CHAPTER 2
ANALYSIS AND OPTIMISATION OF INVENTORY IN ENTERPRISES

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Abstract

The analysis and control of inventory in an enterprise is important from the point of view of both costs and customer service management. The appropriate selection of methods of inventory replenishment influences significantly the two mentioned elements. In terms of the costs it enables their optimisation owing to the maintenance of the right products in inventory at an appropriate level, and the inventory replenishment at the relevant time and in the volume adequate to the needs. The proper inventory management affects the appropriate level of availability of the products and thus, the customer service level. This chapter will serve the purpose of presentation of the rules of analysis and optimisation of the inventory, including the selection of the methods of inventory replenishment for products characterised by relatively regular issues.
Keywords: inventory management, inventory replenishment methods, optimisation

2.1. Introduction

Ensuring the availability of the products is an important element for an enterprise from the point of view of maintaining the appropriate customer service level. The rules for ensuring availability are a consequence of the accepted strategy of management of this area in a business.

Selection of the appropriate variant of ensuring availability is determined by many supply chain factors. The most important criteria, which determine the rules of ensuring product availability, are defined in table 2.1.

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Tab. 2.1 Criteria for selection of variants for ensuring product availability

Criterion	**Possible values according to the criterion**		
Frequency of product issues	Very often	Often	Rarely
Costs of deliveries	Attributable to the enterprise	Attributable to the Supplier	
Is the equipment for transporting the product required?	Yes	No	
Has the enterprise got such equipment?	Yes	Yes	
Who is responsible for the organisation of the transport?	Enterprise	Supplier	
Product storage site	Enterprise	Supplier	
Product owner	Enterprise	Supplier	
Party responsible for taking a decision on the volume and moment of ordering of a spare part	Enterprise	Supplier	

Source: own study based on (Kolińska, 2015, p. 80)

The determination of the rules of ensuring availability for each product requires a number of analyses and management decisions. Nevertheless, this stage is important in the context of taking a decision on which products are to be kept in inventory and which are not to be kept in inventory. This chapter touches upon the subjects related to the products which are kept in inventory in an enterprise.

2.2. Analysis of inventory

The product inventory analysis is related to the evaluation of several issues:

- the moving and non-moving product inventory level,
- the coverage ratio,
- the ABC analysis according to the volume/value of issues,
- the XYZ analysis according to the structure of issues,
- the 123 analysis according to the frequency of issues.

The moving and non-moving product inventory level

As the first step, the performance of the analysis of the inventory levels requires the identification of moving and non-moving products. The moving products are considered to be such products which were in inventory during the period under analysis and were issued from the enterprise's warehouse. On the other hand, the products which were in inventory during the period under analysis and could be received at the warehouse facility but were not subject to issues are considered to be non-moving products.

The analysis of non-moving products requires checking the inventory levels of the respective products, the length of the period during which the particular products were not issued, the chances of selling the given product, e.g. because of its shelf life. Upon carrying out the detailed analysis, it is necessary to take actions aimed at elimination of this type of the inventory. The examples of actions may be as follows:

- the blocking of the purchase of such products – elimination of the possibility of increasing the non-moving inventory,
- the sale of non-moving products – despite the lack of profit, elimination of the products which remain in inventory for a longer period of time, and thus, generate costs related to the maintenance of inventory, and the chance to release the capital frozen in the inventory,
- scrapping/disposal of non-moving products – just like in the case of sale – the reduction of the costs of inventory maintenance and the possibility of releasing the capital frozen in the inventory.

The analysis of moving products requires further specification. The analysis of the inventory level per se is not sufficient in this case. It is necessary to associate the inventory levels with the implemented level of issues and the product classification. Only such analysis may constitute the basis for drawing correct conclusions and taking decisions on the management of inventory and evaluation of their level.

