

# **Applying Demand Aggregation to Improve Forecasting Accuracy**

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## **Abstract**

Forecasting accuracy is an important issue for effective decision making in the areas of strategic planning, production planning, inventory management and other areas. In particular, this aspect is most relevant for items that have demand patterns with important levels of intermittency and lumpiness. This work describes the efforts of a Mexican company to look for opportunities to improve the level of forecasting accuracy through the application of demand aggregation to all the items of the company's catalogue. The level of demand aggregation considered is a period equivalent to the review plus de response time periods of the periodic review management system used by the firm. Initial results are obtained from a pilot study carried out in all the stores of the Tijuana plaza of the company. The resulting forecasting mean squared error (MSE) was decreased significantly in the range of 32 to 56%. The firm estimates a reduction in the order of 17.7 to 33.9% in safety stock requirements will be possible due to the improvement in forecasting accuracy.

## **Keywords**

Replenishment inventory; display inventory; retail echelon; erratic demand

## **1. Introduction**

Forecasting is a prediction of future events used for planning purposes that has to do with the estimation of the value of a variable (or set of variables) at some future point in time. Monks (1987) defined forecast as estimate of occurrence, timing or magnitude of future events, that an operations manager uses as a rational basis for planning and scheduling activities, even though actual demand is quite uncertain. Krajewsk, et al., (1998) see forecast as a prediction of future events used for planning purpose and this is needed to aid in determining what resources are needed, scheduling existing resources and acquiring additional resources.

Decision making in Supply Chain Management requires the use of demand forecasting to manage future uncertainties and risk. Strategic and operational planning success depends in a great extent on the accuracy of forecasts. Thus, managers are willing to spend money, time and effort to achieve it.

According to Kurzak (2012), the level of competitiveness of a market economy determines the variability of demand for particular goods. The level of production should reflect customer demands that can be estimated by means of forecasting. The goal of forecasting is providing possible most objective and substantial prerequisites for making business decisions and analysis of the events that might occur. The need for forecasting is inherent in each enterprise, regardless of whether they manufacture, provide services or sell goods. Therefore, it is essential that forecasting is used in decision-making processes as it might contribute to improved accuracy of decision-making. Forecasting in production enterprises allow for finding the most probable course of processes. When defining the most important tasks for the enterprise, the managers should be based on the forecasts.

An essential part of managing enterprises is ability to forecast future events, i.e. forecasting. No decision can be made without accurate and precise forecasts as they are primarily concerned with the enterprise's future. Therefore, the causes of development of forecasts in the enterprise are:

- uncertainty,

- delay in time between the moment when the decision is made and its effects.

Therefore, the process of planning should differentiate between forecasting and planning. According to Cieślak (2001) a forecast is a scientific judgement concerning the likelihood of a particular events in the future. Although this judgement is uncertain, it is acceptable. On the other hand, Nowosielski (1997) states that planning is a process where:

- the relationships between the forecast variables are analyzed and the type and tactics for operations are chosen,
- the future effects of decisions are defined in order to limit the uncertainty of operations,
- the best (according to a particular criterion) variant of activities is chosen and deviations for performing this variant are analyzed.

Therefore, planning includes forecasting methods, extended with irrational behaviours, experiences, manager's intuition and experts. Thus, forecasting is a part of the process of planning (Nowicka-Skowron 2011). The process of planning, and, consequently, forecasting should be carried out based on the following planes (Nowosielski 1997):

- strategic (long-term): in strategic forecasting, the tangible-market strategies and the tangible, human and financial resources are defined,
- operational and tactical (short-term and aggregate for partial plans): the focus in operational and tactical forecasting is on short-term activities that affect the enterprise's strategy, and of particular interest impact the level of total inventory.

