Acta logistica - International Scientific Journal about Logistics
Volume: 11 2024 Issue: 3 Pages: 461-472 ISSN 1339-5629

https://doi.org/10.22306/al.v11i3.532 *Received: 26 Jan. 2024; Revised: 28 May 2024; Accepted: 03 July 2024*

Utilization of the intersection of ABC and XYZ analysis in stock planning in the warehouse by Covid period

Iveta Kubasakova
Department of Road and Urban Transport, Faculty of Operation and Economics of Transport and Communications, University of Žilina, Univerzitná 8215, 010 26 Žilina, Slovak Republic, EU, iveta.kubasakova@uniza.sk
Jaroslava Kubanova
Department of Road and Urban Transport, Faculty of Operation and Economics of Transport and Communications, University of Žilina, Univerzitná 8215, 010 26 Žilina, Slovak Republic, EU, jaroslava.kubanova@uniza.sk (corresponding author)

Keywords: mobility, warehouse, stock planning.
Abstract: The aim of this article is to find the most appropriate inventory storage strategies in a new warehouse according to the Covid period. Based on the company's analysis and preferences, we have concluded that the most suitable inventory storage strategy will be ABC, XYZ and penetration analysis according to which the inventory will be produced to the company's warehouse. The result of the paper is the intersection of these analyses. Based on the penetration analysis, we found that AAXX group has 27% of the product items. The CXX group of manufactured items has a high turnover, but accounts for only 1% of the total items. The AA category has a low turnover but accounts for only 0.63% of the product items. As a result of the penetration analysis, we concluded that the categories AAXX, AAX, AXX, AX and BXX are suitable to be produced in large quantity in stock. For categories AAY, AY, BX and BY, it is recommended to plan the production of items for stock with caution and not to produce them in such large quantities. The regularity of the analysis of these methods is very important. The intersection of ABC and XYZ analyses indicates the regularity of applying these methods due to the existence of excess or non-replenishable stocks.

1 Introduction

The Group's systems within the company are the same worldwide, but each subsidiary can set them up according to its own requirements, as the systems offer several possible strategies. Each process can be carried out in several ways, so it is up to each branch to decide how it achieves the result, which is always the same. In this thesis, the commonly used ABC and XYZ analysis methods and their interpenetrations have been used. These methods were implemented on the stock data with some variations as several categories were used due to the large volume of material in large volumes. Based on the methods used in this way, it will be possible to categorize the different items in the company's warehouse differently. However, the use of these methods must be repeated in view of the changing product range in the company in terms of customer interest. In order not to create 'dead stock' in the warehouse by meaningless ordering for production, which would be easily available to the warehousemen and would not be of interest to the customer. The work also results in less frequent application of ABC and XYZ intersection analysis, which results in better use of handling equipment and there will be fewer empty paths for items that are stored in inappropriate locations. It all depends on which practices are more acceptable for a given country.

2 Literature review

Most distribution centres use simple activity-based classification (ABC) as a method of managing the classification of warehouse work, which can lead to increased operating and warehousing costs or a reduction in the efficiency of the circulation of goods. In addition, many studies in recent years have focused on solving ABC classification problems using a multi-criteria concept, method, or model; however, limitations can be found in these studies.

In the article [1], the authors found that with the help of the tool of dynamic systems it is possible to evaluate the effect generated by the project implementation with regard to the variables that directly and indirectly affect the cash flow of the examined company. Through the performed simulation, it can be stated that the warehouse management project increased the company's cash flow over a period of five years. However, the results are only valid if top management agrees to strengthen employee training processes and greater investment in technologies that enable faster and more efficient logistics processes.

Safety is one of the key aspects of the successful transport of cargo. In the case of road transport, the dynamics of a vehicle during normal events such as braking, steering, and evasive manoeuvre [2]. Safety is directly linked to the state of the infrastructure. How infrastructure affects transport performance can be seen in this case study [3].

The authors found that the ABC / XYZ analysis helps to improve the inventory management system in the supply chain, where proper inventory management is lacking. Monthly data for one year are collected and supplemented by primary data obtained through direct observation and discussion with the company's management. ABC, XYZ and ABC / XYZ matrix analyses were performed to determine the items to consider when implementing Kanban. The analysis shows that the Kanban system can improve inventory costs by about 75% [4-7].

Proposes an analysis of the ABC-XYZ type modified with the observed deficit of goods. An illustrative example shows that the classical ABC-XYZ algorithm underestimates the value of goods when a deficit was observed; the magnitude of the coefficient of variation is also underestimated. The new method corrects this bias and recalculates the total gain and the coefficient of variation [8,9].

Inventory classification requires the use of several criteria to manage different inventory management functions. In this study [10], a new classification algorithm called the FNS (functional, normal and small) algorithm is developed, which combines the classic ABC classification with a new grouping strategy. In their study, the ABC classification method is enriched and combined with the proposed FNS algorithm to create nine different inventory classes. To achieve this goal, the classic ABC classification method is integrated with expert systems, clustering, and fuzzy logic methods [11].

This article [12] demonstrates how to classify inventory items using the TOPSIS model ("Order Preference Technique by Similarity to Ideal Solution"). The case study considered parameters such as unit costs, delivery time, consumption rate, etc. Using TOPSIS, the items are classified into categories A, B and C. The suitability, practicality, and effectiveness of the TOPSIS method used in the ABC classification were assessed using the analysis of variance (ANOVA) technique. A simulation model was used to compare the proposed model with the model of the traditional ABC classification technique.

The goal of inventory management is to decide on the appropriate level of inventory. In practice, it is not possible to check all stocks with equal attention. The most widely used inventory system is the ABC classification system. The ABC-FC authors' approach in Article [13] is implemented based on the required data. The results of their study show that 59 items are identified as a very important group, 69 items as an important group and the remaining 64 items as an unimportant group. Comparing the ABC-FC results with the original data, they found that their ABC-FC analysis showed high classification accuracy.

The aim of this paper [14] is to propose a regression approach to obtain a set of weights for ABC multicriteria inventory analysis that differ according to classification criteria but are common to all inventory items and follow a predetermined descending ordering scheme given the relative importance of classification criteria.

