Demand Seasonality Analysis of High Valued-Added Items: a Kruskal-Wallis Test Application in an Oil and Gas Multinational Company

Santos, Marcos[1]; Vianna, Daniel Viégas[2]; Dias, Fabrício da Costa[3]; Reis, Marcone Freitas[4]; [5]Bahiana, Bruna Russo
[1]Center of Naval Systems Analysis, AMRJ, Ed. 23, Rio de Janeiro, Brazil, 20091-000
[2,5]SENAI CETIQT University, Magalhães Castro Street, 174, Rio de Janeiro, Brazil, 20961-020
[3,4]Fluminense Federal University, Passo da Pátria Street, 156, Niterói, Brazil, 24210-240

***Abstract* — This article has the purposde to realize the Kruskal-Wallis non-oparametric test on a historical series of consumption of the most important items of a multinational company in the oil and gas sector. The objective of this paper is to check if there is seasonality in its demand, thus offering a more adherent forecasting a model for each one of them. The company mentioned has a inventory estimated at US $ 17,500,000.00. There was collected a consumption data from March 2014 to March 2016, and from the binomial composed of the ABC classification and the inventory turnover, items were selected as Class A and as high turnover. It is known that an inventory with low turnover directly impacts on the operating costs of any company. Thus, one needs to analyze the demand behavior for each item, to propose a forecasting model, and therefore establish an inventory policy. Such inventory, as much as possible, should be streamlined, since it enables continuing operations. Given the high value of stored items, the accuracy of the used demand forecasting models plays a key role in the financial health of the company, starting from a leaner structure, one can focus on other domestic sectors, thus establishing a competitive advantage.**

***Index Term*— Kruskal- Wallis test support; oil and gas sector; demand forecast.**

I. Introduction

The development of increasingly improved forecasting techniques along to the new inventory tracking technologies such as ERP (Enterprise Resource Planning), has encouraged companies to seek more and more resources to enable a lower cost. In this context, it can be inferred that the implementation of quantitative forecasting techniques allows managers to use the values obtained with the models as a starting point, and along with their judgment and critical capacity in relation to the market, to set levels or volumes for acquisition of new items. In addition to aiding managers, these models allow to companies a large economy in disregard to the reduction of its inventory value along with the reduction of its warehouses and a smaller investment, besides allowing the same to allocate their resources in other critical parts, may even reaching the generation of new jobs.

According to Slack, Johnston & Brandon-Jones (2015) there are two main approaches in forecasting. Managers sometimes use qualitative methods based on opinions, past experience or even good guesses. There is also a range of quantitative forecasting techniques available to help in the evaluating trends and causal relationships, making predictions for the future.

Slack, Johnston & Brandon-Jones (2015) also mention that quantitative forecasting techniques can also be used in data modelling. Although no approach or technique result in accurate prediction, a combination of qualitative and quantitative approaches can be used with great effect to integrate expert judgments and predictive models.

It is also worth noting that nowadays the social environmental context in which the companies operate, with concerns for air pollution, the greenhouse effect, pollution of rivers and lakes, among others. In this perspective, the decrease in acquisition of new products also improves the image of these companies to the society with respect to its environmental responsibility.

According to Petrobras, in 2014, the oil and gas sector accounted for 13% of GDP (Gross Domestic Product). With the worsening of the economic crisis in Brazil in 2015 and the fall in the price of oil, this sector was largely responsible for the Brazilian GDP decline. According to a study published by SPC (Department of Economic Policy of the Ministry of Finance), the impact of the reduction in investments in the oil and gas sector may account a temporary contraction of excess savings to 2 percentage points of GDP over 2015.

The company studied in this article, is a multinational company of the oil and gas sector located in Brazil. This organization moves annually in its inventory about of US $ 2,300,000.00 per year, using as a reference the items studied in this paper.

II. Literature Review

A perfect understanding of the various quantitative forecasting techniques allow managers to effectively employ the predicted values (or "cold numbers", a term often used in several Brazilian companies) as a starting point for the incorporation of their judgment and sensitivity regarding various market issues as, for example, competitors' actions, promotions, discussion with other issues of the company's departments on planning and capacity and programmed stops of machines for maintenance, definition of service levels and product availability (Wanke & Julianelli, 2006).

