Adjusting Safety Stock Requirements with an AHP-based Risk Analysis

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Abstract

In most cases safety stock is determined based on the variability of the demand and lead time. The focus has been on the statistics and past performance, and the existing frameworks are not taking into account future development. Therefore we want to turn more to the future issues and develop the existing frameworks by implementing future factors to the decision making process. In this paper, the safety stock requirements are determined by applying a well-known decision support tool, the Analytic Hierarchy Process (AHP). While the basis level for the safety stock is calculated by using the well-established calculation rules, the AHP-method is used for adjusting this basis level by taking into account the risks related to e.g. production, logistics or the overall operating environment. By using the AHP, the risk factors are mapped in the various areas, their importances are determined, and their impact on safety stock requirements is analysed. Furthermore, strategic viewpoints such as the strategies of the supplier company and the customers can be included in the process of determining the safety stock level. As the AHP is a flexible decision support tool, the safety stock requirements can easily be adjusted whenever there are changes in the risk or strategic factors. E.g. a strike threat by the logistics service providers would trigger a safety stock requirement analysis. In the paper, the utilisation of the AHP is demonstrated with an illustrative example.

1. Introduction

An important element of customer service and logistics management is to maintain an appropriate level of safety stock. When insufficient safety stock is held, the firm fails to meet its customer service objective [1]. On the other hand, a 100% in-stock policy requires too much safety stock to be practical and profitable [2]. The level of customer service and safety stock is not an external requirement, but it should be determined based on the trade-off between the cost of providing the service and the contribution to revenues [3]. Very often companies are placing emphasis on reducing logistics and other costs to the lowest level possible to maximise the profit potential of sales already on the books. Ideally, marketers should be exploiting logistics capabilities to increase customer satisfaction and maintain customer demand [4].

Surprisingly, many companies are using outdated, simplistic methods for allocating safety stock, and they don't even realise that their system may be using methods older than the electronic calculator [5]. They are calculating safety stock based on old sales patterns, which means that they are not including future issues, such as, company's strategies and future intentions and risks related to business opportunities in their safety stock calculations.

In some companies the determination of the safety stock level is based on sales forecasts. However, variations between actual demand and forecast are inevitable. A fundamental premise of forecasting is that a forecast will be wrong, though we are not sure by how much and when [6]. It's not enough to take sales forecasts to the determination of service level. Instead companies have to consider all future issues in their safety stock calculations. All together, safety stock is a necessary strategic weapon of the business to enhance and maintain customer satisfaction and loyalty [6].

In our study service level is defined as the percentage of orders that can be met from stock within a given period. The elements of service level are the following:

1. The level of safety stock per product;
2. The number of products belonging to the safety stock.

Provided that the sales history for a product forms a routine pattern, the first can be calculated. Often, and especially when the number of deliveries is high, the normal distribution function is used to determine the

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needed safety stock. When the sales pattern follows the normal distribution, the needed safety stock (S) can be defined when the value of its key parameters, safety stock requirement (%), standard deviation of demand in time unit (σ) and lead time (L) are known:

$$S = Z \sigma \% L \qquad (1)$$

This can be classified as a standard safety stock calculation, where Z is the Standard Normal Deviate and its value can be found on the basis of the service level requirement from a standard normal distribution table [7][8]. The problems related to the use of the function are due to the fact that it calculates safety stock based on the demand pattern and deviation of the past. It is not taking care of the future issues, such as strategic viewpoints of the deliverer and risks related to getting a deal with a customer.

The number of products belonging to safety stock can be determined by the ABC -analysis. For example, if 20 per cent of the products (Class A) represent 70 per cent of the volume, then these class A products will establish the safety stock and class B and C can be excluded.

The traditional method for defining the safety stock level relies very much on the historical performance of the supply chain, and it is difficult to incorporate future development into the calculations. The objective of this paper is to present how the well-known decision support framework, the Analytic Hierarchy Process (AHP), can be used for complementing the traditional approach. The AHP enables the decision-makers to take into account the future development of the factors that have an impact on the supply chain performance. Furthermore, it is possible to include the strategic viewpoints, like e.g. the strategies of the supplier and the customers, in the process of determining the safety stock level.

