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Advanced Planning System Applied to Inventory Analysis - An Action Research in a Fuel Distribution Company in Brazil

Dissertação de Mestrado

Dissertation presented to the Programa de Pós-graduação em Engenharia de Produção of PUC-Rio in partial fulfillment of the requirements for the degree of Mestre em Engenharia de Produção.

Advisor: Prof. Hugo Miguel Varella Repolho

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Abstract

Carvalho Neto, Edson Sobreira de; Repolho, Hugo Miguel Varela (Advisor). **Advanced Planning System Applied to Inventory Analysis - An Action Research in a Fuel Distribution Company in Brazil**. Rio de Janeiro, 2017. 52p. Dissertação de Mestrado - Departamento de Engenharia Industrial, Pontifícia Universidade Católica do Rio de Janeiro.

This dissertation addresses the initiatives in the inventory analysis of a fuel distribution company in Brazil. It tells about the continuous search for the state-of-art in terms of logistics modeling and how to deal with several of trade-offs existing in the supply chain. The main objective is to present how this model was created using an Advanced Planning System, how it helped to dimension the safety stocks and finally, what actions need to be taken in order to ensure that a ripening process that adds value to the company can be developed. It still addresses the growing importance of Supply Chain Management software and how the use of these technologies can be useful to tackle inventory analysis problems using an action research approach. This work provided powerful insights like the reallocation of safety stocks according to the transportation times and demand profiles, the potential economy that a more accurate demand forecast can bring to the company and even how investments in infrastructure can be driven by the new comprehension of the inventory dynamics. The new solution proposed implies a reduction of 17.8% in the inventory levels.

Keywords

Safety Stock; Action Research; Demand Forecast; Advanced Planning System; Economic Value Added.

Resumo

Carvalho Neto, Edson Sobreira de; Repolho, Hugo Miguel Varela (Orientador). **Sistema de Planejamento Avançado aplicado a Análise de Inventário – Uma Pesquisa Ação em uma Distribuidora de Combustíveis no Brasil**. Rio de Janeiro, 2017. 52p. Dissertação de Mestrado - Departamento de Engenharia Industrial, Pontifícia Universidade Católica do Rio de Janeiro.

Esta dissertação se propõe a fazer uma análise dos níveis de inventário de uma empresa distribuidora de combustíveis brasileira. Trata da busca contínua pelo estado-da-arte em termos de modelagem logística e como lidar com os diversos trade-offs existentes na cadeia de suprimentos. O objetivo principal é apresentar como este modelo foi criado utilizando um Sistema de Planejamento Avançado, como isso ajudou no dimensionamento dos estoques de segurança e, finalmente, que ações foram necessárias para garantir um processo de melhoria contínua que agregasse valor à companhia pudesse ser desenvolvido. Trata ainda sobre o ganho de importância dos softwares de gerenciamento da cadeia de suprimentos e como o uso destas tecnologias pode ser útil no tratamento de problemas relacionados a análise de inventário utilizando uma abordagem de pesquisa-ação. Este trabalho trouxe percepções valiosas para o negócio, como a realocação dos estoques de segurança a partir dos tempos de transporte e perfil da demanda, a economia potencial que uma previsão de vendas mais assertiva pode trazer para a companhia e ainda como os investimentos em infraestrutura podem ser direcionados pela compreensão da dinâmica do inventário. A nova solução proposta implicou em uma redução de 17,8% nos níveis de inventário.

Palavras-chave

Estoque de Segurança; Pesquisa-Ação; Previsão de Vendas; Sistema de Planejamento Avançado; Valor Econômico Agregado.

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"It is just as I said to Pharaoh: God has shown Pharaoh what he is about to do. Seven years of great abundance are coming throughout the land of Egypt, but seven years of famine will follow them. Then all the abundance in Egypt will be forgotten, and the famine will ravage the land. (…) Let Pharaoh appoint commissioners over the land to take a fifth of the harvest of Egypt during the seven years of abundance. They should collect all the food of these good years that are coming and store up the grain under the authority of Pharaoh, to be kept in the cities for food. This food should be held in reserve for the country, to be used during the seven years of famine that will come upon Egypt, so that the country may not be ruined by the famine" Genesis 41:28-36 – around 1900 BC.

1
Introduction

For almost 4,000 years, logistics challenges have been a reality. Since man abandoned subsistence agriculture and began organized production activities, the three main logistics functions emerged: the excess production becomes *stock*, stock integrity demands correct *storage* and trading this production demands *transportation*. In the Bible text included as an epigraph to this dissertation Joseph suggests the Pharaoh to store food in the seven years of abundance before the famine that would take place in the following seven years.

The action suggested is *strategic planning* and included several challenges: How many warehouses would be necessary to store food for seven years for the population of the whole empire? Built one single and huge centralized warehouse or many smaller warehouses decentralized? How these warehouses should be built in order to provide the ideal conditions to maintain the stored food in good conditions? What type of non-perishable food would they have to store that could keep the Egyptians well-nourished during the years of famine? What about the distribution of the food to the people during the years of famine? How to ensure that certain families would not receive a double portion and others receive nothing? How to manage the stocks to avoid stock-outs? How much should be charged of the foreigners that for sure would come to Egypt in the years of shortage searching for food?

The challenges reported in this episode are equivalent to the ones faced today by most organizations and corporations. Finding and implementing efficient and feasible solutions requires now, as it did back then, knowledge, great leadership skills to manage conflicts and to allocate the right people in the right places. In this dissertation, a focus will be placed in similar issues faced by Joseph more than 4,000 years ago applied to a Brazilian fuel distribution supply chain network.

The fuel distribution supply chain network consists basically of five types of players: refineries, biofuel plants, distributors, customers and final consumers. Refineries produce petroleum derivatives such as gasoline and diesel. Biofuel plants produce biodiesel and ethanol. Legislation determines the percentages of 73% of ethanol mixed in gasoline and 8% of biodiesel mixed in diesel. In almost all storage terminals, each product is stored separately and the final mixture is obtained during the truck loading process.

The distribution process in Brazil is controlled by basically four distribution companies that hold together almost 80% of the market. One of them is the company object of this dissertation but for confidentiality reasons the name will not be mentioned. In general, these four distributors own primary and secondary storage terminals. The designation of primary derives from the fact that they receive gasoline and diesel straightly from refineries by pipelines or ships. As for the secondary terminals, they are supplied by railways, waterways and roadways from primary terminals and are usually located far away from refineries, usually in the interior of the country. The end of the supply chain is composed by the customers: service stations, wholesale consumers and retail sellers. The flow of products between refineries and biofuel plants to primary and secondary terminals as well as from primary to secondary terminals is called inbound logistics. The outbound logistics consists of all product flows from primary and secondary terminals to customers.

Due to the transportation lead times, a certain stock level of each product must be held in each terminal. How much inventory to hold? This is not a simple question to answer. According to Wanke (2000) a company may choose basically between two options: 1- a fast response policy determined by a stock centralization or 2- a demand anticipation policy with decentralized stocks. In the first policy, the company has very low dependence on demand forecasting but needs an intensive express transport. In the second policy, the decentralized stocks located closer to the customers, demands intensive consolidated shipments. The fuel distribution market is an example of the second policy. Fuel is a commodity characterized by a low added value product with low obsolescence risk. Furthermore, it has a relatively stable demand profile even in recessive economy, reducing demand forecast errors and the risks associated with stock decentralization. This second type of policy has an important implication: a strong dependence on demand forecasting in order to balance in a better way the stock level at each node of the supply chain. The element that adds value to this strategy is the expectation that the additional costs related to stock maintenance is compensated by economies of scale in consolidated shipments.

In this dissertation an Advanced Planning System (APS) called Supply Chain Guru® developed by LLamasoft is used to tackle the inbound logistics, aggregating the customers demand in the storage terminals and analyzing transportation times and demand variability. The study will focus on *safety stock* and the methodology used follows a disciplined process known in the academy as *action research*. The general question to be answered in this dissertation is as follows: is it possible to adequate the service levels for each product at each terminal individually, reducing the global inventory?

1.1
Motivation

The fuel distribution company concerned has never used any approach to periodically deal with safety stock analysis. This work intends to provide some interesting insights in order to propose a solution to this issue using an action research approach. This approach emerged as a great opportunity since the author works as a logistic consultant in the company object of this paperwork, producing a scientific text besides achieving applied results.

1.2
Research Objectives

This dissertation proposes to fill a gap in the literature showing how an APS can be successfully used in order to manage inventory in a fuel distribution market. The main objective is to determine, for each product, the most adequate safety stock level that should be held in each of the dozens of fuel storage terminals spread throughout the Brazilian country. Safety stock levels are a critical decision for a company's success: the definition of the most appropriate policy to serve the customer.

Secondary objectives are: to measure the impact of the variation of the safety stocks to the EVA (Economic Added Value); determine the impact of forecast errors in the safety stocks; show how the correct stock dimensioning can support investment decisions in storage terminals.

1.3
Scope Delimitations

There are important delimitations in the present approach. The first one is that the inventory located at customers such as service stations or wholesale consumers will not be analyzed, but only in primary and secondary terminals.

The second delimitation is that only petroleum derivatives fuels (gasoline and diesel) were considered in the inventory analysis, since their prices change on a monthly basis, differently from what happens with biofuels. So, historical data split in months is a reasonable approach to calculate average demands and standard deviations. Biofuels on the other hand have a different dynamic since their prices are very volatile and require a shorter planning horizon (maybe in weeks). However, the influence of biofuels cannot be completely ignored since in some specific terminals biofuels and petroleum derivative fuels are stored together. So, biofuel prices in these exceptional cases were aggregated in storage terminals by weighted averages including the freights charged in the transport from plants to each storage terminal.