Coverage ratio

The coverage ratio determines the number of days for which the inventory of assortment items is sufficient at the average daily consumption. It is calculated on the basis of the following formula:

$$WP_i = \frac{Z_{śr}}{Wr_w} \cdot d \quad (1)$$

where:

$Z_{śr}$ – average inventory value during the analysed period,

Wr_w – value of issued items during the analysed period,

d – number of days during the analysed period.

Drawing correct conclusions on the basis of the indicated coverage ratio requires confrontation of this value with, among others, lead times of the respective products, the policy of increased purchases at a lowered price implemented in the enterprise and the applied inventory replenishment rules.

ABC analysis

The ABC analysis, also called the Pareto method, allows the definition of the items with a high volume/value of issues during the analysed period. This is important from the point of view of management of inventory of these items as their inventory also demonstrate a high volume/ value. From among the defined groups, group A, which includes assortment items that constitute about 20% of the entire assortment but generate 80% of the total volume/value of issues according to the assumptions of the method, is of key significance. The other two groups are, in principle, more numerous, but their percentage share in the total value is significantly smaller. In terms of the volume and value, the percentage share is usually as follows: group B – 30% in the overall number of items and 15% in the overall value; group C: 50% and 5% respectively. The quantity ratios for the respective groups are not rigid however, their value may differ. Nevertheless, the percentage share of the respective groups in influencing the total value is constant (Ramanathan, 2006, p. 695-696). The division of assortment items in accordance with the ABC method is presented in figure 2.1.

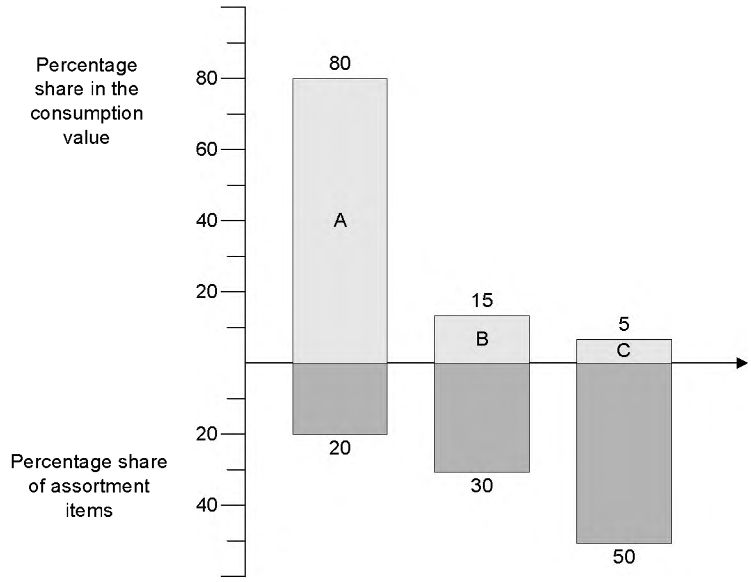

Fig. 2.1. Division of assortment items in accordance with the ABC method
Source: (Cyplik, Głowacka, Fertsch, 2008, p. 68)

XYZ analysis

The XYZ is a variety of the ABC analysis and is based on the classification of goods according to the structure of their consumption. (Scholz-Reiter, Heger, Meinecke, Bergmann, 2012, p. 445-446), The decision on assignment of a group is determined by the coefficient of variation which is understood as the percentage share of the value of the standard deviation of consumption in the average volume of issues during the analysed period.

$$V_P = \frac{\sigma_P}{P} \quad (2)$$

where:

σ_P - standard deviation

P - average volume during the studied period

The calculated percentage coefficient of variation categorises the respective products into the respective groups. The classic characteristics of the products assigned to the respective groups is presented in table 2.2.

