Multicriteria classification model for spare parts

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Abstract: This paper presents a multi-criteria classification model for spare parts management. Maintenance operations, in particular corrective ones, involve a great amount of spare parts inventory that often is one of the main part of the immobilized capital in many industry firms. The proposed model as a mainstay for an effective spare parts management. The meaning is to support managers in the proper spare parts management inventory choice for each component through the evaluation of a different number of criteria. A three step scale of evaluation for each criteria is generated, considering all the possible values. Each criteria is weighted through the application of the Analytic Hierarchy Process. On this basis a decision tree is generated in order to lead managers to the definition of the appropriate management policy for each material, requiring only a single value for each attribute. The aim of this work is a model definition in order to manage spare parts inventory in a more efficient way.

Keywords: Maintenance, Spare parts classification, AHP

1. Introduction

The increasing globalization that characterizes the international markets creates a competition among all the several businesses in the field of flexibility, technology and products innovation. In addition, the moment of strong decrease of industrial growth determines the need to minimize the management costs, thus individuating all sectors where the differential among actual and ideal costs is highest. The technical materials warehouse is often one of the most causes as they represent a great fraction of the businesses immobilized capital.

On the other hand, at a world level there is a need of an increasing competitiveness requiring high production levels and high industrial plants availability, that may be obtained only through an efficient maintenance service.

In this context, it is also crucial a “lean” management of spare parts - the technical materials - that is able to guarantee a high service level of the maintenance department through the use of a low capital immobilized in stocks.

It is worth noting that the term “technical materials” or “maintenance materials” refers to equipments, spare parts, lubricants, materials normally used for maintenance, individual protection devices. Consequently, they refer to materials that are assembled mounted on an equipment, being functionally and dimensionally equivalent to damaged mechanical organs that they have to replace. Also known as consumer materials, these materials are also strongly employed over the time: widely employed and low unit cost-spare parts, such as lubricants, clothes, etc., that are subjected to their storage and, hence, to their management.

The present work aims to propose a lean management model of technical materials that is based on the classification into a limited number of groups.

A suitable management policy will be associated to each group, thus allowing to minimize the purchase and maintenance costs. At the same time, this will allow to obtain a high service level of the maintenance service thanks to the minimization of logistic delays due to the technical materials.

2. Peculiar features of technical materials

The technical materials management is a very complex subject showing many peculiar features.

The policies that rule the management of technical materials stock are different from those normally used for the management of raw materials stock, finished products and components, which can rise or drop, thus modifying the frequency of supply, production rate of the systems, improving the product quality, etc…

On the contrary, the levels of technical materials supply are related to the system use and to the maintenance management. The demand of certain components can be partially or temporarily satisfied “cannibalizing” other parts or units, which means to replace a damaged element using a similar one or a modified element that may suitably function in that place.

If there are many redundant components in the system, it is possible to keep few unities as supply for emergencies and to replace all the non functioning parts using the same materials. When the system redundancy is low, it is necessary to have higher supply levels in order to ensure a high and immediate availability of the various components.
The programmed maintenance interventions, that determine a decrease of the damages frequency and hence of an unexpected demand of materials and at the same time generates a sure demand, is a further factor which strongly influences the management.

It is worth noting that these interventions can be delayed or deleted in case the material is not available.

Another drawback may arise when a machine becomes obsolete and it results possible that quickly specific technical materials will be not available.

It is difficult to estimate how many units for each obsolete machine must be hold as stock, as well as it results complex to replace a component that is not eventually held as supply.

In the field of lean management of technical materials, the aim is to make available the materials that are needed for maintenance when they are required and in the right amounts at the minimum global cost.

The basic problem is to mediate between two opposite needs:

- Immediate availability at occurrence, whose data is unknown in the case of damage, and, hence, the minimization of shortage cost.
- Minimization of purchase and holding costs.

The main purpose of spare parts lean management is to minimize the global cost that is evaluated as the sum of purchase, holding and shortage costs.

