Optimization of the sales forecast algorithm for a supermarket supply chain

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Abstract: This paper presents the results of the study of different forecasting models applied to sales data of products sold by Auchan Portugal, with the objective of improving/optimizing its main storehouse stock management. The paper focuses on a study of three forecasting models: moving averages, weighted moving averages and moving averages with exponential smoothing. The study was performed using weekly sales data of the same product, in order to compare the results obtained.

Keywords: Sales forecast, optimization, replenishment operation, stocks.

1. Introduction

Auchan is a multinational distribution company that was founded by Gérard Mulliez. The company opened its first supermarket in 1961 in Roubaix, a town in northern France. In 1981 the company started its international expansion by opening the Alcampo chain of supermarkets and hypermarkets in Spain. Auchan entered the Portuguese market in 1996 with the acquisition of the Pão de Açúcar supermarkets.

In 2012, Auchan was present in 13 countries across 2 continents, as can be seen in Figure 1.

The Company counts 287,000 employees and has 1495 supermarkets in its portfolio. Nowadays, the Company owns 32 stores in Portugal (between the Pão de Açúcar supermarkets and Jumbo hypermarkets). The Company's main storehouse for FMCG (major consumer goods), from where the replenishment operation of the company's stores is performed, is located at Vila Nova da Rainha, municipality of Azambuja (40 km North of Lisbon).

In order to prevent out-of-stock situations from happening at store level, these situations must be prevented at the main storehouse level. This paper focuses on a study of different forecasting models that can be used to predict the main storehouse necessities of a given product, on a weekly basis. The forecasting models studied are the moving averages model, the weighted moving averages model and the moving averages with exponential smoothing model (Schoenfeldt, 2008). These methods
are applied using weekly sales data of one brand product sold by Auchan (from now on referred to as Product A), with a known lead time of seven days.

### 2. Forecasting and supply chain

Supply chain can be defined as the series of operations and companies that a product has to go through in order to reach the final consumer. This paper approaches the study of Auchan’s supply chain in Portugal. Figure 2 presents a simplified scheme of the Company’s supply chain for major consumer goods.

In order to prevent out-of-stock situations at store level we must, as previously mentioned, prevent out-of-stock situations at the main storehouse level. For this purpose, product orders to the supplier, which in the Company’s case are performed by the various sections of the Replenishment Department, must be placed with adequate quantities and with enough time to forestall flaws in the replenishment of products to the stores. (The various sections of the Replenishment Department are sub-departments of Logistics, which are named after the different types of products that can be found at the Auchan stores in Portugal.)

Currently, the amount of product that must be ordered is decided by the representative that is responsible for a given section of the Replenishment Department, and his decision is based in the comparison of two product consumptions: the recent consumption of the product (that is basically the sales of the last month for the product) and the consumption of the product in the same period of the previous year. Having in consideration this comparison, the free stock available in the main storehouse and the product lead time (period of time between the issue of the purchase order and the delivery of the product ordered to the storehouse), the representative must decide if a purchase must be issued or not. Other important aspect that may affect the representative’s decision is the scheduling of promotional sales activities, which usually infers an increase to product sales. At the Company, each product is usually analyzed on a specific day (or days) of the week.

The objective of the study is to help the representative of each section in his decision, by presenting the sales forecast results for the product. The study was performed using Product A, which has a lead time of seven days and for which the amounts ordered in each purchase, for the period between March and September of 2012, varied between 35000 units and 100000 units. The purchase orders for that time period were placed, generally, every two weeks.
3. Forecasting Models

There are several models that can be used in order to perform the sales forecast for a product, which are usually based on the statistical data of previous sales of the product. This paper presents a comparison of the results obtained by three different models used to perform sales forecasts: the moving averages model, the weighted moving averages model and the moving averages model with exponential smoothing. All models presented will use the same nomenclature, as is presented next:

- **SF**: Sales Forecast;
- **VNDs-x**: Sales of the x previous week (1 means previous, 2 means second previous and so on);
- **n**: number of observations (weeks analyzed).

All sales forecast models will be applied for a period of weeks \( n=3 \).

**3.1. Moving Averages Model**

The most straightforward model to perform a sales forecast is the moving averages model, which can be described by Eq. (1).

\[
SF = \frac{VND_{S-1} + VND_{S-2} + \cdots + VND_{S-n}}{n} \quad (1)
\]

For the time period studied, where \( n \) will take the value three, the model can be described by Eq. (2).

\[
SF = \frac{VND_{S-1} + VND_{S-2} + VND_{S-3}}{3} \quad (2)
\]

This model is nothing more than the calculation of the average sales expected weekly, using the statistical sales data of the previous three weeks.

