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Simulation of the decision models to align Forecast and Inventory in the supply chain strategy

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Abstract:

The sales forecast is a prerequisite for the inventory decisions in the practical life. The right selection of the forecasting model to improve the inventory management can increase the customer service level and determine a better performance for the supply chain. The forecast performance should not only be evaluated by its standard error, but also its impact in the organization performance measures. The sales forecast should not be considered an individual function, but as an important part of supply chain management.

The paper presents the forecasting models found in the literature and evaluates the impacts on the inventory management using real data to simulate and to compare the behavior of each variable of the more representative models used in the companies.

Keywords: Supply Chain, Forecast, Inventory, Simulation

1. Introduction

The sales forecast is a prerequisite for the decisions of stock in practical life. Unfortunately most researchers on stocks ignores the sales forecast and simply assume known distribution of demand and all its parameters (Wanke 2003) and similarly there is little conclusive research in the area of sales forecasting to evaluate the its impact more broadly (Filders, 2008; Kerkkanen et al, 2009; Gardner, 1990, and Boylan, 2008).

According to Fildes et al (2008), the methods proposed of sales forecast has been more effective when they are linked to the application area and should be seen as a larger system. Forecast performance should not only be judged by its measurement error standard, but on the performance measures of the organization. Similarly, Kerkkanen et al (2009) show that the sales forecast should not be considered an individual function, but as an important part of managing the supply chain. He studied a case on one company who was seeking to improve accuracy in sales forecast to improve control of inventory policy and further clarification is needed to evaluate if the companies really align their forecasting systems with their actual impacts of the forecast errors.

Thus, it is proposed a study of models for sales forecast to assess the impact on inventory management that affect the alignment of supply chain.

Careful selection of the forecasting model for a better inventory management can increase customer service and establish a better performance for the supply chain.

It will be identified and selected some methods for sales forecast and performed simulation with real data to compare the behavior of the variables of each model and its impact on inventory management.

2. Objectives:

Investigate the impact of sales forecast in the inventory control for the strategic alignment of the supply chain.

Specific Objectives:

- Identify and evaluate different methods of sales forecasting and its impact on safety stocks applied to a real context
- Structure the steps to evaluate different methods of forecast and safety stock

3. Literature Review

3.1 Strategic Alignment Strategy in the Supply Chain

According to Chopra & Meindl (2003), the competitive strategy of a company define the set of consumer needs to be satisfied through its products and services. The competitive strategy alignment and supply chain strategy should consider three basic steps:

1. Understanding the customer: First, the company needs to understand customer needs in each segment. These requirements help the company to define the desired costs and required services. Chopra & Meindl (2003) suggest one key measure, which captures the variations of the different customer segments characteristics, called “uncertainty of implicit demand”. There is a difference between demand uncertainty and uncertainty implicit demand. The first one refers to the uncertainty of customer demand for a product. The second is the uncertainty due to supply chain, given the proportion of demand that the chain must handle and attributes desired by the customer.
2. Understanding the supply chain: The best way in which a company meets the demand is through its alignment with the type of supply chain. This alignment is related to responsiveness of the supply chain. The response would be to respond to large scopes, for example, quantities required, meet with short lead times, handle a wide variety of products, produce highly innovative products and meet a very high service level. For each strategic decision in order to increase responsiveness, more costs will be added, efficiency will reduced and buffer stocks will be higher to meet the unexpected demand, but the supply chain will be faster to meet customer requirements (with reduced manufacturing time and delivery, increased capacity and supply).

3. Doing the strategic alignment: It must have a matching between what the supply chain is doing and what was set in competitive strategy, otherwise one of them (competitive strategy or strategy of the chain) should be revised. To achieve complete strategic alignment, a company must consider the functional strategies within the value chain, ensuring that have coherent strategies to support the competitive strategy. It is worth noting that all sub-strategies within the supply chain must also be consistent with the degree of responsiveness of the chain. The degree of supply chain responsiveness must be consistent with the uncertainty implicit demand uncertainty. For a high level of performance, companies must conduct their competitive strategy and its strategy of supply chain toward the area of strategic alignment.

