

# COMPREHENSIVE APPROACH TO THE INVENTORY CONTROL SYSTEM IMPROVEMENT

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**ABSTRACT**

This paper describes a methodology for inventory analysis and reduction, which was developed at the Department of Industrial Engineering, Faculty of Mechanical Engineering, University of Zilina. The methodology describes the optimal procedure for the application of basic analytical methods and tools in practice. The results of the analysis are in the algorithm linked to the subsequent actions realized to improve inventory management system and to minimize inventory level in the company. Described procedure is the result of methodology examination and verification in practical conditions of production enterprises. In the following sections of this paper, there are presented a comprehensive approach to the inventory analysis and the own algorithm, which contains 3 phases: inventory analysis on enterprise level, summary analysis of individual item groups and individual analysis of material items. In the last section, there are described examples of results from such analysis and conclusions. The presented approach is an attempt to create a universal procedure of analysis which integrates methods and tools described in various publications.

**KEYWORDS**

inventory control system, inventory analysis, ABC/XYZ analysis.

## Introduction

The continuous development of market and customer requirements, shortening of innovation cycles, globalization and rising competition makes high requirements for the companies in terms of dynamics and flexibility. The excess of supply over demand and the excess manufacturing capacity in every industrial segment gives customers a choice among several products from different manufacturers. The customer always selects a product that provides the optimal mix of parameters as quality, price, flexibility and innovation.

At present, the dominating parameter is time. Higher company flexibility can be achieved by accelerating of material flow. That requires a comprehensive solutions and harmonization of tangible and

intangible operations in the production and logistics processes [1, 2].

Inventory control system, as a part of logistics system, provides several important functions:

- inventory control system as integration element in logistics chain – inventories occur along whole logistics chain and only their coordination ensures the fluent movement of the material,
- inventory as a tool of customer service increasing – right inventory assortment provides quick response to customer requirements and delivery of right material items in shorter time,
- inventory as an indicator of company „health“ – company which controls your material flows optimally, has low inventory level and high inventory turnover; creation and existence of inventory indicates places in logistics chain, where material flow

is interrupted,

- inventory as balance tool:
  - balancing of different sized material flows,
  - time balancing – different terms of item delivery, production and consumption,
- inventory as a buffer against uncertainty – inventory makes a safety to unexpected situations, as such delivery delays, quality problems, failures of the machines, organizational weaknesses, etc.

The current competitive environment makes a strong pressure on companies in terms of costs and expenses reduction [3]. Modern business philosophies like Just-in-Time, Lean Manufacturing, Supply Chain Management and other, assume a maximum slimming, which means, that the company have to eliminate all wastes associated with the transformation process [4, 5]. Inventories represent one of the most wastes, which have a significant economic impact on business results. The goal of the modern 'lean' logistics is therefore a maximum inventory reduction through increasing the flexibility of logistics and production processes and through the maximum synchronization and coordination of all processes associated with material flow [6, 7].

From this perspective, inventory control can be understood as an important problem area of logistics management, but at the same time as a significant source of savings. At present, when the inventory share in the company's assets is from 15 to 25% of total assets and costs associated with inventory holding are from 10 to 20% of the total cost, inventories represent a significant source of financial savings [8].

It should be noted, that with the reduction of inventory are linked not only the direct financial savings resulting from a lower tying of capital in inventories. Inventory reduction means also:

- space savings (storage space may be from 15 to 30% of overall company space),
- personnel savings (every stock and every storage needs office and handling workers),
- technical equipment savings (requirements for handling units, storage equipments, handling equipments depends on inventory level) ,
- evidence simplification and transparency increasing,
- simplification of logistics flow control,
- improve the company image.

### **A comprehensive approach to the inventory analysis and reduction**

For effective evaluation of inventory, their control systems and proposal of corrective actions, we

have to apply individual analytical tools wisely and in the right order [9, 10]. This is the only way how to achieve the best effects in the shortest time and at the lowest cost. The commonly used analysis (ABC analysis, XYZ analysis, evaluation through indicators) are often applied not systematically, without any definite conclusions for the inventory control system. The result is an incorrect setting of the customer order decoupling point concept for individual customers and products, wrong inventory structure, the high inventory value and low customer service.

The algorithm shown in Fig. 1 describes the individual steps of the inventory analysis and reduction, as the author has designed and verified in practical conditions in several Czech and Slovak companies. The algorithm describes the best practice for application of methods and tools for inventory analysis and their connection to the decisions of optimal parameters of inventory control system (optimal ratio between the customer service level and the inventory value in the logistics system).