The third delimitation is that the APS used proposes an approach in which the optimization of the network needs to be realized prior to the safety stock analysis. Optimization problem becomes very complex when the company has several storage terminal facilities and they cannot be considered completely independent in economic terms according to Ballou (2006, pp. 442). Figure 1 illustrates how Ballou (2006, pp. 450) suggests the generic behavior of the supply chain trade off costs as the number of facilities varies:

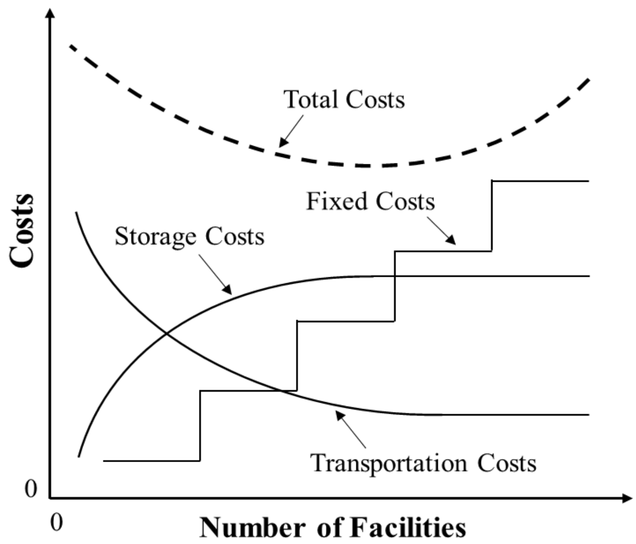

Figure 1 – Supply Chain Trade-offs (Source: Ballou, 2006).

The number of facilities in the present case is 67. So, in order to manage stocks in a satisfactory way by adjusting the service levels, the APS needs an optimized network already defined. In the first step the optimized network is obtained through the definition of the product costs, transportations freights, storage fees and taxes. Finally, the objective function in which the costs are minimized subject to several restrictions can be run, in order to achieve the optimal flows to attend the customer demands. More details of the network optimization approach of the same fuel distribution supply chain can be found in the article written by the author (SOBREIRA, 2016).

1.4
Outline

In section 2 the problem statement will be defined. Afterwards in section 3, an overview of the literature is shown, in order to provide a stronger theoretical base to the analysis. In section 4 all methodological approach followed to create the optimization model will be presented and how the results were achieved. In section 5 results and implications will be discussed. Finally, in section 6, conclusions and suggestions for future developments are presented.

2
Problem Statement

Logistics bottlenecks have been an issue in Brazil for many years. Despite having continental proportions, the country figures at the last position in almost all transportation modes among the BRIC (Brazil, Russia, India and China), the top four emerging economies in the world. Table 1 summarizes the extensions of the different transportation modes (in thousands of kilometers) in these nations considering the Unites States as the benchmark:

Table 1 – Country Comparisons (Source: World Fact Book, 2017).

Transportation Mode	BRASIL	RUSSIA	INDIA	CHINA	USA
Roadways (paved)	213	927	1,860	3,454	4,304
Railways	28	87	68	124	294
Waterways	50	102	15	110	41
Pipelines	17	252	35	70	2,225

In the last few years the impact of logistic bottlenecks in the fuel distribution supply chain, such as lack of railway infrastructure and deterioration of roadway network, have become more evident in Brazil. The impact reaches R$ 50 million a year and represents 6% of the service station´s margins and 20% of the distributor´s margins. The cost to adequate the railways and solve this problem reaches R$ 700 million (FIGUEIREDO, 2006). These bottlenecks are increasing the systematic use of roadways, the less economic transportation mode. In a country where the energy matrix is already very dependent on roadways, it puts more pressure on inflation, since these additional costs are transferred to domestic consumers.

Additionally, the lack of investments by the Brazilian government to increase production capacity in refineries is resulting in larger price gaps between them, putting even more pressure on the usage of roadways (SOBREIRA, 2016). Brazil has 16 refineries spread in 10 different states and 11 of them are located in the southern region. These units operate close to their capacity limits, especially in São Paulo in which more than 90% of their capacity is already being used (WERNECK and RODRIGUES, 2013). Unfortunately, new refineries that were planned by 2015 will not be finished, or will operate in a level much below initially designed (PETROBRÁS, 2017). The consequence is that Brazil will probably become more dependent on fuel imports in the next years.

These factors bring a straight impact in the fuel distribution supply chain since many structured transfer flows that used to be practiced for a long time are no longer the most economic ones. Structured flows are all flows that are not emergency ones. Emergency flows are practiced to compensate daily problems related to the operation. Due to the great flexibility that exists when the roadway mode is used, it is becoming more common in this market to see different logistic supply flows from one month to another. This new scenario motivates the company to update their inventory target levels more often instead of doing it annually. But where should this inventory be hold? Figure 2 illustrates a typical fuel distribution supply chain.

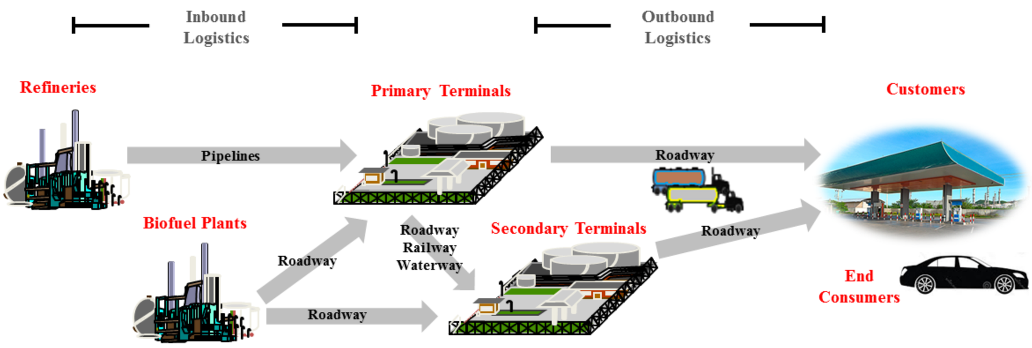

Figure 2 – Fuel Distribution Supply Chain.

The company under study manages three different types of stocks: *cycle stock*, *in-transit inventory* and *safety stock*. The combination is called *target* as shown in Figure 3.

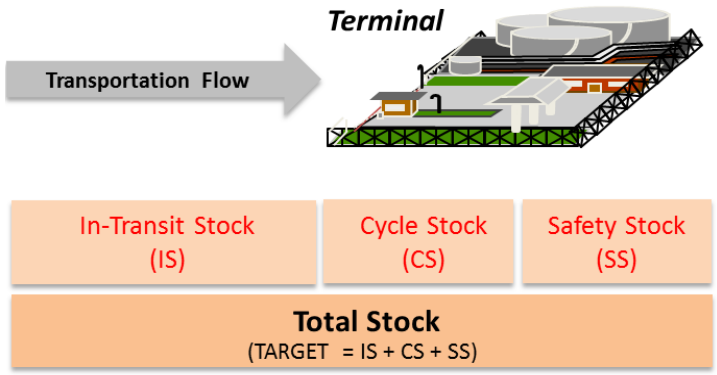

Figure 3 – Definition of the Target.

The in-transit inventory is the amount of stock located between the links of the supply chain. The cycle stock is the amount of stock necessary to guarantee the supply between successive arrivals. The safety stock is the amount of stock hold in order to ensure against uncertainties of the demand and the replenishment frequency. As the Figure 3 suggests, the cycle stock and the safety stock are located inside the terminals and are represented in Figure 4. Though the company updates the targets to all storage terminals annually, this dissertation will focus only in the calculation of the safety stocks. It is important to say that in the company under study no statistical method has been used in the calculation of the safety stocks and that is why the usage of an APS tool can provide a great contribution to the company.

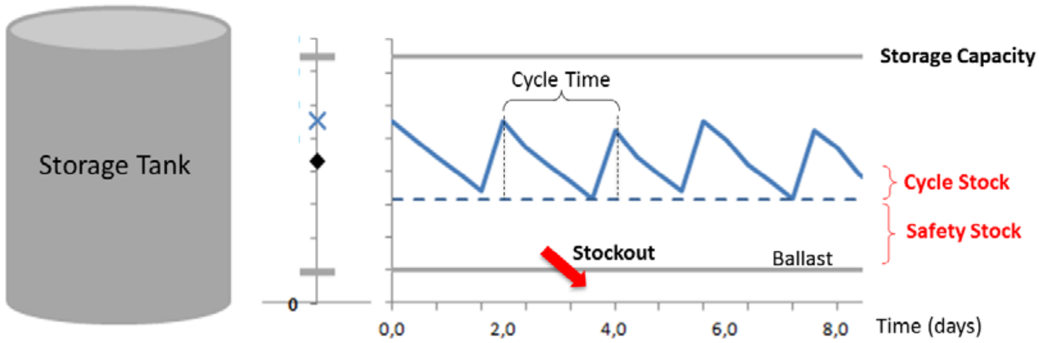

Figure 4 – Inventory Dynamics.

3
Literature Overview

Logistics costs in Brazil represented 11.5% of the GDP in 2012 while in the United States it reached 8.3% in the referred year. A closer look at these costs, shows that almost one third of them are related to stocks (LIMA, 2014). Inventory holding costs can still represent 20 to 40% of its value per year (BALLOU, 2006 pp. 271). Furthermore, according to Stadler and Kilger (2004) the often claimed citation like “inventory hide faults” suggest to avoid any inventory in a supply chain and is due to the Just-in-Time philosophy. This is possible only in some specific industries on certain parts of the supply chain and for selected items. In all other situations inventories in supply chains are always a natural result of inflow and outflow processes like production and transportation. So, isolated minimization of inventories is not a reasonable objective of supply chain management. Because of all these factors mentioned, it is necessary to manage stocks carefully and associated to the corresponding supply chain processes.