3.2 Coordination of supply chain alignment

The lack of alignment / coordination in the supply chain can bring problems such as bullwhip effect, mentioned by Lee (1997), which describes it as a frequent problem encountered in the supply chain, where demand is increased along its movement in the supply chain, bringing a number of inefficiencies such as excess inventory, poor level of service etc. This phenomenon was raised by Forrester (1961) through a series of case studies, noting that the basic policies used by an organization can lead to undesirable behaviors in the supply chain. Sterman (2000) created a way of teaching inventory management to demonstrate this phenomenon through the causal structure of the Beer Game. Fildes et al (2008) says that the bullwhip effect and the benefits of information sharing have provided a valuable opportunity for the academic models, but their results so far have not reached the forecasters, or academics or practitioners, in part because some of researchers did not show any signs of having spent time in field work. Chen et al (2000) reported that the bullwhip effect is due the effects of sales forecast and even with the sharing of information through all stages of the supply chain, the effects remain.

3.3 Demand / Sales Forecast

Considering the importance of demand forecasting in the context of supply chain, Chopra & Meindl (2003) says that the forecast of future demand is the basis for all strategic decisions and planning in a supply chain. Managers plan all activities of the supply chain based on an estimate of when the sale to the customer will occur.

The sales forecasts have the following characteristics: they are always wrong and should therefore include the expected value and a measure of forecast error, the long-term forecasts are usually less accurate than short-term, and i.e., long term forecasts have a standard deviation higher than the short-term ones, aggregated forecasts are usually more accurate than the forecasts not aggregated.

The demand has a systematic component and a random one. The goal of forecasting is to estimate the random component and to foresee the systematic component. The estimate of the random component is a measure of uncertainty of demand. The random component is usually estimated as the standard deviation of demand.

3.4 Relationship between Demand Forecasting and Inventory

According to Wanke (2003), a key element to define the inventory policy in a company is the demand visibility. The extent, to which real demand penetrates in the supply chain towards to the supplier, is known as a point of demand decoupling. This is directly related to the coordination of the supply chain, as mentioned earlier. Under very specific conditions, to react to demand in the production and distribution and, production planning through sales forecasts can be a good inventory management policy.

According to Ballou (2004), stocks are held by companies to:

- increase the service level offered to customers
- reduce costs

Some studies have been conducted to evaluate the forecast performance related to inventory management (Gardner ,1990, Campbell, 1995, Peixoto et al, 2006 and Boylan,2008).

Zinn and Marmorstein (1990) compared two methods of determining inventory levels. In the first method, called System Demand, he refers to the level of safety stock which depends on the variability of demand and the second method, called Forecasting System, which depends on the variability of the forecast errors demand. The simulation to compare the two methods indicated that the forecast system typically requires 15% safety stock to provide the same level of safety stock.

Most researchers on stocks ignore the sales forecast and simply assume known distribution of demand and all its parameters (Wanke 2003). It was assumed a distribution whose parameters are estimated from actual data. Sometimes it is not clear what the correct estimates for the mean and standard deviation related to sales forecasting.

3.5 Product Availability of product / service level

The service level is directly related to meet the customer demand, i.e., the product availability associated to the inventory level to maintain the availability. There are several models to determine the product availability or service level, and some models to minimize the inventory cost or supply and others maximize the service level considering the costs and inventory constraints.

Using service level eliminates the need for the materials manager to specify a precise cost, to establish a criterion for an acceptable quality of service.

Product availability reflects the company's ability to meet the requests from the available inventory. If the customer orders arrive when the products are not available, the company will not be able to attend them. There are several ways to measure the product availability. All measures of availability are defined on average over a period of time (Chopra & Meindl, 2003)

Schneider, H (1981) lists three types of service levels:

- Alpha service level: the probability that the inventory on hand at the end of any period does not fall below a critical level (this is also known as the “ready rate”)
- Beta service level: the expected fraction of demand met directly from inventory on hand in any period (also known as the “fill rate”)

- Gamma service level: expected fraction of cumulative demand met directly from inventory to total cumulative demand during the lead time plus a review period (this measure is similar to beta, except the ratio is taken over a number of periods, rather than a single period).

3.6 Inventory Management

According to Ballou (2004) there are several stocks classifications (stock in transit, cyclical, seasonal, safety, speculative and obsolete), but this study focuses on safety stock, which is maintained as a protection against demand fluctuations replenishment lead time.

Safety stock is maintained in order to meet a demand that exceeds the amount for a particular period. Safety stock exists because the demand forecasts are inaccurate and there may be lack of product if the demand exceeds the planned volume.