Tab. 2.2 Classification of goods in the XYZ analysis

Material	Value of the coefficient of variation	Structure of consumption	Supply	Forecast accuracy
X	Below 25%	Regular consumption with low level of fluctuations	Synchronisation with production	High forecast accuracy
Y	25-60%	Variable consumption (subject to seasonal trends or fluctuations)	Based on determination of the warehouse inventory level	Average forecast accuracy
Z	Above 60%	Irregular consumption	Individual, related to a specific order type	Low forecast accuracy

Source: own study

123 analysis

The 123 analysis is based on the frequency of issues from the warehouses of the enterprise during the analysed period. The effect is the definition of three groups of items: 1, 2 and 3 from which the goods belonging to group 1 will be issued most frequently. The ranges of affiliation to the respective groups are specified on an individual basis for each analysis.

2.3. Inventory optimisation

The process of inventory optimisation should be preceded by the selection of the strategy of product availability management, that is, the indication of how and in compliance with what rules, the availability of the respective products must be ensured in order to fulfil the expectations of the customer, and also to strive for optimisation of costs of the enterprise. Based on such a selection, products which are kept in inventory at the enterprise and are managed by it, are identified, therefore, they can be covered by the inventory optimisation process.

Inventory optimisation is a complex process and requires a number of analyses carried out by the enterprise, as well as preparation of rules for inventory replenishment, parameterisation, and ultimately implementation of the developed solutions.

The inventory optimisation process consists of the following elements:

- the development of the rules for product classification, i.e. the use of the ABC, XYZ and 123 methods, etc.
- the development of the rules for the S&OP process functioning (Sales and Operation Planning),
- the selection of the inventory replenishment methods for the respective products and parameterisation of the selected algorithms,
- the development of the inventory monitoring and control system, i.e. the set of reports and indicators, rules of their determination and responsibility,
- the selection of the IT functionalities necessary to implement the developed issues,
- the preparation of manuals and procedures.

From the point of view of the impact on the customer service level and the costs of the enterprise, one of the most important elements is the selection of inventory replenishment methods and the following part of this chapter will refer to this issue.

Selection of the inventory replenishment methods

During the process of selection of the inventory replenishment methods, it is possible to carry out the selection from among the following methods:

- BQ – this method is based on reorder point B (informational level) and assumes the placement of the orders at constant quantity Q,
- ST – this method is based on the periodical review and assumes that the products will be ordered up to the set level S,

- BS – this method is based on reorder point B (informational level) and assumes that the products will be ordered up to the set level S,
- sS – this method is based on the established decision level s, and assumes that the products will be ordered up to the set level S.

The most important features of each of the methods mentioned above are presented below.

BQ method

The BQ method has the following features:

- constant ordering level – B,
- constant order volume – Q,
- large number of small orders, an order may be placed at any time.

Specifying the informational level (reorder point) B. In the classic approach, the informational level B is specified on the basis of dependence:

$$B = D \cdot L + SS \quad (3)$$

where:

D – mean demand in an adopted time unit (e.g. mean daily/weekly demand)

LT - replenishment lead time between review and receipt of delivery.

SS - safety inventory expressed in the following way:

$$SS = \varpi \cdot \sigma_{DLT} \quad (4)$$

where:

ϖ – safety coefficient, dependent on adopted service level and type of distribution of demand occurrence frequency,

σ_{DLT} - standard deviation of demand in replenishment cycle time.

In general cases (random variability of demand and replenishment cycle time), the following formula applies:

$$\sigma_{DLT} = \sqrt{\sigma_D^2 \cdot LT + \sigma_{LT}^2 \cdot D^2} \quad (5)$$

where:

σ_D – standard deviation of demand in an adopted time unit (the same as for D)

σ_{LT} – standard deviation of replenishment lead time.

ST method (Krzyżaniak, 2014, p.74-75)

Determining the controlling parameters:

- determination of the required service level (POP),

- calculation of the demand distribution in a unit of time (only random changes),
- determination of the replenishment lead time LT,
- determination of the review cycle time T (it can depend on the volume of an economic order or result from the arrangements with the supplier),
- calculation of the S level.

