CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

FACULTY OF ENGINEERING

OPTIMISATION OF SPARE PARTS INVENTORIES IN A SELECTED ORGANISATION

Master of Science Thesis

by

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DIPLOMA THESIS TOPIC

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Topic: **Optimisation of spare parts inventories in a selected organisation.**

Optimisation of selected spare parts management processes and spare parts inventory in a chosen organization based on analysis of current state.

Length of thesis: 40-60 pages including figures, charts and tables

Guides to writing a thesis:

1. Analysis of the current state of spare parts management processes
2. Analysis of the current spare parts inventory (with application of standard spare parts inventory analysis methods like ABC analyses using various criteria)
3. Identification of existing problems and inefficiencies (from the process point of view and inventory point of view)
4. Proposal of solution or optimization of selected problems supported with application of suitable methods of process optimization and inventory management.
5. Economic evaluation of proposed solutions (savings, return on investment etc.)
6. Conclusion: summary of achieved results and economic evaluation (savings)

Selected bibliography:

1. GOULD, F.J. EPPEN, G.D. SCHMIDT, C.P.: Introductory management science. Prentice Hall, Singapore, 1997, ISBN: 981-3076-99-2
2. Gopalakrishnan, P., Banerji, A. K.: Maintenance And Spare Parts Management. PHI Learning Pvt. Ltd., New Delhi, 2006, ISBN: 81-203-0669-4
3. HLADIK, T.: EFFECTIVE SPARE PARTS MANAGEMENT. Proceedings of the 21st Congress Euromaintenance 2012 - Maintenance Excellence for Sustainable Development. Belgrade, 2012, ISBN: 978-86-89141-00-9
4. Wilson, A.: Asset Management Focusing on Developing Maintenance Strategies and Improving Performance. Conference Communication, 2013, ISBN: 0950646563

DECLARATION

"I hereby declare that I prepared the Master thesis on the topic "Maintenance and optimization of spare parts inventories in a selected organization" independently, under the expert guidance and consultations of Ing. Tomáš Hladík, Ph.D., and implemented in a selected organization. All the data used in the thesis are based on credible sources of information, which I have cited in the text. I entirely agree that my Master thesis can be kept in the library of the Czech University of Life Sciences Prague and used for prospective study purposes".

Prague, April 4th 2015 ....

Signature

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First of all and foremost I would like to express my profound gratitude to my scientific supervisor Ing. Tomáš Hladík, Ph.D. for his highly professional guidance, valuable advices and support.

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ABSTRACT

The present diploma project deals with the analysis of maintenance and optimization of spare parts inventory in a selected organization operating in automotive industry. Theoretical and methodological part of the study reviews main approaches as well as existing methods and tools of effective inventory management. The empirical research was conducted at the VALEO AUTOKLIMATIZACE k.s., located in Rakovník, Czech Republic. It manufactures heating, air conditioning units and control panels for automotive industry. The analysis of spare parts inventory was done with the use of MS Excel with the purpose of determining the proper safety stock quantity for each spare parts component. The service level, standard deviation of consumption and lead time factor were selected as determinants (influencing parameters) for the analysis. In accordance to Pareto principle the spare parts components were categorized into three groups, namely, high, medium, and low value items. As a result of the research the calculation method of optimum level for inventory was suggested to support the company's SAP enterprise resource planning system. Applying the revealed calculation method the value of inventory average for 2016 was reduced by 1 356 492 CZK at 98% service level with minimum probability of stock outs.

KEYWORDS:

Spare parts

Maintenance

Forecasting intermittent demand

Inventory management

ABC analysis

Croston method

ABSTRAKT

Tato diplomová práce se zabývá problematikou údržby a optimalizace zásob náhradních dílů ve vybrané organizaci působící v automobilovém průmyslu. Teoretická a metodologická část studie zkoumá hlavní přístupy, existující metody a nástroje efektivního řízení zásob. Empirický výzkum byl proveden ve společnosti VALEO AUTOKLIMATIZACE k. s. se sídlem v Rakovníku v České republice. Vyrábí topení, klimatizační jednotky a ovládací panely pro automobilový průmysl. Analýza zásob náhradních dílů byla provedena s použitím analytického nástroje MS Excel za účelem stanovení správného množství pojistné zásoby pro každý náhradní díl. Servisní úroveň, standardní odchylky ve spotřebě a dodací lhůty byly vybrány jako determinanty (nejvyznamější ovlivňující parametry) pro analýzu. V souladu s Paretovým principem byly náhradní díly rozděleny do tří skupin podle různých kritérií. Výstupem analýzy byl návrh metody výpočtu optimální úrovně zásob, která se může být implementována do firemního ERP systému SAP. Použitím navržené výpočtové metody byla průměrná hodnota zásob pro rok 2016 snížena o 1 356 492 Kč při zachování 98% úrovně logistického servisu a zároveň s minimální pravděpodobnosti výskytu stock outů.

KLÍČOVÁ SLOVA:

Náhradní díly

Údržba

Předpovídání sporadické spotřeby

Řízení zásob

ABC analýza

Crostonova metoda

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1. INTRODUCTION

The reality today is characterized by fast growing competition among market players and constantly changing balance between demand and supply forces. That is why the problem of rational and effective management of disposable resources becomes one of the most crucial ones in terms of gaining and keeping the competitive advantage. To achieve this goal an organization that deals with mass production and consequently being incorporated into a sophisticated value adding chain needs to perform on the frontier of its production possibilities. Enabling factors contributing to this among others are effective maintenance and optimization of spare parts inventories. Being a component of a Strategic service management process, maintenance aims at smooth, cost effective operation of an enterprise and helps to ensure that right spare part and resources are at the right place and at the right time. Predictive inventory optimization contributes to better inventory managing within the organization. It is used to support management decision making process aimed at avoiding downtimes, which in turn appear due to seasonally varying demand. The main idea is to ensure proper coverage of both scheduled and unscheduled requirement of maintenance for a set of operating machinery. Taking into account possible risks replenishment of these parts becomes quite a complex task.

The present research rests on the real data provided by the VALEO AUTOKLIMATIZACE k.s., Rakovník, Czech Republic. The latter manufactures heating and air conditioning units as well as control panels for automotive industry. The analysis of spare parts inventory will employ the MS Excel analytical tool with the purpose of determining the proper safety stock quantity for each spare parts component. The service level, standard deviation of consumption and lead time factor will serve as determinants (influencing parameters) for the analysis. All spare parts components will be categorized, in accordance to Pareto principle, into three main groups: high, medium, and low value items. It is expected to calculate an optimum level for inventory with minimum probability of stock outs to support the company's SAP enterprise resource planning system.

2. OBJECTIVES OF WORK

Being rest on the analysis of spare parts management processes and inventory in terms of quantity of spare parts to be kept in stock the main purpose of the present study is to optimize the latter. This quantity is crucially important for the company due to its strong influence on incurred costs, which may vary in response to change in inventory level. It is distinguished between the following costs: acquisition costs, ordering costs and stock out or shortage costs. Therefore in order to reduce these costs it is necessary:

1) to detect an optimum level of safety stock quantities (in units) for all types of spare parts in inventory, and
2) hold it on its required and sufficient minimum via recalculation of forecast, defining optimum value of service level.
3) to detect an optimum quantities and value inventory level (in units and CZK) for all types of spare parts.

Applying the standard spare parts inventory analysis methods such as ABC, XYZ analyses etc. and using various criteria the identification of existing problems and inefficiencies from the process point of view and inventory point of view becomes a cornerstone of the present study.

To achieve stated goal the following research questions were posed and answered:

- Is it possible to reduce the safety stocks of some key spare parts?
- What level of spare parts inventory can be considered as optimal?
- Which forecast method does fit the company’s data most of all?
- What inventory management policy (including inventory control parameters, such as re-order points and safety stocks) is the most suitable for the selected company?
- What are main determinants contributing to and factors impeding realization the inventory management policy?

The results of the analysis will help to determine main directions of improving the company performance resulting in gaining better position in the market among its competitors, as well as to create an analytical framework in promoting a long-term planning policy contributing to the company’s financial and operational sustainability.

3. THEORETICAL AND METHODOLOGICAL FRAMEWORK OF THE STUDY

In the first instance, before practical part of the research will be done, it is necessary to study the existing theory with the purpose of gaining the holistic and complex view on the subject of the study and be able to implement the most appropriate and sufficient approaches. Thus, at first we define all the notions that will be used in the present analysis. During the research we will deal with the following terms: supply chain management (SCM), enterprise resource planning (ERP), material resource planning (MRP), spare parts, inventory, inventory management, maintenance and many others. Then the most applicable and generally used methodological approaches in maintenance and optimization of spare parts inventories will be described and discussed. In the subchapters listed below all definitions with their brief theoretical and methodological background will be given consequently.

3.1. SUPPLY CHAIN MANAGEMENT AND ENTERPRISE RESOURCE PLANNING

The supply chain management (SCM) elaborates and implements plans, controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements.[1] In general SCM functions can be divided into the following main groups: Materials management, Channel management and Distribution (or physical distribution). To varying degrees, SCM also deals with sourcing and procurement, production planning and scheduling, packaging and assembly, and customer service.

Summing up, the following five basic components can be distinguished within SCM:

"**1. Plan.** This is the strategic portion of SCM. Companies need a strategy for managing all the resources that go toward meeting customer demand for their product or service. A big piece of SCM planning is developing a set of metrics to monitor the supply chain so that it is efficient, costs less and delivers high quality and value to customers.

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[1] The CSCMP's (Council of Supply Chain Management Professionals) Definition. Available online at http://cscmp.org/about-us/supply-chain-management-definitions

2. Source. Companies must choose suppliers to deliver the goods and services they need to create their product. Therefore, supply chain managers must develop a set of pricing, delivery and payment processes with suppliers and create metrics for monitoring and improving the relationships. And then, SCM managers can put together processes for managing their goods and services inventory, including receiving and verifying shipments, transferring them to the manufacturing facilities and authorizing supplier payments.

3. Make. This is the manufacturing step. Supply chain managers schedule the activities necessary for production, testing, packaging and preparation for delivery. This is the most metric-intensive portion of the supply chain—one where companies are able to measure quality levels, production output and worker productivity.

4. Deliver. This is the part that many SCM insiders refer to as logistics, where companies coordinate the receipt of orders from customers, develop a network of warehouses, pick carriers to get products to customers and set up an invoicing system to receive payments.

5. Return. This can be a problematic part of the supply chain for many companies. Supply chain planners have to create a responsive and flexible network for receiving defective and excess products back from their customers and supporting customers who have problems with delivered products".[2]

To link and coordinate all mentioned above activities in real time companies implement an enterprise resource planning system/software (ERP). "The main advantage of an ERP system is its capability to integrate information across the entire organization, allowing companies to better understand their business. With ERP software, companies can standardize business processes, concentrating their efforts on serving their customers and maximizing profit".[3]

ERP provides an integrated view of core business processes, often in real-time, using common databases maintained by a database management system. ERP systems track business resources—cash, raw materials, production capacity—and the status of business commitments: orders, purchase orders, and payroll. The applications that make up the system share data across the various departments (manufacturing, purchasing, sales, accounting, etc.) that provide the

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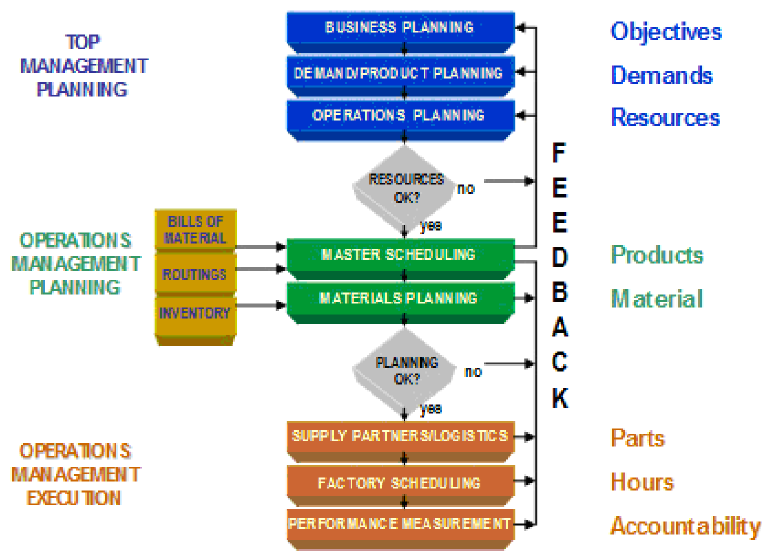
[2] Wailgum, T., Worthen, B. (2007), Supply Chain Management Definition and Solutions. [online] Available at: http://www.cio.com/article/2439493/supply-chain-management/supply-chain-management-definition-and-solutions.html

[3] Apolloni, S., Lando, M., Savino, M. Failure-Based Maintenance Organization through ERP Software Evolution. [online] Available at: http://unina2.academia.edu/StefanoApolloni/Papers.

data.[4] The ERP system is considered a vital organizational tool because it integrates varied organizational systems and facilitates error-free transactions and production.[5]

Material requirements planning (MRP), being an integrated part of ERP, is a narrower process, which involves planning the use of materials necessary for manufacturing business products.

Figure 3-1-1. Enterprise resource planning scheme.



Source: ERP & Supply Chain Management. Buker, Inc Management Education and Consulting. [online] Available at: http://www.buker.com/erp-enterprise-resource-planning

"Material requirements planning (MRP) is a computer-based inventory management system designed to assist production managers in scheduling and placing orders for items of dependent demand. Dependent demand items are components of finished goods — such as raw materials, component parts, and subassemblies — for which the amount of inventory needed depend on the level of production of the final product".[6] An MRP system is intended to simultaneously meet three following objectives:

- Ensure materials are available for production and products are available for delivery to customers,
- Maintain the lowest possible material and product levels in store,

[4] http://searchsap.techtarget.com/definition/ERP
[5] SHAUL, L., TAUBER, D. (2012), CSFs along ERP life-cycle in SMEs: a field study. Industrial Management & Data Systems, 112 (3), pp. 360-384.
[6] Material requirements planning. Available from: http://www.inc.com/encyclopedia/material-requirements-planning-mrp.html. Accessed [Online], [18/11/2014]

- Plan manufacturing activities, delivery schedules and purchasing activities.[7]

MRP calculates and maintains an optimum manufacturing plan based on master production schedules, inventory status, sales forecasts, open orders and bills of material. If properly implemented, it will reduce cash flow and increase profitability. MRP helps to be pro-active rather than re-active in the management of inventory levels and material flow.[8]

3.2. INVENTORY MANAGEMENT AND ITS MAIN FUNCTIONS

Malakooti (2013) defines "inventory" or "stock" as a pool of goods and materials that a business holds for the ultimate purpose of resale (or repair)[9]. Business dictionary in turn gives two variants of definition:

- An itemized catalog or list of tangible goods or property, or the intangible attributes or qualities;
- The value of materials and goods held by an organization to support production (raw materials, subassemblies, work in process), for support activities (repair, maintenance, consumables), or for sale or customer service (merchandise, finished goods, spare parts).

"Inventory is often the largest item in the current assets category, and must be accurately counted and valued to determine a company's profit or loss. The optimum level of inventory for an organization is determined by inventory analysis".[10]

Bernard Taylor (2013) emphasizes that inventory is kept on hand by an organization to use to meet customer demand. "A level of inventory is normally maintained that will meet anticipated or expected customer demand. However, because demand is usually not known with certainty, additional amounts of inventory, called safety, or buffer, stocks, are often kept on hand to meet unexpected variations in excess of expected demand. Additional stocks of inventories are sometimes built up to meet seasonal or cyclical demand. Companies will produce items when

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[7] Wikipedia definition: Material requirements planning. Available from: http://en.wikipedia.org/wiki/Material_requirements_planning. Accessed [Online], [17/11/2014]

[8] Inventory Solutions Logistics Corp. Available from: http://www.inventorysolutions.org/def_mrp.htm. Accessed [Online], [18/11/2014]

[9] Malakooti, Behnam (2013), Operations and Production Systems with Multiple Objectives. John Wiley & Sons. ISBN 978-1-118-58537-5

[10] Business dictionary [on-line]. Available from: http://www.businessdictionary.com/definition/inventory.html#ixzz3QPaKvDTh. Accessed [Online], [22/11/2014]

demand is low to meet high seasonal demand for which their production capacity is insufficient."[11] To operate stocks efficiently companies implement inventory management.

Inventory management according to Investopedia is a tool that helps to minimize inventory costs.[12] "The objective of Inventory management is to provide uninterrupted production, sales, and/or customer-service levels at the minimum cost. Since for many companies inventory is the largest item in the current assets category, inventory problems can and do contribute to losses or even business failures". [13]

"Many companies find it necessary to maintain in-process inventories at different stages in a manufacturing process to provide independence between operations and to avoid work stoppages or delays. Inventories of raw materials and purchased parts are kept on hand so that the production process will not be delayed as a result of missed or late deliveries or shortages from a supplier. Work-in-process inventories are kept between stages in the manufacturing process so that production can continue smoothly if there are temporary machine breakdowns or other work stoppages. Similarly, a stock of finished parts or products allows customer demand to be met in the event of a work stoppage or problem with the production process."[14]

Main functions of Inventory management are: inventory control, profitability increase, supply and demand balancing, safety stock and geographical specialization.

Inventory Control allows the business to supply production or customer needs at the precise moment needed and at the minimal price. Successful inventory control maintains waste and surplus at a minimum level and efficiently operates storage, production and distribution of inventory items. Profitability increase being a primary function of inventory management allows eventually getting the maximum amount for the future business' investments. Supply and demand balancing involves replacing consumed items and liquidating seasonal items, i.e. organizational steps that contribute to smooth performance at the precise time, for the least amount of money, without a surplus. Safety stock implies having a buffer stock in case of an unexpected delay in replenishing inventory or excess sales. The last but not least function -

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[11] Taylor, Bernard W. (2013), Introduction to management science / Bernard W. Taylor III.—Ed. 11. ISBN-13: 978-0-13-275191-9, ISBN-10: 0-13-275191-7

[12] Investopedia dictionary. Available from: http://www.investopedia.com/terms/i/inventory.asp. Accessed [Online] [22/11/2014]

[13] Business dictionary. Available from: http://www.businessdictionary.com/definition/inventory-management.html#ixzz3QPuS07uI. Accessed [Online] [23/11/2014]

[14] Taylor, Bernard W. (2013) Introduction to management science / Bernard W. Taylor III.—Ed. 11. ISBN-13: 978-0-13-275191-9 ISBN-10: 0-13-275191-7

geographical specialization - must take into consideration the following factors: energy costs, location, labor and transportation.[15]

3.3. SPECIFICS OF SPARE PART INVENTORIES

Inventory items, similarly to assets, have a lifecycle of the following kind: procure-store-consume-dispose. If some assets are critical to a company's operations, having them available is essential to do preventive maintenance or when a breakdown occurs. The opposite situation takes place at the end of the asset lifecycle, namely when a company no longer needs or maintains the asset then there is no longer necessity to keep its spare parts in inventory. "As with all lifecycles, the expensive mistakes are the ones that are discovered at the end, so it is important to be careful about which spare parts we procure at the start. To decide which items to keep in store and in what quantity helps analytical approach of setting the level of inventory based on the type and probability of failure that occurs in the operating environment. Logically, if we have a preventive maintenance program that enables to collect and analyze asset failures, then it should be the primary mechanism for setting the inventory level for critical parts. The next best indicator used is a past usage, or consumption, of the item. Store only those spare parts for which have historical or probability-based evidence that we will need to consume in the future. In both scenarios, can help to identify which items are critical and set the appropriate reorder points to optimize stock level".[16]

A database of information is kept by a manufacturing company, known as an inventory master file, contains an extensive amount of information on every item that is ordered in the system. It includes such data as detailed description of an item, on-hand quantities, on-order quantities, lot sizes, safety stock, lead time and past usage figures. It updates the physical inventory count, summarizes the item year to date usage. Accuracy of inventory transactions is essential to keep inventory levels at minimum.[17]

A conservative policy is adopted to avoid stock-outs of spare parts at any cost, considering difficulty in predicting rate of failure, long lead time for imported items, and lack of professional

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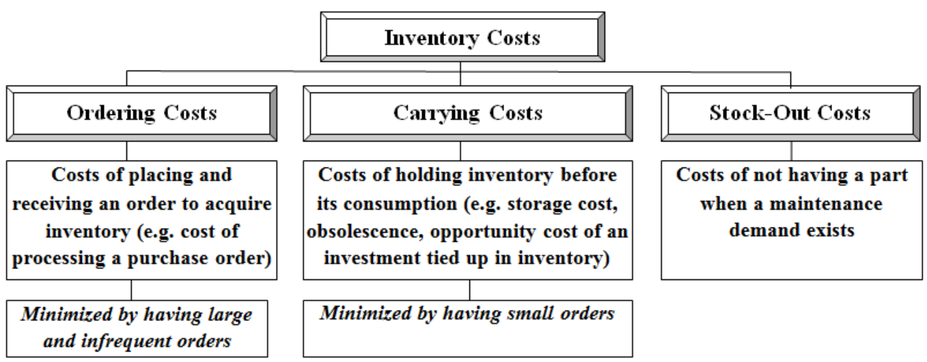
[15] Wild, Antony (2002), Best Practice in Inventory Management, Institute of Operations Management, 265 p.

[16] Waller, Nick (2014). Available from: https://www.linkedin.com/pulse/20140807105706-3594305-2-rules-for-maintenance-spares-inventory. Accessed [Online], [3/12/2014]

[17] Russel, S. Roberta, Taylor, W. Bernard (2000), Operations Management, 3rd Edition, Prentice-Hall, Inc., Upper Saddle River, N.J.07458, ISBN: 0-13-013092-3

scientific conscious approach to spare parts management, which could lead to increased stock level. Inventories are held for many reasons. They smooth out the time gap between supply and demand, and are categorized into consumable, insurance, overhauling, and project surplus.[18]
Most of the professional literature indicates the following branches dealing with Inventory management: (1) electronic industry, including computers; (2) automotive industry; (3) aviation industry and (4) production companies keeping stock of parts for maintenance. "The electronic industry, the automotive industry, and the airline operators more and more tend to outsource service parts management".[19] This research will focus on inventory management of the automotive industry.
There are a number of costs associated with an inventory activity. Generally they can be divided into the three main types. Figure 3-3-1 provides theirs brief descriptions.

Figure 3-3-1. Costs associated with inventory activity.



Source: Eric Y.W. Leung, "Inventory Management". Available on-line at http://www.hkiaat.org/images/uploads/articles/PBE_II_Inventory_Management_Eric_Leung.pdf

Schematic planning and control framework for spare parts maintenance is given below in the Figure 3-3-2. Within each process authors distinguish different decision levels. Decisions that are not made very frequently, i.e. once a year, are marked by them as "S/T" (strategic/tactical decisions); decisions made regularly, i.e. once a month or quarter, are marked "T" (tactical decisions) and decisions made frequently, i.e. once a day/week, are marked "O" (operational decisions).

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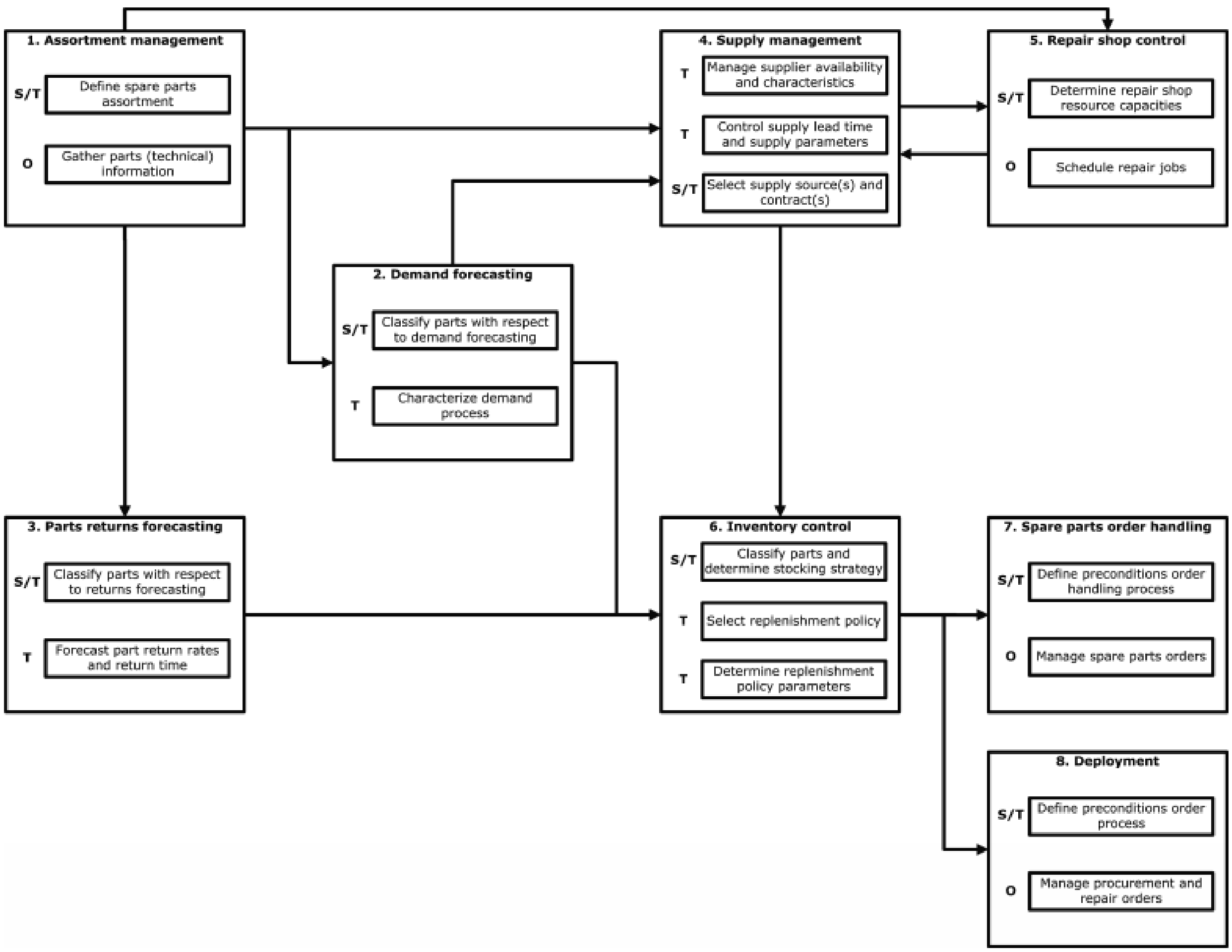
[18] Eppen, G.D., Gould, F.J., Schmidt, C.P., Moore, H. Jeffrey, Weatherford, R, Larry R. (1998), Introductory Management Science, 5th Edition. Prentice Hall, Inc., Upper Saddle River, NJ07458, ISBN: 0-13-889395-0.
[19] Botter, R., Fortuin, L. (1998), Stocking strategy for spare parts. Available from: http://cms.ieis.tue.nl/beta/files/workingpapers/beta_wp33.doc. Accessed [Online], [4/12/2014]

Data analysis is a critical part of managing inventory. A spreadsheet program is a tool used to build an optimization model out of a series of smaller simple calculations, that would be made up of a value targeted to be optimized, in other words maximized or minimized, having a mathematical relationship with one or more changeable values.[20,21]

Figure 3-3-2. Overview and clustering of decisions in maintenance logistics control.



Source: Driessen, M.A. et al (2010), Maintenance spare parts planning and control: A framework for control and agenda for future research.

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[20] Piasecki, J. David (2009), Inventory Management Explained, 1st Edition. OPS Publishing, ISBN: 0972763112

[21] Tamer. Abdelhadi Awad Mohamed (2014), Optimization of industrial spare parts inventories' management system improving machine availability within production processes in a selected organization. MSc. Thesis, CULS, Prague.

3.4. SPARE PARTS CLASSIFICATION

The categorization of spare parts may vary depending on the goal and implemented approach. Being a critical step in managing spare parts inventories it helps to differentiate a company's stocking policies, to understand the layout of an inventory and to identify overstock situations.

In a broad sense spare parts can be divided into two main categories:

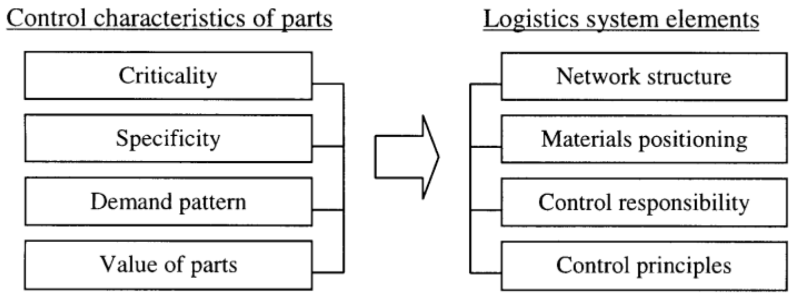
- Repairables - parts that are repaired rather than procured, i.e. parts that are technically and economically repairable. In case of failure, such a part is swapped with a new one and sent to a repair centre. After repair the part becomes ready-for-use again.
- Consumables or non-repairable parts - parts that are technically and/or economically not repairable. In case of failure the part is replaced by a new one and scrapped.[10]

As for more precise and deep categorization of spare part inventory management researches suggest different types of multi-dimensional classifications. "Duchessi et al. (1998) used a two-dimensional classification scheme combining inventory cost and part criticality as criteria. Flores and Whybark (1989) also used multiple criteria classification in maintenance inventory control. Cohen and Ernst (1988) introduced a general grouping method that can be used to define group-based operational control policies. Petrovic et al. (1992) designed an expert system model for advising on spare part inventory control. The heuristic decision rules used in the model were based on several operational characteristics of spare parts: availability of required system, essentiality, price, weight, and volume of the part, availability of spares in the market, and efficiency of repair. Gajpal et al. (1994) elaborated the criticality analysis of spare parts by using the analytic hierarchy process (AHP) for classifying the spare parts".[22]

In the seminal work of Huiskonen (2001) the main control characteristics while the spare parts classification were given as follows in the figure 3-4-1.

[22] Huiskonen, Janne (2001), Maintenance spare parts logistics: Special characteristics and strategic choices. Int. J. Production Economics, Issue 71, pp. 125-133

Figure 3-4-1. Relevant control characteristics and logistics system elements.



Source: Huiskonen, Janne (2001), Maintenance spare parts logistics: Special characteristics and strategic choices. Int. J. Production Economics.

In the same paper the author suggested the categorization of control situations and respective strategies and policies (see table 3-4-2).

Table 3-4-2. Categorization of control situations.

			Criticality	
			Low	High
Standard parts	Value	Low	• Order processing simplified e.g. by automated orders or • Outsourcing of inventory control to a supplier	• User's decentralized safety stocks and generous replenishment lot-sizes
		High	• Stock pushed back to the supplier	• Optimized user's safety stock (with high and smooth demand) • Time-guaranteed supplies from established service company (for lower and irregular demand) • Several users' co-operative stock pools (for very low demand)
User-specific parts			• User's own safety stock + partnership with local supplier to shorten leadtimes, to increase dependability and get priorities in emergency situations. • In the long run, standardization of parts when possible.	

Source: Huiskonen, Janne (2001), Maintenance spare parts logistics: Special characteristics and strategic choices. Int. J. Production Economics.