2. The proposed approach

The Analytic Hierarchy Process (AHP) is a theory of measurement for dealing with tangible and intangible criteria that has been applied to numerous areas, such as decision theory and conflict resolution [9]. The AHP is a problem-solving framework and a systematic procedure for representing the elements of any problem [10]. The AHP is based on the following three principles: decomposition, comparative judgements, and the synthesis of priorities. The AHP starts by decomposing a complex, multicriteria problem into a hierarchy where each level consists of a few manageable elements which are then decomposed into another set of elements [11]. The second step is to use a measurement methodology to establish priorities among the elements within each level of the hierarchy. The third step in using the AHP is to synthesise the priorities of the elements to establish the overall priorities for the decision alternatives. The AHP differs from conventional decision analysis methodologies by not requiring decision-makers to make numerical guesses as subjective judgements are easily included in the process and the judgements can be made entirely in a verbal mode [12].

According to Saaty [13], the Analytic Hierarchy Process forms a systematic framework for group interaction and group decision making. Dyer and Forman [14] describe the advantages of the AHP in a group setting as follows: (1) both tangibles and intangibles, individual values and shared values can be included in an AHP-based group decision process, (2) the discussion in a group can be focused on objectives rather than on alternatives, (3) the discussion can be structured so that every factor relevant to the decision is considered in turn, and (4) in a structured analysis, the discussion continues until all relevant information from each individual member in the group has been considered and a consensus choice of the decision alternative is achieved. A detailed discussion on conducting AHP-based group decision making sessions including suggestions for assembling the group, constructing the hierarchy, getting the group to agree, inequalities of power, concealed or distorted preferences, and implementing the results can be found in [15] and [13].

In this paper, we propose the following approach to adjusting the safety stock level with the AHP:

1. **Select the basic service level**: The first step is to determine the basic service level for a customer. The basic service level is expressed in terms of a service level percentage (e.g. 99 %).
2. **Calculate the safety stock requirement**: The basic safety stock requirement is calculated by using the traditional calculation rule, i.e. on the basis of the standard deviation of the demand and the lead time.
3. **Define the relevant factors with an impact on the safety stock requirement**: The third phase of the approach involves determining the relevant future or strategic factors that have an impact on the safety stock requirement. Examples of these factors are risks related to the supply chain (production, logistics etc.) and the future strategies of the supplier company and the customer.
4. **Analyse and quantify the impact of the factors with the AHP**: The AHP is used for analysing the impact of the defined factors on the safety stock requirement. With the AHP, the

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factors are broken down into a hierarchy, the elements in the hierarchy are prioritised and the overall impact on the safety stock level is determined. As a result of this phase, the impact of each analysed factor is known as percentage adjustment of the basic safety stock level that was determined in the phase 2.

5. **Summarising the results of the analyses**: The final step of the approach includes summarising the results of the analyses in the previous phase. This gives the overall need for adjusting the safety stock requirement.

The utilisation of the proposed approach is demonstrated with an illustrative, numerical example.

3. An illustrative example

In this illustrative example, we focus on the utilisation of the AHP, i.e. on the steps 4 and 5 of the proposed approach. The basic set-up of the example, which covers the steps 1-3 of the approach, is as follows:

- the supplier company A wants to determine the safety stock level for one of its major customers, the customer B; i.e. the analysis is carried out for a single customer-product combination
- the time frame is six months ahead
- the basic service level requirement is 99 % and the corresponding safety stock level based on the traditional calculation method is 2 000 stock keeping units (SKUs)
- the supplier company has defined three major factors that need to be analysed with the AHP in order to adjust the safety stock level: (1) the importance of the customer B – reflecting the future strategy of the supplier company, (2) the estimated future development of the customer B – reflecting the future strategy of the customer, and (3) the potential risks related to the supply chain during the next six months

3.1 Analysing and quantifying the impact of the identified factors

The impact of customer importance

The first of the factors to be analysed with the AHP is the importance of the customer B for the supplying company. According to the basic principles of the AHP, the first step in the analysis is to break down the decision problem into components and to structure them into a hierarchy. Normally, the basic structure of an AHP-hierarchy is as follows: (1) the goal of the analysis or the decision process is located at the first level, (2) the criteria and the subcriteria at the following levels and (3) the decision alternatives at the lowest level of the hierarchy.

In this analysis, the goal is to analyse the impact of the customer B´s importance on the safety stock level. The following criteria are included in the analysis: (1) profitability prospects of the customer B for the supplying company, (2) the impact of the customer B on the supplying company, i.e. what the role of the customer B is in the customer portfolio of the supplying company in the future, and (3) the nature of relationship between the customer B and the supplying company. These criteria are located at the second level of the hierarchy. The third (i.e. the lowest level) of the hierarchy includes the decision alternatives, which in this case are the alternative adjustment percentages for the basic safety stock level. The hierarchy is presented in the Figure 1. The described AHP-hierarchy can be considered an application of the AHP to forecasting, and the structure of the hierarchy is a simplified version of the one presented by Dyer and Forman [16] for forecasting enrolment growth of certain educational programs. Applications of the AHP for forecasting and prediction can be found in e.g. [13], [17], [18] and [19].

