Effective control and management of spare parts are essential for many companies in most industries. The management of spare parts, enables companies to achieve high service levels without unnecessary high inventory cost.

Spare parts are often characterized of having intermittent and lumpy demand patterns with several periods of no demand mixed with sudden demand spikes (as illustrated in figure 1).

Furthermore, spare parts might have stock-out cost being disproportionally high in relation to the value of the component, and are thus very critical to have on stock, to prevent expensive downtime.
Companies acknowledge these challenges, but often do not have proper competence and knowledge to control these factors effectively, which leads to low service levels and high spare part inventories at unnecessary high cost.

This article suggests a structured method to manage the demand for spare parts, and illustrates a business case in a large global production company, where this method was applied. Not surprisingly, the economical benefits were very significant.

Effective management of spare parts is essential for many companies, from production companies to service companies. Managing the spare parts in a proper way, enables companies to maintain a high service level without unnecessary high inventory cost. However, intermittent demand patterns are often characterizing spare parts, having periods of zero demand, with occasional periods with non-zero demands and in addition can be highly variable in quantity size. Furthermore, companies must recognize that some spare parts can be outmost critical, and might have stock-out costs that are disproportionately high compared to the value of the item.

Balancing the proper service level is an important aspect in this field. It can be argued that for some spare parts, the effect of stockout will significantly be more financially remarkable than "normal" SKUs, and thus has to be considered thoroughly. The intermittent demand coupled with the importance of balancing the service level, makes the planning of spare parts very difficult. In our experience, many production companies struggle to manage their spare part inventories sufficiently due to the high complexity, and thus many unnecessary costs are allocated to this area.

Many companies neglect the spare part business to the finished goods. However, researches have showed that spare parts and related after-sales services accounted for 8% of the US Gross Domestic product (GDP) in 2008 - which illustrates a huge area of spending and revenues for companies, and is thus subject for great effects.

Why are spare parts so special?

It is important to stress that spare parts have different factors and variables affecting them compared to those of “typical” SKUs like finished goods, and thus have to be managed differently. Companies have often not the competence and knowledge on how to evaluate each spare part, for the purpose of determine what the inventory levels should be - this lack of transparency will eventually lead to costly overstocking, or insufficient service levels. Also, it should be stated, that some of the traditional inventory management tools cannot be applied in this context, e.g., JIT (just-in-time) and ABC analysis for finding most profitable item (e.g. profit per unit/no. of picks).

One of the main problems with the management, forecasting and control of spare part components is due to their lumpy demand characteristics. In the case of spare parts, the demand arises whenever a component fails or requires replacement, and as such it is different from that associated with a “typical” stock-keeping unit. In other words, this type of demand could be characterized as “intermittent”, which means that demand arrives infrequently and is dispersed by time periods with no demand at all, and can thus be extremely sporadic. The complexity of spare parts might stretch even more due to the high variability in quantity, size demanded.

Furthermore, spare parts have many factors/variables effecting the way to manage them - there is a huge difference in the level of criticality of the spare parts, some are much more critical than others and might have stock-out costs that are disproportionately high compared to the
Managing the demand for spare parts

Very low value can be outmost critical for the operation. In many cases, slow moving and intermittent items will be made-to-order (MTO), and thus the lead time might be very long.

Companies must recognize that spare parts often are “specific to employ”, which means in most cases spare parts have to be employed only for the specific use and the function for which it has been purchased. This might lead to the risk of accumulating large holdings of obsolete stock, that you would not be able to use.

Due to the intermittent nature that characterizes many spare parts, “normal” forecasting principle and techniques may be inapplicable and inaccurate, and thus alternative methods will have to be utilized. This also holds good for the performance measurement tools used for measuring intermittent item.

Often companies have several thousand spare parts to manage, and all of these should obviously not be managed in the same way. Without a structured management approach, it would be extremely difficult to do.

Framework for approaching management of spare parts

The suggested approach for managing the spare parts properly consists of three steps: (1) determining input variables, (2) segmentation, (3) optimization. These steps are illustrated in figure 2, and will be elaborated in the following. It is important to underline that these steps should not be considered autonomously, but in derived conjunction as illustrated.

1. Input variables

The input variables enable a specification and differentiation of the spare parts, for the purpose of a differentiated management approach. A segmentation/classification enables better decision-making towards each spare part, and thus less unnecessary cost.

