Inventory Model for Raw Material: A Case Study of a Chemical Company

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Abstract

Proper management of inventories within any company is important because they represent an asset with considerable investment and mishandling generates waste. Within the types of inventories, there are raw materials takes, which require greater control, since their proper planning depends on the subsequent activities of the supply chain. By making a situational diagnosis at the company under study it was determined that there were economic losses due to inventory obsolescence in the warehouse, delays in deliveries which led to fines and claims, demonstrating the need to apply an inventory model that allows to reduce its costs and meet delivery deadlines. It starts by classifying inventories according to their level of importance with respect to the level of sales, in order to determine which of them are the most demanded by customers. The dispersion of the data is analyzed to form the database and look for outliers. The demand forecast was made with the Statistical Package for the Social Sciences (SPSS) and R Version 3.6.2, specifically with the package nnfor for neural networks. For the planning of the stock keeping unit (SKU) it is done with the models Silver Meal (SM), Wagner Whitin (WW) Fragmented Period Balance (BFP); determining an optimal result with a reduction of 57,89%, compared to the value of placing a monthly order during the period.

Keywords
Inventory model, ABC classification, Variability coefficient, Demand forecast, Silver Meal, Wagner Whitin, Fragmented Period Balancing.

1. Introduction

Within any company, the management of inventories is considered as one of the most important administrative functions since it encompasses the management of raw material, in-process product, and finished product; considering that inventories account for a good part of the capital and can have an impact in areas such as production, marketing, and finance, they also influence the achievement of the company's overall objectives. (Schroeder, 2011). Focusing on the cost of inventories and that mishandling would lead to significant losses, not-so-reliable options are proposed as opting for a minimum inventory to lower costs and reduce loss of obsolescence or maintain excess inventory to meet all demands, avoiding fines for non-compliance and lost sales; proving that the challenge is not in reducing costs with a minimum or a maximum of inventory, but in maintaining the right amount for the company to reach its competitive priorities efficiently. (Krajewski, 2008). In the market we find services and asset processing companies, in which, regardless of their business, they will need an inventory; for the realization of this work is proposed as a case study to a company dedicated to the production and marketing of chemicals; because of its commercial activity much of the company's capital is invested in raw materials, forcing the company to investigate ways to properly manage its resources, thus seeking to maintain production times and avoiding the dissatisfaction of the Customers.

According to (Cristina, 2019) the importance of this work lies in the fact that the studied company does not have an adequate inventory model, so its administration is empirical, which prevents it from knowing the levels of rotation, the number of orders to be placed and the products to be supplied in a certain period; another of the problems that are anchored by not having an inventory model is the loss of time in operations such as production and distribution that generates discomfort and demand of customers. Therefore, this study is based on the design of an inventory model, which, through bibliographic research, the forecast, and the calculation of the coefficient of variability will be adapted to the needs of the company, in addition to providing with recommendations and thus respond quickly to the needs of its customers.

2. Methodology

For the conduct of the research was considered a total of 30 finished products, disaggregated in 48 SKU. It then proceeds to identify the items that are most sold in the company, so that we can analyze them according to their dispersion. Once the database is formed, the seasonality and trend of the values is analyzed, and with this the demand forecast is made for the next period. Analysis of the variation of the database made it possible to determine that the models that best fit the current situation of the company are the Silver Meal, Wagner Whitin and Fragmented Period Balance models, due to the applicability based on the objective function of minimizing the total cost of inventories.

2.1 Clasification ABC

Through the application of the classification methodology, the classification of the inventory was carried out, in order to prioritize the raw materials that have the most impact or that are most important in production, the intention is to develop the design of a management system stock for all raw materials provided.

For the ABC classification (Krajewski, 2008) assumes that, regarding the selection of star SKU, for this we analyzed the historical data of 36 periods in terms of product orders the database for the execution and selection of inventory types was developed, by the ranges of distribution and criterion characteristics that provides an appropriate classification approach for assessed data. The table 1 shows the ABC classification of inventories that identified the items that are most sold in the company.

