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SUPPLY CHAIN FOR TEXTILE REINFORCEMENTS

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DISSERTAÇÃO DE MESTRADO APRESENTADA
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Supply Chain for Textile Reinforcements

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"The line between disorder and order lies in logistics…" - Sun Tzu

Abstract

This project was developed within the company Continental – Indústria Têxtil do Ave that is part of the automobile industry. The aim of this thesis was to provide the company, a deep analysis of the stock that was being held at the moment, if it was the right amount, at the optimum location and with the correct distribution.

This information is important to redefine the target safety stock level both of raw materials and finished goods in order to optimize the whole supply chain balancing inventory costs and supply risk.

The production policy used is make-to-stock so the company uses forecasts provided by the customers to order production in batches. The problematic of erroneous forecasts raises the need to hold safety stock of finished goods to achieve the desired service-level.

In terms of raw materials, there are constant delays in shipping because some suppliers are located in Asia, incurring in additional problems in customs. The need for safety stock is therefore mandatory in order to continue production without supply problems.

Finally, a breadth analysis of the supply chain both in terms of inventory and transportation is addressed providing some ideas for future developments.

Statistical analysis of forecasts, safety stock definition methodologies and inventory management policies were used to develop some programs that will support decision-making in these fields through algorithms and simulation.

The main conclusions about the project were that the need for holding finished goods safety stock is real, because of the quality of the forecasts, the calculation of raw materials safety stock can be more methodological and done more frequently to adapt to transportation reality. An important inference is that to optimize the supply chain process, both transportation and inventory policies must be defined at the same time because without doing that, the optimum stage will never be reached.

Moreover, this project had raised the attention from the headquarters of Continental, and therefore, it is possible that these analysis and methodologies can be adopted to other companies and supply chains from the Group which is a major achievement.

Gestão da cadeia de abastecimento de reforços têxteis

Resumo

O projeto foi desenvolvido dentro da empresa Continental - Indústria Têxtil do Ave que faz parte da indústria automóvel. O objetivo desta tese foi o de fornecer à empresa, uma análise mais teórica e metódica sobre o nível de inventário, como deveria ser calculado o *stock* de segurança e perceber o estado atual da distribuição do stock na cadeia de abastecimento.

Esta informação é importante para redefinir o nível de *stock* de segurança tanto nas matérias-primas como para os produtos acabados, a fim de otimizar toda a cadeia de abastecimento equilibrar os custos de inventário e risco de abastecimento.

A política de produção utilizada é *make-to-stock*, para isso a empresa utiliza as previsões fornecidas pelos clientes para lançar ordens de produção em lotes. O problema dos erros nas previsões levanta a necessidade de manter um nível de inventário superior ao desejado sendo que estas variações podem não poder ser absorvidas por alterações na produção, devido ao elevado tempo de produção.

Em relação às matérias-primas, existem constantes atrasos no transporte. Alguns fornecedores situam-se na Ásia o que leva a problemas adicionais tanto no transporte em si como nas alfândegas. A necessidade de manter *stock* de segurança é, portanto, obrigatória, a fim de continuar a produção sem problemas de abastecimento mantendo-se o nível de serviço desejado.

Finalmente, uma análise global à cadeia de abastecimento, tanto em termos de inventário como de transporte, tendo em conta os custos associados aos dois, é abordada ficando definidas algumas ideias para futuros desenvolvimentos.

A análise estatística das previsões, metodologias para definição de *stocks* de segurança e políticas de gestão de inventário são utilizados para desenvolver alguns programas com o objetivo de ajudar na tomada de decisão, sendo assim possível ter uma abordagem mais científica e previsivelmente mais eficiente aos problemas do dia-a-dia da empresa através de algoritmos e simulação.

As principais conclusões sobre o projeto foram que existe a necessidade de manter *stock* de segurança ao nível do produto-acabado, por causa da qualidade das previsões e para manter o nível de serviço expectável. O cálculo do *stock* de segurança de matérias-primas pode ser mais metódico e feito com mais frequência para se adaptar à realidade do transporte na cadeia de abastecimento e à sua evolução. Uma conclusão interessante é a que para se obter o melhor desta cadeia de abastecimento, será sempre necessário gerir globalmente os custos de transporte e armazenamento para redefinir as políticas de reabastecimento aos clientes que mais benefícios trazem à empresa.