These documents propose a new approach to the ABC classification, which includes a non-compensatory aggregation procedure based on the ELECTRE III simplified method for calculating the score of each inventory item. The non-compensatory aggregation scheme means that an item's poor score in some important criteria cannot be compensated by its high performance in other criteria. A comparative study carried out on two actual data sets shows that the classification of the items produced by their proposed approach produced the lowest value of inventory costs among the items produced by all the classification models tested [14,15].

To bridge the gap that arises in the effective way of classifying inventory items into ABC analysis classes, articles has been created that proposes a model to adapt to the possibility of incorrect classification in the information. The maximum probability method is used to estimate the parameters in the model. The proposed method is verified by simulated and real data sets. The results show that the proposed method performs better in terms of classification accuracy and can learn the classification rules of experts from the training set and use them to classify new items [16,17].

These papers present a new approach to solving the problem of multicriteria classification of ABC stocks using stochastic multicriteria acceptability analysis. All possible preferences between the evaluation criteria were considered. Due to the fact that even with a certain preference, it is difficult to reach a group consensus on the exact values of the weights together with each criterion, they calculated the preference-specific intervals for each preference and then formulated a stochastic decision problem [18-20].

Authors in these papers describes a differentiated inventory management model of the ABC-XYZ classification matrix in relation to the inventory of a commercial enterprise. Inventory management is a very current topic, as the company has several branches, co-operates with many suppliers and the range of office supplies includes more than 30,000 items. The ABC-XYZ stock analysis of this business allowed them to identify inventory optimization strategies and identify groups that should be removed from the product range and, conversely, should be available in stock due to constant demand [21,22].

The issue of assortment optimization, whether in commercial companies or warehouses, is relatively topical. These papers show the analysis performed using the ABC - XYZ matrix of a specific product group and suggests possible optimization pathways [23,24].

A lot of authors discuss the multi-criteria ABC inventory classification and the methodology for standardizing each criterion and its weight in the classification. The weight for each criterion is based on a simple exponential assignment of smoothing weights. Including the weight for each criterion and normalizing the data, a score is obtained for each item and classification is performed based on the normalized score. This process of standardizing criteria and weights is easy for inventory managers to under-stand in practice [25-29].

Inventory management (IMP) procedures predominate in the organization and control of inventory in a company. The aim of these studies is to measure the performance of companies by determining the impact of distribution turnover and inventory automation on competitive strength and operational efficiency. The study concludes that IMP has a significant impact on the company's performance and also contributes to the existing body of knowledge by helping inventory management professionals in the manufacturing industry [30-32].

3 Material and methods

Some countries have old WMS, e.g., Romania does not yet have a radio frequency system in place, so they are working in an off-line version. This means that before the start of the change, the warehouse handler receives a printed paper from the team leader, on which he has listed the codes of the products and the racking or pallet positions that need to be handled. The warehouse manipulator gradually marks the work performed and then hands over this paper to the team leader, who records these movements into the system. This way of working is much slower than the online system, where each warehouse handler has his own reader, with which he scans barcodes and the changes made are immediately visible in the system. Also, other small regional warehouses e.g., in Portugal, Spain or southern Italy may have the old system. Currently, four versions of this system are possible: old paper, old radio frequency, new paper and new radio frequency version. The analysed warehouse in Považská Bystrica uses the highest version of the system, i.e., a new radio frequency version. The new system will be gradually introduced in all branches, but it is proceeding from the largest plants.

Thus, the system provides some variability, but only in some things. As for customer requirements, they are centralized and cannot be changed, we can only adjust individual processes.

Another difference may be the different age requirements of the products. While in some countries, for example to Saudi Arabia, it is possible to ship only those products that are not older than half a year, within Europe there is a common requirement for products to be two years old [33,34]. As for specific customers this limit is set at nine months. If the products exceed the maximum permissible age for the customer, even by only one day, it is not possible to ship them, no exception is allowed here. Subsequently, these products are blocked in the system and can be sold, for example, to another country, where the sensitivity for the age of the products is not so high.

We can also compare prices for renting warehouse space in Slovakia and abroad. For this comparison, we chose Germany because the company's headquarters and central warehouse are located here. The company tries to have warehouse space under its direction, but it is not always possible, such as a warehouse in Považská Bystrica. The amount of rent for this warehouse is 3 €/month/m^2. The amount of rent for warehouse space in Germany as well as in Slovakia depends on several factors, e.g. from location, warehouse equipment, rental period, etc. If we take, for example, the city of Munich, we find warehouses whose rental amount ranges from 3 €/month/m^2 to 8 €/month /m^2 [35].

Method ABC analysis using to products a storage area of company

This analysis categorizes individual products stocks according to the article number parameter. This parameter was chosen because it best describes the nature of the problem. All tires for trucks and cars accepted into the warehouse in Považská Bystrica in the monitored period were included in the analysis. In this analysis, the individual items were classified into four categories, namely: AA, A, B, C. These categories were chosen because they correspond best to the production volume.

In order to compile this analysis, it was first necessary to modify the data so that it was possible to work with them. We worked with the file, which contained data on the number of the article, the number of articles and the number of products received for storage in a given month, their size, brand and other information. For the purposes of this analysis, data on the article number and the number of products received were sufficient.

Initially, it was necessary to recalculate each item from each piece to the number of pallets by month for both types of pallets. This is necessary because when designing the warehouse, we are not interested in the number of stored products, but the number of stored pallets. In this section, we worked with the "stock" and "number of products per pallet" files. Here it was necessary to combine these two files and, using the VLOOKUP function in Excel, to assign to each article the number of products on one pallet.

After knowing how many tires of a given article were on one pallet and how many of these tires were in stock, it was easy to calculate how many pallets of each article were in stock for a given period.

And therefore (1):

$$\textbf{number of pallets} = \textbf{number of stocks} / \textbf{number of tires per pallet} \quad (1)$$

We have rounded the result down to the whole number, because the number of stored pallets is always an integer and the rest of the tires, with which it is no longer possible to fill the entire pallet, should be stored on shelves as fractional pallets.