Driessen et al (2010) also distinguish so called "insurance" spare parts. ""Insurance" spare parts are parts that are very reliable, highly critical to system availability and not readily available in case of failure. <…> The decision to stock insurance parts is not based on demand forecasts or on the contribution to a certain service level, but is based on other criteria such as supply availability, failure impact or initial versus future procurement price." Two types of spare parts are considered also in the light of demand forecasting: “parts for which information on future demand is used and parts for which no future demand information is used. In case there is no information available or it is decided not to use it, then all demand is accumulated and one single demand stream is considered. Otherwise, two demand streams, i.e. planned and unplanned, are separated”.[23]

3.5. INVENTORY CONTROL SYSTEMS

Once a spare part is included in the assortment, technical information of the part is gathered and maintained. Gathering and maintaining this technical information is conducted on the basis of the following important spare parts planning and control characteristics: criticality, redundancy, commonality, specicity, substitution, shelf life, position in the configuration (that is similar to the Bill of Materials) and repair ability.[24]

An inventory control system is a process of disposable objects or materials observing and controlling with a purpose of their effective management. In general, the term may refer to the software components. “To record an inventory transaction, the system uses a barcode scanner or radio-frequency identification (RFID) reader to automatically identify the inventory object, and then collects additional information from the operators via fixed terminals (workstations), or mobile computers”.[25]

An inventory control system is a system that brings together all aspects of managing a company’s inventories, namely purchasing, shipping, receiving, tracking, warehousing and storage, turnover, and reordering. All these activities must be performed in sequence in order to have a well-run inventory control system. Computerized inventory control systems allow

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[23] Driessen, M.A., Arts, J.J., Houtum, G.J., Rustenburg, W.D., Huisman, B. (2010), Maintenance spare parts planning and control: A framework for control and agenda for future research, Beta Working Paper series 325, ISBN 978-90-386-2358-0. Available from: http://cms.ieis.tue.nl/Beta/Files/WorkingPapers/wp_325.pdf. Accessed [Online], [5/12/2014]

[24] Driessen, M.A., Arts, J.J., Houtum, G.J., Rustenburg, W.D., Huisman, B. (2010), Maintenance spare parts planning and control: A framework for control and agenda for future research, Beta Working Paper series 325, ISBN 978-90-386-2358-0. Available from: http://cms.ieis.tue.nl/Beta/Files/WorkingPapers/wp_325.pdf. Accessed [Online], [10/12/2014]

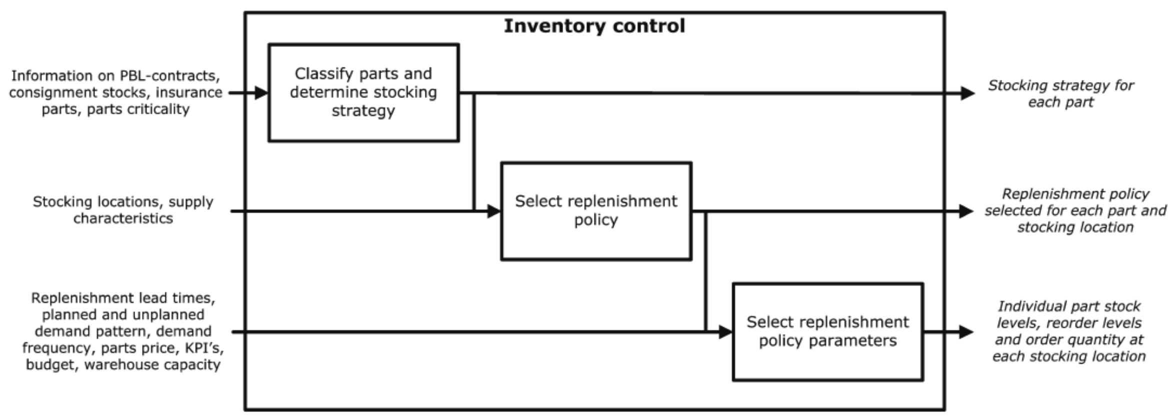
[25] MIDCOM Data Technologies, Inc., "Grocery Store Inventory Control". Midcomdata. Available from: http://www.midcomdata.com/grocery-store-inventory-control/. Accessed [Online], [7/12/2014]

integrating the various functional subsystems that are a part of the inventory management into a single cohesive system.[26]

An inventory control system, being a software based tool, can be formalized via the SAP MM module. The latter "handles the procurement and inventory functions of organizations that engage in large volumes of purchasing by giving them hands-on control of inventory management, batch management, purchasing, client categorization, valuation, invoice verification and procurement process".[27]

"The inventory control process is concerned with the decision which spare parts to stock, at which stocking location and in what quantities. The inventory control process is visualized in Figure 3-5-1".

Figure 3-5-1: Process overview of controlling inventories.



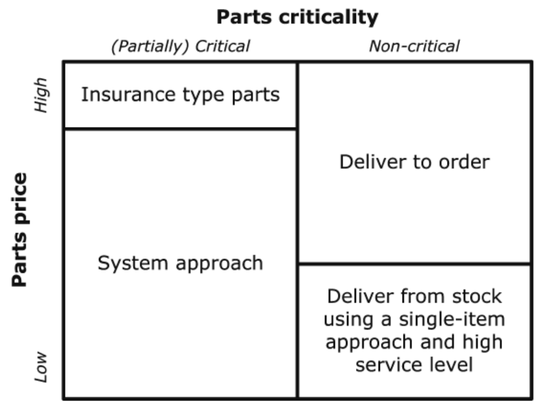
Source: Driessen, M.A. et al (2010), Maintenance spare parts planning and control: A framework for control and agenda for future research.

"Inventory control determines the desired stock levels based on the remaining demand uncertainty during the supply lead time". With the purpose of inventory control the spare parts may be classified the way as in Figure 3-5-2 shown.

[26] Inventory Control Systems. Available from: http://www.inc.com/encyclopedia/inventory-control-systems.html. Accessed [Online], [11/12/2014]

[27] Reid, J. (2014). SAP MM Module For Beginners. Available from: https://blog.udemy.com/sap-mm-module/. Accessed [Online], [12/12/2014]

Figure 3-5-2. Classification of parts with respect to inventory control.



Source: Driessen, M.A. et al (2010), Maintenance spare parts planning and control: A framework for control and agenda for future research.

In a wider sense inventory control approaches can be divided into the following groups:

- "regular" inventory control methods (that are mainly based on selective methods, such as ABC-analysis, XYZ-analysis, more detailed review of which will be done below in the 4th chapter),
- statistical inventory control (require that each spare part, irrespective of its criticality, be given equal importance. The re-order quantity, the safety stock and the minimum and maximum inventory levels require to be determined for each of the items in the stores.[28]) and
- "critical" spare parts inventory control (Sherbrooke (1968) suggested a Multi Echelon Technique for Recoverable Item Control (METRIC) model that is valuable for controlling expensive critical parts that are replaced (mostly) correctively).

The unavailability of a critical part leads to system downtime. Thus, control for these parts becomes a paramount task.[29,30] The main criteria for consideration, when applying inventory control methods, are lead time, consumption, criticality, cost of the items and expected/possible procurement difficulties.

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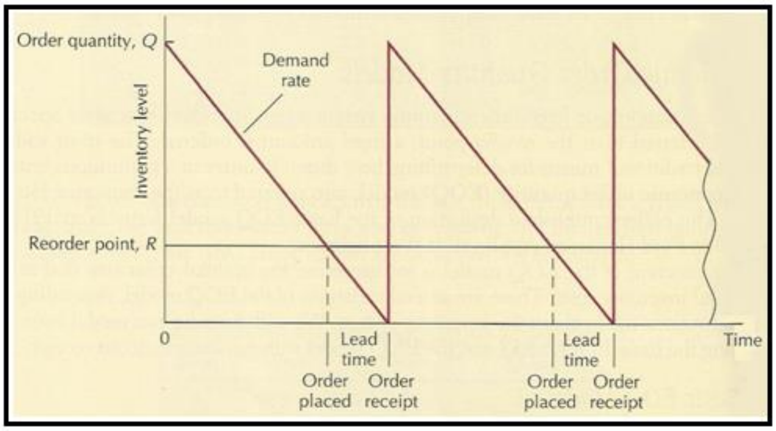
[28] Bhadbury, B. (Editor), Shenoy, D.(Editor) (1998). Maintenance Resource Management: Adapting Materials Requirements Planning MRP. ISBN-13: 978-0748406487

[29] Hopp, W.J. Spearman, M.L. (2001), Factory physics. McGraw-Hill.

[30] Sherbrooke, C.C. (1968). Metric: A multi-echelon technique for recoverable item control. *Operations Research*, 16(1), pp. 122-141.

Figure 3-5-3. The inventory order cycle.



Source: Russel & Taylor, (2000), Operations Management.

The amount of carried safety stock depends on the accuracy of forecasts, consistency of supply and processes, as well as desired service level. Lead time is defined as the amount of time needed to conduct the following procedure: ordering, purchasing and delivering of an item, or the amount of time it takes for a manufactured item to be completed after it is ordered. [31]

3.6. OPTIMIZATION AND MAINTANACE OF SPARE PARTS INVENTORIES

Hladik (2012) argues that "management of spare parts and other materials needed for realization of maintenance process is one of key functions in physical asset management".[32]
Spare parts inventory management and optimization brings together the diverse disciplines of maintenance management, inventory management, supply chain, procurement and logistics. This adds layers of complexity that aren't found with other inventory types.[33]
Maintenance means preventing situations when the crisis management would have to step in. It doesn't imply that a warehouse will be full of spare parts. Instead, the aim is to implement functional methodology for setting the optimal amount that will prevent breakdowns. As a result the minimal required amount of spare parts allows not to lock up capital in unnecessary spare parts.

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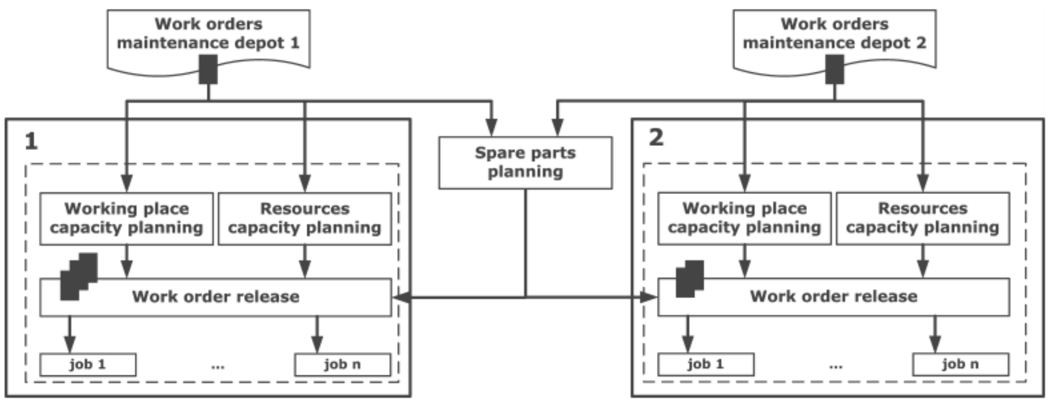
[31] Piasecki, J. David (2009). Inventory Management Explained, 1st Edition. OPS Publishing, ISBN: 0972763112
[32] Hladík, T. (2010), Effective spare parts management in maintanance. Proceedings of international conference Euro Maintenance, Verona, Italy.
[33] Best Practice Spare Parts Inventory Management. Available from: http://sparepartsknowhow.com/. Accessed [Online], [2/03/2015]

There are several limiting factors that complicate efficient maintenance inventory management in a significant manner:

- high value (price) of individual parts,
- high storage expenses,
- a risk of part unavailability with potential consequences in production and safety,
- long delivery times,
- sporadic consumption (a high number of periods with null consumption),
- difficult forecasting of future consumption.

In general, these characteristics lead to overstocking of some items and understocking of others. Existing modern sophisticated methods and tools can solve the complex issue of spare parts inventory management.[34]

Figure 3-6-1. Hierarchical planning framework for maintenance of high-value capital assets.



Source: Driessen, M.A. et al (2010), Maintenance spare parts planning and control: A framework for control and agenda for future research.

In general, maintenance process can be divided into the following main types:

- Preventive maintenance (PM).

It is also often referred to as planned maintenance – is designed to preserve and restore equipment reliability by replacing worn components before they actually fail. It is manifested in maintaining equipment and facilities in satisfactory operating condition through providing

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[34] Maintenance and spare parts inventory management is crucial for every production. Available from: http://www.logio.cz/en/maintenance-and-spare-parts-inventory-management.html. Accessed [Online], [2/03/2015]

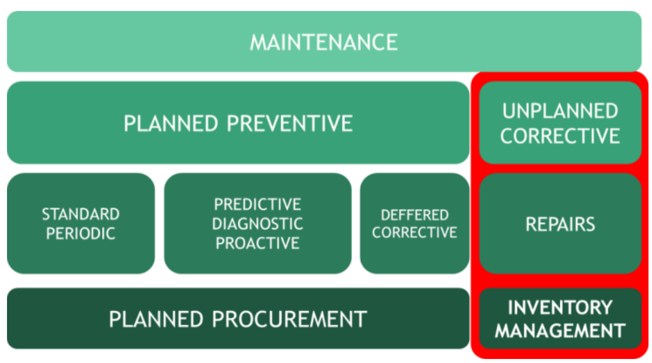
systematic inspection and correction of incipient failures either before they occur or before they develop into major defects.

- Predictive or corrective maintenance (PdM).

It is also often referred to as unplanned maintenance – is designed to assist routine or time-based preventive maintenance with a purpose of cost savings and conducted only when warranted. The main promise of PdM is to allow convenient scheduling of corrective maintenance, and to prevent unexpected equipment failures.

The main idea behind PdM implementation is "the right information in the right time". By knowing which equipment needs maintenance, maintenance work can be better planned and what would have been "unplanned stops" are transformed to shorter and fewer "planned stops", thus increasing plant availability. Other potential advantages include increased equipment lifetime, increased plant safety, fewer accidents with negative impact on environment, and optimized spare parts handling.[35]

Figure 3-6-2. Managing spare parts for preventive and corrective maintenance.



Source: Hladík, T. (2012), Effective spare parts management.

“Spare parts inventory management in maintenance is specific by distinct approach to defining required availability of an item. <…> The general goal of spare parts inventory optimization is to decrease inventory value together with maintaining or improving inventory availability. Minimization of inventories and reduction of unavailability risk seem to be two quite

[35] Kennedy, S. (2006), New tools for PdM. Plant Services.

contradictory objectives. However, by effective application of specialized information systems and sophisticated spare parts management methods it is possible to achieve both".[36]

In the following chapter the most applicable and generally used methodological approaches and practical methods will be described and discussed.

3.7. SELECTIVE INVENTORY CONTROL METHOD: ABC ANALYSIS

"ABC Method is an inventory management technique to categorize items based on their importance. The higher cost items (categorized as A) are given more emphasis and preference compared to lower cost ones (categorized as B). Items categorized as C are the lowest category".[37] ABC method of classifying spares (an acronym for Analysis Based on Consumption) is an analytical tool based on analyzing annual consumption values. Analysis employs the Pareto's principle to classify maintenance spares based on consumption values. Pareto principle can be formulated the following way: "The significant items in a given group normally constitute a small portion of the total items in a group and the majority of the items in the total will, in aggregate, be of minor significance".[38]

In this regard ABC classification will be as follows:

- "A" items: approximately 10% of total spares contributing towards 70% of total consumption value.
- "B" items: approximately 20% of total spares which account for about 20% of total consumption value.
- "C" items: nearly 70% of total spares which account for only 10% of total consumption value.

In a specific spares control system, it is quite possible that in a single year, many spares would not have been consumed at all. In such cases, it is recommended to perform ABC analysis on longer consumption period data, for instance, 3 years. Then no spares will be left out in this classification.

The annual consumption value is calculated with the formula:

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[36] Hladík, T. (2010), Effective spare parts management in maintanance. Proceedings of international conference Euro Maintenance, Verona, Italy.

[37] FREE ONLINE DICTIONARY FOR PROJECT MANAGEMENT TERMS. Available from: http://www.projectmanagementlexicon.com/abc-method/. Accessed [Online], [2/03/2015]

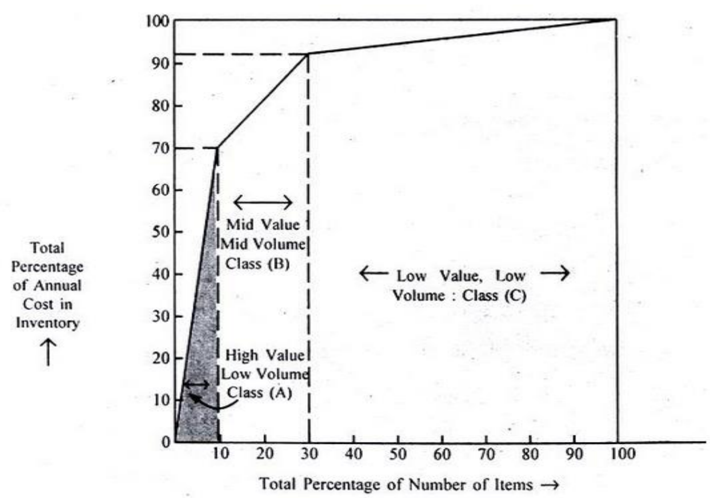
[38] DATTA, A. K. (2008), MATERIALS MANAGEMENT: PROCEDURES, TEXT AND CASES.

$$C_A = (\text{Annual demand}) \times (\text{item cost per unit}); \quad (1)$$

Through this categorization it becomes possible to identify inventory hot spots, and separate them from the rest of the items, especially those that are numerous but not that profitable.[39]

With respect to particular classes (A, B or C) different inventory management policies are implemented. For “A” items the required policy is manifested in: Maximum control, Value Analysis, More than one supplier, Control by top executives. For “B” items the required policy is manifested in: Minimum control, Bulk Orders, More items from same supplier. For “C” items an inventory management policy consist of having only 1 unit on hand, and of reordering only when an actual purchase is made; this approach leads to stock-out situation after each purchase which can be an acceptable situation, as the C-items present both low demand and higher risk of excessive inventory costs.[40]

Figure 3-7-1. The Pareto’s principle of the ABC analysis.



Source: Transtutors. Inventory control: ABC analysis. Available from: http://www.transtutors.com/homework-help/industrial-management/inventory-control/abc-analysis.aspx. Accessed [Online], [2/03/2015]

[39] Oxford Brookes University. ABC analysis. Available from: https://www.google.cz/url?sa=t&rct=j&q=&esrc=s&source=web&cd=5&cad=rja&uact=8&ved=0CEMQFjAE&url=https%3A%2F%2Fwww.brookes.ac.uk%2Fservices%2Fupgrade%2Fmaths-stats%2Fdocs%2FABC%2520analysis1234.pptx&ei=nvH2VLryJoX6Ur71g-AC&usg=AFQjCNH92DxeQCyrdDxxU2mPkPZ6kcYimA&sig2=GcGjV0hdkMMw3jmO2a1ceQ&bvm=bv.87519884,d.d24. Accessed [Online], [2/03/2015]

[40] Ramakrishnan Ramanathan (2006), ABC inventory classification with multiple-criteria using weighted linear optimization. Computers & Operations Research. Volume 33, Issue 3, pp. 695–700.

This method aims to draw managers' attention on the critical few (A-items) not on the trivial many (C-items). The control strategy for the different categories of items within ABC analysis is as follows from the Table 3-7-2.

To sum up, ABC analysis may be carried out on the basis of various criteria, such as inventory consumption, inventory stock, safety stock, consumption demand etc., and applying different meseauring units, i.e. price, quantity and so on and so forth. This provides us with understanding what item brings the most or the least contribution with regard to one or another category.

Table 3-7-2. The control strategies.

S.N.	Items Factors	A-Type Inventory	B-Type Inventory	C-Type Inventory
1.	Percentage use	10-20%	20-30%	60-70%
2.	Percentage value in (Rs.)	70-85%	10-25%	5-15%
3.	Control	Very close	Moderate	Low
4.	Supervisor	Top management	Middle management	User department
5.	Safety stock	Very-very low	Low	High
6.	Ordering frequency	Frequent	Moderate	Low
7.	Supplier	Staggered but reliable	—	Bulk suppliers
8.	Follow-up report and review	Regular (weekly)	Moderately timed (monthly)	Infrequent (semi-annually)
9.	Forecasting and material planning	Accurate	Moderate	Low quality (rough)
10.	Value engineering effort and waste reduction emphasis	More	Moderate	Less
11.	Type of records	Complete and accurate	Compete and accurate	Simplified

Source: Flores, Benito E., Whybark, D. Clay (1986) "Multiple Criteria ABC Analysis", International Journal of Operations & Production Management, Vol. 6, Iss: 3, pp.38 – 46.

3.8. A CATEGORIZATION METHOD: XYZ ANALYSIS

"The XYZ analysis is used to generate the strategy for the supply and inventory control and production strategy. This analysis enables us to perform the next step of the inventory analysis. The following classification has been generally established:

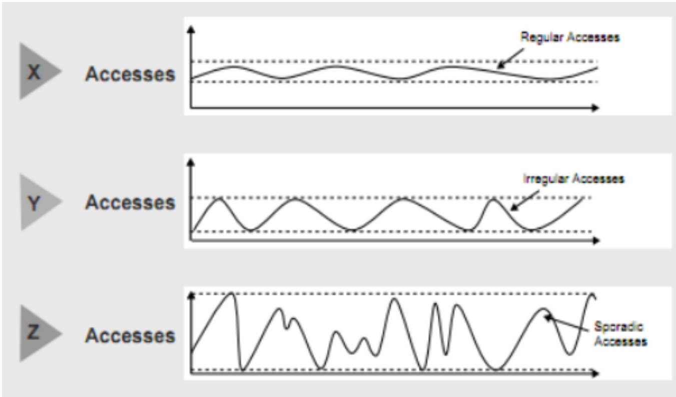
- X materials that are characterized by a constant, non-changing usage over time.
  The requirements fluctuate only slightly around a constant level so that the future demand can basically be forecast quite well.

- Y materials, the usage of which is neither constant nor sporadic.

  With Y materials, we can often observe trends, for example, that the usage increases or decreases for a while, or that it is characterized by seasonal fluctuations. For these materials, it's harder to obtain an accurate forecast. The situation is shown in figure 3-8-1.
- Z materials. These materials are not used regularly.

  The usage can strongly fluctuate or occur sporadically. In these cases, we can often observe periods with no consumption at all".[41]

Figure 3-8-1. The usage based principle of XYZ method.



Source: Petriková A., Šebo, D., Dušan Sabadka (2012), Optimization of logistics processes using XYZ method. MACHINES, TECHNOLOGIES, MATERIALS.

The XYZ analysis, in contrast to ABC analysis (that is based on annual expenditure), classifies planning objects according to the variance in a specific coefficient. "During XYZ analysis, the system assigns each object one of the following indicators: (X) Very little variation. (Y) Some variation, (Z) The most variation. XYZ Analysis is the application of Pareto's Law by which inventory is classified by $ investment in inventory in order to focus attention on those classifications which warrant closest control. One definition states that XYZ Analysis reflects customer demand for finished goods: (X) High demand, (Y) medium demand, (Z) very low or infrequent demand. Some have labeled this as FSN Classification: (F) Fast Moving, (S) Slow Moving, (N) Non Moving. Another definition states that XYZ Analysis reflects criticality: (X) Critically important requiring close monitoring and tight control, (Y) Lower criticality requiring

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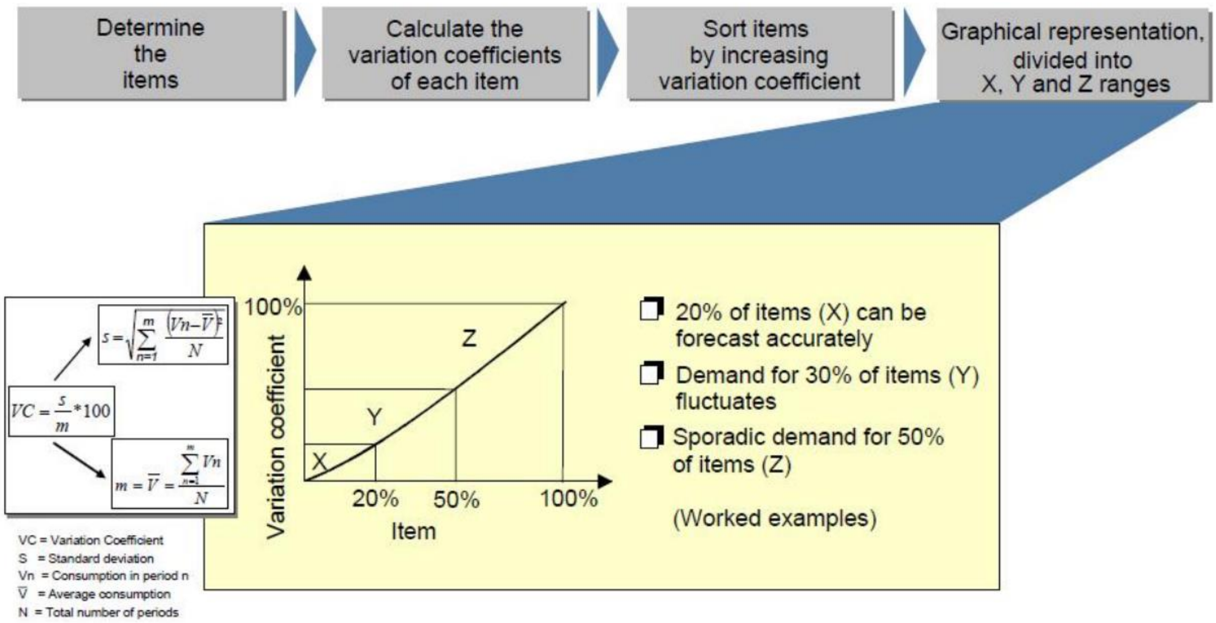
[41] Petriková A., Šebo, D., Dušan Sabadka (2012), Optimization of logistics processes using XYZ method. MACHINES, TECHNOLOGIES, MATERIALS. Available from: http://mech-ing.com/journal/Archive/2012/3/6_68_E_pletikova.pdf. Accessed [Online], [5/03/2015]

standard controls and periodic reviews of usage, (Z) Require the least control and are sometimes issues as “free issue”. Some have labeled this as VED Analysis: (V) Vital, (E) Essential, and (D) Desirable”.[42]

The combination of these two analyses helps to formulate a stock strategy matrix which is often used in inventory optimization.[43]

Figure 3-8-3. Graphical representation of XYZ concept based on the Pareto's principle.



Source: Maciejczak, Mariusz. Supply Chain Management. Available from: http://www.maciejczak.pl/lectures.html.

For XYZ analysis the following calculations have to be done: Sum of Squares, Variances, Standard Deviation (SD) and Coefficient of Variation (CV). Compilation of all these data can be tedious and prone to errors.

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \bar{x})^2}\ , \qquad (2)$$

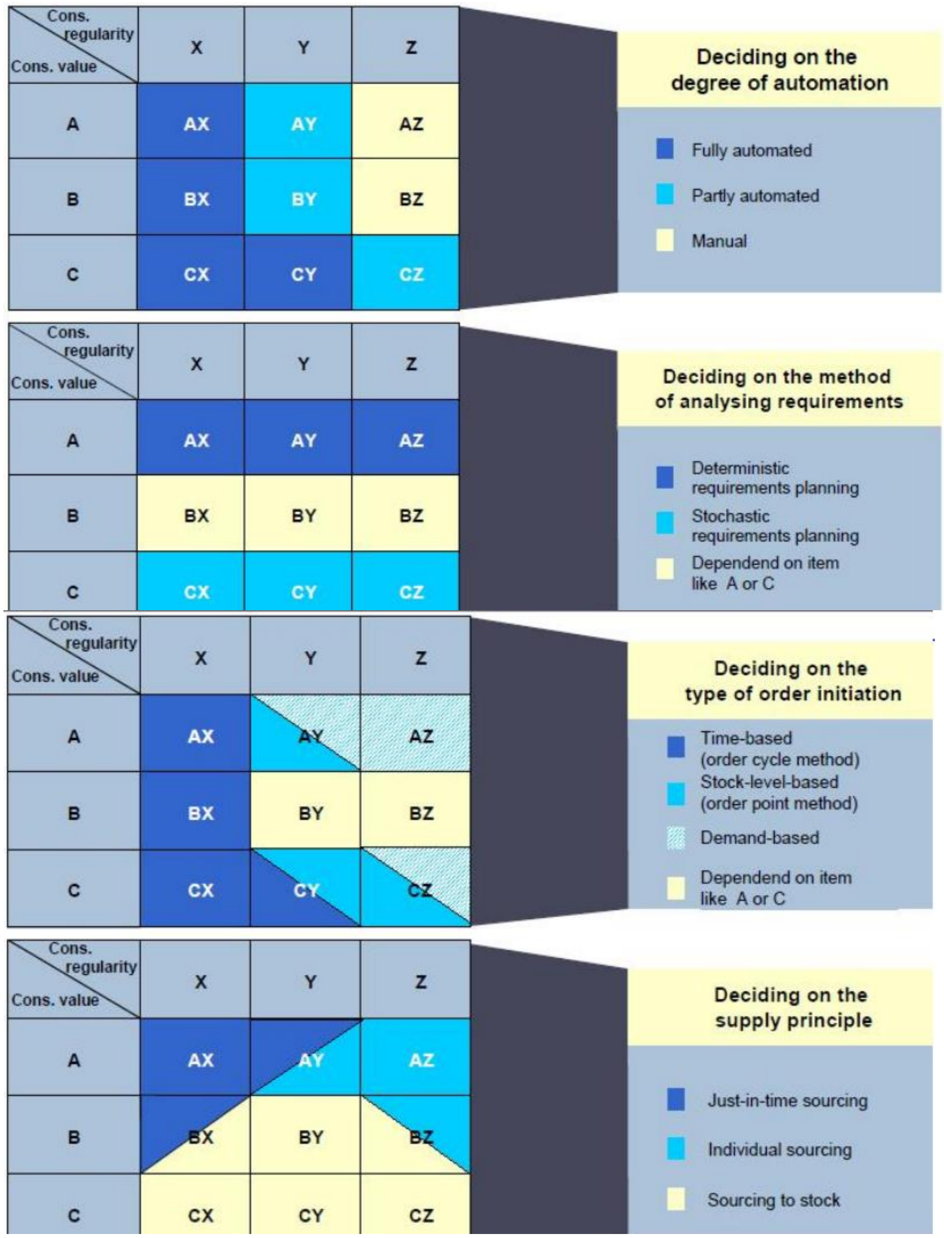
With appropriate use of XYZ analysis possible errors associated with uncertainties in both Supply and Demand forecasting can be reduced. The reduction of forecasting error is critical

[42] Randolph W. (2013). Inventory Management. Available from: https://www.linkedin.com/groups/What-is-different-between-ABC-92679.S.206825884. Accessed [Online], [5/03/2015]

[43] Minh Nguyen (2013). Inventory Management. Available from: https://www.linkedin.com/groups/What-is-different-between-ABC-92679.S.206825884. Accessed [Online], [5/03/2015]

because extrapolation of historical data will amplify the inherent errors also. As periods of planning horizon increases the forecasting errors also increase.[44]

Figure 3-8-4. Planning strategies variations on the basis of ABC and XYZ analyses results.



Source: Maciejczak, Mariusz. Supply Chain Management. Available from: http://www.maciejczak.pl/lectures.html.