According to Battersby (1968), all predictions are wrong. They differ in the extent of their mistakes, and it is usually possible to improve any forecast by additional collection of relevant information, or for processing, more elaborated than is known.

Battersby (1968) also highlights that the one person making the prediction seeks to get the most out of their work but not necessarily with the best accuracy. The money (or time) spent is controlled by executive decisions for which the forecast is made and the action taken, then.

Black (2004) states that the Kruska-Wallis test, developed in 1952 by William H. Kruskal and Wallis W. Allen, and "the one-way analysis of variance" (ANOVA) are used to determine if three or more independent groups are from different populations or not. It also states that considering the "one-way ANOVA" as based on normally distributed populations of premises, independent groups and at least one interval with a data level equal variance. The Kruskal-Wallis test is based on that "n" groups are independent and that data is randomly selected.

Chan & Walmslqr (1997) also reinforces the information that the Kruskal-Wallis test is used to determine whether three or more independent groups are the same or differ in some variable of interest on the ordinal level data, interval level or as the data regarding levels are available.

Hillier & Liberman (2013) states that the annual costs associated with inventory storage are very large, perhaps equivalent to a quarter of its value. Therefore, the costs incurred for storage inventories in the United States are around of hundreds of billions of dollars annually. Reducing these storage costs by avoiding unnecessary large stocks can increase the competitiveness of any company.

A. *Bibliometry*

The development of bibliometric techniques has been motivated by constant changes in science and technology from the dissemination of knowledge. The bibliometry is an object of science that applies statistical methods to explore the evolution of scientific and technological information in certain areas.

As relates Rostaing (1997 apud Hayashi, 2012), this activity began in the 1980s with the American Francis Narin, in his work on the American patent databases. In addition, according to the author, the future focus would be on the application of bibliometric techniques of proprietary data, facilitated by the existence of databases that report international patents in the form of bibliographic reference.

It was researched by the author of this work, in the CAPES platform, the number of records in publications between 2000 and 2015 of the predetermined keyword "Demand Forecast".

The Figure 1 below shows the graph of the results obtained in the bibliometry applied to this work, for the keyword mentioned above.

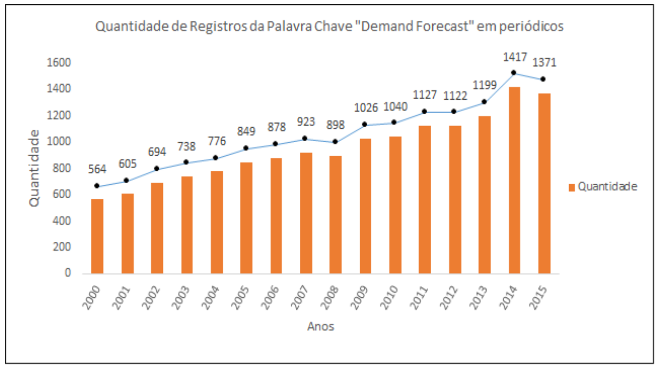

Fig. 1. Bibliometric uplift realized at the CAPES periodcs gateway.
Source: Authors (2016)

For the term "Demand Forecast" the number of registered paper has doubled in the last 15 years, with a smooth fall in 2015, with over 1.371 publications. The peak occurred in 2014, with the register number exceeding 1400 publications.

III. PROBLEM

The research had as object of study the items demand of a multinational company in the oil and gas industry located in Brazil. To establish the demand forecasting model that best suits each item with a minimum inventory model aiming the reduction of the company's assets, generating savings at warehouse maintenance area and the possibility of investing in other processes. The organization has an inventory value of approximately US $ 17,500,000.00, with high losses on non-current assets, that is, items with no inventory out.

The company has mostly of its inventory of spare, repair or operation parts, which are essential for any organization with respect to its operation. This company's main function is the production a set of remotely operated valves that control the flow of fluids produced or injected into the oil. This valves supports high pressures and different temperature ranges.