Inventory replenishment procedure according to the determined parameters - at a specific moment in time determined by the used cycle:

- the available inventory (economic inventory) Se is calculated:

$$S_e = S_W + S_O + S_{er} - S_b \quad (6)$$

where:
S_w - inventory physically available in the warehouse (on-hand),
S_o - orders placed, but not yet implemented,
S_{er} - inventory en route,
S_b - inventory already booked,

- a procurement order is placed for the volume:

$$q = S - S_e \quad (7)$$

In the classic approach, the relation between the parameter S (also called the maximum inventory level) and the service level is as follows:

$$S = D \cdot (LT + T) + SS_1 \quad (8)$$

where:
D - mean demand in a unit of time used (e.g. day, week)
T - review interval (time between two successive reviews (orders)),
LT - replenishment cycle time - time between the review and delivery of goods.
SS_1 - safety inventory, expressed as:

$$SS_1 = \varpi \cdot \sigma_{D-LT,T} \quad (9)$$

where:
ϖ - safety factor, which depends on the applied service level and the type of the demand frequency occurrence distribution,
$\sigma_{D-LT,T}$ - standard deviation of demand in the time equal to the sum of review interval and inventory replenishment time.

In a general case (random variation of demand and inventory replenishment time), the following formula applies:

$$\sigma_{D-LT,T} = \sqrt{\sigma_D^2 \cdot (LT + T) + \sigma_{LT}^2 \cdot D^2} \quad (10)$$

where:

σ_D – standard deviation of demand in a unit of time used (the same as for D)

σ_{LT} – standard deviation of replenishment lead time.

BS method

General rules governing the execution of the BS system include (Krzyżaniak, 2015, p. 284-285):

Determining the controlling parameters:

- setting the required service level (method of factor definition and factor value),
- calculating parameters of demand distribution in an adopted time unit (random changes exclusively),
- determining SS.

In order to determine the informational level (reorder point) B, formulas 3, 4 and 5 must be used.

On the other hand, while determining the inventory maximum level S, formulas 8, 9 and 10 must be used.

sS method (Fechner, Krzyżaniak, 2013, p. 130)

The principle of implementation of the sS method is as follows:

- the inventory is review in constant cycle T. Each time the quantity of the available inventory is determined, whereby: Available inventory = (inventory in warehouse) + (previously placed but still not completed orders) + (inventory en route) – (any bookings),
- at the moment of the review, the order is placed only in the case when the available inventory is equal to or smaller than then adopted decision level s,
- in such a case, the quantity of the order is calculated as the difference between the maximum inventory S and currently available inventory (just like in the classic periodical review system): WZ = S – ZD,
- if at the moment of the review, the quantity of the available inventory is bigger than the decision level, the order is not placed. This means that

another possibility of placement of the order will take place only after the expiry of another review cycle with duration T.

During the determination of the inventory maximum level S, formulas 8, 9 and 10 which are presented in this chapter, must apply.

The application of the inventory replenishment methods mentioned above is presented in the next chapter based on the example of selection of the appropriate method for product inventory replenishment.

2.4. Case study

A commercial enterprise, which offers several thousand products with different characteristics of issues, used min-max (BS) as the inventory replenishment method. All the products were replenished in accordance with the same system, with the adoption of the same methods of determination of the controlling parameters. As a result of the conducted analysis, it turned out that the adopted replenishment method for some products was not appropriate because of the high level of inventory or because of the very frequent product deficiencies, thus, there was no possibility of serving the customer without the necessity of waiting for the goods.

As a result of such an analysis an attempt was made at selection of the appropriate, more effective methods of inventory replenishment, taking into account the characteristics of the respective products.

The rules for performing such a selection and the results obtained for 5 selected products are presented below.

The procedure of selection of the inventory replenishment methods runs in accordance with the following steps:

- step 1 – preparation of the data about historical issues – 1-year period – for the respective products,
- step 2 – preparation of information for the respective products with regards to the following parameters: lead time [days] LT, standard deviation of lead time σ_{LT}, logistic minimum, established/constant delivery volume Q, review time T, service level, average inventory,
- step 3 – evaluation of the obtained results on the basis of the following parameters: coverage ratio, number of deliveries, average inventory, customer service level (POP – demand service level).