[44] Dhoka, Dinesh Kumar, Choudary, Y. Lokeswara (2013), "XYZ" Inventory Classification & Challenges. IOSR Journal of Economics and Finance (IOSR-JEF). Volume 2, Issue 2, PP 23-26. e-ISSN: 2321-5933, p-ISSN: 2321-5925.

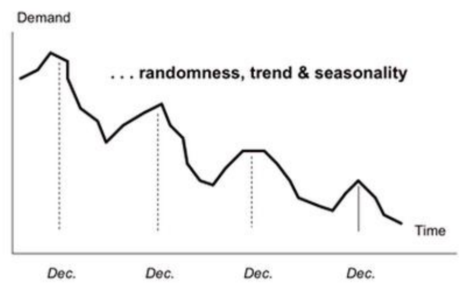
3.9. CONSUMPTION DEMAND TIME SERIES ANALYSIS

The Time Series Models are quantitative forecasting models that use chronologically arranged data to develop forecasts, assuming that what happened in the past is a good starting point for predicting what will happen in the future. These models can be designed to account for the following components of demand (see Figure 3-9-1):

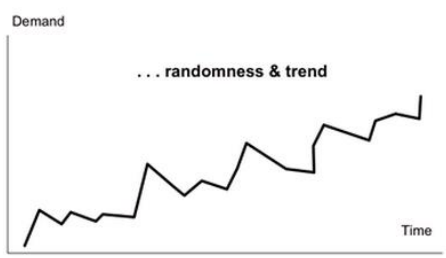
Figure 3-9-1. Time Series Components of Demand.

Randomness:

Seasonality effects:



Trend:



Source: Shumway, R.H. and D.S. Stoffer, (2000), Time Series Analysis and Its Applications, SpringerVerlag, N.Y.

The basic idea behind time series models is to distinguish between random fluctuations and true changes in underlying demand patterns.[45]

No where the cliché "History repeats itself" is more true than in consumption demand forecasting. In Time-series modeling, we just postulate that all we need is past values of the variable we are trying to forecast. So if we are trying to predict the demand for a specific item over the next six months, we use the monthly history of the item over the past two to three

[45] Bozarth, Cecil (2011), Time Series Models: Approaches to Forecasting. Available from: http://scm.ncsu.edu/scm-articles/article/time-series-models-approaches-to-forecasting-a-tutorial#2. Accessed [Online], [5/03/2015]

years."[46] Demand forecasting deals with the determination of particular spare parts will be demanded in the near future and in what quantity.

Thus, time series methodology examines the data's past history for the following criteria:

- **Historical Average.** This is also referred to as the level of consumption that you have achieved on average.
- **Trend.** This is the growth or decline in consumption (demand) over time.
- **Seasonality.** The tendency for consumption (demand) to either peak in specific periods or dip in specific periods during the week, month or the quarter.
- **Cyclicality.** Consumption (demand) volumes may go through and be affected by economic cycles. Typically, since supply chain forecasting is more focused on a time window less than one month, this is often ignored as a relevant factor affecting time-series.
- **Outliers.** Consumption (demand) may be subject to a one-time, sporadic event that may not be expected to repeat (unusual levels).[47]

Time series models assume that observations vary according to some probability distribution about an underlying function of time. The probability distribution describes the possibility that certain value, or set of values, will occur within an analyzed set of data. Due to existence of uncertainty in the spare parts consumption demand, this lead to a bias that indicates a systematic error. This error is assumed to be normally distributed. A normal distribution is defined by two parameters - its mean "μ" and variance "σ^2". The variance within the historical data is used as a good explanation in estimating the forecast error variance.[48]

Thus, among main objectives of time series analysis the following are typically listed: data compression (provide compact description of the data), explanatory (seasonal factors and relationships with other variables), signal processing (extracting a signal in the presence of noise) and prediction (use the model to predict future values of the time series).

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[46] Demand planning: Time Series. Available from: http://demandplanning.net/time_series.htm. Accessed [Online], [5/03/2015]

[47] Box, G.E.P and G.M. Jenkins and G.D. Reinsel, (1993). Time Series Analysis, Forecasting, and Control, Third Edition, Prentice Hall, Englewood Cliffs, NJ.

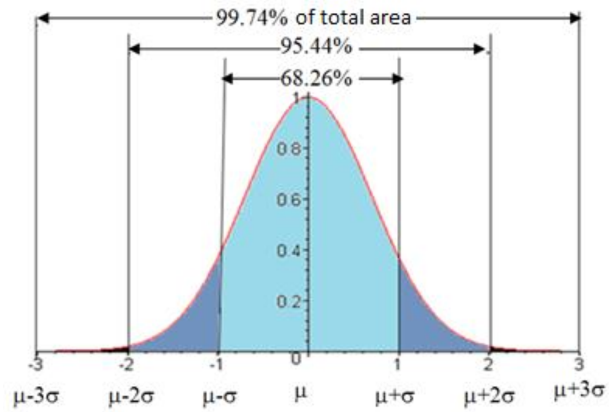
[48] Tamer, Abdelhadi Awad Mohamed (2014), Optimization of industrial spare parts inventories' management system improving machine availability within production processes in a selected organization. MSc. Thesis, CULS, Prague.

Figure 3-9-2. The Normal distribution graphical representation.

Normal Distribution

Parameters: μ, σ

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} exp\{\frac{-(x-\mu)^2}{2\sigma^2}\} \text{ for } -\infty < x < \infty$$

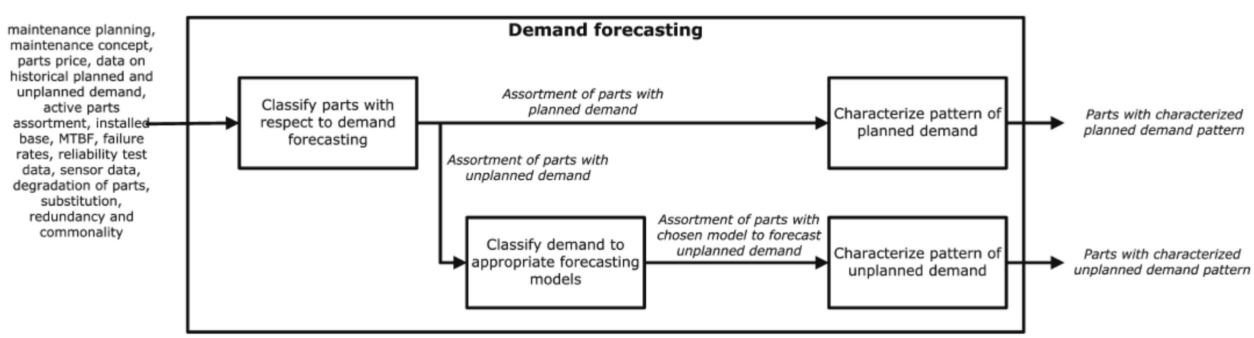


Source: Gopalakrishnan & Banerji, "Maintenance & Spare Parts Management", (2008), The University of Texas at Austin. Supplements: Probability models. Available from: https://www.me.utexas.edu/~jensen/ORMM/supplements/units/probability/prob_models.pdf. Accessed [Online], [5/03/2015]

3.10. CONSUMPTION DEMAND FORECASTING METHODS

Future demand for spare parts could be planned (partially) or unplanned. Thus, demand forecasts can either be based on historical data, known future demand data or a combination of both. It is necessary to decide whether to use the information on future demand or not. Based on this decision a forecast method is chosen to forecast or, in case of planned demand only, determine future demand for spare parts.[49] The demand forecasting process is visualized in Figure 3-10-1.

Figure 3-10-1. The demand forecasting process.



Source: Driessen, M.A. et al (2010), Maintenance spare parts planning and control: A framework for control and agenda for future research.

[49] Driessen, M.A. et al (2010), Maintenance spare parts planning and control: A framework for control and agenda for future research.

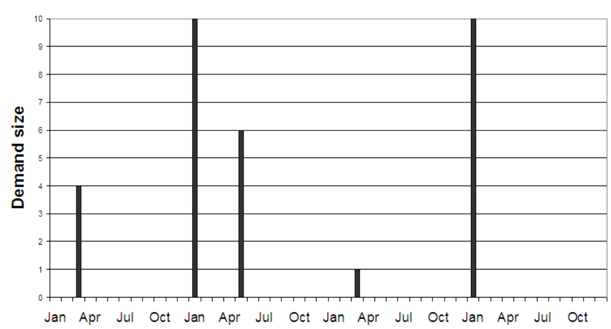
The most commonly used Demand metrics are: Forecast Attainment (how much of the forecast is actually attained, being a comparison of Consumption demand to Forecast from a prior period); Forecast Bias (a sum of signed forecast errors over either actual or forecast data); Mean Absolute Percent Error (the traditional MAPE used by academics to infer the quality of the model or Model Fit); Weighted Absolute Percent Error (the Classic Weighted MAPE used to measure the forecast error in most supply chains - volume weighted); Mean Percent Error (an average of individual MAPEs, not a very useful measure); Root Mean Squared Error (RMSE is an average of squared errors, a more rigorous measure since it weights higher errors more heavily).[50]

Popular forecast techniques that are based on Time Series are: Moving average and growth models, Simple Exponential Smoothing, Winters Models, Holt Winters Methodology, Simple Trend Seasonal Models, Logarithmic Models, ARIMA models.

Observing time series it may turn out that analyzed demand is intermittent, i.e. the demand that occurs at infrequent, irregular and often unpredictable intervals. It is also referred to as sporadic.[51]

The problems with assessing the sporadic demand are caused not only by significant variability and a relatively small demand but, above all, by prolonged periods with no demand at all.[52]

Figure 3-10-2. Typical intermittent demand pattern.



Source: Teunter, Ruud (2006), Intermittent demand: Forecasting and Inventory control. Lancaster University Management school. Available at: www.forecasters.org/.../ISF08presentation.ppt.

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[50] Demand planning: Demand metrics. Available from: http://demandplanning.net/time_series.htm. Accessed [Online], [6/03/2015]

[51] Read more: http://www.businessdictionary.com/definition/intermittent-demand.html#ixzz3UAP3MRZX

[52] Dyntar, Jakub, Kemrová, Eva, Gros, Ivan (2010), Simulation approach in stock control of products with sporadic demand. Ekonomika a management. Available at: http://www.vse.cz/eam/107.

Accurate demand forecasting is one of the most crucial aspects in inventory management. "The characteristic of demand for spare parts inventories is difficult to predict because of not only random demand but also a large proportion of zero values". A widely used method to predict this kind of demand is a Croston's method (1972), which involves exponential smoothing forecasts on the size of demand and the time periods between demands.[53]

Let's introduce into the analysis the following terms that are necessary for prospective calculations of forecasts:

- Lead time (LT).

"A LT in the supply chain management is the time from the moment the customer places an order (the moment you learn of the requirement) to the moment it is ready for delivery. In the absence of finished goods or intermediate (work in progress) inventory, it is the time it takes to actually manufacture the order without any inventory other than raw materials".[54] The amount of time that elapses between when a process starts and when it is completed. The LT minimization is normally preferred.[55] "It can be computed as the sum of the forecasted values for the future periods that intersect the lead time segment.

Let T be the period and L the LT. Then:

$$L = k * T + \alpha * T, \tag{3}$$

where k is integer and $0 \leq \alpha < 1$. Let D be the LT demand. Then, the final expression for the LT demand is:

$$D = (\Sigma_{n=1\ldots K} y'_n) + \alpha y'_{k+1}, \tag{4}$$

where y'_n is Forecasted demand for n^{th} period in the future.

The forecast error variance is computed as:

$$\sigma^2 = E\,[\,(y_t - y')^2] \text{ and } y' = D / (k+\alpha), \tag{5}$$

where y' is Average forecast per period".[56]

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[53] Vinh, Dang Quang, Forecasting irregular demand for spare parts inventory. Department of Industrial Engineering, Pusan National University, Busan 609-735, Korea. Available at: http://ike.ie.pusan.ac.kr/w/images/9/9e/08fp4-1.pdf.

[54] Rajaniemi, J. (2012), Lead Time Terminology in Manufacturing. Available at: *www.leadtimes.org*

[55] Investopedia. Lead Time definition. Available at: http://www.investopedia.com/terms/l/leadtime.asp.

[56] Tamer, Abdelhadi Awad Mohamed (2014), Optimization of industrial spare parts inventories' management system improving machine availability within production processes in a selected organization. MSc. Thesis, CULS, Prague.

Yet, σ2 is computed as per-period variance. Let σL2 be the adjusted per LT variance needed to match the LT. Therefore adjusted per LT variance will look like:

$$\sigma L2 = (k+\alpha)\ \sigma 2{,}57 \tag{6}$$

- Service level of inventory (SL).

SL represents the expected probability of not hitting a stock-out. This percentage is required to compute the safety stock. Intuitively, the service level represents a trade-off between the cost of inventory and the cost of stock-outs (which incur missed sales, lost opportunities and client frustration among others)".58 The service level of the basic safety stock can be calculated as the percentage of periods in which all demand is expected to be met, if at the beginning of each period an available spare parts amount equals exactly to the mean demand plus the result of the service factor multiplied by the standard deviation.64 "Service factor" is a term defied as the multiplier that represents number of standard deviations that will be used to calculate Safety stock.

- Safety stock (SS)

SS is the margin of error required based on the customer service level and the deviation of the demand during the lead time. The safety stock coverage level is the z-value in standard statistics for calculating the confidence interval for a customer service level.

SS = Required Inventory Coverage Level * RMSE * Square-root of (LT).[59]

Another approach to safety stock calculation is represented by multiplying standard deviation of error by the service factor, theoretically represented by the following equation: [60]

$$SS = \sigma * \mathrm{icdf}\,(P), \tag{7}$$

where SS is a Safety stock, σ - Standard deviation (the square root of σ^2 is the variance), icdf - Inverse cumulative normal distribution (z-value mean & variance equal to 1), P - Service level.

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[57] Piasecki, J. David (2009). Inventory Management Explained, 1st Edition. OPS Publishing, ISBN: 0972763112
[58] Vermorel, Joannès (2012), OPTIMAL SERVICE LEVEL FORMULA FOR INVENTORY OPTIMIZATION. Available at: http://www.lokad.com/service-level-definition-and-formula.
[59] Safety Stock Coverage at different service levels. Available at: http://demandplanning.net/safety_stock_coverage_levels.htm.
[60] Piasecki, J. David (2009). Inventory Management Explained, 1st Edition. OPS Publishing, ISBN: 0972763112

3.10.1. Common statistical methods of forecasting

"The method of moving averages is used most effectively to forecast demand data which varies slowly (a horizontal pattern or a slow-varying trend). Moving averages forecasts are not typically useful when seasonal or cyclical effects are present in the demand data. Moving average techniques data for demand data involve computing the mean of the N most recent past values and using this mean as a forecast for the next period".[61]

In the next subchapters the two main types of moving averages will be presented, namely simple moving averages and weighted moving averages. Also the Naïve method will be described.

3.10.1.1. Simple moving averages

A simple moving average equally weights all N past demand data values with the purpose of forecasting the future demand. The more periods are included in the analysis, the more stable the forecast will be.[67]

$$\text{Simple Moving Average Forecast} = \frac{\sum \text{demand in previous } n \text{ periods}}{n}, \tag{8}$$

where n is the number of periods in the moving average.

Thus, the core assumption behind the simple moving averages models is that the average performance of the recent past is a good predictor of future performance.[62]

3.10.1.2. Weighted moving average

A weighted moving average assigns different weights (which must add to 1) to some of the N past demand data values than to others with the purpose of forecasting the future demand. Typically, more weight is given to the more recent values of past demand.[63]

$$\text{Weighted Moving Average Forecast} = \frac{\sum (\text{weight for period } n) \cdot (\text{demand in period } n)}{\sum \text{weights}}, \tag{9}$$

Weighted moving average forecasts which place more weight on recent past demand values are more responsive to trends in the data than simple moving average forecasts.[68]

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[61] Chiulli, Roy M. (1999), Quantitative Analysis: An Introduction. CRC Press: 592 p.

[62] Eppen, G.D., Gould, F.J., Schmidt, C.P., Moore, H. Jeffrey, Weatherford, R, Larry R. (1998). Introductory Management Science, 5th Edition. Prentice Hall, Inc., Upper Saddle River, NJ07458, ISBN: 0-13-889395-0.

[63] Chiulli, Roy M. (1999), Quantitative Analysis: An Introduction. CRC Press: 592 p.

3.10.1.3. Naïve forecasts

It is applicable for stationary time series data only. "All forecasts are simply set to be the value of the last observation. That is, the forecasts of all future values are set to be y_t, where y_t is the last observed value".[64] The Naïve forecast for any period equals the historical average:

$$\widehat{y}_{t+h|t} = y_t\,, \tag{10}$$

Naïve methods are the most simple and effective forecasting models enabling to set a benchmark against which more sophisticated models can be compared.

3.10.2. Intermittent demand forecasting methods

Classical forecasting methods such as described above are usually applied in common supply management systems and become ineffective when used with regard to sporadic (intermittent) demand for mainly the following reasons:

- Classical methods do not take into account the importance of zero demand periods.
- Classical methods are not focused on the distribution function forecast of demand during the order lead time period, which is very important for the effective flow of such materials.[65]

For that reason the most applicable methods related to sporadic demand will be discussed below.

3.10.2.1. Single (or simple) exponential smoothing (SES)

An exponentially smoothed moving average is a weighted moving average in which the weight factors are powers of S, the smoothing constant. An exponentially smoothed moving average is computed over all the data accumulated so far instead of being chopped off after some number of periods.

$$S_t = \alpha X_t + (1-\alpha) S_{t-1}\,, \tag{11}$$

where: α is the smoothing parameter,

X_t is the observed value of both zero and non-zero demand,

S_t is the smoothed average as well as the forecast for next period.

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[64] Hyndman, Rob J., Athana-sopou-los, George (2014), Forecasting: principles and practice: Some simple forecasting methods. Available at: https://www.otexts.org/fpp/2/3

[65] Dyntar, Jakub, Kemrová, Eva, Gros, Ivan (2010), Simulation approach in stock control of products with sporadic demand. Ekonomika a management. Available at: http://www.vse.cz/eam/107.

Or using another and more usual designation the Exponential Smoothing Forecast is:

$$F_t = F_{t-1} + \alpha(A_{t-1} - F_{t-1}), \tag{12}$$

where F_t = New Forecast,

F_{t-1} = Previous Forecast,

α = Smoothing Constant: $(0 \le \alpha \le 1)$,

A_{t-1} = Previous Period's Actual Demand.

"Although SES is widely used to forecast intermittent demand, the method has important limitations. Exponential smoothing weights recent data more heavily, which produces forecasts that are biased high just after a demand occurs and biased low just before a demand. Replenishment quantities are likely to be determined by forecasts made just after a demand, resulting in unnecessarily high stock levels most of the time".[66]

3.10.2.2. Exponential smoothing with trend adjustment

Forecast Including Trend: $F_t = \alpha(A_{t-1}) + (1 - \alpha)(F_{t-1} + T_{t-1})$, (13)

Trend: $T_t = \beta(F_t - F_{t-1}) + (1 - \beta)T_{t-1}$, [67] (14)

where F_t = Exponentially smoothed forecast for period t,

T_t = Exponentially smoothed trend for period t,

A_t = Actual demand for period t,

α = Smoothing constant for the average $(0 \le \alpha \le 1)$,

β = Smoothing constant for the trend $(0 \le \beta \le 1)$.

The "best" α and β can be found by Solver. A higher value of β indicates a larger portion of the most recent trend being added to the next period's forecast. The β value can also be iteratively changed like α to minimize error values.[68]

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[66] Syntetos, Aris A., Babai, M. Zied, Gardner, Everette S. (2014), Forecasting Intermittent Inventory Demands: Simple Parametric Methods vs. Bootstrapping. Available at: http://www.bauer.uh.edu/gardner/docs/pdf/Forecasting%20intermittent%20demand%20R2%20%28JBR%29%203.pdf.

[67] Bozarth, Cecil (2011), Time Series Models: Approaches to Forecasting.

[68] Gentry, T., Wiliamowski, B., Weatherford, L. (1995), A comparison of traditional forecasting techniques and neural networks. *Intelligent engineering systems through artificial neural networks.* Volume 5. Available at: http://www.eng.auburn.edu/~wilambm/pap/1995/ANNIE%2795_A_comparison_of_traditional_forecasting.pdf.

3.10.2.3. Croston's method

Croston (1972) suggested modification of exponential smoothing for sporadic demand time series. [69] The core of this method is not only the estimation of average demand volume, but also estimation of time interval length between two non-zero demands.[71] "In an attempt to compensate for mentioned above problems with SES, Croston's (1972) method forecasts two components of the time series separately, the observed value of nonzero demand (D_t) and the inter-arrival time of transactions (Q_t). The smoothed estimates are denoted (Z_t) and (P_t), respectively:

$$Z_t = \alpha D_t + (1-\alpha) Z_{t-1}, \tag{15}$$

$$P_t = \alpha Q_t + (1-\alpha) P_{t-1}, \tag{16}$$

Croston assumes that the value of the smoothing parameter α is the same in both equations. The estimate of demand per unit time, i.e. the forecast for next period (Y_t) is then:

$$Y_t = (\alpha D_t + (1-\alpha) Z_{t-1}) / (\alpha Q_t + (1-\alpha) P_{t-1}) \ , \tag{17}$$

If there is no demand in a period, Z_t and P_t are unchanged. Note that when demand occurs every period the Croston's method gives the same forecasts as conventional SES. Thus the same method can be used for both intermittent and non-intermittent demands.

3.10.2.4. Modified Croston's method

"Many improvements to Croston's original method have been published, including Johnston and Boylan (1996), Snyder (2002), Syntetos and Boylan (2005), Shale, Boylan, and Johnston (2006), and Teunter, Syntetos, and Babai (2011). The Syntetos and Boylan method (known as the SBA method), is the only Croston's improvement that has substantial empirical support".[70] The modifications to Croston's method can provide improved forecast accuracy. It was shown that Y_t

[69] Croston, J.D. (1972), Forecasting and stock control for intermittent demands. Operational Research Quarterly 23, 289-303.

[70] Syntetos, Aris A., Babai, M. Zied, Gardner, Everette S. (2014), Forecasting Intermittent Inventory Demands: Simple Parametric Methods vs. Bootstrapping. Available at: http://www.bauer.uh.edu/gardner/docs/pdf/Forecasting%20intermittent%20demand%20R2%20%28JBR%29%203.pdf.

is biased to over-forecast.[71] Later the SBA method was developed[72] to a modified version of equation (18) that is approximately unbiased:

$$Y_t = (1-\alpha/2)(Z_t/P_t) \quad , \tag{18}$$

It is recommended on the grounds of simplicity, the variance of the forecast errors to estimate by the exponentially smoothed mean squared error (MSE) over the lead time plus review period.[73]

3.10.2.5. The Holt-Winters (HW) method

Holt (1957) extended SES method to allow forecasting of data with a trend. This method involves a forecast equation and two smoothing equations (one for the level and one for the trend):

Forecast equation: $\hat{y}_{t+h|t} = \ell_t + hb_t$, (19)

Level equation: $\ell_t = \alpha y_t + (1-\alpha)(\ell_{t-1} + b_{t-1})$, (20)

Trend equation: $b_t = \beta^*(\ell_t - \ell_{t-1}) + (1-\beta^*)b_{t-1}$. (21)

where ℓ_t denotes an estimate of the level of the series at time t,

b_t denotes an estimate of the trend (slope) of the series at time t,

α is the smoothing parameter for the level, $0 \leq \alpha \leq 1$ and

$\beta*$ is the smoothing parameter for the trend, $0 \leq \beta^* \leq 1$ (where $\beta=\alpha\beta^*$).[74]

3.11. ASSESSMENT OF FORECASTING ACCURACY

"A fundamental concern in forecasting is the measure of forecasting error for a given data set and a given forecasting method. Accuracy can be defined as … how well the forecasting model is able to reproduce data that is already known."[75]

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[71] Syntetos, A.A., & Boylan, J.E. (2001). On the bias of intermittent demand estimates. International Journal of Production Economics, 71(1-3), pp. 457-466.
[72] Syntetos, A.A., & Boylan, J.E. (2005). The Accuracy of Intermittent Demand Estimates. International Journal of Forecasting, 21(2), pp. 303-314.
[73] Syntetos, A.A., & Boylan, J.E. (2006). On the stock control performance of intermittent demand estimators. International Journal of Production Economics, 103(1), pp. 36-47.
[74] Hyndman, Rob J., Athana-sopou-los, George (2014), Forecasting: principles and practice. Holt-Winters seasonal method. Available at: https://www.otexts.org/fpp/7/2.
[75] Gentry, T., Wiliamowski, B., Weatherford, L. (1995), A comparison of traditional forecasting techniques and neural networks. *Intelligent engineering systems through artificial neural networks.* Volume 5. Available at: http://www.eng.auburn.edu/~wilambm/pap/1995/ANNIE%2795_A_comparison_of_traditional_forecasting.pdf.

The forecasting methods are compared with each other utilizing several measures of forecast error. There are a number of approaches and measures to assess forecast accuracy. Commonly used Measures of aggregate error are: Mean Absolute Deviation (MAD), Mean Absolute Percentage Error (MAPE), Mean squared error (MSE) and Root Mean Square Deviation (RMSD).

The MAPE is the most common measure of forecast error. MAPE is the best variant when there are no extremes to the data (including zeros).[76]

$$MAPE = \frac{1}{N}\sum_{i=1}^{N}\frac{\left|X_t - \widehat{X}_t\right|}{X_t} * 100\%, \tag{22}$$

where X_t equals the actual (demand or consumption) value,

$\widehat{X}_t$ equals the fitted (forecasted) value,

N equals the number of observations.

The MAD is an average of the difference between the forecast and actual demand, as computed by the following formula [80]:

$$MAD = \frac{\sum_{i=1}^{N}| X_t - \widehat{X}_t |}{N} * 100\%, \tag{23}$$

MAD can reveal which high-value forecasts are causing higher error rates. Outliers have less of an effect on MAD than on MSE.

The MSE is the average of the squared errors between the actual and the forecasted demand data:[77]

$$MSE = \frac{\sum_{i=1}^{N}(X_t - \widehat{X}_t)^2}{N} * 100\%, \tag{24}$$

The Mean Absolute Error measures the average magnitude of the errors in a set of forecasts, without considering their direction. It measures accuracy for continuous variables. Calculation of

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[76] Gentry, T., Wiliamowski, B., Weatherford, L. (1995), A comparison of traditional forecasting techniques and neural networks. *Intelligent engineering systems through artificial neural networks.* Volume 5. Available at: http://www.eng.auburn.edu/~wilambm/pap/1995/ANNIE%2795_A_comparison_of_traditional_forecasting.pdf.

[77] Chiulli, Roy M. (1999), Quantitative Analysis: An Introduction. CRC Press: 592 p.

MAE is relatively simple. It involves summing the magnitudes (absolute values) of the errors to obtain the 'total error' and then dividing the total error by n[78]:

$$MAE = \frac{1}{N}\sum_{i=1}^{N}\left|X_t - \widehat{X}_t\right|, \qquad (25)$$

The Absolute Scale Error:

$$ASE = \frac{\left|X_t - \widehat{X}_t\right|}{MAE}, \qquad (26)$$

The Mean Absolute Scale Error:

$$MASE = \frac{1}{N}\sum_{i=1}^{N}\frac{\left|X_t - \widehat{X}_t\right|}{MAE}, \qquad (27)$$

where X_t equals the actual (demand or consumption) value,

$\widehat{X}_t$ equals the fitted (forecasted) value,

N equals the number of observations.

3.12. CALCULATION OF RE-ORDER QUANTITIES AND INVENTORY LEVEL

The reorder point is the amount of stock that is set to trigger an order of a specific item. Usually, because of the uncertainties, it is generally calculated as the expected usage during the lead time plus safety stock. If there is no uncertainty and future demand is perfectly known and supply is perfectly reliable, the reorder point would simply be equal to the total forecasted demand during the lead time. Assuming that for a given lead time, future demand forecast is produced, the lead time demand can be calculated as the sum of the forecasted values for the future periods that intersect the lead time segment.[79] Thus, the initial formula of re-order point calculation is as follows:

$$R = y' + y * icdf\ (P) \qquad (28)$$

where R Re-order point,

y' Average forecast per period,

icdf Inverse cumulative normal distribution (zero mean &variance equal to one),

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[78] Willmott, Cort J., Matsuura, Kenji (2005), Advantages of the mean absolute error (MAE) over the root mean square error (RMSE) in assessing average model performance. CLIMATE RESEARCH. Vol. 30: 79–82.
[79] Piasecki, J. David (2009). Inventory Management Explained, 1st Edition. OPS Publishing, ISBN: 0972763112

σ Standard deviation,

P Service level.

The final formula of the reorder point is as:

$$R = D + \sigma_L * \mathrm{cdf}(P) \tag{29}$$

where D Lead time demand,

σ_L Adjusted per lead time standard deviation,

cdf cumulative normal distribution function.

The Quantity of order is calculated with the following formula:

$$\text{Order} = F_{LT} + SS - Stock \tag{30}$$

where Stock Inventory level of spare part,

LT Lead Time of spare part,

F Forecast of spare part during the LT,

SS Safety Stock of spare part.

The Inventory level of spare part is calculated with the formula[80]:

$$\text{Inventory level} = Stock_t - F_{LT} + Order_{LT} \tag{31}$$

where Stock Inventory level of spare part in the beginning of period t,

F Forecast during the LT,

Order Quantity of ordered spare part during the LT.