In the following topics of this section, theoretical basis is presented to support the results achieved by the inventory analysis model created to manage stocks of the fuel distribution company concerned.

3.1
Implementing an APS with an Action Research Approach

How an APS can be used to manage stocks and why an action research approach is necessary in the whole process? Regarding new IT technologies, after the vertiginous growth of the Enterprise Resource Planning (ERP) systems, in the 90s a new wave of Supply Chain Management technologies (SCM) began to emerge. According to Mckinsey Consulting, between 1999 and 2002, more than US$ 15 billion were sold in SCM licenses, not including expenses on implementation or maintenance (AROZO, 2003). However, acquiring licenses for these new technologies is not enough to guarantee the success of their use. Many companies have already given up their SCM solutions because some (or several) important issues were not taken into account. Some golden rules were defined to drive efforts in order to help in the correct use of these powerful tools. Among them, six that are key concepts for the present study can be listed: commitment of the senior management, project aligned with business goals, understand the software capabilities, a step by step approach for incremental value gains, being prepared to change business processes and measure success with Key Performance Indicators - KPIs (FAVILLA and FEARNE, 2005). Favilla and Fearne (2005) point that strong leadership is the most important factor for the success of a supply chain transformation. The top executives must be actively involved in the entire project. Without their commitment, the impetus for change can quickly fade out. Top executives still have to be able to recognize the skill gaps in their own organization and search for outside partners with new ideas and new software capabilities.

There is an emerging trend related to the acceptance of third party software and support systems for supply chain applications. Even companies with internal capabilities to develop their own solutions are recognizing the value of partnerships with software vendors and consultants. The reason for this is based on the emphasis that is being given to modularity and expandability that allows supply chain participants to add modules and programming interfaces as needs arise. Since most SCM software firms have formed partnerships with ERP companies, integration is no longer the problem it once was (GREEN, 2001).

According to a survey by Arozo (2003), companies are making a great effort to build end-to-end solutions for SCM such as SAP, Manugistics (acquired by JDA in 2006), I2 (acquired by JDA in 2010), CAPS-BAAN e Synquest (acquired by Penske in 2002). There are three main criteria used by companies to select SCM solution providers: trust in the solution provider, integration/compatibility and adherence to their needs. The same survey by Arozo (2003) performed an after implementation evaluation and identified three major negative aspects: non user friendly solution, implementation time and total investment. Arozo also evinces the main difference between ERP systems and SCM software (APS). ERP systems are focused on the operational level, not having many analytic capabilities to help in decision making processes. ERP systems can show, for example, the current stock level in a certain site, but they are not ready to answer what should be the most adequate stock level at this site. So, the second part of the problem can be answered by an APS software. Stadler (2005) also wrote about the importance of APS to fill a gap left by ERP systems, since its strength is not in the area of planning. On the other hand, APS systems do not replace ERP but complement it (Fleischmann and Meyr, 2003).

There are a wide variety of supply chain management functionalities in APS. Figure 5 is an adaptation of the supply chain planning matrix presented by Stadler and Kilger (2004, pp. 87 apud Rhode et al. 2000).

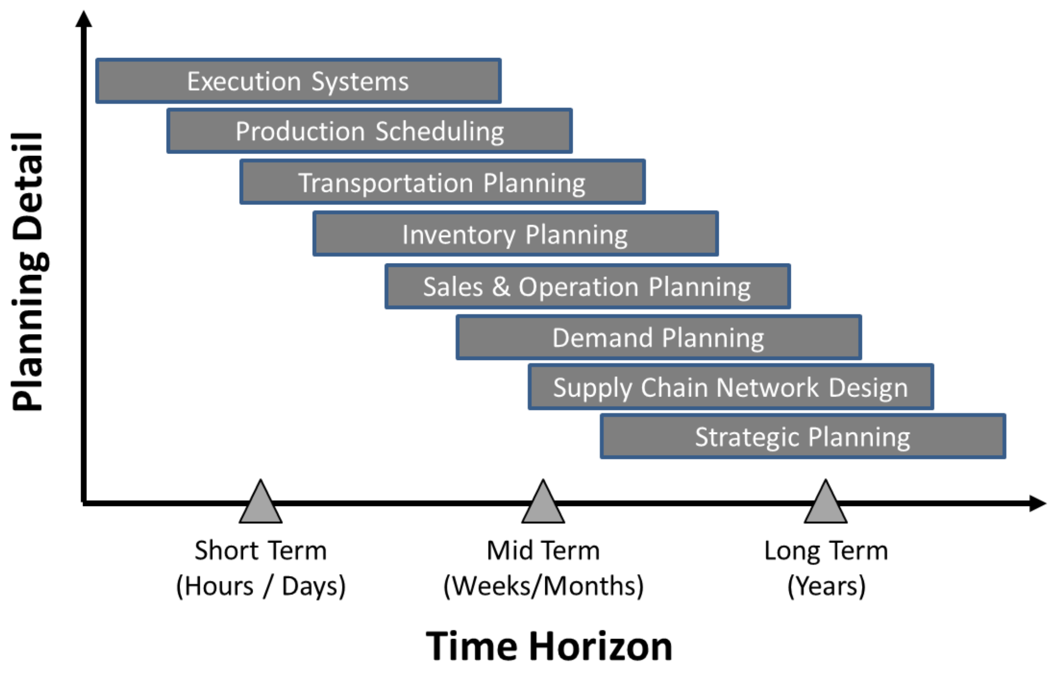

Figure 5 – APS solutions related to time horizon (Adapted from Stadler, 2004).

This dissertation will focus on the application of a customized SCM software, named Supply Chain Guru®. The fields of action of this tool are: supply chain network design, inventory planning and transportation planning. The inventory planning of the present work can be considered as a tactical approach (mid-term), because the time horizon is one month. A software was chosen and the team trained in order not to create a dependent relationship with any consultancy company. But the main benefit is that the implementation had to follow a cyclical process that produced a ripening process in the acquisition of this new knowledge, allowing the team to learn with problems that came up. This apprentice procedure would be very difficult to happen if the company decided to hire an external consulting firm. According to Coughlan et al (2002), action research and consultancy are different in some aspects. Two of them are listed: consultants work under tighter time and budget constraints; consultation process is frequently linear (engage, analyze, act and disengage). On other hand, action researches are cyclical – gathering data, analyzing data, planning action, taking action and evaluating, leading to further data gathering and so on. The expression *research* refers to knowledge production and the expression *action* refers to the intentional modification of reality (OQUIST, 1978).

The implementation provided a solution that allows the company to periodically update the targets (modification of reality) and produce valuable insights to the academic community (knowledge production).

3.2
Inventory Policy Definition

In many different markets, companies decide to carry a certain stock level, since they are necessary in order to guarantee the service level and not lose sells. But which factors are involved in the definition of the inventory policy? Wanke et al. (2006) suggest basically four different aspects: the lot size order; when to order; how much safety stock to maintain; where to allocate.

Pagh et al (1998) suggest a framework for a generic supply chain focused on the downstream part of it called *P/S-Matrix*. The main idea of the P/S Matrix is to combine postponement and speculation strategies creating four basic classifications: 1- full speculation, 2- the logistics postponement, 3- the manufacturing postponement and 4- the full postponement. The *full speculation* strategy is the most often used by companies and is characterized by a profile in which the product is stocked close to customers and distributed through a decentralized distribution system. The *logistics postponement* strategy is defined when the manufacturing is based on speculation while the logistics is based on postponement. In the *manufacturing postponement* strategy, the final manufacturing operations are performed at some point downstream in the supply chain, after the product has been differentiated in the logistics operations. Finally, the *full postponement* represents the highest level of postponement application among the others and the customer reorder point initiates the last stage of the manufacturing process.

3.3
Safety Stock Calculation

The initial approach to the safety stock calculation is to determine the probability of no stock out in a single period analysis. Based on this probability, the safety stock is calculated and added to the reorder point. By definition, when no safety stock is held, there is a 50% of probability of stock out, considering a normal distribution for the demand profile. For a single period analysis the probability of no stock out can be determined by the unit cost of absence and the excess (WANKE, 2011). Still according to Wanke et al. (2006, pp.193) the risk associated to these two variables can be determined:

Unit Cost of absence (Ca) – considers the contribution margin that is lost when one unit of the product is unavailable to the customer plus the damage to the image of the corporation.

Unit Cos of excess (Ce) – considers the opportunity cost to maintain one unit of the product in stock plus lost provoked by obsolescence or perishability.