### 3. Basic features of technical materials management

A project that involves the reorganization of the technical materials management have to take into account the situation that is determined by the inner and outer real environment. In particular, it has to take into consideration the technological features of production systems, the logistic features related to materials supplying and storage, and finally the administrative aspects that are related to the financial-economic reality.

Generally, the management of technical materials cannot be univocal as all the materials present different characteristics, such as critical features in their production, purchase cost, etc… The criteria related to the materials management must ensure a reasonable compromise between service level and immobilization cost.

The more frequent classification of the technical materials allows to individuate and manage parts using homogenous groups, that represents a basic step for a next standardization of the parts and reduction of their assortment as function of their commercial feature:

- Consumer goods, that are widely consumed, almost independently from the specific business. In this context, typical examples are lubricants, assortment of screws, gloves, paints, etc…;
- Generic spare parts, that are not related to a specific good or material and that may be bought in place and standardized taking into consideration their physical, chemical and geometrical characteristics. In this context, typical examples are bearings, joints, electric motors, hydraulic cylinders, etc…;
- Specific spare parts, that are suitably designed and manufactured for one or at most few goods. They have to be suitable designed or bought by their specific manufacturer;
- Unfinished or semi-finished materials, from which it is possible to obtain specific spare parts using successive workings. Typical examples are represented by bars, plates, etc…
- The selection of technical materials occurs when new goods have to be bought or when the warehouse must be reorganized because of several reasons (i.e., search for new suppliers, replacement of obsolete components, improvements of proactive maintenance)

As reported in literature, there are two different approaches to develop possible models in the field of technical materials management: mathematical models and classification-based models.

The first approach encompasses models based on the linear programming, dynamic programming, goal programming, simulation, and so forth, that generally aim to optimize the holding cost as a function of the service level.

These models are generally complex, abstract or excessively simple, and, hence, they are rarely applied.

On the other hand, the classification-based models are widely applied in the industrial field. Among them, the most widely employed are the models based on the Pareto principle that divide the materials into three classes as a function of the annual total cost or the use frequency. These models are based only on one or two criteria and, consequently, neglect further parameters that need to be considered in the classification.

To overcome this limit, many authors have developed multicriteria classification models that allow to consider a great number of not homogeneous criteria (with units of measurement that are not directly comparable). Accordingly, using a unique evaluation step, it is possible to take up both the economic criteria and the extra-economic criteria that may be only measured physically and qualitatively, thus offering a more realistic methodological scheme that benefits from the several contributions of current research fields such as the set theory, matrix algebra, operational research, and computer science.

In particular, some authors have proposed to apply the Analytic Hierarchy Process (AHP) for the classification on the basis of a changeable number of criteria.

### 4. An original AHP-based classification model

The aim of the model is to assign the most suitable management policy to each technical material.
Basically, three different policies are defined as follows:

- The MRP management— that is the most desirable;
- Stock management with unit stock;
- Stock management with multiple stocks.

The selection of the suitable management policy is performed after all the spare parts used in the specific business reality have been divided into five classes, A, B, C, D, E.

The material class that is denoted as A encompasses all the materials that require an appropriate MRP management, the C class is related to materials that need a stock management with unit stock, and the E class refers to materials that need a stock management with multiple stocks.

In order to define a certain flexibility in the model application, two further material classes are defined. Even though no univocal management policy is assigned to these two further classes, however, two different policies are available for them: to select as a function of the service level that would be ensured and spare parts values.

The further two classes are B, that involves both an MRP management and a stock management with unit stock as well, and D class to which is associated a stock management, even if the selection between unit and multiple supply needs to be properly evaluated for each specific case.

The class selection is a function of 14 different criteria highlighting the importance of the material for the product quality and productivity (that means system availability and production rate) that are influenced by the absence of the material. As a first approximation, it is possible to state that they depend upon the machine(s) where the material is a component. It results possible to consider the possibility of the domino effect, that is the failure of the considered component can occur contemporarily with other failures or it can create further damages.