Além disto, este projeto foi acompanhado pela central da Continental culminando com uma apresentação para os responsáveis pela gestão da cadeia de abastecimento centralmente. Desta apresentação resultou a possibilidade de alargar este projeto a outras cadeias do grupo o que é mais uma fonte de reconhecimento do trabalho desenvolvido.

Acknowledgements

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Last but not least, to my mother and father, for their unconditional support and because they are responsible for the opportunity of graduating and doing this master thesis. To my brother that helped me to relax and enjoy in the most stressful moments.

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Acronyms

C-ITA: Continental – Indústria Têxtil do Ave, SA

CMIP: Continental Mabor - Indústria de Pneus

EDI: Electronic Data Interchange

ERP: Enterprise Resource Planning

JIT: Just-in-Time

MRP: Material Requirements Planning

OEM: Original Equipment Manufacturer

SKU: Stockkeeping unit

SOP: Sales Operations Planning

VMI: Vendor- managed Inventory

WIP: Work-in-process / Work-in-progress

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1 Introduction

Quality of service delivered and the ability to analyse costs and to get this balance to the optimum level is a must-be in today's economy. The competitiveness of the automobile industry, which is above average, forces Continental Group and consecutively C-ITA to develop strategies to become as efficient as possible. In this chapter both the company and the scope of this project will be contextualized being therefore easier to comprehend the real problem and the proposed solutions.

1.1 The Industry

The automobile industry is in a stage of continuous metamorphosis in order to cope with customers' expectations day after day. This tends to raise the "nervousness" of the supply chain's companies upstream. New products being launched in a regular pace, experiments, tests and consequently small batches influence the efficiency of the plants. All of this makes it more difficult to plan, organize and optimize the whole supply chain.

If tire manufacturers develop new tires, for example, to raise the life-cycle, to increase the sustainability, to reduce costs and increase efficiency, Continental - Indústria Têxtil do Ave, producer of textile reinforcements and therefore being in the upstream of the chain, will have to respond in a flexible and timely manner.

C-ITA is part of supply chains that have different markets as destiny. The OEM (Original Equipment Manufacturers) in which the clients of C-ITA, the tire plants, sell the tires to the car manufacturers who use them as components of their final product (Figure 1):

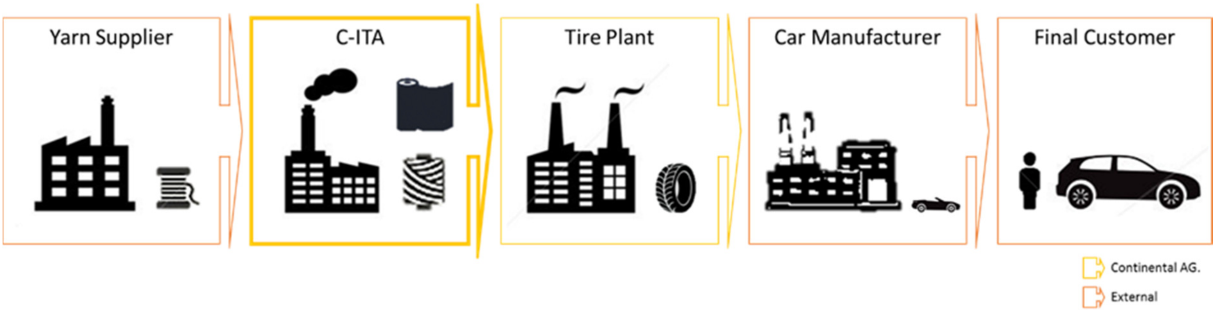

Figure 1 - OEM supply chain

As well as the replacement market that is characterized by having retailers that sell to final customers as part of the supply chain (Figure 2):

