



## **DEMAND FORECASTING: PROPOSAL OF A MODEL FOR A GLASS TEMPERING INDUSTRY**

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### **ABSTRACT**

The given article aims to evaluate different quantitative demand forecast methods through a case study on a glass tempering company. The analysis were held based on historical data series, which allowed the use of a part of this data for method application and another part for comparison and validation of the model's results. The methods were compared based on obtaining the mean absolute error. In the studied company, the raw material request for the suppliers was made when new orders are ordered (pulled production). This method results in longer responsiveness, mainly due to the waiting time of raw material arrival. The application of those different demand forecasting models were analysed over three types of products on the tempered glass category, which represents a total volume of 65% of the company's costs. As a result, two methods were better adapted to the real data, providing absolute errors between 0.25 and 0.29. This given work showed that the application of the demand forecasting methods would reduce orders delivery time, what could lead to real gains to the analysed company.

**Keywords:** Demand Forecasting; Quantitative Models; Glass Tempering.



## 1. INTRODUCTION

Management decisions affect competitiveness, growth, achievement of strategic objectives and the economic outcomes of organizations. Thus, the orientation of short, medium and long-term planning variables can aid managers to achieve better results in key organizational issues such as: improve logistics efficiency, faster decision-making, greater robustness over adversities and costs reduction. When a problem or need is addressed beforehand, companies can develop better plans to solve them, what makes demand-forecast methods a tool of great relevance for increasing their competitiveness (LEMOS, 2006).

According to Lemos (2006), forecasting methods can be applied to several areas, such as "finance and accounting, engineering and research, production, distribution and logistics, human resources, marketing and sales."

The present work is based on the sales data of products on a small glass tempering company, located in Campinas-SP. Since 2012, the company has been distributing flat glass for architecture, civil construction, decoration and furniture; selling mirrors, tempered glass, laminates, common, lid tables, silicone, accessories and ironmongery.

Currently, the given company does not use any forecast method to plan its future demand and manage its inventories levels. In order to verify a method that suits the demands of this type of company, five methods of forecasting demands were analysed and compared: last period method, global simple average method, simple average method per period, moving average method and least squares method.

The purpose of this study was to compare the analysed methods and to identify which of those better suits companies' marketing history, therefore assisting in the decision-making regarding inventory levels and thus avoiding unnecessary costs and reducing responsiveness over customers' orders. For that goal, we analysed the sales data from January 2015 to April 2017.

The current paper is split on the following sections: first a literature review on demand forecasting, quantitative forecast methods, an overview on the glass industry and the case study. Afterwards, the methodology used will be presented followed by its results, and at last, this work's conclusion.

## 2. LITERATURE REVIEW

### 2.1. Demand Forecasting

Economic and political instability as well as the development of new technologies can make demands planning a difficult task, when becomes necessary, not only the correct modelling, but the identification of scenario changes, which raises uncertainties and risks; this identification usually requires the expertise of a skilled-professional in the area. Expert predictions apply to external, non-controllable events (LEMOS, 2006).

Lindberg and Zackrisson (1991) list the four major problems associated with the use of predictions:

- a) The uncertainty about of the future, which is connected to forecast the degree of precision;
- b) The choice of the method used to generate the forecast;
- c) The quality and reliability of the input data set in the method; and
- d) The correct interpretation of the forecast, that is, how forecasts will be used in decision-making.

Regarding the methods of demands forecasting, there are quantitative methods, based on historical series, and qualitative methods involving subjectivity, such as expert opinion. Lemos (2006) points out that several studies show signs that the integration of the two methods is the best approach to obtain better predictions.

There are regular and irregular demands. Lemos (2006) list five patterns of regular demand: average demand for the period, trend (demand movement over time), seasonality (repeating peaks and valleys), cyclical factors, and random variation (unexplained).

Regarding the pattern of irregular demand, this occurs in cases of high uncertainty about the moment and level of demand. This scenario is particularly difficult to predict, and may occur due to several factors such as large orders from some non-frequent customer and demand derived from other products or events (BALLOU, 2001).



In the literature it is noted that the Box Jenkins model, also known as ARIMA (Auto Regressive Integrated Moving Averages), has been widely used for predictions. This model aims to capture autocorrelation between the values of a time series and make future predictions (Werner and Ribeiro, 2003). Despite its good results, a survey conducted in Brazilian food companies indicates that this method is one of the least used because of the difficulty in understanding it (CECATTO; BELFIORE, 2015).

Some studies have pointed to better results with the use of the ARIMA method such as Werner (2003), who uses this model to forecast demand in the computer technical assistance area, and Arthus et al. (2016), which compares forecasting methods for soybean crop in west of Pará State in Brazil.

