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Demand Forecasting Applied to Radio Frequency Identification Technology

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Abstract. Nowadays, companies have concern about having accurate inventories, inventory control is vital for employee organization, cost control and business profitability, therefore if the company do not have a proper administration there may be **s**tock shortages, accumulation of unwanted inventory, due to lack of automation, consequently generating wrong forecasts. Using RFID technology for inventory control, in addition to reduce efficiency problems in a logistics warehouse it's possible to analyze effectively the demand, and through different mathematical models, be able to generate a more accurate demand forecast, reducing uncertainty and making decisions regarding the forecasts obtained. The investigation allowed to conclude that, due to the particularities in the rotation of the PL's of the Ryder warehouse, it is appropriate to use the seasonal index method obtains a mean absolute percentage error (MAPE) of 13% in the forecast, adapting to the real demand.

Keywords: RFID, forecast, radio frequency identification, trend, seasonality, forecast error, product line, demand, MAPE.

1 Introduction

The purpose of this document is to expose different mathematical models to generate forecasts, leveraging the benefits of an inventory control system using RFID technology, where the control of input, output and updates the products in the inventory, will be controlled in a more efficient and faster way, avoiding delays in the operation, as well reducing of human errors.

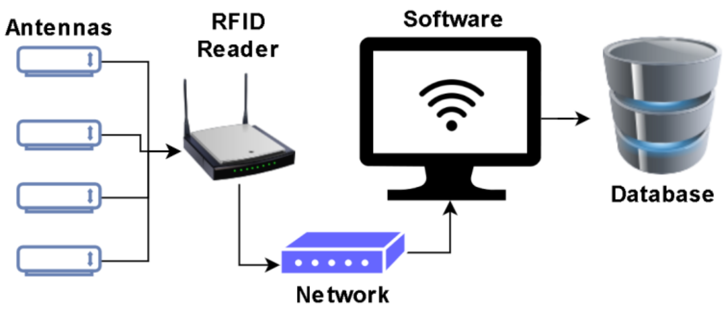

Fig. 1. RFID Structure.

2 Theoretical Framework

2.1 Structure of an RFID System

Radio frequency identification is a wireless and remote identification technology in which the RFID reader device linked to a computer, communicates through an antenna with a tag, over electromagnetic radio waves, generating a remote data storage and recovery system.

The basic components of an RFID system are:

Tags: also known transponders. Tags are composed of an antenna that is responsible for transmitting information, a radio transducer that converts the information, transmitted by the antenna and a microchip capable of storing the identification number and other data:

– **Passive tags:** They don't need an internal power supply, they are resonating circuits. They can reach distances between a few millimeters and 7 meters. Their size is smaller than usual. They are usually inserted in stickers' tags and have a lower cost.
– **Active tags:** They have an internal battery, so their coverage (hundreds of meters) and storage capacity is bigger. It can be used in areas with water, or with metal presence, and they are still suitable. They are more reliable and safer, therefore, more expensive and have a larger size.
– **Semi-passive tags:** A combination of the previous two tags.

RFID reader: The reader receives the information transmitted by the tags and transfers the data to the processing system. Composed by an antenna, a transceiver and a decoder.

Data processing subsystem: Software that is the intermediary between the reader and the application. It filters the data it receives, so only the useful information reaches the application.

To read the information of a tag, RFID readers emit a radio signal, once the tag is within reach of a reader, allowing the tag to be identified.

It is important to mention that the labels can be read remotely as shown in figure 1, without direct physical contact or aligned to the reader [1].

The antenna is responsible for transmitting and receiving through radio waves to perform communication between the components, making the energy transfer. Antennas are the most sensitive component of an RFID system.

RFID readers can generate interference with each other when installed incorrectly. These types of problems must be considered when making the definition and implementation plan to ensure an optimal installation. Therefore, the system has a mechanism that allows filtering to detect and remove duplicated RFID tags, likewise the anti-collision algorithm that is integrated in the RFID reader must be activated, because if more than one tag is read the data would be mixed and could not be read.

It’s necessary to place the antenna in a position where the energy transmission is directed towards the tags, in this way, the data transmission is emitted optimally.

There are 3 characteristics of the antennas that contribute to the optimal reading of an RFID tag [2]:

Radiation pattern: It’s the 3D energy field that an antenna creates. Also known as the reading area.

