Spare Parts Inventory Control at Mantena Sverige AB

Introduction

This article is an excerpt from a master thesis made at Mantena Sverige AB, a company providing maintenance for commuter trains at three different locations in Sweden. At the depot in Helsingborg in the south of Sweden, Mantena is responsible for maintaining around 50 trains that serve the region of Skåne. In the near future Mantena is facing a new challenge, namely to organize purchasing, sourcing, inventory control etc. Up until now, it has been the manufacturer of the trains that has provided Mantena with these functions but as the agreement between the two companies are about to expire, Mantena will have to set up these functions itself.

The purpose of this master thesis has been to develop a tool that can support Mantena in its work with inventory control. The tool provides forecasts and classifications as well as a suggested re-order point and order quantity. With the aid of this tool the authors hope that the work process can become more systematic and automated.

Spare Parts management

Working with spare parts poses several challenges. First of all the number of spare parts can be very high. A train contains thousands of components, some of which are made up of several sub-components. Adding to this is the very high value of some of these components. Having too high inventory levels will occupy a lot of physical space and will result in high holding costs.

Furthermore the spare parts must be available throughout the train’s life cycle which can be several decades. Finally the demand pattern is often irregular, making predictions about future demand hard to make.

The tool

The tool has been developed in Visual Basic and it is used in Microsoft Excel. The input is data from the company’s ERP system including the dates the different spare parts has been demanded, in which quantity they have been demanded and a description of each spare part.

Categorization

The first thing that the tool does when used is that it gives each article a category based on two parameters. The first is the average demand interval (ADI) and the second is a coefficient of variation of the quantity demanded called CV².

The category gives the user an indication of how the demand pattern looks, but it is also important in the next phase of the calculations, namely forecasting.
The category of the article decides which forecasting method to use.

**Forecasting**

Because of the irregular demand pattern of spare parts, with long periods without demand, ordinary forecasting methods such as exponential smoothing or moving average are unsuitable to use. The main reason for this is that they lower the forecasts for each period without demand, with time giving significantly lower forecasts than what can be expected.

Instead the tool makes forecasts based on Croston’s forecasting method. It is based on exponential smoothing but it only updates the forecasts in periods with positive demand. This makes the method well suited for spare parts forecasting.

The results of the forecasts are estimated values of the inter-demand intervals and demanded quantity as well as estimates of the variation of these parameters.

**Re-order point system**

The final calculation the tool does is to calculate an order quantity and a re-order point. Together they make up a so called re-order point system. There are several types of re-order point systems but the one used in the tool is a so called (R,Q)-policy. The principle is the following: As soon as the inventory level goes below a certain point R, the re-order point. A purchase order is made of Q units, i.e. the order quantity. R and Q are chosen so that the probability of shortage does not exceed a pre-defined service level to a minimal cost.

**Making a demand model**

To be able to calculate R and Q, it is necessary to construct a model of the demand of the spare parts. In particular, there are two elements that need to be modelled, the time intervals between days with demand and the quantity demanded. The intervals are modeled with a Bernoulli process; the reason for this is based on an observation of how demand can occur. Any given day there can either be demand or not. In other words, a day can be seen as a Bernoulli trial where demand occurs with a probability p. The next day is a new Bernoulli trial and the day after that etc. resulting in a Bernoulli process. With this way of looking at demand it is natural to assume that the number of days between demands can be represented by the geometric distribution, which can be seen as the number of trials needed until a successful trial. In the same way the number of days with demand in a given time interval can be seen as binomially distributed. The Binomial distribution can be seen as the number of successful trials among a number of trials.

There are however no similar way of looking at the demanded quantity at each day with demand. Instead the historical values are used to make an empirical distribution. This means that the demand size is modelled to follow the historical values.
With these two components a model for demand during a time period can be made and it is as follows:

\[ P(D(t) = j) = \sum_{k=0}^{\infty} \binom{t}{k} p^k (1 - p)^{t-k} f_j^k \]

\( \binom{t}{k} p^k (1 - p)^{t-k} \) is the binomial distribution used to represent how often demand occurs. \( f_j^k \) is an empirical distribution and means the probability that \( j \) units are demanded during \( k \) days.

**Order Quantity**

To calculate the order quantity, \( Q \), the so-called economic order quantity model is used. It balances the cost of making an order and the cost of keeping units in stock. A small \( Q \) means that inventory levels, and thus the inventory holding costs, will be low. At the same time this requires orders to be made more often, increasing order costs. With a large order quantity the opposite is true. The economic order quantity finds the optimal balance between these two costs.

**Re-order point**

Which re-order point that is chosen is closely related to the level of service that is required. In the developed tool, service is defined as the fill rate, or as the fraction of demand that can be satisfied immediately from stock on hand. When the desired service level is defined, the re-order point can be calculated as the lowest possible level that satisfies the service requirement. To ensure that the re-order point is the lowest possible, the calculations are iterative and initially with a very low re-order point. After each round of calculations, the achieved service level is compared to the desired. If it did not reach the required level, the re-order point is increased by one unit and the calculations are run again. This is repeated until the service level meets the desired service requirement.

**Implementation at Mantena**

As Mantena starts to run inventory control under its own management, this tool could be a support in the decision-making process. The authors are well aware of the big variety of elements that influence decisions and that need to be taken into account. Therefore it is important to stress that other factors that might be hard to quantify also should be a part of the decision. It can however be a way of introducing a systematic way to define re-order points and order quantities. It is also independent of the user, meaning that it is not affected by the users own opinions.

**Quality measurements**

When and if the tool is used at Mantena, it might be by people from very different backgrounds. Many users might not, for example, be at ease with the theoretical foundation that the model is based on. Great care has therefore been taken by the authors to ensure that it is possible to use the tool regardless of theoretical knowledge.

**Sources of Errors**

It can be noted that the program is sensitive to a few types of errors. First and foremost it is sensitive to input errors into the ERP system, as the information from it is the base of all calculations.
Furthermore it is using the same probability distribution, i.e. the geometric distribution for the inter-demand intervals, for all articles. Tests show that this is a good approximation; however there might be articles for which the geometric distribution does not represent the variation of the demand intervals in a good way.

Finally the constants that are used in the calculations, such as the order cost, inventory holding cost etc. are estimated by the authors. To give better results, a deeper analysis is needed to define these constants more carefully.

**Conclusion**

The purpose of this master thesis was to develop a tool that can support Mantena in its work with inventory control. This has been done by build a program using Excel and Visual Basic. The tool provides forecasts and an (R,Q)-policy for each spare part based on theoretical models and methods. It allows Mantena to work with inventory control in systematic and automated way.

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