Another method found in the literature is the Hierarchical Analytical Process, which uses comparisons in pairs of variables that affect product's demand, the weight given to each variable are defined by specialists. Silva and Werner (2016) use this method to predict demand in the animal food sector.

There are also applications of neural networks for demands forecasting, this is the case of demands forecasting to industrial production of different segments made by Fávero and Zoucas (2016).

## **2.2. Last period method**

In this method the future demand, month  $n+1$ , is calculate based on the previous month real demand, month  $n$ ; in other words month by month the last period real demand is repeated.

## **2.3. Simple Average method (global e per period)**

In this method the future demand is calculated using the average of previous periods demands. For the global simple average all previous months are considered; to calculate the demand from period  $n+1$  the demands of months from 1 to  $n$  are used. For the simple average per period a period is choosen, for exemple if the quarter period is choosen the calculated demand for January, February and March is equal to the three first months real demands average.

Since all values, distant and recent, have the same weight, the method does not have a rapid response to the last period data changes (WANKE ; JULIANELLI apud CAMBI; JACUBAVICIUS, 2016).

#### **2.4. Moving Average method**

The moving average method is largely used for ease of execution and need of very few historical data. In it the number of observations (n) considered for the calculation of the average is kept constant and then the arithmetic or weighted average of n observations is calculated, eliminating the most distant observation and including the most recent one.

For n equal to three, for example, the demand for the month of April would be the average of the demands from January to March and the one of May would be the average of the months from February to April. As this method disregard more distant data it may not be suitable for series with trend and seasonality (MAKRIDAKIS; WHEELWRIGHT; HYNDMAN apud LEMOS, 2006).

#### **2.5. Least Square Averages method**

This method consists of fitting two parameters, a and b, of the equation of a line ( $y = ax + b$ ), where y is the prediction for period x, in order to minimize the sum of the quadratic differences between the line and the predicted points divided by square of the standard deviation (FILHO et al., 2011).

#### **2.6. The glass industry**

There are a numerous utilities and features of the glass such as: brittle material with much greater compressive than flexural strength, transparent material, high resistance to chemical attack, thermal insulation efficiency and capacity of maintenance a vacuum. Nowadays glass manufacturing technologies and methods have been evolving thus widening its application for a variety of uses, in an estimated 800 glass types (SHREVE; BRINK JR., 2008).

Physically, glass can be defined as a rigid sub-cooled liquid with an indefinite melting point and high viscosity that prevent crystallization (SHREVE; BRINK JR., 2008); chemically is the result of the union of non-volatile inorganic oxides, sands and other substances that form a random atomic structure. Even with numerous new formulations for glass, lime, silica and soda still make up approximately 90% of the

glass in the world, however the small changes introduced can have effects with great impact in future (SHREVE; BRINK JR., 2008).

Among the numerous glass classes there are special glasses, which include coloured, opaline, translucent, safety glasses, including laminated glass and tempered glass, photosensitive and special for chemical and industrial use (SHREVE; BRINK JR., 2008).

On the manufacturing of these products, processes used aim not only at the form and precision required, but also at the properties that their use requires. The properties are the result not only of the chemical composition, but also of its microstructure, which depends, among other factors, on the thermal exposure suffered by the product during its processing. The properties, in turn, will determine the performance of the product (KIMINAMI; CASTRO; OLIVEIRA, 2013).

The heat treatment consists of controlled succession of heating and cooling that aims to alter the microstructure of the material giving it the desired characteristics. The controlled thermal annealing, which causes the non-uniform stresses to be replaced by controlled, uniform and low-intensity voltages, characterizes tempered glass manufacturing (SHREVE; BRINK JR., 2008). These techniques are used to obtain various types of glass, such as tempered glass that is a strong and tough type, which has high internal stresses that shatters the glass when it is broken.

## **2.7. Study case**

According to Gil (2002), a study case is a deep and exhaustive study of some object, allowing its ample and detailed knowledge. Yin (2001) cites that for long the study case has been viewed as a method with insufficient rigor, not providing basis for generalizations.

Thus Yin (2001) brings the characteristics of all phases of research that distinguish this method from others, guiding the researchers who are using it to confer rigor to their work. For Yin (2001), this strategy of research conducting aims to respond how or why something happens, there is no control over behavioural events and there is focus on real events.



The study case research deals with a unique situation in which there are more variables of interest than data points; is based on various sources of evidence and uses for its benefit the prior development of theories.