The methodology of inventory analysis is based on top-down systems engineering approach, which talks that it first needs to be solved globally, principally problems, which gradually disintegrate to partial problems, aimed to solving details. This makes it achieve the best synergistic effect from subsequent remedial measures in the system of management inventory.

Top-down approach contains 3 phases (Fig. 2):

1. Inventory analysis on enterprise level.
2. Summary analysis of individual item groups.
3. Individual analysis of material items.

### **Inventory analysis on enterprise level**

Data source for the first phase of inventory analysis is financial statement data (balance sheet, income statement). Target of this analysis is to evaluate total inventories level, inventory structure and inventory progress. In this phase we work with inventories allocated as follows: raw material, work in process, finished products and goods.

The principle of analysis is to determine the values of basic indicators and their subsequent evaluation [11, 12]. Following indicators are used for inventory evaluation:

1. Absolute indicators:
  - (a) inventory value [€] in structure: raw material ( $I_{RM}$ ), work in process ( $I_{WIP}$ ), finished goods ( $I_{FG}$ ), total inventory (I)
  - (b) sales [€] ( $S_a$ )

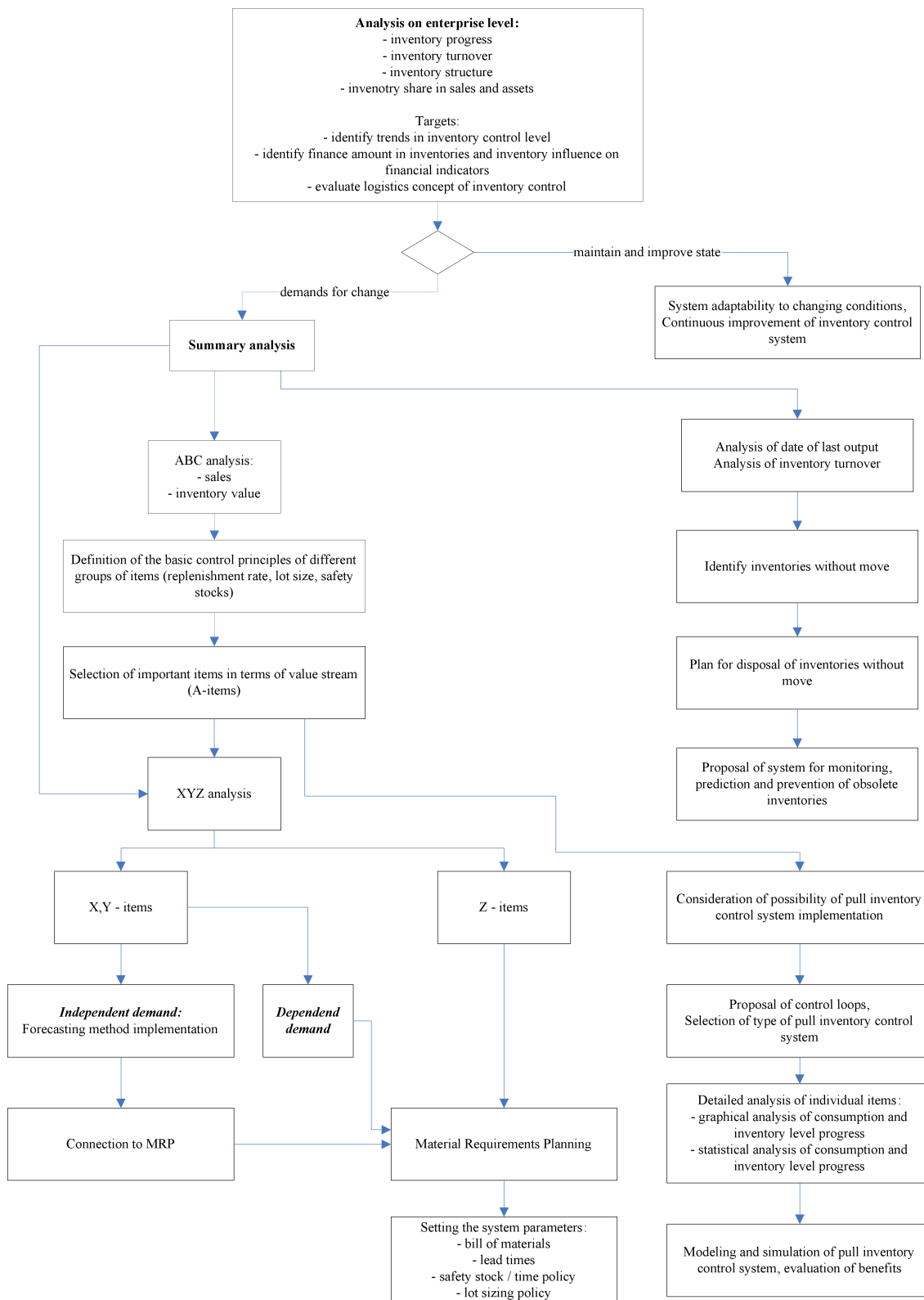


Fig. 1. Succession of activities in the analysis and reduction of company inventories.