The second step in using AHP is to derive priorities for each element in the hierarchy. The priorities are set by comparing each set of elements in a pairwise fashion with respect to each of the elements in a higher level [11]. A verbal or a corresponding 9-point numerical scale can be used for the comparisons which can be based on objective, quantitative data or subjective, qualitative judgements. In a group setting, there are several ways of including the views and judgements of each person in the priority setting process including e.g. (1) consensus, (2) vote or compromise, (3) geometric mean of the individuals' judgements, and (4) separate models or players [14].

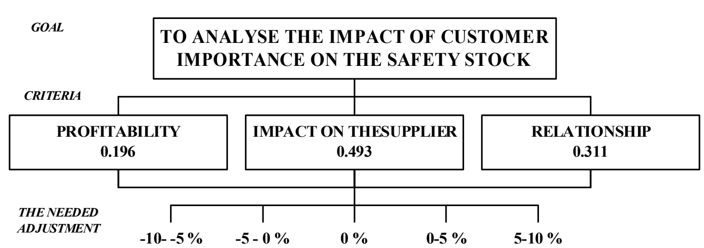

Figure 1. The analysis of the impact of the customer importance

With the hierarchy in the Figure 1, the priority setting process is started by comparing the criteria at the second level pairwise with regard to the goal. The criteria are compared to each other on the basis of their importance in the process of determining customer importance. After finalising the pairwise comparisons of the criteria, the alternative adjustment rates at the third level of the hierarchy are compared pairwise separately with regard to each criterion. For example, with regard to profitability, the comparison process starts by asking the following: "With regard to profitability, which is more preferable – to adjust the basic safety stock level by 5-10 % or by 0-5 % -and how much more preferable is the preferred alternative?" By following this procedure, the alternative adjustment rates are prioritised with regard to each criterion. The overall priorities for the alternative adjustment rates in the hierarchy are calculated by summarising the priorities the adjustment rates have with respect to each criterion.

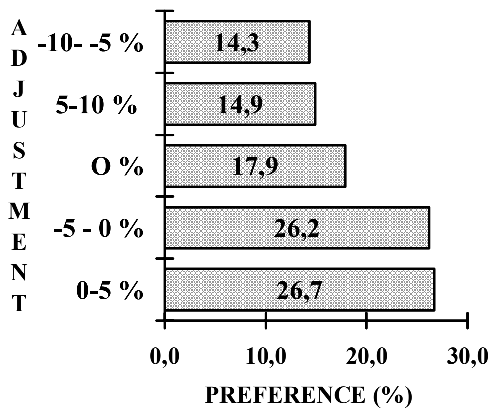

Figure 2. The priorities of the alternative adjustment rates

The resulting priorities can be seen in the Figure 1. The most important criterion is the impact on the supplier company with a priority of 0.493. The priority of the criterion "relationship" is 0.311 and that of the criterion "profitability" is 0.196. The overall priorities of the alternative adjustment rates can be seen in Figure 2.

The results presented in Figure 2 show the overall preferences of the alternative adjustment rates with regard to the importance of the customer B. As shown in the figure, the adjustment rate 0-5 % has the highest preference. In order to calculate the composite adjustment of the safety stock level related to a customer importance, the preferences of the alternative adjustment rates are combined by multiplying the average of each adjustment rate by its overall preference. The composite adjustment is then defined by calculating the sum of the multiplication results (see e.g. [18]). The calculation of the composite adjustment rate is presented in Table 1.

As shown in Table 1, the composite adjustment rate is 0.05 %. The interpretation of this figure is the following: taking into account the future importance of the customer B to the supplying company A, the basic safety stock level should be increased by 0.05 %. Although the adjustment is only small, it shows that the customer B is so important that the supplying company wants to secure the customer service capability for this customer.

