Quantifying the savings potential by optimizing inventory parameters

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1. INTRODUCTION TO CASE ABB

1.1. Research problem

ABB Drives has thousands of different kinds of products they need to manufacture for their own product collection. It is important for ABB to be able to deliver the products to their customers just in time. That is why they have to stock an undesirable amount of extra raw materials. As they keep large storages of raw materials they reach a high certainty level in their availability. Although service level is the most important factor when thinking the size of the stock there are also several reasons why ABB should not keep too much materials in the stock:

- Keeping the building for the stock costs usually plenty of capital
- Usually the real prices of the raw materials get lower by time, so it is more sensible to buy them later than to buy them now and let them lay in the stock.
- The amount of capital that is in the stock does not contribute to profit.
- Instead of keeping the capital in the stock they could invest it to some more productive target.

If the demand for the raw materials were fixed, the optimal size of the storage would be easy to calculate. In real life demand is rarely stable. That brings some uncertainty to estimating the right size of the stock. While we can not tell the demand for some individual part we have to estimate i.e. forecast it. At the moment ABB Drives does not have any automated system for the optimization. Instead the employees check the consumption of the products once in a 12 weeks period and make a forecast for the next 12 weeks.

What are the greatest problems with the present system? The person that creates the forecast knows that ABB wants to deliver the completed products on time for the customers. In that kind of situation there is a tendency to make oversized orders of raw
materials rather than take the risk of getting in a stock-out situation. And of course the time spent making the forecast costs a lot for the firm.

There are products that have too variable a demand to get any advantage of the periodical optimization of the storage parameters. For them a large safety stock has to be maintained to respond to the spiky demand. But for the most of the products we can be confident in developing a forecast of the future demand when we first look in to the past. For these products the storage parameters should be optimized every once in a while. The basic solution can be done by using an automatic computational system. In addition to automized calculation there is often a need for judgement if there exists expert available.

1.2. Objectives

Instead of dealing with all the products codes ABB limited the information to about one thousand products. The assignment was to analyze the data to find out whether there is any saving potential in the stock. The results of the project were used to find out whether ABB Drives should invest in an inventory management program or not.

To find out the savings potential we calculated the inventory costs, if ABB had used an appropriate optimization algorithm during the year 2009. As the demand of the whole year 2009 was known, it was easy to create a model and test that against the last year’s data.

Next we give an introduction to inventory management in large companies. Then we will discuss the ABB case and its results.
2. CHALLENGES IN THE FIELD OF INVENTORY MANAGEMENT

2.1. Optimizing the safety stocks

Companies seek to fulfill the demand of their customers. “Objective of inventory control is to balance conflicting goals” (Axsäter 2006). There is usually an employee who is responsible for the capability to respond to varying demand. He could be called marketing manager and he prefers large storage of finished goods. Production manager wants to keep the storage of raw materials at high level to prevent interruptions. There can also be found an employee, for example a purchasing manager who wants to order large batches to keep the order costs as low as possible. From the storage point of view the aim is to keep them as low as possible.

Lack of products is usually to be avoided. It is more difficult to show that the storage levels are at too high a level than it is to show that they have been at too low a level. Employees responsible for the storage like to avoid stock-out situations at the cost of keeping too high storage levels.

Excessive storage levels lead to different kinds of problems. It is useful for the company to deploy all its capital as productively as possible. Unproductively deployed capital costs plenty of money for companies.

Many products depreciate value. For example keeping cars in a stock is expensive action not only from the viewpoint of tied up capital but also from the viewpoint of discount factor. A new car loses tens of percents of its value every year although if it is not in use.

Typically, storage space is expensive. Warming, ventilation and lighting for example often cost a lot of money.
2.2. Estimating demand

As creating demand is one of the key factors of making business, estimating demand is the most important phase in inventory control. An estimate of demand is required before any other factors in an inventory control model can be calculated. “In many standard implementations of inventory control systems, continuous demand is assumed and a service-level constraint is applied” (Larsen et al. 2008). This general approach can work well especially for high-volume products. Problems occur when demand is lumpy which is the case in the research of Larsen et al. (2008).