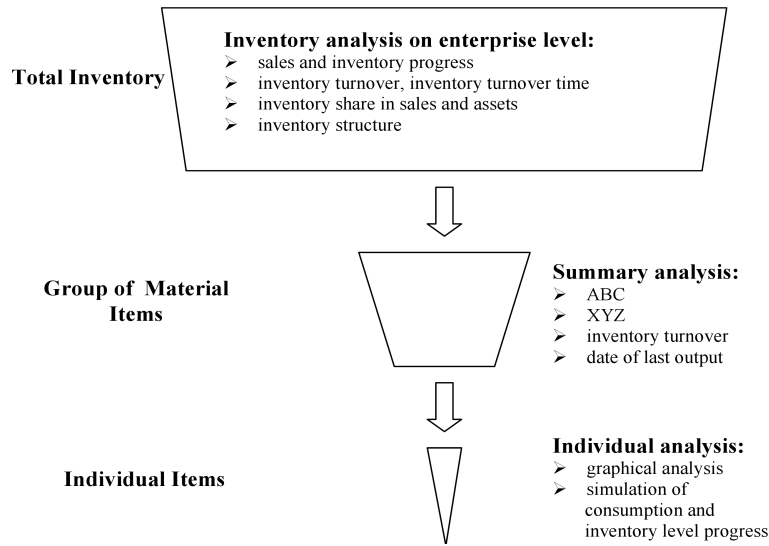


Fig. 2. Top-down approach to inventory analysis.

2. Ratio indicators:

(a) inventory turnover:

$$IT = \frac{S_a}{I} \quad (1)$$

(b) inventory turnover time:

$$ITT = \frac{I * 365}{S_a} \quad (2)$$

(c) inventory share on sales:

$$ISS = \frac{I}{S_a} \quad (3)$$

(d) inventory share on assets

$$ISA = \frac{I}{A} \quad (4)$$

(e) inventory group (raw material, *WIP*, finished goods) share on total inventory:

$$IS_{RM} = \frac{I_{RM}}{I} \quad (5)$$

$$IS_{WIP} = \frac{I_{WIP}}{I} \quad (6)$$

$$IS_{FG} = \frac{I_{FG}}{I} \quad (7)$$

where  $S_a$  – annual sales (€),  $I$  – total inventory (€),  $A$  – total assets (€),  $I_{RM}$  – raw material inventory (€),  $I_{WIP}$  – work in process inventory (€),  $I_{FG}$  – finished goods inventory (€).

Indicators evaluation is performed by 3 ways:

1. Evaluation of progress in time (Fig. 3) – the goal is to determine if the indicator improves or deteriorates.
2. Comparison of indicator values with industry averages – the goal is to compare indicator value with the average value of the indicator in the industry.

3. Comparison of indicator values with the competitors (Fig. 4) – the goal is to compare indicator value with the indicator values in the main competition.

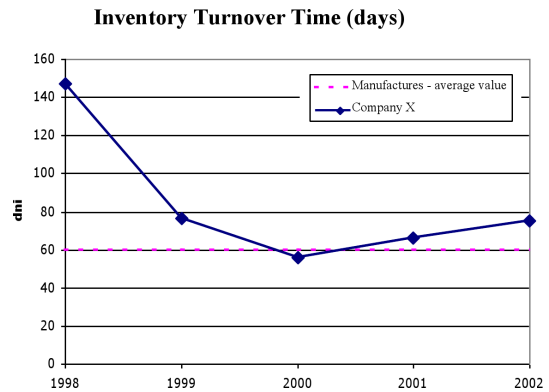


Fig. 3. Progress of inventory turnover time.

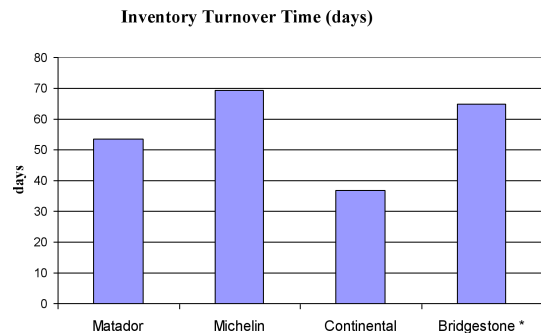


Fig. 4. Comparison of inventory turnover time indicator with selected competitors (tires manufacturing).