The risk associated to hold safety stock is given by:

$$SS\ Risk = 1 - \frac{Ca}{Ca + Ce} \tag{1}$$

For high value added products with a high obsolescence risk like computing equipment, the risk associated with maintaining safety stock is considerably high (almost 1). In this case, the safety stock held should be as low as possible. On the other hand, in the fuel distribution market there is a low value-added product with a low obsolescence risk. Furthermore, as previously mentioned, it is a very competitive market and that is why the damage to the image of the corporation has to be taken into account when a sale is lost. In this case, the *SS Risk* could be located between 50 and 60%, which means, it could be preferable to take the risk of maintaining some safety stock and dedicate some time and effort to reduce demand forecast errors. Figure 6 illustrates that:

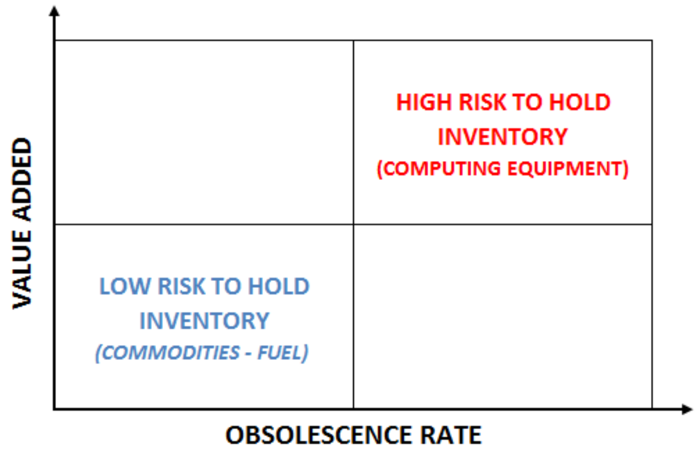

Figure 6 – Value Added x Obsolescence Rate Matrix.

In a multi-period analysis, safety stock calculation should consider not only the probability of not stocking out, but the demand variability (standard deviation) and the probability distribution of the demand in the lead time (WANKE, 2011). Considering the demand and the lead time as two independent random variables, it is possible to determine the mean and the standard deviation of the demand in the lead time. What really matters is the demand in the lead time, since the inventory management is subject to shortages only in the period between the placement of the order and the exact moment when it arrives. In Figure 7 there is an explanation of Supply Chain Guru's manual for the complete cycle:

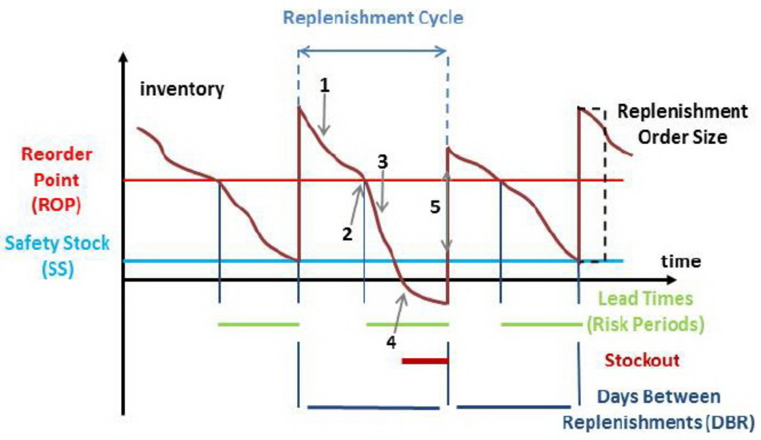

Figure 7 – Inventory cycle (Source: Supply Chain Guru's manual, 2017).

Periods:

1- Inventory is used until it hits the Reorder Point (ROP).
2- An order is placed.
3- Inventory continues to go down as the order is processed and shipped.
4- If the facility runs out of inventory, this is called a shortage or stockout.
5- The order arrives and the process begins again.

Wanke (2011) still addresses that according to statistical theory the standard deviation of two independent random variables (A and B) is given by the equation:

$$S_{A\times B} = \sqrt{(S_A \times B)^2 + (S_B \times A)^2 + (S_A \times S_B)^2} \tag{2}$$

A – mean of the random variable A

S_A – standard deviation of the random variable A

B – mean of the random variable B

S_B – standard deviation of the random variable B

Assuming A and B the demand (D) and the lead time (LT) respectively, the standard deviation of the demand in the lead time is given by the equation:

$$S_{D\times LT} = \sqrt{(S_D \times LT)^2 + (S_{LT} \times D)^2 + (S_{LT} \times S_D)^2} \tag{3}$$

However, it is common in the literature such as Bowersox (2001, pp. 249) and Ballou (2006, pp. 290) to find another alternative expression (the complete demonstration of this result can be found in Mentzer et al., 1988):

$$S_{D\times LT} = \sqrt{LT \times S_D^2 + D^2 \times S_{LT}^2} \tag{4}$$

The APS used in this action research uses the Expression 4 to calculate the safety stock (*SS*), multiplying it by *k*, the number of standard deviation of the demand during the lead time associated to the desired service level:

$$SS = k \times \sqrt{LT \times S_D^2 + D^2 \times S_{LT}^2} \tag{5}$$

The probability of *No Stock Out*, φ (NSO), is given by the Expression 6 and highlighted in Figure 8 in which φ is the normal cumulative distribution function:

$$\varphi(NSO) = D \times LT + SS \tag{6}$$

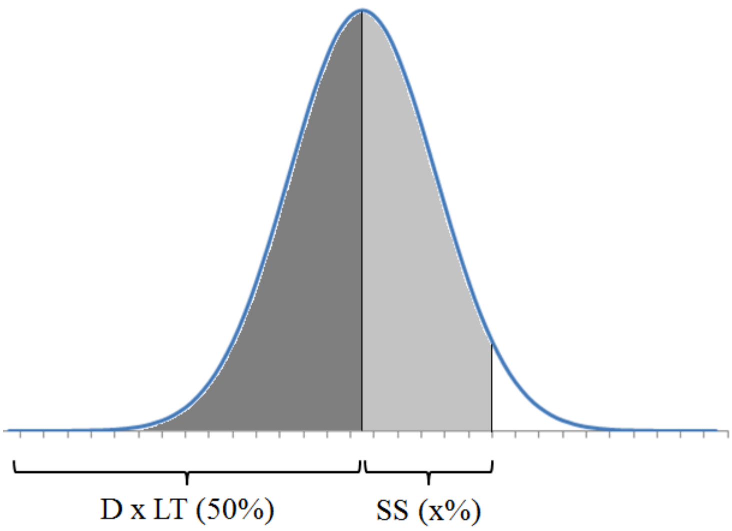

Figure 8 – Probability of No Stock Out.

Assuming that the demand variability follows a normal distribution, important implications can be pointed according to Wanke et al. (2006, pp. 192): as the level of competition increases, errors in the demand forecast increase as well. A high standard deviation implies in a high safety stock level. This phenomenon is important in the fuel distribution market because as it can be seen in Figure 9, that shows a normal distribution. For standard deviations over 1.65 (95%) a smaller increase in the probability of no stock out is observed. Furthermore, the additional cost beyond this point increases rapidly, which suggests a careful analysis to set very high service levels.

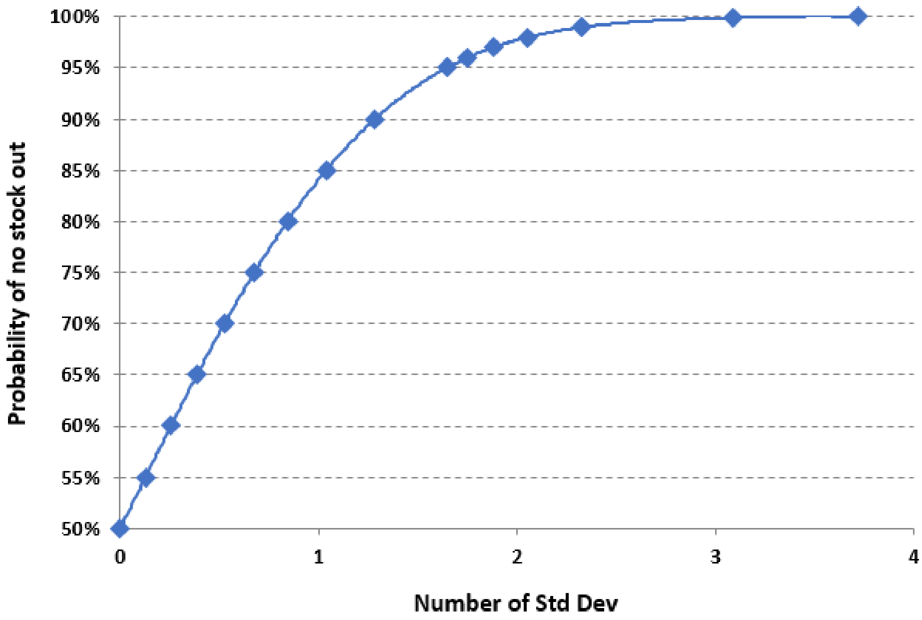

Figure 9 – Probability of no stock out x Number of Std Dev.

In order to prove that the demand can be approximated by a normal distribution, the demands of two products were chosen (gasoline and diesel) for two different terminals in one year period split in a daily basis. The software @Risk provides some statistical tests that allowed to conclude that these demands follow a normal distribution. These tests gave the confidence to consider the normal distribution to all demand series of all terminals.

Safety stock levels should be influenced by the demand forecasts, since a low accurate forecast must be compensated by a higher amount of inventory to absorb these uncertainties. So, it is important to define if the current demand forecasting process in the company is performing well or not.

One of the indicators used to evaluate the forecast errors is the *MAPE* (Mean Absolute Percentage Error). According to Julianelli (2001), an extensive research made in Brazil with 94 companies from 20 different sectors shows that companies that use more sophisticated statistical technics in their demand preview achieved a better result, 15% of MAPE against 22.1% for those that did not use (32% reduction). The average for all companies is around 19%. The MAPE is given by:

$$MAPE = \frac{100}{n} \sum_{t=1}^{n} \left| \frac{D_t - F_t}{D_t} \right| \tag{7}$$

Where n is the number of periods, D_t is the demand in period t and F_t is the forecast demand value for the same period t.