### **3. METHODOLOGY**

The study evaluated how the company's demand behaves based on its real historical sales, and, from the application of these data, it was analysed the results of the five forecast methods, what explains the case study strategy chosen.

#### **3.1. Data collect and minning**

In order to obtain the data and understand the current status of the demands planning of the analysed company, interviews were conducted with the company's production manager, from whom the historical sales were obtained. The received data are the monthly reports, in PDF format and separated by product category, of all products sold in the period from January 2015 to April 2017.

For delimitation of the scope, necessary for the beginning of the analyses, the category that represents the highest total sales value was chosen. For the products of this category, all the data were prepared and, through the elaboration of ABC curves of the quantity of material (m<sup>2</sup>) and cost price, the three most representative products were identified in terms of cost and, consequently, inventory. The validation and data mining were done through interviews and discussions with the company's production manager.

#### **3.2. Demand forecast methods application**

The use of methods with time series analysis is based on the assumption that there is constancy in the data patterns used in the forecasting process, the model is adjusted to past data.

After the choice of products to be analysed, five forecasting methods were applied. The following methods were used: last period method, global simple average method, simple average method per period, quarterly period, moving average method (with previous number considered equal to three) and method of the least squares average.

The data obtained from the company comprise a period of twenty-eight months, between January 2015 and April 2017. From those, the period until March



2017 were used as a basis for the application of the five methods, while the data from January 2016 onwards were used to compare the actual demands against the calculated demand by the applied models, and verify which model best suits the real curve.

### 3.3. Prevision and real forecast comparison

After the application of the forecasting methods, the obtained models were used to predict the sales of the last 16 months (from January 2016 to April 2017) and then the results of the five forecasts methods were compared with the real demands through the absolute average errors of the sample (SANTOS; RODRIGUES, 2006). After this comparison, the method that best suited with the actual data (lowest error) was chosen for the three products analysed.

The following equation was used to calculate the absolute mean error:

$$AME = \sum_{k=0}^n |R_k - P_k| / n \quad (1)$$

Where, "R<sub>k</sub>" is the real demand for period "k", "P<sub>k</sub>" is the expected demand in period k and "n" is the total of periods considered.

## 4. RESULTS

In the analysed company, the usual period for manufacturing orders, which works from Monday to Friday, is two days, and the delivery period to customers is seven calendar days. At the time these study were held, when a new purchase order is placed, an inventory report is issued and analysed to verify the requirements for production.

In case of stock scarcity of the necessary raw material, the suppliers are contacted for procurement. The usual raw material delivery lead time is three to five days, but there may be delays, especially in the periods when the suppliers' furnaces are under maintenance. Thus, when there is no raw material available there may be delays on the delivery deadline agreed with customers.

The twenty-eight reports obtained have data of more than thirty products, separated in the following categories: common glass, mirror, laminated glass, labour,



scrap and tempered glass. For each of those products, the reports contain the following data: quantity of parts sold, weight, area (m<sup>2</sup>), cost price and sales value.

Among the categories, the Temperate Glass was chosen for analysis, since it is the category that represents the majority of total raw material costs and company revenues. As for costs, temperate glass represented 93% in 2015, 73% in 2016 and 73% in the first four months of 2017, with an average of 83% for the 28 months analysed. Regarding billing, it represented 84% in 2015, 65% in 2016 and 59% in the first four months of 2017, with an average of 73% for the 28 months analysed.

In order to delimit the products of the chosen category that would be analysed, an ABC curve of the cumulative percentage of total cost price of the 28 months per product was elaborated, according to Figure 1 below.