[80] Piasecki, J. David (2009). Inventory Management Explained, 1st Edition. OPS Publishing, ISBN: 0972763112

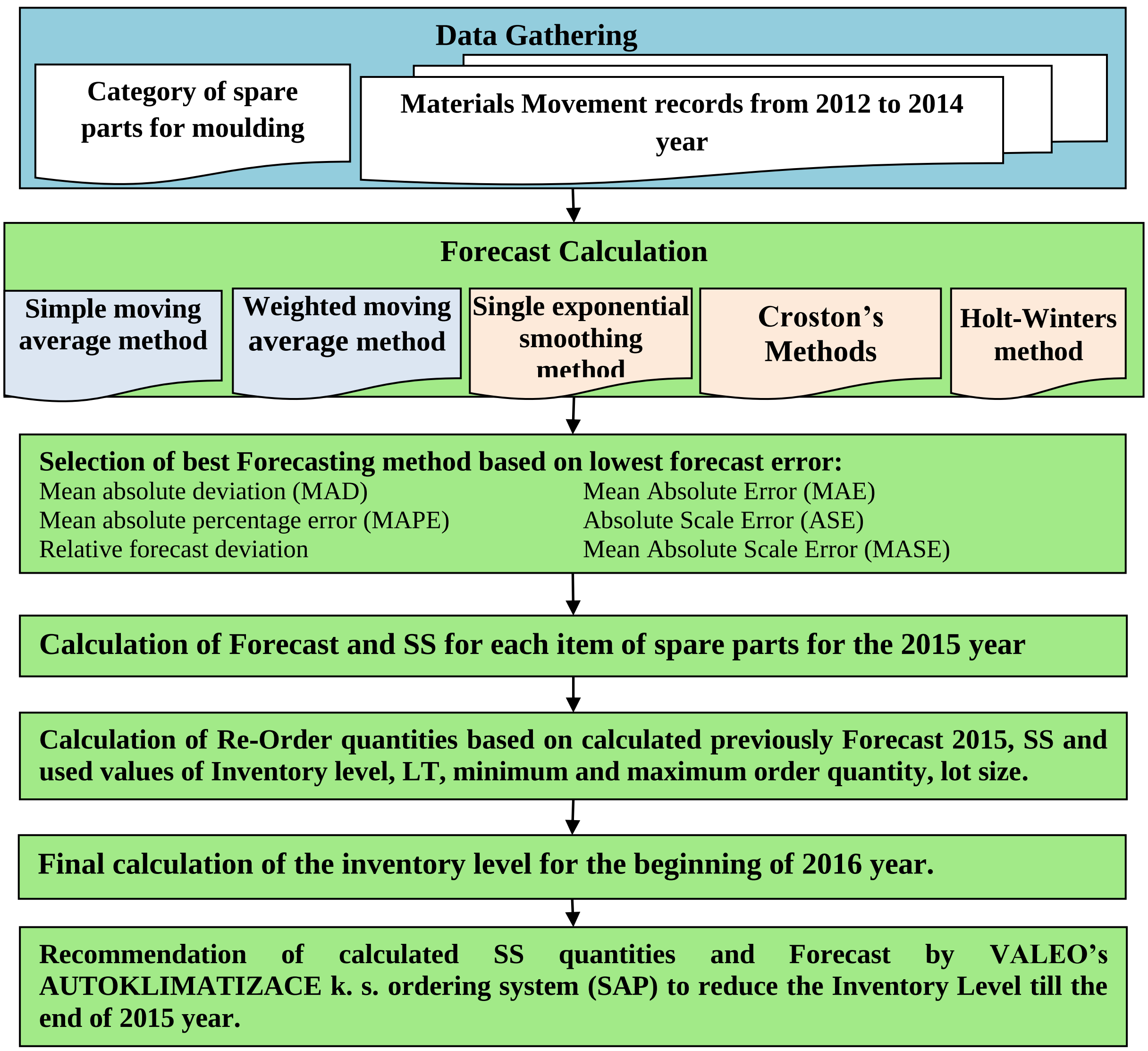
4. MATERIALS AND METHODS

We begin this chapter with an interpretation of the provided by VALEO AUTOKLIMATIZACE k. s. data with the purpose of better understanding of their specifics and consequently selection the most suitable and appropriate methods for their further processing.

4.1. THE RESEARCH MAP

The research framework is represented in the following map on the Figure 4-1-1.

Figure 4-1-1: The research framework.



Source: Author's graphical representation.

4.2. INTERPRETATION OF PROVIDED DATA AND PLAN OF THEIR PROCESSING

The raw data received from VALEO AUTOKLIMATIZACE k. s. Company were represented in several exported from SAP® software to MS Excel spreadsheets containing information on all items' (various spare parts and components) movements/consumptions and stocks. To each item, among all available in raw data spare parts, yet in SAP system was assigned a unique number. Namely these unique numbers will be utilized during the calculations. The plan of the data processing is as follows:

1. Provided data interpretation and gathering resulted in grouping all the items into the categories according to function (see enclosure 1).
2. Then to each item of spare parts within each category the following information was matched:
   - Consumption per month for the period 2012-2014 (see enclosure 2),
   - Quantity and Value of Inventory level (Stock) for the beginning of each year from 2012 till 2014,
   - Safety stock for the beginning of 2015 year / current value (in CZK and quantity items),
   - Lead time for the beginning of 2015 year / current value (days),
   - MOQ = Minimum order quantity for the beginning of 2015 year / current value (in quantity items),
   - Total received materials for the period 2012-2014 (in CZK and quantity items),
3. The calculation of total values both in CZK and item's units for each category, creation of overall summary table for the period 2012-2015 year.
4. ABC analysis of Consumption and Inventory level for the period 2014-2015 (in CZK and quantity units); the input data are provided by the summary table from par.1 (see above).
5. Comparison the results of ABC analysis for Consumption in CZK with Inventory level in CZK and Consumption in item's units with Inventory level in item's units.
6. XYZ analysis of Consumption per each item for the period 2012-2014.
7. The standard deviation calculation and results ranking (<0.1=X; >0.25=Y; the rest=Z).
8. Compilation the results of ABC and XYZ analysis into a single table per item's units and CZK.

9. Here is the starting point for forecasts calculation. Using the summary table from par.1 we apply consequently one after another the following methods:
   - Simple Moving Average (periods of 3, 6 and 12 months were taken one after another to construct 3 forecasts), used formula (8): $\frac{\sum \text{demand in previous } n \text{ periods}}{n}$,
   - Weighted Moving Average (periods of 3, 6 and 12 months were taken one after another to construct 3 forecasts), used formula (9): $\frac{\sum (\text{weight for period } n) \cdot (\text{demand in period } n)}{\sum \text{weights}}$,
   - Naïve method, used formula (10): $\widehat{y}_{t+h|t} = y_t$,
   - Simple Exponential Smoothing, used formula (12): $F_t = F_{t-1} + \alpha(A_{t-1} - F_{t-1})$,
   - Croston's method, used formula (17): $Y_t = (\alpha D_t + (1-\alpha)Z_{t-1}) / (\alpha Q_t + (1-\alpha)P_{t-1})$,
   - Modified Croston's method, used formula (18): $Y_t = (1 - \alpha/2)(Z_t / P_t)$,
   - Holt-Winters method, used formulas are (19), (20), (21):

     Forecast equation: $\hat{y}_{t+h|t} = \ell_t + hb_t$,

     Level equation: $\ell_t = \alpha y_t + (1-\alpha)(\ell_{t-1} + b_{t-1})$,

     Trend equation: $b_t = \beta^*(\ell_t - \ell_{t-1}) + (1-\beta^*)b_{t-1}$.
10. On the basis of the received prognosis values the following forecast accuracy assessments have to be done in order to detect the most accurate forecast among applied:
    - Forecast deviation, used formula: Forecast value (F) – Actual consumption (A),
    - Relative forecast deviation, used formula: (F-A)/A=F/A-1,
    - Mean Absolute Deviation, used formula (23): MAD = $\frac{\sum_{i=1}^{N} | X_t - \widehat{X}_t |}{N} * 100\%$,
    - Mean Absolute Percentage Error, used formula (22): MAPE = $\frac{1}{N} \sum_{i=1}^{N} \frac{|X_i - \widehat{X}_i|}{X_i} * 100\%$,
    - Mean Absolute Error, used formula (25): MAE= $\frac{1}{N} \sum_{i=1}^{N} |X_i - \widehat{X}_i|$,
    - Absolute Scale Error, used formula (26): ASE = $\frac{|X - \widehat{X}|}{MAE}$,

- Mean Absolute Scale Error, used formula (27): MASE = $\frac{1}{N}\sum_{i=1}^{N}\frac{\left|X_i - \hat{X}_i\right|}{MAE}$.

11. The results of these calculations are gathered into a single table, were they are compared with the purpose of selection the most accurate/precise one.
12. Appling the most suitable forecast method have to be calculated forecast for each item of spare parts for the 2015 year.
13. Calculation of safety stock for each item of spare part (see enclosure 4), used formula (7) :

$$SS = \sigma * \text{icdf}\,(P),$$

14. Calculation of each spare parts inventory level at the beginning of 2016 year (in CZK and quantity items, see enclosure 4), used formulas (29), (30) and (31):

Reorder point equation: R = D + σ_L * cdf (P)

Quantity of order equation: Order = $F_{LT} + SS - Stock$

Inventory level of spare part equation: $Stock_t - F_{LT} + Order_{LT}$

15. The calculation of total values both in CZK and item's units for each category, creation of overall summary table for the period 2015-2016 year.

5. RESULTS OF EMPIRICAL DATA ANALYSIS

This chapter provides the results of empirical data analysis. The main emphasis is done on the selection of the most appropriate forecasting method that fits the selected company's management policy best.

5.1. A SELECTED COMPANY DESCRIPTION

The selected for the research company is VALEO AUTOKLIMATIZACE k.s. that is a part of a multinational concern VALEO. Company focuses on a design, production and sale of the systems, modules and components for the automotive industry. It consists of manufacturing, conveyor system and administrative areas. The basic facts and figures about the company are given below in the Table 5-1-1.

Table 5-1-1. The basic facts and figures of VALEO AUTOKLIMATIZACE k.s.

Turnover 2007:	▪ air conditioning systems: CZK 8.2 bln, ▪ control panels: CZK 1.5 bln.
Number of employees:	▪ 900 production operators, ▪ 400 technical-administrative employees. TOTAL: 1300.
Production area:	35.000 m2 (out of it 27 000 m2 production and warehousing spaces)
Production program:	▪ plastic parts moulding for the air conditioning systems, ▪ air conditioning systems and control panels assembly.

Source: VALEO AUTOKLIMATIZACE k.s. Available at: http://www.valeorakovnik.cz/about-valeo-2/the-basic-facts-and-figures/.

Manufacturing area forms 27,000 m^2 for production and storage facilities, aims to streamline the flow of materials and finished products, throughout 24 pre-assembly and final assembly lines with buffer stocks, before it is finally inspected by operators and loaded into trucks for shipment either internally or externally. The plant is equipped with 20 plastic injection moulding machines with 1 374 replaceable moulds, including three machines newly installed in December 2012, and put into operation in 2013 and in 2014 years.

Figure 5-1-2. An example of a Plastic injection moulding machine. DuraLine Group, United States, Model: 1075 Clamping forces: 600 to 60,000 kN.

Source: VALEO AUTOKLIMATIZACE k.s. Available at: http://plasticextruder.co/injection-molding-machine-energy-saving-series/

In the Czech Republic there are two additional plants feeding automotive industry:

- located at Žebrák, focused on the production of heat exchangers, evaporators and air heaters.
- located at Humpolec, focused on the manufacture of compressors used in automobile air conditioning systems.

More over VALEO concern has a number of others affiliated companies that provide development and technical support for manufacturing plants all over the world.

5.2. THE ENTIRE INVENTORY REVIEW AND CATEGORIZATION

The spare parts inventory is grouped into twenty categories of spare parts components (see enclosure 1), where each material is identified by a unique identification code (IDH), including items with various functions.

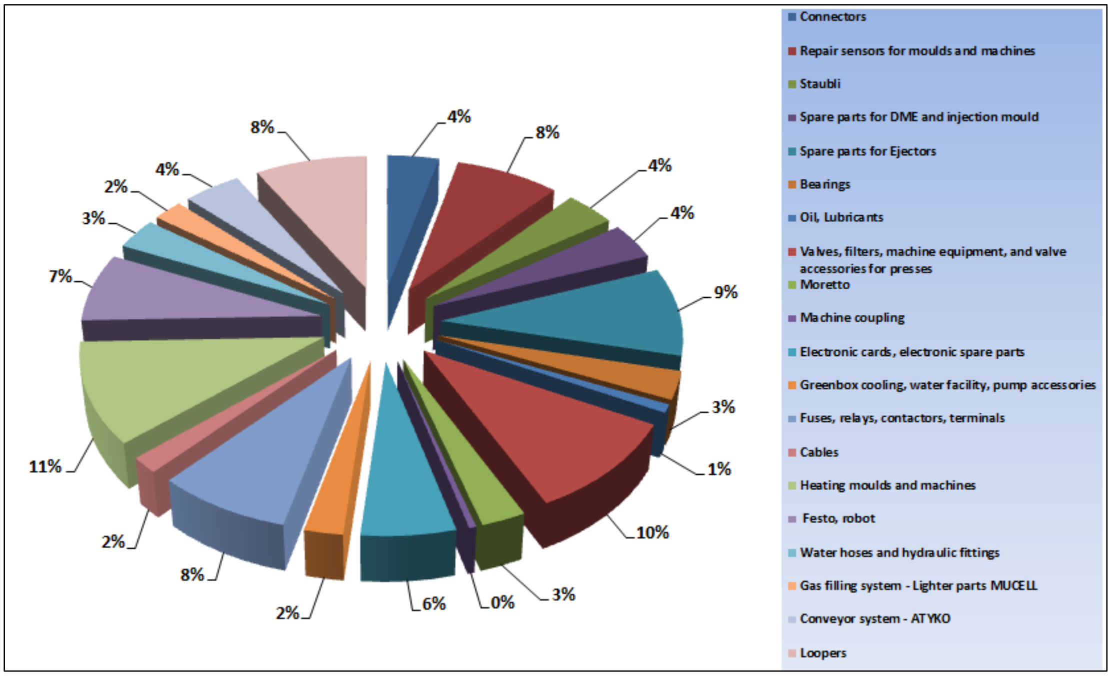
Table 5-2-1. Categorization of spare parts.

Ordinal Nr.	Description	Category Nr.	Number of spare part components	Relative Quantity of inventory level for each category	Relative Value of inventory level for each category
1	Connectors	1	53	2%	1%
2	Repair sensors for moulds and machines	2	107	3%	4%
3	Staubli	3	52	5%	2%
4	Spare parts for DME and injection mould	4	53	1%	4%
5	Spare parts for Ejectors	5	129	20%	9%
6	Bearings	6	41	1%	3%
7	Oil, Lubricants	7	12	0%	0%
8	Valves, filters, machine equipment, and valve accessories for presses	8	140	2%	27%
9	Moretto	9	37	2%	1%
10	Machine coupling	10	6	0%	0%
11	Electronic cards, electronic spare parts	11	78	1%	7%
12	Greenbox cooling, water facility, pump accessories	12	32	1%	2%
13	Fuses, relays, contactors, terminals	13	111	6%	1%
14	Cables	14	24	8%	0%
15	Heating moulds and machines	15	149	6%	17%
16	Festo, robot	16	100	2%	8%
17	Water hoses and hydraulic fittings	17	45	6%	1%
18	Gas filling system - Lighter parts MUCELL	18	31	0%	9%
19	Conveyor system - ATYKO	19	59	1%	1%
20	Loopers	20	115	32%	3%
	Total		1 374	100%	100%

Source: data of VALEO AUTOKLIMATIZACE k.s., author's calculations.

The calculated relative quantity of each category is compared with each other to understand what groups have the highest number of spare parts. The highest numbers of spare parts belong to groups Heating moulds and machines (11%), Valves, filters, machine equipment and valve accessories for presses (10%) as well as Spare parts for Ejectors (9%), while the lowest number of spare parts belong to gorups the Machine coupling (0.4%), Greenbox cooling, water facility, pump accessories (2%) and Cables (2%) (see Figure 5-2-2).

Figure 5-2-2. The share of spare part categories in entire inventory in the 2015 year.

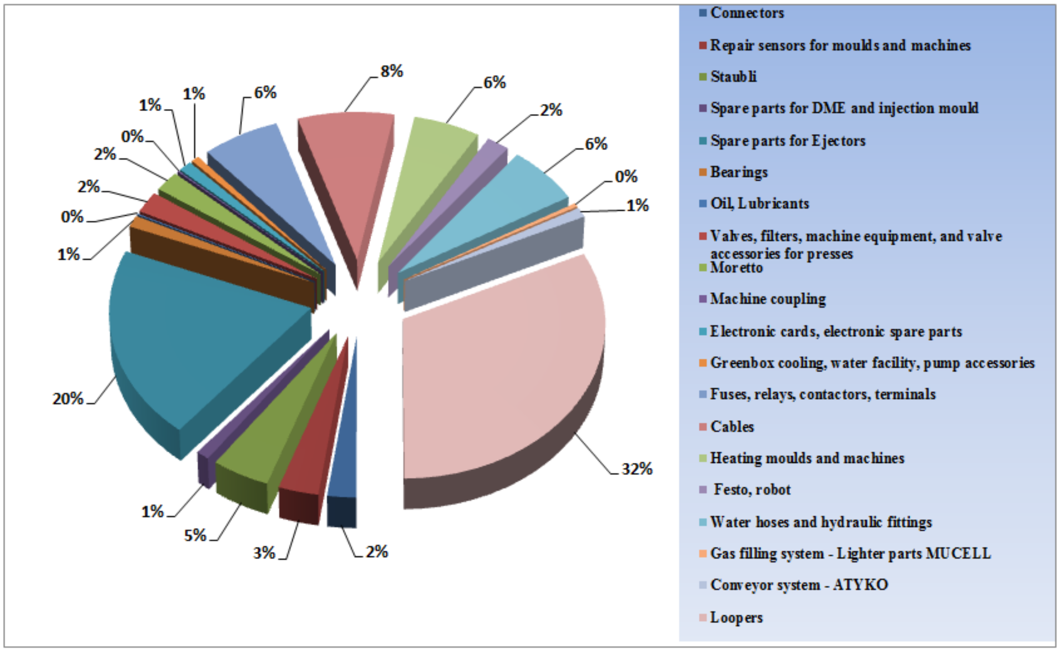


Source: data of VALEO AUTOKLIMATIZACE k.s., author's calculations.

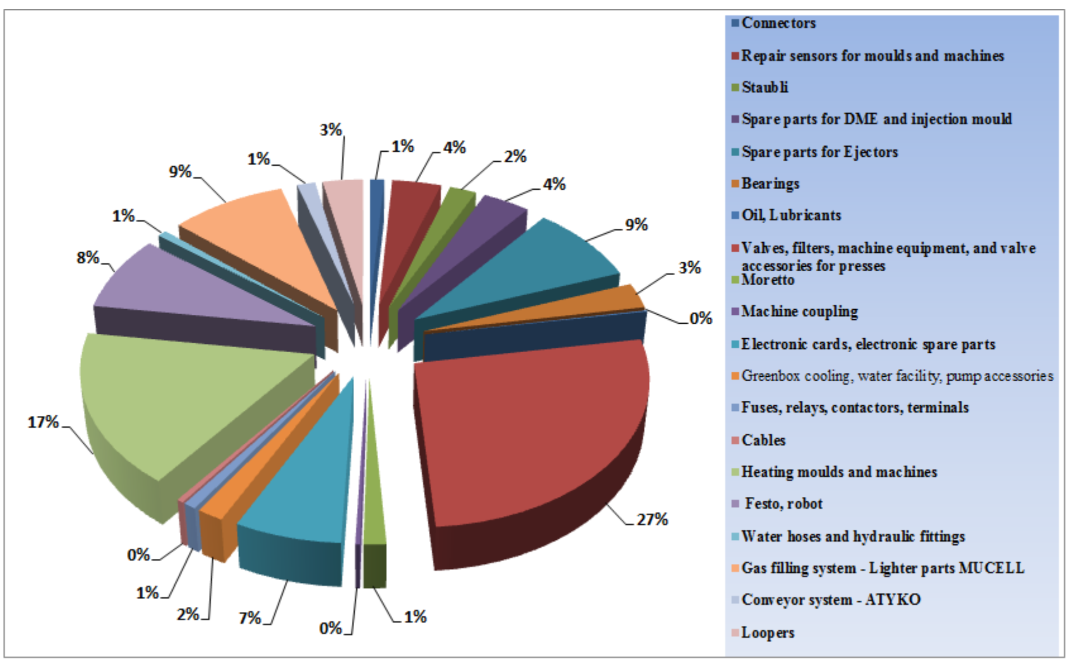
The calculated relative quantity of inventory level in each category is compared with each other, where categories for Loopers (32%) and Spare parts for Ejectors (20%) have the highest quantity inventory level, while Gas filling system - Lighter parts MUCELL, Machine coupling, Oil, Lubricants have the lowest quantity of inventory level (see Figure 5-2-3 (a)).

The highest relative value of spare parts inventory level were found at categories for spare parts for Valves, filters, machine equipment, valve accessories for presses (27%) and Heating moulds and machines (17%), while Oil, Lubricants, Machine coupling, Connectors, Moretto, Fuses, relays, contactors, terminals and Water hoses and hydraulic fittings have the lowest value of inventory level, as shown in Figure 5-2-3 (b).

Figure 5-2-3. Quantity (a) and Value (b) of Inventory level for each category at the beginning of 2015 year.



5-2-3 (a)



5-2-3 (b)

Source: data of VALEO AUTOKLIMATIZACE k.s., author's calculations.

The received from VALEO data were interpreted and represented in the form of two convenient and readable pivot tables. One table contains information on SS, LT, MOQ and inventory level for each item of spare parts at the beginning year for the period from 2012 to 2015 year (see Table 5-2-4 (a)). The another table contains monthly consumption for each item of spare parts for the period from 2012 to 2014 year, as shown in Table 5-2-4 (b).

Table 5-2-4. Sample pivot tables with quantities and values of Inventory level (a) and monthly consumption (b) for the period from 2012 to 2015 year.

	A	B	C	E	F	G	H	I	J	K	L	M	N	O	P	Q
2	Ordinal Nr.	ID	Description	Category Nr.	SS (units)	SS (czk)	LT (days)	MOQ (units)	Quantity of Inventory Level at the beginning year (units)				Value of Inventory Level at the beginning year (czk)			
3									2012	2013	2014	2015	2012	2013	2014	2015
1333	1353	LIS908018	K000012216 Hydraulické trojité #erpadlo	8	1	491 628	98	1	0	0	0	1	0	0	0	491 628
1334	1354	LIS909001	DN60 MUCELL spicka uzaverky sneku	8	1	33 075	60	1	2	2	2	2	66 000	66 300	66 150	66 150
1335	1355	LIS909002	DN50 spicka uzaverky sneku	8	1	17 600	60	1	0	3	3	3	0	52 800	52 800	52 800
1336	1356	LIS909003	DN 55 spicka uzaverky sneku	8	1	17 700	60	1	1	3	2	2	17 700	53 100	35 400	35 400
1337	1357	LIS909004	DN 110 spicka uzaverky sneku	8	1	35 000	60	1	3	3	3	3	105 000	105 000	105 000	105 000
1338	1358	LIS909005	DN 90 spicka uzaverky sneku	8	4	175 550	60	1	4	4	4	4	172 000	172 000	172 000	175 550
1339	1359	LIS909006	DN 105 zp#tná uzáv#rka #neku	8	2	92 000	60	1	1	1	1	0	46 000	46 000	46 000	0
1340	1360	LIS909007	DN 35 spicka uzaverky sneku	8	1	8 867	60	1	2	2	2	1	24 300	24 300	17 733	8 867
1341	1361	LIS909008	DN 45 spicka uzaverky sneku	8	1	16 500	60	1	2	2	2	2	33 000	33 000	33 000	33 000
1342	1362	LIS909009	DN 60 spicka uzaverky sneku	8	1	23 905	7	1	1	1	1	2	19 350	19 350	19 350	47 810
1343	1363	LIS910001	DN 105 operny krouzek	8	1	15 000	30	1	1	1	1	0	15 000	15 000	15 000	0
1379			Total		9 460	14 810 091			6 310	6 712	6 967	10 879	13 637 549	14 385 097	13 677 996	16 513 944
1380			Average Result		7	12 901			10	10	8	10	21 443	20 939	16 480	15 833

5-2-4 (a)

	A	B	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
2	IDH	Description	Category Nr.	Current SS (units)	Current Stock (units)	Consumption (units)			Total Consumption (units)	Monthly Consumption between 2012 - 2014 (units)													
3						2012	2013	2014		1.12	2.12	3.12	4.12	5.12	6.12	7.12	8.12	9.12	10.12	11.12	12.12	1.13	2.13
816	LIS401004	rychlospojka 612KFTF13MVN	3	20	19	12	46	21	79		8	2				1					1		
817	LIS401005	rychlospojka 612SFAW17MXN	3	10	5	12	28	20	60					12								1	1
818	LIS401006	rychlospojka 612SFAW21MXN	3	10	12	1	28	12	41			1											
819	LIS401007	rychlospojka 608SFAW10MXN	3	15	15	2	31	5	38			2											
820	LIS401008	rychlospojka 608SFAW13MXN	3	20	21	43	23	30	96	11		2		8	16				2	1	3		
821	LIS401009	rychlospojka 608SFAR17MXN	3	10	18	4	11	1	16						4								
822	LIS401010	RPL 08.1252	3	5	14	26	58	17	101						2					24		2	
823	LIS401011	rychlospojka 608KFTF12MVN	3	15	15	17	18	19	54					4	5				3		5	1	
824	LIS401012	rychlospojka 608KFTR12MVN	3	15	12	41	55	28	124		2			4	8	5	6			16			
825	LIS401013	RPL 08.6812/RO	3	0	0	23	11	0	34						4	2					17		
826	LIS401014	RPL 12.1102 přímá samice vniti	3	0	0	8	78	0	86		8												
1379		Total		9 460	10 879	3 608	4 187	5 472	13 267	189	214	228	130	243	190	179	129	308	56	299	1 443	195	222
1380		Average Result		7	10	9	9	10	15	3	5	3	3	5	3	3	3	7	2	6	6	4	3

5-2-4 (b)

Source: data of VALEO AUTOKLIMATIZACE k.s., author's calculations.

For each category of spare parts were obtained overall value of the SS, inventory level and consumption for the period from 2012 to 2014 year, where the quantity of inventory level of spare parts belongs to connectors category is equal 350 units and value respectively equals to 323 071 CZK at the beginning of 2012 year. The quantity of SS for connectors' category is 236 units and value of SS equals to 222 234 CZK. Overall results of SS, inventory level and consumption for the period from 2012 to 2014 year are shown in table 5-2-5.

Table 5-2-5. Summary table of overall inventory level, consumption and safety stock for each category of spare parts for the period from 2012 to 2014.

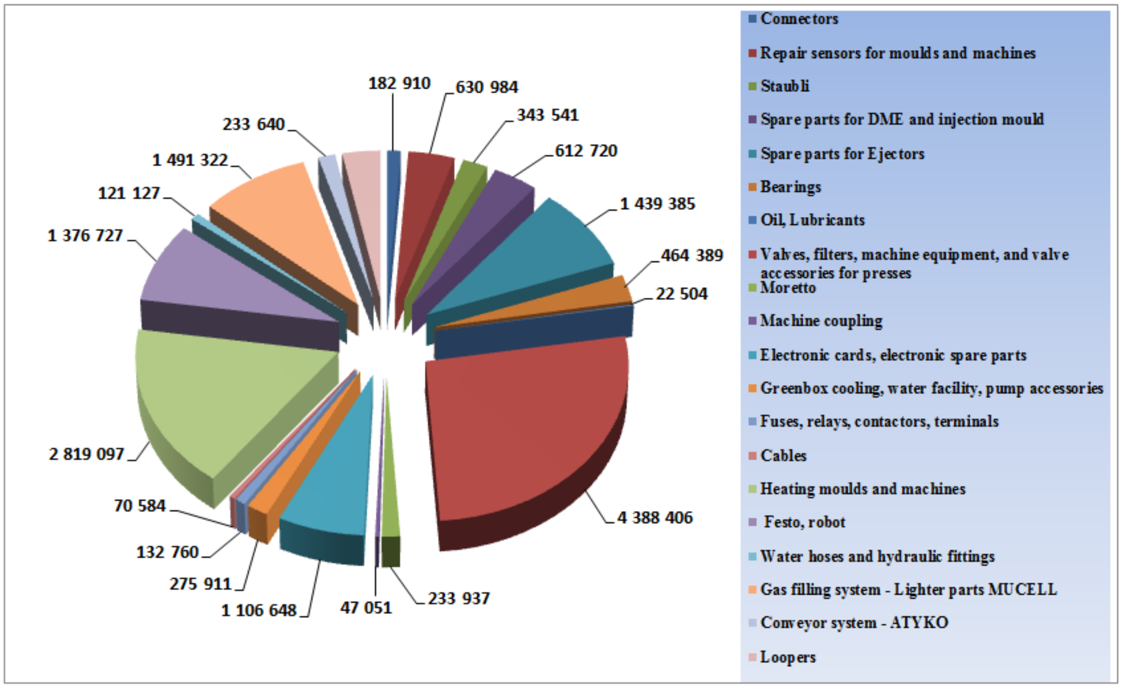
	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
2	Description	Category Nr.	SS (units)	SS (czk)	Quantity of Inventory level at the beginning of year (units)				Value of Inventory Level at the beginning year (czk)				Consumption (units)			Total Consumption (units)	Consumption (czk)		Total Consumption 2012-2014 (czk)
3					2012	2013	2014	2015	2012	2013	2014	2015	2012	2013	2014		2013	2014	
4	Connectors	1	236	222 314	350	396	268	245	323 071	367 892	248 684	182 910	293	517	477	1287	263625	231 299	575 164
5	Repair sensors for moulds and machines	2	217	534 955	430	508	373	340	685 559	744 687	620 143	630 984	217	369	209	795	437467	276 131	1 119 348
6	Staubli	3	460	294 705	498	827	508	491	339 348	458 055	410 735	343 541	502	853	446	1801	243770	247 937	817 988
7	Spare parts for DME and injection mould	4	137	579 219	68	96	126	113	565 508	667 153	654 132	612 720	70	69	91	230	160328	173 798	560 289
8	Spare parts for Ejectors	5	973	452 720	2799	2363	2234	2189	1 691 917	1 547 159	1 495 121	1 439 385	742	167	195	1104	76434	157 333	594 766
9	Bearings	6	107	274 012	75	119	97	132	393 213	501 354	403 307	464 389	18	64	78,7	160,7	229538	244 034	524 075
10	Oil, Lubricants	7	28	32 377	13	11	9	12	43 097	20 046	20 518	22 504	16	11	25	52	16797	40 114	119 730
11	Valves, filters, machine equipment, and v	8	216	5 044 783	190	231	227	243	2 754 770	3 413 242	3 036 307	4 388 406	90	93	89	272	1182142	2 029 703	4 273 076
12	Moretto	9	181	166 601	17	118	127	231	112 064	210 558	198 493	233 937	95	111	86	292	113771	47 566	321 706
13	Machine coupling	10	10	32 467	0	0	7	14	0	0	20 994	47 051	0	0	1	1	0	829	829
14	Electronic cards, electronic spare parts	11	132	1 053 009	41	59	53	121	1 301 880	787 917	768 597	1 106 648	38	94	42	174	619082	266 414	1 880 119
15	Greenbox cooling, water facility, pump ac	12	92	247 224	39	49	53	72	162 690	345 317	190 449	275 911	98	51	23	172	757781	70 911	1 587 881
16	Fuses, relays, contactors, terminals	13	319	118 788	469	625	746	701	61 382	98 452	117 517	132 760	132	261	202	595	51305	52 702	124 589
17	Cables	14	982	63 309	355	205	746	865	48 618	32 438	85 498	70 584	450	477	893	1820	41535	88 775	176 838
18	Heating moulds and machines	15	402	1 926 523	533	530	607	602	3 158 870	2 881 267	2 867 206	2 819 097	234	187	120	541	437096	360 546	1 870 102
19	Festo, robot	16	290	1 410 170	83	83	133	205	884 057	953 896	1 091 882	1 376 727	64	71	22,03	157	593237	118 216	1 025 400
20	Water hoses and hydraulic fittings	17	1114	167 032	291	432	550	669	30 217	58 654	77 957	121 127	465	752	1165	2382	101949	230 558	408 906
21	Gas filling system - Lighter parts MUCELL	18	47	1 464 796	33	34	30	43	1 039 255	1 212 794	1 217 848	1 491 322	59	12	7	78	101610	739 935	1 650 625
22	Conveyor system - ATYKO	19	102	216 778	26	26	73	111	42 034	84 216	152 610	233 640	25	28	43	96	37501	22 283	78 165
23	Loopers	20	3415	508 309	0	0	0	3480	0	0	0	520 300	0	0	1257	1257	0	155 372	155 372
24	Total		9 460	14 810 091	6 310	6 712	6 967	10 879	13 637 549	14 385 097	13 677 996	16 513 944	3 608	4 187	5 472	13 267	5 464 967	5 554 458	17 864 968
25	Deviation between current and previous year					402	255	3 912		747 548	-707 100	2 835 948		579	1 285				
26	Deviation from Stock at the beginning 2015 year			1 703 853								0						10 959 486	-1 351 024
27	Rate from Stock at the beginning 2015 year			-10%								0%						-66%	8%

Source: data of VALEO AUTOKLIMATIZACE k.s., author’s calculations.