Aattenuation: the signal can be reduced or attenuated to limit the reading range of the tag or direct it to the tags that need to be read.

Polarization: is the orientation of the electromagnetic field transmission.

Passive tags are cheaper; therefore, it would be more suitable for implementation in a warehouse [3], due to the quantity of materials registered. Passive tags don’t need any type of power supply. Through the signal emitted by the readers / antennas they create a small electric current, which is enough to operate the circuit of the tag in such a way that it can generate and transmit information [1].

Using RFID technology in an inventory generates different benefits [4]:

a) Identification of a product in the supply chain, automatically and accurately.
b) Reading is fast and accurate, without a direct line of sight [1].
c) Reduction of stock shortage.
d) Ability to inform the people in charge when it’s time to replace the products on the shelves or when the items have been placed in a wrong place. [5]
e) Optimize the monitoring of products on pallets or boxes.
f) Tags can be reused.
g) Product recall control.

This leads to an increase in sales of products that are always available, optimizing the distribution process, reducing the excess inventory in the warehouse. RFID technology is frequently used to control products, being used in warehouse to control merchandise sold [6].

Some experts estimate that 30% of the inventory in the supply chain corresponds to existing safety stocks because the information of demand and supply is not accurate, nor is not updated in real time [7].

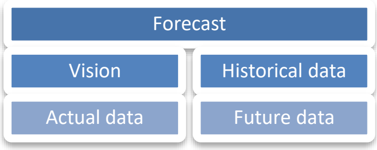

Fig. 2. Forecast elements [10].

RFID technology can provide automation for the process of identification of products, human intervention can be reduced, but not be eliminated, and however, there would be an increase in productivity, efficiency and quality of processes and an increase speed of product collection and product control.

Using the information obtained from the RFID system, additionally from the information obtained by the warehouse register, an optimal demand forecast can be generated, it's necessary to have a reliable database to generate an successful forecast [8], in this manner the information will be analyzed to select the most appropriate prediction method for the product line, depending on the category in which the product line is found.

If we can generate a more accurate forecast, the risks of product obsolescence can be reduced, the coordination of product arrival can be improved, advance reacting to high demand, improving customer services.

2.2 Forecast Demand Planning

Demand planning is the process of analyzing the evolution of sales and market in order to estimate their values in the future, this means, anticipate customer needs and determine strategies for production, purchasing and inventory that they can offer high availability with high profitability [9].

The future demand for a product line in a company can be modified by many factors and sometimes it is difficult to select an appropriate method to generate forecasts. The four elements of a forecast (see Figure 2) are: vision, historical, present and future data.

Statistical methods use historical data to find relationships within the time series [11], in this manner, the actual demand of a product line is examined, in which different factors that influence the series are analyzed, consequently generating an optimized forecast, closer to the demand that will be generated in the future. An optimal forecast allows a logistics warehouse to be prepared to manage the warehouse.

There are different demand behaviors for different product lines, which in some cases can be classified to use appropriate methods for the demand it generates, among these factors are [12]:

Seasonality: Demand changes because cyclical events, where a pattern of increases or decreases is repeated every certain months or season.

Trend: Average incline of increase or decrease over time.

Randomness: Unpredictable changes in demand.

Cyclic: Patterns of increments or decrements, which are presented in the course of longer periods.

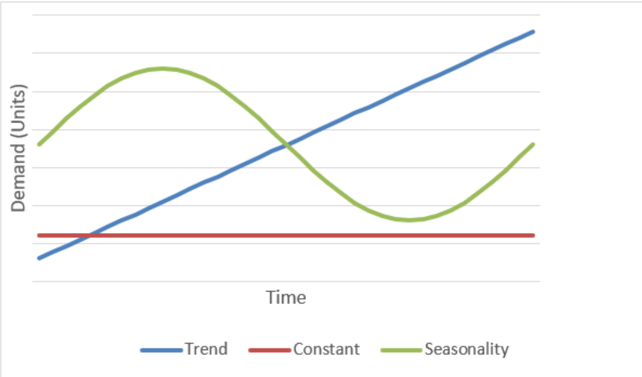

Fig. 3. Factors that affect demand [12].