Based on the indicators progress and benchmarking comparison with the guide values, respectively the values of competitors, should the company decide about the need of other analyzes for improving the system of inventory management.

## Summary analyses of individual groups of inventories

Summary analyses are used to analyze some group of the material items. They are usually focused on the evaluation of item groups in material flow such as raw material, work in process and finished products, or item groups stored at the same place (the same storage). Their goal is to divide the items into several subgroups in terms of their significance, the pattern of consumption, turnover, etc. and to apply for individual subgroups different approaches of inventory control and optimization [13].

### ABC analysis

It is uneconomic to deal with all material items with the same attention. It results from the Pareto rule, which says “80% of all the consequences caused only about 20% of causes”. This means, when we evaluate a large set of items, individual items have not the same effect on the observed parameter. In this case it is advisable to sort items according to their impact on the observed parameter and divide them into certain categories (groups).

ABC analysis (Pareto analysis) is used just in this area. Basic principle of ABC analysis is items separation into three categories/subgroups (A, B and C), according to their percentage of the total value of the selected parameter (Fig. 5). Percentage of total consumption value (total assortment, total sale, total inventory, etc.) is a primary classification criterion in inventory analysis:

$$CS_i = \frac{C_i}{C_T} \quad (8)$$

where  $CS_i$  – share of the  $i$ -th item in total consumption,  $C_i$  – consumption of the  $i$ -th item (€),  $C_T$  – total consumption (€).

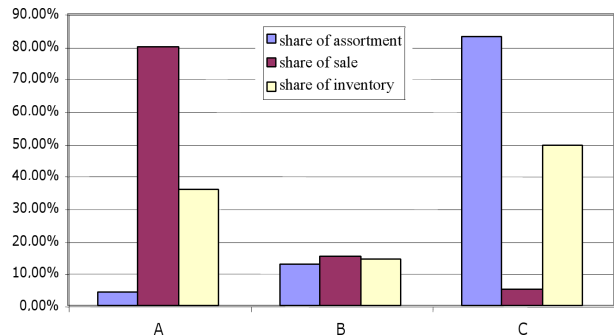


Fig. 5. Example of item distribution into groups according to the principle of ABC analysis.

For dividing items to groups we can use graphical presentation of cumulative Lorenz curve (Fig. 6). Main target of ABC analysis is determining of basic inventory control rules differentially for different groups ABC (Table 1).

### Analysis of inventory value structure

This analysis represents the variation of ABC analysis using another evaluation parameter. While ABC analysis by turnover talks about how which item influences economic result of the company, the result of the analysis of inventory structure is knowledge of the share of inventory items to the total value of inventory [14].

Table 1  
Consequences of ABC analysis for inventory control.

	A	B	C
Characteristic	high turnover	middle turnover	low turnover / slow moving
Approach to inventory control	minimum stocks	optimum stocks	sufficient stocks
Order frequency	high (days – weeks)	middle (weeks – months)	low (2 – 4 times per year)
Order quantity	small	middle	big
Safety stock	low, precisely determined	middle, simple determination approach	high
Material requirements determining	precisely – deterministic approaches	deterministic and stochastic approaches	stochastic approaches / according to the direct requirements
Evidence	precisely evidence of inventory level, inventory inputs and outputs, orders, deliveries, prices and quality	evidence of inventory level, inventory inputs and outputs, other data according to material groups	visual evidence of inventory level and movement
Position in storage	closest to expedition area	middle part of storage	farthest from expedition area

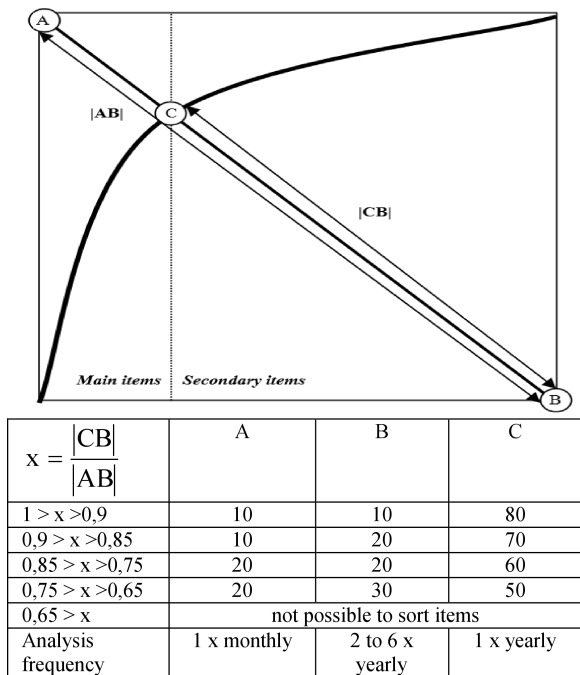
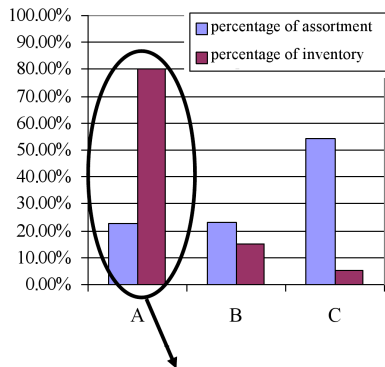


Fig. 6. Determining of group limits in ABC analysis.

