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Determinants of spare parts inventory management in the automotive sector

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Abstract

This paper presents the determinants of managing the maintenance spare parts inventory and has developed an original classification of maintenance spare parts for suppliers of the automotive sector. The author, through a review of selected methods of controlling spare parts stocks and identifying determinants of managing the stock of maintenance spare parts for suppliers of the automotive sector, proposed an original division of spare parts in maintenance dedicated to the automotive sector and guidelines for each of the developed groups. This classification was developed on the basis of the determinants of inventory management identified in the study.

Chapter 1

The first chapter presents the problems of the functioning of the spare parts logistics system, with a discussion of other logistics systems of the production company. The author emphasizes the importance of spare parts logistics as a system that has an impact on other systems of the company. In the context of this work, the author accepts the systemic approach to logistics (as a system of operation within the entire enterprise) as the most accurate. In a comprehensive systemic approach, it emphasizes the interrelationships and interactions between individual elements of the enterprise,

and emphasizes the dependence between subsystems and the impact of this phenomenon on the entire organization. This understanding of logistics draws attention to the importance of the spare parts logistics subsystem as an important element of the whole, which may determine the functioning of the company. All elements of the logistics system should be interconnected, enabling the effective implementation of basic logistics tasks. Disturbances in the functioning of one subsystem may affect the malfunctioning of the entire system, and thus of the enterprise. Among the two most important features of a logistics system is a high degree of consistency and flexibility. Due to the high degree of consistency, each change in one subsystem entails changes in other subsystems. This is due to the fact that the individual subsystems are strongly interconnected and dependent on each other.

The chapter also discusses in detail the elements of the spare parts logistics system. Functional spare parts logistics include logistics for the supply of spare parts, logistics for the storage of spare parts, maintenance logistics and logistics for the distribution of spare parts.

The activities of spare parts supply logistics focus on obtaining spare parts from the supply market (including repair service providers) by transporting them and storing spare parts in the warehouse and delivering them to the place of use (production line or spare parts warehouse in production). Spare parts are ordered directly on the line as part of planned inspections or breakdowns and are managed by the maintenance staff (maintenance logistics). Spare parts are replaced, and worn or damaged parts should be appropriately returned to the distribution warehouse or other designated location for shipment for repair or disposal. An important element of the logistics of spare parts supply in the analyzed subsystem is the generation and handling of orders.

Planning or placing orders may start with a lack of parts in stock or the presence of a spare part in a quantity smaller than required. Then it is necessary to immediately place an order with the supplier to replenish the stock. The storage of spare parts takes place in warehouses located near the production sites and directly supplying the object of servicing the repair activity. These warehouses are located in the manufacturing enterprises themselves or at the repair service provider. One of the most important tasks of storing spare parts is determining the storage location and recording material movements (acceptance of spare parts to the warehouse, releases for production to fulfill the order from the maintenance department, returns to the warehouse, and shipment). Incorrect recording of material movements may result in discrepancies in stocks,

therefore their level should also be controlled physically. Inventory control may be periodic or continuous. Organized appropriate places for spare parts helps to estimate their physical quantity and makes it easier to find and identify them. This is crucial in case of breakdowns and production stoppages, as it reduces the waiting time for ordering parts and their unnecessary search. With a large number of indexes in the warehouse, it is impossible to manage inventory without a specially designed IT system.

Spare parts as modules, components and elements are planned to be used without modification to replace the original part are intended to meet the maintenance objectives. The task of maintenance is to minimize unplanned downtime and cost-generating failures. In case of breakdown of the end element, it is necessary to repair it quickly in order to avoid downtime with all its consequences. In this case, this is done through corrective maintenance, usually provided by Original Equipment Manufacturers (OEMs) after-sales departments or by external service providers. In maintenance, effective inventory management can effectively reduce the risk of unplanned failures, as well as shorten the repair time and reduce its costs. It is precisely because of the cost of downtime that organizations tend to hold large amounts of spare parts in the event of a breakdown, which naturally leads to high inventory maintenance costs.