In the calculations, it was necessary to distinguish two types of pallets: OP1 and KSP. These pallets differ only in internal dimensions. While KSP pallets are CMR pallets, they have a less robust construction than OP1 pallets, which are pallets still used by Matador. When designing a warehouse, it will not be a problem that there are two different types of pallets, because the external dimensions have both types the same and will therefore be able to be stacked on top of each other. The only disadvantage is that the OP1 pallets have slightly smaller internal dimensions due to their more robust construction and are there-fore mainly used for storing car products. However, this is not the rule, we will also find several types of truck tires stored in them. On the contrary, truck products are mainly stored in KSP pallets. CMR therefore had to create its own name for the pallets used in one company in order to be able to distinguish them in the system from the KSP pallets given by the headquarters, as a different number of products would fit in each. We worked with a total of 1 577 articles to compile the analysis, with the total number of products to be included being 9 906 460.

The following table (Table 1) shows, by way of example, the conversion of several items from pieces to the number of pallets.

Table 1 Conversion of articles to the number of pallets [authors]

Article	Pallet	Number of tires	Number of pieces per pallet	Number of pallets	Rounded
3410270000	OP1	325	50	6.50	6.00
3410560000	OP1	373	32	11.66	11.00
3410890000	OP1	268	32	8.38	8.00
3410990000	OP1	210	32	6.56	6.00
3411110000	OP1	573	60	9.55	9.00
4120640000	KSP	266	18	14.78	14.00
4120690000	KSP	887	22	40.32	40.00
4220490000	KSP	143	18	7.94	7.00
4220580000	KSP	1 282	22	58.27	58.00
4220760000	KSP	78	18	4.33	4.00
3413060000	OP1	432	36	12.00	12.00
3420220000	OP1	5	50	0.10	0.00
3420650000	OP1	245	60	4.08	4.00
3420940000	OP1	163	50	3.26	3.00
3434880000	OP1	59	60	0.98	0.00
3435130000	OP1	160	32	5.00	5.00
3435140000	OP1	291	60	4.85	4.00
3435200000	OP1	690	36	19.17	19.00
3435330000	OP1	486	32	15.19	15.00
5251380000	KSP	201	8	25.13	25.00
5251670000	KSP	267	8	33.38	33.00
5251680000	KSP	371	8	46.38	46.00
5304200000	KSP	227	10	22.70	22.00
5304210000	KSP	164	10	16.40	16.00

Subsequently, the number of pallets received was sorted in descending order from the largest to the smallest, and the cumulative percentages were calculated. Based on the accumulated percentages, we gradually assigned individual categories to the items (Table 2). The percentage limits set for each category were set by the company, based on their experience in planning and organizing warehouses.

Table 2 Categorization of articles [authors]

Article	Number of pallets	Pallets received in %	Cumulated pcs	Cumulated %	Category
5320820000	19 502	5.3890	19 502	5.3890	AA
3561010000	1 537	04257	70 596	19.5077	
15810370000	802	0.2216	121 588	33.5983	
3629830000	508	0.1404	179 648	49.6420	
4703130000	506	0.1398	180 154	49.7818	A
3450020000	367	0.1014	222 668	61.5297	
15545650000	324	0.0895	235 335	65.0300	
4512240000	299	0.0826	242 497	67.0090	
3585310000	299	0.0826	242 796	67.0917	B
15506440000	240	0.0663	266 780	73.7191	
4515600000	220	0.0608	274 535	75.8621	
3553340000	168	0.0464	296 871	82.0342	
5320860000	143	0.0395	308 916	85.3626	
4516800000	143	0.0395	309 059	85.4021	C
15810710000	124	0.0343	318 360	87.9722	
3451320000	106	0.0293	327 139	90.3981	
4520570000	44	0.0122	354 103	97.8491	
3446250000	1	0.0003	361 887	100.0000	
⋮	⋮	⋮			
Total sum	361 887	100.00			

In Table 3, the resulting ABC analysis is performed, where the percentage of articles, the number of articles, the number of pallets received and the percentage of received pal-lets are given separately for each category.

It is clear from the table that there are a small number of articles in groups AA and A, but if we look at the number of pallets received, only group AA alone includes almost the same number of pallets as the other three groups combined. The largest representation of articles is in the last group and therefore in group C. There are up to 937 articles, but after conversion to pallets we see that there are only 52 971 (Figure 1). When designing a warehouse, it will be necessary to take this into account and place this group furthest from the picking zone. This will also be taken into account when creating pallet blocks. In terms of per-centage revenue, it can be seen that almost half of all pallets received per year are in the AA category, which should be the most important and most beneficial for the company.

Table 3 ABC analysis [authors]

Category	% of articles	Number of articles	Number of pallets received	% of received pallets
AA	10.1	160	179 648	49.6
A	10.1	160	62 849	17.4
B	20.3	320	66 419	18.4
C	59.4	937	52 971	14.6
SUM	100.0	1 577	361 887	100.0

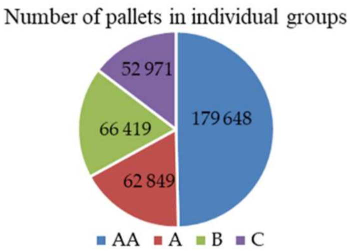

Figure 1 Frequency in individual groups [authors]

It may seem that in group A there is a small number of received pallets compared to group B, but there are half as many items in it and thus a larger storage block can be cre-ated without the problem of handling a pallet with a particular item. So it does not hap-pen that the handler will have to disassemble entire stacks of pallets in order to get to one particular pallet. Another advantage is that this saves space, as it will not be necessary to create so many handling aisles.

For the analysis to remain effective, it must be evaluated regularly, as the level of stocks is constantly changing, and therefore the placement of items within categories will also change.

Warehouse layout

When we had recalculated all the items for the number of pallets, we made a clear table where we arranged the categories, months and number of pallets received. This sorting was necessary to see how many pallets from a particular category are accepted into the warehouse each month and to be able to further adjust the layout of the entire warehouse accordingly (Table 4). Another important step was to determine the average, minimum and maximum stock values for each category.