Similar to ABC analysis, there is a need to use the criterion in financial units and in terms of establishing a common unit for disparate range of material items as well as in terms of the effectiveness of the resulting classification.

It uses another evaluation parameter – percentage of total inventory value.



Great potential for inventory value reduction – the need for individual analysis  
 Fig. 7. Importance of group A for inventory reduction.

Results of this analysis can be used for rapid and effective inventory value reduction, because material items are divided into following subgroups:

- Group A – Material items with the largest share of the total inventory value. This group represents the greatest potential of inventory value reduction (Fig. 7), because group contains small number of

items, which generate the dominant share of the total inventory value.

- Group B – Subgroup items with an average height of inventories and an average total inventory value.
- Group C - Material items with low share of the total inventory value. Potential for inventory reduction is insignificant in this subgroup.

### XYZ analysis

XYZ analysis is the next summary analysis, which is used in inventory control and optimization. XYZ analysis is based on items classification in three subgroups according to pattern of demand (consumption). Together with the ABC analysis makes a base frame of the process of inventory control.

XYZ analysis divides items to three subgroups:

- Group X – Items with stationary demand pattern. These items are easily and precisely forecasted.
- Group Y – Items with variable demand pattern. Demand pattern contains trend and/or seasonal components. These items are forecasted with middle accuracy and middle difficulty.
- Group Z – Item with intermittent (sporadic) demand pattern. Demand forecast of these items is difficult or impossible with using standard forecasting methods.

By applying XYZ analysis for chosen group of items we obtain division of this group into three subgroups. These three subgroups define the possibility of using quantitative forecasting (time series analysis) methods (Fig. 8) [15].

Groups X and Y represent item groups, which are suitable for forecasting method application with sufficient forecast accuracy.

Group Z represents items with intermittent demand – for demand forecasting have to be used special methods and approaches, such as Croston method, bootstrapping, etc.

### Inventory turnover analysis

Inventory turnover analysis uses inventory turnover indicator calculated for individual items. The goal of analysis is a classification of material items according to inventory turnover and identification of slow-move and obsolete inventories (Fig. 9).

$$IT_i = \frac{C_i}{I_i} \tag{9}$$

where  $IT_i$  – inventory turnover of the  $i$ -th item (per year),  $C_i$  – consumption of the  $i$ -th item (number of units sold or used/year),  $I_i$  – inventory of the  $i$ -th item (average number of units/year).