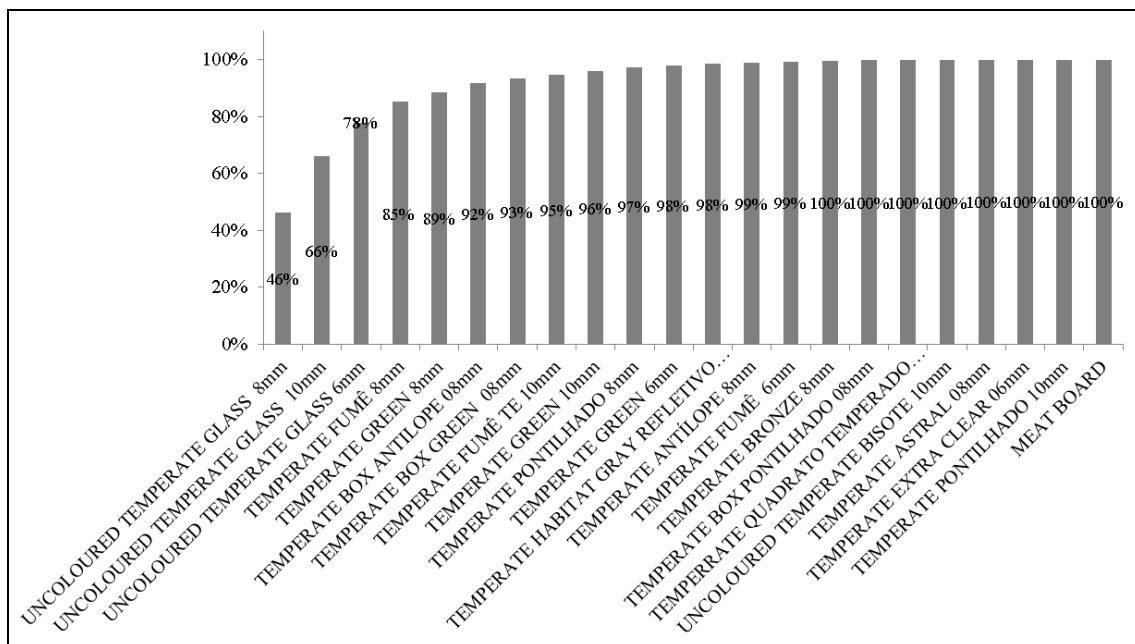


Figure 1: ABC curve of accumulated percentage from total cost per product.  
 Source: Elaborated by the authors.

Note from this curve that 14% of the products (first three) represent 78% of the procurement costs and, hence, of this category's inventory. Therefore, were chosen for analysis the three more representative: uncoloured temperate-glass 8mm, uncoloured temperate-glass 10mm and uncoloured temperate-glass 6mm. As for the whole company's purchasing cost for raw materials, these products correspond to 65%, while only 57% of the net revenue.

Once the samples were defined, the analysis begun from sales history with focus on area (m<sup>2</sup>) sold from each product. See Figure 2 (below) for their data.

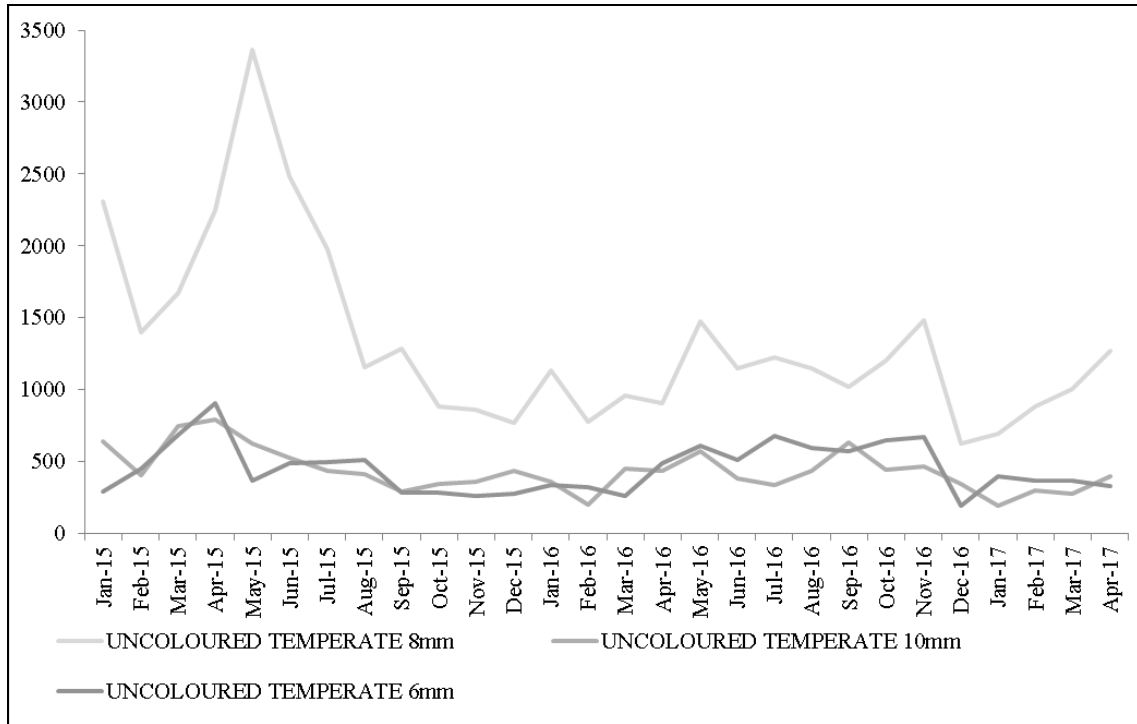


Figure 2: Sales history in m<sup>2</sup>/product per month  
 Source: Elaborated by the authors.