The importance of a forecast for demand management is therefore essential to optimize all these processes, as well to be competitive, profitable and productive. [3]

Adjusting the appropriate algorithms for handling the data obtained from the RFID system, a demand forecast can be generated optimally for the product line, since there will be more control of input and output of the product in the warehouse.

It is important to mention that the product lines that are new, are not suitable for testing in this investigation, since it does not guarantee product rotation and there is a risk that they will not be formulated in future periods and remain in the inventory [13], therefore we will use stable PL's in the market, discarding new products for this investigation.

The different tools and prediction methodologies that were used in this research are described below.

2.2.1 Seasonal Indexes

The method of seasonal indexes is recommended in cases where the demand of a product has a well pronounced seasonal pattern.

Changing this pattern in series of times in a year. The seasonal index of the time series shows variability due to the influence of the seasons for example year by year.

This variation corresponds to the events that occur in the same months, where it can be modified by weather, holidays, school events, sports, etc.

The equations that are used are [14]:

$$\hat{X}_t = \frac{\sum X_{t+} Y_t}{2},$$

$$Z = \frac{\sum \hat{X}_t + \cdots + \hat{X}_{t+n}}{n},$$

$$S_t = \frac{\hat{X}_t}{Z},$$

$$P_t = d * S_t.$$

X_t	Demand for the seasonal period of the current year
Y_t	Demand for the seasonal period of the last year
$\widehat{X'}_t$	Average of the seasonal period of the current and previous year
S_t	Seasonal index
d	Calculated demand
Z	Average of the entire seasonal series
P_t	Forecast of the seasonal period

2.2.2 Simple Exponential Smoothing

The simple exponential smoothing method calculates the average of a time series with a self-correcting mechanism that searches for adjust the forecasts in the opposite direction to the deviations of the past, through a correction that is affected by a smoothing coefficient.

The simple exponential smoothing forecast is optimal for time series where demand has random patterns, to reduce the impact of irregularities.

The simple exponential smoothing method works through a smoothing constant alpha (α) that has a value between 0 and 1, where the value usually varies between 0.05 and 0.30 [15]:

$$\hat{X}_t = \hat{X}_{t-1} + \left(\alpha * \left(X_{t-1} - \hat{X}_{t-1}\right)\right).$$

$\hat{X}_t$	Forecast for the current period
$\hat{X}_{t-1}$	Forecast for the previous period
X_{t-1}	Demand of the previous period
α	Smoothing constant (values between 0.0 y 1.0)

2.2.3 Triple Exponential Smoothing (Holt-Winters)

The Holt-Winters method is an improved extension of the simple exponential smoothing method, while the smoothing technique provides a general impression, long-term movements in the data allows the elaboration of short-term forecasts [16].

It´s recommended to consider at least 21 previous periods of sales, which allow adjusting the values of the different components of the model [17].

The Holt-Winters method forecast is generated using the following equations [18]:

$$I_t = \left(\alpha * \frac{Y_t}{S_{t-L}}\right) + [(1-\alpha) * (I_{t-1} + T_{t-1})],$$

$$S_t = \left(\gamma * \frac{Y_t}{I_t}\right) + [(1-\gamma) * (S_{t-L})],$$

$$T_t = \beta * (I_t - I_{t-1}) + [(1-\beta) * (T_{t-1})],$$

$$F_{t+m} = (I_t + mT_t) * (S_{t+m-L}).$$

I_t	Exponential smoothing for the current period
S_t	Seasonality estimation for the current period
T_t	Trend estimation for the period
F_t	Forecast for the current period
Y_t	Demand for the current period
L	Number of months it takes for seasonality to be repeated
α	Smoothing coefficient (values between 0.0 and 1.0)
β	Smoothing coefficient for trend (values between 0.0 and 1.0)
γ	Smoothing coefficient for seasonality (values between 0.0 and 1.0)

2.2.4 Absolut Error on Forecast

This value calculates the absolute difference between the demand of the period and the forecast generated, adjusting the values in the equation to minimize the error in any forecast method [15]:

$$e_t = |X_t - \hat{X}_t|.$$

$\hat{X}_t$	Forecast of the current period
X_t	Demand of the current period

3 Methodology

3.1 Base Information for the Research

To implement the development of this methodology, historical data from 2017-2019 outputs from the Ryder warehouse were used, using the HP Inc. section, located in Guadalajara Jalisco.