The appropriate level of safety stock is determined by the following factors: uncertainty in demand and desired level of product availability. As the uncertainty of supply and demand grows, the level of safety stock required increases. As it increases the safety stock, the greater the level of customer service (Chopra & Meindl, 2003)

3.6.1 Demand Forecasting Models

The evolution of forecasting management or methods has been studied by several authors as Jain (2003), Sanders and Manrodt (2003) and McCarthy et al (2006).

According to Jain (2003), forecasting models are the heart of the forecast. To achieve best results the right data must be combined with the correct model. Each dataset has a set of standards and each model follows a pattern.

According to Wanke (2006), a forecasting technique is the mathematical or statistical calculation used to convert historical data and parameters in future quantities.

The forecasting techniques are divided into (Chopra & Meindl, 2003, Jain, 2003, Wanke, 2006):

- Qualitative techniques: they depend on exclusively on the expertise of the forecaster, They are more appropriate when there are few historical data available or when the experts have market intelligence, crucial to the achievement of the forecasts.
- Quantitative techniques:
 - o Time Series: the forecasts are prepared to extrapolate the past data. Assume that the past pattern will continue in the future. They usually work for short-term forecasts, when the situation is stable and the pattern of demand does not vary significantly. There are more than 60 methods that fit this definition and will be listed only the main ones:
 - Time Series Models Fixed: show equations defined based on prior evaluations of the existence of certain components of historical
 - Simple Average
 - Simple Moving Average
 - Dual Moving Average
 - Simple exponential
 - Double Exponential Damping - Method Brown
 - Double Exponential Damping - Method Holt
 - Time Series Model Open: analyze the time series to identify which components are actually present, thus creating a single model that projects such components, predicting future values.
- Causal Models: when there is a cause (called independent variable) and there is an effect (called dependent variable). Determine the average relationships between dependent and independent variables to forecast the future. These models are used when there is a strong relationship between cause and effect and the relationship between them and do not change significantly at least during the forecast period.

- Simulation: reproduce the consumer choices that generate demand. Using the simulation, the company can combine time series models and causal to answer questions about the impact of a sales price, the impact of opening up a store of a competitor, etc.

3.6.2 Selection of Forecast Method

A company needs to decide which model is most appropriate for the forecast. Indeed, several studies indicate that the use of multiple prediction models, and then combining their predictions in real prediction is more effective than the choice of an individual mode (Chopra & Meindl, 2003)

Wanke (2006) notes two types of technique selection:

- Evaluation of the technique and its applicability. It is relevant to know the factors, such as seasonality and trend, and the size of historical data available and complexity of deploying and maintaining the technique
- Choosing the forecast accuracy. There are a number of measures of forecast accuracy, some examples are listed below:
 - Method Mean Absolute Deviation (MAD) to evaluate the error of the estimate to the influence of signals, thus a negative error will not invalidate a positive error.
 - Method Mean Percentage Error (MPE): checks if the forecasting model has some tendency, that is, if the estimated values of the forecast are systematically above or below the demands
 - Method Mean Absolute Percentage Error (MAPE): aims to assess the magnitude of error in relation to the series. The calculation is done in percentage
 - Method Mean Squared Error (MSE) to estimate the variation of the error of a forecast, rising to the mean square errors and dividing the result by the number of periods.

Armstrong (1992) listed several guidelines for the measures of error selection. He comments that a change made in one model should be easy to see because it affects the performance.

For the selection of the forecasting methods, the primary criteria are:

- Reliability: address the question whether the application of a procedure will produce similar results.
- Construct validity: there is a measure to measure what is supposed to measure.
- Protection against the points off (outliers)
- Sensibility: calibration is desirable to have a measure of error sensitive to reveal the effects of changes. This measure should indicate the effect on accuracy when a change is made in the parameter for a given model
- Relationship to decision making.

According to McCarthy et al (2006), lack of familiarity with quantitative and qualitative techniques can lead to dependence on the techniques familiar to the individual and not proper applicable to the product. He also commented on the criteria for effective evaluation of sales forecasting found in studies conducted by them: accuracy, reliability, performance, customer service, ease of use, inventory turns, amount of data required, cost and return on investment.

3.6.3 Calculation of safety stock from service level

In practical situations, companies have a desired level of product availability and they want to develop replenishment policies that achieve this level. The desired level of product availability can be determined by the trade-off of the cost of maintaining the stock with the cost of a depletion of stock. Whereas a policy of continuous review replenishment, i.e. the stock is continuously monitored and an application for lot size is done when the stock falls to the reorder point (ROP). Continuous monitoring of the stock allows the manager to adjust the time of the request for replenishment depending on the demand presented. The concern is only with the uncertainty of demand during lead time.