The last period, global simple mean, simple average per period, moving average and least square method were applied to the available data-series. Figures 3, 4 and 5 show the comparison from actual demand, withdrawn from the sales reports (January 2016 to April 2017), and the results of forecasting methods calculated from previous data to match report period.

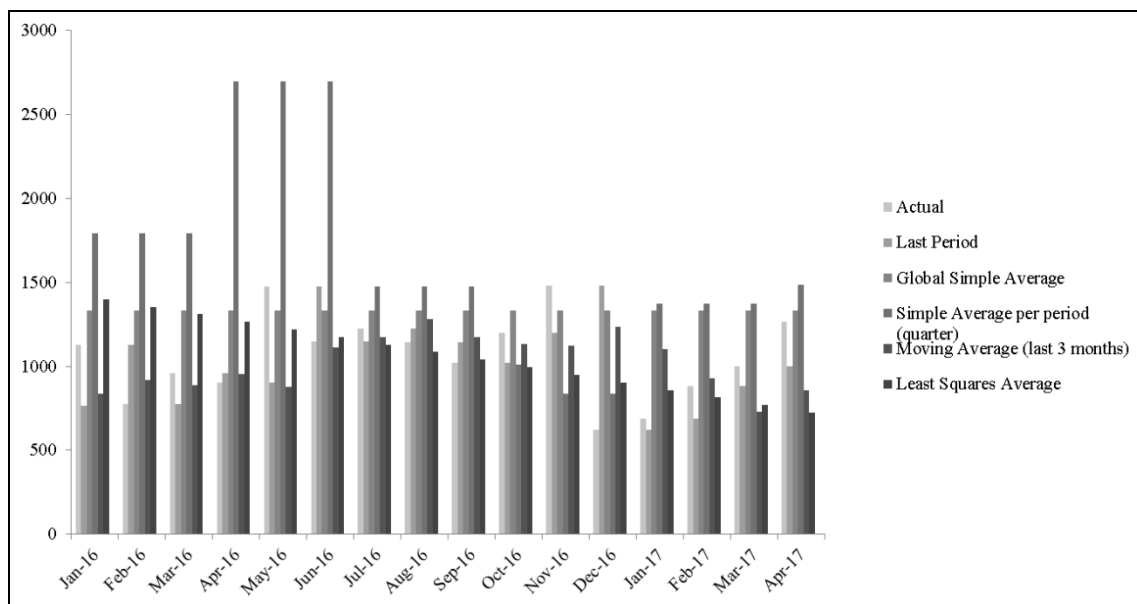


Figure 3: Uncoloured Temperate Glass 8mm - actual and demand forecast (m<sup>2</sup>) per month  
 Source: Elaborated by the authors.

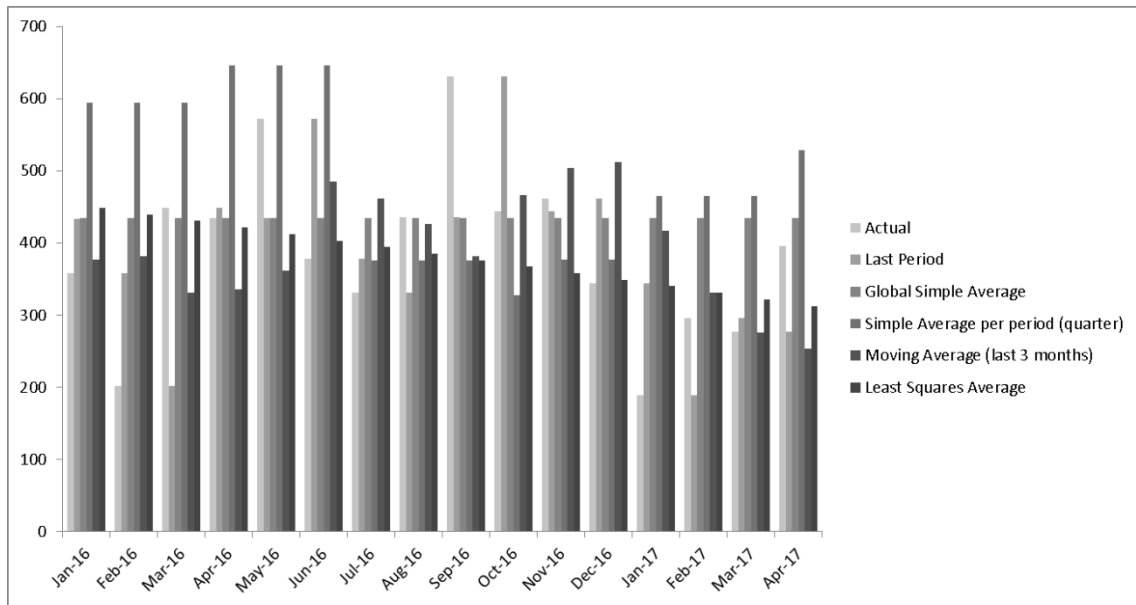


Figure 4: Uncoloured Temperate Glass 10mm - actual and demand forecast (m<sup>2</sup>) per month