Step 1

The data coming from the IT system were collected for 5 products in reference to the daily volume of issues of these products for the year 2015, expressed in the unit of measure characteristic for the respective products. In the case of each of the 5 analysed products, these were single items. The histograms of issues of the respective products are presented in figures 2.2. – 2.6.

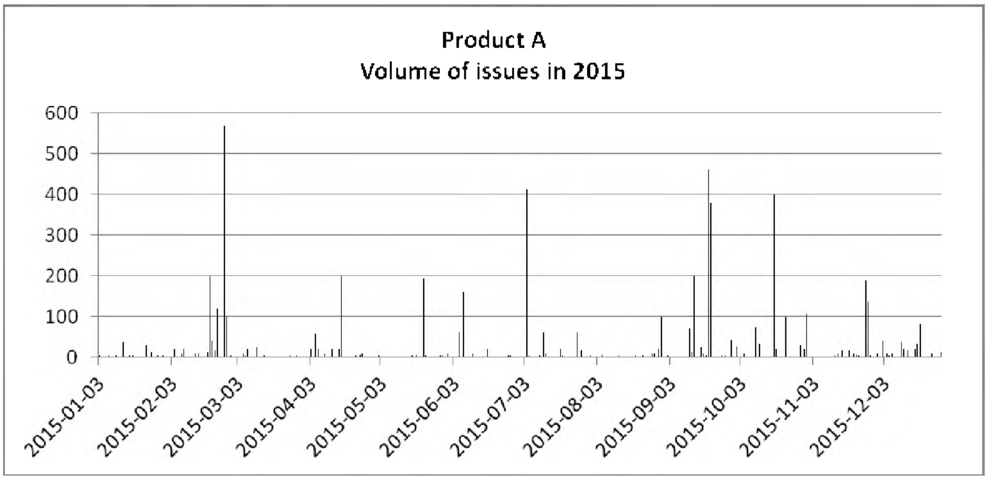

Fig. 2.2. Volume of issues in 2015 for product A
Source: own study

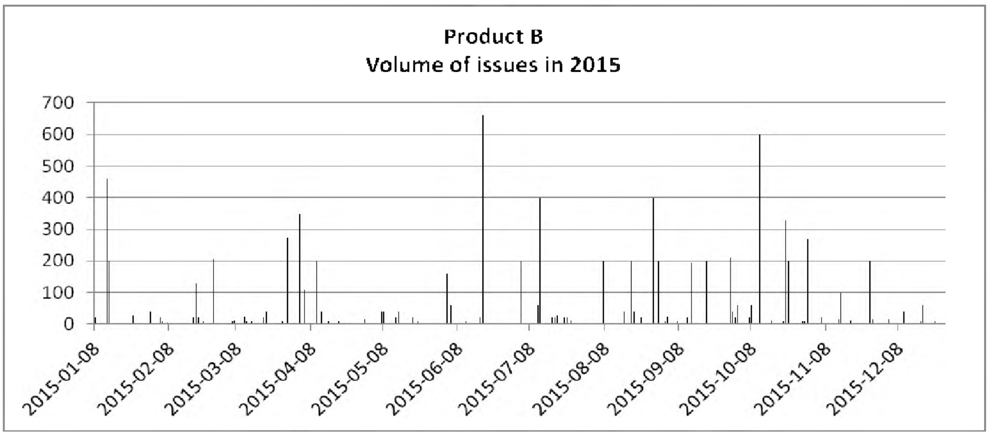