However, given the impossibility of analyzing all inventory items, approximately 7,000 SKUs (stock keeping unit), it came to the conclusion that the best way to achieve considerable results with the greatest possible relevance would be using ABC stock classification,' and using only the classification of materials "A". But this could not be used purely and simply as a parameter for obtaining the items, because it would not be effective to forecast a SKU that has a cost of R$ 100,000.00, but is used once every two years, so it was needed to also use an inventory turnover analysis provided by the company. For this analysis it was considered the period from March 2014 to March 2016 (two years) as well as predictive analysis.

For the classification of the item as to its inventory turnover it was recorded the months that the materials had a stock out, so if the material was transacted in a month, is was accounted the number one. For this reason the sum is a maximum of 24 units. For classification, the following table was used:

- Low Turnover: < 8 months of transition
- Medium Turnover: > = 8 e < 16 months of transition
- High Turnover: > = 16 months of transition

Is worth noting that these numbers are for an amount of 24 months and that the values for the classification were obtained from the company's employees, who have a great knowledge of the process.

Based on these filters it was found a quantity of eight items that have a great importance in regards to the representativeness of inventory and their monthly consumption, as we can see in the Table I below.

Table I
Used Itens

Item Code	Quantity	Representativeness
XX4YWZ	32.00	1.39%
XX11YWZ	111.00	0.75%
XX28YWZ	54.00	0.38%
XX30YWZ	64.00	0.36%
XX31YWZ	47.00	0.36%
XX51YWZ	8,868.00	0.27%
XX97YWZ	6,490.76	0.17%
XX168YWZ	375.00	0.11%

The consumption value of these items in the analyzed period reaches the level of approximately US $ 4,600,000.00, representing a percentage of approximately 26% of the inventory value of the analyzed data, justifying the choice putting them together for analysis.

According to Wanke (2003 apud Santos & Gilbert 2014), it is growing the importance attributed to inventory management as a key element for reduction and total cost control and improving the level of service provided by the company. In general, the inventory appears in the value chain in many formats (raw materials, goods in process and finished products) and characteristics, and requires, for each format, different planning and control procedures, significantly influencing the inventory management.

However, before establishing inventory levels from a demand forecasting model, it is necessary to observe the behavior of the samples. If it is seasonal, sporadic, cyclical or random, as can be seen in Figure 2, below:

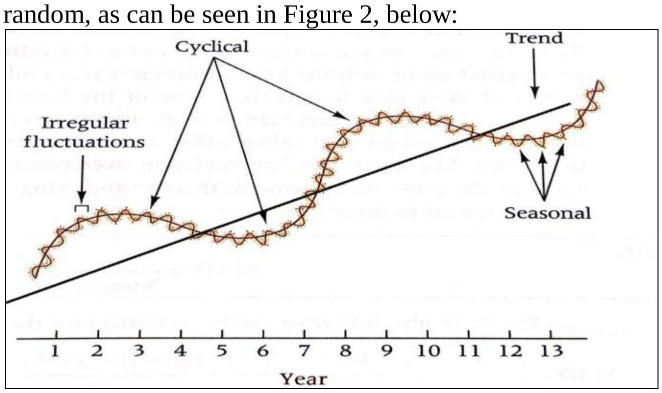

Fig. 2. Sample's behavior

From the was described above, the purpose this paper is to determine whether the demand of the studied items has seasonality or not. To perform such verification it will be applied the nonparametric Kruskal-Wallis test in a 4 semesters sample (March 2014 to March 2016).

IV. 4. Methodology

This is a bibliographic research of exploratory character, since it consists of a study on a small sample that therefore also allows authors a better definition of the problem and hypothesis formulation with more precision. It is also characterized as a case study.

This research has had, as its main sources of information, books, articles and academic papers related to both the Kruskal-Wallis test, as the demand forecasting methodologies and inventory management. This research may also be characterized as a quantitative na qualitative field research.

Then, with the help of Minitab software, the Kruskal-Wallis test was applied in order to determine whether the series of data were arising from the same group of data, or if they were independent, that is, observe the existence of seasonality or not in the sample of the consumption items.

From the results obtained with Minitab, it was found that 7 of 7 samples studied exhibited a sporadic nature, that is, it has proven its randomness and has no seasonal relationship, not belonging to the same data group.