An important sector in the Mexican economy where forecasting is a key tool for success is the retailing sector. The Mexican C-S sector was located in position 11 among the first 15 biggest world markets in year 2014 with total sales of 8500 million dollars. This level of sales was generated by 17,450 stores established throughout Mexico. The leading company in this sector contributed with 12,853 stores and a market share of 88% in that year. This firm will be called "The One" hereafter. One of the greatest challenges of C-stores to be competitive refers to inventory management. This is fundamental to maintain high levels of product availability and insure customer satisfaction. This aspect represents an important weakness for "The One". The average level of inventory in stores for "The One" is estimated in 30 days which is considered very high considering replenishment cycles of seven days.

This work has the purpose of describing the efforts of "The One" to increase the level of forecasting accuracy and measure its impact on the level of inventory in the distribution centers and stores of the company. The document is structured as follows. The first section presents an introduction and general context. Second section describes a summary of bibliographic research relevant to the problem of interest. The following section provides a description of the general methodology followed to treat the problem. Then, the application of this methodology is given in the fourth section, followed by the fifth section of results and conclusions.

## **2. Review of concepts and methodology for forecasting**

With regard to the type of the data used for forecasting, with particular focus on building models used as a basis for forecasts, there are qualitative and quantitative forecasting methods (Jacobs et al., 2011).

- **Quantitative methods** are based on forecasting models constructed based on time series. They include e.g. models of trends, linear regression, econometric models. Therefore, forecasting of the future utilizes statistical and economical models, mathematical models and optimization models. Opportunities for using quantitative methods are determined by availability of particular data. Therefore, it is necessary to collect, process and extrapolate historical data. Although quantitative methods are regarded to be more objective than the qualitative ones, application of these methods makes sense mainly in short-term forecasts.
- **Qualitative methods** allow for description and forecasting of events that cannot always be examined based on the historical data. They are based on intuition and experience from the past, concerning the way a particular variable changes. The qualitative methods are also termed as intuitive methods and are numbered among subjective methods since the results obtained depend on conscious creation of the past and on the ability of a forecaster to order and associate particular pieces of information with each other.

The consequences for an organization when the forecasting precision is limited can be severe, especially if the precision continues to be limited for a longer period of time. An underestimation of a future need may result in lost sales or inability to fulfil the undertaking of the organization for example medical supply. Overestimation on the other hand may lead to excessive capital tied to a stock that in the end is impossible to sell. In inventory control the conflicting goals between keeping the inventory low and avoiding stockouts and lost sales must be balanced.

If a company wants to be successful it is not enough to focus on the most moved items with the highest sales. According to Johnston et al., (2003) approximately 75% of the item lines are moved six times or fewer in most branches. The slow moving items are responsible for over 40% of the income and require approximately 60% of the total investment in stock. According to Putts (2014), a slow moving item “has a very low demand compared to the average products. Due to batch sizes the minimum order quantity of these products can be very high in comparison with the demand. This will result in ordering and storing a large quantity of products when the inventory level drops below the ordering point. A preliminary analysis has shown that for some slow moving items the minimum order quantity is enough to satisfy demand for a whole year.” Figure 1 presents an example of the demand pattern behaviour of a C – F item. In short, this type of items presents an intermittent demand pattern with very infrequent demand arrivals and high demand size variability.



Figure 1 Illustration of the demand pattern behavior for chocolate turin

The accuracy of a forecasting method for a particular product depends on characteristics exhibited by the product's demand history. Consequently, demand time series are sometimes divided into several discrete categories in order to assign the best forecasting method. The idea of categorizing demand patterns initially appeared in Williams (1984), who studied the classification of products by demand type, stock control policies for different categories of products, and methods of forecasting demand for the different categories of products. A new approach to this problem was suggested by Syntetos et al., (2005) (to be called SBC hereafter). SBC categorize demand based on the expected mean square error of each forecasting method under some assumptions. They compare the method suggested by Croston (1972) (hereafter CRO) and a bias-adjusted version of Croston's method due to Syntetos et al., (1999) and hereafter referred to as SBA. From this comparison they propose the four discrete categories of demand shown in Figure 2 which they label 'erratic', 'lumpy', 'smooth' and 'intermittent'. The four quadrants are uniquely specified by two parameters  $p$  and  $v$ , where  $p$  is the average inter-demand interval and  $v$  is the squared coefficient of variation of the demand when it occurs. SBC argue that CRO should only be used for smooth demand series and that demand series from the other three quadrants are best forecast using SBA. The threshold values defining the quadrants are given as  $p = 1:32$  and  $v = 0:49$  respectively. Both CRO and SBA use a smoothing constant  $\alpha$  for producing exponentially smoothed estimates of positive demands. They also both use the parameter  $p$  to denote the average inter-demand interval.