They analyzed inventory control of the refrigeration and air-conditioning (RA) division of Danfoss Group. The division makes about one half of the 2 200 M€ turnover of the corporation (2005). The division was facing typical inventory problems, i.e. frequent shortages of certain items and on the other hand a relatively high aggregate level of capital tied up in inventory. The team identified that one reason to the problems in stock control was the demand assumption of underlying process. In a later phase of the case study they noticed that the Poisson process was not the optimal way to describe the demand but a renewal process could be used instead.

A Greek commercial enterprise RODA was facing same kind of problems as Danfoss. They were managing inventories of thousands of different items supplied by more than 20 European and Asian manufacturers. The key feature of the problem was that the demand for the vast majority of the items is highly variable and irregular (Nenes et al. 2010). According to Nenes et al., almost all large companies and many of the medium-sized and small companies try to apply the analytical methods in their inventory management. This is often limited to very simple calculations, for example estimating the economic order quantities or re-order points. Nenes et al. propose that one of the reasons why scientific methods have not yet made a real breakthrough is that the standard textbook material on inventory control is based on the assumption that the demand follows normal or Poisson distribution. Yet it may be that there are not enough analytical
skills in the company when the demand can not be estimated with those standard distributions. This was the case also with Danfoss in Denmark and RODA in Greece.

One worst case scenario of the irregularity of demand is considered by Dolgui and Pashkevich (2008). They found out that 37,3 % of the approximately 145 million storage keeping units that the UK Royal Air Force (RAF) kept in stock at the beginning of year 2000 had fewer than 10 demand transactions over a period of 6 years.

Larsen et al. (2008) point out that in many texts term ‘advance-order information’ is not considered. This means that in those texts it is assumed that when customer makes an order he assumes that he gets the product immediately. This means that the delivery lead time (DT) is zero. This is the case also with ABB Drives below. In reality DT is seldom zero. For example, if DT of some items was longer than storage replenishment lead time (LT) the storage keeper wouldn’t have to keep any of these items in the storage. So these storage items can be removed from the stochastic analysis. To some extent the issue of non-zero DT has been treated in the literature (see e.g. Hariharan et Zipkin 1995 and Marklund 2006).

2.3. Adoption of inventory control system

Once a company has made a decision to optimize its inventory control in a new way, it starts the implementation phase. If the optimization of the order sizes and safety stocks was done earlier with the use of evaluation of experienced workers, it takes a considerable effort to get the new manner to replace the previous process.

The case studies show that two types of knowledge is important within the organization implementing a new inventory control system: technical and organizational process knowledge (Newell & al. 1993). Technical knowledge is knowledge about hardware and software. It can be said that technical side is the gate to successful implementation but the
organizational knowledge is the key factor in creating a new inventory control innovation.

Employees need to be trained for the new process. From this point of view it is crucial that the new system, its logic and user interface is designed also from the workers basis. Otherwise fine and sophisticated inventory control tool may be totally ineffectual if it is too difficult for the current employees to use. It is also possible that the next generation inventory control system is so automated that the company needs to lay off useless employees that used to run the inventory control process before. These kinds of side effects need to be considered with a certain care before taking actions. In the case ABB Drives below it was very important for the company that the new inventory control system was to become simple enough for the employees to use.

2.4. Problems in finding a general solution

Often large companies want to focus on their core business which may lead to outsourcing of processes considered less important. Inventory control problems are usually so complicated that they need a real professional to get solved. Outsourcing of inventory control may lead to considerable side effects.

It can happen that a company buys a solution to too specified a problem. Then the solution can be used for the time being but the inventory control system needs adjusting just as running the inventory does. And this is may a business case for the company that delivers the control system. For example ABB Drives had ordered an algorithm that solves the optimal parameters to be used in their inventory control. Of course these parameters had to be calculated every couple of months. In this case the user interface was so difficult to use that ABB had to pay plenty of money every time the deliverer company updated the parameters. Updating was quite an easy and quick to do but as ABB didn’t have anyone capable to do it they had to pay unreasonably much for this little but significant action.
It’s not just a question about the capital spent but also about the ability of the company to adjust their process just as often as they want to. The adjusting gets quite complicated when there is always needed some outside the company to calculate the parameters.