Table 4 Overview of categories by months[authors]

Category→ Month↓	AA	A	B	C	Sum	Average
01.10.2018	10 017	3 798	4 667	7 237	25 719	6 430
01.11.2018	10 502	4 108	4 357	5 940	24 907	6 227
01.12.2018	9 718	3 673	4 057	5 935	23 383	5 846
01.01.2019	8 933	3 975	4 672	6 421	24 001	6 000
01.02.2019	7 961	3 513	4 185	6 402	22 061	5 515
01.03.2019	7 399	3 480	3 849	5 431	20 204	540
01.04.2019	7 290	3 847	4 464	5 851	21 452	5 363
01.05.2019	8 339	3 994	4 400	5 869	22 206	5 651
01.06.2019	9 501	4 179	4 947	6 519	25 146	6 287
01.07.2019	11 248	4 541	5 660	7 673	29 122	7 281
01.08.2019	12 389	5 379	6 068	7 886	31 722	7 931
01.09.2019	8 408	3 941	5 049	6 872	24 270	6 068
01.10.2019	9 391	3 894	4 860	6 427	24 572	6 143
Sum	121 096	52 332	61 280	84 463	319 161	
Average	9 315	4 025	4 710	6 497		
MIN	7 290	3 480	3 849	5 431		
MAX	12 389	5 379	6 068	7 886		

Based on the previous table, the sizes of pallet blocks for individual zones were determined. The average number of pallets in the warehouse in individual categories and how many items are in the given category were important for us. The size of the zone is just in other words how many stacks of pallets will be in the zone. The number 6 in the calculation will mean the maximum possible number of pallets in the stack. We calculate it as follows (2):

number of stacks = number of pallets in a group / 6 (2)

Before we start calculating the number of stacks, it will be necessary to determine how many rows of pallets will be in the block (Table 5).

Table 5 Number of rows of pallets in a block [authors]

Category	AA	A	B	C
Number of rows of pallets in a block	5	4	2	1

Once we know how many rows of pallets will be in each block, we can proceed to the calculations of the number of stacks and then calculate how many blocks will be needed to be able to store all these pallets. In the calculations, we will again consider the average monthly number of pallets in each category.

number of blocks = number of stacks / number of rows of pallets in a block (3)

Table 6 Calculation of the number of blocks and stacks [authors]

Category	Calculation	Number of stacks	Calculation	Number of blocks
AA	9 315 / 6	1 553	1 553 / 5	311
A	4 025 / 6	671	671 / 4	168
B	4 710 / 6	786	786 / 2	393
C	6 497 / 6	1 083	1 083 / 1	1 083
SUM		4 093		1 955

Table 6 shows that we will need 1 553 stacks to store average monthly AA stocks, which will be in 311 pallet blocks. It is necessary to store an average of 671 stacks of pallets in group A, which will be arranged in 168 blocks. There will be 786 stacks of pallets in group B and 1 083 stacks in group C.

Further calculation will be necessary to find out how much space we will need to store average stocks in each category (Table 7). As we know that the pallet dimensions 240 x 120 x 150 cm, i.e., one pallet occupies an area of 2.88 m^2, we can calculate what minimum area needs to be set aside for each category. The calculation will be as follows:

area size = number of stacks in the category * 2.88 m^2

Table 7 Required area for each category [authors]

Category	AA	A	B	C	Sum
Area needed to store average stocks (m^2)	4 472.64	1 932.48	2 263.68	3 119.04	11 787.84
Area needed to store maximum stocks (m^2)	5 947.20	2 581.92	2 912.64	3 785.28	15 227.04

Handling alleys

In general, the width of the aisle must be at least 40 cm wider than the widest dimension of the forklift trucks used in the warehouse or the largest width of the load handled in the warehouse. In the conditions of this warehouse, this would mean that the largest dimension of the forklift truck is 3.886 mm, in which case the width of the aisle would have to be at least 4.286 mm.

For our design, we will recalculate the ratio between the storage place and the aisles using a coefficient of 0.7, which means that there will be 0.7 pallets per 1 m2. The coefficient was obtained by calculating the average of the ratios between storage places and aisles in each category. These ratios are different because there is a different number of stacks in a row in each category. While there are up to 5 rows of pallets in category AA, there is only one row in category C. When we imagine in this category that we start to stack stacks of pallets from the wall, immediately after the first stack, an aisle must follow and again a stack of pallets. which, however, is already touching the back of another stack. In category AA, up to five stacks of pallets are stored in a row in our case, and only after these five stacks is an alley. So, the more rows of pallets we have behind us, the better the use of storage space. The coefficients for each category are as follows (3):

- AA: coefficient 0.9,
- A: coefficient 0.75,
- B: coefficient 0.60,
- C: coefficient 0.55.

This means that if we have a storage area of 34 539 m^2, we will calculate as follows:

$$34\,539\ m^2 * 0.7 = 24\,177\ m^2$$

From the calculation, we found that the area on which the pallets can be stored has a size of 24 177 m2, so the handling aisles will occupy an area of 10.362 m2. If we wanted to find out how many pallets can be stored in the warehouse at one time, we would divide the area designated for storage by the area occupied by one pallet, and thus:

$$24\,177\ m^2 / 2.88\ m^2 = 8\,394.79 \text{ pallets}$$

It is clear from the calculation that it is possible to store 8 394 pallets in one layer in this warehouse at a time. However, if we made stacks out of all the pallets, we would multiply this number by six (maximum possible stack height) and we would get a result of 50.364 pallets.

Racks

In addition to the zoning of the warehouse according to categories AA, A, B and C, it will also be necessary to design a rack that is designed for partial pallets and is located at the picking zone. This rack is usually 1.5 times the number of articles. As there are 1 577 items in stock, the procedure will be as follows:

1 577 * 1.5 = 2 365.50 pallets.

For these racks, the maximum permitted height is five pallets on the rack. It will be necessary to store 2 366 pallets at the picking zone, when we divide it by the number 5 we get: 2 366 / 5 = 474 stacks. It will therefore be necessary to prepare 474 racks with 2 366 pallet places. The total area required for one rack position is 3.12 m^2. The area (Table 8) required for the rack is:

474 stack * 3.12 m^2 = 1 478.88 m^2

Table 8 Total warehouse area [authors]

Name	Area (m^2)
Total storage area	34 539
Net pallet storage area, of which:	24 177
- rack regal	1 478.88
Handling alleys	10 362
Administrative and technical premises	1 243

Method XYZ analysis using to products a storage area of the company

For a more comprehensive inventory classification, XYZ analysis was also added as another method for processing the warehouse design. This analysis, unlike the ABC analysis, does not look at the number of stocks, but at their turnover. As with the ABC analysis, we considered all items. In this case, we worked with the same inventory. In this case, the classical XYZ analysis was extended to four categories, namely XX, X, Y and Z.