Using the demand for the GP product line as a sample, where no new product lines have been considered, since the lack of historical data affects directly on the reliability of the results of this study.

Table 1. Seasonal index applied.

Period	2018-2019	2017-2018	Monthly average	Season index	Forecast
1	72593	95498	84045.5	1.22	85196.4
2	82510	78180	80345	1.16	81445.2
3	71561	84162	77861.5	1.13	78927.7
4	77277	80561	78919	1.14	79999.7
5	67099	71150	69124.5	1.00	70071.1
6	95321	98306	96813.5	1.40	98139.3
7	28710	62726	45718	0.66	46344.1
8	50449	36585	43517	0.63	44112.9
9	83875	81640	82757.5	1.20	83890.8
10	28276	74527	51401.5	0.74	52105.4
11	37463	58717	48090	0.70	48748.5
12	67526	72593	70059.5	1.01	71018.9
	Total		**758593**		
		Average	**69054.38**		

3.2 Definition of Forecast Models

The demand for the product line was taken to define the most appropriate forecasting method. Performing development simulation, through the Excel tool, the future requirements were determined using the methods of Seasonal indexes, Simple Exponential Smoothing and Holt-Winters, making comparisons between the methods to define the most appropriate, using as criteria the minor absolute error.

4 Results

4.1 Seasonal Indexes

Seasonal indexes method is used in demand series where there is a pronounced seasonality, this means that, there is a repetition of the increments and decrements every certain months.

The following example expose that the product line has a very pronounced seasonality, that is repeated year after year, so it's possible to get the seasonal index, for a forecast closer to his historical demand, see Fig. 5 and Fig. 6.

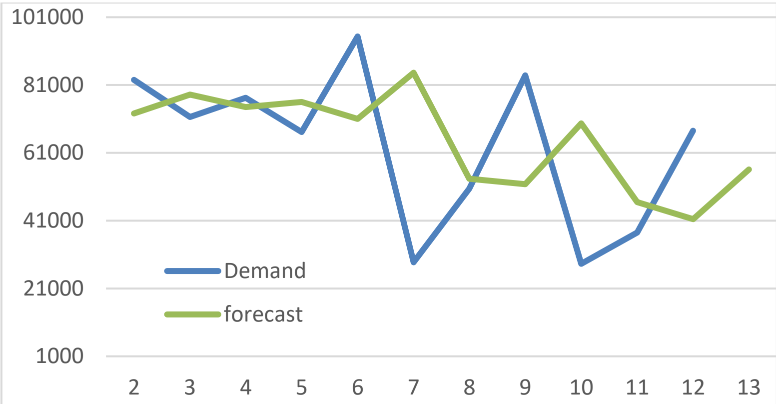

Fig. 5. Simple exponential smoothing.

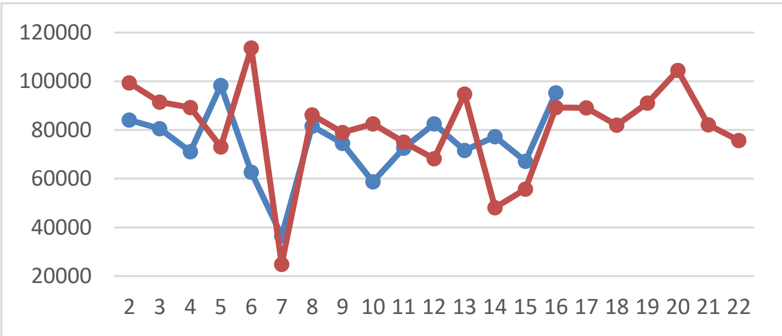

Fig. 6. Triple exponential smoothing.

This method adapts to the irregular behaviour of the demand, taking the seasonal index per month, because the series generated in this warehouse has annual cycles, so it is appropriate to use as historical data from the same period in previous years, without taking into consideration the trend of previous months on the same year, this method generated a mean absolute percentage error (MAPE) of 13%.

4.2 Simple Exponential Smoothing

Using the data obtained from the "GP" product line, assigning α = '0.56'. This method, as it was mentioned before, search's for reduce the peaks that are generated in an irregular demand, by random patterns.

