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# Analysis of Forecasting Errors in Supply Chain

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**Abstract**

Demand forecasting is one of the important activities in a supply chain which provides all the supply chain planning processes with market information crucial for efficient supply chain management. Its performance is measured by forecasting error, which is defined using the difference between forecast and actual sales. In this paper, we classify the forecasting error types based on the cases the discrepancy takes place through the supply chain. We demonstrate that different products can have different combinations of these forecasting error types. Finally, we indicate shortcomings of common forecasting error measures and conclude the paper with remarks on desirable forecasting error measures.

**Keywords:** Forecasting Accuracy, Forecasting Error Measure, Supply-Demand Matching

## 1. Introduction

Demand forecasting is considered as one of the basic operations which enable the whole supply chain management activities. Based on the demand forecast, the manufacturer decides how many products to make, how much capacity to be needed, and how much raw material to buy. By its nature, forecasting is rarely correct. Inaccurate forecasting results in either excessive inventory or lost sales opportunity [1, 2].These are the typical examples of costs to avoid in today's business environment where demand changes rapidly and product lifecycle is short. Therefore, the manager is interested in monitoring and controlling forecasting errors in order to enhance forecasting accuracy. In practice, it is common to use a single metric to measure the accuracy of demand forecasting. Several measures have been suggested and adopted to manage forecasting error by quantifying how much the actual sales deviate from the forecast [3]. In this paper, we first identify the several cases which create the difference between forecast and actual sales. Next, we show that the possible forecasting error causes can be associated with product characteristics and emphasize that the forecasting error measures should be designed to recognize each error types.

## 2. Forecasting Error Types

It is traditionally the making and sales (M/S) who are responsible for demand forecasting. They have frequent contacts with the customers and better understanding of the market. Depending on product types, market size, and sales volume, M/S usually has several segments for demand forecasting. For example, they can make forecasting on each product or group several products and make forecasting on the group. How to organize forecasting segments is tightly related to the company's marketing strategy. Once they create the forecasting segment, M/S make periodical demand forecasting for each segment. The forecasting period is commonly chosen to be the same as the production planning period, since demand forecast is one of the input data for production planning.

Considering demand forecast and other information such as production capacity, the manufacturing (MNF) function decides the production plan. Once it finalized, the production plan is informed to M/S in form of Return To Forecast (RTF). Since there are other considerations for making production plan, RTF is sometimes smaller than the demand forecast. After receiving RTF, M/S establishes its own marketing and sales plan, called demand management, to sell as much as RTF. At the same time, MNF does its efforts to produce and deliver the planned quantity, RTF. If MNF fails to meet the target production quantity for some reasons, M/S may not have enough products to sell. Here, we have two causes for forecasting error. We call the forecasting error Type 1when it is due to RTF smaller than demand forecast and Type 2 when it is due to Available quantity To Sell (ATS) less than RTF.

There are several explanations for why these forecasting errors happen. The mismatch of forecast and RTF (Type 1 error) is very common for the products whose demand is so high that the capacity of MNF is not enough to meet all the demand forecast. In this case, an allocation problem arises in order to decide how to distribute the limited number of products to M/S segments. Whatever allocation rule to be used, it is inevitable that most M/S segments would receive RTF smaller than demand forecast. Note that RTF is kind of a promised quantity that MNF will deliver for a specific period in the future. There are a lot of uncertainties which make MNF unable to keep it. It may be from internal causes such as production delay, facility breakdown, or from external ones such as material supply discontinuity, distribution network problem.

ATS is the inventory level which is available for M/S to meet the customer orders. Obviously, actual sales cannot exceed ATS even though there are more demands for the product. On the other hand, if demand is not as much as ATS, another type of forecasting errors occurs. This type of forecasting error (Type 3 error) is usually contributed to the tendency of M/S to over forecast product demands. Especially, when M/S are not careful about demand forecasting and have a misguided belief that they can sell as much as they have, over forecasting frequently happens for the product which MNF has enough capacity to produce.

Unlike the forecasting error types discussed so far (Type 1, 2, and 3), the last type (Type 4) happens when the demand is underestimated and the actual sales have been more than the forecast [4]. Depending on the management's attitude, under forecasting does not attract much attention than over forecasting because they are happy with the fact that the sales were beyond their expectations. Actually, once the supply chain is carefully designed to keep low level of safety stock, under forecasting does not take much account of forecasting errors because MNF produces at most as much as forecast. A large Type 4 forecasting error caused by under forecasting needs to evaluate the current supply chain performance and modify production and inventory policies.

Figure 1 depicts the four types of forecasting errors. As explained previously, Type 1 through 3 errors are subcategories of over forecasting error (Sales < Forecast) while Type 4 is another name of under forecasting error (Sales > Forecast). Since each forecasting error has different reasons and responsibilities, it would be desirable that the forecasting error or accuracy measure captures all the error types and identifies the main challenge for improving demand forecasting.