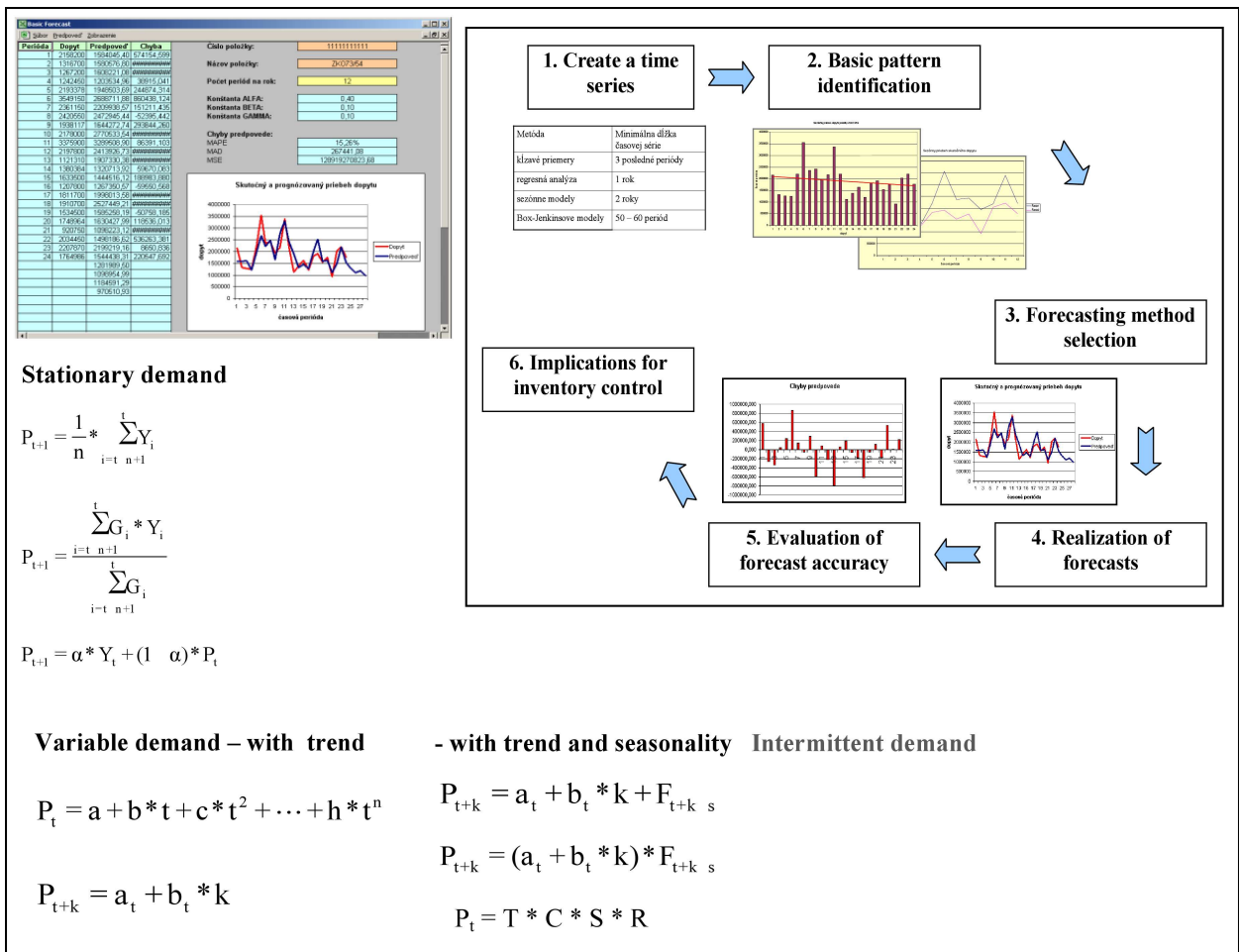


Fig. 8. Using XYZ analysis in forecasting method selection.

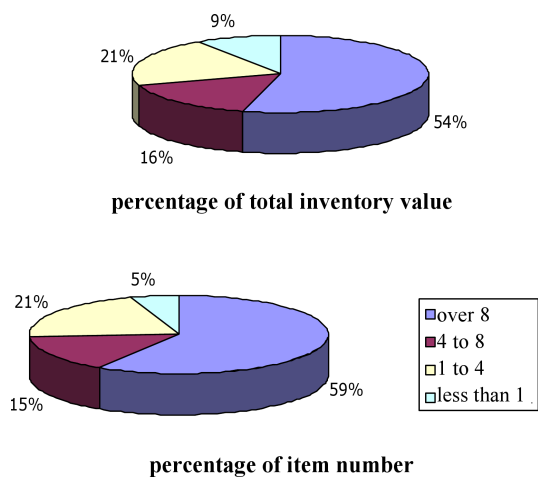


Fig. 9. Results of inventory turnover analysis.

The inventory turnover analysis can sort items into four groups as follows:

1. Fast-moving inventory (inventory turnover > 8 times/year) – target: keep the high inventory turnover

2. Middle-moving inventory (inventory turnover = 4 to 8 times/year) – target: keep and increase inventory turnover
3. Slow-moving inventory (inventory turnover = 1 to 4 times/year) – target: increase inventory turnover, review the assortment
4. Obsolete inventory (inventory turnover < once per year) – target: eliminate inventory – unnecessary inventory

Main importance of inventory turnover analysis is the more precise identification of obsolete inventories (fourth group).

### Individual inventory analysis

Individual inventory analysis are applied to items, which have the most potential of inventory value savings and in which each inaccuracy in setting of inventory control system will cause significant problems (stock out or significant increase in stock value). In this final level of analysis we are look-

ing at each item, we are detecting the adequacy of stock level compared with consumption level and replenishment mode of the material items. In regard to time-consuming and the expected benefits, these analyses are fully applied only to A- items from the ABC classification.

**Analysis of consumption and inventory level progress**

The goal of this analysis is to detect, whether there is any relationship between item consumption level and item inventory level, i.e. whether inventory level of analyzed item corresponds to the maximum item consumption. The principle of this analysis is shown in Fig. 10.