There are some ways to calculate safety stock and it will be adopted Replenish Lead time (RLT - time between the time the order is placed and when it is received) and a Service Level (SL) fixed and, a single point of stock.

Average demand during lead time = Rl

Deviation of demand during lead time = σl

Safety stock = SS

Standard Distribution Function = F

Probability (demand during the lead time $\leq Rl + SS$) = SL

$$SS = F^{-1} * (SL) * \sigma l \text{ (equation 1)}$$

Using Excel: $SS = \text{NORMSINV}(SL) * \text{STDEV}(Rl)$

4. Methodology:

According to the literature review, the sales forecast has consequences throughout the supply chain and little attention has been given to measure the impacts, mainly the impact on inventory management.

The approach of the work is based on the qualitative and quantitative research based on empirical models.

According to Bertrand and Fransoo (2002), quantitative research is classified as an approach to generate rational knowledge, based on the assumption that can build models that explain (part of) the behavior of real life processes or operation that can capture (part of) the problems of decision making that are encountered by managers in the operational processes of real life. The models can be used to predict the future of the modeled processes rather than being restricted to the explanation of the observations, already dealing with causal relationships and quantitative.

This type of research is concerned with testing the validity of scientific models used in theoretical or quantitative research to test the applicability and performance of solutions obtained from quantitative research in theoretical operational processes in real life.

The methods used for forecasting and inventory in this investigation were already developed by previous research.

It was performed simulation using quantitative technique forecast focused on Time Series Models Fixed.

It was followed the steps listed by Bertrand and Fransoo (2002) for this type of research:

- Identification of basic assumptions related to the process to be studied and the type of processes and decision problems considered establishing criteria for selection of such processes.
- Identification and selection of the types of conceptual models / science applied to the types of processes and problems considered. Example: sort according to profiles of demand (seasonality, low or high demand), history of product data and lifecycle of the product
- Development of hypotheses / propositions
- Development of measurement system to measure the relevant variables and observe their relationships.
- Selection of companies to collect data.
- Collection of data derived from the measurement system and the observations
- Interpretation of data and understanding of causal relationships
- Simulation of the models selected using the input data of the actual process required in each model, including also the simulation with all historical data available
- Analysis of the results compared with the results of the real against the simulation models
- Conclusion: confirmation, rejection or improve the designs or gaps in the survey results or the study itself

It was selected data from one large supply chain in Brazil, an emergent country.

The collection of data was send by the responsible for the data generation (production planners) and it was focused on consumer products. It was considered 41 weeks of data, from beginning of the life cycle of each product. Data was divided in two periods of 20 weeks and 21 weeks.

Inconsistent data was replaced by the average of the two previous weeks. Data was considered inconsistent if only one week was below or above of 80% from the average of the two previous weeks in a period of 8 weeks.

It was considered 90% of the service level.

Mean absolute deviation was considered to compare the methods even knowing that this kind deviation maybe is not proper to evaluate some methods, but as a comparison method is still valid.

Each of the models was analyzed in detail and the following propositions were listed:

- 1) impacts on stocks vary according to the methods of forecasting, but the same forecasting methods are affected by the life cycle of the product
- 3) The larger the forecast errors, greater impact on stocks and greater impact on the level of customer service

5. Results

Summary of 4 types of products (A,B,C,D) is showed in the Table 1.

The average distribution of 4 products in total volumes is:

A= 30 % of total volume

B= 40% of total volume

C= 20% of total volume

D= 10% of total volume

A1, B1, C1, D1 = first period: 20 weeks

A2, B2, C2, D2 = second period: 21 weeks

D3: third period: 20 weeks

It was found a lot of variation among the methods

Product	A1	A2	B1	B2	C1	C2	D1	D2	D3	D2+D3
Simple Average (SA) - Safety Stock	5724	9778	15625	16460	7386	6463	6262	2558	2996	2788
Error	81%	47%	84%	56%	84%	36%	129%	129%	95%	111%
Mean absolute deviation(MAD)	4466	7630	12192	12844	5763	5043	4886	1996	2338	2175
Simple Moving Average (SMA) N=2 - Safety Stock	3589	12713	10256	11250	2587	3126	1478	2857	1989	2449
Error N=2	68%	70%	88%	73%	75%	26%	92%	77%	93%	84%
Mean absolute deviation(MAD)	2800	9920	8003	8779	2019	2439	1154	2229	1552	1911
Simple Moving Average (SMA) N=3 - Safety Stock	3163	13014	10278	11489	2311	2772	1193	2925	1805	2396
Error N=3	69%	68%	91%	67%	77%	24%	51%	83%	95%	87%
Mean absolute deviation(MAD)	2468	10155	8020	8965	1803	2163	931	2283	1409	1869
Simple Moving Average (SMA) N=4 - Safety Stock	2714	13260	9979	11705	2111	2587	1103	2962	1741	2415
Error N=4	78%	69%	84%	69%	77%	17%	53%	86%	97%	86%
Mean absolute deviation(MAD)	2118	10347	7786	9134	1648	2019	860	2311	1359	1885
Dual Moving Average (DMA) N=2 - Safety Stock	6118	15073	16315	13978	4631	4542	2747	3385	3224	3243
Error N=2	106%	91%	140%	95%	108%	35%	72%	127%	128%	127%
Mean absolute deviation(MAD)	4774	11761	12731	10907	3614	3544	2143	2641	2516	2530
Simple exponential (SE) - Safety Stock	1300	7907	5218	9557	1004	2083	4395	2768	2489	2622
Error	64%	51%	67%	56%	83%	30%	213%	103%	69%	86%
Mean absolute deviation(MAD)	1014	6170	4071	7457	784	1625	3430	2160	1942	2046
Dual Exponential (SE) - Method Brown - Safety Stock	3180	12792	9484	11986	1915	2784	2746	2765	2086	2436
Error	68%	65%	83%	72%	63%	21%	106%	99%	82%	88%
Mean absolute deviation(MAD)	2481	9982	7400	9353	1495	2173	2143	2157	1628	1901
Dual Exponential (SE) - Method Holt - Safety Stock	1895	6100	4677	7812	919	1587	5320	2810	2507	2651
Error	54%	49%	56%	50%	76%	38%	252%	99%	67%	82%
Mean absolute deviation(MAD)	1478	4760	3649	6095	717	1238	4151	2193	1956	2068

Table 1 – Forecast Methods and Safety Stock summary

Best results are showed in Table 2:

A1	A2	B1	B2	C1	C2	D1	D2	D3	D2+D3
Dual	Dual	Dual	Dual	Dual	Dual	Simple Moving Average (SMA)	Simple Moving Average (SMA)	Simple exponential (SE) or Dual Exponential (SE) - Method	Simple Moving Average (SMA)
Exponential (SE) - Method	Exponential (SE) - Method	Exponential (SE) - Method	Exponential (SE) - Method	Exponential (SE) - Method	Exponential (SE) - Method	N=3 or Simple Moving Average (SMA)			
Holt	Holt	Holt	Holt	Holt	Holt	N=4	N=2	Holt	N=2

Table 2 – Best forecast methods found

6. Analysis

There is a lot of variation of safety stock level among the forecast method used.

High volume products seems not to be affected by the life cycle of the product related to the forecast method selection, but it is possible to identify clear distinction of the 2 periods related to the safety stock levels and demand increases. The forecast method can be the same because it is aligned to the safety stock level in the both periods.

Medium volume products can have conflicts with the errors and safety stock levels related to forecast method selection. Higher error not always correspond to higher safety stock

Low volume products can have higher variation of the forecast and it is difficult to select the best method. Three periods was evaluated and seems that Simple Moving Average (N=2 or N=3) should be the better selection to maintain forecast method for whole period, not having optimized safety stock, but a balance between error and safety stock.

7. Conclusion

The selection of the method of sales forecast can not only consider the standard deviation of the error and should be analyzed under the impacts on the results of the company. This study has considered the impact on the level of service by establishing the appropriate level of inventory to meet customer orders.

It was shown a structure of concepts and how to evaluate the forecast methods considering the safety stock. It was possible to show the high variation of safety stock to be maintained depending on the method of forecasting, the lifecycle of the product and its sales volume.

There are some limitations in the study, for example, no comparison to other types of safety stock calculation commented by some other authors in the literature or to use other types of forecast errors evaluation, but that could be taken into account in future studies using the same structure comparison. Other categories of products should be also evaluated.

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