Source: Elaborated by the authors.

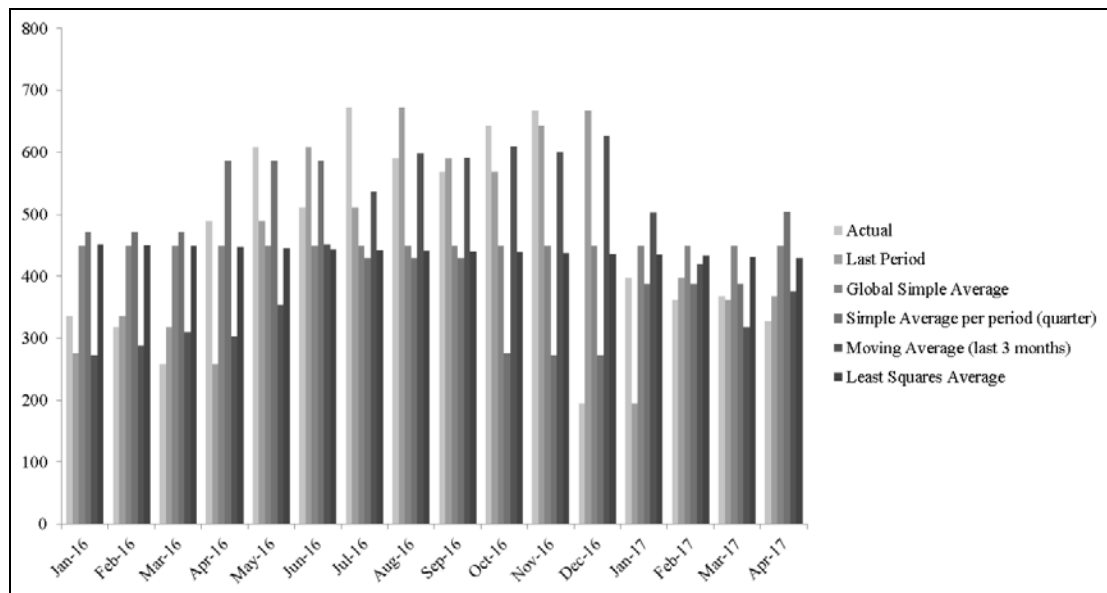


Figure 5: Uncoloured Temperate Glass 6mm - actual and demand forecast (m<sup>2</sup>) per month

Source: Elaborated by the authors.

For the 8mm uncoloured tempered glass, the model with the lowest mean absolute error was the Moving Average method, with an error of 0.24 followed by the least squares (0.25), last period (0.27), global simple mean (0.36) and simple average per period (0.68).

For the uncoloured 10mm glass, the model with the lowest mean absolute error was the least squares model, with an error of 0.27, followed by the moving average method (0.33), global simple mean (0, 33), last period (0.34) and simple average per period (0.53).

For the uncoloured 6mm glass, the method with the lowest mean absolute error was the moving average method, with error of 0.29, followed by the last period (0.32), simple average per period (0.33), the least squares (0.34) and global simple mean (0.35).

Figures 6, 7 and 8 below show the comparison of the actual demands with the demands foreseen by the method that best suited each product per month.