The data have been collected from the inventory turnover reports and ABC classification, pre-established in the company. Then the items that had the classification "A" were selected and the "status" of high turnover, with the purpose of having more importance to the research.

For the test, the data were stratified into semesters so as to be inserted into Minitab and thus analyze the results of the Kruskal-Wallis test.

V. Math

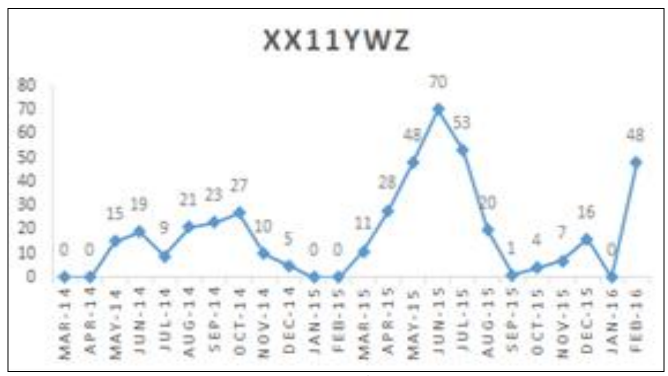

Fig. 3. Consumption of Item XX11YZW

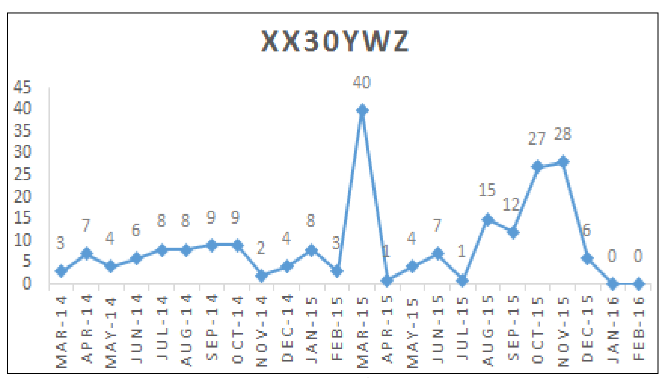

Fig. 4. Consumption of Item XX30YZW

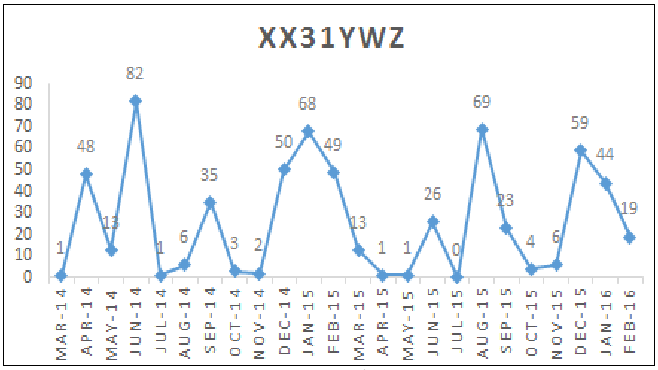

Fig. 5. Consumption of Item XX31YZW

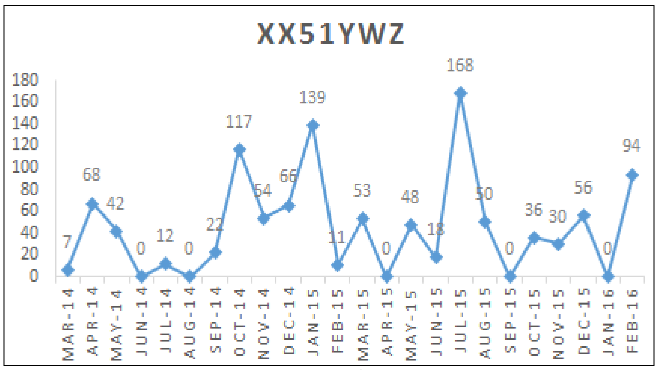

Fig. 6. Consumption of Item XX51YZW

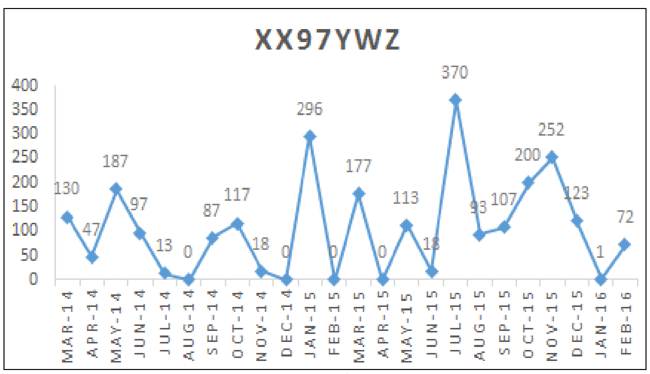

Fig. 7. Consumption of Item XX97YZW

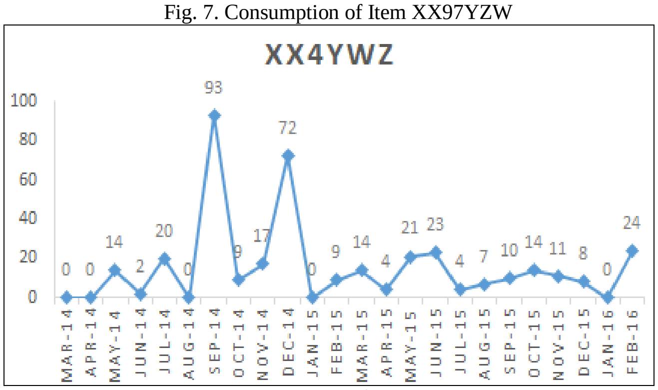

Fig. 8. Consumption of Item XX4YZW

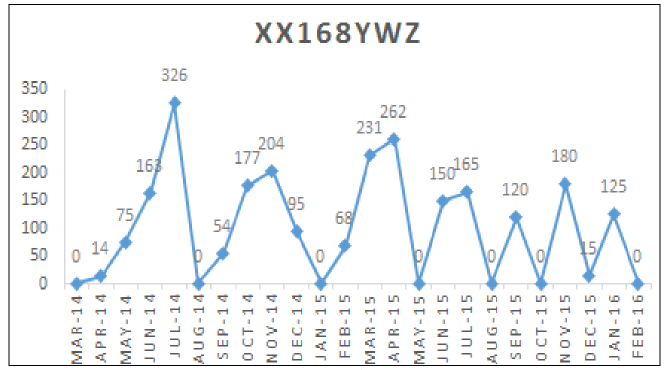