The Mean Absolute Deviation (MAD) is given by:

$$MAD = \frac{1}{n} \sum_{t=1}^{n} |D_t - F_t| \tag{8}$$

According to Domburg (2011 apud Kolossa and Schütz, 2007), the relationship MAD divided by the Mean Ratio can be called a generalization of the MAPE. So, it is possible to consider:

$$MAPE \approx \frac{MAD}{D} \tag{9}$$

Where D is the mean demand. Considering that the mean absolute deviation (MAD) of the normal distribution is given by:

$$MAD = \sqrt{\frac{2}{\pi}} \times S = 0.7978 \times S \tag{10}$$

Where S is the normal distribution standard deviation. Combining Expressions 9 and 10 one obtains the expression that allows to include the demand forecast error in the safety stock calculation:

$$S_D = 1.25 \times MAPE \times D \tag{11}$$

Expression 11, which results from the combination of expressions 5 and 11, measures the impact of a low demand forecast accuracy in the final inventory. But what is the role that the demand forecasting to the different departments of a company? The demand forecasting process helps to anticipate market dynamics and generates valuable information. Wanke and Julianelli (2011) relate some benefits to each department, with some additional information made by the author:

1. Marketing and Sales: demand forecasting allows managers to compare sales targets defined in the strategic planning with the estimated sales. This type of comparison helps in the definition of the best merchandising strategy, promotions or development of new distribution channels.
2. Procurement: an assertive forecast can help in the acquisition of the most appropriate volume of product and in some cases justifies anticipation of purchase taken into account, for example, an increase in the oil price.
3. Finance: the importance of the demand forecast for this department is to monitor the evolution of the working capital, or even to plan cash flows applying additional resources or search for fundraising in the case of an absence of liquidity. A reduction in the safety stock levels, allowed by a more accurate forecast, can bring a straight impact in the EVA (Economic Added Value).
4. Logistics: this department is one of the main users of demand forecasts, since this information allows in the identification of the most appropriate location for facilities and warehouses, optimizing the distribution costs. Moreover, it helps to identify better transfer flows between storage terminals or even hire third part logistics partners when necessary.

3.4
Measuring the Final Result with EVA

At the end of this research it is important to measure the final impact that the new safety stock levels bring to the company in economic terms and monitor the evolution of this indicator. Two main financial indicators can be used for this purpose: Earnings per Share (EPS) and Economic Value Added (EVA). The EPS is the portion of a company's earnings allocated to each share of common stock in a certain period and is calculated as the net income divided by outstanding common shares. And the EVA is the net income produced by a company above the expectations of the market based on the company's cost of capital and its total invested capital (ASSAF, 2014). According to Stern et al. (1995) they argue that three decades after the World War II, the main challenge of top management was to achieve huge economies of scale in manufacturing. The top down approach to managing large corporations was well suited to the relatively stable business environment of this period. In this way, the EPS model of financial management was an adequate indicator. But in a highly competitive environment, the EPS shows important disadvantages since it tolerates the widespread practice of corporate cross-subsidization, in which the surplus cash flow of profitable divisions was wasted in futile efforts to shore up unpromising divisions. The result was what they called "politicization" of corporate investment, in which the most persuasive managers received too much capital resulting chronic overinvestment in some areas and underinvestment in others.

Stern et al. (1995) propose that a different performance management should be used by modern companies that push decision making down into lower levels of the organization in order to gain competitiveness. The EVA then becomes an internal measure management that can be used as the basis for a completely integrated financial management system. It provides a common language for employees across all corporate functions, linking strategic planning with the operating divisions. Assaf (2014) reiterates the importance of modern firms to seek value, showing that the globalization is creating a single worldwide market. In this way, investors are able to rapidly change their capital flows seeking for more attractive opportunities in any part of the world. Assets that do not create value are easily identified by these investors provoking their fast depreciation in all markets.

For the given reasons, the EVA is being used by many companies to evaluate projects and the firm itself. What is the best way to evaluate a firm? This question is proposed by Samanez (2007) and introduces the twelfth chapter of his book in which he presents the EVA concept. This indicator is used by the company object of this work to measure if the investments or initiatives are creating value to the stockholders or not. According to Samanez (2007), the EVA can be understood as the remaining net operating profit after taking into account the minimum return on the capital invested. In other words, a company does not create value when the *Net Operating Profit After Tax* (NOPAT) does not exceed the alternative income on the capital invested. It is not enough to a company to present a positive operational profit, if the capital used to achieve this result is proportionally high. The EVA is given by:

$$EVA = NOPAT - Capital\ Invested\ \times WACC \tag{12}$$

To raise funds a company may choose between using its own capital or third party capital. The costs of these two types of funds are different, the first one is known as the *cost of equity* and the second one is the *cost of debt*. The *WACC* (Weighted Average Cost of Capital), as the own name suggests, is the cost of capital resulting from the weighted average of both costs. All investments made by a company need to have a return beyond the weighted average costs of the different sources of capital.

Ashayeri and Lemmes (2005) measured the impact on the EVA that a smaller forecast error resulting from a proper demand planning can cause. In their case study in a large supplier of tubes for use in television and computer monitors, an improvement of sales planning reliability of only 3% improved the EVA by € 2.5 million yearly. They point at least two facts for that: the delivery service provided to the customer and the reduction of the operational costs. The first factor occurs because a higher service level result in a decrease of stock outs and consequently less lost sales. The second factor is related to the reduction of the inventory holding costs which reduces the operational costs.

In the present study, the interest is in the impact of the stock levels to the working capital, which has a straight influence in the EVA, since it can raise or reduce the free cash flow. To protect the confidentiality of the company, it is used the default value of 12% per year used by Supply Chain Guru to the WACC. With all this concepts in mind, whenever the model points an increase on the stock level to a specific terminal it means the cash flow increases as well, which in turn, produces a negative impact on the EVA. On the other hand, when the model points a decrease on the stock level, it means less capital has to be tied up. Another important aspect that has to be taken into account is the fact that the variation of the stock levels affects the NOPAT, because stocks usually implies in operating expenses. However, after evaluating this impact, it represents less than 1% of the total economy, so it won't be considered.

4
Action Research Methodology

This chapter presents the methodology used to fulfill the objectives defined for the work. It is divided in two subsections, action research object and methodological procedure. The former is about the procedures that have to be followed in order to provide the necessary alignments among internal departments and ensures that the results can be implemented. In the latter, the procedures taken in the APS to calculate the safety stocks is detailed.

It is important to emphasize that the methodology presented is restricted to the company’s action research and the APS in question. However, the general concepts can be adapted to other companies that use different APS software and similar results are expected.

4.1
Action Research Object

The action research has four stages as mentioned in the literature overview: gathering data, analyzing data, planning action and take action. In the first stage all data that is necessary to run the model is gathered, selecting the best data sources available from each department. The second stage is important because all data gathered is found in different files format, with different measures and, not rarely, with non-relevant information. It is important to separate what is really necessary and decide how to connect all this data. After this analysis, the third stage takes place where the planning action is necessary to determine the best strategy to achieve the desired result. At this point the inventory analysis model is run. After completing the first three stages of the action, the following stage is the involvement of a committee created by the senior managers to validate the results in order to *take action*, which means, the definition of the new service levels to each product at each terminal. But it is important to bring to this meeting an initial proposal to the service levels and that is the *planning action* that will be shown how it is created.

There are some important aspects that have to be taken into account as part of the action research approach. The first one is the dynamic of the fuel distribution market concerning the purchase process. Petrobrás is the main supplier of the country and even though it is possible to import product from external suppliers, the national infrastructure such as ports and railways are very limited to support this operation. So, the fuel distribution companies in Brazil are still very dependent of Petrobrás that demands a two month anticipation period for purchases. The implication is that the concept of lot size order and when to order, two of the four aspects proposed by Wanke in the definition of the inventory policy, are aspects that the distributors have no flexibility to deal with. The lot size has to be the size of the two months ahead demand for each primary terminal. So, the demand forecasts become a crucial task, since greater forecast errors will result in higher safety stock levels. Therefore, inventory policy in the fuel distribution market is basically a challenge of defining how much safety stock to maintain and where to allocate it, ensuring that the forecasts errors are as low as possible.

The second aspect is the full speculation strategy proposed in the P/S Matrix by Pagh et al. (1998). This is the strategy adopted by the fuel distributors as a result of the first aspect mentioned. Despite the benefit of large lot-sizes in distribution flows, inventory investment is the highest of all four strategies. Also, the full speculation strategy implies in higher transfer costs between storage terminals. As the fuel distribution market is a very competitive market in Brazil it is mandatory for a fuel distribution company to guarantee high service levels allocating stocks close to the customers and distributed through a decentralized distribution system.

These aspects mentioned result in a challenging trade off. On one side there is a pressure by the financial department to reduce the high stock levels. On the other side the sales department force is to increase stock levels to guarantee that stock outs never occur and protect markets from competitors. Regardless of the fact that the APS provides a statistical approach to balance this trade off in question, the action research must involve representatives from financial and sales departments in order to ensure that the inventory analysis model results will be implemented.

4.2 Methodological Procedure

In this section Supply Chain Guru's (SCG) approach will be detailed to run the safety stock calculation in five steps: data collection, network optimization, extraction of the optimized network, demand analysis and safety stock analysis (Figure 10). All these steps belong to the first three stages of the action research process: gathering data, analyzing data and planning action:

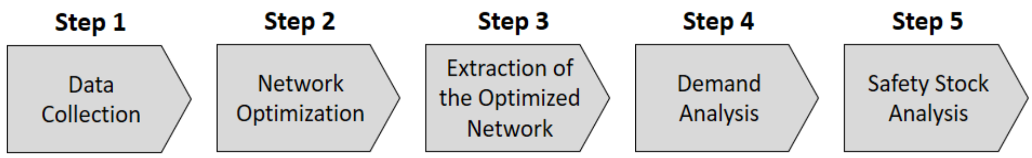

Figure 10 – Supply Chain Guru's approach.