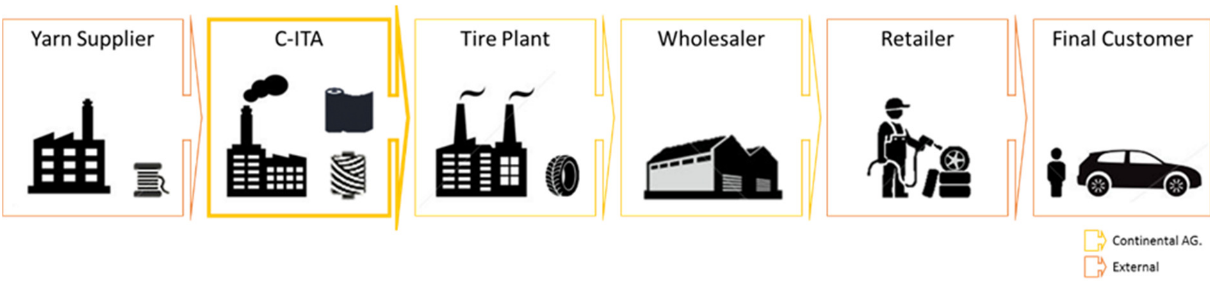

Figure 2 - Retailing supply chain

Even if the diverse markets for which C-ITA is a producer require different approaches in terms of quality control of tires, the textile reinforcement processes are not differentiated according to the market.

Automobile supply chain is classified by having a convergent (assembly) structure. This is, various suppliers along the supply chain are inputting materials that will result in a shorter range of final products (Beamon & Chen, 2001).

The tire industry is characterized by holding too much stock of finished goods, the costs associated with it are huge, but since profits are higher than in other industries, brands could not afford to lose sales. The inventory between tire plants and final customers are enormous, nevertheless, these plants have to react quickly to demand variations from the market. As Muller (2011) says "it costs money to make money" so inventory is not a bad thing, it is absolutely necessary, however having excess of stock just because it is not managed properly can cause serious problems to an organization.

All the links in the chain have their own understanding of what is the demand. The variations in demand that occur over time, make all the organizations afraid of not being able to supply that demand. This fear results in extra orders and productions in order to become secure, effect that is higher if there is human-being interference. These variations are amplified throughout the system creating the well-known bullwhip-effect.

The main objective of the project is to search ways to deal with these variations in the most efficient way.

There were mainly two possible ways of tackling this issue:

- Reduce production lead time by increasing flexibility.
- Create safety stocks to deal with the demand variability.

Holding safety stock to increase service level and production stability was the choice. It was defined that firstly, C-ITA will build up safety stocks to achieve the desired service-level since it produces to stock and that is the way to handle the forecast-demand mismatch. After being sure that with this level of inventory all the targeted demand will be satisfied, the focus should pass to increase flexibility, hence reducing production lead time which will result in the reduction of the previously defined levels of safety stock.

This approach will offer the plant the desired stability by having a more steady production plan, set from the forecasts provided from the customers.

The textile reinforcements industry can be settled in the Process industry group, so it is a capital intensive industry meaning that the machinery needs to be used 24/7, 365 days an year because "of the relatively expensive equipment and the relatively low flexibility in output rate"(Silver, Pyke, & Peterson, 1998).

Therefore, having the possibility to plan the production with more time and in a more stable way, savings in setup time will show up and the machinery utilization will certainly increase.

In order to analyse inventory levels of finished products it is necessary to separate two different realities: Continental plants and external clients. The main reason for that is that the plant produces continuously to Continental plants, which produce tires all over the year and use these reinforcements. The external clients order textiles in episodic occasions and the quantities needed are not comparable with the demand of tire plants.

In order to come up with new solutions and methods of managing the supply chain inventory in the most efficient way, some methodologies were implemented in the mandatory adaptations to the real case of C-ITA and its customers. From statistical analysis of forecasts, inventory management policies, safety stock definition methodologies to demand forecasting, all these topics were taken into account when developing the range of solutions proposed to solve the stated problem.

1.2 The Company

Continental – Indústria Têxtil do Ave is part of Continental Group since 1993. The plant is located in Lousado, Famalicão and was built in 1950. Back at that time the company was named Indústria Têxtil do Ave and no relation with the Continental Group, the plant was producing textile fibres, what its suppliers are producing today.