An interesting mechanism for improving the forecasting performance was recently provided by Nikolopoulos et al., (2011). This is called “An Aggregate-Disaggregate Intermittent Demand Approach (ADIDA)”. This approach is mainly based upon a non-over-lapping temporal aggregation of demand in higher level time buckets (say, from days into weeks for example). The result of the application of this tool is the reduction of zero-demand periods, having a new demand pattern showing a smoother behaviour with lower variability levels. The authors suggest the use of periods equal to the review period plus the response lead time when a company is using periodic review management inventory systems.

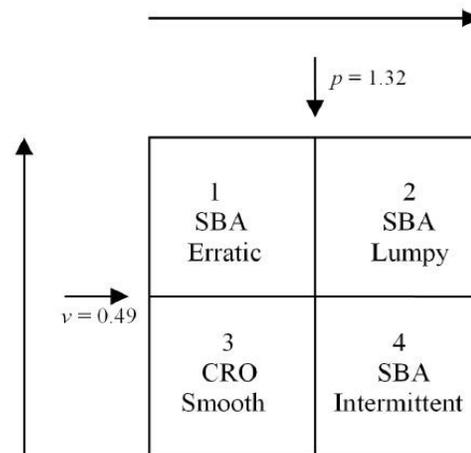


Figure 2 Illustration of intermittent demand pattern categories

This mechanism made it possible for supply chain managers to successfully use forecasting methods that were until now suitable only for fast-moving data to forecast intermittent demand, such as slow-moving items. This was possible to a reduction of the accumulated demand's intermittency. Not only was the forecaster's toolkit expanded to incorporate popular methods, for example, exponential smoothing methods and the theta method, but also ADIDA seemed to improve the accuracy of forecasting methods specific to intermittent demand. Nikolopoulos et al., (2011) empirically showed that ADIDA can result in lowered forecasting errors and characterized it as a forecasting method self-improving mechanism.

Spithourakis et al., (2011) illustrates that ADIDA also performs well in many cases for non-intermittent demand data. Similarly to the fact that cumulative demand of intermittent series will exhibit significantly less intermittence, any aggregate series would be expected to have a considerable reduced coefficient of variation compared to the original series. In other words, aggregation may smooth out time series randomness.

The most important benefit of ADIDA is that it is an inexpensive scheme for managers to estimate highly accurate forecasts. Therefore, ADIDA can be regarded as a cost efficient and universally implementable forecast accuracy-improving mechanism. For the special case of using the resulting forecasts for inventory management, Nikolopoulos et al., (2011) proposed a managerial heuristic for the aggregation level, setting it equal to an item's lead plus its review time. This is particularly useful for periodic review inventory management systems.

### 3. Description of Methodology

The study conducted in "The One" followed the following steps; The initial work is focused on the analysis of the company's context including its supply chain structure, product catalogue, forecast characteristics and the like. The following task corresponds to the identification of the demand patterns and types of items included in the study. Then, The current forecasting and inventory management procedures used, together with their actual performance are analyzed. The fourth step was designed to include an initial simulation study of the impact of using ADIDA for a sample of fast and slow moving items sold by "The One". Afterwards, and considering the achievement of positive results in the simulation, a pilot program would be devised for a significant sample of products sold at the Tijuana and Mexicali plazas was carried out. The results of this program were the basis for convincing the management of the firm to pursue the implementation of the mechanism for the rest of the store network nationally during year 2018.