As can be seen from the table 5-2-5, the overall results of SS value is equal to 14 810 091 CZK while total consumption for the period from 2012 to 2014 is equal to 17 864 968 CZK and total value of inventory level at the beginning of 2015 year is 16 513 944 CZK (see Table 5-2-5). The total value of safety stock, being approximately equal to the total value of consumption for period from 2012 to 2014, suggests that the safety stock in the SAP system is incorrect and reviewed rarely. The total value of inventory level for 2015 year is increased on the 2 835 948 CZK compared with the total value of inventory level for the 2014 year.

The value of inventory level for each category of spare partes at the beginning of 2015 year is compared with each other, where categories for Valves, filters, machine equipment, and valve accessories for presses (4 388 406 CZK) and Heating moulds and machines (2 819 097 CZK) have the highest value inventory level, while Oil, Lubricants, Machine coupling, Cables, Water hoses and hydraulic fittings and Connectors have the lowest quantity of inventory level, as shown in Figure 5-2-6.

Figure 5-2-6. The value of inventory level for each category of spare parts at the beginning of 2015 year.



Source: data of VALEO AUTOKLIMATIZACE k.s., author's calculations.

5.3. PROBLEM DESCRIPTION

Plastic injection moulding machine manufactures semifinished product for main assembling lines. The lack of spare parts in stock, when they are needed for repairing of these machines, results in stoppings of the assembling lines manufacturing finished products. Such production downtimes lead to huge costs for VALEO AUTOKLIMATIZACE k.s., as it leads to additional expenses associated with staff salaries, increased value of inventory level in stock (raw materials and spare parts in CZK), and the last but not least - to reduction in the service level of the finished product, i.e. to lower sales and profits.

The main reason for lack of spare parts for Plastic injection moulding machine is an incorrect prognosis of spare parts safety stocks, untimely or incorrect material movements records done in SAP system. Also the occasional delays in delivery of spare parts by a supplier could be thr reason for that.

On the other hand incorrect forecasts results in excessive inventory levels, because it is calculated on the basis of safety stock and new parts are ordered.

Also, the cost of spare parts is more than 50% of the total maintenance cost in the industry, at the same time the company financial department might face a problem of increasing locked up capital in spare parts inventory.

The problems described above are not specific to the VALEO AUTOKLIMATIZACE k.s. company alone, but also they are actual and for all manufacturing companies. Solving these problems becomes one of the top priorities in order to remain competitive on the market.

5.4. THE PATTERN OF SPARE PARTS CONSUMPTION AND DEMAND

The received from VALEO AUTOKLIMATIZACE k.s. data on consumption of spare parts from January 2012 to December 2014 on monthly basis demonstrate a classical intermittent demand pattern. A big portion of zero values, which is combined with non-zero values, proves that fact. Items with such a demand are considered as slow moving items and are commonly very expensive and have low LT demand. The high variability of intermittent or irregular demand pattern is revealed from data shown in the Table 5-4-1. To reduce the possibility of spare parts' shortages appearance to a reasonable low level the different demands probabilities must be taken into consideration. Calculation of the latters can be employed then in various logistic decisions related to stock facilitating and procurement.

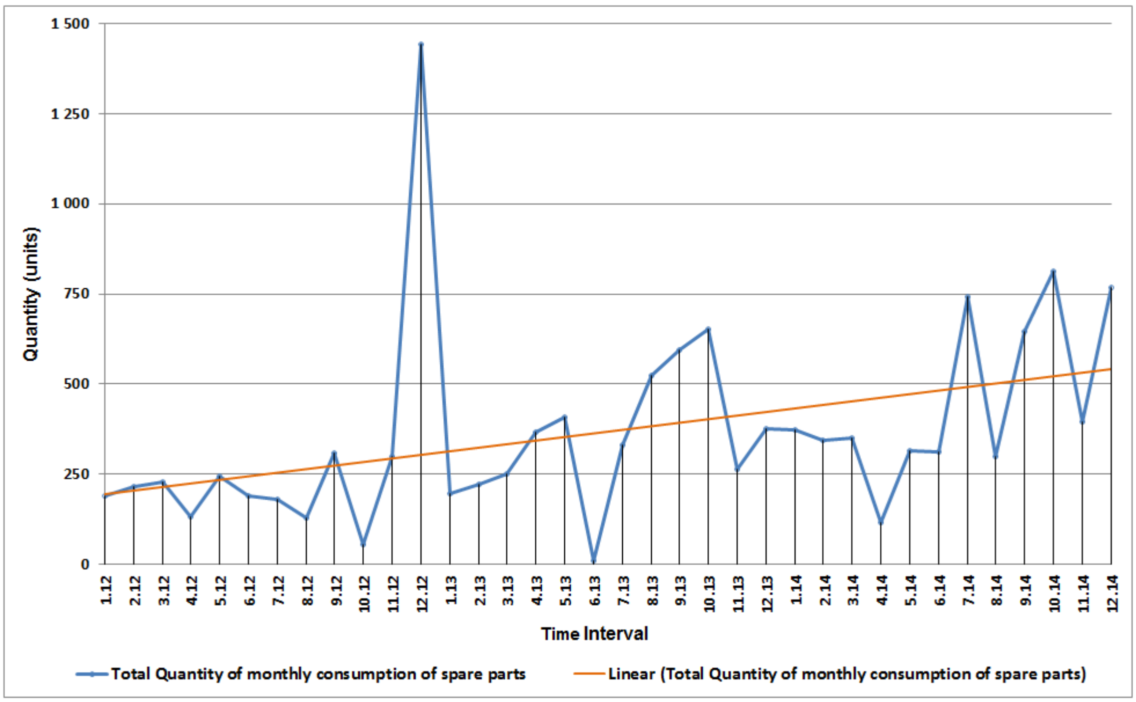
Table 5-4-1. Monthly consumption for the period from 2012 to 2014.

	A	B	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
2	IDH	Description	Category Nr.	Current SS (units)	Current Stock (units)	Consumption (units)			Total Consumption (units)	Monthly Consumption between 2012 - 2014 (units)											
3						2012	2013	2014		1.12	2.12	3.12	4.12	5.12	6.12	7.12	8.12	9.12	10.12	11.12	12.12
4																					
816	LIS401004	rychlospojka 612KFTF13MVN	3	20	19	12	46	21	79		8	2				1					1
817	LIS401005	rychlospojka 612SFAW17MXN	3	10	5	12	28	20	60					12							
818	LIS401006	rychlospojka 612SFAW21MXN	3	10	12	1	28	12	41			1									
819	LIS401007	rychlospojka 608SFAW10MXN	3	15	15	2	31	5	38			2									
820	LIS401008	rychlospojka 608SFAW13MXN	3	20	21	43	23	30	96	11		2		8	16				2	1	3
821	LIS401009	rychlospojka 608SFAR17MXN	3	10	18	4	11	1	16						4						
822	LIS401010	RPL 08.1252	3	5	14	26	58	17	101						2					24	
823	LIS401011	rychlospojka 608KFTF12MVN	3	15	15	17	18	19	54					4	5				3		5
824	LIS401012	rychlospojka 608KFTR12MVN	3	15	12	41	55	28	124		2			4	8	5	6			16	
825	LIS401013	RPL 08.6812/RO	3	0	0	23	11	0	34						4	2					17
826	LIS401014	RPL 12.1102 přímá samice vniti	3	0	0	8	78	0	86		8										
1379	Total			9 460	10 879	3 608	4 187	5 472	13 267	189	214	228	130	243	190	179	129	308	56	299	1 443
1380	Average Result			7	10	9	9	10	15	3	5	3	3	5	3	3	3	7	2	6	6

Source: data of VALEO AUTOKLIMATIZACE k.s., author's calculations.

The relation between the consumed quantities of spare parts and time interval from January 2012 to December 2014 shows fluctuations in consumption quantity, where sudden drops existed in October 2012, June 2013 and April 2014. The highest quantity of consumed units (1443) was detected in December 2012, when company was making the physical inventory counting on the warehouse (see Figure 5-2-7). The linear trend shows increasing of monthly quantity of consumption during the period from 2012 to 2014.

Figure 5-2-7. Overall results of monthly quantity consumption of spare parts for the period from 2012 to 2014 year.



Source: data of VALEO AUTOKLIMATIZACE k.s., author's calculations.

5.5. INFLUENCING FACTORS

Among main determinants of the current state of spare parts inventory in VALEO AUTOKLIMATIZACE k. s. can be named the following:

1. A wide variety of spare parts categories as well as their high total amount (1 374) brings complications to a control and management process.

2. Due to the high variety of items the consumption rates per years also differ among them from extremely high (150 units) for some to a very low (0-1 units) for others.

3. Uncertainty regarding the quantity of some spare parts and exact time of their delivery.

4. A number of existing in the analysis spare parts are not easily affordable on the market because of various reasons, as for example new models of machinery are introduced to incorporate design improvements.

5.6. DATA ANALYSIS BY USING “ABC” AND “XYZ” METHODS

Using ABC method all the available in stock spare part items (totally 1374) and represented in two different time series from 2012 till 2014 were classified upon different criteria: net quantity, net value, consumed quantity, consumed value, frequency of consumption, received quantity, received value, and frequency of receipt for total 1374 items in stock. Then items have been prioritized using a Pareto principle (more details are available in subchapter 3.7).

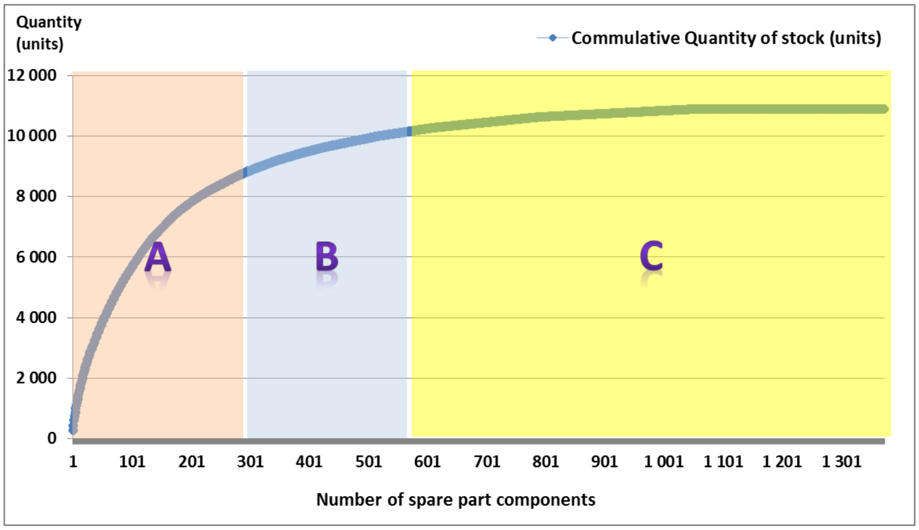
5.6.1. ABC analysis of Inventory level

In order to identify what items or categories make the largest and the smallest contribution into the inventory level we implement ABC analysis.

The first calculation is based on sortation of all items from the highest value to the lowest one. The next we calculate cumulative quantities of inventory level for the beginning of 2015 year in order to apply Pareto principle at the end of the calculation.

From the conducted ABC analysis it became obvious that 283 items form group “A” that counts around 80% of stock at the beginning of 2015 year and it is represented by 8700 different quantity units. The others 361 items form group “B” that covers 15% or 1634 quantity units from the whole inventory quantity. The last 730 items form group “C” that equals 5% or 545 quantities of units from the whole inventory quantity (see Figure 5-6-1-1).

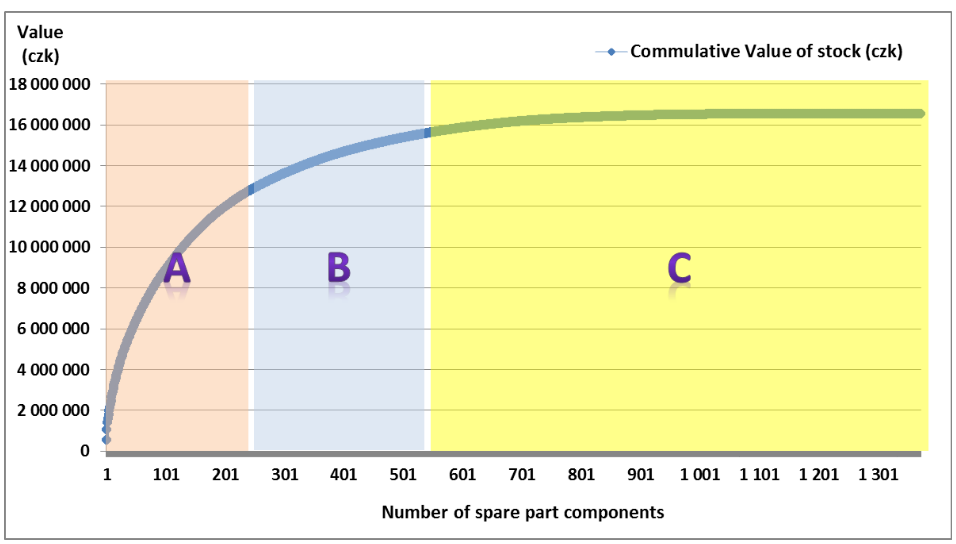
Figure 5-6-1-1. ABC analysis of inventory level quantities for the beginning of 2015.



Source: data of VALEO AUTOKLIMATIZACE k.s., author's calculations.

The second step was classification of items in terms of their total value within the stock in CZK. It turned out that only 272 items form group "A" (from the total amount of 1374 items) and have the highest value of inventory level of 13 209 300 CZK or 80%. The others 291 items form group "B" with the value 2 478 490 CZK, and the last 811 items form group "C" which equals to 826 154 CZK. To increase the company profit the focus should be done on items of "A" group. Perhaps, at the expense of less important items from group "C" which influence only 5% from whole value of inventory level (see Figure 5-6-1-1).

Figure 5-6-1-2. ABC analysis of inventory level value for the beginning of 2015.



Source: data of VALEO AUTOKLIMATIZACE k.s., author's calculations.

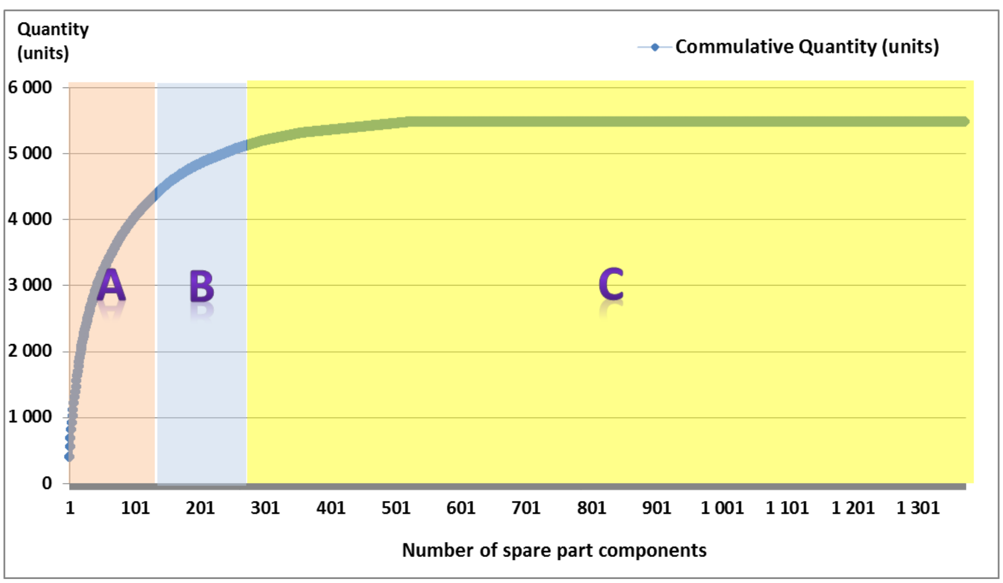
5.6.2. ABC analysis of Consumption for the period from 2012 to 2014

The same calculation idea as described in subchapter 3.7 was applied to make ABC analysis of consumption quantities for 2014 year and also overall results consumption quantities during the period from 2012 to 2014.

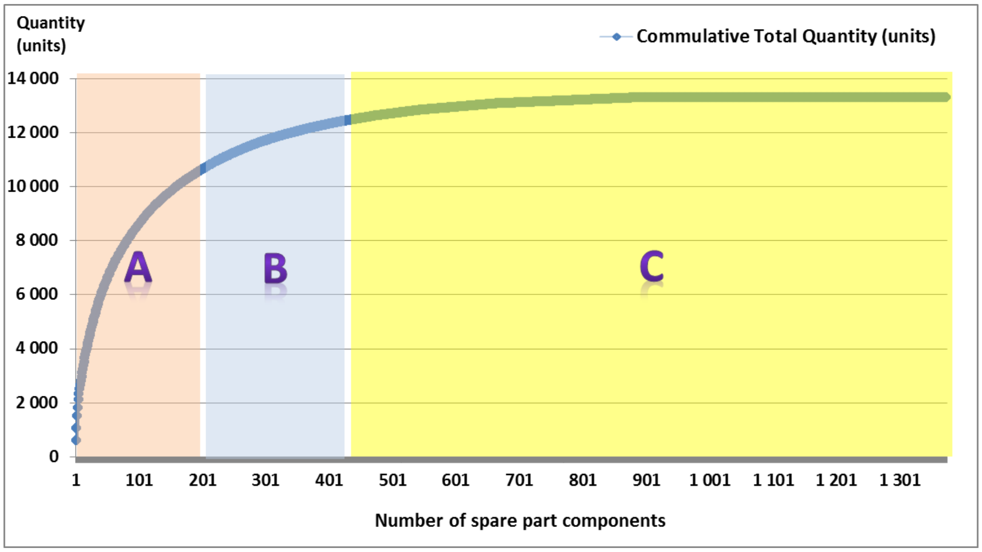
As a result, in first case the 134 items group A are represented to 80% (or 4370 consumed units in the 2014 year) from whole of consumed quantity. The others 170 items group B are covered 15% (or 827 consumed units in 2014 year) from whole of consumed quantity and the last 1070 items group C are equal 5% (or 275 consumed units in 2014 year) from whole of consumed quantity in the 2014 year (see Figure 5-6-2-1 (a)).

In second case the 200 items group A are represented 10604 (80%) consumed units in the 2014 year. The others 273 items group B are covered 827 (15%) consumed units in 2014 year and the last 901 items group C are equal 667 (5%) consumed units in 2014 year (see Figure 5-6-2-1 (b)).

Figure 5-6-2-1. ABC analysis of consumed quantity in the 2014 year (a) and consumed quantity during the period from 2012 to 2014 year (b).



5-6-2-1 (a)



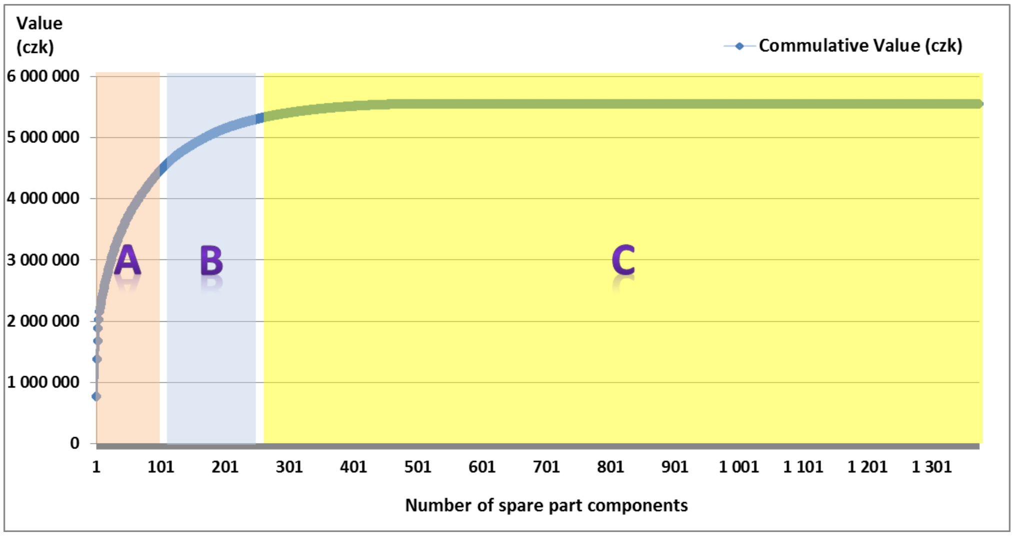
5-6-2-1 (b)

Source: data of VALEO AUTOKLIMATIZACE k.s., author's calculations.

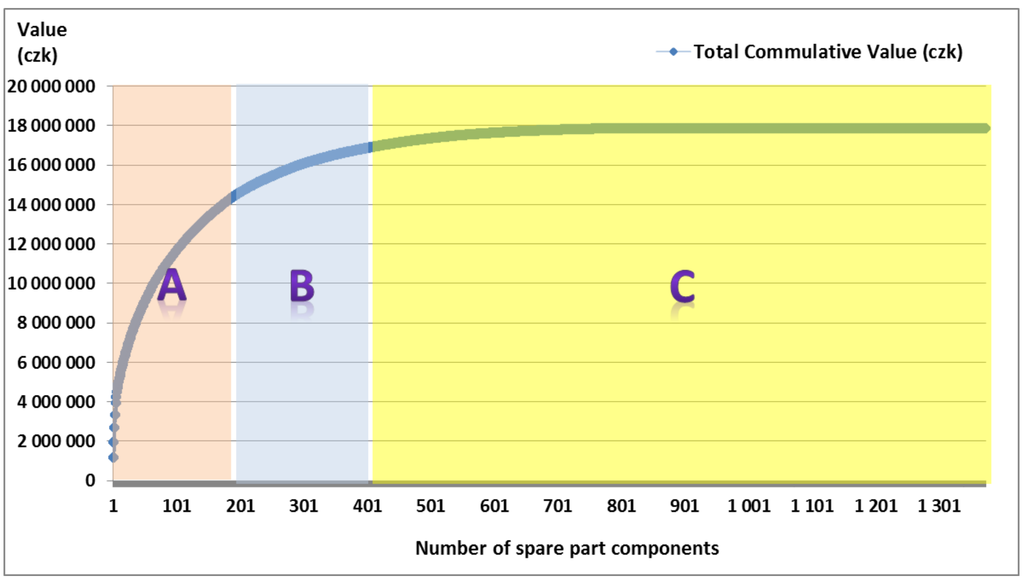
From ABC analysis by consumed value in the 2014 year is shown that only 98 items group A (from 1374 of whole spare parts items) are represented highest consumed value (4 434 395 CZK or 80%). The others 143 items group B are covered 842 124 CZK from whole consumed value in the 2014 year, and the last 1133 items group C are equal 277 939 CZK from whole consumed value in this year (see Figure 5-6-2-2 (a)).

From ABC analysis by consumed value during the period from 2012 to 2014 is shown that only 186 items group A (from 1374 of whole spare parts items) are represented highest consumed value (14 279 733 CZK). The others 235 items group B are covered 2 690 511 CZK from whole consumed value during the period from 2012 to 2014, and the last 953 items group C are equal 894 724 CZK from whole consumed value in this year (see Figure 5-6-2-2 (b)). To increase the profit company should focus more attention on items group A for rising forecast accuracy and increasing safety stock recalculation frequency.

Figure 5-6-2-2. ABC analysis of consumed value in the 2014 year (a) and consumed value during the period from 2012 to 2014 year (b).



5-6-2-2 (a)



5-6-2-2 (b)

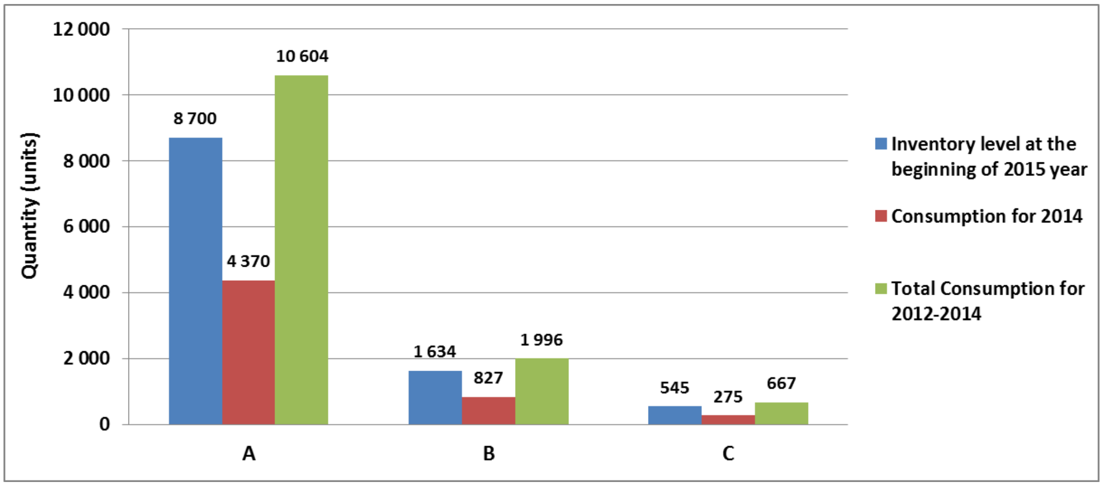
Source: data of VALEO AUTOKLIMATIZACE k.s., author's calculations.

5.6.3. Comparison analysis of ABC classifications upon different criteria.

The conducted ABC analysis and the resulted classifications can be compared either among different groups, i.e. "A", "B" and "C" or within each group. This comparative analysis could be applied for capturing overall picture and to identify common trends and dependencies.

The calculations revealed that the quantity of inventory level at the end of 2014 year (8700 units) was approximately twice bigger than the quantity of consumed items during the year 2014 (4370 units), as shown in Figure 5-6-3-1.

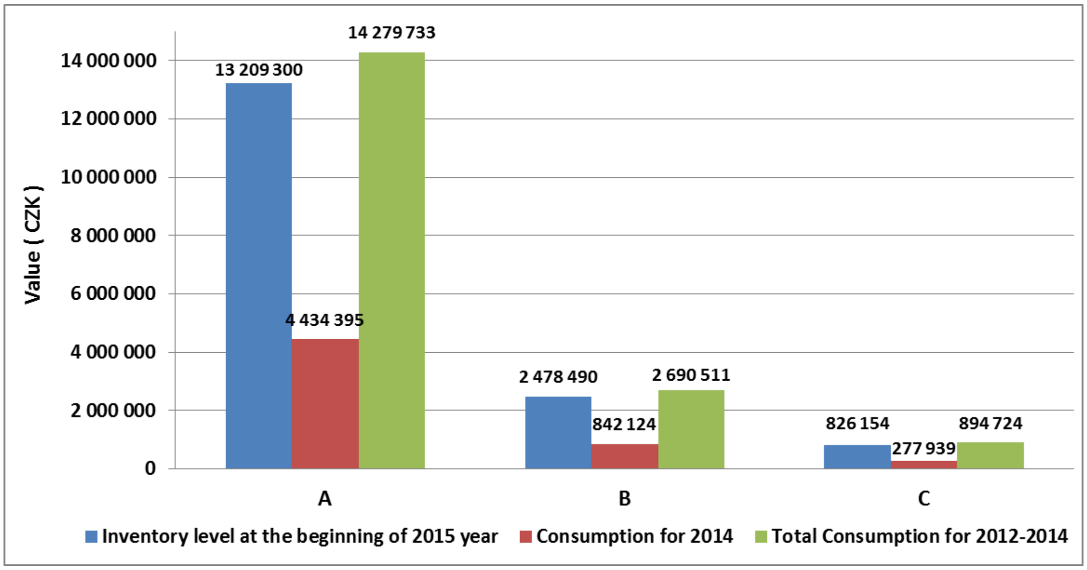
Figure 5-6-3-1 The comparison of ABC classifications in terms of quantities.



Source: data of VALEO AUTOKLIMATIZACE k.s., author's calculations.

The value of inventory level of items in group "A" at the end of 2014 year (13 209 300 CZK) approximately equals to the value of items in group "A" consumption (14 279 733 CZK) for the period from 2012 to 2014, as shown in Figure 5-6-3-2.

Figure 5-6-3-2. The comparison of ABC classifications in terms of CZK values.



Source: data of VALEO AUTOKLIMATIZACE k.s., author's calculations.

The highest number of spare parts components refers to group “C” and their number are the following: 730 items for quantity of inventory level at the beginning of 2015 year, 1070 items for quantity of consumption in the 2014 and 901 items for consumption for the period from 2012 to 2014. As for, number of spare parts components refers to group category “A” and “B”, their quantity approximately are near to each other in the range from 134 to 361 items for inventory level and consumption quantities. The total value of inventory level at the end of 2014 year (16 513 944 CZK) approximately equals to the total value of consumption (17 864 968 CZK) during the period from 2012 to 2014 (see Table 5-6-3-3). It becomes obvious that the VALEO AUTOKLIMATIZACE k. s. has overstock of spare parts with total duration of turnover more than 2.5 years.

Table 5-6-3-3. The summary table of ABC classifications comparison results.

	A	B	C	D	E
3	**Description**	**A**	**B**	**C**	**Total**
4	Quantity of Inventory level at the beginning of 2015 year (units)	8 700	1 634	545	10 879
5	Number of spare part components	283	361	730	1 374
6	**Value of inventory level at the beginning of 2015 year (czk)**	**13 209 300**	**2 478 490**	**826 154**	**16 513 944**
7	**Number of spare part components**	**272**	**291**	**811**	**1 374**
8	Quantity of Consumption for 2014 (units)	4 370	827	275	5 472
9	Number of spare part components	134	170	1 070	1 374
10	Total Quantity of Consumption for 2012-2014 (units)	10 604	1 996	667	13 267
11	Number of spare part components	200	273	901	1 374
12	**Value of Consumption for 2014 (czk)**	**4 434 395**	**842 124**	**277 939**	**5 554 458**
13	**Number of spare part components**	**98**	**143**	**1 133**	**1 374**
14	**Total Value of Consumption for 2012-2014 (czk)**	**14 279 733**	**2 690 511**	**894 724**	**17 864 968**
15	**Number of spare part components**	**186**	**235**	**953**	**1 374**

Source: data of VALEO AUTOKLIMATIZACE k.s., author’s calculations.

5.6.4. XYZ analysis of Consumption

The first classification is based on calculation of annual consumed quantities for the periods 2012-2014, applying variation coefficient to each spare part in the following order: group “X” has variation coefficient less than 10%, group “Y” has variation coefficient in range from 10% to 25%, group “Z” has variation coefficient more than 25%. The calculation results revealed that group “X” consist of 12 items with consumed quantity of 258 units, group “Y” consists of 20 items with consumed quantity of 1097 units and group "Z" consist of 1349 items with consumed quantity of 11912 units (see table 5-6-4-1).