An important element of distribution logistics is the distinction of two types of spare parts: parts for repair (parts that are repaired and not ordered, i.e. parts that are technically and economically repairable) and non-replaceable parts or consumables (parts scrapped after replacement). The inclusion of a given spare part as repairable and remanufactured consists in classifying the part for repair and determining its technical costs. The availability and price of a given product on the market are also checked. If the part is repairable, and the repair itself is profitable, the damage should be identified (this can also be done by a service technician). In addition, spare parts or the entire machine may be repaired under the manufacturer's warranty at the time of failure. Then, from an economic point of view, the damaged element should be immediately returned to the manufacturer or service technician.

Chapter 2

The second chapter presents the specificity of spare parts inventory management and the decision problems resulting from the specific characteristics of spare parts. The types of spare parts mentioned in the literature and the existing types of methods of managing spare parts inventories are discussed. The purpose of inventory management is to maintain inventory at the lowest cost possible, taking into account the goals of ensuring uninterrupted supply for day-to-day operations. The systems approach assumes that there are different types of stocks within individual subsystems. Inventories fulfill various functions in an enterprise and there are various factors influencing their level. As the author notes, previous research on spare parts inventory management has been limited mainly to planning and operational aspects, such as determining the level of spare parts inventory and re-ordering policy. The methods of managing spare parts inventories available in the literature are considered too complicated from the point of view of practitioners or too costly.

The reason for creating inventories in the enterprise is the necessity to equalize various intensities of flow streams and to maintain a high level of customer service. Customer satisfaction is the most important value of a company. Service level measurement is closely related to inventory management as it can affect customer relationships and, depending on the nature of the business, can determine a significant impact on profitability. The level of inventories in the enterprise is closely related to the adopted enterprise strategy in the field of logistics services and the effectiveness of the inventory monitoring and management system.

The main challenges of managing spare parts inventory are: reducing inventory costs (costs of part shortage risk and costs of frozen capital), reducing the probability of missing parts, linking the level of inventory of parts with the criticality of equipment for production, and determining the needs and optimal level of inventory.

Firstly, at the initial stage of inventory management (the planning phase), there are decision-making problems related to the determination of the assortment items for which the company will maintain the inventory and the appropriate setting of the parameters of the parts. For new parts, a decision must be made about the desired stock of the part

Secondly, you need to determine how much to order at one time. After deciding on the stock of goods, the next question to be answered is the size of a single order, taking into account the minimization of the total costs of ordering (renewing, replenishing stocks) and the maintenance costs of the cyclical part of the stock. Having too many items in stock can result in high maintenance costs. On the other hand, having too few items in stock can result in high penalty costs.

The third important consideration is determining when to place a new order. The point at which an order must be placed with the supplier is called the reorder point. The level of re-ordering depends on the timing of the order and the demand of the company at that time, and whether the company maintains a safety stock.

As shown by the literature review, companies lack system solutions and an efficient supply chain, and point to inaccuracies in forecasting the demand for spare parts. In addition, there is a gap between the areas of demand forecasting and inventory management both in research and in practice. In the literature on the issues of inventory control with spare parts, few studies presented consider implementing a specific solution, and there are no case studies. Existing research on the management of spare parts inventory encourage the use of case analysis methods for this purpose, as well as the adaptation of inventory management methods to economic practice, which was the aim of this thesis. The author's considerations show that despite the high importance of the availability of spare parts in maintenance, this area is not given much attention. The methods and tools used indicate low investments in this area.

An analysis of the types of inventory and the multiplicity of classifications shows that it is necessary to categorize the inventory of spare parts in order to determine service requirements for different classes of parts and to facilitate the assignment of the most appropriate inventory management methods and inventory control rules. Proper management of spare parts requires dividing the parts and materials used in the company into appropriate categories.

The most popular criteria relate to the cost and criticality of parts. Other common types of criteria are: volume of demand or value, delivery characteristics - such as replenishment lead time, supplier, availability and non-delivery risk, demand volatility, lead time. The criteria proposed by a smaller number of researchers relate to the life cycle.