Fig. 9. Consumption of Item XX168YZW

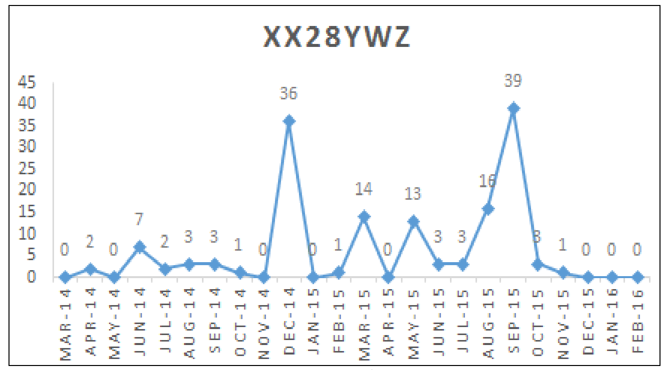

Fig. 10. Consumption of Item XX28YZW

From this information, the Kruskal-Wallis test - that has the following set - was applied:

$$K = \left[\frac{12}{n(n+1)}\sum_{j=1}^{c}\frac{T_j^2}{n_j}\right] - 3(n+1)$$

with,
c = number of groups
N = amount of samples
Tj = total ranking in group
Nj = amount of samples in a group
K ≈ X2, as $df = c - 1$

From the Kruskal -Wallis test, we obtained the results shown in Figures 11 to 18:

```
Kruskal-Wallis Teste: Quantity versus Semester

Kruskal-Wallis test on Quantity

Semester   N    Median    Ave Rank       Z
  A        6    12,000      10,2     -0,93
  B        6     7,500      10,3     -0,87
  C        6    38,500      19,4      2,77
  D        6     5,500      10,1     -0,97
Overall   24                12,5

K = 7,66  GL = 3  P = 0,378
K = 7,73  GL = 3  P = 0,373  (Adjusted for ties)
```

