ECONOMIC AND BUSINESS REVIEW

Volume 11 | Issue 2 Article 1

12-31-2009

# Minimising inventory costs by properly choosing the level of safety stock

Liljana Ferbar Tratar



Recommended Citation
Ferbar Tratar, L. (2009). Minimising inventory costs by properly choosing the level of safety stock. *Economic and Business Review, 11*(2). https://doi.org/10.15458/2335-4216.1262

# MINIMISING INVENTORY COSTS BY PROPERLY CHOOSING THE LEVEL OF SAFETY STOCK

**LILJANA FERBAR TRATAR***

ABSTRACT: *Markets are everyday becoming ever more demanding and companies are adjusting in different ways. The objective of forecasting in a demand-driven supply network is to identify the probable range of expected demand so that supply can cover demand anywhere within the statistical range. Supply can cover the range either through having the capacity to replenish within lead times or by carrying excess inventory (safety stock). Nowadays, many companies put a lot of their energy and finance into setting the right level of safety stock and reducing related expenses. In this paper, we improve an existing method for calculating the safety stock for a particular Slovenian company. We present the existing and proposed methods for calculating safety stock and derive a cost model. Finally, we prove that the proposed method not only reduces average costs but also helps to meet the target customer service level – making it also applicable to other Slovenian companies encountering situations where demand is seasonal.*

**Keywords:** *Safety stock; Inventory; Cost model; Optimisation*

**UDC:** 330.522.4

**JEL classification:** G31; C61

## 1. INTRODUCTION

The objective of forecasting in a demand-driven supply network is to identify the probable range of expected demand so that supply can cover demand anywhere within the statistical range. Supply can cover the range either through having the capacity to replenish within lead times or by carrying excess inventory (safety stock). Safety stock is the amount of material needed to compensate for supply and demand inefficiencies. In an organisation where marketing is tasked with growing the market, and supply is tasked with reducing working capital, the decision on the amount of safety stock to carry can become very contentious.

* University of Ljubljana, Faculty of Economics, ,Kardeljeva ploščad 17, 1000 Ljubljana, Slovenia, Email: liljana.ferbar@ef.uni-lj.si

Companies are aware of the importance of safety stock so they set it in many different ways. Unfortunately, there is no universal method that would yield the optimal level of safety stock. As a result, many companies set their level of safety stock in relation to actual sales in the past year. Most safety stock calculations within ERP systems use standard APICS calculation methods (Akkermans, et al. (2003), Kelle and Akbulut (2005), Gupta and Kohli (2006) et al.). These methods appear to work well for situations where demand is stable, but not for situations where demand is seasonal.

The objective of this paper is to propose an alternate method for calculating safety stock for seasonal products in order to reduce total costs and retain the service level according to the company's policy (as is established in the existing method).

The paper is organised as follows. First, we present the existing method for calculating safety stock, which is used by Danfoss District Heating, a Slovenian company. Then we describe the proposed method for calculating safety stock for seasonal products, which is an extension of Herrin's method (Herrin, 2005). In the third chapter, we derive a cost model in order to compare the existing and proposed method. Finally, based on our study in which we have included 4,247 products we prove that the proposed method for calculating safety stock can reduce average costs by almost 12%.

## 2. CALCULATION OF SAFETY STOCK

The optimal level of safety stock is related to many components and some of them can hardly be controlled (Winston, 1993). This paper will only address the demand component or amount needed to cover the inherent variability in the sales forecast.

### 2.1 The existing method

To calculate safety stock according to the existing method used in the company Danfoss District Heating we have to rely on sales in the previous year. At the beginning we must divide a year into 14-day periods and count out the number of products to be sold per period (see Table 1).

TABLE 1: *Yearly sales for 2006 for product X divided into 14-day periods*

| Period | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sale | 21 | 2 | 3 | 13 | 14 | 14 | 22 | 14 | 18 | 6 | 33 | 20 | 24 | 28 | 41 | 31 | 31 | 48 | 43 | 16 | 4 | 2 | 7 | 8 | 13 | 15 |

After doing this, we calculate the average sales for each product *i*:

$$\bar{y}_i = \frac{\sum sales_{\text{year}}}{26} \tag{1}$$

In our case, the average sales for product X is 19 (rounded value).

Then we have to sort the quantities by ascending the value of sales and calculate the percentile of the sorted values according to an ABC classification and related service level.

The company classifies its products in A, B or C classes. This classification depends on the price and predicted number of orders in the next year (products with classification A have more than 48 orders per year and products with classification C have fewer than 5 orders in one year). If the selected product is in class A the related service level (according to the company policy) is 98% (products in class B have a service level of 90% and the service level for class C products is 0% as they are only made when specially demanded by the customer). This means that 98% of the market demand can be covered by products that are in the warehouse.