Table**Error! Bookmark not defined.**Analysis results ABC

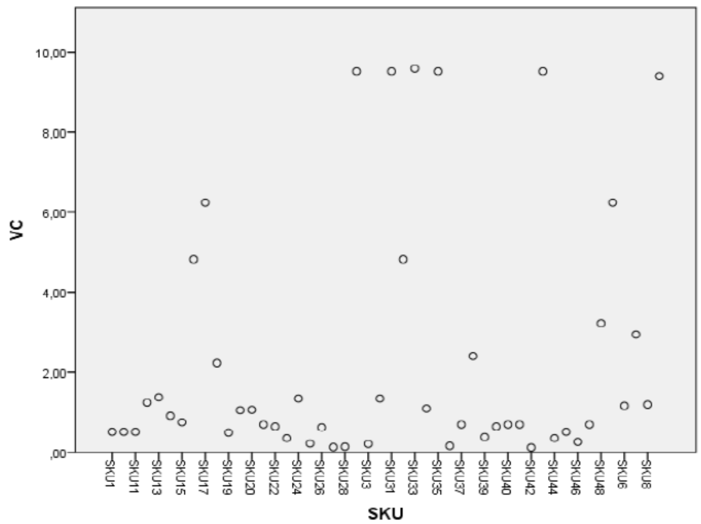
ABC			Accumulated	
	Number of items	Sales	Accumulated items	Accumulated sales
A	10	597717,11	10	597717,11
B	9	125533,58	19	723250,69
C	29	35059,62	48	758310,31
ABC	Percentages		Accumulated	
	Number of items	Sales	Accumulated items	Accumulated sales
A	20,83%	78,82%	20,83%	78,82%
B	18,75%	16,55%	39,58%	95,38%
C	60,42%	4,62%	100,00%	100,00%

2.2 Coefficient of variation

It is a statistical measure that allows you to determine the inventory management method to be used as it is a metric that, through its formula, provides information on the relative dispersion measures of a dataset which eliminates possible distortions. This coefficient is determined assuming that the demand is a discrete random variable over the analysis period, each with probability equal to 1/N. Considering that the standard deviation and the mean demand square are calculated using the ecuration1.

$$VC = \frac{N \sum_{j=1}^{N} S_j}{\left[\sum_{j=1}^{N} D_j\right]} \qquad [1]$$

For the case presented the results obtained were those shown in Figure 1, which shows a scatter plot of these results:



: Scatter plot

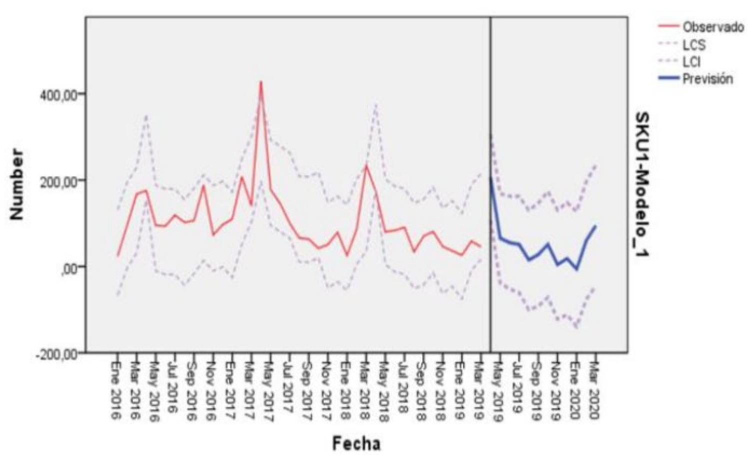
2.3 Demand Forecasting

2.3.1 Demand forecast with SPSS

For the elaboration of the forecast (Lorente-Leyva, 2019) through the SPSS program, we proceed to enter the historical data of each of the SKU to be analyzed. The optimal forecast model is automatically determined and that best fits each, as a result you have a graph indicating the months predicted based on the data. In addition, forecast errors are shown, as shown in Figure 2.

Resumen del modelo

Estadístico de ajuste	Media
R-cuadrado estacionaria	,825
R-cuadrado	,589
RMSE	48,862
MAPE	37,206
MaxAPE	182,058
MAE	35,109
MaxAE	132,629
BIC normalizado	7,966



Demand forecast through SPSS

2.3.2 Demand forecast with Neural Networks

Using the packages nnfor (forecast with neural networks), el forecast (time series and linear model) y el ggplot2 (creating graphics) it allowed to analyze the demand forecast, determine the input and hidden layers automatically, and analyze the forecast error, as shown in Figure 3.