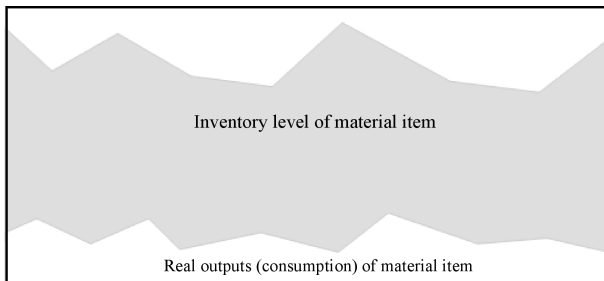


Fig. 10. Principle of graphical analysis of consumption and inventory level progress.

Analysis of consumption and inventory level progress provides quick sorting of the material items and identification of items with an inadequate inventory and thus items, which have the potential to reduce inventory levels. The analysis is realized only in a graphical way, which is used for sorting the items for further analysis (Fig. 11), based on the evaluation level of consumption and inventory level.

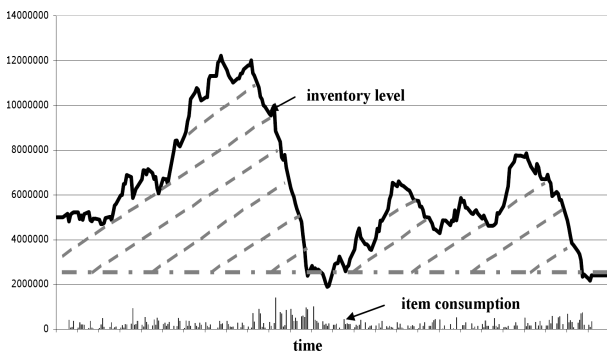


Fig. 11. Material item with excess inventory.

**Statistical analysis of inventory**

Items sorted by previous analysis, should be detailed analyzed using statistical analysis. Output of

this analysis is a specification of the inventory control parameters for individual item. Statistical analysis therefore evaluates the rightness of inventory control system through the analysis of basic statistical parameters (average consumption, standard deviation, seasonal indices, etc.).

The procedure for the statistical analysis (Fig. 12):

1. Analysis of historical consumption progress.

It consists in the processing of complex time series of storage inputs, consumption and inventories of material items [16]. Because of the exclusion / confirmation of seasonality, it is appropriate to choose a time horizon within 1-2 years. The goal of this step is to evaluate the actual item consumption and its basic statistical parameters: average, standard deviation, trend or seasonality.

2. Determining of the basic parameters.

Based on the results of previous step and knowledge of other parameters of item replenishment (delivery time, order quantity), they are determined the normative values of inventory control system:

- a) safety stock,
- b) minimum stock level,
- c) maximum stock level,
- d) inventory reorder level (if the inventory control system requires it).

3. Simulation of inventory order and replenishment process.

In an appropriate computer system we create a model, that will work with the real parameters of the ordering process (realistic delivery times, order quantities, consumption) and with inventory control parameters determined in previous step. This model will serve to simulation of inventory replenishment. For purposes of simulation we can use specialized software for discrete computer simulation (Arena, Witness) [17, 18], but satisfactory results gives simulation in MS Excel too [19].

4. Comparison of real and simulated progress.

Finally, we evaluate the benefits of new parameter setting of inventory control system of the material items [20, 21], mainly:

- change of average inventory level (in pieces and €),
- new service (coverage) level,
- change of ordering cost and inventory holding cost.



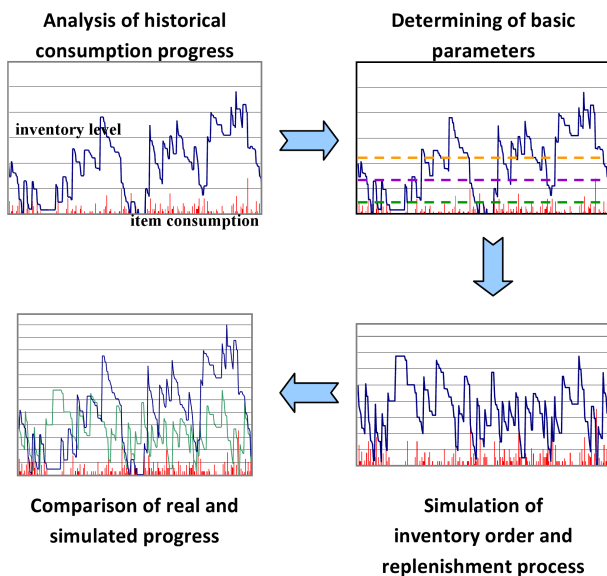


Fig. 12. Statistical analysis of consumption and inventory level progress.