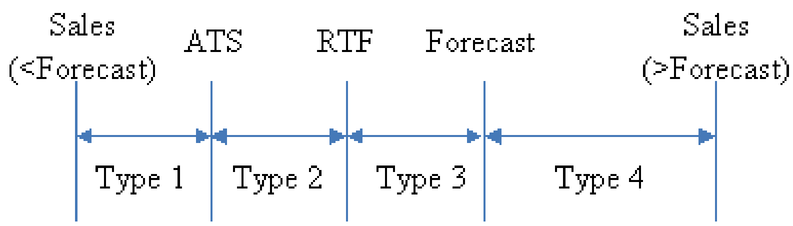


**Figure 1. Types of Forecasting Errors**

## 3. Forecasting Error Measures

In many companies focusing on improving supply chain performance, forecasting accuracy is one of the key performance index measuring M/S functions. Matching supply with demand is the ultimate goal of most supply chain managing activities. Demand forecasting is the starting point of all the efforts to achieve this goal. It is more desirable approach to ask M/S for reliable forecasting than just requiring MNF to produce as much as forecast. However, the measure should be carefully designed to work as intended. As discussed in the previously section, there are several types of forecasting errors and not all of them are attributable to the poor performance of M/S. Since demand forecasting is one the main roles of M/S, it is often neglected that the whole supply chain should work together to achieve perfect forecasting accuracy. Especially in over forecasting cases, many causes outside of M/S functions can deteriorate forecasting accuracy. Even if M/S exactly predicts customer demands, for example, supply shortage makes Type 2 or 3 error and in turn poor performance in sales forecasting. Therefore, forecasting accuracy measure should be designed to make it easy to recognize the responsibility and find out possible reasons.

The most common measure for forecasting error adopts Absolute Deviation (AD) from the original forecast; Forecasting Error = |Forecast – Sales|/Forecast. Figure 2

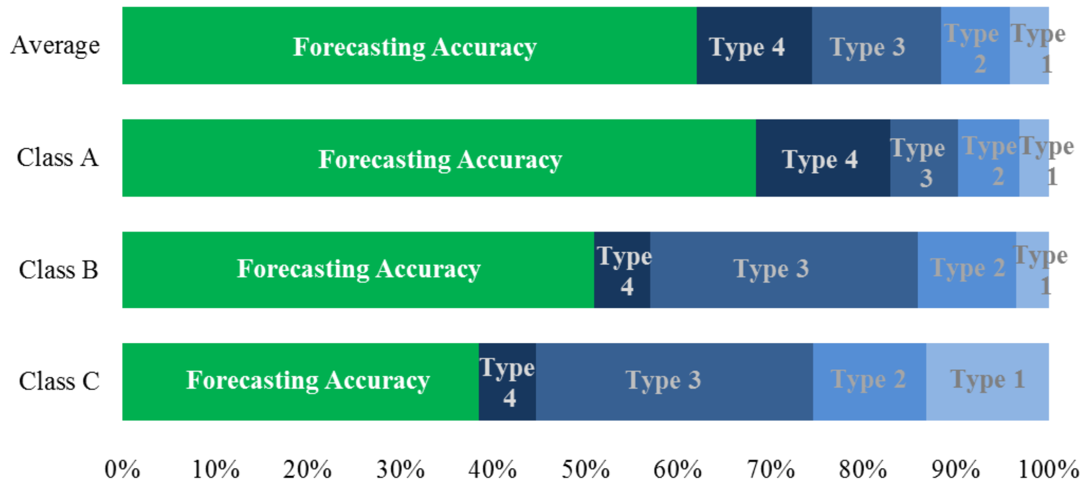


**Figure 2. Forecasting Error Example by ABC Classification**

depicts a typical example of forecasting errors measured by AD and shows how much proportion each error type takes for the error.

In order to demonstrate characteristics of forecasting error types, we categorize the products into three classes using the ABC classification. In the descending order of sales volume, Class A, B, and C takes the first 80, the next 15, and the remaining 5 percentage of total sales, respectively. While it accounts for a large (small) portion of sales, Class A (C) includes a small (large) number of product items. Hence, it is more likely that M/S focuses most of their attention and efforts to Class A and, in return, it achieves higher forecasting accuracy than Class B or C as shown in Figure 2. The fact of a product item being in Class A implies that it has high demands and more chance for lost sales than other class items. Figure 2 shows that Type 4 (under forecasting) error is observed more often in Class A than B and C. On the other hand, the forecasting errors by over forecasting happen more frequently for Class C product items. Out of three error types for over forecasting, Type 1 and 3 take most of the error causes.

The most notable problem with AD measure is that it does not distinguish under- and over-forecasting errors. This problem can be solved by simply taking off the absolute value; positive value means over forecasting and negative one means under forecasting error. However, this non-absolute deviation measure has a shortcoming of cancelling-out effect over multiple periods. When over- and under-forecasting errors coexist, their plus and minus forecasting errors are added into a relatively small total and average forecasting error. For this reason, this simple type measure is not desirable in practice where they measure their operation’s performance over a long rage and prefer to use the average as the single number representing the performance.

**4. Concluding Remarks**

In order to reduce forecasting error, every function through the supply chain including MNF should carry on its duty in addition to M/S trying their best efforts to understand the uncertain nature of customer demands. Managing by simple measures of forecasting error may neglect this interdependency between supply chain functions for attaining high level of forecasting accuracy. Depending on its type and reason, forecasting error should be identified and improved by taking appropriate remedy actions in the proper function. It is probably one of the first things to devise effective performance measures which can drive the right function into the right direction to better forecasting [5].

It would be not possible to identify and measure all the forecasting error types explained in this paper by a single forecasting error metric. Also, it would not be desirable to measure the performance of different supply chain functions (e.g., M/S and MNF) with the same metric. Different definitions of forecasting errors can help each function pursue their own contribution for improving the whole supply chain optimality [6]. However, from the managerial viewpoint, it is bothering and inefficient to devise and apply multiple performance measures. It is an open area for research to analyze the trade-off between using a single and multiple forecasting error measures and find out how to coordinate each supply chain function for achieving the optimal demand forecasting.

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