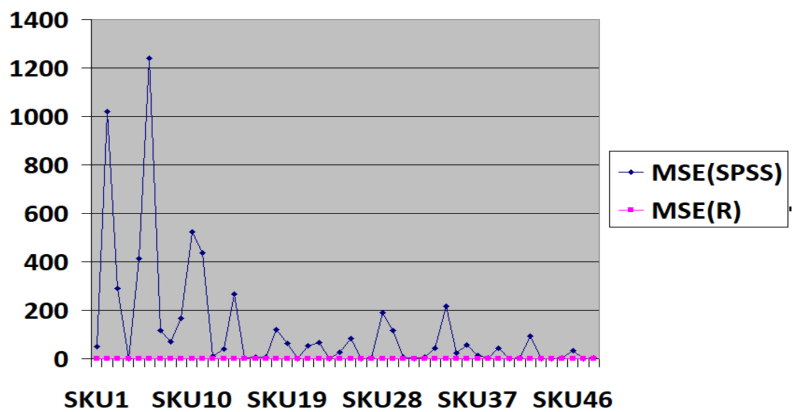
```
library(nnfor)
library(forecast)
library(ggplot2)
SKU<-read.csv("DB.csv",header=T,sep=",")
SKU=ts(SKU$SKU1,freq=12,start=c(2017,1))
y <- SKU
y
h <- 1*frequency(y)
frequency(y)
Fit1<- mlp(y, reps = 200, lags =NULL,difforder = NULL,hd.max = NULL)
plot(Fit1)
forecast(Fit1)
plot(forecast(Fit1))
summary(forecast(Fit1))
```

: Forecast with neural networks

Source: (Alexandra, 2019)

2.3.3. Comparison of forecast results.

For comparison of forecast methods is considered the result of the Square Mean Error (MSE) which must be a value close to zero. Figure 4 shows how this value varied with respect to one software and another, making it notable that the forecast calculated by means of neural networks is the closest to the reality of the company.



Error! Bookmark not defined.: Comparison of the MSE

2.4 Inventory models

Silver Meal, Wagner Whitin, Fragmented Period Balancing models are applied for SKU planning. They select the one with the highest total cost optimization compared to all the company's inventory management models.

2.4.1 Silver Meal

Created by Halan Meal and Edwars Silver, the Silver-Meal algorithm is a heuristic method that aims to obtain the minimum cost in order of purchase and the cost of maintaining inventory for several future periods, say m, achieving the minimum average cost per period for the time of m periods. It is considered as variable cost to the total cost of inventory, in this case, at the cost of ordering more the cost of maintaining inventory, where future demand for n periods is given by (Sipper & Bulfin, 1998) the following equation:

$$(D_{1t}, D_{2t}, \dots D)$$

Be TCUT(m) the average variable cost per period if the peak order m periods. This would mean that the cost to maintain is at the end of the period and that the amount required for the period is used at the beginning of the period. Sorting D in period 1 results in:

$$TCUT(1) = S = Cost\ to\ roder$$

In the case of ordering D1 + D2 in period 1, you get:

$$TCUT(2) = \frac{1}{2}(S + hD_2)$$

Where h is the cost to keep a unit in storage for a period, in this case D2 units are stored, this quantity is multiplied by h and divided by 2 in order to obtain the average cost. In the case of ordering 3 periods applies:

$$TCUT(3) = \frac{1}{3}(S + hD_2 + 2hD_3)$$

In case of 4 to more periods the equation is applied.

$$TCUT(m) = \frac{1}{m}(S + hD_2 + 2hD_3 + \dots + (m-1)hD_m$$

It calculates K(m), m-1, 2, 3,...,m, and stops when

$$TCUT(m+1) > TCUT(m)$$

In other words when the period in which the average cost per period begins to grow. In period 1 an amount is ordered that meets the demand for the following m periods where:

$$Q_x = S + \ D_2 + \dots + D_m$$

Where Q is the ordered quantity in the iy period and covers more future periods. In the case that the order is issued in period i, then the Qx is zero. The process is repeated in the period (m+1) and continues over the planned time horizon.

After the model is resolved, raw material planning is performed, where the total costs are calculated as shown in Table 2.