### 4. Application of Methodology

The leading C-store company, "The One", has grown in an impressive manner during the last decade. The supply chain structure includes 16 Regional Distribution Centers (RDC) that service a total of 15, 225 store outlets as of the end of year 2016 with a market share of 88% in Mexico. "The One" has a two-echelon divergent inventory system, also known as the one warehouse and N-retailers inventory system (Axsäter 2000).

The company uses simple exponential smoothing for forecasting daily demand for all A and B items. For all C – F items, “The One” utilizes simple moving averages to forecast daily demand. All inventories managed in “The One” use a periodic review system with a review period of one week. The average level of inventories per store is estimated in 30 days. A further analysis of the importance of the different type of items is presented in Figure 3 using a Pareto analysis. Items type A and B represent 80% of the sales volume. However, their inventory levels are the lowest among the rest of the types. On the other hand, C - F items which account for the remaining 20% of sales volume are the ones with the highest levels of inventory days. These latest types of items are part of the so called slow moving items (Putts 2013). Given the results previously illustrated, the management of “The One” decided to pursue inventory reduction efforts for C – F items.

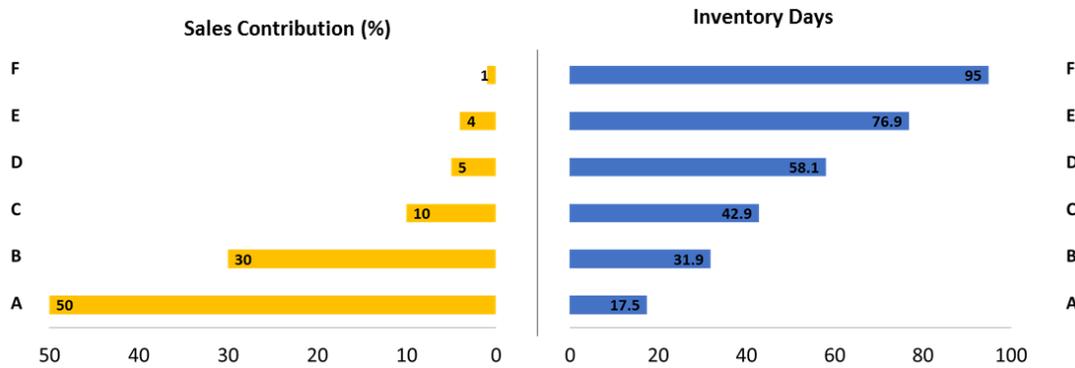


Figure 3 Level of importance of different types of items in inventory level

#### 4.1 Description of current forecasting and inventory management schemes

Before embarking into the description of the forecasting and inventory management schemes for items, it is important to review their demand patterns behavior. For this purpose, a matrix suggested by Syntetos et al., (2005) is used. Figure 4 illustrates that the demand pattern for C – F items can be classified as lumpy and erratic. Items A are all practically classified as smooth items and items B are mostly erratic. Considering that “The One” is currently utilizing simple exponential smoothing and moving averages to forecast daily demand, it seemed logical to consider the possibility of exploring the potential benefits of using ADIDA to improve forecasting accuracy. In particular for items B and C – F.