This method is looking to counter the peaks generated on the demand, as we can observe on the figure, however this method is suitable for series that have very pronounced cycles where the cycle is notorious, and this method is not appropriate for the demand for the product line GP because of the irregularities on the series, that are not on a cycle every certain months of the year, generating a MAPE of 33%.

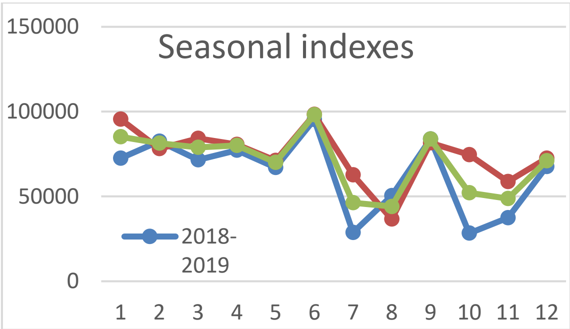

Fig. 4. Seasonal index applied.

Table 2. Simple exponential smoothing.

Period	Demand	Forecast
1	72593	
2	82510	72593
3	71561	78146.52
4	77277	74458.63
5	67099	76036.92
6	95321	71031.68
7	28710	84633.7
8	50449	53316.43
9	83875	51710.67
10	28276	69722.69
11	37463	46512.54
12	67526	41444.8
13		56050.27

4.3 Triple Exponential Smoothing

This method considers seasonality also the trend. Using the data obtained from the "GP" product line, the equation generated in the Holt-Winters method will be using α = '0.32', β = '0', γ = is assigned '0.64'.

In this case, the trend is repeated every few months, therefore I used a semi-annual trend, so 6 periods are added to calculate the seasonality, exposing them as the negative periods (-6, -5, -4, -3, -2, -1, 0) in the table.

This also allows to generate a forecast of 6 months in the future, the first 6 values of seasonality St in the 6 periods, are obtained by the seasonal index's method, mentioned previously.

Table 3. Triple exponential smoothing.

Period	Demand	At	Tt	St	ft+1
-6				1.22	
-5				1.16	
-4				1.13	
-3				1.14	
-2				1.00	
-1				1.40	
0				0.36	
1	95498	95498.000	0.000	1.1	
2	78180	85398	0	1.0	116230
3	84162	81177	0	1.1	99361
4	80561	78034	0	1.1	91531
5	71150	72937	0	1.0	89182
6	98306	81101	0	1.3	73011
7	62726	69354	0	0.7	113702
8	36585	79907	0	0.7	24871
9	81640	78534	0	1.0	86225
10	74527	77100	0	1.0	78991
11	58717	69923	0	0.9	82484
12	72593	69197	0	1.0	75000
13	82510	73910	0	1.2	68145
14	71561	68075	0	0.9	94701
15	77277	81464	0	0.9	48035
16	67099	86832	0	0.9	55733
17	95321	88757	0	1.0	89200
18					89132
19					82062
20					91034
21					104417
22					82129
23					75645

This method has adapted to the irregular behavior of the demand, since 6-month cycles are taken, however, it is impossible to prevent product falls for reasons beyond the control of the company, so there is (MAPE) of 24%.

4 Conclusion and Future Work

Forecasts are a very useful and important on the management of the inventory control because the information generated affects in different ways to the operation, allowing knowing how much product will receive, as well, the staff that will be required, improving the management of the operation.

The information obtained during this research reveals that, there is no method that fits all demands, because each PL has different characteristics, trend and seasonality.

In this scenario, it's important to make a classification of PL's to find the appropriate method for distinct time series, identifying which product lines have trend, as well seasonality, determine which product lines handle only seasonality, trend, or cycles. Because, generalizing a method for all PL's can generate forecasts distanced from real demand, meanwhile, analyzing the data series, it's possible to properly categorize, selecting the best method specified by the small differences between the classifications, creating a more accurate and appropriate estimation.

For the PL taken in the sample, it has been observed that the seasonal index method obtains a mean absolute percentage error (MAPE) of 13%, so it has been taken as the appropriate method for this system, since it shows a more accurate forecast.

Part of the future work consists in implementing different statistical methods to find which method generates the minor error in the forecast and define which method to use.

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