The first step was to determine the average annual stock of each item. This stock ranged from 1 to 10 846 item per year. Subsequently, we assigned exports to each item in addition to inventory. Once the average stock was quantified and matched with exports, the turnover time and turnover of the articles could be calculated.

Turnover time was calculated first. Turnover time means the average number of days during which stocks are tied up in the company until they are used up or, in our case, sold. In general, the best possible turnaround time for a company is the lowest time. It is calculated according to the formula (4):

turnover time = (average stock * 365) / export (4)

In this case, we got values from 0.62 to 160.198 days. At these extreme values, we find items that were produced, stored, and not removed at all or only a small part was removed during the period under review. These are a few dozen items that are characterized by the fact that the company ordered a new dimension of items, but when they were made, they found that there was not much demand for them and thus remained in stock.

If we know how many days the average turnover time of individual items lasted, we can continue by quantifying the turnover, which means how many times a year the company's stocks turn. We will use the formula for this (5):

turnover = export / average stock (5)

Turnover in our calculations ranges between 0 and 592 times a year. Again, there are extremes created because the items were stored before the period under review, there is a minimum of stocks, but many of them have been released from the warehouse. The following table (Table 9) exemplifies a few items recalculated according to turnaround time and turnover.

Table 9 Turnaround time and turnaround [authors]

Article	Average stock in pcs	Export in pcs	Turnover time in days	Turnover
15496930000	10 846.00	39 575	100.03	3.65
15852680000	7 381.94	111 000	24.27	15.04
4733570000	6 478.62	72 457	32.64	11.18
4511770000	6 334.29	10 640	217.29	1.68
3539290000	5 292.00	103 651	18.64	19.59
4515570000	5 055.29	5 036	366.40	1.00
15810490000	4 869.00	46 002	38.63	9.45
15808960000	4 721.08	46 347	37.18	9.82
4280470000	4 705.77	40 725	42.18	8.65
3567930000	4 496.69	26 449	62.05	5.88
4512000000	4 401.43	15 458	103.93	3.51
15853410000	4 334.33	43 780	36.14	10.10
3732070000	4 314.00	63 145	24.94	14.64
15852830000	4 312.83	68 548	22.96	15.89
4511980000	4 297.00	13 348	117.50	3.11
3732350000	3 534.73	24 389	52.90	6.90
3575980000	3 499.08	13 735	92.99	3.93
3561010000	3 406.69	65 312	19.04	19.17
15810220000	3 387.89	25 424	48.64	7.50
4514920000	3 367.00	1 000	1228.96	0.30
15852630000	3 340.67	76 708	15.90	22.96
15810120000	3 305.38	33 166	36.38	10.03
3592480000	3 216.54	2 654	442.36	0.83
⋮	⋮	⋮	⋮	⋮

After consultation with the company, the boundaries of the individual categories were set as follows:

- XX: 15%,
- X: 15%,
- Y: 30%,
- Z: 40%.

These limits were determined in the same way as in the ABC analysis according to the number of articles. Thus, for category XX, 15% was multiplied by the total number of articles.

Acta logistica - International Scientific Journal about Logistics
Volume: 11 2024 Issue: 3 Pages: 461-472 ISSN 1339-5629

To be able to assign a category to each article, it was necessary to rank the turnover from the largest to the smallest and then categories could be assigned, with the first 15% of articles falling into category XX, another 15% into category X, the following 30% into category Y and the remaining 40% to category Z. Turnover values are by category in the following ranges:

- XX - from 17.03 to 592 times a year,
- X - from 11.36 to 17.02 times a year,
- Y - from 5.35 to 11.28 times a year,
- Z - from 0 to 5.34 times a year.

In the end, we made a clear table (Table 10), where the individual groups are converted to the number of articles, the number of items and the percentage expression of the category on the total number of tires.

Table 10 Clear table of articles

Category	% of articles	Number of articles	Number of items exported	% of export
XX	15	256	3 928 527	40
X	15	256	2 545 939	26
Y	30	510	2 580 739	26
Z	40	682	851 543	8
	100.00	1,704	9 906 748	100.00

It can be seen from the resulting table that up to 40% of all exported items belong to the category with the highest turnover, i.e., to category XX. Items that fall into this category need to be placed near the picking zone as part of the stock distribution, as they will be picked much more often than items in groups X, Y or Z. This step will again increase the productivity of order picking. There are approximately the same number of exported items in categories X and Y, which are around 26%, but in terms of the number of articles, there are half as many articles in category X as in category Y. These articles can be described as medium speed. Within the warehouse, it is appropriate to place them outside the category XX. The last category Z is characterized by low turnover and consists of only 8% of all items that left the warehouse during the period under review (Figure 2). Items from this category are recommended to be placed deeper in the warehouse, as they will not be picked up as often as items from other categories.

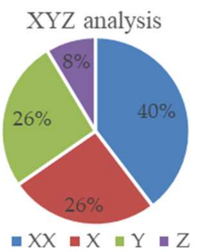

Figure 2 XYZ analysis [authors]

The purpose of this analysis was to point out the regularity of demand for specific articles. Like the previous analysis, this one should be re-evaluated on a regular basis in or-der to maintain storage efficiency.

4 Results and discussion

Application of ABC/XYZ analysis

ABC and XYZ analyzes are often used together in practice. These analyzes comple-ment each other and thus disseminate information on solved stocks. By combining them, we get more accurate information about how individual stocks behave and how they need to be approached. At the same time, we will find out whether items that are produced in large quantities really belong to high-turnover and, conversely, those that are produced in smaller quantities are low-turnover. We get a total of 16 categories that stocks can fall into, they are:

- AAXX, AAX, AAY, AAZ,
- AXX, AX, AY, AZ,
- BXX, BX, BY, BZ,
- CXX, CX, CY, CZ.