The differentiation of used parts into categories and their analysis serves to select the parts for storage and allows you to reduce the cost of maintaining inventory by reducing the number of inventory items. The classification of spare parts inventory is important to the organization as the number of items held makes it difficult to implement a control system for each item. Rather than trying to control each element, organizations try to divide them into different groups while the groups are assigned different rules. The classification of spare parts is crucial to controlling a huge number of parts, which also vary widely. Spare parts are classified by companies into groups in order to facilitate their management and to avoid their loss through improper handling or storage (fragile, heavy, small parts, etc.). In some cases, parts have a long order processing or shipping time. On the other hand, there are parts that can be handled and inspected in a simple way - low cost versus storage cost, fast shipping time etc. Dividing spare parts into groups has many advantages, especially in large warehouses where any change in storage or your control system will be difficult to establish and can also be costly. By classifying spare parts, companies can apply appropriate management practices for each group without affecting other groups (including increasing or reducing the control system as needed).

Chapter 3

Chapter three focuses on the sector in which the research was carried out. The author describes in detail the automotive sector, its specificity and methods of managing spare parts inventories used in the automotive sector. The automotive sector operates in a highly competitive environment characterized by increasingly demanding customers around the world. These challenges are the result of, inter alia, globalization, development of innovation, strong competition, market fluctuations and increasing customer demands. Hence the need to develop an effective logistics model that would meet the challenges of customers and manufacturers of the automotive industry. The internationalization of the car industry makes it unique compared to other mass industries that have developed global production networks and do not show a tendency towards regionalization. The modularization of production also had a great impact on the automotive industry. It was originally intended to reduce manufacturing costs. Ultimately, it has become very important in the process of accelerating the production and delivery of the vehicle to the market. Modularization means breaking down a production process into steps. This resulted in minimizing the flow of

information between individual stages of production and allowed to increase the autonomy of the production stages carried out, as well as the location of these stages in different places. The use of modular production has a great impact not only on the final product itself, which is a finished car, but also on the organizational structure of manufacturers. The author indicates the main objectives of inventory management in the automotive sector, such as: minimizing inventories and the costs associated with their maintenance in the production process and in the supply chain; the need to immediately respond to the demand and deliver the necessary products and components in the shortest possible time; the requirement to achieve continuity of production flow to meet emerging demand without delay or waste; ensuring full reliability of deliveries of the necessary components and materials at the right time. These goals are supported by specific management tools described by the author, such as: TQM, TPM, jidoka, Kanban system, JiT, pull system.

Chapter 4

In the fourth chapter, the author identifies the factors influencing the inventory management and the management of spare parts inventory. Then, as a result of the research carried out in the automotive sector, the author identifies the determinants of spare parts inventory management in maintenance in the automotive sector. The identification and analysis of factors influencing the level of inventories in manufacturing enterprises allows the identification of key areas where efforts can be made to implement inventory reduction initiatives, increase inventory availability, improve inventory turnover, and reduce inventory costs. Identification of all factors influencing inventory management is the basis for determining the factors influencing the management of spare parts inventory and on this basis the development of the classification of spare parts and guidelines for the management of spare parts inventory in the automotive sector. By separating the factors of spare parts inventory management, it is possible to establish the principles of spare parts inventory management and their classification. Managing spare parts categories can lead to improvements in the selection of inventory management policies and replenishment control techniques. An important area is the possibility of applying the same planning and control methods for supplements for all products constituting a category structure or in its subcategories. Thanks to this solution, the effect of organizing control and decision-making activities in relation to a specific group of products is obtained.

In the literature, you can find many factors influencing inventory management, as well as various ways of their division. The author's particular attention was drawn to the classification of factors according to the type of stock, in which spare parts were omitted. Among the factors in the literature for the main groups of inventories, it is possible to distinguish factors that will have an impact on the management of spare parts inventories. They will be: assortment structure, frequency of deliveries, order fulfillment time, price of used stocks, storage conditions, criticality for maintaining continuity of production, number of products in which a given material is located, structure and length of the production cycle, type and construction and technological structure of products, the structure of goods being a derivative of the object, the variability of the customer's demand. In the face of hundreds or even thousands of assortment items present in the inventories of enterprises and subject to control, it is necessary to find a way to reduce the multidimensionality of this issue and to estimate which items from parts included in the structure of the machine will be kept in stock. It is possible, as in the case of finished products, to resign from certain assortment items, but it is associated with the risk of a shortage.