Fig. 2.3. Volume of issues in 2015 for product B
Source: own study

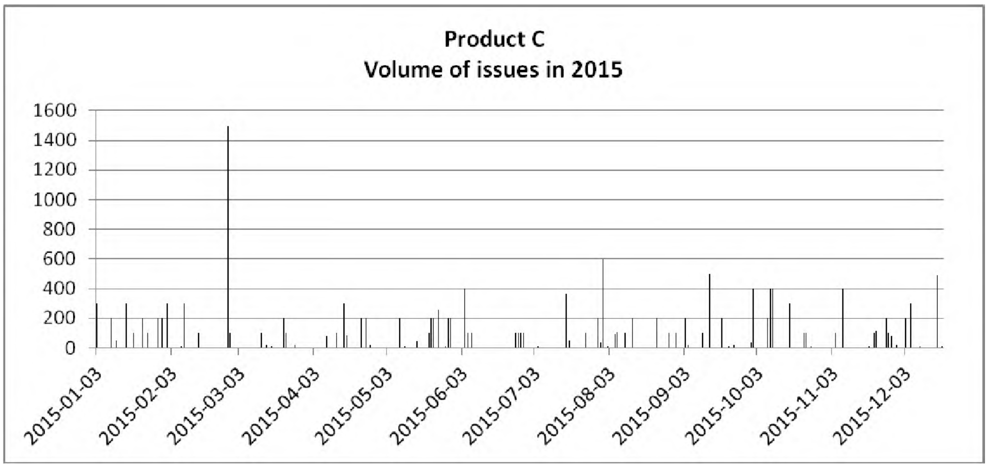

Fig. 2.4. Volume of issues in 2015 for product C
Source: own study

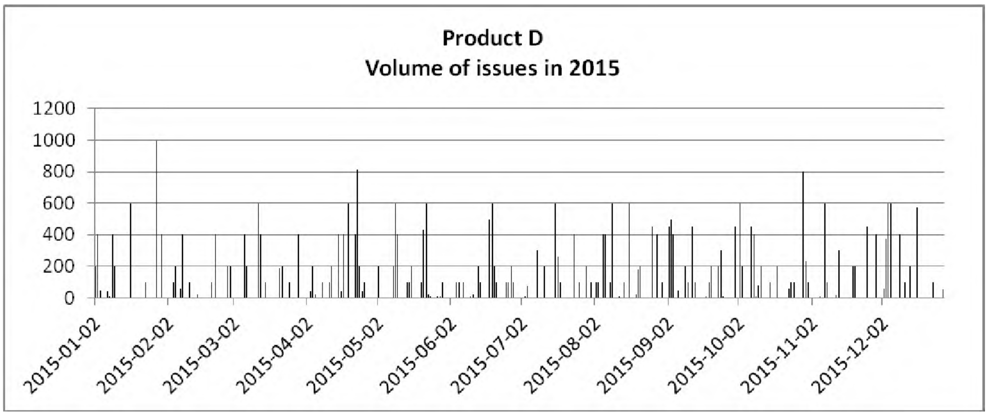

Fig. 2.5. Volume of issues in 2015 for product D
Source: own study

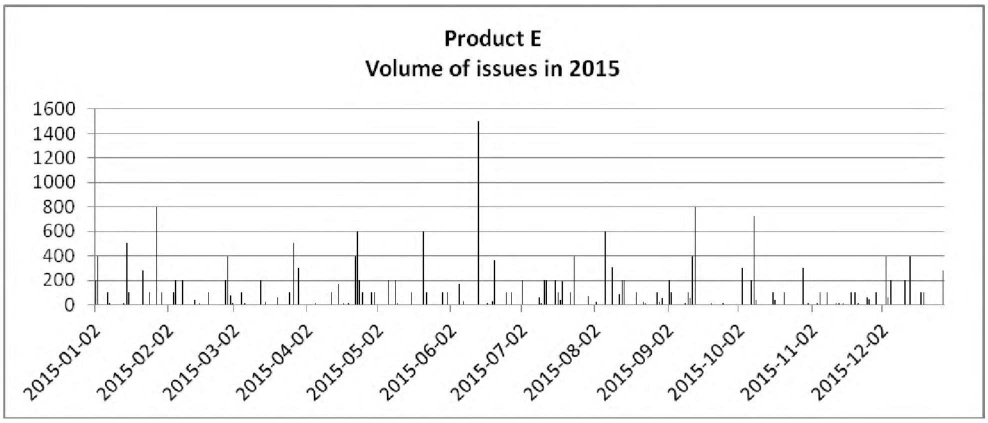

Fig. 2.6. Volume of issues in 2015 for product E
Source: own study

The aforementioned products are characterised by quite regular issues with relatively low number of sales fluctuations.