Adjustment	Preference	Range average	Preference * Range average
5-10 %	0,149	7,5 %	1,11 %
0-5 %	0,267	2,5 %	0,67 %
0 %	0,179	0 %	0 %
-5-0 %	0,262	-2,5 %	-0,66 %
-10 - -5 %	0,143	-7,5 %	-1,07 %
TOTAL	**1**		**0,05 %**

Table 1. The composite adjustment rate

The impact of the future development of the customer

The second factor to be analysed is the future development of the customer. The goal of the analysis is to determine the impact of the customer's future business development on the safety stock requirement. The criteria that are used in this analysis are the following:

- **stability of the customer's business**, i.e. will the requirements of the customer be stable during the next six months or can a significant increase or decrease be expected
- **vulnerability of the customer** to shortages of the products supplied by the supplying company A, i.e. do the products of the supplying company have a critical role in the production process of the customer
- **supplier policy of the customer**, i.e. what is the role of the supplying company A in the supplier portfolio (a sole supplier or one among many suppliers)
- **new requirements**, i.e. will the customer B expand its business with new product launches during the next six months resulting to increased requirements towards the supplying company A

The AHP-hierarchy has the same structure as the hierarchy that was used for analysing the impact of customer importance. The goal is located at the highest level, the criteria at the second and the alternative adjustment rates at the lowest level. The hierarchy is shown in Figure 3.

The priorities for the elements in the hierarchy are derived by using the pairwise comparisons. The most important criterion is “supplier policy”, which has a priority of 0.340. The priorities of the alternative adjustment rates of the basic safety stock level are shown in Figure 4 and the calculation of the composite adjustment rate is presented in Table 2. Based on the analysis of the customer’s future development, the basic safety stock level should be adjusted by –0.08 %.

The impact of supply chain-related risks

The third factor to be analysed is the impact of supply chain-related risks. This analysis enables the supplying company to take into account and predict future events that could have an effect on the performance and functionality of the supply chain. The following criteria are included in the analysis:

- **production efficiency**: This criterion refers to the production capabilities of the supplying company taking into account e.g. the expected maintenance and investment shutdown periods and the estimated production efficiency (production rate per day) during the next six months.
- **booking situation**: The predicted booking situation of the production machinery has a significant impact on the supply chain performance. In a high-demand season, the production is running full thus decreasing flexibility and increasing the risk for delays of customer deliveries.
- **transportation reliability**: The transportation part of the supply chain can be affected by multiple factors, such as predicted strikes.
- **transportation availability**: This criterion takes into account the availability of transportation capacity which could become a problem especially during a season of very high demand.
- **warehousing**: This criterion refers to all warehousing-related factors with an impact on the supply chain performance.

The hierarchy structure and the priority deriving procedure are similar to the two previous analyses. The AHP-hierarchy is shown in Figure 5, the priorities of the adjustment rates in Figure 6 and the composite adjustment rate in Table 3. The composite adjustment rate is 2.49 %, which shows that the supplying company A expects to have some supply chain –related problems in the future and wants to secure the service level for the customer B by increasing the basic safety stock level.

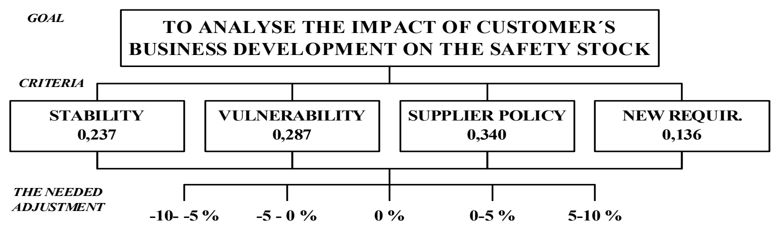

Figure 3. The AHP-hierarchy for analysing the impact of the future development of the customer

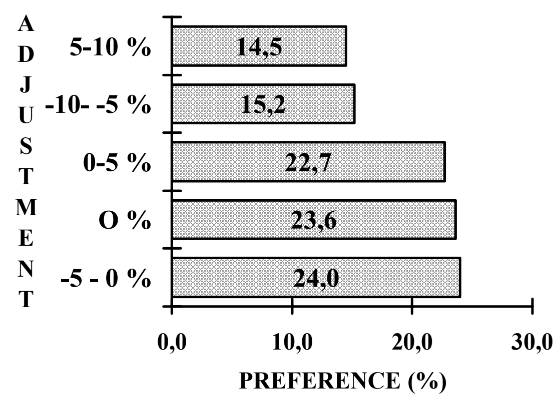

Figure 4. The priorities of the adjustment rates

Adjustment	**Preference**	**Range average**	**Preference * Range average**
5-10 %	0,145	7,5 %	1,09 %
0-5 %	0,227	2,5 %	0,57 %
0 %	0,236	0 %	0 %
-5-0 %	0,240	-2,5 %	-0,6 %
-10 - -5 %	0,152	-7,5 %	-1,14
TOTAL	**1**		**- 0,08 %**