The mission of C-ITA is to "Create Value to the Continental world wherever textile competence is a differentiating factor". Continental Tire Division had a strategy of vertical integration and some previous Continental suppliers became part of the Group. Aldora Mills is the other plant producing textile reinforcements that is held by Continental AG.

Acquiring companies like these made it possible to integrate processes and systems and gain efficiency globally. Continental AG vision is "Your Mobility. Your Freedom. Our Signature." providing "Highly developed, intelligent technologies for mobility, transport and processing make up our world.".

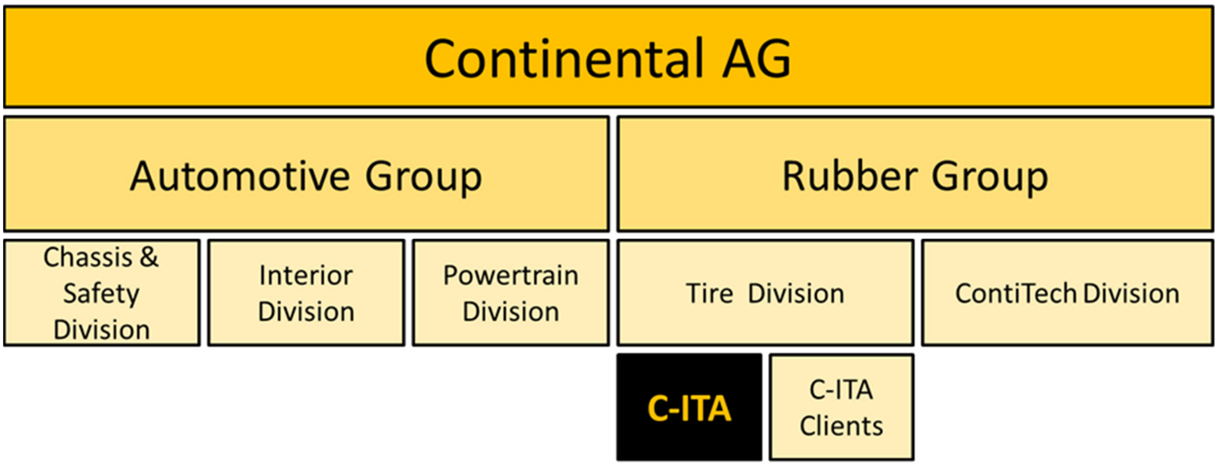

Figure 3 -C-ITA inside Continental AG

C-ITA could be a common textile plant since the processes from raw material to finished good are similar to the production of textile from which clothing is made of. Nevertheless, the fibres used and the parameters defined in production make the product special and fully customized to tire production applications.

In synthesis, the process begins the reception of fibres as nylon, polyester, rayon or aramid that are firstly transformed into cord by the process of twisting. After this step, roughly one thousand and six hundred bobbins of cord are joined to produce the greige fabric in the weaving machines. Before the last process, the product has the normal look of known textile fabrics, though the main characteristic that makes this fabric useful to tires is not present yet, the ability to get linked to the rubber. Only after dipping the product is finished and ready to enter tire plants' production lines.

The main role of the textile reinforcement in tires is to prevent them to expand indefinitely as it roles and gets warmer. Apart from the textile there are metallic reinforcements and the rubber composites from which the aspect of the tire is known.

The complete process is slow at C-ITA, so the flexibility of supply is not as high as desired. To deal with regular variations throughout the supply chain having stock is the wise option. Thus, this stock should be managed in order to be the minimum without compromising the service level which is a key factor for C-ITA's success.

The processes related to the range of products that will be analysed during the project are presented in the figure 4. Note that two of the products analysed, the dipped cord that is also incorporated in some types of tires, do not have the process of weaving and the dipping process is slightly different as well as the incorporation process in tire plants.