3. CASE ABB

3.1. The Data

The data that was given by ABB has the following information of about one thousand products:

- **A**: The fixed cost of making an order for one product (independent of the magnitude of the replenishment quantity)
- **D**: A weekly demand inside ABB during 53 weeks
- **k**: Safety factor
- **LT**: The average lead time in days (i.e. the time from sending the order to the time the order is in the stock)
- **σ_L**: Standard deviation of errors of forecasts over a replenishment lead time, in units
- **P_2**: The fraction of demand to be satisfied routinely from the shelf, fill rate
- **r**: The inventory carrying cost, the cost of having one euro of the item tied up in inventory for one year
- **s**: Reorder point
- **v**: The unit variable cost of the item. The average price of the product when ordered in to the stock.
- **\( \hat{x}_L \)**: Forecast or expected demand over a lead time
3.2. Basics about inventory management

First we assume the demand is fixed all the time. Then the order quantity $Q$ is optimal when the total costs of holding the inventory are minimized i.e. when the economic order quantity (EOQ) is reached. It is reached at the point where ordering costs equal inventory carrying costs as can be seen in the chart below.

**Cost Minimization Goal**

![The Total-Cost Curve is U-Shaped](image)

**Figure 1 – Estimating the economic order quantity**

The order should be made so that the order is received just before the available stock drops below the safety stock level. In the figure 2 the bottom line represents the safety stock level.

Lead time is the time between placing the order to the time the order is received. As we know the lead time for the product we can calculate the reorder point.

If demand were fixed, as above, we would not need any safety stock. In reality, demand varies and we have to prevent stock out situations by having a safety stock, $SS$. The function of the safety stock is to make sure that there does not exist too many stock-outs.
even if the demand during the lead time were to exceed its average value. Stock outs could be avoided by having a huge safety stock but this would lead to enormous inventory carrying costs.

**Profile of Inventory Level Over Time**

![Profile of Inventory Level Over Time](image)

Figure 2 – Profile of inventory level over time

### 3.3. The Model

Definitions:

\[ f_x(x_0) \] The probability density function of the demand during the lead time

\[ f_x(x_0)dx_0 \] The probability that the total demand during the lead time is between \( x_0 \) and \( x_0 + dx_0 \)
A decision rule for the specified fraction of demand satisfied directly from the shelf was chosen to be used in the optimization. This model optimizes the size of the safety stock while it still keeps the service level in the wanted region.

The derivation according to Silver, Pyke and Peterson (1998):

Safety stock \( SS \) = \( E(\text{Net stock just before the replenishment arrives}) \)

\[
= \int_0^\infty (s - x_0) f_x(x_0) dx_0
\]

After opening the integral

\[
SS = s - \hat{x}_L
\]

Prob(stockout during a replenishment lead time) = Prob(\( x \geq s \))

\[
= \int_s^\infty f_x(x_0) dx_0
\]

Expected shortage per replenishment cycle is

\[
ESPRC = \int_s^\infty (x_0 - s) f_x(x_0) dx_0
\]

We assume that the average of backorders is very small relative to the average on-hand stock.

\[
E(\text{Net stock}) = E(\text{On hand}) – E(\text{Backorders}),
\]

which in turn give

\[
E(\text{OH}) \approx E(\text{NS})
\]

and

\[
E(\text{OH just before replenishment arrives}) \approx \text{Safety Stock (SS)}
\]

\[
= s - \hat{x}_L.
\]
Now we choose to express the safety stock as the multiple of two factors,

$$SS = s - \hat{x}_L = k\sigma_L$$

As the OH level drops linearly during a cycle right after replenishment arrives we get

$$E(OH) = \frac{Q}{2} + (s - \hat{x}_L) = \frac{Q}{2} + k\sigma_L$$

We denote by \( u \) a normal distributed variable that has a mean value 0 and a standard deviation 1. Then we denote:

$$G_u(k) = \int_{-\infty}^{\infty} (u_0 - k)f_u(u_0)du_0$$

We assume that the demand during the lead time follows normal distribution and has a mean of \( \hat{x}_L \) and a standard deviation of \( \sigma_L \). Thus we get

$$ESPRC = \sigma_L G_u(k).$$

As

$$P_2 = 1 - \frac{ESPRC}{Q},$$

the former reduces to

$$G_u(k) = \frac{Q}{\sigma_L} (1 - P_2).$$

Assuming the demand was fixed, the optimal order quantity comes to following form

$$Q = EOQ = \sqrt{\frac{2AD}{\sqrt{vr}}}$$

Now we know what \( G_u(k) \) should be. The value for \( k \) can be approximated by

$$k = \frac{a_0 + a_1 z + a_2 z^2 + a_3 z^3}{b_0 + b_1 z + b_2 z^2 + b_3 z^3 + b_4 z^4}$$

where

$$z = \sqrt{\ln\left(\frac{25}{(G_u(k))^2}\right)}$$

and a’s and b’s are given constants. See Silver, Pyke and Peterson for details.
3.4. The Results