Step 2

Table 2.3 presents the specification of parameters for the respective products, with reference to: lead time [days] LT, standard deviation of lead time σ_{LT}, logistic minimum, set/constant delivery volume Q, review time T_o, service level, average inventory.

Tab. 2.3 Parameters

Product	Lead time [days]	Lead time deviation	Logistic minimum [unit of measure]	Delivery volume [unit of measure]	Review time [days]	Service level	Average inventory from source data [unit of measure]
A	7	1	1	100	7	0,95	20
B	10	1	1	150	7	0,98	10
C	7	1	1	280	5	0,95	15
D	12	1	1	450	4	0,98	10
E	20	1	1	300	5	0,95	20

Source: own study

Step 3

As a result of the conducted simulation, the results presented in table 2.4 are obtained.

Tab. 2.4 Simulation results

	BQ					ST					BS			
Product	Q	Coverage ratio	Customer service level	Number of deliveries	Average inventory	To	Coverage ratio	Customer service level	Number of deliveries	Average inventory	Coverage ratio	Customer service level	Number of deliveries	Average inventory
A	100	26	74.21%	19	246	7	31	78.48%	47	299	24	71.05%	29	226
B	150	29	93.88%	25	478	7	35	96.71%	48	578	27	93.82%	34	446
C	280	25	94.40%	28	689	5	27	96.04%	53	752	22	93.79%	41	613
D	450	22	99.97%	47	1595	4	24	100.00%	82	1748	21	99.84%	72	1502
E	300	27	100.00%	33	926	5	29	100.00%	62	996	25	100.00%	47	881

Source: own study

For results obtained as a consequence of each simulation, the following parameters obtained on the basis of application of the given inventory replenishment method were determined:

- coverage ratio,
- customer service level,
- number of deliveries,
- average inventory.

Depending on the strategy adopted by the enterprise, it is possible to select the inventory replenishment method on the basis of the parameters mentioned above, assuming the appropriate weights for them. If the customer service level is the most important parameter for the enterprise, then 100 is the value to be assigned to this parameter, and 0 must be assigned to the remaining parameters. In such a case, for product A, the best method of inventory replenishment is the ST method.

2.5. Conclusions

The analysis of inventory and the selection of the effective systems for shaping their volume still remain in the centre of interest of managers at different levels of management. Despite the development of new logistic concepts aimed at reduction of inventory, still, in many cases, ensuring the high level of customer service is based on ensuring appropriate availability of the inventory, determined by the purchase of the adequate quantity and appropriate goods at the right moment.

The main objective which is to be accomplished as a result of designing the inventory replenishment system, including the determination of such controlling parameters as Zmin and/or Zmax, is the optimisation of the total level and cost of inventory of goods in the given enterprise, while ensuring the required level of availability of the goods to customers. The designed system should improve the purchasing decision-making process with regards to replenishment of the inventory of goods by indicating the optimal moments for submission of an order to suppliers and the volume of such orders.

While searching for the optimal inventory replenishment system in the enterprise, it is necessary to analyse the classic inventory replenishment systems, taking into account the basic characteristics and conditions of their application. The analysis should be based on historical data regarding the turnovers of the respective products. It is important to define the resulting parameters such as the average inventory or coverage ratio, and then to calculate their value so that they could become the basis for selection of the system which is best adapted to the specifics of the respective products.

Selection of the appropriate inventory replenishment systems should ultimately lead to the optimisation of the inventory levels and the improvement of their structure, and owing to this, the release of the capital frozen in the maintained inventory. This will allow ensuring the required level of inventory availability (service level) while making economical investments.

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