Then, it is possible to consider the number of the potential material suppliers and the mean time that is needed for a delivery, if the material can be repaired by the staff, and if it is possible to cannibalize a similar material in the case of absence of this material.

In addition, several factors, such as the material purchase cost, the space needed for stocking, the eventual material deterioration over the time, the possibility of obsolescence related to the delivery of an updated version of the material, have to be evaluated. Finally, the number of the component units installed in the factory, the eventual presence of redundancy in the installations, the degree of damage and the possibility to control the failure phenomenon through suitable preventive maintenance policies and/or component monitoring have to be assessed.

Using 14 criteria, the spare parts may be classified into four groups, thus defining a two-level hierarchical structure. The first group is defined as “criticality of the component for the system” and encompasses:

- product quality,
- productivity,
- domino effect.

The second group is defined as “criticality of the component supply” and involves the following points:

- number of potential suppliers,
- supplying time,
- possibility of reparation,
- possibility of cannibalism.

The third group determines the so-called “criticality of component storage” and it is defined by the following elements:

- purchasing cost,
- necessary space,
- obsolescence.

Finally, the fourth group, that is defined as “criticality of the component utilization”, is defined by the following factors:

- failure rate,
- control of failure phenomenon,
- number of installed components,
- redundancy.

Once the hierarchical structure is created, the model provides a comparison between the couples of criteria and, consequently, the definition of the relative weight.

These comparisons have been performed in a rapid and simple manner by means of the “Expert Choice 11.5” software, which allows a comparison between two elements through verbal, numerical assessments or using graphs. Benefiting from these data, the above mentioned software automatically elaborates comparison matrices and evaluates the consistency indexes of these assessments.

As an example, table 1 reports the resulting matrix obtained from the comparison among the criteria related to the criticality for the system; the bold values indicate that the element reported in the row is preferred to the element of the column, whilst the values reported in italics style attribute a greater importance to the element in the column. It is worth noting that in this case the inconsistency index is null.
Matrice di confronto rispetto a "Criticità per l’impianto"

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Table 1. Matrix comparison among the criteria related to the criticality for the plant.

The “Expert Choice 11.5” software automatically evaluates the relative and absolute weights starting from the comparison criteria matrix. The relative and absolute weights related to all the criteria are reported in the following table 2.

Table 2. The relative and absolute weights related to all the criteria

The second part of the process related to the developed model proposes for each criterion with the lowest level to define a scale of values characterized by three steps that allows to classify the possible values into three groups. The selection of the appropriate scales depends on the appropriate reference sector and on the specific business reality, and, for this reason, in this general context, quantitative values may also be suitably defined. Moreover, it is recommendable to carry out a periodic revision of the scales as a function of the results obtained from the application of the model and eventual processes changes.

Table 3. Scale of values

With regard to the second level criteria, the values are directly defined as a function of weight and impact of the criteria that are reported below. First, the three values of the products, weight impact for each criterion, can be evaluated obtaining the values reported in the table 4.

Table 4. Weight impact for each criterion

All the possible combinations of the criteria impacts of the i-level (inferior on node-father) can be considered. Finally, an evaluation scale is established to define the important and desirable critical values. The selection of limit values is strongly related to the specific criterion and to the amount of materials that one wants to manage with a supply and, hence, to the specific business reality. It is possible to summarize all the results obtained from the materials classification process using decision trees. They allow a “lean” implementation of the proposed model, providing a definition of the macrocriteria impact as a function of the values of the element reported below, and, successively, the class of the technical materials as a function of the macrocriteria impacts. Figures 1, 2, 3, 4, 5, and 6 report the trees used to determine industrial plant criticality, supply criticality, and utilization criticality, as a function of the subordinated criteria.