From the original data the following factors were calculated.

\[ \hat{x}_L \] The average demand during the lead time
\[ \sigma_L \] The average standard deviation in the lead time
\[ k \] The safety factor
\[ SS \] The safety stock
\[ s \] The reorder point

Now we know all the factors that we need to make the inventory work in an optimal way according to the model chosen. As we do not know how this model will work in we have to test it using historical validation by using the data of the year 2009. As the demand will vary during a year we can not use fixed values for the safety stock, the order point and the order quantity.

The basic solution used at ABB at the moment is that we calculate the values for the next 12 weeks from the data of the previous 12 weeks. So an Excel algorithm that calculates the values every 12 weeks was developed. This algorithm also tells us the values for back orders, the service level and the average value of the stock if this kind of model had been used.

Finally there was feasible data of 717 products held in the storage of ABB Drives. It was tested how the model above would have worked with these products in the year 2009. The variety of products is vast. Some of them had almost stable demand during the year and some of them are delivered only for some special projects for example.

Next the products had to be categorized in to two groups: (i) The groups that use the model and (ii) the group that has no use for the model introduced earlier. The criterion for the first category was the fill rate that would have been realized, which is introduced in the chart below.
Figure 3 – The distribution of fill rate

The model takes fill rate as one of its parameters and as the service level is an important factor for ABB I have used the level of 99 % as mentioned earlier. Although the model “tries” to reach the fill rate wanted the result of course finally depends of the real life demand. Finally 423 products of the 717 would have had a fill rate of above 98 %. So from the service level point of view the model is applicable for 67 % of the products. From the chart below it can be seen that 64 % of the products had a fill rate of 99 % or more.
Figure 4 – The distribution of fill rate

Service level is one of the most important factors but also costs matter. As the service level for these 423 products was over the target by using the model, the next question is that how well they managed from the money point of view. If we keep staring just the fill rate it is easy to reach good performance by keeping the storages in an unreasonably high level. And this kind of action has a considerable opportunity cost. Hence we have to measure how the 423 products would have succeeded economically.

The average size of the storage during the year for each product was calculated. As the price of every product was known, the average value of the storage could be calculated. The statistics of the real storage levels during the year 2009 were given, from which also the realized average value of the storage during the year could be calculated. Two numbers which tell whether the model gets better results than the practice used in ABB Drives at the moment.
The result is that if ABB had used the model introduced above during the year 2009 they would have reached a fill rate of more than 98% and the average value of the storage for these products would have dropped 31%.

In euros this means that for these products ABB would have had to hold just 661 k€ instead of 956 k€. So from just these 423 products ABB would have got 295 k€ to use in some interest-bearing investment. As ABB has thousands of items in their storage there is a millions of euros potential to become gained.

3.5. The Future

After this preliminary study, there is still plenty of investigation and optimization work to be done. As already mentioned, ABB Drives is forecasting its inventory parameters from the previous twelve weeks for the upcoming twelve weeks. It should be investigated whether this is the optimal way to go or not. It might be convenient to have different kinds of forecasting periods for different kinds of products. The performance of different lengths of the forecasting periods can be easily calculated with the Excel-sheets used in making this report.

The cost of having a fill rate of more than 98% should be investigated and can be derived easily from the calculations and results of this report. It is more difficult to estimate how valuable almost certain availability is from the customer point of view.

Besides finding a theoretically optimal forecasting and ordering strategy there is a lot of work to be done in the field practical implementation. The whole physical process dealing with forecasting and ordering has to be re-organized. The reordering process should be automated so that there would be no need for labor in reporting the storage levels. All the storage parameters should come automatically in to the optimizing algorithm and after the calculations all the ordering should be automated in order to achieve savings in the labor costs too.
References