Table 2. The composite adjustment rate

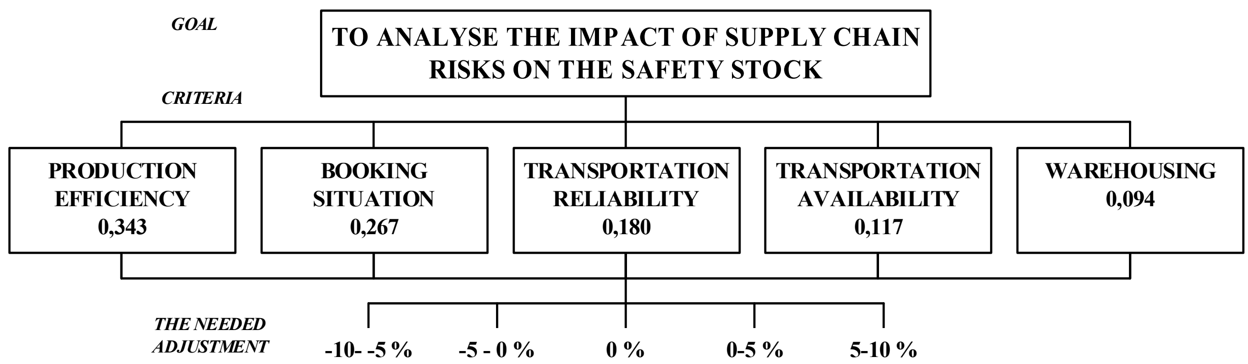

Figure 5. The AHP-hierarchy for analysing the impact of supply chain –related risks

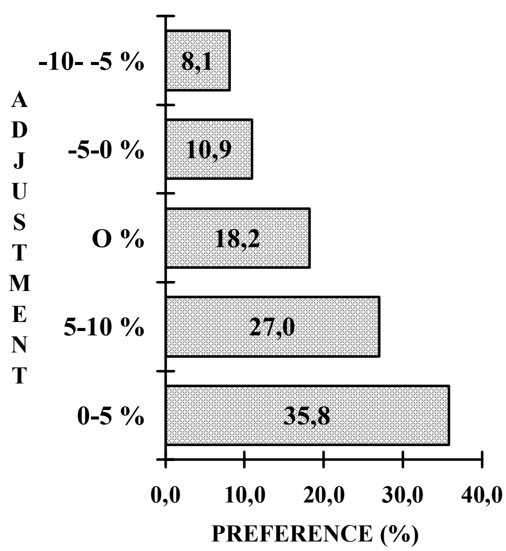

Figure 6. The priorities of the adjustment rates

Adjustment	**Preference**	**Range average**	**Preference* Range average**
5-10 %	0,358	7,5 %	2,69 %
0-5 %	0,270	2,5 %	0,68 %
0 %	0,182	0 %	0 %
-5-0 %	0,109	-2,5 %	-0,27 %
-10 - -5 %	0,081	-7,5 %	-0,61
TOTAL	**1**		**2,49 %**

Table 3. The composite adjustment rate

3.2 Summarising the results of the analyses

The last step of the proposed approach is to combine the results of the AHP-analyses into one figure that shows the overall needed adjustment of the basic safety stock level. In this illustrative example, three AHP-analyses were conducted resulting to the following adjustment rates: (1) 0.05 %, (2) –0.08 %, and (3) 2.49 %. The simplest way to combine these results is to calculate their average which in this case would be 0.82 %. This result means that the basic safety stock level (2000 SKUs) of the customer B should be increased by 0.82 % on the basis of the customer importance analysis, the future development of the customer's business and the analysis of the supply chain –related risks.

However, the implicit assumption in calculating the arithmetic average is that all the analyses have the same importance. The AHP could be applied even in this step to prioritise the analyses, as there might be differences between the importance of the different factors. The priorities of the analyses would then be used to calculate the weighted average of the results of the analyses.

4. Conclusions

Traditionally, the safety stock level has been determined based on statistics and past performance. The proposed approach provides the decision-makers with improved possibilities to complement the traditional safety stock calculation process by quantifying the impact of strategies and future events on the safety stock level. The proposed approach results to an adjustment rate that tells the needed increase or decrease of the traditionally calculated safety stock level.

The decision support tool used in this paper, the Analytic Hierarchy Process, provides a systematic and flexible framework for analysing the impact of factors, such as the importance of the customer, the future development of the customer and the supply chain-related risks. The flexibility of the AHP enables decision-makers to adapt the approach to match the specific circumstances of a certain situation. The AHP makes it possible to include both qualitative and quantitative factors in the analysis as well as subjective judgements by the decision-makers. An important aspect of the AHP is that with it and the corresponding Expert Choice – software the analysis process can be documented in detail. This also means that the analyses can easily be revised if e.g. new important information about a certain factor has been received.

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