## Actions to improve the inventory levels and inventory control system

Results of analysis (mainly summary and individual analysis) serve to following implementation of corrective actions for improving of inventory control system:

1. Setting the concept of customer order decoupling point, which requires:
  - Customer analysis and segmentation: Customer segmentation is based on identification of customer’s requirements for logistics parameters of delivery service (required lead times, quantities, products packaging and labeling, handling units, mode of transport).
  - Analysis of purchasing, manufacturing and distribution processes: In terms of determining the position of decoupling point in the logistics chain it is especially important knowledge of process time characteristics (purchasing lead time, production and assembly lead times, distribution lead time).
  - Evaluation of restrictive conditions: Main restrictive conditions influencing the position of decoupling point are:
    - impacts of manufacturing process: long lead times, high setup costs, deliveries from unreliable or critical suppliers, unreliable and poorly managed processes,
    - impacts of products and market: variation of the products, price and spe-

cific product properties, small number of customers, irregular and difficult predictable demand.

- Proposal of logistics concept for individual combinations “product – market segment”: Result is determining the optimal position of decoupling point for specific combination “customer – market segment” as optimum between inventory level and customer service level.
2. Elimination and prevention of obsolete inventories.
 

Obsolete inventories are the source of „dead“ capital, which causes large losses for a company. Value of company losses is depended on time and value added in manufacturing process. Effective tools for identifying obsolete inventories are summary analysis of date of last output and inventory turnover analysis. The tolls must not only identify existing obsolete inventory, but must also help by the prevention of new obsolete inventories in the future.
  3. Increase the accuracy of input data for inventory control using forecasting methods.
 

Capabilities of forecasting methods application in inventory control are not limited only to demand forecasting for final products in the “make-to-stock” or “make and distribute-to-stock” concept, but their application is also possible in the other logistics concepts (decoupling point is located closer to supplier). The only exceptions are the concepts “engineer-to-order” or “purchase-to-order”, where are no “free” (unbound) inventories.
  4. Setting the control parameters according to the importance of material items.
 

The basis for setting the parameters of inventory control is previous item classification into different classes using the ABC analysis. Own parameter setting process has to keep the following principles:

    - A-items have to be ordered with high frequency and in smaller quantities, thereby will be ensured an acceptable level of average inventory, amount of capital bounded in inventories and low inventory holding costs, in conditions of high rate of material item consumption turnover. These items also require very accurate evidence and rigorous and frequent monitoring of compliance with the norms.
    - Main decision factor by B-items, in terms of inventory optimization, is an ordering costs level. While A-items can be frequently or-

dered (high consumption of these items allows effective deliveries by high delivery frequency), B-items have to be ordered in longer cycles because it is necessary to ensure effective spending of ordering costs and on the other side the impact of extended order cycle on inventory value is lower than by A-items.

- Both groups are suitable for application of supplier milk-run concept that ensures low inventory level by optimal ordering cost spending. In this case, they are designed the circular routes, which connect several suppliers to one common route. In this case, transportation is effective, when we are picking small quantities from individual suppliers.
- C-items should represent the smallest share of total order processes, though they are the largest group (in terms of items number). The basic principle is ordering these items at long cycles and inventory checking and control using simple methods based on visual inspection or automatic ordering process.

#### 5. Implementation of control loops in pull inventory control systems.

Another way to reduce inventory levels in the company is implementation pull inventory control system instead of the standard push system. Pull inventory control systems are advantageous because they respond to real consumption progress and actual inventory level and based on evaluation of these parameters they determine the moment of ordering and order quantity.

In terms of inventory minimization and reduction stock out risk, pull systems operating with reorder level appear as the best solution. The reorder level in this case helps to cover a part of random fluctuations in consumption. If the item consumption is higher than we expected (planned), the reorder level will be reached and new item quantity will be ordered earlier. Then the safety stock covers only fluctuations during the delivery time.

## Conclusion

Comprehensive methodology of inventory analysis and reduction described in this paper and represented by the algorithm in Figure 2 represents the result of several years' experience in solving logistics projects in industrial practice. As a part of application and improvement of methodology it have been developed several software solutions (modules operating in an environment of VBA for Excel), which are implemented to the individual steps of methodology

(such as ABC analysis, inventory turns, demand forecasting, optimization of control parameters in pull inventory control systems, etc.), automate of data processing and analysis and help to reduce the time needed to obtain desired results.

Next research in inventory control area is focused on wider integration of material and information flows and design of integrated supply chains (Supply Chain Management). Within this concept the aspect of inventory control acquires a new dimension, because the coordination of supply chain is becoming a common task for all stakeholders (primary and secondary suppliers, manufacturers, distributors) and main target is to achieve a synergistic effect in the whole supply chain, not in one subject.

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