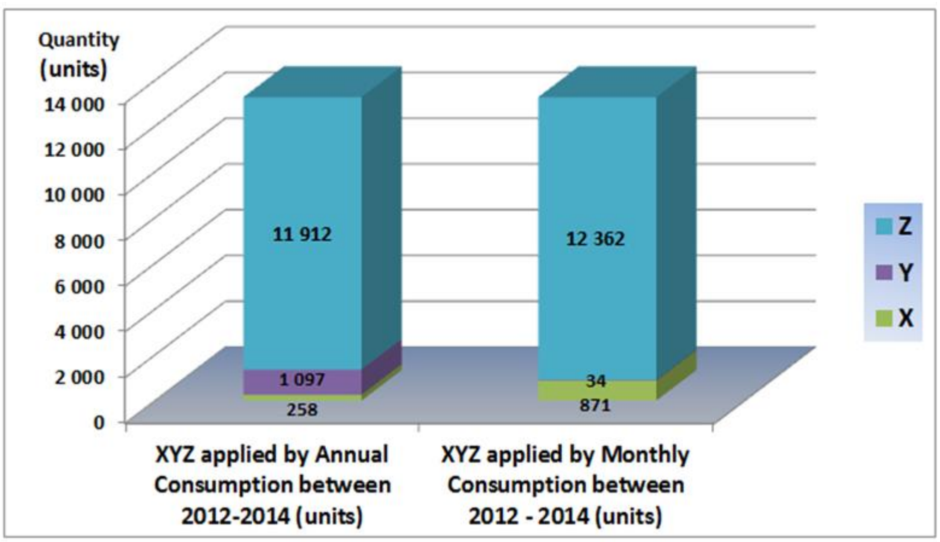
Table 5-6-4-1 The XYZ classification of spare parts.

Description	X	Y	Z	Total
XYZ applied by Annual Consumption between 2012-2014 (units)	258	1 097	11 912	13 267
Number of spare part components	12	20	1 349	1 381
XYZ applied by Monthly Consumption between 2012 - 2014 (units)	871	34	12 362	13 267
Number of spare part components	211	5	1 165	1 381

Source: data of VALEO AUTOKLIMATIZACE k.s., author's calculations.

The second classification is based on calculation of monthly consumed quantities during the period from 2012 to 2014, applying variation coefficient to each spare part and category the same way as it was described above. As a result 211 items with consumed quantity of 871 units were found in group "X"; 5 items with consumed quantity of 34 units were found in group "Y"; 1165 items with consumed quantity of 12362 units were found in group "Z" (see figure 5-6-4-2).

Figure 5-6-4-2 The comparison of XYZ classifications in terms of unit numbers.



Source: data of VALEO AUTOKLIMATIZACE k.s., author's calculations.

5.6.5. The output of a joint ABC and XYZ methods application

The combination of the results from ABC and XYZ analyses allow to get a widest more precise picture about quantitative and qualitative characteristics of spare parts (see enclosure 3).

Application of this combination contributes to a more correct decision making process. For example, items from AZ group (244 items with the value of inventory 12 015 843 CZK at the beginning of 2015 year) the change in consumption / demand and change in quantity in stock should be monitored both through system and actual presence in warehouse. Also the regular recalculation of the safety stocks for this group of items is strongly recommended.

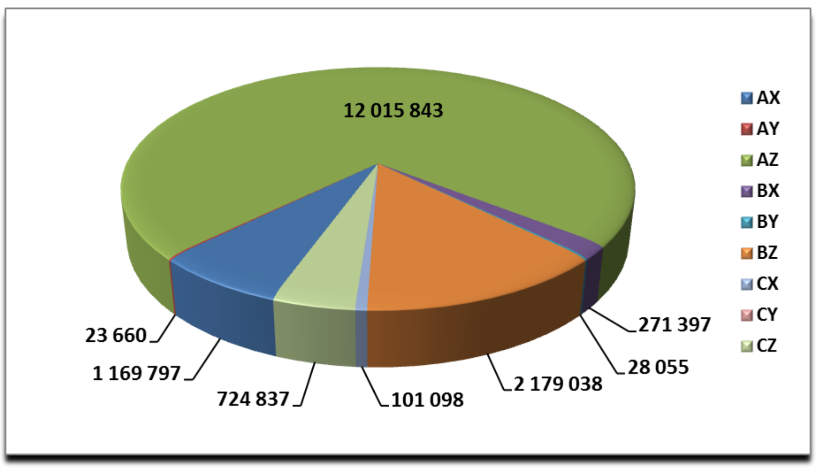
The AX, BX and CX groups are more stable in terms of consumption / demand fluctuations and require less attention, the forecast and re-order points for these items should be recalculated manually resting on individual information on them in the system. For spare parts from CZ group (660 items) with the value of safety stock 724 837 CZK and BZ group (254 items) with the value of safety stock 2 179 038 CZK the control and monitoring of Inventory levels have to be carried out quite frequently (see Table 5-6-5-1 and Figure 5-6-5-2).

Table 5-6-5-1 The summary results of XYZ and ABC analyses combination in terms of quantities and values.

Description	AX	AY	AZ	BX	BY	BZ	CX	CY	CZ	Total
Combined ABC and XYZ by Value of Inventory Level with Consumption (czk)	**1 169 797**	**23 660**	**12 015 843**	**271 397**	**28 055**	**2 179 038**	**101 098**	**220**	**724 837**	**16 513 944**
Number of spare part components	27	1	244	34	3	254	150	1	660	1 374
Combined ABC and XYZ by Quantity of Consumption (units)	**423**	**0**	**10 181**	**226**	**34**	**1 736**	**222**	**0**	**445**	**13 267**
Number of spare part components	14	0	186	38	5	230	159	0	742	1 374

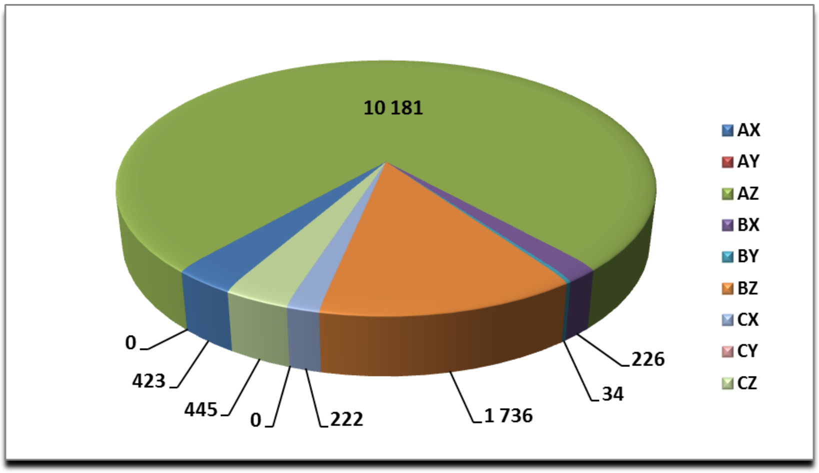
Source: data of VALEO AUTOKLIMATIZACE k.s., author's calculations.

Figure 5-6-5-2 Combined the ABC and XYZ analyses by Inventory Level at the beginning of 2015 year and by Consumption during the 2012-2014 period in terms of CZK values.



Source: VALEO AUTOKLIMATIZACE k. s. data, author's calculation.

Figure 5-6-5-3 The XYZ and ABC analyses combination in terms of quantities during the 2012-2014 period.



Source: data of VALEO AUTOKLIMATIZACE k.s., author's calculations.

As it can be seen from the Figures given above the most volatile in terms of coefficient of variation and, at the same time, with the highest consumption is the group AZ (10 181 units of 186 different items). The others highly variable groups are BZ (230 items) and CZ (742 items) with consumptions for the period from 2012 till 2014 year 1736 units and 445 units respectively.

5.7. FORECASTS CALCULATION AND SELECTION THE MOST FITTED ONE

On the basis of the received data on material movements the summary table with monthly consumptions from 2012 till 2014 year was created (see enclosure 2). Then for all spare parts types (the total amount is 1374 items) the forecasts were calculated (for the 2013-2014 period) following the recommendations given in the Theoretical and Methodological chapters of the diploma. Several samples of these calculations are provided below (see Table 5-7-1: a, b, c.)

Table 5-7-1 The samples of forecasts calculation: a) SES method; b) Modified Croston method; c) Holt-Winter method.

alfa => 0,8

SINGLE EXPONENTIAL SMOOTHING METHOD

	IDH	Description	Category Nr.	1.12	1.13	2.13	3.13	4.13	5.13	6.13	7.13	8.13	9.13	10.13	11.13	12.13	1.14	2.14	3.14
828	LIS309002	elektronicke rele triak celduc SOD845180	2	0	0	22	4	1	2	8	2	0	0	4	8	2	2	0	0
829	LIS309003	triak 35 A s ledka SO 943 460	2	3	3	9	2	0	0	2	0	2	8	2	3	1	0	0	1
830	LIS401001	rychlospojka 608KFTR10MVN	3	0	0	0	0	0	2	5	1	0	19	4	1	0	0	0	0
831	LIS401002	rychlospojka 612KFTR13MVN	3	0	0	0	0	0	0	9	2	0	0	1	0	1	3	1	0
832	LIS401003	rychlospojka 608KFTF10MVN	3	6	6	1	0	0	0	2	0	0	0	0	0	0	2	0	0
833	LIS401004	rychlospojka 612KFTF13MVN	3	1	1	0	0	10	16	10	2	0	5	1	2	0	0	0	3
834	LIS401005	rychlospojka 612SFAW17MXN	3	0	0	1	1	0	0	14	3	1	3	1	3	1	0	0	0
835	LIS401006	rychlospojka 612SFAW21MXN	3	0	0	0	0	13	3	9	2	0	0	0	1	0	1	0	3
836	LIS401007	rychlospojka 608SFAW10MXN	3	0	0	0	0	0	0	4	1	0	21	4	1	0	0	3	1
837	LIS401008	rychlospojka 608SFAW13MXN	3	3	3	1	0	0	2	5	1	9	3	1	0	0	1	9	2
1403	Total				1 451	446	267	257	359	405	91	284	477	580	638	340	370	372	350

MAM | WMAM | ESM | MAM&ESM by Q | CROSTON'S | CROSTON'S modified | Croston's by Q | Holt | Naïve | Main

5-7-1 (a)

alfa => 0,8

Croston's Forecast modified

	IDH	Description	Category Nr.	1.13	2.13	3.13	4.13	5.13	6.13	7.13	8.13	9.13	10.13	11.13	12.13	1.14	2.14	3.14
828	LIS309002	elektronicke rele triak celduc SOD845180	2	0	22	22	22	5	11	11	11	11	4	8	8	4	4	4
829	LIS309003	triak 35 A s ledka SO 943 460	2	3	9	9	9	9	2	2	2	4	4	3	3	3	3	1
830	LIS401001	rychlospojka 608KFTR10MVN	3	0	0	0	0	1	4	4	4	7	7	7	7	7	7	7
831	LIS401002	rychlospojka 612KFTR13MVN	3	0	0	0	0	0	2	2	2	2	1	1	1	2	2	2
833	LIS401004	rychlospojka 612KFTF13MVN	3	0	0	0	4	13	7	7	7	4	4	3	3	3	3	2
834	LIS401005	rychlospojka 612SFAW17MXN	3	0	1	1	1	1	5	5	5	3	3	3	3	3	3	3
835	LIS401006	rychlospojka 612SFAW21MXN	3	0	0	0	5	5	5	5	5	5	5	2	2	1	1	2
836	LIS401007	rychlospojka 608SFAW10MXN	3	0	0	0	0	0	1	1	1	5	5	5	5	5	3	3
837	LIS401008	rychlospojka 608SFAW13MXN	3	0	0	0	0	1	5	5	5	4	4	4	4	1	5	5
839	LIS401010	RPL 08.1252	3	0	2	2	2	2	5	5	5	8	5	6	6	6	6	6
1403	Total			203	195	317	420	398	419	393	363	388	451	534	533	520	548	494

MAM | WMAM | ESM | MAM&ESM by Q | CROSTON'S | CROSTON'S modified | Croston's by Q | Holt | Naïve | Main

5-7-1 (b)

alfa => 0,68 beta => 0,3

Holt Forecast Method

	IDH	Description	Category	Category Nr.	1.13	2.13	3.13	4.13	5.13	6.13	7.13	8.13	9.13	10.13	11.13	12.13	1.14	2.14
511	LIS1903001	DN 10 EPDM	Water hc	17	0	0	0	0	0	35	12	2	1	2	2	2	1	1
512	LIS1903002	DN 13 EPDM	Water hc	17	27	1	16	9	15	34	6	4	7	6	5	3	2	25
513	LIS1903003	DN 19 EPDM	Water hc	17	0	0	0	0	0	27	9	2	1	5	1	8	2	0
514	LIS1903004	DN 25 EPDM	Water hc	17	0	0	0	0	0	0	4	2	0	0	0	0	0	0
515	LIS1903005	Push-Lok navlékací hadice 836-6-RL	Water hc	17	5	14	8	4	2	1	0	0	0	0	0	0	0	0
516	LIS1903006	Push-Lok navlékací hadice 801-8-GRA-RL	Water hc	17	45	41	39	30	21	14	9	5	3	2	176	202	61	3
517	LIS1903007	Push-Lok navlékací hadice 836-8-RL	Water hc	17	0	0	0	0	0	0	0	0	0	0	0	71	25	5
1403	Total				492	794	640	546	501	511	528	192	339	573	675	698	456	445

MAM | WMAM | ESM | MAM&ESM by Q | CROSTON'S | CROSTON'S modified | Croston's by Q | Holt | Naïve | Main

5-7-1 (c)

Source: data of VALEO AUTOKLIMATIZACE k.s., author's calculations.

In order to understand what forecasting method is the most appropriate one for the consumption / demand circumstances in the company the forecasting accuracy assessment have to be done (errors calculations) between prognosis and actual values or quantities for the same period.

The errors calculations were conducted following the recommendations provided in the Theoretical and Methodological chapters of the diploma (see subchapters 3.12 and 4.2). The results of these calculations are given below.

Table 5-7-2. The samples of Errors calculation: a) Absolute Error of Moving Average method; b) Absolute Scaled Error of Moving Average method; c) Deviations between total forecast demand and consumed units during the same period.

	A	B	D	EH	EI	EJ	EK	EL	EM	EN	EO	EP	EQ	ER	ES	ET	EU	EV	EW	EX	EY	EZ	FA	FB	FC	FD	FE	FF
2	IDH	Description	Category Nr.	Absolute error of SIMPLE MOVING AVERAGE METHOD (period - 6 month)																								
3				1.13	2.13	3.13	4.13	5.13	6.13	7.13	8.13	9.13	10.13	11.13	12.13	1.14	2.14	3.14	4.14	5.14	6.14	7.14	8.14	9.14	10.14	11.14	12.14	In sample MAE
4																												
16	LIS101003	Samice jadro 1-16 9200162812	1	1	6	1	1	10	4	1	4	3	1	3	1	2	0	1	0	1	1	1	1	1	3	3	2	2,1
17	LIS101004	Samice jadro17-32 9200162813	1	1	3	2	0	0	1	2	2	1	0	1	1	1	0	0	1	2	1	1	1	1	1	2	2	0,9
18	LIS101005	Na prodluzovak nahoru 9200160441	1	3	2	0	0	2	1	1	1	1	1	3	1	2	0	2	2	0	1	1	1	0	2	1	0	1,1
19	LIS101006	Harting 09200160541	1	2	0	0	0	4	1	1	1	2	0	1	0	1	0	1	1	3	1	1	1	1	1	1	0	0,9
20	LIS101007	Nizke formy 9200160301	1	4	1	1	1	1	1	0	0	0	5	1	0	1	1	1	1	1	0	0	0	0	0	0	0	0,8
21	LIS101008	Vysoká formy 9200160252	1	1	2	0	0	0	0	3	1	2	1	1	2	2	1	1	0	1	1	1	1	0	0	0	0	0,8
22	LIS101009	Harting 09200102612	1	1	1	1	1	19	4	1	2	3	3	0	1	1	16	5	5	1	5	4	4	0	6	2	24	4,5
23	LIS101010	Samice 10pin 9200102812	1	1	1	1	1	4	1	1	4	1	2	1	2	2	1	2	2	1	1	1	2	1	1	4	1	1,6
24	LIS101011	Harting 19200101440	1	3	1	1	1	0	1	1	2	1	1	1	1	1	3	1	2	1	0	1	1	1	0	4	3	1,3
25	LIS101012	Harting 09200100301	1	1	1	0	0	0	0	0	7	1	0	0	2	2	2	0	0	0	0	0	0	0	0	2	1	0,8
26	LIS101013	Harting 09200100321	1	0	0	0	0	16	3	3	2	3	3	3	1	4	6	3	3	2	2	2	1	0	0	0	5	2,6
27	LIS101014	Harting 19200100251	1	0	0	0	0	0	0	0	7	1	1	2	2	2	4	1	1	1	0	1	1	1	1	2	1	1,1
28	LIS102001	jadra velke formy do strany 9200320270	1	1	2	1	1	0	1	1	1	1	2	1	1	1	0	1	1	2	1	1	1	0	0	0	0	0,8
29	LIS102002	jadra bez vyvodky 9200320301	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	1	0,3
30	LIS102003	Harting 09200320420	1	0	3	0	1	1	1	1	1	0	1	0	0	0	0	0	0	5	1	1	1	1	0	0	0	0,8
31	LIS102004	Harting 09200320520	1	0	3	2	1	1	1	1	1	1	1	1	1	1	4	1	1	1	1	1	1	0	0	2	0	1,0
32	LIS103001	Harting 09330242701	1	3	1	5	1	4	5	2	2	4	7	2	2	4	7	4	4	0	3	1	3	4	1	2	23	3,9
33	LIS103002	Samec topeni konektor 9330242601	1	2	3	3	1	0	5	3	3	2	3	5	1	5	6	5	5	4	3	1	2	3	1	1	2	2,8
34	LIS103003	Stroj topeni formy spodek 9300240301	1	4	1	1	1	2	1	1	1	1	1	2	0	0	0	0	0	9	2	2	2	2	2	2	1	1,4

5-7-2 (a)

	A	B	D	FG	FH	FI	FJ	FK	FL	FM	FN	FO	FP	FQ	FR	FS	FT	FU	FV	FW	FX	FY	FZ	GA	GB	GC	GD	GE
2	IDH	Description	Category Nr.	Absolute Scaled Error of SIMPLE MOVING AVERAGE METHOD (for period - 6 month)																								
3				1.13	2.13	3.13	4.13	5.13	6.13	7.13	8.13	9.13	10.13	11.13	12.13	1.14	2.14	3.14	4.14	5.14	6.14	7.14	8.14	9.14	10.14	11.14	12.14	MASE
4																												
16	LIS101003	Samice jadro 1-16 9200162812	1	0	2	0	0	4	2	0	2	1	0	1	0	1	0	0	0	0	0	0	0	0	1	1	1	0,8
17	LIS101004	Samice jadro17-32 9200162813	1	1	3	2	0	0	1	2	2	1	0	1	1	1	0	0	1	2	1	1	1	1	1	2	2	1,1
18	LIS101005	Na prodluzovak nahoru 9200160441	1	2	2	0	0	1	1	1	1	1	1	2	1	1	0	1	1	0	1	0	0	0	1	0	0	0,9
19	LIS101006	Harting 09200160541	1	1	0	0	0	3	1	1	1	2	0	1	0	1	0	1	0	2	1	1	1	0	0	0	0	0,8
20	LIS101007	Nizke formy 9200160301	1	4	1	1	1	1	1	0	0	0	5	1	0	1	1	1	1	1	0	0	0	0	0	0	0	0,8
21	LIS101008	Vysoká formy 9200160252	1	1	2	0	0	0	0	3	1	2	1	1	2	2	1	2	0	1	1	1	1	0	0	0	0	1,0
22	LIS101009	Harting 09200102612	1	0	0	0	0	3	1	0	0	1	1	0	0	0	3	1	1	0	1	1	1	0	1	0	4	0,8
23	LIS101010	Samice 10pin 9200102812	1	0	0	0	0	2	0	0	2	0	1	0	1	1	0	1	1	1	1	1	1	1	1	2	1	0,8
24	LIS101011	Harting 19200101440	1	2	1	1	1	0	1	1	2	0	1	1	1	1	3	0	2	1	0	1	1	0	0	4	3	1,2
25	LIS101012	Harting 09200100301	1	1	1	0	0	0	0	0	8	1	0	0	2	2	2	0	0	0	0	0	0	0	0	2	1	1,0
26	LIS101013	Harting 09200100321	1	0	0	0	0	6	1	1	1	1	1	1	0	1	2	1	1	1	1	1	0	0	0	0	2	0,9
27	LIS101014	Harting 19200100251	1	0	0	0	0	0	0	0	5	1	1	1	1	1	2	1	1	1	0	1	1	0	0	1	0	0,7
28	LIS102001	jadra velke formy do strany 9200320270	1	1	3	2	1	0	1	1	1	1	2	1	1	1	0	1	1	2	1	1	1	0	0	0	0	1,0
29	LIS102002	jadra bez vyvodky 9200320301	1	1	1	1	1	1	1	0	0	0	0	0	4	1	1	1	3	1	1	1	1	1	1	4	3	1,1
30	LIS102003	Harting 09200320420	1	0	3	0	1	1	1	1	1	0	1	0	0	0	0	0	0	6	1	1	1	1	0	0	0	0,9
31	LIS102004	Harting 09200320520	1	0	3	1	1	1	1	1	1	1	1	0	0	0	3	1	1	1	1	1	1	0	0	1	0	0,9
32	LIS103001	Harting 09330242701	1	1	0	1	0	1	1	0	0	1	1	0	0	1	1	1	1	0	1	0	1	1	0	0	4	0,8
33	LIS103002	Samec topeni konektor 9330242601	1	1	1	1	0	0	2	1	1	1	1	2	1	2	2	2	2	2	1	0	1	1	0	0	1	1,1
34	LIS103003	Stroj topeni formy spodek 9300240301	1	3	0	0	0	2	1	1	0	0	0	1	0	0	0	0	0	6	1	1	1	1	1	1	1	0,9

5-7-2 (b)

	A	B	D	GL	GM	GN	GO
1	alfa =>	0,8					
2–3	IDH	Description	Category Nr.	Total Deviation of Croston's 2013 , Items	Total Deviation of Croston's 2014 , Items	Total Relative Deviation of Croston's 2013 , %	Total Relative Deviation of Croston's 2014 , %
4							
832	LIS401003	rychlospojka 608KFTF10MVN	3	5	4	-92%	-97%
833	LIS401004	rychlospojka 612KFTF13MVN	3	4	7	-10%	-35%
834	LIS401005	rychlospojka 612SFAW17MXN	3	1	4	-4%	-18%
835	LIS401006	rychlospojka 612SFAW21MXN	3	12	6	-44%	-46%
836	LIS401007	rychlospojka 608SFAW10MXN	3	-9	23	30%	-465%
837	LIS401008	rychlospojka 608SFAW13MXN	3	9	16	-37%	-55%
838	LIS401009	rychlospojka 608SFAR17MXN	3	-4	8	40%	-810%
839	LIS401010	RPL 08.1252	3	-10	25	18%	-147%
840	LIS401011	rychlospojka 608KFTF12MVN	3	4	4	-23%	-20%
841	LIS401012	rychlospojka 608KFTR12MVN	3	-16	10	30%	-37%
842	LIS401013	RPL 08.6812/RO	3	39	74	-350%	0%
1403	TT	Total		369	832	-9%	-15%
1405							

MAM / WMAM / ESM / MAM&ESM by Q / CROSTON'S / CROSTON'S modified / Croston's by Q / Holt / Naive / Main

5-7-2 (c)

Source: data of VALEO AUTOKLIMATIZACE k.s., author's calculations.

The summary table containing the overall results of forecasting accuracies and deviations between forecasting method and overall results consumed units. The lowest rate of relative deviations of forecasted values from the actual ones was detected for SMAM method with period 6 month (-2%) and for WMAM method with period 6 months (2%). The value of MAD equals to 1.85 and MAPE - 38% for MAM method with period of 6 month. For WMAM method with period 6 month the value of MAD equals to 1.92 and MAPE - 39%. However, the values of MAD and MAPE for SMAM and WMAM methods with period of 6 months were not the lowest ones among all calculated forecasting methods (see Table 5-7-3).

Table 5-7-3 The results of the forecasts accuracy assessment.

	Overall results of Forecasts accuracy for the period 2013-2014								
Description of Method	Consumption (units)	Forecast (units)	Forecast Deviation (units)	Relative Deviation (%)	MAD (units)	MAPE (%)	Absolute Scaled Error (%)	MAE (units)	MASE (-)
Naïve	9 750	10 433	683	7%	4.96	101%	100%	237	1.00
MOVING AVERAGE METHOD (period 3 month)	9 750	10 111	361	4%	2.73	56%	87%	206	0.87
MOVING AVERAGE METHOD (period 6 month)	9 750	9 515	-235	-2%	1.85	38%	76%	181	0.76
MOVING AVERAGE METHOD (period 12 month)	9 750	8 848	-902	-9%	1.63	33%	63%	150	0.63
WEIGHTED MOVING AVERAGE METHOD (period 3 month)	9 750	10 313	563	6%	2.72	56%	90%	226	0.90
WEIGHTED MOVING AVERAGE METHOD (period 6 month)	9 750	9 927	177	2%	1.92	39%	90%	214	0.90
WEIGHTED MOVING AVERAGE METHOD (period 12 month)	9 750	9 414	-335	-3%	2.29	47%	70%	192	0.70
EXPONENTIAL SMOOTHING METHOD	9 750	10 683	933	10%	1.28	26%	98%	232	0.98
Croston's	9 750	12 553	2 803	29%	1.78	36%	77%	183	0.77
Croston's modified	9 750	10 184	434	4%	1.24	25%	69%	164	0.69
Holt Forecast	9 750	12 615	2 866	29%	1.70	35%	98%	234	0.99

Source: data of VALEO AUTOKLIMATIZACE k.s., author's calculations.

The best forecasting result was demonstrated by the modified Croston method: the value of MAD is 1.24, MAPE - 25% and MASE - 0.69. These values are the lowest among all the rest, as it can be seen above from the Table 5-7-3.

As the Modified Croston's method (MCM) showed the most accurate prognosis, namely this method was selected for calculation the forecast for the 2015 year. The results of these calculations are given below in the pivot Table 5-7-4.

Table 5-7-4 The results of Forecasts based on MCM for the 2015 year.

	A	B	D	T	W	Y	Z	AA	AD	AE	AF	AI	AJ	AK
2 3	ID	Description	Category Nr.	Stock 01.01.2015 (units)	Forecast 2015 correction (units)	SS calculated (units)	SS correction (units)	Re order quantity (units)	ABC (Value from Total Cons.)	Group of XYZ	SS from SAP (czk)	Stock 01.01.2015 (czk)	Forecast (czk)	SS calculated (czk)
4														
1270	LIS905006	Magnetventilset DN12; Typ 290; 9360348	8	1	0	0	0	0	C	Z	3 589	3 589	0	0
1271	LIS906001	Bosch 0 811 404 607	8	2	1	1	1	0	A	Z	88 641	88 641	44 321	29 315
1272	LIS906002	Bosch 0 811 404 601	8	4	0	0	0	0	C	Z	48 056	192 222	0	0
1273	LIS906003	Bosch 0 811 404 606	8	2	0	0	0	0	A	Z	93 109	93 109	0	0
1274	LIS906004	Bosch 0 811 404 624	8	2	1	1	1	0	A	Z	37 347	74 693	37 347	24 702
1275	LIS906005	VT-DFPE-A-22/G24KO/2A1E/V	8	2	1	1	1	0	A	Z	42 816	85 632	42 816	28 320
1276	LIS906006	Bosch 0 811 404 163	8	3	1	1	1	0	A	X	48 000	144 000	48 000	31 749
1277	LIS906007	VT-DFPE-C-21/G24KO/2A0V/V	8	3	3	1	2	1	A	Z	514 758	154 427	154 427	58 973
1278	LIS906008	VT-DFPE-A-22/G24KO/2A0F/V-017	8	2	2	1	1	1	A	Z	89 609	89 609	89 609	41 911
1279	LIS906009	VT-DFP-B-21/G24KO/0/V	8	6	1	1	1	0	A	Z	97 549	146 323	24 387	16 131
1379		Total		10 879	6 279	3 046	3 272	4 450			14 810 091	16 513 944	5 745 852	2 737 420
1380		Average Result		7,9	4,6	2,2	2,4	3,2			10779	12019	4182	1992

Source: data of VALEO AUTOKLIMATIZACE k.s., author's calculations.

5.8. CALCULATION OF SAFETY STOCKS AND RE-ORDER QUANTITIES

The accuracy of safety stocks calculation is one of the most important tasks along with forecast accuracy. Because the inventory level of the company and the amount of monetary funds, that will be blocked (frozen) in a warehouse, directly depend on namely this calculation.

Above all the surplus funds could be otherwise spent on investment in production, its expansion (increase in output), modernization of equipment with the aim of improving the quality of the product. In addition these surplus funds can help to avoid additional costs associated with the need to borrow money from banks in form of loans or credits. To prevent this the proper inventory management should be carried out.

There are a number of formulas and principles for safety stocks calculation, each of which has a right to exist and can provide with satisfactory result in a given situation. After analyzing the level and frequency of consumption of spare parts during the 2012-2014 period, it was decided to use the formula (7) described in the Theoretical framework of the present study, the calculation of which was carried out based on the standard deviation and the service level (was taken the Service Level considered as standard level and recommended by the number of authors - 98%).

The results of analysis calculations revealed that for spare part "Koleno 3/8" (ID LIS1901012) the recommended SS has to be 14 pcs. However the current used by the company SS for that Item was indicated in SAP on the 40 pcs level. The latter belongs to the CZ group (as was in ABC and XYZ analysis shown) practically does not influence on the value of inventory level, despite the rather high of variation coefficient. As we can see from the Table 5-8-1, the value of SS for this Item was reduced from 3 808 CZK to 1 272 CZK. The overall SS quantity was reduced from 9 460 units to 3 272 units, at the same time the value was reduced from 14 810 091 CZK to 2 737 420 CZK.

Table 5-8-1 The Results of SS calculations for the 2015 year, in quantities and values.

	A	B	D	I	J	N	O	S	W	X	Y	Z	AD	AE	AF	AK
2–4	ID	Description	Category Nr.	Consumption 2013 (items)	Consumption 2014 (items)	Max. Consumed 2014 (units)	LT (days)	SS from SAP (units)	Forecast 2015 correction (units)	Standart Deviation	SS calculated (units)	SS correction (units)	ABC (Value from Total Cons.)	Group of XYZ	SS from SAP (czk)	SS calculated (czk)
331	LIS1601017	Unitronic FD CP plus UL 25x0,25 *00288	14	0	50	50	14	25	25	3,7	24	25	B	Z	4 282	4 191
339	LIS1701001	MT D 1 x 250, TEF004270	15	9	12	9	40	28	13	2,0	10	10	A	Z	40 860	13 921
340	LIS1701002	Termo#lánek MT D 1,5x250mm, TEF003	15	51	19	7	40	21	30	1,0	7	8	A	Z	27 216	9 390
342	LIS1701004	Termo#lánek MT D 1,5 x100mm, TEF00	15	22	13	8	40	15	15	2,0	10	11	A	Z	15 300	10 452
582	LIS1901008	Spojka maticová M18x1,5 - M18x1,5	17	5	15	11	14	3	15	2,0	10	11	C	Z	269	918
585	LIS1901011	T-kus M18x1,5 sm	17	0	10	10	14	40	10	2,2	9	10	C	Z	4 536	1 044
586	LIS1901012	Koleno 3/8" zm	17	4	11	11	14	40	11	2,2	10	10	C	Z	3 996	964
587	LIS1901013	Koleno 3/8" zz	17	1	14	14	14	40	14	2,7	13	14	C	Z	3 808	1 272
589	LIS1901015	Záslepka 12/M18x1,5	17	0	15	9	14	40	15	2,0	10	11	C	Z	692	177
590	LIS1901016	Matice M18x1,5	17	0	10	6	14	40	10	1,4	6	6	C	Z	400	59
591	LIS1901017	Záslepka ku#el 12/M18x1,5	17	0	10	6	14	40	10	1,4	6	6	C	Z	828	122
602	LIS1902009	Elite hadice s koncovkami / 400mm	17	1	10	6	14	7	6	2,0	6	7	C	Z	1 234	1 142
1022	LIS5020033	zaji#»ovací kamen do klapa#ek HASCO	4	12	15	8	30	10	17	1,0	5	6	B	Z	7 250	3 954
1220	LIS803001	Maznice SKF LAGD 125/HB2	7	0	16	16	14	20	17	3,0	16	17	B	X	13 512	11 055
1379		Total		4 187	5 472		19 886	9 460	6 279		3 046	3 272			14 810 091	2 737 420
1381		Deviation from previous Value														-12 072 670

Source: data of VALEO AUTOKLIMATIZACE k.s., author's calculations.