The input criteria for the specification and categorization of the spare parts into homogeneous groupings have to be chosen, with the focus on differentiating the forecasting and inventory approach, and thus the criteria have to be chosen according to this.

Three steps of spare parts management

![Three steps of spare parts management](image-url)
The input variables that need to be considered are: criticality, demand characteristics and supply condition.

**Spare part criticality**

The criticality is a very important aspect in spare parts management. Obviously, not every spare part is equally important, and should thus be managed accordingly. Spare parts that are crucial for the production to operate will need to have a higher service level requirement and thus larger safety stock, than spare parts of lesser importance. In theory, the criticality is not very difficult to calculate, as it is based on only two variables: the cost of understocking and the cost of overstocking.

In practice however, it will in most cases be impossible to calculate the exact cost of having one unit too little and one unit too much on inventory. In practice, it will often be enough to make qualified subjective assessment of a few degrees of criticality, e.g., highly critical, moderately critical and low critical – as illustrated in table 1.

<table>
<thead>
<tr>
<th>Highly critical</th>
<th>Highly critical spare parts are those, which are absolutely essential for mission success</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderately critical</td>
<td>Moderately critical parts are such that if they are out of stock at the time of demand, it will have only a moderate effect on mission success</td>
</tr>
<tr>
<td>Low criticality</td>
<td>Low criticality parts are not absolutely essential for mission success</td>
</tr>
</tbody>
</table>

**Demand characteristics**

The actual characteristics of the demand, is another area that needs to be considered. As stated, spare parts can often be characterized as having very intermittent and lumpy demand patterns, having periods with zero demand, with occasional periods of non-zero demand. This area needs to be explored, for the purpose of separating stable spare parts from unstable spare parts. This separation will be done according to 2x2 segmentation matrix, segmenting on the demand frequency (lines per lead time) and the demand size variability (coefficient of variation (CV)) – see table 2 (next page).

While spare parts being in the predictable box (many lines per lead time and low CV), do not raise any significant forecasting and inventory control difficulties and can be managed with simple techniques, the spare parts characterized as being intermittent, erratic and lumpy, requires a different approach. Especially, spare parts characterized as being lumpy where demand history contains a large percentage of zero values, interspersed with spikes of non-zero demand that occur randomly, raises issues. For items like these, there is no apparent structure or pattern in the data, a phenomenon that most traditional forecasting methods do not manage well. The fact is however, that the majority of items in spare part inventories have these characteristics.

Extracting demand information regarding the sales cycle levels (phase-in, phase-out), will create a more accurate decision platform. Statistically forecasting analyses of historical demand patterns will not be possible for newly introduced items, and thus casual forecasting techniques should be utilized over statistical techniques for these. On the other hand, spare parts without demand records for many periods, might allow to be phased out. Furthermore, for spare parts with only a few of demand incidences registered, the data quality will be too limited for statistically analyses.

**Supply conditions**

The supply conditions and the inbound flow of materials are another important area that needs to be specified and differentiated upon. To manage the supply and inbound flow of spare parts, it is important to consider the supply source,
Managing the demand for spare parts

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Predictable
Spare parts with higher frequency demand incidences, and with low variability in the demands. This demand pattern does not raise any significant forecasting or inventory control difficulties.

Intermittent
Spare parts classified as intermittent, are characterized by extremely sporadic demand (therefore, a long period with no demand) with a non-significant variability in the quantity of the single demand.

Erratic
The fundamental characteristic of spare parts classified as erratic, is the great variability of the requested quantity, with demand incidences happening very frequently.

Lumpy
Spare parts classified as lumpy, are the most difficult to control, because it is characterized by a lot of intervals with zero demand and a great variability in the quantity.

Table 2

<table>
<thead>
<tr>
<th>C(V) - Variance</th>
<th>High</th>
<th>60%</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>8 Lines/lead time</td>
<td>High</td>
<td></td>
</tr>
</tbody>
</table>

Lines/lead time

2. Spare part segmentation
The segmentation of spare parts should be done on the basis of the previous variables presented. This enables a specified management approach for each, instead of a uniform approach for all spare part items.