Using Excel, we combined the two analyzes and created two 4 x 4 matrices with the number of articles and the number of items in each group.

Table 11 ABC/XYZ number of articles [authors]

	AA	A	B	C	Sum
XX	81	61	60	48	250
X	36	52	93	76	257
Y	33	29	121	306	489
Z	10	18	46	507	581
Sum	160	160	320	937	1 577

Table 11 and Table 12 show the number of articles in each category. This table confirms the theory that articles that are produced in large quantities also have high consumption. Of course, there are also articles that fall into the AA category, i.e., they are produced in bulk, but their turnover is low, but it is only 0.63% of articles (Figure 3). It is recommended to produce as few pieces as possible in stock for these items, so that there is no demand for them. Most articles are in the CZ group, but if we look at Figure 3 below, we find that after calculating the number of items, it is only 5% that fall into this group.

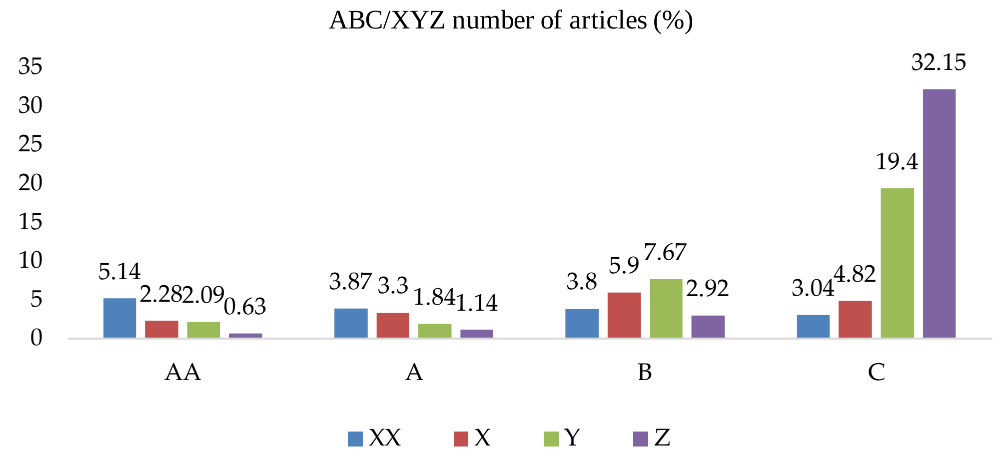

Figure 3 ABC/XYZ number of articles [authors]

Table 12 ABC/XYZ number of articles [authors]

	AA	A	B	C	Sum
XX	2,625,905	727,184	382,607	138,574	3,874,270
X	1,013,508	629,458	616,942	260,054	2,519,962
Y	751,844	371,124	680,063	681,227	2,484,258
Z	163,441	153,178	185,657	525,694	1,027,970
Sum	4,554,698	1,880,944	1,865,269	1,605,549	9,906,460

Also, in the case of conversion of articles to the total number of items, it was con-firmed that the most produced items have also the biggest turnover (Figure 4). The largest numbers of items are thus arranged around the diagonal.

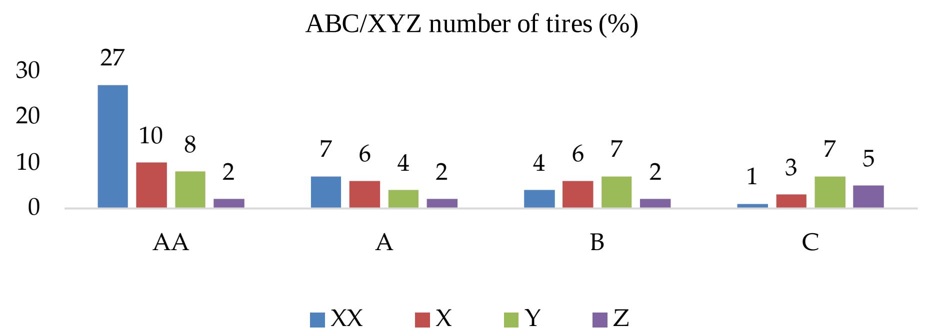

Figure 4 ABC/XYZ number of items [author]

The AAXX category represents up to 27% of the total number of items produced, which is the most of all categories. It is immediately followed by the AAX and AAY categories. In the case of category AAZ, consideration should be given to the need to produce items for stock. However, in this category, as mentioned above, there are items that have been ordered in large quantities by car companies and subsequently there has been no demand for them. The lowest percentage of items is in the CXX category, i.e. in the category where few items are produced but have a high turnover, but it is only 1% of the total number of items.

An article is currently in a certain category does not mean that it will be in the same category, e.g. in two years. This is due to the constant development of the market, hence the change in demand and the portfolio of company. That is why the regularity of analysing these methods is very important. Otherwise, items that are no longer in demand could still be in stock and placed as close as possible to the picking zone. As a result, they will unnecessarily take up space in the warehouse with other items that are in high demand. If the company adheres to the distribution of stocks according to these methods, it will be guaranteed an efficient method of storage.

5 Conclusion

The conclusion will be presented outputs of article and formulate the benefits of the proposal and any recommendations for companies.

This article was aimed at finding the most suitable strategies for storing stocks in new warehouse. This search was preceded by various analyzes of the warehouse, which is currently used in the company, but will soon be replaced by our proposed warehouse.

Based on these analyzes and the company's preferences, we have come to the conclu-sion that the most appropriate strategy for storing stocks will be ABC analysis. The dis-tribution of stocks according to this analysis will ensure that the items that are accepted into the warehouse in the largest numbers will be stored as close as possible to the picking zone and, conversely, the items produced in lower numbers will be placed deeper in the warehouse. Furthermore, this division will make it possible to reduce the ratio between the storage site and the handling aisles, so that in categories where many items are received but there is a low number of articles (category AA), we can make storage blocks where the ratio of handling aisles as in categories where many different items are received (category C), so it is not possible to create as large a storage block as in the first case. This is due to the fact that the handling of individual pallets would be more demanding and lengthy. If the pallet with the required item were stored, for example, only in the third row of pallets, there would be an unnecessary waste of time.