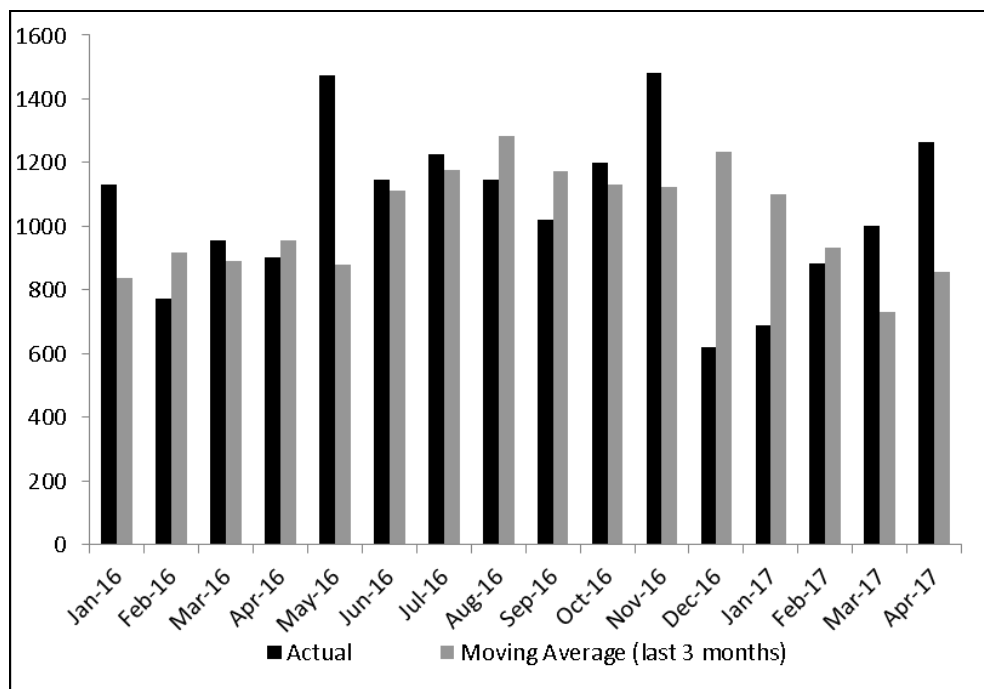


Figure 6: Uncoloured Temperate Glass 8mm (m<sup>2</sup>)  
 Source: Elaborated by the authors.

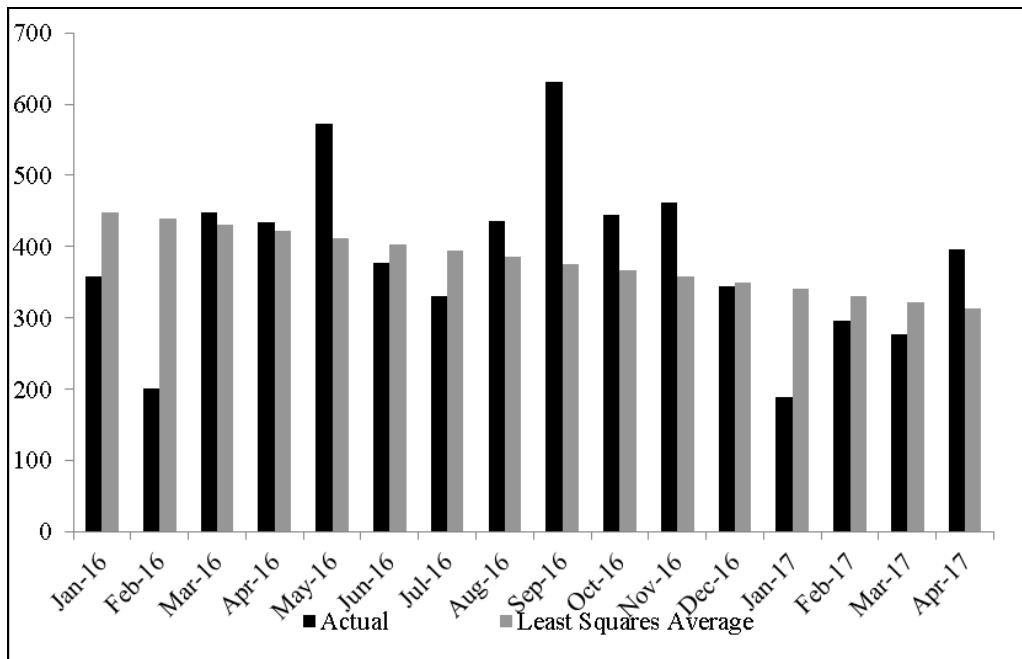


Figure 7: Uncoloured Temperate Glass 10mm (m<sup>2</sup>)  
 Source: Elaborated by the authors.