Analysing the spare parts with regards to different variables presented might reveal differentiated clusters, with the same kinds of characteristics. The benefit of clusters is that a more tailor-made approach can be developed towards each cluster. Establishing homogenized groups of spare parts into categories simplifies the task of facilitating decision-making with regards to inventory control and forecasting per category, instead of each SKU separately.

3. Forecasting and inventory optimization

Forecasting
Determining the proper forecasting approach is crucial for reducing the inventories while maintaining the required service level. As argued for in an earlier section, spare parts characterized as having predictable demand patterns do not raise any special concern, and normal forecasting techniques can be utilized. However, for spare parts with intermittent and lumpy patterns, these techniques may be very inaccurate. Croston developed an approach for forecasting intermittent demand patterns in 1972, which has been established as the benchmark in both theory and practice since then. Shortly, it should be noted that different from traditional methods, Croston’s method uses the intermittent nature of the demand by separately updating the demand size and the demand interval, this will in many cases be more accurate for spare parts.

Companies must also be aware that when it comes to performance measurement tools, some forecast error measures like
mean absolute percentage error (MAPE) is not fit for zero-demand periods, and thus cannot be utilized when demand pattern is intermittent.

**Inventory levels and safety stock**
The inventory level and the safety stock represent the minimum amount of stock allowed for mitigating the risk of being stock-out. Due to the huge difference between criticality on the spare parts, there will be different service level requirements and thus safety stock. Furthermore, does a long lead time and intermittent demand pattern require a large safety stock inventory and vice versa. This means that, for spare parts determined as being highly critical (as input variable), and having a long lead time, the safety stock should be large. However, for items being highly critical but have day-to-day delivery lead time, the safety stock requirement allows to be very low or even none. This specification, segmentation and differentiation of inventory level requirements enables the ability to optimize the inventory to the specific spare part, and thus a more accurate and reduced inventory can be achieved.

Measuring the achieved service level (fill rate) on the specific segment on a regular basis insures that the inventory actually perform as intended, or if it needs to be reevaluated or modified.

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**Business Case**
The management approach suggested in this article was developed and applied in the context of a large international production company. The approach and findings will be illustrated in the following - not surprisingly, the economical effects of introducing this approach were significant.

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![Diagram of inventory levels and safety stock](image_url)

**Figure 3. Example of the segmentation in the business case**

Segmentation

Spare parts

- **Data quality**
  - Insufficient
  - Sufficient

- **Demand characteristics**
  - Predictable
  - Intermittent
  - Erratic
  - Lumpy

- **Lead time**
  - Short
  - Long

- **Criticality**
  - High
  - Moderate
  - Low

- **Group**
  - 1
  - 2
  - 3
  - 4
  - 5
  - 6
  - 7
  - 8
  - 9
  - 10
Managing the demand for spare parts

The company was struggling with huge amount of spare parts inventories for their production lines, without knowing how to manage them effectively.

The management of their spare parts inventories were characterized by lots of tacit knowledge and subjective decision making, which leads to great risk of overstocking. The company was thus a perfect subject for optimization.

After establishing a profound foundation of knowledge in relation to the spare part criticality, demand characteristics, etc., we were able to analyse the relevant input variables in the context of the company and thus specify the spare part on a formal basis. This enabled a segmentation by clustering the spare parts characteristics, and 20 grouping were found (see figure 3). The input variables used were:

- **Data quality**, was defined with regards to amount of historical demand data records available
- **Demand characteristics**, were defined with regards to demand frequency and demand size variability
- **Lead time**, was defined regards to MTO (long lead time) and MTS (low lead time)
- **Criticality**, was defined with regards to the required service level

From this, 20 differentiated segments arose, and a differentiated inventory optimization could be established. For these segments, several forecasting methods were tested, incl. SES, SMA and Croston's method, and the most accurate was chosen for each cluster. Furthermore, the required safety stock level was calculated based on the lead time, demand variability and the determined service level.

After establishing the inventory levels derived from the suggested management approach, a comparison between the suggest inventory level and the actual inventory levels were established. By still maintaining the required service level of the spare parts, the total inventory level across all spare parts could, by utilizing the suggested approach, be reduced by approximately 33%!

- Reduced inventory levels
- Increased service level
- Reduced cost caused by obsolescence
- Increased transparency, and thus increased knowledge on how to manage the spare parts
- Reduced tacit knowledge, by formalizing component specification

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