Error! Bookmark not defined. Silver Meal Model Results

SKU1	70.15	SKU13	180.24	SKU25	137.67	SKU37	39.84
SKU2	164.26	SKU14	200.04	SKU26	18.70	SKU38	43.37
SKU3	126.43	SKU15	21.83	SKU27	42.01	SKU39	145.48
SKU4	195.11	SKU16	42.31	SKU28	195.47	SKU40	55.92
SKU5	90.19	SKU17	49.50	SKU29	30.29	SKU41	37.16
SKU6	168.94	SKU18	58.52	SKU30	51.72	SKU42	114.37
SKU7	158.82	SKU19	135.92	SKU31	20.06	SKU43	17.62
SKU8	108.51	SKU20	16.99	SKU32	42.12	SKU44	18.14
SKU9	179.25	SKU21	71.58	SKU33	167.88	SKU45	88.36
SKU10	126.31	SKU22	165.09	SKU34	159.25	SKU46	86.42

SKU11	125.26	SKU23	18.88	SKU35	24.18	SKU47	21.97
SKU12	35.19	SKU24	53.49	SKU36	108.96	SKU48	19.98

2.4.2 Algorithm Wagner Whitin

Developed by Harvey Wagner and Thomson Whitin in 1958 with the aim of obtaining optimal solutions to the problems of inventory management; by means of dynamic scheduling which is based on the calculation of a variable cost matrix for all order alternatives over a time horizon.

This algorithm aims to minimize the cost of sorting and maintaining inventory; resulting in a minimum cost of an amount to order optima, evaluating all possible ways of ordering to meet demand in each time horizon; this algorithm is written mathematically as follows.

$$K_{tl} = A + H\left[\sum_{j=t}^{l}(j-t)Dj\right] \qquad j \geq 1$$

$$t = 1,2,\dots,n \;\; ; \quad l = t+1, t+2, \dots, n$$

$$K_l = min_t = 1,2,\dots,l\{K_{t-1} + K_{t,l}\}$$

$$l = 1,2,\dots,N$$

Where:
$A =$ Cost of purchase order or production preparation
$H =$Cost of inventory maintenance per period
$D_j =$Demand for the j-period
$K_l =$Minimum cost from period 1 to l with zero inventory at the end of period l
$D_j =$It is defined as zero, and the minimum cost solution is given byK_N

As any mathematical model should follow steps for its development:

- Define the criterion of the target function, which is to minimize costs of maintaining and sorting.
- Identify and define variables in addition to balance, demand, binary, limit, and non-negativity constraints.
- Decision variables:

$$X_i = \text{Number of units to be ordered in the period i}$$
$$I_i = \text{in units at the end of the period i}$$
$$W_i = \text{it ordered in the period i}$$
$$i = \{1,2,3,4,5,6,7,8,\dots,n\}$$

Formulation of the target function

$$Z_{MIN} = S(W_1 + W_2 + W_3 + W_n) + H(I_1 + I_2 + I_3 + I_n)$$

The application of the algorithm for each of the SKU, and the calculation of the total costs is shown in Table 3.

Error! Bookmark not defined. Wagner Whitin Algorithm Results

SKU1	69.90	SKU13	180.24	SKU25	137.66	SKU37	35.32
SKU2	161.96	SKU14	200.04	SKU26	18.70	SKU38	41.03
SKU3	126.44	SKU15	21.83	SKU27	27.74	SKU39	142.03
SKU4	195.11	SKU16	30.52	SKU28	195.47	SKU40	55.92
SKU5	90.21	SKU17	36.06	SKU29	30.29	SKU41	25.85
SKU6	168.79	SKU18	64.35	SKU30	51.73	SKU42	112.14
SKU7	158.83	SKU19	132.69	SKU31	20.07	SKU43	17.62
SKU8	99.24	SKU20	17.00	SKU32	30.58	SKU44	18.13

SKU9	179.25	SKU21	71.59	SKU33	167.73	SKU45	86.68
SKU10	120.46	SKU22	165.09	SKU34	159.25	SKU46	86.41
SKU11	118.42	SKU23	18.87	SKU35	24.18	SKU47	21.97
SKU12	35.20	SKU24	53.48	SKU36	108.96	SKU48	19.97

2.4.3 Fragmented Period Balance

This method attempts to minimize the sum of the variable cost for all batches, balancing the cost of ordering an order and the cost of maintaining inventory considering the future needs of the next batch. Consideration should be given to the EOQ analysis that, if the demand is uniform, the cost of sorting is equal to the cost of storing, although this does not apply to irregular demand.