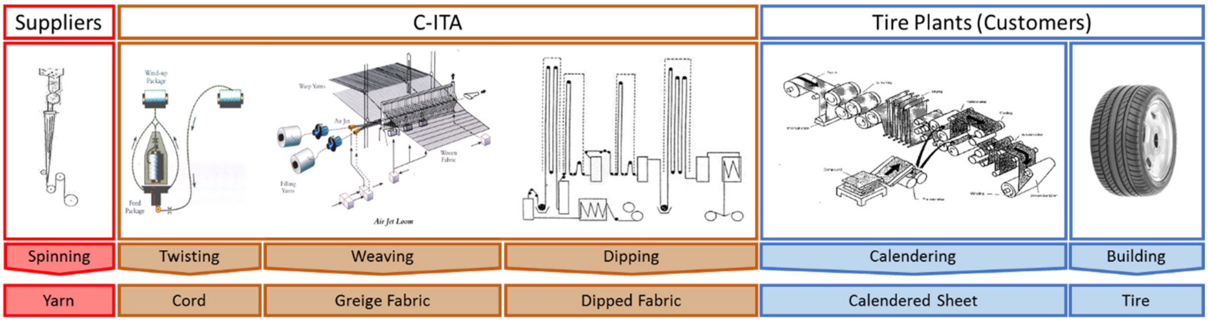

Figure 4 - Supply chain partners, processes and products

The project evolved within the company Continental – Indústria Têxtil do Ave, part of Continental AG, more specifically in the Logistics Department, responsible department for purchasing raw materials (inbound logistics) and selling finished goods (outbound logistics). The corporate purchasing division from Continental AG headquarters in Hannover has been part of the project therefore existing the possibility of enlarging this type of analysis to other companies and supply chains of the Group.

Continental - Indústria Têxtil do Ave has as the main activity the production of technical textiles to industrial application, of which 98% is production of dipped fabric and dipped cable to tire manufacturing. The annual production capacity of the C-ITA's plant is around 15000 tons/year depending mainly on the product mix that is supplied during the year.

Continental - Mabor Indústria de Pneus, the tire plant also located in Lousado, is the most important customer and represents approximately half of C-ITA's revenues (data from 2013). CMIP produces almost exclusively to the export market, only 3% of the produced tires have the Portuguese market as destiny.

Continental - Indústria Têxtil do Ave is betting in the area of the technological development on which is getting an interesting return. The new focus on the Research and Development Division is making it possible to be recognized within the Group as a technologically advanced unit, setting up great relations with local universities and consequently gathering investment to this area.

The company is facing a reorganization in the methods and principles of thinking and working, the main direction is to create a leaner company, which has to begin with a more responsible and proactive workforce through a teamwork based organization.

The corporate Group Continental AG is among the leaders in the areas it is involved, all of them are on the automobile business, although it is not only working in the tire division which is the area from where the majority of the customers recognize the brand.

C-ITA has now the objective of diversifying its businesses. Even if the inside the automobile bias, the plant had begun the production of a new range of products. This new product-family is the knitted fabric which is used in the interior part of cars. There was the need of an important investment to begin this activity since all the processes are different from the existing ones and new machinery was acquired.

The company aim is to continue to diversify its businesses in order to aid the parent company in providing “Highly developed, intelligent technologies for mobility, transport and processingmake up our world.”. This global view of the company could put it as a leader in the OEM parts suppliers ranking, in 2012 Continental AG was the third company in this top[1].

Since there are many plants from the Group that have to buy their supplies from outside companies, C-ITA’s administration is eager to get these customers and begin to produce other products to different Continental customers. Despite this breadth in business activity, the focus will endure within the textile business in order to continue using the historical know-how from a company that is working on textiles since 1950 remaining linked to its core competences while following C-ITA’s mission.

1.3 Problem Statement and Project Structure

Safety stock definition requires a thoroughly search of critical data, such as, historical forecasts provided by customers, inventory level evolution, and actual orders. After having these figures, the process of “cleaning” the numbers and making them useful started.

The core of this project was divided in three main parts, finding the right target of raw materials stock, finding the right target for finished goods inventory and analysing the supply chain globally both in terms of inventory and transportation costs. The definition of the finished product target stock level was the most critical because it has a direct influence in supply risk and is responsible for higher inventory costs.

To define which products should be studied it was performed an ABC analysis in terms of clients since there is a major difference between internal and external clients as detailed before.