However, before detailing these steps, it is important to mention that Supply Chain Guru is a software that does not allow any modification in the programing codes. Nevertheless, it contains several tables that need to be filled in and the relationship among them need to be established. It is designed to attend any kind of different supply chain market and so a certain ability of the modeler is required to achieve the desired results.

Step 1: Data Collection

The first step begins with the data collection. Basically, all information needed to build the supply chain model is collected, such as: products prices, supply, all possible combinations of flows, freights to all the possible flows, taxes, new sites, constraints, storage fees, daily demand, transportation times by mode and days between replenishment. All this information can be gathered in the company's internal systems like ERP (Enterprise Resource Planning) and BI

(Business Intelligence). Note that the daily demand, transportation times and days between replenishment include variability that need to be considered in order to calculate all of the three portions of the stock mentioned before: in transit inventory, cycle stock and safety stock.

Once all information is gathered, the SCG's tables can be filled in. There are basically seven tables: Products, Sites, Bill of Materials, Sourcing Policies, Inventory Policies, Transportation Policies and Demand. More details about the model's structure can be found in the article written by the author (SOBREIRA, 2016). Afterwards, the model is ready to run the network optimization.

Step 2: Network Optimization

The second step regards the optimization of the network. SCG's mathematical solver is based on linear programming and mixed integer programming. In this model, the costs associated with the objective function as shown in Expression 13 is minimized:

$$Min\ Z = Product\ Costs + Taxes + Storage\ Fees + Freights \qquad (13)$$

The output of the model gives all costs and the amount of product that flows from each pair of nodes (origin x destination) of the supply chain, beginning in the refineries and ending in the terminals, in which all customers' demand is aggregated. In this step, the inventory in transit and the cycle stock are calculated as well.

Step 3: Extraction of the Optimized Network

The third step is the simple application of a tool called "Optimized Network" and basically consists in the generation of a new model considering only the flows effectively used in the previous step. In other words, all flows that were not used in the network optimization are erased and the program ends up with the optimized network.

Step 4: Demand Analysis

The fourth step is a functionality of SCG to exclude outliers and classify the demand profile like Figure 11 shows:

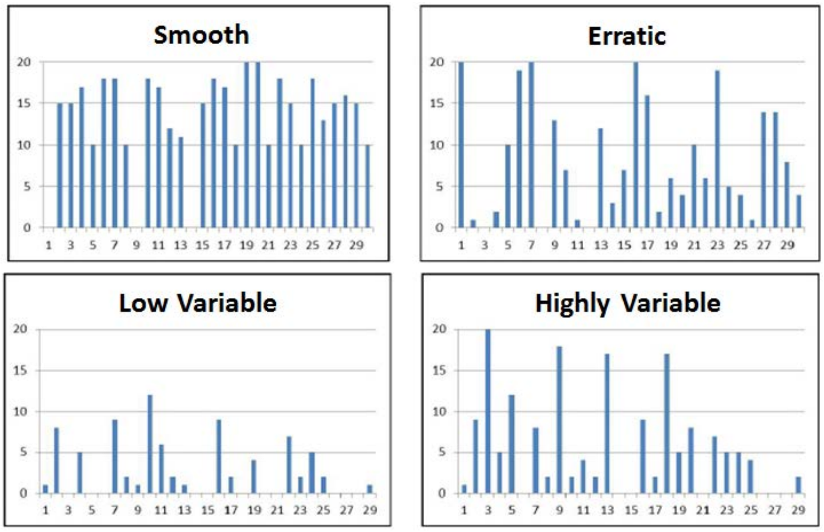

Figure 11 – Demand Classes (Source: Supply Chain Guru's manual, 2017).

These classes are important because depending on the demand profile the user might be interested in making adjustments in the data. However, all demand profiles of the company under study fit in the class *smooth* since the fuel distribution market is a mature market, as previously said.

Step 5: Safety Stock Analysis

The fifth and the last step in the process is the calculation of the safety stock, the amount of inventory that must be held to protect against demand and lead-time variability. Right after the fourth step the model is ready to run the safety stock analysis for each node and each product of the supply chain, summing around 180 combinations. In each case SCG's inventory output table shows for each combination in cubic meters: Safety Stock (SS), Cycle Stock (CS) and In-transit inventory Stock (IS). Dividing these values by the demand mean calculated in the fourth step, the final target in *days of stock* is achieved. With this approach, the current target also given in days of stock can be compared with the new values provided by the software.

Taking Action in the Action Research Cycle

After the presented approach in which the first three stages of the action research were accomplished, the following stage is another important part of the process: the involvement of a committee created by the senior managers to validate the results in order to *take action*. This group will effectively make it happen, which means, effectively define what are the new service levels. But it is important to bring to this meeting an initial proposal that is the *planning action*.

The variability of the demand and the variability of the lead time determine the amount of safety stock. So, the chosen approach to create the initial proposal to the committee is obtained by crossing the MAPE with the standard deviation of the lead time. The demand forecast error is related to the demand variability and the standard deviation of the lead time is related to the lead time variability. Figure 12 shows the four possible quadrants for one product (diesel). Each dot in the graph represents one storage terminal:

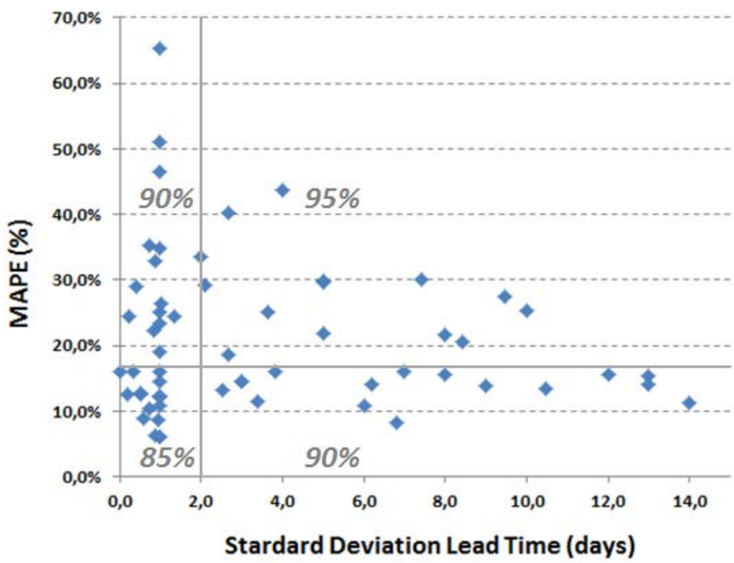

Figure 12 – MAPE x Standard Deviation Lead Time.

It is important to say that there is no theoretical basis for the Figure 15, since it is an author proposal based on the 3 possible quartiles in which all data are spread. So, the service level initially proposed for each terminal depends on the quadrant in which the respective dot is located. The second quartile was calculated for each axis and, in this example, the MAPE value of *16%* and the standard deviation value of *2 days* were used to divide the quadrants. So, terminals with more than 16% of MAPE and more than 2 days of standard deviation will have 98% of service level. Terminals with less than 16% of MAPE and less than 2 days of standard deviation will have 90% of service level. The other terminals located in the last two quadrants will have a service level of 95%. After defining the appropriate service levels by these four quadrants, the model is run and the results are taken to the committee that will decide the new strategy for each terminal and the respective products. The committee can decide to follow the four quadrants suggestion or change it based on the debates. After the final adjustments the new safety stock levels are finally implemented.

The last stage of the action research in the *evaluation*. This stage is managed by the supply department with the help of the logistics department. All analysis made in this stage produces powerful insights to be taken to the next committee meeting.

5
Results and Discussions

In this section the general question is answered, showing that it is possible to adequate the service levels for each product at each terminal individually, reducing the global inventory. Other important results are presented and new opportunities are paved for future works.

5.1
Service Level and Safety Stocks

One important result was anticipated in section 3.2 according to Wanke et al. (2006, pp. 192), for over 1.65 standard deviations, which correspond to a service level of 95%, costs increase rapidly as a higher safety stock level is set beyond this point. To confirm this expectation a specific storage terminal located in the south region of Brazil (Terminal 5) was selected. Setting a service level at 80%, implies a cost of 3.6 million reais for all 3 products. For a service level set at 85% the cost increases 23%. For a service level set at 90%, the cost becomes 24% higher. Another 5% of variation in the service level, 95% is achieved and now the cost increases 28%. Finally, for a 99% service level the cost increases 41% reaching more than 9.9 million reais. These results can be seen in Figure 13:

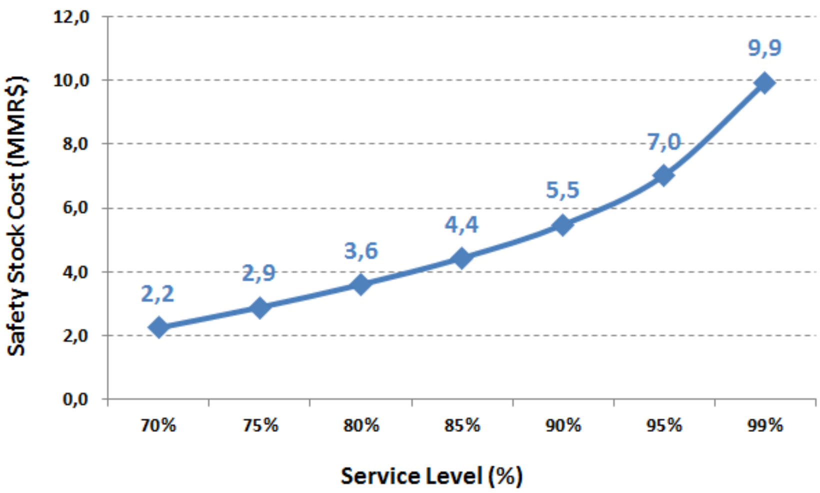

Figure 13 – Service Level x Safety Stock Cost (Terminal 2).