Fig. 11. Test on Item XX11YZW

IJENS

```
Kruskal-Wallis Teste: Quantity versus Semester

Kruskal-Wallis test on Quantity

Semester  N   Median   Ave Rank      Z
  A       6    6,500     12,1     -0,17
  B       6    6,000     12,3     -0,10
  C       6    5,500     12,4     -0,03
  D       6    9,000     13,3      0,30
Overall  24              12,5

K = 0,10  GL = 3  P = 0,992
```

Fig. 12. Test on Item XX30YZW

```
Kruskal-Wallis Teste: Quantity versus Semester

Kruskal-Wallis test on Quantity

Semester  N   Median   Ave Rank      Z
  A       6    1,000      8,3     -1,67
  B       6   13,000     15,2      1,07
  C       6   10,500     13,5      0,40
  D       6   10,500     13,0      0,20
Overall  24              12,5

K = 3,09  GL = 3  P = 0,378
K = 3,12  GL = 3  P = 0,373  (Adjusted for ties)
```

Fig. 13. Test on Item XX4YZW

```
Kruskal-Wallis Teste: Quantity versus Semester

Kruskal-Wallis test on Quantity

Semester  N   Median   Ave Rank      Z
  A       6    1,000      8,3     -1,67
  B       6   13,000     15,2      1,07
  C       6   10,500     13,5      0,40
  D       6   10,500     13,0      0,20
Overall  24              12,5

K = 3,09  GL = 3  P = 0,378
K = 3,12  GL = 3  P = 0,373  (Adjusted for ties)
```

Fig. 14. Test on Item XX28YZW

```
Kruskal-Wallis Teste: Quantity versus Semester

Kruskal-Wallis test on Quantity

Semester  N   Median   Ave Rank      Z
  A       6    9,500     11,7     -0,33
  B       6   42,000     15,0      1,00
  C       6    7,000      9,6     -1,17
  D       6   21,000      3,8      0,50
Overall  24              12,5

K = 2,04   GL = 3  P = 0,564
K = 2,05   GL = 3  P = 0,562  (adjusted for ties)
```

Fig. 15. Test on Item XX31YZW

```
Kruskal-Wallis Teste: Quantity versus Semester

Kruskal-Wallis test on Quantity

Semester  N   Median   Ave Rank      Z
  A       6    9,250      8,8     -1,47
  B       6   60,000     16,3      1,53
  C       6   49,000     13,5      0,40
  D       6   33,000     11,3     -0,47
Overall  24              12,5

K = 3,66   GL = 3  P = 0,301
K = 3,69   GL = 3  P = 0,297  (adjusted for ties)
```

Fig. 16. Test on Item XX51YZW

```
Kruskal-Wallis Teste: Quantity versus Semester

Kruskal-Wallis test on Quantity

Semester  N   Median   Ave Rank      Z
  A       6   44,21      11,5     -0,40
  B       6   81,66      13,0      0,20
  C       6   157,50     14,5      0,80
  D       6   67,50      11,0     -0,60
Overall  24              12,5

K = 0,90   GL = 3  P = 0,825
K = 0,92   GL = 3  P = 0,820  (adjusted for ties)
```

Fig. 17. Test on Item XX97YZW

```
Kruskal-Wallis Teste: Quantity versus Semester

Kruskal-Wallis test on Quantity

Semester  N   Median   Ave Rank      Z
  A       6   72,10      11,4     -0,43
  B       6   52,50      10,4     -0,83
  C       6   103,00     13,3      0,33
  D       6   114,91     14,8      0,93
Overall  24              12,5

K = 1,40   GL = 3  P = 0,706
K = 1,41   GL = 3  P = 0,704  (adjusted for ties)
```

Fig. 18. Test on Item XX168YZW

In this case, the value of the chi-square distribution is $X^2_{\alpha,df}$ to α 0,05 e df to 1 3, $X^2_{0.05,3}$ 7,81 .