Now we compare average sales and sales in the 98th percentile (because the related service level is 98%). If the ratio is greater than 1:5, we have to calculate the sales value at the 90th percentile. With this correction we eliminate products with a high deviation. In our case, for product X, with classification A, the sales value at the 98th percentile is 50 ($y_{X;0,98}$ = 50). Since the ratio $y_{X;0,98}/\overline{y}_X$ = 50/19 = 2,6 is less than 5, product X is a product with a low deviation and its service level is 98%.

After that, we calculate the difference between the maximal admissible value at the 98th (or 90th) percentile ($NPVN_i$) and average sales:

$$DIF_i = NPVN_i - \overline{y}_i. \tag{2}$$

In our case, the value of $NPVN_X$ is 50 and the difference is $DIF_X = 31$.

The supply time of the product (lead time) is also taken into account. Usually the lead time ($LT_i$) is in days so we have to recalculate it on a 14-day basis:

$$LT_i = \frac{lead\_time(in\_days)}{14} \tag{3}$$

The supply time of the selected product X is 18 days, so $LT_X = \sqrt{18/14} = 1{,}13389$.

The next step is multiplying the calculated difference and lead time to obtain the first value of safety stock:

$$SS_i^1 = DIF_i \cdot LT_i. \tag{4}$$

Then we have to consider some obligations such as:

$$SS_i^2 = \begin{cases} \overline{y}_i/2; & \text{if } SS_i^1 < \overline{y}_i/2 \\ 3\cdot\overline{y}_i; & \text{if } SS_i^1 > \overline{y}_i/2 \text{ and } SS_i^1 > 3\cdot\overline{y}_i \\ S_i^1; & \text{if } SS_i^1 > \overline{y}_i/2 \text{ and } SS_i^1 < 3\cdot\overline{y}_i \end{cases} \tag{5}$$

The collected results have to be compared with the production status of the product, the ABC classification and the safety stock in the previous year:

$$SS_i^2 = \begin{cases} 0; & \text{if} \quad classification = C \\ SS_{i,t-1}^3; & \text{if} \quad classification \neq C \text{ and } status \neq XP \\ SS_i^2 & \text{if} \quad classification \neq C \text{ and } status = XP \end{cases} \tag{6}$$

where *XP* means that the product can be produced.

Finally, safety stock for the product is calculated by the following equation which takes into account the predicted growth of sales (*r* is the predicted growth of sales in the following year (in %)):

$$SS_i^4 = SS_i^3 * \sqrt{1 + \frac{r}{100}} \tag{7}$$

For our selected product X we calculate (from equation (4)): $SS_X^1 \doteq 35$ $SS_X^1 \doteq 35$. Since 35 $= SS_X^1 > \bar{y}x/2 = 9{,}5$ and $35 = SS_X^1 > 3 \cdot \bar{y}x/2 = 57$, we obtain (from equation (5)): $SS_X^2 = SS_X^1 =$ 35. As product X with classification A has an XP status, we obtain (from equation (6)): $SS_X^3 = SS_X^3 = 35$. If we assume that we will sell 550 units of product X in the next year, the predicted growth is 12% and the final value of the safety stock is calculated with regard to equation (7): $SS_X^4 = SS_X^3 \sqrt{1{,}12} = 37$.

TABLE 2: *Data for product X and results obtained with the existing method*

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Actual sales** | 23 | 16 | 28 | 36 | 24 | 53 | 52 | 72 | 79 | 59 | 6 | 43 |
| **Month's sales (in %) of the annual total** | 4.68 | 3.26 | 5.70 | 7.33 | 4.89 | 10.79 | 10.59 | 14.66 | 16.09 | 12.02 | 1.22 | 8.76 |
| **Forecast** | 27 | 27 | 34 | 30 | 20 | 30 | 44 | 43 | 40 | 55 | 45 | 28 |
| **Safety stock** | 37 | 37 | 37 | 37 | 37 | 37 | 37 | 37 | 37 | 37 | 37 | 37 |
| **»Pumping« from safety stock** | 0 | 0 | 0 | 6 | 4 | 23 | 8 | 29 | 39 | 4 | 0 | 15 |

As Table 2 shows, the monthly sales were between 1.22% and 16.09% of the annual total, which means that sales are highly seasonal. In this case, the safety stock of 37 units would have seen a shortfall in the month of September of 2 [79 — (40+37)] units and over-estimated the safety stock for all of the out-of-season months.

## 2.2 The proposed method

The standard method for calculating safety stock uses the targeted customer service level and cumulative forecast error over the most recent historical periods to determine the minimum amount of safety stock needed to cover sales until the next scheduled re-supply, which is computed as follows:

1. Compute the forecast deviation for each month.
2. Square each deviation.
3. Compute the standard deviation:

$$\sigma = \sqrt{\frac{\text{Deviations Squared}}{N-1}}, \tag{8}$$

where $N$ is the number of observations.