So, before setting service levels beyond 95% it is necessary that the departments of the company involved in this decision to be aware of the implications to the cash flow.

5.2
Shifting Safety Stocks Between Terminals

The safety stock analysis reveals a very important result that represents a turnaround in the way the company deals with its inventory. In this section three examples containing 18 different storage terminals are shown to highlight that these results are not isolated effects. Basically, the effect of shifting the safety stock from primary to secondary terminals can be seen and the benefits achieved measured with this new approach proposed by the model.

Pole is defined as a group of terminals that contains one primary terminal and all secondary terminals that are supplied by it. In the first example, the Pole A has the Terminal 1 that supplies three different terminals with diesel S10 and five different terminals with diesel S500. Table 2 presents the results:

Table 2 – Pole A Results.

Pole A - Diesel S10

Type	Storage Terminal	Product	Current Safety Stock (days)	Proposed Safety Stock (days)	Current Service Level (%)	Proposed Service Level (%)	Safety Stock Variation (m³)
Primary	1	Diesel S10	2.00	0.83	99%	85%	-961
Secondary	2	Diesel S10	2.00	6.61	70%	95%	295
Secondary	3	Diesel S10	2.00	5.47	74%	95%	832
Secondary	4	Diesel S10	1.00	1.87	77%	95%	79
							245

Pole A - Diesel S500

Type	Storage Terminal	Product	Current Safety Stock (days)	Proposed Safety Stock (days)	Current Service Level (%)	Proposed Service Level (%)	Safety Stock Variation (m³)
Primary	1	Diesel S500	3.00	1.04	99%	85%	-6,087
Secondary	5	Diesel S500	2.00	4.05	79%	95%	1.035
Secondary	2	Diesel S500	2.00	3.72	75%	90%	282
Secondary	6	Diesel S500	1.00	4.07	65%	95%	1,779
Secondary	7	Diesel S500	2.00	3.79	75%	90%	760
Secondary	3	Diesel S500	2.00	5.47	55%	95%	2,337
					TOTAL		**106**

As it can be seen in both products there is a small increase in the global inventory. Diesel S10 increases 245 cubic meters and diesel S500 increases 106 cubic meters. The primary terminal (Terminal 1) has a large reduction of its safety stocks levels compensated by an increase in secondary terminals. The explanation for the reduction of the service level required to Terminal 1 in both cases from 99% to 85% is due to the fact that this terminal is supplied by the refinery through pipelines every day with almost no ruptures. Furthermore, forecasts errors in this terminal are not representative. So, Terminal 1 fits in the quadrant of 85% service level for both products. However, the service levels are too low at secondary terminals specially those supplied by railway like Terminal 3 that has a transportation time of 4.96 days (mean) and 2.71 days (standard deviation). Terminal 6 is another case supplied by railway and has a transportation time even higher: 7.17 days (mean) and 3.19 days (standard deviation) but the service level in this case is only 55%. This fact represents a high risk associated to stock outs due to the variability of this transportation mode. In practice, stock outs hardly ever occur because the company always has the option to appeal to the roadway mode. The usage of trucks is a fast and effective response in emergency situations, but for sure it is not the cheapest one. That is why the model points an increase in the service level in secondary terminals.

In the second example, the Pole B has the Terminal 8 that supplies five different terminals with gasoline and three different terminals with diesel S10. Table 3 presents the results:

Table 3 – Pole B Results.

Pole B - Gasoline

Type	Storage Terminal	Product	Current Safety Stock (days)	Proposed Safety Stock (days)	Current Service Level (%)	Proposed Service Level (%)	Safety Stock Variation (m³)
Primary	8	Gasoline	2.00	1.06	98%	85%	-1,711
Secondary	9	Gasoline	2.00	3.76	80%	95%	223
Secondary	12	Gasoline	2.00	2.45	84%	90%	367
Secondary	13	Gasoline	3.00	2.90	90%	90%	-48
Secondary	10	Gasoline	2.00	4.83	75%	95%	572
Secondary	11	Gasoline	2.00	2.99	80%	90%	387
					TOTAL		-210

Pole B - Diesel S10

Type	Storage Terminal	Product	Current Safety Stock (days)	Proposed Safety Stock (days)	Current Service Level (%)	Proposed Service Level (%)	Safety Stock Variation (m³)
Primary	8	Diesel S10	2.00	0.95	98%	85%	-826
Secondary	12	Diesel S10	2.00	5.28	70%	90%	246
Secondary	10	Diesel S10	2.00	4.95	74%	95%	313
Secondary	11	Diesel S10	2.00	3.40	82%	95%	276
							9

Once again there is a great reduction in the safety stock levels of the primary terminal (Terminal 8), compensated by an increase of the service levels at the secondary terminals (exception for Terminal 13). In the case of gasoline the global reduction achieved 210 cubic meters. However, in the case of diesel S10 there is a small increase of 9 cubic meters despite the reduction of 826 cubic meters in the primary terminal.

In the third example, the Pole C in which Terminal 14 is located supplies two different terminals with gasoline. Table 4 presents the results:

Table 4 – Pole C Results.

Pole C - Gasoline

Type	Storage Terminal	Product	Current Safety Stock (days)	Proposed Safety Stock (days)	Current Service Level (%)	Proposed Service Level (%)	Safety Stock Variation (m³)
Primary	14	Gasoline	2.00	1.04	97%	85%	-1,854
Secondary	15	Gasoline	1.00	2.19	76%	95%	276
Secondary	16	Gasoline	2.00	3.42	76%	90%	279
					TOTAL		-1,299

Once again the service level in the primary terminal (Terminal 14) is reduced from 97% to 85% for the same reason addressed in the first two results. Secondary terminals on this pole have their safety stocks increased like the previous examples, but in pole C a new aspect for the gasoline can be observed. The network optimization output pointed that four secondary terminals that have always been supplied by Terminal 14, are now being supplied by imported products traded by new competitors in the market. Imported products are becoming very representative in the Brazilian fuel distribution market for the reasons mentioned in section 2, and this volume is supplied straight from these new competitors' terminals to the secondary terminals of the company under study. The 1,299 cubic meters reduction on the pole C, in the case of gasoline, represents an impact of more than 4 million reais a year in the cash flow. So there is a great opportunity to reduce the global safety stock level not only in this pole but in others that are being impacted by imported products.

All these results are perfectly aligned with the considerations made by Wanke (2000) as mentioned in section 2 when he points that the fuel distribution supply chain is a demand anticipation policy with decentralized stocks. In this policy, the decentralized stocks located closer to the customers requires in one hand a more accurate demand forecast, but on the other hand assures a higher service level to the customers. Another aspect to be taken into account is the fact that primary terminals are supplied by refineries through pipelines with very low standard deviations in the transport time. So, disruptions in this transport mode are very rare, differently from railways that contain serious bottlenecks. For this reason there is no need to hold high levels of safety stocks in primary terminals. This proposal represents a drastic change in the company's inventory allocation strategy.

5.3
Importance of the Demand Forecast Accuracy

As mentioned in section 3.3, the demand forecast error can be included in the calculation of the safety stock. This section will show how forecast accuracy reduces the safety stock and the cash flow as well. The result for one single terminal is presented and then the total result for all terminals is analyzed. Figure 14 illustrates the comparison between the real demand and the demand forecast for Terminal 19, for one year period (2016):

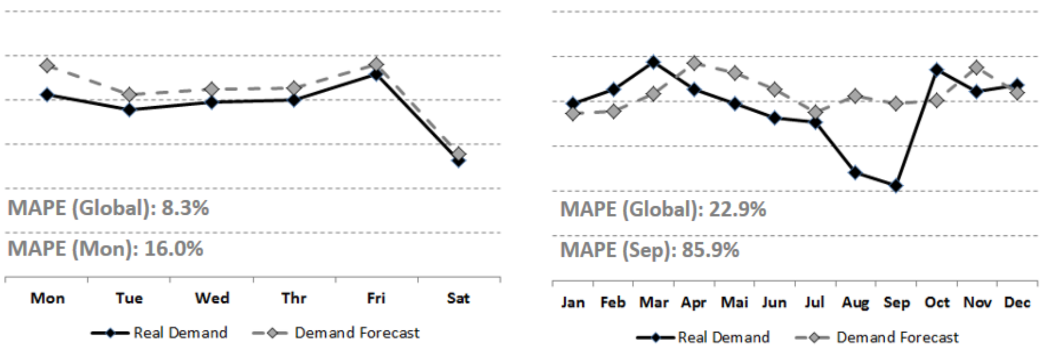

Figure 14 – Real Demand and Demand Forecast (Terminal 19).

For this specific terminal the global MAPE in a weekly basis was around 8% (all three products). However, Mondays showed a MAPE of 16%, the worst result. For a monthly basis the global MAPE was around 23%, while September achieved almost 86%. It is clear that a specific event occurred in that month that dropped the sales below expectations. These values were highlighted to show that large MAPEs will provoke higher safety stock levels. This terminal fits in the 95% service level quadrant producing the safety stocks shown in Table 5:

Table 5 – Terminal 19 (Real MAPE).