Re-Order quantities were calculated on the basis of formula (32) described in Theoretical and Methodological part of the study. The overall results of Order quantities calculations is given in Table 5-8-2. From the Table it can be seen that for spare part "Koleno 3/8" (ID LIS1901012) the necessary order quantity equals to 21 pcs. The total value of the order equals to 4 450 units for the period of 2015 year taking into account the forecast for that period and quantities in stock (inventory level) for the same period.

Table 5-8-2 The Results of Re-order quantities calculations for the 2015 year.

	ID	Description	Category Nr.	Consumption 2013 (items)	Consumption 2014 (items)	LT (days)	MOQ (units)	Stock 01.01.2015 (units)	Forecast 2015 correction (units)	SS correction (units)	Re order quantity (units)
331	LIS1601017	Unitronic FD CP plus UL 25x0,25 *00288	14	0	50	14	1	0	25	**25**	49
339	LIS1701001	MT D 1 x 250, TEF004270	15	9	12	40	1	19	13	**10**	4
340	LIS1701002	Termo#lánek MT D 1,5x250mm, TEF003	15	51	19	40	1	6	30	**8**	31
342	LIS1701004	Termo#lánek MT D 1,5 x100mm, TEF00	15	22	13	40	1	14	15	**11**	11
582	LIS1901008	Spojka maticová M18x1,5 - M18x1,5	17	5	15	14	1	0	15	**11**	25
585	LIS1901011	T-kus M18x1,5 sm	17	0	10	14	1	0	10	**10**	19
586	LIS1901012	Koleno 3/8" zm	17	4	11	14	1	0	11	**10**	21
587	LIS1901013	Koleno 3/8" zz	17	1	14	14	1	0	14	**14**	27
589	LIS1901015	Záslepka 12/M18x1,5	17	0	15	14	1	0	15	**11**	25
590	LIS1901016	Matice M18x1,5	17	0	10	14	1	0	10	**6**	16
591	LIS1901017	Záslepka ku#el 12/M18x1,5	17	0	10	14	1	0	10	**6**	16
602	LIS1902009	Elite hadice s koncovkami / 400mm	17	1	10	14	1	2	6	**7**	10
1022	LIS5020033	zaji#»ovací kamen do klapa#ek HASCO	4	12	15	30	1	11	17	**6**	11
1220	LIS803001	Maznice SKF LAGD 125/HB2	7	0	16	14	1	4	17	**17**	29
1379		**Total**		**4 187**	**5 472**	**19 886**	**1 374**	**10 879**	**6 279**	**3 272**	**4 450**

Source: data of VALEO AUTOKLIMATIZACE k.s., author's calculations.

5.9. CALCULATION OF INVENTORY LEVEL FOR THE BEGINNING OF 2016

On the basis of the received data of inventory level to each spare part and calculation of forecast demands for the 2015, re-order points and re-order quantities was made the summary table with inventory level of each spare part at the beginning of 2016 year. The quantities of inventory level of each spare part were calculated using formula (31) described in Theoretical and Methodological part of the study. Several samples of these calculations are provided below (see Table 5-9-1). From the Table it can be seen that for spare part "SANG-A #roubení IQSL 188 R1/8 8mm" (ID LIS2305008) the inventory level quantity equals to 20 pcs and value equals to 710 CZK at the beginning of year 2016. The total quantity of inventory level equals to 9 050 units and value equals to 15 157 452 CZK at the beginning of year 2016.

Table 5-9-1 The Results of Inventory level (stock) calculations at the beginning of 2016 year, in quantities and value.

	A	B	D	T	W	Y	Z	AA	AB	AD	AE	AF	AI	AJ	AK	AL
2 3	ID	Description	Category Nr.	Stock 01.01.2015 (units)	Forecast 2015 correction (units)	SS calculated (units)	SS correction (units)	Re order quantity (units)	Stock 01.01.2016 (units)	ABC (Value from Total Cons.)	Group of XYZ	SS from SAP (czk)	Stock 01.01.2015 (czk)	Forecast (czk)	SS calculated (czk)	Stock 01.01.2016 (czk)
4																
777	LIS2305006	SANG-A #roubení IQSL 184 R1/8	20	37	16	9	**9**	0	21	C	Z	634	1 173	507	285	666
778	LIS2305007	SANG-A #roubení IQSL 186 R1/8	20	29	1	1	**1**	0	28	C	X	951	919	32	21	888
779	LIS2305008	SANG-A #roubení IQSL 188 R1/8	20	42	38	20	**20**	16	20	C	Z	726	1 525	1 379	710	710
780	LIS2305009	SANG-A #roubení IQSL M54 4mı	20	41	10	8	**9**	0	31	C	Z	1 815	1 488	363	304	1 125
781	LIS2305010	SANG-A #roubení IQSL M56 6mı	20	46	5	4	**5**	0	41	C	Z	880	2 024	220	195	1 804
782	LIS2305011	SANG-A spojka IQSG 40 4mm	20	30	11	10	**10**	0	19	C	Z	1 328	996	365	320	631
783	LIS2305012	SANG-A spojka IQSG 60 6mm	20	45	37	12	**13**	4	12	C	Z	1 695	1 526	1 254	409	409
784	LIS2305013	SANG-A spojka IQSG 80 8mm	20	20	56	30	**30**	66	30	C	Z	1 855	742	2 078	1 102	1 102
785	LIS2305014	SANG-A spojka IQSG 100 10mm	20	33	20	18	**18**	5	18	C	Z	974	1 607	974	864	864
786	LIS2305015	SANG-A spojka IQSL 40 4mm	20	36	5	4	**4**	0	31	C	Z	634	1 141	159	122	983
787	LIS2305016	SANG-A spojka IQSL 60 6mm	20	35	28	18	**18**	11	18	C	Z	1 017	1 187	949	593	593
1379		**Total**		**10 879**	**6 279**	**3 046**	**3 272**	**4 450**	**9 050**			**14 810 091**	**16 513 944**	**5 745 852**	**2 737 420**	**15 157 452**
1380		**Average Result**		7,9	4,6	2,2	2,4	3,2	6,6			10779	12019	4182	1992	11032

Source: data of VALEO AUTOKLIMATIZACE k.s., author's calculations.

5.10. SUMMARY RESULTS OF CALCULATION

On the basis of all the listed above and interpreted calculations the two convenient and readable pivot tables were created. The first table contains information on quantities of SS, demand forecast for 2015 year and inventory level for the beginning of 2016 year per each category of spare parts (see Table 5-10-1 (a)). The second one contains information on values expressed in CZK of SS, demand forecast for the 2015 year and inventory level for the beginning of 2016 year per each category of spare parts, as shown in Table 5-10-1 (b). The similar but initial data that were exported from SAP system and received from VALEO AUTOKLIMATIZACE k.s. company, namely SS, consumption per each year from 2013 to 2014 and inventory level at the beginning of 2014 and 2015 years were added to the table in order to compare them with the results obtained in the research in terms of quantities and values for each category of spare parts.

Table 5-10-1: The comparison of summary calculated results and initial data upon SS, demand forecast and IL expressed in units (a) and in CZK (b).

	A	B	C	D	E	F	G	H	I	J	K
2	Ordinal Nr.	Description	Category Nr.	SS from SAP (units)	SS calculated (units)	Quantity of Inventory level at the beginning year (units)			Consumption and Forecast (units)		
3						2014	2015	2016	2013	2014	2015
4	1	Connectors	1	236	209	268	245	237	517	477	524
5	2	Repair sensors for moulds and machines	2	217	121	373	340	246	369	209	290
6	3	Staubli	3	460	242	508	491	391	853	446	591
7	4	Spare parts for DME and injection mould	4	137	45	126	113	79	69	91	106
8	5	Spare parts for Ejectors	5	973	126	2234	2189	2049	167	195	279
9	6	Bearings	6	107	39	97	132	102	64	78,7	97
10	7	Oil, Lubricants	7	28	21	9	12	26	11	25	27
11	8	Valves, filters, machine equipment, and valve accessories for presses	8	216	71	227	243	215	93	89	113
12	9	Moretto	9	181	68	127	231	181	111	86	154
13	10	Machine coupling	10	10	1	7	14	13	0	1	1
14	11	Electronic cards, electronic spare parts	11	132	26	53	121	117	94	42	54
15	12	Greenbox cooling, water facility, pump accessories	12	92	20	53	72	52	51	23	38
16	13	Fuses, relays, contactors, terminals	13	319	113	746	701	610	261	202	230
17	14	Cables	14	982	479	746	865	866	477	893	779
18	15	Heating moulds and machines	15	402	100	607	602	515	187	120	177
19	16	Festo, robot	16	290	24	133	205	185	71	22,03	40
20	17	Water hoses and hydraulic fittings	17	1114	670	550	669	695	752	1165	1277
21	18	Gas filling system - Lighter parts MUCELL	18	47	7	30	43	36	12	7	15
22	19	Conveyor system - ATYKO	19	102	27	73	111	91	28	43	51
23	20	Loopers	20	3415	863	0	3480	2345	0	1257	1436
24		Total		9 460	3 272	6 967	10 879	9 050	4 187	5 472	6 279
25		Deviation between current and previous value			-6 188		3 912	-1 829		1 285	807
26		Rate between current and previous value			-65%			-17%			15%

5-10-1 (a)

	A	B	C	D	E	F	G	H	I	J	K
28											
29	Ordinal Nr.	Description	Category Nr.	SS from SAP (czk)	SS calculated (czk)	Value of Inventory Level at the beginning year (czk)			Consumption / Forecast (czk)		
30						2014	2015	2016	2013	2014	2015
31	1	Connectors	1	222 314	115 610	248 684	182 910	197 866	263 625	231 299	251 810
32	2	Repair sensors for moulds and machines	2	534 955	135 683	620 143	630 984	556 437	437 467	276 131	372 877
33	3	Staubli	3	294 705	125 940	410 735	343 541	299 191	243 770	247 937	281 528
34	4	Spare parts for DME and injection mould	4	579 219	86 212	654 132	612 720	549 599	160 328	173 798	224 224
35	5	Spare parts for Ejectors	5	452 720	70 943	1 495 121	1 439 385	1 337 351	76 434	157 333	187 350
36	6	Bearings	6	274 012	63 358	403 307	464 389	364 244	229 538	244 034	192 035
37	7	Oil, Lubricants	7	32 377	19 055	20 518	22 504	34 327	16 797	40 114	45 576
38	8	Valves, filters, machine equipment, and valve accessories for presses	8	5 044 783	842 694	3 036 307	4 388 406	4 187 809	1 182 142	2 029 703	1 469 654
39	9	Moretto	9	166 601	34 018	198 493	233 937	200 754	113 771	47 566	97 595
40	10	Machine coupling	10	32 467	548	20 994	47 051	46 222	0	829	829
41	11	Electronic cards, electronic spare parts	11	1 053 009	90 342	768 597	1 106 648	1 036 003	619 082	266 414	223 149
42	12	Greenbox cooling, water facility, pump accessories	12	247 224	33 367	190 449	275 911	176 010	757 781	70 911	133 227
43	13	Fuses, relays, contactors, terminals	13	118 788	26 470	117 517	132 760	122 575	51 305	52 702	50 511
44	14	Cables	14	63 309	41 144	85 498	70 584	78 759	41 535	88 775	69 511
45	15	Heating moulds and machines	15	1 926 523	256 856	2 867 206	2 819 097	2 541 414	437 096	360 546	517 849
46	16	Festo, robot	16	1 410 170	146 652	1 091 882	1 376 727	1 355 597	593 237	118 216	249 103
47	17	Water hoses and hydraulic fittings	17	167 032	112 446	77 957	121 127	119 514	101 949	230 558	244 930
48	18	Gas filling system - Lighter parts MUCELL	18	1 464 796	420 490	1 217 848	1 491 322	1 369 909	101 610	739 935	925 977
49	19	Conveyor system - ATYKO	19	216 778	13 041	152 610	233 640	215 451	37 501	22 283	29 835
50	20	Loopers	20	508 309	102 550	0	520 300	368 422	0	155 372	178 282
51		Total		14 810 091	2 737 420	13 677 996	16 513 944	15 157 452	5 464 967	5 554 458	5 745 852
52		Deviation between current and previous value			-12 072 670		2 835 948	-1 356 492		89 491	191 394
53		Rate between current and previous value			-82%			-8%			3%
54		Rate between SS and Forecast		258%	48%						

5-10-1 (b)

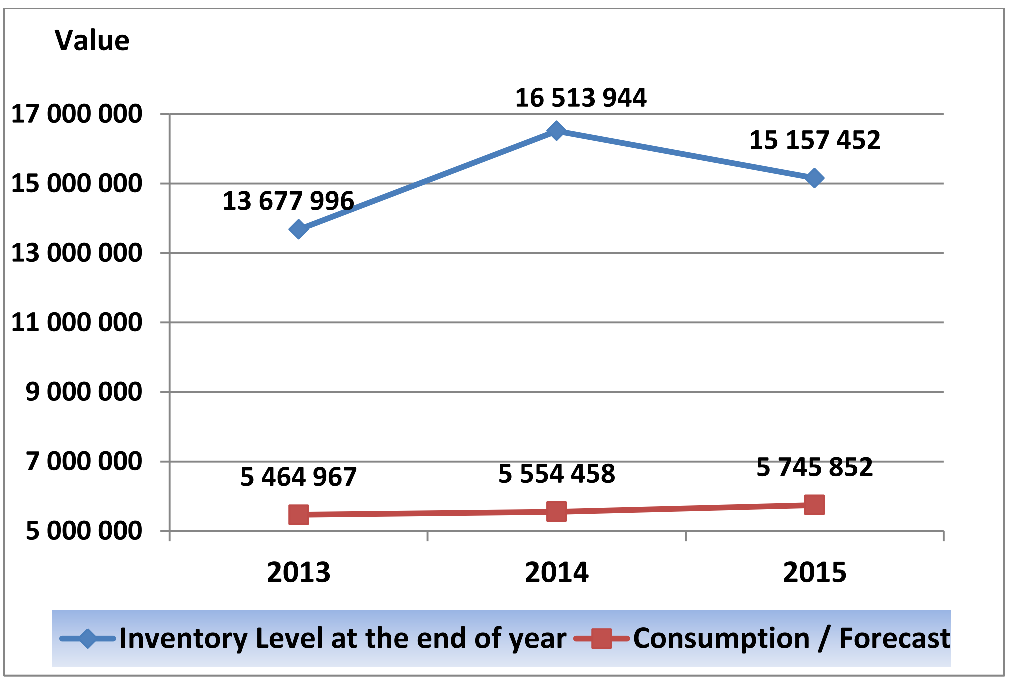
Source: data of VALEO AUTOKLIMATIZACE k.s., author's calculations.

As it can be seen from table 5-10-1 (a) the total calculated quantity of SS equals to 3 272 units, its value is 2 737 420 CZK. However, the forecasted quantity of total demand for 2015 equals to

6 279 units with the value of 5 745 852 CZK. That is 807 units or 191 394 CZK more in comparison to the actual consumption from the previous 2014 year. This difference appeared due to increasing trend of consumption for all periods that were under investigation, because VALEO AUTOKLIMATIZACE k.s. made a decision to increase production capacity and has installed 2 new molding machines.

The detected for VALEO AUTOKLIMATIZACE k.s. optimum SS level will enable to decrease the inventory level quantities by 1 829 units, that is 17% less, as well as inventory level value by 1 356 492 CZK, that is 8% less, for the beginning of the 2016 year comparing to quantities and values of inventory level at the beginning of year 2015 (see Table 5-10-1 (a), (b) above and Figure 5-10-2 below).

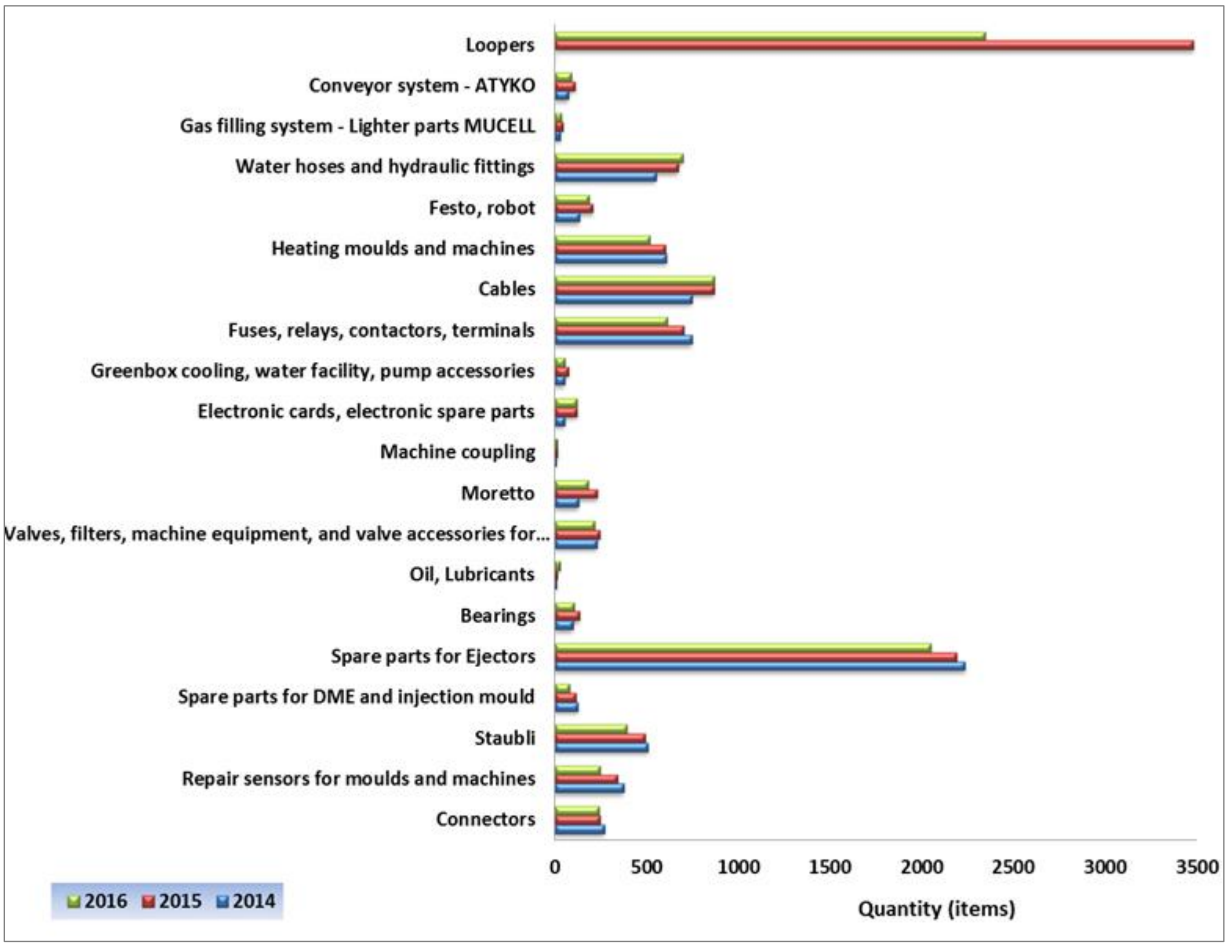
Figure 5-10-2: The total value of Inventory level for the end of year, Consumption and Forecast during the 2012-2014 period.



Source: data of VALEO AUTOKLIMATIZACE k.s., author's calculations.

As we can see from Figure 5-10-3 given below the sharpest decline in inventory level quantities for the beginning of 2016 was observed for the "Loopers" category of spare parts. Their stock has dropped by 1135 units comparing to initial quantities on stock for the beginning of 2015 year, namely from 3480 to 2345 units. The least decline in inventory level quantities was observed for “Machine coupling” category of spare parts. Their stock has dropped by just 1 unit comparing to initial quantities on stock for the beginning of 2015 year, namely from 14 to 13 units.

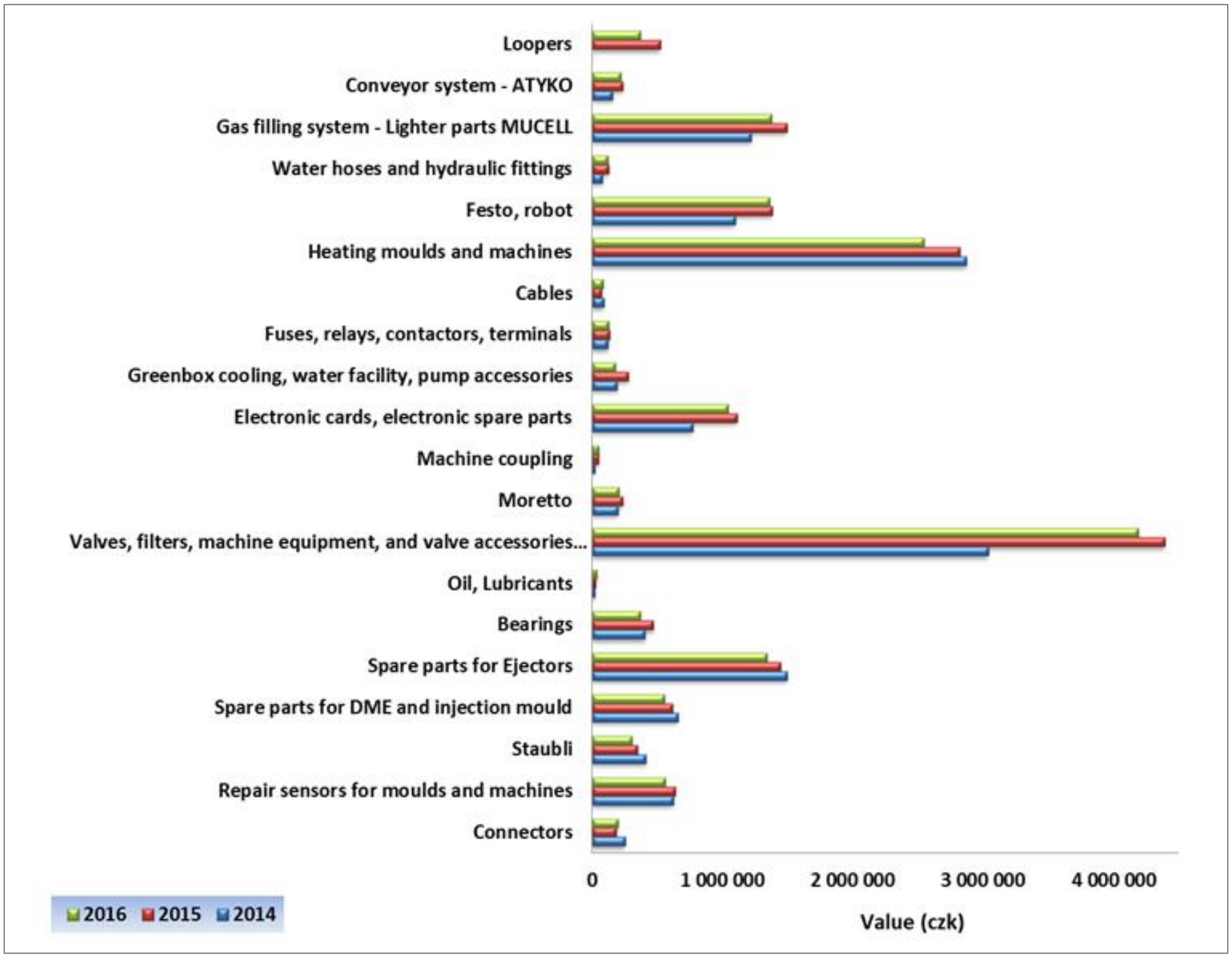
Figure 5-10-3: The quantity of Inventory Level per each category of spare parts for the beginning of 2016 year.



Source: data of VALEO AUTOKLIMATIZACE k.s., author’s calculations.

As we can see from Figure 5-10-4 given below the sharpest decline in inventory level value for the beginning of 2016 was observed for the “Heating moulds and machines” category of spare parts. It stock has dropped by 277 684 CZK comparing to initial quantities on stock for the beginning of 2015 year, namely from 2 819 097 CZK to 2 541 414 CZK. The least decline in inventory level value was observed again for “Machine coupling” category of spare parts. It stock has dropped by just 829 CZK comparing to initial value on stock for the beginning of 2015 year, namely from 47 051 CZK to 46 222 CZK.

Figure 5-10-4: The value of Inventory Level per each category of spare parts for the beginning of 2016 year.



Source: data of VALEO AUTOKLIMATIZACE k.s., author's calculations.

6. DISCUSSION

The present study was conducted on the basis of real data provided by VALEO AUTOKLIMATIZACE k.s., Rakovník, Czech Republic, that operates in automotive industry. Being a main purpose of the study, the analysis of spare parts management processes and inventory in terms of value, quantity and frequency of consumption of each spare part in stock has been carried out with the use of Statistical techniques via Microsoft Excel® spreadsheets.

For all available spare parts represented in 20 categories (the initial safety stock consisted of totally 9 460 units with value of 14 810 091 CZK) the inventory level were recalculated through determining forecasts, safety stocks (new quantities of which are 3 272 units with value of 2 737 420 CZK), re-order points, re-order quantities for each spare part. These calculations have been done employing historical data (from 2012 till 2014) time series analysis and further implementation various forecasting techniques (for the period 2013-2014), such as SES, Croston method, modified Croston method, Holt-Winters model etc., among which the most appropriate one (for company's conditions) was selected resting on the forecasts' accuracy assessments. Commonly used measures for this are: Mean Absolute Deviation (MAD), Mean Absolute Percentage Error (MAPE), Absolute Scale error (ASE), Mean Absolute error (MAE), Mean Absolute Scale error (MASE). All of them were implemented in the research as well as deviation and relative deviation between forecasted values of consumption and actual ones.

The received accuracy assessments results received have revealed that the most precise forecasts belong to the Modified Croston method. The latter allowed to predict the demand of all spare parts items for one year 2015 in advance, thus the total forecasted demand will be 6 279 units with the total value of 5 745 852 CZK (what is 191 394 CZK more than the total consumption in 2014 due to the production expansion – two new moulding machines were bought).

In order to reduce the degree of uncertainty connected with decision making process in terms of incurring costs, the following procedure is recommended:

1. Estimation of spare parts intermittent consumption and demand during the period under analysis in terms of existing trend, minimum/maximum consumed units and lead-times between consumed units, consumption in average per item.

2. Classification of spare parts according to ABC and XYZ methods based on the value of inventory level quantities (both in quantities and CZK). Via implementing these analyses all available spare parts (1 374 items) have to be categorized into three different groups: high, medium, or low, according to the value (in CZK) and quantity (in pieces or meters) of items in each category. Thus, the key spare parts in terms of quantity and CZK value will be determined.

   Mentioned classifications are helpful in a decision making process for key areas of inventory management. For example, a safety stock for items from group A (which make the largest contribution to the cost of consumption and the level of stock) should be reconsidered as frequently as possible, especially for items with coefficient of variation higher than 25% (group Z). A safety stock for items from group C (that make the least contribution to the cost of consumption and the level of stock) and with coefficient of variation less than 10 % (group X) is recommended to recalculate quite rare. The table 6-1 shows the overall result of the conducted analyses.

Table 6-1 The ABC and XYZ analyses combination results.

Description	AX	AY	AZ	BX	BY	BZ	CX	CY	CZ	Total
Combined ABC and XYZ by Value of Inventory Level with Consumption (czk)	**1 169 797**	**23 660**	**12 015 843**	**271 397**	**28 055**	**2 179 038**	**101 098**	**220**	**724 837**	**16 513 944**
Number of spare part components	27	1	244	34	3	254	150	1	660	1 374
Combined ABC and XYZ by Quantity of Consumption (units)	**423**	**0**	**10 181**	**226**	**34**	**1 736**	**222**	**0**	**445**	**13 267**
Number of spare part components	14	0	186	38	5	230	159	0	742	1 374

Source: data of VALEO AUTOKLIMATIZACE k.s., author's calculations.

3. Establishing an appropriate inventory management policy that enable to accelerate the ordering process of key spare parts (and the rest) via proper determining the following control parameters – re-order points, safety stocks and demands during the lead time.

   The best solution for this problem is an implementation and integration with the SAP system a new program (platform), which enables a quick recalculation of all necessary values and carries out seamlessly monitoring of inventory at any time.
4. Detecting an optimum (minimum and sufficient) on stock level for all types of spare parts in inventory. On the basis of the author's created analytical inventory management tool the optimum inventory level was suggested as 15 157 452 CZK for the beginning 2016 year.

5. In case of new spare parts appearance, for which a historical data on demand and actual consumption were not accumulated, forecasted values of the latter, as well as minimum and maximum levels of it, have to be determined on the basis of technical documentation (specifications) for new moulding machines and on the basis of experts' opinions working on the production (service personnel, engineers and technicians). Information received this way will serve as a base for safety stock level and forecasts determination.
6. By implementing the obtained calculations, taking into account suppliers' lead times, re-order quantities of spare parts will be distributed to the warehouse in right time. Lead times are specific to each spare part depending on its distribution channel: either local or abroad.

These calculations are necessary to ensure proper coverage of both scheduled and unscheduled demands of spare parts. Reduction in quantities of spare parts kept as a safety stock is quite essential and was considered as the main aim. Thus, the inventory level review is crucial for decision making in placing a replenishment schedule and procurement ordering. The optimum level of inventory was obtained, where a procurement order is placed in advance prior to the time of scheduled maintenance.

Spare parts inventory optimization, aiming at cost effective operation of an enterprise, helps to ensure that the right spare part will be at the right place at the right time. Predictive inventory optimization, contributing to a better inventory managing within the organization, is used to support decision making process aimed at avoiding downtimes, appearing due to seasonally varying demand. Thus, the main idea was to ensure proper coverage of both scheduled and unscheduled required maintenance for a set of operating machinery. At the present time, that is characterized by constantly changing market environment and strongly increasing competition among its players, maintenance and optimization of spare parts inventories becomes one of the cornerstones of an effective and rational management for any company in automotive industry. Monetary funds that are not invested in unnecessary or superfluous spare parts can be employed in further prospective activities to achieve better results in business and keep more favorable position among competitors on the market. As a result of the conducted analysis and calculations done the saved amount totals 1 356 492 CZK. According to calculations, the value of inventory level at the beginning of 2016 year will total 15 157 452 CZK, that is less than the value of inventory level at the beginning of 2015 year (16 513 944 CZK) by 8 %. The total saved amount on average inventory level value was reached at a service level of 98% and considered as an optimum level of inventory stock at minimum costs, which avoids extended down-times and ensures moulding machine availability within a production process.

