 7.

Table 7. The results of multi-criteria ABC analysis for current stock. [10.]

Group of items, alphabetically	Sales figures	Profit on sales	Rotation	Utility function
Mechanics	0,18	1,00	1,00	0,836
Electricity	1,00	0,22	0,15	0,350
Hydraulics	0,00	0,44	0,33	0,310
Others	0,15	0,45	0,22	0,299
Automation	0,33	0,24	0,18	0,235
Pneumatics	0,09	0,11	0,09	0,099
Electronics	0,22	0,00	0,00	0,045
WEIGHTS	**0,2**	**0,4**	**0,4**	

In single-criterion analysis of current stock, area of mechanics, hydraulics and other parts generates ca. 80% of the profit; in comparison to other areas, they are most often replenished in the warehouse during the investigated time period. For sales figures criterion, group A is formed by the groups of items from electricity, electronics and automatics areas, comprising ca. 80% of sales figures for all the goods.

Comparison of these results to those obtained in case I (Fig. 1.) reveals obvious change for the criterion of sales figures, where areas in group A are completely different. For the other two criteria, the change occurs only for automation area, which, as a current stock, moves to group B and is exchanged by the area of other parts. The reason for differences in the results is the level and the value of safety stock, by which total stock was reduced.
Summing up the results of multi-criteria analysis for current stock, area of mechanics generates highest profits and it is most often replenished. As far as the demand from customers for the goods not included in safety stock is concerned, it is highest for mechanics and electricity, thus procurement company should focus on these areas. They generate highest sales figures and lowest costs of warehousing through frequent rotation.
Comparison of the results of multi-criteria analyses for the cases in question reveals areas of warehouse which show highest value for all the criteria (Fig. 6.).

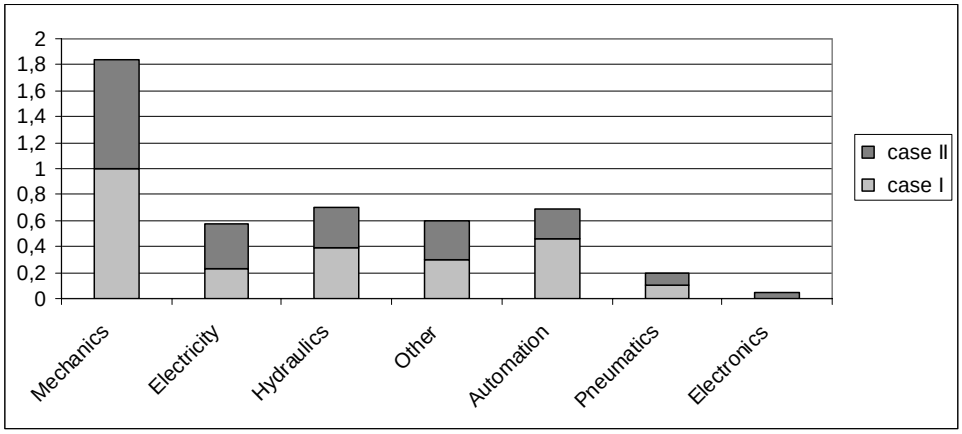

Figure 6. Comparison of the results of multi-criteria analysis for both cases. [10.]

Results of multi-criteria analyses reveals domination of mechanics in both cases. This might result from minimal level of safety stock in this area. Mechanical spare parts generate ca. 45% of profit and 40% of rotation rate among other parts. Another areas which are characterized by highest demand include hydraulics, automation and electricity and others.

3. Summary

Single-criterion ABC analysis carried out in the warehouse differs for both of the investigated cases. In consideration of total inventory level for spare parts and the defined criteria, area of goods such as mechanics, automatics and hydraulics form group A. This means that, for each of the investigated criteria, the same results of analysis were obtained. Therefore, it is assumed that the abovementioned areas dominate in terms of sales figures, profit and rotation. In the case of analysis focused on current stock only (without safety stock), the results of the analysis were similar for criterion of profit and rotation. Changes occurred in the case of automatics, which was excluded from A group in exchange for the group of other parts. This change was caused by the level of safety stock, which was highest for automatics. In the case of sales figures, the dominating areas included electricity, automatics and electronics. This difference might result from the margin for a particular product, which is lower for these areas as compared to the possible profit. If warehouse managers were to perform warehousing activities only towards the results of single-criterion

analysis, they should focus on storage of parts from mechanics and hydraulics groups, which generate highest profits and are characterized by higher rotation.
The results of multi-criteria analysis for total inventory converge with the results of single-criterion analysis for this case. They point to investing in spare parts from mechanics, hydraulics and automatics groups. These area generate highest profits, show highest sales figures and are most frequently renewed from among the range of goods in the warehouse. Multi-criteria analysis for current stock inventory levels was similar to the results of single-criterion analysis, where mechanics and hydraulics were included in group A for the criterion of profit and rotation. The group of goods prevailing in terms of values of all the criteria was extended by electricity area, which, devoid of safety stock, also takes part in generation of advantageous financial result in the investigated warehouse.
Since maintaining of safety stock in this example is obligatory and its level is 'superiorly' defined, the results of multi-criteria analysis for the stock in total will suit the needs in the warehouse better. Therefore, management of the groups of goods should focus on storage of spare parts from mechanics, hydraulics and automation. The listed groups of items constitute a development potential of the company which is the owner of the analysed warehouse.
The conducted analysis of both cases aimed to e.g. point to differences resulting from storage of safety stock, which was done within the study. Finding a solution for warehouse areas which generate the most of benefits, however, emphasizes one of the investigated cases.
The areas of pneumatics and electronics bring lowest profits, they are rarely replenished and their storage in the warehouse generate unnecessary additional costs. The company should maintain only safety stock for this groups of items.
ABC analysis is a key element of efficient inventory management, particularly if quantity of the stored items is considerably high. Conducting analysis allows for categorization of the products performed on the basis of certain grouping criteria. This leads to distinguishing of the most important, from the standpoint of the defined criteria, items, whose storage should ensure enhanced efficiency of the warehouse. ABC analysis also defines those groups of items whose storage should be limited to minimum due to high inventory costs.

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