As with the inventory of production materials, the frequency of deliveries has an impact on the replenishment policy. However, it should be noted that the frequency of deliveries may be predetermined and unchanged, but may change under risk conditions.

In addition, a good and flexible supplier can accelerate or delay deliveries accordingly. Cooperation with the supplier and flexibility of deliveries is also a factor that should be taken into account when planning stocks.

Order fulfillment time as a factor influencing inventory management occurs for each group of materials. The time in logistic customer service relates primarily to the duration of the order fulfillment cycle. Customers expect the shortest possible delivery time, and enterprises, by building specific relationships with other participants in the supply chain, try to meet customer expectations. From the perspective of the inventories of each assortment group, the inventory held is to shorten the delivery time to the customer from the moment of the demand. Individual groups differ only in terms of the client. For finished products it will be an external customer, for raw materials - production, and for spare parts - maintenance.

The unit price has a significant impact on the costs of inventories and the financial result of the enterprise. This factor is important for each group of materials, including spare parts, and affects

the size of the planned inventory. It is true that an excessively low level of inventories adversely affects sales, reducing the financial result, but a too high level increases costs, in this case the cost of inventories, which has a negative impact on the financial result of the enterprise.

The storage process should function in accordance with the storage technology. This includes the rules and methods of storing goods using appropriate warehouse equipment. Hence, the conditions in which goods are stored are so important. The factors that affect storage include, but are not limited to: humidity, temperature, air, light, and microorganisms. Temperature is the main factor affecting humidity. The storage temperature is determined separately for each product. Incorrect level of it may lead to the spoilage of stored goods, and thus a loss and a negative impact on the company's financial result, as well as the availability of goods to the customer's needs. Air, and mainly oxygen, can also have an adverse effect on product quality. It often leads to oxidation, whereby goods may darken, decompose, etc. Direct exposure to air also includes contamination which can affect product quality.

Spare parts are designed to ensure continuity of production, so the criticality factor is quite obvious. Just as the availability of raw materials critically affects the continuity of production, the stock of spare parts is a key element in eliminating downtime. This factor is common in the literature for all classifications of spare parts and methods for managing spare parts inventory.

The number of products containing a given material as a factor influencing the management of spare parts inventory should be modified, because spare parts do not directly enter the structure of products, but machines. The number of machines that contain a given spare part must also be taken into account when planning the spare parts inventory. The lack of its availability may affect a larger number of devices, which indirectly affects its criticality.

The structure and length of the production cycle, i.e. the type of production, its frequency and cycle, affect the wear of machines, including spare parts. It should be noted that the manner of use and its frequency affect the condition of the machine and its durability. This directly affects the consumption of spare parts and their stock.

The type and constructional and technological structure of products are indirectly related to the specificity of a given assortment group, and the uniqueness of a given spare part directly affects

its availability on the market and delivery time. This factor will also be indirectly related to the management of spare parts inventory.

In the case of spare parts, it is also possible to use substitutes, which on the one hand reduce the risk of stopping production, because the lack of one spare part can be supplemented with a replacement, on the other, they increase the number of assortment items, and also complicate the inventory management process. Taking into account the characteristics of spare parts and their number, substitutes should be used in justified cases.

Demand volatility is a factor influencing the management of spare parts inventory directly related to the customer's demand, in this case it is an independent demand. As for finished products, the demand can only be estimated. While the planned repairs and their course allow to determine the number of orders, failures are part of the demand that cannot be accurately estimated. In addition, the planning of the demand for spare parts depends on the availability of the wear history, i.e. the phase of the life cycle of a given spare part. Inventory planning is very difficult for new parts with limited wear information.