As another method, XYZ analysis was chosen, which had the task of providing more detailed information about the stocks, and thus to point out the regularity of demand for specific items. Its essence is the distribution of stocks according to turnover, i.e., according to how often specific items are released from the warehouse. In category XX, there are such types of items that are exported from the warehouse most often and are therefore best sold. There are 256 articles here. Also in category X there is the same number of articles, but al-ready a lower number of exported tires. Group Y includes items that have a medium ex-port frequency, and group Z includes items that are sold the least. From this analysis, we found that up to 40% of items belong to the high turnover group. Excluding extreme val-ues, items falling into this category are exported from the warehouse 17 to 52 times a year. Both categories X and Y account for 26% of items exports, so this is a medium turnover. The only difference between these categories is the number of articles. There are half as many articles in category Y as in category X. The last category accounts for only 8% of to-tal items exports, but there are 40% of all articles. It is therefore a low-turnover category.

At the end of the article, these two analyzes were combined to create a comprehensive overview inventories. From the result of this analysis, it is possible to recommend which items are suitable for production in larger quantities for stock and for which, on the con-trary, it is appropriate to minimize stocks. Categories AAXX, AAX, AXX, AX and BXX can be included in the group for which it is appropriate to produce items in large quantities in stock. For categories AAY, AY, BX and BY, it is recommended that the planning of the production of items for stocks be done carefully and not produced in such large quantities, because there are higher fluctuations in demand. For the remaining categories, it is rec-ommended to produce as few items as possible in stock, as they are the least stable in terms of demand. This analysis confirmed that the items produced in the largest numbers are also the most in demand. This is illustrated in particular by the AAXX category, which includes up to 27% of all items produced per year. The opposite was also confirmed, and thus that the items with the least turnover are also the least produced. This analysis can be helpful in production planning and demand forecasting.

References

[1] ORTIZ, S.J., PAREDES-RODRÍGUEZ, A.M.: Evaluación sistémica de la implementación de un sistema de gestión de almacenes (WMS), *Revista UIS Ingenierías*, Vol. 20, No. 4, pp. 145-160, 2021. https://doi.org/10.18273/revuin.v20n4-2021012 (Original in Spanish)

[2] GNAP, J., JAGELČÁK, J., MARIENKA, P., FRANČÁK, M., KOSTRZEWSKI, M.: Application of MEMS Sensors for Evaluation of the Dynamics for Cargo Securing on Road Vehicles, *Sensors*, Vol. 21, No. 8, pp. 1-31, 2021. https://doi.org/10.3390/s21082881

[3] GNAP, J., SENKO, Š., KOSTRZEWSKI, M., BRÍDZIKOVÁ, M., CZŐDÖROVÁ, R., ŘÍHA, Z.: Research on the Relationship between Transport Infrastructure and Performance in Rail and Road Freight transport—a Case Study of Japan and Selected European Countries, *Sustainability*, Vol. 13, No. 12, pp. 1-20, 2021. https://doi.org/10.3390/su13126654

[4] GOBACHEW, A.M., KITAW, D., BERHAN, E., HAASIS, H.: ABC/XYZ Analysis for Kanban System Implementation in Pharmaceutical Supply Chain: A Case of Ethiopian Pharmaceutical Supply Agency, *International Journal of Information Systems and Supply Chain Management*, Vol. 14, No. 3, pp. 63-78, 2021. https://doi.org/10.4018/ijisscm.2021070104

[5] SIBANDA, H., POOE, D.: Enhancing Supply Chain Performance through Supply Chain Practices, *Journal of Transport and Supply Chain Management*, Vol. 12, pp. 1-13, 2018. https://doi.org/10.4102/jtscm.v12i0.400

[6] MARION, G.: What Is Kanban in Small Business Supply Chain? The Balance Small Business, [Online], Available: https://www.thebalancesmb.com/what-is-kanban-2221436 [20 Jan 2024], 2021.

[7] ZIMON, D., MADZÍK, P.: Standardized Management Systems and Risk Management in the Supply Chain, *International Journal of Quality & Reliability Management*, Vol. 37, No. 2, pp. 305-327, 2020. https://doi.org/10.1108/ijqrm-04-2019-0121

[8] ZENKOVA, Z., MUSONI, W., TARIMA, S.: *Accounting for deficit in ABC-XYZ analysis*, 5th International Conference on Logistics Operations Management (GOL) 2020, pp. 1-6, 2020. https://doi.org/10.1109/gol49479.2020.9314731

[9] TEUNTER, R.H., BABAI, M.Z., SYNTETOS, A.A.: ABC classification: Service levels and inventory costs, *Production and Operations Management*, Vol. 19, No. 3, pp. 343-352, 2010.

[10] AKTEPE, A., ERSOZ, S., TURKER, A., BARISCI, N., DALGIC, A.: An inventory classification approach combining expert systems, clustering, and fuzzy logic with the ABC method, and an application, *The South African Journal of Industrial Engineering*, Vol. 29, No. 1, pp. 49-62, 2018. https://doi.org/https://doi.org/10.7166/29-1-1784

[11] LIN, H.L., MA, Y.Y.: A New Method of Storage Management Based on ABC Classification, *SAGE Open*, Vol. 11, No. 2, pp. 1-19, 2021. https://doi.org/10.1177/21582440211023193

[12] BHATTACHARYA, A., SARKAR, B., SANAT, K.M.: Distance-based consensus method for ABC analysis, *International Journal of Production Research*, Vol. 45, No. 15, pp. 3405-3420, 2007. https://doi.org/10.1080/00207540600847145

[13] CHING-WU, C., GIN-SHUH, L., CHIEN-TSENG, L.: Controlling inventory by combining ABC analysis and fuzzy classification, *Computers & Industrial Engineering*, Vol. 55, No. 4, pp. 841-851, 2008. https://doi.org/10.1016/j.cie.2008.03.006

[14] KARAGIANNIS, G., PALEOLOGOU, S.M.: A regression-based improvement to the multiple criteria ABC inventory classification analysis, *Annals of Operations Research*, Vol. 306, pp. 369-382, 2020. https://doi.org/10.1007/s10479-020-03788-1

[15] DOUISSA, M.R., JABEUR, K.: A non-compensatory classification approach for multi-criteria ABC analysis, *Soft Computing*, Vol. 24, pp. 9525-9556, 2020. https://doi.org/10.1007/s00500-019-04462-w