Figure 1. The industrial plant criticality

Figure 2. The supply criticality (stage one)
On the other hand, in the following figures it can be noticed the higher level decision tree that allows to determine the suitable class of material as a function of the values associated with the macrocriteria by means of the previously described trees.

The basic aim of the present work is to introduce a spare parts lean management in order to optimize the maintenance service level and to decrease cost materials. It is possible to individuate three essential elements:

- The classification of the materials into several groups in order to define management policies for homogenous groups. These basic features are needed to normalize successively all the articles and the decrease of their assortment;
- The availability of information about the materials criticality and anticipatory data on the needs that determine the supply operational levels;
- The use of an informative tool that is suitably dedicated to the management, the control of the use and the supplying of the technical materials.

The classification of these materials into homogenous groups by taking into account their key-features and the availability of these information allows to assign a suitable management policy to the materials, and eventually to define an optimal supply. Accordingly, it has been decided to assign critical values of a material for the system in a direct mode, taking into consideration the criticality of the machinery/system where the material is a component. For this reason, for all the components of machineries/systems that are critical in terms of quality (which is related to standards of good manufacturing)
and/or “bottleneck”, they will have a criticality value for the system which is equal to 5; a value of 3 in case of those determining losses of productivity greater than 3%, whilst a value of 1 is considered for the other cases. The case of materials that are usable with many machineries/systems has to be considered as the worst case. The component supply criticality is defined using the evaluation scales that are reported in the table. As for the criticality of use, it has to be first taken into consideration that specific policies, that are able to monitor the material conditions and to allow the prediction of failure events or data related to the components failure frequency, do not exist in a business. In this case the situation may be represented by the Pareto chart. For these reasons, in order to simply the classification procedure, it has been decided to assign a value of 5 to an amount of components equal to 10% that the maintenance superintendent responsible for maintenance and utilities consider as more used from their experience (it is worth noting that an expertise on spare parts use does not exist), a value of 3 to an amount of 20% of materials that they consider as meanly used, and a value of 1 to the remaining part (70%).

Table 5. Definition of utilization criticality

Finally, with regard to the criticality related to the materials storage, both materials degradation and obsolescence risks have been considered as neglectable; the unit purchase cost. The unit purchase cost is defined as critical if it is lower than 200€, as desirable if it results greater than 2000€, as important for intermediate values. With regard to the space necessary to stock, the values proposed by the theoretical model have adopted.

Table 6. Definition of plant criticality

The determination of the component storage criticality may be obtained by means of the decision tree reported in figure. All the criteria, that are used for the materials classification, and the scales, that determine the impact on the desirable supply and need choice, have been summarized in table 7.

Table 7. Criteria of material classification

Figures 7, 8, 9, and 10 report the materials classification as a function of the macrocriteria by means of the decision tree that allows a “lean” implementation of the proposed model.

4. Conclusions

The present work was suitably developed taking into account the businesses specific needs of technical materials management, while ensuring a high service level to the maintenance department using a low capital immobilized into stocks. The study aims to propose a lean management model of spare parts materials based on a multicriteria classification that may be simply applied, even if a great number of parameter is considered. The inspiration has come from the Analytic Hierarchy Process (AHP), that is used to compare m decision choices as a function of n parameters. Benefiting from the hierarchical structure, the model provides a classification of the technical materials into five groups (A, B, C, D, E), in order to define a unique management policy for each group. As for A, C and E groups, the most suitable policy is defined whilst for B and D groups two different policies have been proposed. This flexibility allows the management to make a choice taking into account the total value of spare parts that should be immobilized and the service level that should be ensured, thus trying to find a compromise between these two needs. It is worth noting that the technical materials management is continuously ongoing. However, even though it is well organized and carried out, it is also subjected to a progressive loss of efficiency over the time. For this reason, independently from contingent conditions, the model proposes a critical periodical analysis of the stocks in order to better define the evaluation scales of the parameters, thus identifying for each material the appropriate management policy that satisfies the specific requirements.

References