4. Compute the safety stock:

$$SS = Z\sqrt{LT \cdot \sigma^2} \tag{9}$$

where $Z$ is the value based on customer service and $LT$ means the lead time.

However, the standard method for calculating safety stock does not give satisfactory results for the highly seasonal products we have in the company Danfoss District Heating. Seasonality occurs across multiple months within a given year. However, looking at a given month across multiple years helps to account for seasonality. Based on this observation we propose a slight change in the method. Instead of calculating the standard deviation across months within a given year, we calculate the standard deviation for a specific month across all available years. We then calculate the safety stock for each month independently.

As mentioned, the safety stock depends on many factors and probably the most problematic one is the difference between the forecast and actual sales. With the intention of achieving better demand forecasting, in our proposed method we use the additive Holt-Winter method which takes into account the trend, seasonality and the average worth value of the variable (e.g., Makridakis et al. 1998 and Winston, 1993).

We optimise the forecast with regard to smoothing and *initial* parameters (the forecast results for product X are in Table 3), what is also our contribution to the article on which this research is based (Herrin, 2005) - the results obtained with the basic Herrin's method are not better from those calculated with the existing method.

TABLE 3: *Comparison of actual sales and forecast as calculated by the additive Holt-Winter method for product X*

| Months 2003 | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Forecast | | | | | | | | | | | | |
| Actual sale | 9 | 20 | 8 | 15 | 44 | 50 | 47 | 25 | 29 | 50 | 11 | 7 |

| Months 2004 | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Forecast | 37 | 23 | 29 | 36 | 36 | 37 | 45 | 59 | 50 | 42 | 16 | 18 |
| Actual sale | 42 | 31 | 36 | 33 | 39 | 36 | 38 | 62 | 41 | 48 | 43 | 9 |

| Months 2005 | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Forecast | 24 | 11 | 17 | 25 | 27 | 29 | 39 | 55 | 48 | 43 | 18 | 20 |
| Actual sale | 31 | 10 | 13 | 32 | 43 | 21 | 50 | 53 | 46 | 42 | 27 | 28 |

| Months 2006 | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Forecast | 29 | 17 | 24 | 34 | 37 | 38 | 50 | 67 | 61 | 58 | 36 | 36 |
| Actual sale | 23 | 16 | 28 | 36 | 24 | 53 | 52 | 72 | 79 | 59 | 6 | 43 |

To calculate the safety stock we must take the next four steps:

1. Instead of calculating the standard deviation across months within a given year (equation (8)), we now calculate the standard deviation for a specific month across all available years (equation (10)). In Table 4 you can find the calculations for product X, where the actual and forecast data for the month of May in 2004-2006 are given.

TABLE 4: Calculating the deviation between the forecast and actual sales

| Product X | Sale | Forecast | Deviation | Deviation squared |
|---|---|---|---|---|
| May 2004 | 39 | 36 | -3 | 9 |
| May 2005 | 43 | 27 | -16 | 256 |
| May 2006 | 24 | 37 | 13 | 169 |
| | | | **Sum** | **434** |

We calculate the deviation between sales and the forecast and use the following formula to calculate the standard deviation:

$$\sigma = \sqrt{\frac{\sum \text{ Deviation squared}}{N-1}} \tag{10}$$

In our case, we obtain

$$\sigma = \sqrt{434/2} \doteq 14,73.$$

2. To use the proposed method in a proper way, we also have to adjust the supply time of a product. The lead time (LT) of a product is usually in days and it must be recalculated on a monthly basis. The supply time of the selected product is 18 days so the recalculated lead time is $LT = 0,592$ [18 days → 18/(30.4167) → 0.592 month (30.4167 = average number of days in one month (365/12)].

3. Now we have to adjust the desired level of service. Since the product we are dealing with is an A class product, i.e. its related service level is 98%, we have to recalculate this using standard statistical tables. Assuming that sales fit a normal distribution, the Z value (which is based on customer service) can be obtained by using the NORMSINV function in Excel, which gives us Z = 2.054.

4. Finally, we calculate the safety stock by using equation (9):
$SS_{X;May} = Z^* \sqrt{LT^*\sigma^2} = 2,054 \cdot \sqrt{0,592 \cdot 14,73^2}\ 0 \doteq 230$

## 3. COMPARISON OF THE EXISTING AND THE PROPOSED METHODS

In this study, in which we have included 4,247 products, we calculated the safety stock for every product using both methods presented above and formed a cost model to examine which method is more cost-efficient. Based on the reports gathered from the company and information acquired about the actual sales for the first six months of 2007 (Demand plan and monthly sales, 2007), we formed a table with the amounts of sales, safety stock and sales forecast.