[16] FU, Y., LAI, K.K., MIAO, Y., LEUNG, J.W.: A distance-based decision-making method to improve multiple criteria ABC inventory classification, *International Transactions in Operational Research*, Vol. 23, No. 5, pp. 969-978, 2016. https://doi.org/10.1111/itor.12193

[17] ZHANG, Z., LI, K.W., GUO, X., JUN, H.: A probability approach to multiple criteria ABC analysis with misclassification tolerance, *International Journal of Production Economics*, Vol. 29, p. 107858, 2020. https://doi.org/10.1016/j.ijpe.2020.107858

[18] FLORES, B.E., WHYBARK, D.C.: Multiple Criteria ABC Analysis, *International Journal of Operations & Production Management*, Vol. 6, No. 3, pp. 38-46, 1986. https://doi.org/10.1108/eb054765

[19] LI, Z., WU, X., LIU, F., FU, Y., CHEN, K.: Multicriteria ABC inventory classification using acceptability analysis, *International Transactions in Operational Research*, Vol. 26, No. 6, pp. 2494-2507, 2019. https://doi.org/10.1111/itor.12412

[20] DURBACH, I.N., CALDER, J.M.: Modelling uncertainty in stochastic multicriteria acceptability analysis, *Omega*, Vol. 64, pp. 13-23, 2016. https://doi.org/10.1016/j.omega.2015.10.015

[21] KADZIŃSKI, M., TERVONEN, T., FIGUEIR, A.J.R.: Robust multi-criteria sorting with the outranking preference model and characteristic profiles, *Omega*, Vol. 55, pp. 126-140, 2015. https://doi.org/10.1016/j.omega.2014.06.004

[22] TRUBCHENKO, T.G., KISELEVA, E.S., LOSHCHILOVA, M.A., DREVAL, A.N., RYZHAKINA, T.G., SHAFTELSKAYA, N.V.: Application of ABC and XYZ Analysis to Inventory Optimization at a Commercial Enterprise, *SHS Web of Conferences*, Vol. 80, pp. 1-6, 2020. https://doi.org/10.1051/shsconf/20208001007

[23] KISELEVA, E.S., BERKALOV, S.V., DOROSHENKO, S.V., KHMELKOVA, N.V., PETROVA, G.A., KRUKOVA, E.M., KARELINA, A.A.: *The Importance of Customers' Character Accentuations*, III International Scientific Symposium on Lifelong Wellbeing in the World - WELLSO 2016, The European Proceedings of Social & Behavioural Sciences, pp. 318-328, 2017. http://dx.doi.org/10.15405/epsbs.2017.01.43

[24] NATSYPAYEVA, E., IVASHINA, M., EFREMOVA, N., CHISTYAKOVA, S., MELNICHENKO, V.: Optimization of the assortment of retailers based on the use of ABC and XYZ analysis: Access la success, *Calitatea*, Vol. 21, No. 179, pp. 157-160, 2020.

[25] SCHOLZ-REITER, B., HEGER, J., MEINECKE, C., BERGMANN, J.: Integration of demand forecasts in ABC-XYZ analysis: Practical investigation at an industrial company, *International Journal of Productivity and Performance Management*, Vol. 61, No. 4, pp. 445-451, 2012. https://doi.org/10.1108/17410401211212689

[26] MISHRA, A., LSONI, M.: ABC analysis technique of material towards inventory management, *International Journal of Management Research and Reviews*, Vol. 2, No. 12, pp. 2092-2097, 2012.

[27] MILLSTEIN, M.A., YANG, L., LI, H.: Optimizing ABC inventory grouping decisions, *International Journal of Production Economics*, Vol. 148(C), pp. 71-80, 2014.

[28] GRIMASHEVICH, O.N., IVASHINA, M.M., NATSYPAEVA, E.A., ANDREEVA, T.A., KOLESNIKOVA, D., KONTOROVICH, E.: Improvement of industrial enterprise quality management system based on risk-oriented approach implementation, *Quality - Access to Success*, Vol. 20, No. 169, pp. 42-46, 2019.

[29] ZHUKOV, O.V., SAZONOV, S.P., ONOPRIENKO, Y.G., MERSHIEVA, G.A.: The methodology for using ABC/XYZ analysis for inventory management in an enterprise ERP system, *Bulletin of VGUIT*, Vol. 1, No. 71, pp. 477-484, 2017.

[30] PANIGRAHI, R.R., JENA, D., TANDON, D.: Inventory management and performance of

manufacturing firms, *International Journal of Value Chain Management*, Vol. 12, No. 2, pp. 149-170, 2021. https://doi.org/10.1504/ijvcm.2021.10033598

[31] HE, S., ZHANG, J., ZHANG, J., CHENG, T.C.E.: Production/inventory competition between firms with fixed-proportions co-production systems, *European Journal of Operational Research*, Vol. 299, No. 2, pp. 497-509, 2022. https://doi.org/10.1016/j.ejor.2021.06.041

[32] LI, W., WENG, L., ZHAO, K., ZHAO, S., ZHANG, P.: Research on the Evaluation of Real Estate Inventory Management in China, *Land*, Vol. 10, No. 12, pp. 1-29, 2021. https://doi.org/10.3390/land10121283

[33] SHARMA, S., ABOUEE-MEHRIZI, H., SARTOR, G.: Inventory Management under Storage and Order Restrictions, *Production and Operations Management*, Vol. 29, No. 1, pp. 101-117, 2020. https://doi.org/10.1111/poms.13097

[34] MOKHTARI, H.: Joint ordering and reuse policy for reusable items inventory management, *Sustainable Production and Consumption*, Vol. 15, pp. 163-172, 2018. https://doi.org/10.1016/j.spc.2018.07.002

[35] POLIAK, M., SVABOVA, L., KONECNY, V., ZHURAVLEVA, NA., CULIK, K.: New paradigms of quantification of economic efficiency in the transport sector, *Oeconomia Copernicana*, Vol. 12, No. 1, pp. 193-212, 2021. https://doi.org/10.24136/oc.2021.008

Review process

Single-blind peer review process.