After knowing how the clients could be divided, the focus went to which of these internal customers represented the majority of the sales. A group of six customers (20%) held 95,7% of the revenues, data from 2013. This cluster of clients from the following locations Lousado, Aachen, Otrokovice, Puchov, Timisoara and Hannover became the range of study in this project. The division in products does not follow the Pareto law, so that, the clusters defined relented on each customer and the products C-ITA is selling to those clients.

With all the products to be studied defined, there was a deep search to discover important data about the forecasts received from customers, potential correction made when there was the belief that, for some reason, the forecasts were not matching reality, sales, and consumptions both in C-ITA and in clients, being important for the definition of safety stock through consumption variations.

[1] (http://www.autonews.com/assets/PDF/CA89220617.PDF).

Until now, as Davis (1993) says “firms have traditionally relied on a combination of experience and intuition” which is the case of C-ITA, being important to develop intelligent procedures that will make it possible to achieve the best balance between inventory level and supply risk.

There was the need to develop a model to link all this data and define methodologies to calculate the safety stock levels. The model was constructed as well as a simulator to analyse what would happen along the weeks with the recommended safety stock calculation.

With various methods to calculate safety stock levels, the simulator is an important tool to understand what would happen with different parameters and help in the decision of which would be the best calculation method.

1.4 Document Organization

The following chapter is reserved to the literature review where the whole group of methodologies and theories adopted and used during the project are explained.

The project had three main fields of development: Safety stock of raw materials, safety stock of finished goods and supply chain management. Therefore, there will be the same division in this document. For each of these parts the present situation will be presented, the proposed solution explained and also some results and the discussion will be approached.

Finally, some conclusions about the project and some future developments and ideas are going to be presented.

2 Literature Review

The research field in which the project can be resumed is inventory management although literature about supply chain management, inventory policies and forecasting were also reviewed. This research is mandatory to solve an all-encompassing problem as defining safety stock for raw materials and finished goods in the textile reinforcements industry as well as the supply chain management issues. Chapter 2 will be divided in two main objects of research: Supply Chain Management and Inventory Management. In each of these, there will be specific topics explored.

2.1 Supply Chain Management

To make a supply chain to perform better than the others, there are fields where you have to excel, namely forecasting methods, flexibility, transportation efficiency, data analysis and the most important for the project, have a robust inventory management system.

A supply chain is, according to Mentzer et al. (2001), “A set of three or more entities (organizations or individuals) directly involved in the upstream and downstream flows of products, services, finances, and/or information from a source to a customer.”.

A Supply Chain requires a different type of Management that is, according to Silver, Pyke and Peterson (1998), “The term used to describe the management of materials and information across the entire supply chain, form suppliers to component producers to final assemblers to distribution and ultimately to the consumer”.

Lynch (2009) stated that the right way to manage the materials that flow across the supply chain and set up a good business strategy it to: Remain agile to avoid risk; Be resilient to respond, adapt and absorb risk; Develop methodologies that are sustainable to scale and maintain risk solutions.

A great example of excelling through a new idea of how to manage a supply chain is Dell Computers. Dell has gained competitiveness by skipping distribution and retail steps which used to be controlled by manufacturing firms. This way, Dell made it possible for consumers to “get the latest models at very competitive prices in only five or six days” and become a huge success in the 90’s (Aswathappa, 2008).

Even being a very good example of how can a supply chain be organized in innovative ways, this model can not be applied to all products and customer groups, there has to be a deep analysis on the market and all its influencers in order to get the best out of it without compromising the future of the company. For instance, not every customer is willing to wait almost one week until receiving their Personal Computer instead of going to a retailer and buying it at the moment, all these risks and opportunities must be taken into consideration when designing a supply chain (Jacobs, 2002).

A supply chain is a complex group of interconnected firms working to meet or, if possible, exceed customers’ expectations. It is like a “picture of how organizations are linked together as viewed from a particular company” (Jacobs, 2002). This complexity is not easy to manage and the problem is extended the farther you are from the customer.

Bullwhip Effect

One of the biggest problems in supply chains is called the bullwhip effect. Also named Forrester effect, in respect to its main researcher, which represents the increase in demand variability while moving up the supply chain from consumers to producers (Silver et al., 1998). Forrester, by means of simulation, identified the root causes of these variations amplification: Information distortion and information delays (de Kok et al., 2005).