After that, there was established the following hypothesis were.

$H_0: \tau_1 \quad \tau_2 \quad \tau_3 \dots \quad \tau_k$

$H_1: \tau_1, \tau_2, \tau_3, \dots \tau_k$ (não são todos iguais)

The analysis consists in verify if $K \leq X^2_{0.05,3}$,at this case the hypothesis is not null, that is, the data comes from an equally distributed population (seasonal). If not, $K > X^2_{0.05,3}$, the hypothesis that the data comes from an equally distributed population is rejected.

VI. Results Achieved

From the results achieved in the previous section we can see that the SKUs XX11YZW, XX30YZW, XX4YZW, XX28YZW, XX31YZW, XX51YZW, XX97YZW and XX168YZW, did not obtain the rejection of the null hypothesis, that is, all of them come from an equally distributed population, which means they came from a seasonal behavior.

The results of the Kruskal-Wallis test make more sense when looking at the sum of the data of each group, as it is observed that there isn't a big difference between the groups and the average of them after sorting data in rankings. It is natural that the items sometimes show some consumption peaks, as there are times of the year in which the Brazilian oil market is more or less active, following the example of the barrel of petroleum.

In addition, obtained with the kruskal-wallis test results were also aligned with the opinions of managers of the area in which the information was collected. This quantitative and qualitative analyze, suggest more reliability and sturdiness at the establishment to the most appropriate forecasting model.

VII. CONCLUSION

The purpose of the paper has been reached as far as the application of an analytical model allowed the identification of seasonality in all samples. This fact is of fundamental importance for the selection of the the most appropriate forecasting model for these items, according to the nature of the demand thereof. Deepening the research presented here, will be given by means of the selection of three demand forecasting models and the analysis of their mean squared errors, in order to verify the compliance of each model. Selecting a larger grip model will allow the development of an inventory policy more consistent and coherent with the strategic objectives of the organization.

As pointed out, this type of study can avoid an excessive inventory, amounting to approximately US $ 17,500,000.00, especially regarding the high turnover items, allowing such resources to sanitize other strategic sectors of the company.

REFERENCES

Basic format for books:

[1] BALLOU, Ronald. Gerenciamento da Cadeia de Produção. Bookman,2003

[2] BATTERSBY, Albert. Previsão de Vendas. Zahar,1968

[3] BLACK, Ken. Business Statistics Contemporary Decision Making. Wiley, 2004

[4] CALÔBA, Guilherme; CALÔBA, Luiz; SALIBY, Eduardo. Cooperação Entre redes neurais Artificiais e Técnicas 'Clássicas' Para Previsão de Demanda de uma Série de Vendas de cerveja na Austrália. Pesquisa Operacional, v.22, n.3, p.345-358, julho - dezembro de 2002.

[5] Chan Y, Walmsley Roy. Learning and understanding the Kruskal-Wallis one-way analysis-of-variance-by-ranks test for differences among three or more independent groups. Phys Ther. v.77, n. 12,p.1755-1762, Dec. 1997.

[6] HAYASHI,M. C. P. Sociologia da Ciência Bibliométrica e Cientometria: Contribuições para a Análise da Produção Científica. Seminário de Epistemologia e Teorias da Educação,2012. Campinas, São Paulo, Brasil.

[7] HILLER, Frederick. Introdução à Pesquisa Operacional. AMGH, 2013.

[8] SANTOS, Gilberto. Lógica Fuzzy: uma Proposta de Aplicação na Gestão de Estoque. XVII Simpósio de Pesquisa Operacional e Logística da Marinha, vol. 1 num. 1, Aug. 2014.

[9] SANTOS, Gustavo; JUNIOR, Jose; BERNARDO, Yan. Previsão de Demanda: Revisão Bibliográfica e análise acadêmica atual. XXXV ENEGEP, Fortaleza, oct.2015

[10] SLACK, Nigel; BRANDON-JONES, Alistair; JOHNSTON, Robert. Administração da Produção. Atlas, 2015.

[11] WANKE,Peter; JULIANELLI, Leonardo. Previsão de Vendas: Processos Organizacionais & Métodos Quantitativos e Qualitativos. Atlas, 2006.