Chapter 5

Chapter five presents the classification developed for spare parts in maintenance for enterprises in the automotive sector and the guidelines for managing the inventory of spare parts in an automotive sector enterprise proposed by the author. The aim of the study was to identify determinants of spare parts inventory management in the automotive sector. However, the research focused on spare parts used in maintenance, i.e. the user of these parts. The knowledge that the author wanted to reach using the case study method was the factors influencing the approach to spare parts inventory management and how to manage spare parts inventory in maintenance in the automotive sector. In order to obtain answers to these questions, the author decided to use a qualitative method - a case study, and the tool used to collect data was an interview. The research was conducted among first-tier suppliers for the automotive sector operating in Poland. Four companies participated in the survey. The selection of cases was deliberate, motivated by my own experience, observation and analysis of documents. The actual survey consisted in conducting in-depth direct interviews with persons managing the spare parts inventory on a daily basis (specialist, department

manager). The advantage of an interview is the possibility of obtaining a range of valuable information that would not be possible to obtain using another method, for example, a questionnaire. Based on the interviews, it was possible to develop a general scheme of the inventory management process. The analysis of the interviews conducted by the author allowed for the identification of factors that affect the management of spare parts inventories in the automotive sector. The frequency of occurrence of a given factor in the responses indicated its importance in the entire process, and in addition, the questions in the interview directly referred to which, according to the respondents, are the most important at each stage of spare parts inventory management in maintenance, and which have the least impact on the decisions made.

The only factor that was mentioned as the most important one by all respondents is the criticality of parts for the continuity of production, understood as the impact on the downtime of the entire production plant or the entire production line. According to experts, the second and third factors that are the most important at each stage of decisions related to the management of spare parts inventory in maintenance are: the type of demand and the availability of parts on the market. Information about the planned work and the related planned wear of parts and its size allows you to accurately determine the time and amount of demand. Hence the high impact on the method of managing the spare parts inventory. Proper maintenance management and the implementation of planned inspections, maintenance or repairs have an impact on the frequency of failures, and thus on the unplanned consumption of spare parts. Unplanned downtime is associated with unplanned work on machines and equipment, for which there are justified difficulties in forecasting spare parts used to remove a failure, defect, etc. The availability of parts on the market as another determinant is closely related to the next three factors - waiting time, type of parts and the price, with the price being second best. These factors often influence each other. The availability of parts, i.e. the number of suppliers, is related to the specificity of the parts, and thus the waiting time for delivery. Standard parts are generally available, often cheap. They have a large number of suppliers and their production time is short, as is the order fulfillment time. Similarly, parts made to order, for a specific machine and on the basis of a specific specification, require longer waiting times for the implementation of the order, but also a limited number of suppliers.

The penultimate factor influencing inventory management is the nature of demand and the related volatility and predictability. Large fluctuations make it necessary to increase the stock, parts with

stable wear may not require special buffers. Future requirements can be determined with great accuracy. Another factor indicated by experts as important for inventory management is the life cycle phase of the spare part and the availability of the wear history, which is closely related on the one hand to the nature of the demand and the possibility of its determination, as well as the life cycle of the spare part. In the initial phase of inventory management of a new spare part, the demand for which is unknown and the wear history does not exist, delivery planning is significantly difficult. . The factors considered to be the least important are: the number of devices with the spare part and the storage conditions. It is also a confirmation of the developed classifications of spare parts, in which the last-mentioned factors are not taken into account. Summing up, both the analysis of the frequency of the factor occurrence in response to individual questions and the analysis of the respondents' statements indicate the presence of specific determinants of spare parts inventory management in maintenance in the automotive sector.

The results of the research presented by the author indicated that the factors that most affect inventory management in the automotive sector are: criticality of parts for maintaining production continuity, type of demand, availability of parts on the market, waiting time for an order, price of parts, type of parts and variability of demand. The remaining 3 factors that were assessed by experts have a low impact on the management of spare parts inventory, therefore they were not taken into account when creating the classification of spare parts proposed by the author.

The determinants of spare parts inventory management in the automotive sector and their impact at each stage of the process, selected by the author, allowed for the development of the classification of spare parts in maintenance. The developed classification of spare parts is aimed not only at selecting the appropriate method of managing spare parts inventory, but also the method and frequency of monitoring the level of stocks and placing orders. The applied procedure allowed for the selection of 3 main groups of parts for which classifications were developed. The starting point for the developed classification was the planned consumption (as one of the determinants identified in the interview). As established, the planned demand does not require the differentiation of spare parts. This classification concerns the management of spare parts inventories for unplanned wear, and the determinant that was used to divide spare parts at the first stage of differentiating these parts is the life cycle of the spare part. According to the author, the life cycle directly influences other factors, such as the availability of a spare part, the available wear history

from which future demand values can be estimated, and delivery times. The life cycle of a part has therefore become the starting point for dividing parts into unplanned wear. Further on, the division of parts according to the criticality and specificity, price or regularity of wear was proposed, and a strategy for dealing with a given group of spare parts was proposed. In the scope of inventory inspection, for the control of the inventory of critical parts, continuous inspection should be used, for non-critical ones - periodic inspection, with a higher frequency in the case of parts with irregular demand, and for parts with regular demand, the ordering process should be automated as possible or the supplier should be involved in the monitoring of the stock level and its replenishment.