If we define $[X]^+ = \max\{0,x\}$, we can calculate the costs using the following formula:

$$C_t = c_h * [(F_t + S\ _t) - Y_t]^+ + c_s * [Y_t - (F_t + S\ _t)]^+, \tag{11}$$

where:
$C^t$ = costs in period t
$Y^t$ = actual sales in period t
$F^t$ = sales forecast in period t
$SS^t$ = safety stock in period t
$c_h$ = holding costs
$c_s$ = stockout costs

We defined the expenses that have arisen according to calculated difference in the data. When there is a positive difference between the actual sales and the amount of the forecasted sales and safety stock, we have holding costs (presumption: $c_h$ (holding cost) = 1 EUR). When there is a negative result, we have stockout costs (presumption: $c_s$ (stockout cost) = EUR 2). The stockout costs are greater than the holding costs because a company that cannot carry out an order at any given moment loses some of its future orders and possible contracts with customers.

Considering all the mentioned presumptions we obtain the results presented in Table 5. As is evident, the costs are lower if we use the proposed method for calculating the safety stock.

TABLE 5: *Total expenses (in EUR) due to the inconsistency between actual sales and the amounts of the forecast sales and safety stock*

| Method/ Period | Jan | Feb | Mar | Apr | May | Jun | Jul | Σ |
|---|---|---|---|---|---|---|---|---|
| **Proposed method** | 81,275 | 88,936 | 92,449 | 86,720 | 103,822 | 117,606 | 100,591 | 671,399 |
| **Existing method** | 81,887 | 104,097 | 106,163 | 111,196 | 112,030 | 128,553 | 117,879 | 761,805 |

From the table above we can see that if we calculate the safety stock with the proposed method instead of the existing method the costs can be reduced by almost 12%.

However, there are several disadvantages with regard to the proposed method. One of them is universality. It is a general method that works very efficiently for those markets that can be labelled as more stable than others because they have recurring examples of demand for products. The market in which the company Danfoss District Heating operates experiences very sudden and unexpected changes so it can be described as very dynamic. But we have proven that its inventory costs could in any case be reduced. In addition, there are large companies that offer very similar products so the level of competition is very high. As a result of such an environment, a company is forced to seek every new opportunity for successful management. Entering a new market is one of these opportunities. In the last year Danfoss District Heating successfully entered the Asian market. It opened a new plant near Beijing to address needs arising in that area. Its success here is also shown in increased sales of products in the past year (the growth of sales was also noted for other markets). As the company expects further growth in its sales, the stocks should be adjusted to those bigger sales, too. If the company were to use the proposed method for calculating its safety stock it would have a more efficient inventory policy.

## 4. CONCLUSION

There are many ways of reducing costs and they include setting the optimal level of safety stock. In this paper we present the influence of different methods for calculating safety stock on inventory costs. At the moment, the proposed method can reduce the costs and keep the service level as was set in the existing method. If the safety stock were calculated by the proposed method, costs related to the safety stock would be approximately 11.87% lower than with the existing method. Due to differences between the existing and proposed methods, the proposed method has the potential to improve and reduce costs even more (growth is not yet included in the calculations, enhancing the universality of the method etc.). By including these parameters in the proposed method we are confident that we can reduce expenses related to safety stock even more and give the company Danfoss District Heating a chance of becoming more competitive than its competitors.

**RECEIVED: MAY 2008**

## REFERENCES

Akkermans, H. A., Bogerd, P., Yücesan, E., van Wassenhove, L. N. (2003), "The impact of ERP on supply chain management: Exploratory findings from a European Delphi study", *European Journal of Operational Research* 146(2), 284–301.

Gupta, M., Kohli, A. (2006), "Enterprise resource planning systems and its implications for operations function", *Technovation* 26, 687–696.

Herrin, R. (2005), "How to calculate safety stocks for highly seasonal products", *The Journal of Business Forecasting* 24 (2), 6–10.

Kelle, P., Akbulut, A. (2005), "The role of ERP tools in supply chain information sharing, cooperation, and cost optimization", *International Journal of Production Economics* Volumes 93-94, 41–52.

Makridakis, S., Wheelwright, S.C. and Hyndman, R.J. (1998), *Forecasting: methods and applications*, United States of America: John Wiley & Sons, Inc.

Wild, T. (1997), *Best practice in inventory management*, United States of America, Woodhead Publishing Ltd.

Winston, W.L. (1993), *Operations Research: applications and algorithms*, Belmont: Duxbury Press.

Demand plan (2003-2007), Company's internal report, Ljubljana.
Monthly sale (2003-2007), Company's internal monthly sales reports, Ljubljana.