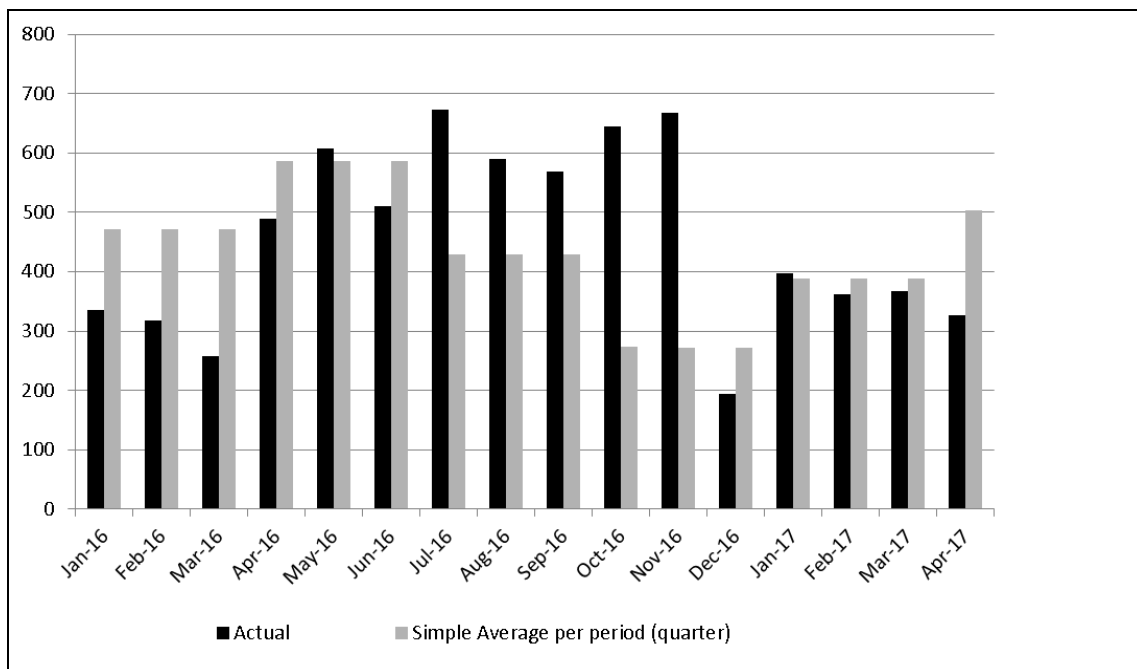


Figure 8: Uncoloured Temperate Glass 6mm (m<sup>2</sup>)  
 Source: Elaborated by the authors.

The demands obtained by the forecasting methods chosen for each product differ from the actual demands of the analysed periods with absolute mean errors of 0.25 to 0.29, where there were periods with larger and lower forecasts than those presented in the real data.

By applying the chosen methods there would be no need to order during the months when the forecasts were higher than the actual demands, and there are no

delays in delivery times to customers due to lack of raw material, however over the months where forecasts were lower than actual demand, there would be a need to purchase raw materials, but with fewer occurrences than those without forecasting (current situation), since new orders would be needed only for the difference between the forecasts and the actual demands.

In both cases, the application of the chosen forecasting methods could increase company's responsiveness on deliveries to customers by reducing production delays due to lack of raw material. The method also reduces bottlenecks in production, reduces idle labour, and increases the company's competitiveness over to competitors.

## **5. CONCLUSIONS**

Among the forecast methods evaluated in this work, the methods that presented the best results (smallest mean absolute errors) were the moving average methods, with an error of 0.24 for uncoloured temperate glass of 8mm and of 0.29 for the uncoloured temperate glass of 6mm, and the method of the average of the least squares average, with error of 0.27 for the uncoloured temperete glass of 10mm.

With the application of forecasting methods, it is expected to reduce delays in delivery to customers generated by lack of raw material to start production. In addition to the reduction of deadlines, the application of forecasting methods tends to reduce bottlenecks in production and idle labor caused by lack of raw material and increase competitiveness compared to competitors due to the reduction in the delivery time of orders to customers.

The three analyzed products represent a total of 78% of the stock value of the analyzed category, tempered glass, and 65% of the total value of the company's stock; as to billing, they account for 73% of the value of the analyzed category and 57% of the total of the company and serve as the basis for structuring the best analysis model. After structuring the model, the application to the other items can be done directly with the existing historical data. This result is effective when compared to no application of any method (as performed by the company).

It is worth noting that the wide range of products (finishings) whose choices are exclusive (the customer who chooses a green tempered glass will not opt for

colorless glass, for example) makes forecasting difficult and statistical models even more relevant.

The applied methods are quantitative, considering only historical data, not counting with the opinion of a specialist. For better results it is indicated that the prevision of na specialist (qualitative method) is incorporated into the quantitative forecasting methods. Modeling serves as support for decision making. By adding the modeling to the forecasts of external events, a more assertive future demand perspective can be obtained. Thus, it is expected that the sum of the methods proposed with the analysis of the managers contributes to the correct acquisition of material, reducing unnecessary stocks and delays in deliveries to the customers.

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