In the decline phase, the last purchase from the supplier is required. In this case, it is recommended to use a regression-based extrapolation assuming an exponential decline in demand. An example is a regression model on log sales over time that assumes an exponential decline in demand over time. For parts that are currently in stock, a decision must be made whether to dispose of the items or not. For items classified as obsolete, a part is still in stock. In addition, when a part is nearing the end of its purchasing capacity, suppliers may be reluctant to produce small quantities. In this rejection phase, a single order size decision must be made to cover all remaining demand (sometimes referred to as "all time buy" or "last time buy").

As part of the inventory classification developed, the time from the inclusion of the spare part to the inventory should be monitored and parts should be moved from the initial phase to the use phase after one year, and if necessary, the parts into service to the decline phase (classification analysis every 3 months). In addition, the spare parts criticality analysis also needs to be updated, but the criticality is not as dynamic as demand and does not need to be updated too often. From a practical point of view, you can decide to update the criticality once a year along with the life cycle phases update. Note that after one year, the part migrates from the inception to the use phase. You will need to specify the criticality for these parts - at the same time, you can update the criticality level for all other items in the use phase. In the case of an inventory of the most critical parts, the warehouse uses the method of replenishing the inventory according to the fixed point order method. This means that there should be a minimum and a maximum level for each item. The order for each critical part is placed at the time of recording the minimum stock and it is the

difference between the minimum and maximum stock, including orders in progress for a given item, so it is permanent.

Summary

The research carried out by the author shows that the management of spare parts inventory is quite difficult, especially for new projects or new spare parts. The availability of information about possible failures is highly limited, and employees rely more on their own intuition than on figures.

. Logistics of spare parts as an element of the entire supply system in the enterprise ensures the continuity of production. Inventory management, like the spare parts inventory management factors, differs from classic inventory control models relating to directly production materials. As confirmed by literature research, proper management of spare parts requires dividing the parts and materials used in the enterprise into appropriate categories. The division of spare parts into categories and their analysis serves the selection of parts for storage and reduces the cost of maintaining inventory. Spare parts are highly varied. They have different service requirements and demand patterns. The range of unit prices for spare parts is also very wide. Therefore, a categorization of spare parts inventory units should be carried out to determine service requirements for different classes of parts and to facilitate the assignment of the most appropriate inventory management methods and inventory control policies. As spare parts differ significantly in criticality, life cycle phase, delivery time and availability, it is important to recognize these characteristics in order to be able to better manage them.

The developed classification scheme is therefore primarily extended to the life cycle phases, which are closely related to the availability of the consumption history, important for planning future orders. By taking advantage of this breakdown, you increase your awareness of purchasing decisions early in the life cycle where data is scarce. The planned quantities of orders at this stage should be carefully estimated using qualitative methods based on technical knowledge of spare parts. The paper presents the classification in relation to the possibility of forecasting the demand

and indicates in the developed guidelines how the classification scheme can be used in order to select the approach and method of replenishment of stocks.

Used in classification as a key criticality criterion, it can be used to support decisions regarding service level requirements - critical parts should be delivered immediately or as soon as possible regardless of the life cycle phase of the replacement part. The classification scheme for inventory control can be improved to better capture the underlying demand pattern for spare parts by designing a hierarchical multi-criteria classification scheme for inventory control including life cycle phase and criticality analysis. The presented classification scheme is intended to improve the process of ordering spare parts and inventory control. The proposed spare parts inventory management guidelines developed for each class constitute a knowledge base on spare parts along with the developed method of handling their inventory. The advantage of implementing the developed guidelines is the lack of additional costs and investments, ease of use and improvement of the effectiveness of decisions made.