The results of the sales forecast are presented in Figures 2 and 3, for the years 2011 and 2012, respectively.

**3.2. Weighted Moving Averages Model**

The weighted moving averages model attributes a certain weight to each observation. In this case, each value of sales used will be multiplied by a coefficient. This coefficient will have the greatest value for the most recent data and the smallest value for the most ancient data used in the calculation. The denominator will be the sum of all the coefficients applied in the
The general formula for this model is presented in Eq. (3).

\[
SF = \frac{nVND_{s-1} + (n-1)VND_{s-2} + \cdots + VND_{s-n}}{\sum_{i=0}^{n} n_i} \quad (3)
\]

For the studied case in particular, the general formula will appear as shown in Eq. (4).

\[
SF = \frac{3VND_{s-1} + 2VND_{s-2} + VND_{s-3}}{6} \quad (4)
\]

Figures 5 and 6 are a graphical representation of the results obtained when applying the weighted moving averages model to the sales data of Product A in 2011 and 2012, respectively.

### 3.3. Moving Averages with Exponential Smoothing

The moving averages with exponential smoothing is very similar to the weighted moving averages model, with the greatest difference being the coefficients applied.

As in the case of the weighted moving averages, each observation is multiplied by a coefficient, but in the case of the moving averages with exponential smoothing the coefficients will be calculated according to Eq. (5).

\[
Coefficient = \alpha(1 - \alpha)^k \quad (5)
\]

In Eq. (5), \(k\) will vary between zero (for the previous week) and \(n-1\) (for the most distant week used), with \(n\) being the number of observations (number of weeks used in the calculation). The value of \(\alpha\) is calculated with Eq. (6).

\[
\alpha = \frac{2}{n+1} \quad (6)
\]

The general formula for the application of this model is given by Eq. (7), but for this equation to be valid, the number of observations (\(n\)) must be as great as to allow the sum of every coefficient (calculated by Eq. (5)) to be 1.

\[
SF = \alpha VND_{s-1} + \alpha(\alpha - 1)VND_{s-2} + \cdots + \alpha(\alpha - 1)^{n-1}VND_{s-n} \quad (7)
\]

Because in the case studied only three observations are used, the sum of the coefficients does not reach 1, so it is necessary to apply the correction presented in Eq. (8).
Substituting each coefficient by the calculated value, this becomes

\[
SF = \frac{0.5VND_{s-1} + 0.25VND_{s-2} + 0.125VND_{s-n}}{0.875} \quad (9)
\]

Figures 7 and 8 present the graphical representation of the results obtained with Eq. (9), for the years 2011 and 2012, respectively.

### Table 1: Comparison between the effective sales and the different models of sales forecast models (Product A)

<table>
<thead>
<tr>
<th>Forecast Model</th>
<th>% of deviation for 2012</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Non-absolute</td>
</tr>
<tr>
<td>(1) Moving Averages</td>
<td>-0.37 %</td>
</tr>
<tr>
<td>(2) Weighted Moving Averages</td>
<td>-0.34 %</td>
</tr>
<tr>
<td>(3) Moving Averages with Exponential Smoothing</td>
<td>-0.36 %</td>
</tr>
</tbody>
</table>

By analyzing the results achieved, it can be concluded that the models that are closer to reality are the ones that use weighted moving averages [(2) and (3) in the Table]. These was expected, has these models give a greater weight to the most recent sales data used when performing the forecast.
It must also be noted that the moving averages with exponential smoothing model was applied using an approximation. If a greater number of observations were used, the results attained could possibly be improved.

4. Conclusions

The study presented in this paper compares various models for performing sales forecasts. As previously shown, the sales forecasts that achieve the results closest to the effective sales are the ones that make use of weight moving averages, which give a greater weight to the most recent sales data. The simple moving averages model [presented in Table 10 as (1)] also follows the evolutionary trend of the effective sales, but presents greater deviations.

The major consumer products market is in constant evolution. As such, the tools used in the management of these types of supply chains should be adapted to changes that occur in consumer behavior. A sales forecast algorithm is extremely important to the performance of any supply chain, but the results obtained by its application should be analyzed and contextualized, since they are usually based in statistical data of previous sales.

5. Acknowledgements

The author would like to thank Prof. Miguel Casquilho, Dr. Fernando Ereio and António Pimenta de Aguiar for providing the opportunity to work on this thesis and for their support during the process.

6. Bibliography

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