7. CONCLUSIONS

The main objective set at the beginning of the present research as well as the research questions were completely fulfilled and answered. The key achieved results of the study are given and explained below:

1). The most appropriate consumption/demand forecasting method for VALEO AUTOKLIMATIZACE k.s. conditions was determined. That is – Modified Croston method.

2). In the Microsoft Excel® summary spreadsheet the two analytical tools were created:

- enabling to conduct an intermittent demand forecasting with the use of various forecasting techniques, for instance Croston method, on the basis of consumption historical data during a lead-time;
- enabling to recalculate SS, re-order points, re-order quantities resting on the forecast done in the previous tool and to estimate an inventory level at the end of forecasted period.

3). Being rest on the real historical data and conducted ABC and XYZ analyses in terms of criticality, the SS for the most vital spare parts were reviewed individually. This resulted in suggesting the following total values: optimum safety stocks (in quantities 3 272 units, in value 2 737 420 CZK), re-order quantities (4 450 units), forecasted demands (in quantities 6 279 units, in value 5 745 852 CZK) and inventory level for all spare parts at the beginning of year 2016.

4). The conducted analyses and calculations revealed the possibility to reduce the inventory level from 16 513 944 CZK (beginning of year 2015) to 15 157 452 CZK (by 1 356 492 CZK or 8 %) at the beginning of the year 2016.

5). The Microsoft Excel® inventory management tool created by the author serves as an analytical framework in promoting a long-term planning policy and supports the organizations' ordering SAP® software system. This tool was designed flexible to permit change in influencing input parameters. Thus, it helps to avoid downtimes by meeting challenges of intermittent consumption/demand of spare parts holding at the same time an adequate stock of spare parts, contributing to a minimization of an average value of inventory and as a result in the company's financial and operational sustainability.

8. BIBLIOGRAPHY

Apolloni, S., Lando, M., Savino, M. Failure-Based Maintenance Organization through ERP Software Evolution. [online] Available at: http://unina2.academia.edu/StefanoApolloni/Papers.

Bhadbury, B., **Shenoy, D.** (Editors) (1998). Maintenance Resource Management: Adapting Materials Requirements Planning MRP. ISBN-13: 978-0748406487

Botsali, A. R. and Peters, B. A. (2005). A network based layout design model for retail stores. Industrial Engineering Research Conference Proceeding.

Botter, R., Fortuin, L. (1998). Stocking strategy for spare parts. Available at http://cms.ieis.tue.nl/beta/files/workingpapers/beta_wp33.doc Accessed [Online], [15/2/2015]

Box, G., **Jenkins, G., Reinsel**, **G**. (1993). Time Series Analysis, Forecasting, and Control, Third Edition, Prentice Hall, Englewood Cliffs, NJ.

Bozarth, Cecil (2011), Time Series Models: Approaches to Forecasting. Available from: http://scm.ncsu.edu/scm-articles/article/time-series-models-approaches-to-forecasting-a-tutorial#2. Accessed [Online], [5/03/2015]

Chiulli, Roy M. (1999), Quantitative Analysis: An Introduction. CRC Press: 592 p.

Croston, J.D. (1972), Forecasting and stock control for intermittent demands. Operational Research Quarterly 23, 289-303.

Datta, A. K. (2008), MATERIALS MANAGEMENT: PROCEDURES, TEXT AND CASES.

Dhoka, Dinesh Kumar, Choudary, Y. Lokeswara (2013), “XYZ” Inventory Classification & Challenges. IOSR Journal of Economics and Finance (IOSR-JEF). Volume 2, Issue 2, PP 23-26. e-ISSN: 2321-5933, p-ISSN: 2321-5925.

Driessen, M.A., Arts, J.J., Houtum, G.J., Rustenburg, W.D., Huisman, B. (2010). Maintenance spare parts planning and control: A framework for control and agenda for future research, Beta Working Paper series 325, ISBN 978-90-386-2358-0. Available at: http://cms.ieis.tue.nl/Beta/Files/WorkingPapers/wp_325.pdf Accessed [Online], [17/2/2015]

Dyntar, Jakub, Kemrová, Eva, Gros, Ivan (2010), Simulation approach in stock control of products with sporadic demand. Ekonomika a management. Available at: http://www.vse.cz/eam/107.

Eppen, G.D., Gould, F.J., Schmidt, C.P., Moore, H. Jeffrey, Weatherford, R, Larry R. (1998). Introductory Management Science, 5th Edition. Prentice Hall, Inc., Upper Saddle River, NJ07458, ISBN: 0-13-889395-0.

Flores, Benito E., Whybark, D. Clay (1986) "Multiple Criteria ABC Analysis", International Journal of Operations & Production Management, Vol. 6, Iss: 3, pp. 38 – 46.

Gentry, T., Wiliamowski, B., Weatherford, L. (1995), A comparison of traditional forecasting techniques and neural networks. *Intelligent engineering systems through artificial neural networks.* Volume 5. Available at: http://www.eng.auburn.edu/~wilambm/pap/1995/ANNIE%2795_A_comparison_of_traditional_forecasting.pdf.

Gopalakrishnan, P., Banerji, A.K. (2008). Maintenance and Spare parts Management, 6th Edition, Prentice-Hall of India Private limited, ISBN: 978-81-203-0669-1.

Hladík, T. (2010), Effective spare parts management in maintanance. Proceedings of international conference Euro Maintenance, Verona, Italy.

Hopp, W.J. Spearman, M.L. (2001), Factory physics. McGraw-Hill.

Huiskonen, Janne (2001). Maintenance spare parts logistics: Special characteristics and strategic choices. Int. J. Production Economics, Issue 71, pp. 125-133

Hyndman, Rob J., Athana-sopou-los, George (2014), Forecasting: principles and practice. Holt-Winters seasonal method. Available at: https://www.otexts.org/fpp/7/2

Hyndman, Rob J., Athana-sopou-los, George (2014), Forecasting: principles and practice: Some simple forecasting methods. Available at: https://www.otexts.org/fpp/2/3

Hyndman, Rob J., Koehler, Anne B. (2006). Another look at measures of forecast accuracy. *International Journal of Forecasting* 22 (4): pp. 679–688.

Kennedy, S. (2006), New tools for PdM. Plant Services.

Langevin, A. Riopel, D. (eds.) (2005). Logistics Systems: Design and Optimization. Springer Science + Business Media Inc. ISBN 0-387-24971-0, 351 p.

Maciejczak, Mariusz. Supply Chain Management. Available from: *http://www.maciejczak.pl/lectures.html*

Malakooti, Behnam (2013). *Operations and Production Systems with Multiple Objectives*. John Wiley & Sons. ISBN 978-1-118-58537-5

Minh, Nguyen (2013). Inventory Management. Available from: https://www.linkedin.com/groups/What-is-different-between-ABC-92679.S.206825884. Accessed [Online], [5/03/2015]

Petriková A., Šebo, D., Dušan Sabadka (2012), Optimization of logistics processes using XYZ method. MACHINES, TECHNOLOGIES, MATERIALS. Available from: http://mech-ing.com/journal/Archive/2012/3/6_68_E_pletikova.pdf. Accessed [Online], [5/03/2015]

Piasecki, J. David (2009). Inventory Management Explained, 1st Edition. OPS Publishing, ISBN: 0972763112

Rajaniemi, J. (2012), Lead Time Terminology in Manufacturing. Available at: *www.leadtimes.org*

Ramakrishnan, Ramanathan (2006), ABC inventory classification with multiple-criteria using weighted linear optimization. Computers & Operations Research. Volume 33, Issue 3, pp. 695–700.

Randolph W. (2013). Inventory Management. Available from: https://www.linkedin.com/groups/What-is-different-between-ABC-92679.S.206825884. Accessed [Online], [5/03/2015]

Reid, J. (2014). SAP MM Module For Beginners. Available from: https://blog.udemy.com/sap-mm-module/. Accessed [Online], [12/12/2014]

Russel, S. Roberta, Taylor, W. Bernard (2000). Operations Management, 3rd Edition, Prentice-Hall, Inc., Upper Saddle River, N.J.07458, ISBN: 0-13-013092-3

Shaul, L., Tauber, D. (2012). CSFs along ERP life-cycle in SMEs: a field study. Industrial Management & Data Systems, 112(3), pp. 360-384.

Sherbrooke, C.C. (1968). Metric: A multi-echelon technique for recoverable item control. *Operations Research*, 16(1), pp. 122-141.

Shumway, R.H. and D.S. Stoffer, (2000), Time Series Analysis and Its Applications, SpringerVerlag, N.Y.

Syntetos, A.A., & Boylan, J.E. (2001). On the bias of intermittent demand estimates. International Journal of Production Economics, 71(1-3), pp. 457-466.

Syntetos, A.A., & Boylan, J.E. (2005). The Accuracy of Intermittent Demand Estimates. International Journal of Forecasting, 21(2), pp. 303-314.

Syntetos, A.A., & Boylan, J.E. (2006). On the stock control performance of intermittent demand estimators. International Journal of Production Economics, 103(1), pp. 36-47.

Syntetos, Aris A., Babai, M. Zied, Gardner, Everette S. (2014), Forecasting Intermittent Inventory Demands: Simple Parametric Methods vs. Bootstrapping. Available at: http://www.bauer.uh.edu/gardner/docs/pdf/Forecasting%20intermittent%20demand%20R2%20%28JBR%29%203.pdf.

Tamer, Mohamed Abdelhadi Awad (2014). Optimization of industrial spare parts inventories' management system improving machine availability within production processes in a selected organization. MSc. Thesis, CULS, Prague.

Taylor, Bernard W. (2013). *Introduction to management science* / Bernard W. Taylor III.—Ed. 11. ISBN-13: 978-0-13-275191-9 ISBN-10: 0-13-275191-7

Teunter, Ruud (2006), Intermittent demand: Forecasting and Inventory control. Lancaster University Management school. Available at: www.forecasters.org/.../ISF08presentation.ppt.

Vermorel, Joannès (2012), OPTIMAL SERVICE LEVEL FORMULA FOR INVENTORY OPTIMIZATION. Available at: http://www.lokad.com/service-level-definition-and-formula.

Vinh, Dang Quang, Forecasting irregular demand for spare parts inventory. Department of Industrial Engineering, Pusan National University, Busan 609-735, Korea. Available at: http://ike.ie.pusan.ac.kr/w/images/9/9e/08fp4-1.pdf.

Wailgum, Thomas, Worthen, Ben (2007). Supply Chain Management Definition and Solutions. Available at: http://www.cio.com/article/2439493/supply-chain-management/supply-chain-management-definition-and-solutions.html Accessed [Online], [18/2/2015]

Waller, Nick (2014). Rules for maintenance spares inventory. Available at: https://www.linkedin.com/pulse/20140807105706-3594305-2-rules-for-maintenance-spares-inventory Accessed [Online], [20/2/2015]

Weiss, J. Howard, Gershon, E. Mark (1989). Production and operations management. Boston: Allyn and Bacon.

Wild, Antony (2002). Best Practice in Inventory Management, Institute of Operations Management, 265 p.

Best Practice Spare Parts Inventory Management. Available from: http://sparepartsknowhow.com/. Accessed [Online], [2/03/2015]

Business dictionary: Inventory definition. Available at: http://www.businessdictionary.com/definition/inventory.html#ixzz3QPaKvDTh Accessed [Online], [22/2/2015]

Business dictionary: Inventory management. Available at: http://www.businessdictionary.com/definition/inventory-management.html#ixzz3QPuS07uI Accessed [Online], [30/1/2015]

Business dictionary: Intermittent demand. Available at: http://www.businessdictionary.com/definition/intermittent-demand.html#ixzz3UAP3MRZX Accessed [Online], [30/1/2015]

The CSCMP's (Council of Supply Chain Management Professionals). Supply chain management definition. Available at: http://cscmp.org/about-us/supply-chain-management-definitions Accessed [Online], [13/2/2015]

The University of Texas at Austin. Supplements: Probability models. Available from: *https://www.me.utexas.edu/~jensen/ORMM/supplements/units/probability/prob_models.pdf*. Accessed [Online], [5/03/2015]

Demand planning: Demand metrics. Available from: http://demandplanning.net/time_series.htm. Accessed [Online], [4/03/2015]

FREE ONLINE DICTIONARY FOR PROJECT MANAGEMENT TERMS. Available from: http://www.projectmanagementlexicon.com/abc-method/. Accessed [Online], [2/03/2015]

INC. encyclopedia. Inventory Control Systems. Available at: http://www.inc.com/encyclopedia/inventory-control-systems.html Accessed [Online], [25/2/2015]

INC. encyclopedia. Material requirements planning. Available at: http://www.inc.com/encyclopedia/material-requirements-planning-mrp.html Accessed [Online], [21/2/2015]

Inventory Solutions Logistics Corp. Available at: http://www.inventorysolutions.org/def_mrp.htm Accessed [Online], [19/2/2015]

Inventory Control Systems. Available from: http://www.inc.com/encyclopedia/inventory-control-systems.html. Accessed [Online], [11/12/2014]

Investopedia dictionary: Inventory. Available at: http://www.investopedia.com/terms/i/inventory.asp Accessed [Online], [29/1/2015]

Investopedia. Lead Time definition. Available at: www.investopedia.com/terms/l/leadtime.asp Accessed [Online], [29/1/2015]

Maintenance and spare parts inventory management is crucial for every production. Available from: http://www.logio.cz/en/maintenance-and-spare-parts-inventory-management.html. Accessed [Online], [2/03/2015]

MIDCOM Data Technologies, Inc., "Grocery Store Inventory Control". Midcomdata. Available at: http://www.midcomdata.com/grocery-store-inventory-control/ Accessed [Online], [27/1/2015]

MIDCOM Data Technologies, Inc., "Grocery Store Inventory Control". Midcomdata. Available from: http://www.midcomdata.com/grocery-store-inventory-control/. Accessed [Online], [7/12/2014]

Safety Stock Coverage at different service levels. Available at: http://demandplanning.net/safety_stock_coverage_levels.htm Accessed [Online], [24/1/2015]

Oxford Brookes University. ABC analysis. Available from: https://www.google.cz/url?sa=t&rct=j&q=&esrc=s&source=web&cd=5&cad=rja&uact=8&ved=0CEMQFjAE&url=https%3A%2F%2Fwww.brookes.ac.uk%2Fservices%2Fupgrade%2Fmaths-

stats%2Fdocs%2FABC%2520analysis1234.pptx&ei=nvH2VLryJoX6Ur71g-AC&usg=AFQjCNH92DxeQCyrdDxxU2mPkPZ6kcYimA&sig2=GcGjV0hdkMMw3jmO2a1ceQ&bvm=bv.87519884,d.d24. Accessed [Online], [2/03/2015]

Wikipedia: Material requirements planning. Available at: http://en.wikipedia.org/wiki/Material_requirements_planning Accessed [Online], [20/2/2015]

9. LIST OF ABBREVIATIONS AND SYMBOLS

ASE	Absolute Scale Error
bln.	billions
CV	Coefficient of Variation
ERP	Enterprise Resource Planning
HW	Holt-Winters method
IL	Inventory Level
k.s.	Limited partnership business entity (in czech = Komanditní společnost)
LT	Lead Time
MAD	Mean Absolute Deviation
MAE	Mean Absolute Error
MAPE	Mean Absolute Percentage Error
MASE	Mean Absolute Scale Error
MCM	Modified Croston's method
METRIC	Multi Echelon Technique for Recoverable Item Control
MOQ	Minimum Order Quantity
MRP	Material Resource Planning
MSE	Mean Squared Error
PdM	Predictive or Corrective Maintenance
PM	Preventive Maintenance
RMSD	Root Mean Square Deviation
SBA	Syntetos-Boylan method
SCM	Supply Chain Management
SD	Standard Deviation
SES	Single (or simple) Exponential Smoothing
SL	Service Level
SMA	Simple Moving Average
SS	Safety Stock
WMA	Weighted Moving Average

10. LIST OF FIGURES

11. LIST OF TABLES

12. LIST OF ENCLOSURES

ENCLOSURES

All the tables given below are taken from resulting pivot Microsoft Excel spreadsheets (which include all 1374 items of spare part components along with all their characteristics) and provide selected calculations for demonstration purposes only.

Enclosure 1: Excerpt of spare parts components description.

ID	Description	Category	Category Nr.
LIS602013	431-30x315 M8	Spare parts for Ejectors	5
LIS602025	431-32x340 šikmý čep A9	Spare parts for Ejectors	5
LIS604004	6,26x465	Spare parts for Ejectors	5
LIS604013	3x255	Spare parts for Ejectors	5
LIS604015	2,9x400	Spare parts for Ejectors	5
LIS604016	3,1 x 254	Spare parts for Ejectors	5
LIS605001	Z45/8x5x200//1000	Spare parts for Ejectors	5
LIS606009	VB 00 79	Spare parts for Ejectors	5
LIS702001	Rexroth MNR. R165321410	Bearings	6
LIS702013	SKF 6314/C3	Bearings	6
LIS702015	Rexroth MNR:R160550331 511368541 2	Bearings	6
LIS801001	DTE26	Oil, Lubricants	7
LIS801003	Mobil Radus 425 kompresorovy olej	Oil, Lubricants	7
LIS801004	DTE25Barel 1000l	Oil, Lubricants	7
LIS801005	DTE26 Barel 1000l	Oil, Lubricants	7
LIS801006	Vactra oil 20Litr balení	Oil, Lubricants	7
LIS802001	RUST BAN 397	Oil, Lubricants	7

Source: data of VALEO AUTOKLIMATIZACE k.s., author's representation.

Enclosure 2: The excerpt of monthly and yearly consumption of some spare parts components from 2012 to 2014 year.

	A	B	D	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
2	ID	Description	Category Nr.	Yearly Consumption (units)			Total Consumption (units)	Monthly Consumption between 2012 - 2014 (units)											
3				2012	2013	2014		1.12	2.12	3.12	4.12	5.12	6.12	7.12	8.12	9.12	10.12	11.12	12.12
4																			
810	LIS309001	elektronicke rele triak 75A SC 7	2	0	5	5	**10**												
811	LIS309002	elektronicke rele triak celduc S	2	2	55	1	**58**	1				1							
812	LIS309003	triak 35 A s ledka SO 943 460	2	18	27	7	**52**		2	2	4		1	3			2	1	3
813	LIS401001	rychlospojka 608KFTR10MVN	3	19	32	4	**55**	4		1			6		8				
814	LIS401002	rychlospojka 612KFTR13MVN	3	43	17	22	**82**		10			23	10						
815	LIS401003	rychlospojka 608KFTF10MVN	3	18	5	4	**27**	2				2	8						6
816	LIS401004	rychlospojka 612KFTF13MVN	3	12	46	21	**79**		8	2				1					1
817	LIS401005	rychlospojka 612SFAW17MXN	3	12	28	20	**60**					12							
818	LIS401006	rychlospojka 612SFAW21MXN	3	1	28	12	**41**			1									
819	LIS401007	rychlospojka 608SFAW10MXN	3	2	31	5	**38**			2									
820	LIS401008	rychlospojka 608SFAW13MXN	3	43	23	30	**96**	11		2		8	16				2	1	3
821	LIS401009	rychlospojka 608SFAR17MXN	3	4	11	1	**16**						4						
822	LIS401010	RPL 08.1252	3	26	58	17	**101**						2					24	
823	LIS401011	rychlospojka 608KFTF12MVN	3	17	18	19	**54**					4	5				3		5
824	LIS401012	rychlospojka 608KFTR12MVN	3	41	55	28	**124**		2			4	8	5	6			16	
825	LIS401013	RPL 08.6812/RO	3	23	11	0	**34**						4	2					17
826	LIS401014	RPL 12.1102 přímá samice vniti	3	8	78	0	**86**		8										
827	LIS401015	RPL 12.1102	3	0	49	5	**54**												
828	LIS401016	rychlospojka 608KFTH12MVN	3	0	4	13	**17**												
1379	**Total**			3 608	4 187	5 472	13 267	189	214	228	130	243	190	179	129	308	56	299	1 443
1380	**Average Result**			9	9	10	15	3	5	3	3	5	3	3	3	7	2	6	6

	A	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT
2	ID	Monthly Consumption between 2012 - 2014 (units)																							
3		1.13	2.13	3.13	4.13	5.13	6.13	7.13	8.13	9.13	10.13	11.13	12.13	1.14	2.14	3.14	4.14	5.14	6.14	7.14	8.14	9.14	10.14	11.14	12.14
4																									
810	LIS309001	1				3				1									2		1	1		1	
811	LIS309002	28			2	9				5	9		2			1									
812	LIS309003	10				2		3	9		3				1				2						4
813	LIS401001				2	6			24							3							1		
814	LIS401002					11				1		1	4				4		4	6	4			1	3
815	LIS401003					2							3								2		2		
816	LIS401004			12	18	8			6		2				4	2	1	1		8					5
817	LIS401005	1	1			17			3	1	4	1				1	6	5				1		1	6
818	LIS401006			16		10					1		1		4	4		2			1				1
819	LIS401007					5			26					4					1						
820	LIS401008				3	6		11	2				1	11		5	5				4	2			3
821	LIS401009					4			4			3				1									
822	LIS401010	2				25		10	17	2	2					6		9		2					
823	LIS401011	1				1		6	6		2		2	2				14			1			2	
824	LIS401012			4		14		17	15	2		2	1	10		1		4	2			7	2		2
825	LIS401013				11																				
826	LIS401014			78																					
827	LIS401015			39		5		1	1			3									2				3
828	LIS401016				3						1					1		12							
1379	**Total**	195	222	250	366	407	8	332	523	593	651	264	376	372	342	352	115	314	312	743	300	646	812	396	768
1380	**Average Result**	4	3	6	6	4	1	6	4	6	7	3	4	5	4	5	2	3	4	9	4	6	9	5	5

Source: data of VALEO AUTOKLIMATIZACE k.s., author's representation.

Enclosure 3: The part of breakdown structure of ABC and XYZ analyses were carried out by inventory level and consumption in terms of quantities and values.

	A	B	C	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
2	Ordinal Nr.	ID	Description	Category Nr.	Quantity of Consumption (units)		Value of Consumption (czk)		QTY of Inventory Level (units)	Value of Inventory Level (czk)	ABC by Quantity of Consumption		ABC by Value of Consumption		ABC by QTY of stock	ABC by Value of stock	Combined ABC and XYZ by Stock & Cons	Combined ABC and XYZ by Consumption
3					2014	Total	2014	Total	2015	2015	2014	Total	2014	Total	2015			
4																		
5	1	LIS101001	Samec jadro 1-16 9200162612	1	21	77	7 069	25 097	5	1 746	A	A	B	A	B	C	CZ	AZ
6	2	LIS101002	Samec jadro17-32 9200162613	1	14	36	4 563	11 040	7	2 310	A	A	B	B	B	C	CZ	AZ
7	3	LIS101003	Samice jadro 1-16 9200162812	1	16	78	6 987	29 784	1	437	A	A	B	A	C	C	CZ	AZ
8	4	LIS101004	Samice jadro17-32 9200162813	1	8	26	3 225	9 902	18	7 256	B	A	B	B	A	B	BZ	AZ
9	5	LIS101005	Na prodluzovak nahoru 92001€	1	5	38	1 461	11 020	10	3 226	B	A	C	B	A	C	CZ	AZ
10	6	LIS101006	Harting 09200160541	1	4	21	1 065	5 242	9	2 445	B	A	C	C	A	C	CZ	AZ
11	7	LIS101007	Nizke formy 9200160301	1	1	12	281	3 318	8	2 250	C	B	C	C	B	C	CZ	BZ
12	8	LIS101008	Vysoká formy 9200160252	1	3	22	1 149	8 370	10	3 829	B	A	C	B	A	C	CZ	AZ
13	9	LIS101009	Harting 09200102612	1	59	101	14 427	22 669	0	0	A	A	A	A	C	C	CZ	AZ
14	10	LIS101010	Samice 10pin 9200102812	1	18	42	4 646	10 418	6	1 549	A	A	B	B	B	C	CZ	AZ
15	11	LIS101011	Harting 19200101440	1	15	31	3 518	6 797	0	0	A	A	B	B	C	C	CZ	AZ
16	12	LIS101012	Harting 09200100301	1	3	20	679	3 840	2	453	B	A	C	C	B	C	CZ	AZ
17	13	LIS101013	Harting 09200100321	1	18	42	5 874	12 921	2	664	A	A	B	B	B	C	CZ	AZ
18	14	LIS101014	Harting 19200100251	1	10	21	3 219	6 454	5	1 731	A	A	B	B	B	C	CZ	AZ
19	15	LIS102001	jadra velke formy do strany 92	1	4	17	2 699	11 105	5	3 374	B	A	C	B	B	C	CZ	AZ
20	16	LIS102002	jadra bez vyvodky 9200320301	1	3	6	1 065	2 090	10	3 551	B	B	C	C	A	C	CZ	BZ
21	17	LIS102003	Harting 09200320420	1	7	14	2 739	5 315	7	2 803	B	A	B	C	B	C	CZ	AZ
22	18	LIS102004	Harting 09200320520	1	8	22	2 720	7 235	5	1 764	B	A	B	B	B	C	CZ	AZ
23	19	LIS103001	Harting 09330242701	1	50	134	17 849	46 775	8	2 920	A	A	A	A	B	C	CZ	AZ
24	20	LIS103002	Samec topeni konektor 933024	1	24	82	7 964	25 823	2	691	A	A	B	A	B	C	CZ	AZ
25	21	LIS103003	Stroj topeni formy spodek 930	1	10	19	2 010	4 749	15	3 015	A	A	C	C	A	C	CZ	AZ
26	22	LIS103004	Spodky topeni na formy PG 93	1	2	16	1 123	8 182	11	6 177	B	A	C	B	A	B	BZ	AZ
27	23	LIS103005	Harting 09300240420	1	41	87	16 038	31 792	11	4 419	A	A	A	A	A	C	CZ	AZ
28	24	LIS103006	na prodluzovak topeni PG do st	1	20	43	6 940	14 161	0	0	A	A	B	B	C	C	CZ	AZ
29	25	LIS103007	Harting 9300240421	1	2	2	784	784	13	5 099	B	C	C	C	A	B	BZ	CZ
30	26	LIS104001	Klapacka pro topeni 900000522	1	13	22	1 289	1 644	0	0	A	A	C	C	C	C	CZ	AZ
31	27	LIS104002	Klapacka pro mala jadra 900000	1	1	8	91	727	5	455	C	B	C	C	B	C	CZ	BZ

Source: data of VALEO AUTOKLIMATIZACE k.s., author's calculations.

Enclosure 4: The results of calculation SS, IL, demand forecast, re-order in terms of quantities and values for the 2015 year.

ID	Description	Category Nr.	Consumption 2013 (items)	Consumption 2014 (items)	LT (days)	MOQ (units)	SS from SAP (units)	Stock 01.01.2015 (units)	Forecast 2015 correction (units)	SS calculated (units)	SS correction (units)	Re order quantity (units)	Stock 01.01.2016 (units)	ABC (Value by Total Cons.)	Group of XYZ	SS from SAP (czk)	Stock 01.01.2015 (czk)	Forecast (czk)	SS calculated (czk)	Stock 01.01.2016 (czk)
LIS101001	Samec jadro 1-16 9200162612	1	28	21	7	1	10	5	25	7	**7**	27	7	A	Z	3 491	1 746	8 728	2 309	2 309
LIS101002	Samec jadro17-32 9200162613	1	17	14	7	1	5	7	14	5	**5**	12	5	B	Z	1 650	2 310	4 619	1 633	1 633
LIS101004	Samice jadro17-32 9200162813	1	11	8	7	1	15	18	10	2	**3**	0	8	B	Z	6 047	7 256	4 031	924	3 225
LIS101006	Harting 09200160541	1	11	4	7	1	5	9	7	4	**4**	2	4	C	Z	1 358	2 445	1 902	951	951
LIS101007	Nizke formy 9200160301	1	11	1	7	1	1	8	6	2	**2**	0	2	C	Z	281	2 250	1 687	456	562
LIS101010	Samice 10pin 9200102812	1	17	18	7	1	10	6	19	6	**6**	19	6	B	Z	2 581	1 549	4 904	1 488	1 488
LIS102002	jadra bez vyvodky 9200320301	1	1	3	7	1	1	10	4	1	**2**	0	6	C	Z	355	3 551	1 421	470	2 131
LIS102004	Harting 09200320520	1	8	8	7	1	5	5	9	4	**4**	8	4	B	Z	1 764	1 764	3 176	1 400	1 400
LIS104001	Klapacka pro topeni 9000005221	1	9	13	7	1	5	0	13	5	**5**	18	5	C	Z	328	0	852	312	312
LIS104002	Klapacka pro mala jadra 9000005	1	2	1	7	1	5	5	2	1	**1**	0	3	C	Z	455	455	182	85	273
LIS104003	Klapacka pro velka jadra 900000	1	5	1	7	1	5	7	3	1	**2**	0	4	C	Z	462	646	277	106	369
LIS105001	Harting 09200042611	1	11	20	7	1	10	7	20	9	**9**	22	9	B	Z	1 589	1 112	3 178	1 410	1 410
LIS105003	Harting 9200031440	1	7	18	7	1	10	2	18	8	**8**	24	8	C	Z	939	188	1 690	738	738
LIS1308003	06809065: Pufferbatterie PB104	11	0	2	7	1	2	0	2	1	**1**	3	1	C	X	0	0	0	0	0
LIS1401002	Calpeda ucpávka X7X72Z7D24/N	12	1	5	20	1	3	2	4	2	**2**	4	2	B	Z	8 345	5 563	11 127	4 249	4 249
LIS1502003	16A/400V Typ.FerrazD01GG40V1	13	0	5	10	1	12	35	5	3	**3**	0	30	C	Z	1 260	3 675	525	311	3 150
LIS1502004	16A/690V PV 510 10 x 38	13	35	20	10	1	17	10	20	8	**8**	18	8	B	Z	1 950	1 147	2 294	882	882
LIS1601001	Olflex-110 clasic 25x1,5 51-021-	14	85	130	10	1	51	40	135	51	**51**	146	51	A	Z	7 774	6 097	20 579	7 732	7 732
LIS1601005	Olflex-SERVO-FD 755 CP 4G 1,5 -	14	0	0	20	1	16	30	0	0	**0**	0	30	C	X	4 000	7 500	0	0	7 500
LIS1601007	Olflex-FD classic 810 CP 7 x 0,5	14	0	70	20	1	50	30	70	50	**50**	90	50	B	Z	7 065	4 239	9 891	7 037	7 065
LIS1601010	UNITRONIC PUR CP 5x 0,25 003	14	120	10	7	1	40	130	65	11	**11**	0	65	C	Z	1 320	4 290	2 145	352	2 145
LIS1601011	UNITRONIC PUR CP 10 x0,25 003	14	55	40	7	1	70	160	48	27	**28**	0	112	B	Z	4 065	9 291	2 787	1 597	6 504
LIS1601012	Olflex-FD classic 810P 3G x 0,5 (	14	0	30	7	1	40	20	30	29	**29**	39	29	C	Z	1 840	920	1 380	1 333	1 333
	Total		4 187	5 472			9 460	10 879	6 279	3 046	3 272	4 450	9 050			14 810 091	16 513 944	5 745 852	2 737 420	15 157 452
	Average Result		3	4			7	8	5	2	2	3	7			10779	12019	4182	1992	11032

Source: data of VALEO AUTOKLIMATIZACE k.s., author's calculations.