The balance of units between periods generates a rate called fragmented period factor (FPF), which is the relationship between the cost of ordering and maintaining the invention. In this type of model to get the cost of maintaining inventory, the fragmented period is entered. As an example, we have 10 units in inventory over a period, these are equal to 10 fragmented periods, which is equal to 5 units in inventory for 2 periods:

$$PF_m = \text{fragmented period for m periods}$$

Like this

$$PF_x = 0$$
$$PF_2 = D_2$$
$$PF_3 = D_2 + D_3$$
$$PF_m = D_2 + D_3 + (m-1)D_m$$

The cost of maintaining inventory is h (PFm), and it is required to select the order horizon w that covers the cost of ordering A, choosing m such that:

$$A = h(PF_m)\text{I mean}PF_m = j$$

This is also the stop rule, where A/h is called the "fragmented period economic factor". Where size is given by the

$$Q_x = D_1 + D_2 + \cdots + D_m$$

This process is repeated starting with the m+1 period. The BPF method is mostly applied in the industry and is also known as minimum total cost.

The method was applied to all inventories, based on demand forecast and total costs are calculated for them, as shown in Table 4.

Error! Bookmark not defined. Results of the Fragmented Period Balance Method

SKU1	75.94	SKU13	180.24	SKU25	137.67	SKU37	49.90
SKU2	170.84	SKU14	200.04	SKU26	18.70	SKU38	48.43
SKU3	136.50	SKU15	21.83	SKU27	27.75	SKU39	146.41
SKU4	195.11	SKU16	30.52	SKU28	195.47	SKU40	55.92
SKU5	90.19	SKU17	49.50	SKU29	30.29	SKU41	25.85
SKU6	168.94	SKU18	59.46	SKU30	53.19	SKU42	118.23
SKU7	158.82	SKU19	143.49	SKU31	20.06	SKU43	17.62
SKU8	108.74	SKU20	16.99	SKU32	30.58	SKU44	18.14
SKU9	179.25	SKU21	85.33	SKU33	174.70	SKU45	92.75
SKU10	120.45	SKU22	165.09	SKU34	159.25	SKU46	88.80
SKU11	118.43	SKU23	18.88	SKU35	24.18	SKU47	21.97

SKU12	48.97	SKU24	53.49	SKU36	122.17	SKU48	19.98

3. Results

After developing each of the models listed above, the is made, as shown in Figure 5,which compares the total inventory costs at the end of SKU planning. It is noted that the method that most minimizes costs is Wagner Whitin's.

Table 5 shows a summary of the results obtained in the application of the 3 heuristic methods, in addition it can be noted that when applying the Wagner Whitin algorithm to the data obtained are positive with respect to the total cost, compared to the values obtained from the calculation of the total cost without the application of some inventory model.

Error! Bookmark not defined.: Result of the application of heuristic methods

	Total cost by applying the SM	Total cost by applying the WW	Total cost by applying the BPF
	$ 3 788,94	$ 3 706,68	$ 3 831,43
Saving ($)	$ 5 012,82	$ 5 095,08	$ 4 970,33
Saving (%)	56,95%	57,89%	56,47%

4. Conclusion

1. With the theoretical basis and fundamentals in inventory management, specifically with the heuristic models for inventory planning was achieved stent the model application that best suits the company under study.
2. The ABC classification of inventories allowed to establish the SKU that generate the most sales, conformers by 78,82%, 16,66% and 4,62% of categories A, B and C, respectively.
3. The forecasting data showed high dispersion in orders, leading to the application of heuristic methods.
4. Forecasting demand over neural networks provided an average MSE of 0,0075, allowing to create a forecast closer to the reality of the company.
5. From the application of the Silver Meal, Wagner Whitin and Fragmented Period Balance inventory models resulted in a total inventory cost of $3 788,94, $3 706,68, and $3,831.43 respectively; from the contrast of the three models, Wagner Whitin's method presented the largest savings, with 57,89%.

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