Product	Current Safety Stock (days)	Proposed Safety Stock (days)	Safety Stock Variation (m³)	Cash Flow Variation (R$/year)
Gasoline	1.0	3.4	648	-2,352,156
Diesel S10	2.0	3.0	210	-522,632
Diesel S500	2.0	2.9	415	-985,675
			1,273	**-3,860,463**

In this terminal the current safety stocks are not well dimensioned and should be higher. However, according to section 3.3, Brazilian companies that use more sophisticated statistical technics achieve 32% in the average reduction of their demand forecast errors (JULIANELLI, 2001). If the 32% factor reduction is incorporated in Terminal 19, the new safety stocks become 17% lower dropping from 1,273 to 1,054 cubic meters. It is still increasing the safety stock levels, but not unnecessarily so high. The new results are presented in Table 6:

Table 6 – Terminal 19 (Reduced MAPE).

Product	Current Safety Stock (days)	Proposed Safety Stock (days)	Safety Stock Variation (m³)	Cash Flow Variation (R$/year)
Gasoline	1.0	3.3	631	-2,290,448
Diesel S10	2.0	2.8	165	-410,639
Diesel S500	2.0	2.5	258	-612,781
			1,054	**-3,313,869**

If the demand forecast becomes 32% more accurate, there will be an impact of more than 540 thousand reais in the cash flow (safety stock variation in R$) only in one single terminal. The same approach can be done for all terminals evaluating the global inventory variation if the forecast becomes 32% more accurate. Table 7 summarizes the results:

Table 7 – Forecast Errors and EVA impacts.

Scenario	Description	Inventory Variation (m^3)	Cash Flow Variation (millions R$/year)	EVA Variation (millions R$/year)
0	Baseline (current targets)	0	-	-
1	Final with MAPE	-17.8%	61.5	7.5
2	Final with MAPE (-32%)	-19.2%	65.9	8.0

Scenario 0 is the baseline and considers the current targets. Scenario 1 represents the final result of the inventory analysis model for all storage terminals with the MAPE of the demand forecasts considered in the safety stocks calculations. The model suggests a 17.8% reduction in the total safety stock which brings an economy of R$ 61.5 millions in the cash flow a year. This impact represents a R$ 7.5 million increase in the EVA (value creation) for the default value of 12% used by Supply Chain Guru to the WACC. In the scenario 2 the reduction of 32% in the MAPE was applied to all storage terminals bringing an increment of 7% in the global EVA (from R$ 7.5 to R$ 8.0 million), another great opportunity to create value by investing in making forecast errors more accurate.

As the company under study does not use any statistical technic of demand forecast, it was assumed that this 32% reduction factor as reference to measure the potential savings and to show that it is worthwhile to invest time and money to achieve more assertive forecasts. It is important to highlight that this 32% factor is valid only in Brazilian market. If the approach presented in this dissertation is used in other countries this factor has to be revised, but surely a reduction provided by a more accurate demand forecast will require less safety stocks.

5.4
Replenishment Frequency and Investments Impacts

Another important result that emerges from the present inventory analysis approach is the possibility to evaluate alternative investments in storage, taking into consideration the replenishment frequency. Terminal 17 is an example of a terminal supplied by waterway with a transportation time mean of more than 20 days with a standard deviation of 5.85 days. Actually the transportation time mean is around 17 days (15% smaller), but this terminal does not have enough storage capacity to unload all barges that periodically arrive at the pier. So these barges usually have to be berthed at the pier for 3 or more days and wait until the stock levels decrease and allow the unloading process to begin. Because of this, the total demurrage cost reaches more than R$ 2 million a year. So, what is the payback period to build new tanks and increase the storage capacity of Terminal 17?

In the new hypothetical scenario in which the barges would not have to wait at the pier to unload, a reduction of 20% is expected in the safety stocks according to expression 5. This reduction occurs due to the fact that a smaller transportation time would reduce the standard deviation as well, reflecting in the total safety stock needed. Supposing the same 15% reduction in the standard deviations, Table 8 presents the simple payback calculation for Terminal 17:

Table 8 – Simple Payback Calculation (Terminal 17).

Product	Safety Stock Variation (m^3)	Product Cost (R$/$m^3$)	Safety Stock Economy (million R$)	Demurrage Economy (million R$)	Total Investment (million R$)	Simple Payback (years)
Gasoline A	-525	3,345	-1.76	-2.29	11.9	1.71
Diesel S10	-300	2,459	-0.74			
Diesel S500	-912	2,406	-2.19			

The safety stock variation is the 20% reduction mentioned expressed in cubic meters. Multiplying it by each cost provides the safety stock economy. The total safety stock economy for all products plus the demurrage economy equals to 6.98 million reais a year. Dividing the total investment by 6.98, results in the simple payback and it shows that the new tanks would be paid in less than 2 years. If the discounted payback was used, the result would be even smaller.

5.5
Action Research Final Step and Future Opportunities

During all procedures detailed, the interaction between the sales and the logistics department becomes closer, each time the action research cycle occurs. Based on this, it is possible to foresee new opportunities coming up. One of them is the possibility to promote dialogues aiming to organize a Sales and Operation Planning (S&OP). This type of meeting demands a better alignment and more mature processes and probably this is a natural trend.

One huge benefit that usually arises from a S&OP is the reduction of the *bullwhip effect*. But what if the fuel distributor decided to take advantage of modern IT technologies such as Vendor Managed Inventory (VMI) to provide integration of the supply chain, managing the stock levels of their customers (wholesale consumers)? Certainly there would be an even greater reduction of the total inventory.

The bullwhip effect is a well-documented phenomenon that consists in the increase of the variance of the order quantity as we go up-stream in the supply chain. A simple search in Scopus, an electronic data base of scientific articles, by the expression "bullwhip effect" returns more than 16,500 citations, being 2,213 of them only in 2014. It is not possible to state that this effect occurs for sure in the fuel distribution market because it was not the objective of this dissertation to identify it. But it is possible to assume that there is a strong possibility for that, since many authors point that multiple companies operating in a serial supply chain produces this effect. Disney and Towill (2003) wrote about the effect of vendor managed inventory on the bullwhip effect; Metters (1997) tried to quantify the bullwhip effect in supply chains; Zhang (2004) analyzed the impact of forecasting methods on the bullwhip effect. Metters (1997) found that under realistic conditions eliminating the seasonal bullwhip effect alone can increase product profitability by 10 – 20%, while decreasing the forecast error bullwhip effect alone can increase profits by 5 – 10%. These results motivate further analysis and maybe the adoption of technologies like VMI can provide lower safety stock levels, once the fuel distributor would have the responsibility to manage the customer´s stock. Disney and Towill (2003) have compared the bullwhip performance of a number of VMI supply chains with two levels supply chains. In all cases there is substantial reduction in bullwhip (typically halving the effect).

6 Conclusions

The dissertation provided a detailed view of the inventory analysis process in a fuel distribution company in Brazil using an APS. An action research approach was used and a successful implementation of the new safety stock levels is being made. Despite this approach was validated to the company and the APS concerned, the general concepts can be adapted to other companies and other APS software with the expectation to achieve similar results.

The acquisition of an APS software and all investment in training proved to be a successful strategy. The empowerment of the logistic department team in addition to the commitment of the senior management, have made this action research possible. In spite of all effort (money and time) needed to engage a consultancy team in the beginning of the project and disengaging it at the end, the logistics department team is able to lead other action researches continuously. In this way the APS acquired is in fact filling a gap left by the company's ERP. The stock levels (targets) originally updated annually now can be updated in a monthly basis, following the new dynamic of the fuel distribution market in Brazil. Additionally, the present study returned other insights not initially defined as the focus but also relevant, like the necessity to increase the in-transit inventory in one specific terminal located in the central region of the country. This terminal used to be supplied by pipelines one year before this study, and in the last months it is being supplied by railway. However, the official target of the company for this terminal is still not considering in-transit inventory and a very low safety stock level, not anymore aligned with the company's supply strategy.

The outcomes provided by the inventory analysis model were related. One of them is the measurable benefit of improving the demand forecast process that has never used statistical techniques. Now it is known that improvements to promote a more accurate forecast can bring significant impact in the EVA of the company, adding value to a very competitive business. If a more accurate forecast is achieved by statistical techniques, less safety stocks need to be hold at each terminal. This result will help the company to define the most appropriate budget to afford the acquisition of a new technology. Moreover, EVA is the company's most important performance indicator and the continuous monitoring of this KPI is one of the golden rules mentioned by Favilla and Fearne (2005) to assure a successful implementation of an APS.

Another outcome is the possibility to estimate the investment payback considering that a larger storage capacity would allow a smaller transportation time, reflecting in less safety stock and no demurrage costs. One terminal was used as an example of how this payback can be calculated, but there are other opportunities that can be tackled in other terminals.

The safety stock shifting from primary to secondary terminals was another important outcome. It was possible to identify that many primary terminals are holding too much inventory with no need, since their supply frequency has almost no disruption in their historic data. By the way, the safety stocks of the secondary terminals were, in many cases, backtracked and allocated at the primary terminals. This strategy was reducing the service levels on secondary terminals, assuming the risk of losing sales and overloading the primary terminals, undermining their operation. The new market dynamic in which imported products are assuming a great representativeness is increasing the relevance of this work and the need to update the targets in a monthly basis.

Finally, this dissertation did not have the intent to exhaust this topic or even to prove that the approach taken in this action research is the only nor the best approach. But it answered the general question that, in fact, it is possible to adequate the service levels of each terminal and each product using a logical and structured procedure proposed by an APS to reduce the global inventory. Furthermore, it paved the way to search for new discussions like: the implementation of a Sales and Operation Planning and the adoption of VMI technology inside the company. Other fuel distribution companies in Brazil and in other countries can implement the approach proposed in this dissertation and will probably achieve the same good results.

7
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