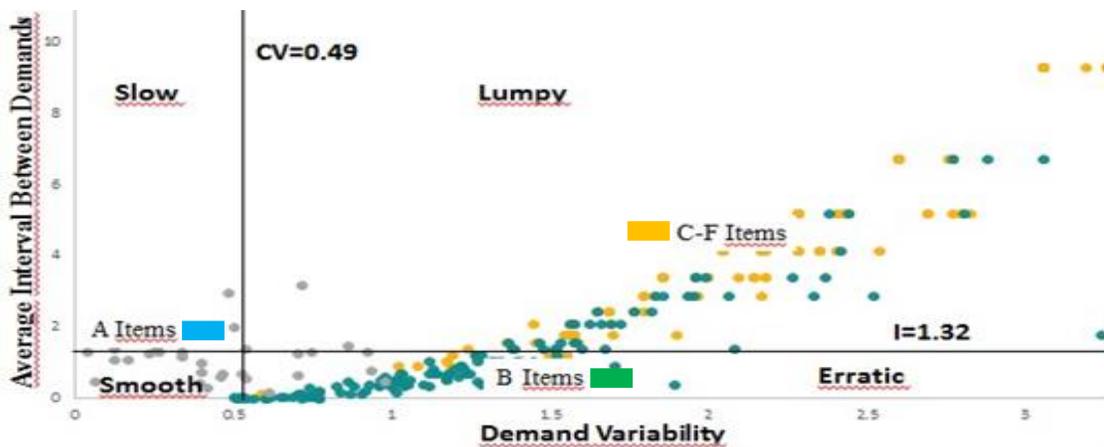


Figure 4 Classification of items according to Syntetos et al., (2005)

The actual inventory management scheme used by “The One” for all items is described as follows. The inventory management system is a periodic review order up to system. The review period is one week and the replenishment delivery frequency is daily. This system includes an order up to maximum quantity,  $M$ , calculated as the average demand during the review period plus the delivery response time and safety stock.

#### 4.2 Identification of inventory reduction initiatives

Given the previous description of the forecasting and inventory management procedures, the identified potential improvement initiative consists of replacing the forecasting procedure considering bigger periods of time (moving from days to weeks).

##### Reviewing the forecasting procedure

From Figure 3, it was concluded that C – F items have a demand pattern that is mostly lumpy and erratic and B items are mostly erratic. Therefore, according to Figure 3, Syntetos et al., (2005) recommend the application of the SBA forecasting procedure for this type of demand pattern. The company is currently using simple exponential smoothing and moving average procedures for this task. Hence, it seems that changing the method would improve forecasting precision. Furthermore, the estimation of at least the Safety Stock will be better with a good chance of being lower.

As previously mentioned in section 2.1, an interesting mechanism for improving the forecasting performance was recently recommended by Nikolopoulos et al., (2011). This is called “An Aggregate-Disaggregate Intermittent Demand Approach (ADIDA)”. Even though this new tool was originally suggested for intermittent demand items, it can also prove useful for non-intermittent demand items as shown by Spithourakis et al., (2011). The tool contemplates four steps; (1) Gather original data; (2) Apply a non-overlapping temporal aggregation at an aggregation level, A; (3) Extrapolate the aggregate time series by means of a forecasting method, F, and; (4) Disaggregate aggregate forecasts back to the original time scale via a disaggregation algorithm, D.

#### 4.3 Impact of the implementation of the pilot program

Thus, in our case, the first step carried out was the application of the ADIDA process. Thus, a significant amount of items (A, B, and C – F) was selected from the Tijuana plaza was selected for running a pilot program of one month. The aggregation period chosen was equal to the review period of one week. Figure 5 presents the impact of aggregating daily demand to weekly demand. As shown, the new demand patterns for items B and C-F present a significant trend towards the smooth category. Under this new category, it will be possible to apply the CRO technique or other procedures such as simple exponential smoothing and moving averages.

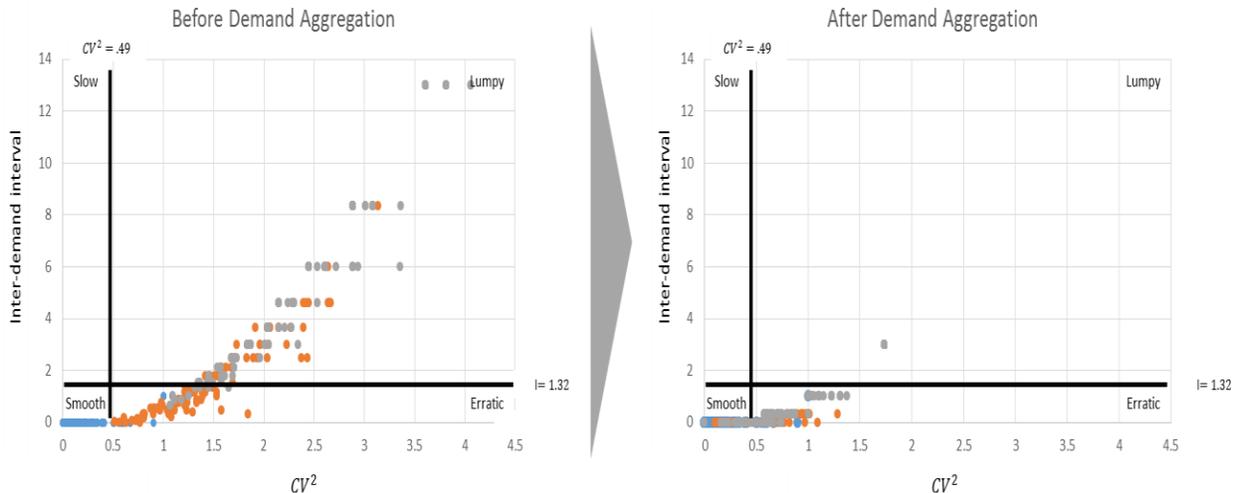


Figure 5 Illustration of the application of the ADIDA process and the CRO procedure

The pilot program was designed to consider demand aggregation and the possibility of using simple exponential smoothing, moving averages and Croston as the forecasting procedures. Table 1 illustrates a summary of the values for the average Mean Square Error (MSE). The value of the average MSE for A items before applying ADIDA is estimated as 211.43. This was reduced to an average of 128.42 (39% reduction). For items type B, the value of SME declined from 44.40 to 30.19, a 32% reduction. Finally, the MSE value for items C – F decreased from 5.99 to 2.61, about a 56% decrease.

#### 4.3 Impact of the implementation of initiatives on inventory

The impact on inventory of the previously described initiatives is described in this section. For our case study, the main impact of improving forecasting accuracy is expected to be on the determination of safety stock. The forecasting and inventory management of “The One” is a dynamic system that is updated every time a new forecast is obtained. The firm estimates safety stock for each item by using a desired service level multiplied by the standard deviation of the forecasting errors.

It should be pointed out that the MSE is an estimate of the variance of the forecast error. Thus, the root mean squared error (RMSE) will also be an estimate of the standard deviation of the forecast errors. Under these circumstances, the management of “The One” is expecting safety stock reduction in the order of 17.7 – 33.9% (Table 1).

Table 1 Summary of average SME and RMSE values after applying ADIDA

Product Type	Forecasting Method	MSE	RMSE	% SS Reduction
A	Before: Simple Exponential Smoothing	211.43	14.54	22.07
	After: Moving Averages	128.42	11.33	
B	Before: Simple Exponential Smoothing	44.40	6.67	17.69
	After: Moving Averages	30.19	5.49	
C	Before: Simple Exponential Smoothing	5.99	2.45	33.87
	After: Croston	2.61	1.62	

## 5. Conclusions and recommendations

The level of competitiveness of the retailing sector is dependent on the level of product availability at the store. Under these circumstances, the effectiveness with which inventory management is performed becomes very important. Too much is expensive, and too little implies the appearance of more frequent stockouts. An important factor that impacts significantly inventory management is forecasting accuracy.

The case of study treated in this paper deals with the improvement of the level of precision of demand forecasting at the store level. The company was dealing with the problem of having excessive level of inventories in its stores in terms of days of inventory. An exhaustive analysis of the contribution to this excess was developed and found that forecasting performance for inventory management purposes could be improved. Thus, an initiative based on the application of the ADIDA (Nikolopoulos et al., 2011) methodology could be implemented for these purposes. The impact expected with the full implementation of the previous initiative is a safety stock reduction in the order of 17.7 – 33.9%. Given these expected results, “The One” management decided to pursue full implementation during year 2018.

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