A good illustration of the bullwhip effect is the famous “beer game”. Participants have different roles that are related to supply chain echelons, specifically customers, retailers, wholesalers and suppliers of a popular beer brand, which is the reason for the name of the game. The main rule is that the communication between players is forbidden and each participant must place orders based on the downstream player’s orders. The important conclusion is that “The ordering patterns share a common, recurring theme: the variabilities of an upstream site are always greater than those of the downstream site, a simple, yet powerful illustration of the bullwhip effect" (Lee, Padmanabhan, & Whang, 1997).

The bullwhip effect can be reduced, and this work can be easily, quickly and more efficiently performed in multiechelon inventory systems. These systems are characterized for being managed globally and centrally so, theoretically, these are leaner than conventional independent firms working as a supply chain.

To make it possible for these systems to perform well, EDI (Electronic Data Interchange) features are a main requirement, increasing accuracy and speed of information flow.

Risk

A supply chain has always an inherent risk, it can come from the first suppliers, problems in machinery during production or even in transportation to the final customer, and these events can have a great impact on the service level. According to Lynch (2009), risk has two essential components: uncertainty and exposure to uncertainty. So, “We face risk when both uncertainty and exposure are present”.

Risk and efficiency are positively correlated, this is, normally, to be more efficient (less inventory in the supply chain) there is the need to take more risk, however, there is an optimal balance that must be pursued. Lee differentiates four supply chain strategies that have diverse methods in accessing these two dimensions (Lee et al., 1997):

a) Efficient Supply Chains: The aim is creating high cost efficiency eliminating non-value-added activities, promoting capacity utilization to achieve economies of scale and using optimization techniques in all stages.
b) Risk-hedging supply chains: When the risk of disruption has so much impact on the chain (high shortage costs), the supply chain must be organized in order to mitigate this risk while diminishing the holding costs. Real-time information on inventory is a must and sharing inventory among companies could be a good situation.
c) Responsive supply chains: The main objective is flexibility, it means that in these supply chains, companies must be agile to respond to demand variations in quantity and form. Efficient customization processes must be the way to meet specific need of customers in the shorter possible period.
d) Agile supply chains: These are a combination of Responsive and Risk-hedging supply chains and have the best of the two worlds: The ability to quickly respond to unpredictable demands while hedging the risk of supply disruptions.

Supply-chain risks are due to unanticipated changes in flow caused by disruptions or delays. This causes problems and consequences must be carefully analysed since they can have great impacts in supply chain performance. For instance, “A machine breakdown may have a relatively minor impact on a manufacturing company with redundant capacity, whereas a war that disrupts shipping lanes can have a major impact on a shipping company.” (Chopra & Sodhi, 2012).

Managing the risk on a supply chain can have a great impact on the success of the organization. There is an example of two different companies that suffered from a supplier’s plant fire (Phillips). Nokia, that was totally dependent of Phillips, had much more difficulties in dealing with this incident than Ericsson. Their different strategies in terms of how to mitigate supply-chain risks resulted in different outcomes, namely lost sales, for the same problem (Chopra & Sodhi, 2012).

The risk is present in various stages of the business, the most important and present in all supply chains is the provided by demand variations. When the direct client is the final customer, the demand is defined stochastic. One never knows exactly what customers are going to want because there are so many variables influencing it that is impossible to be always correct. These variations induce business players to have extra stock than they would not need if the demand was deterministic. This extra inventory, normally named safety stock, positively impacts the service level.

Safety Stock

Safety stocks may also be used for another purposes rather than demand variations such as to deal with lead time variations both from production (which can include order processing time) and from transportation.

This level of buffer inventory can be defined in terms of expected service level or it can be adapted to a constrained demand when the company assumes which amount of demand it want to supply and manage the safety stock level to be efficient within those boundaries (Stephen C. Graves & Willems, 2000).

An easy and common approach for defining safety stock levels is to “simply state that a certain number of weeks of supply be kept in safety stock” (Jacobs, 2002). Nonetheless, this is not the most “clever” way of solving this problem because, for example, if for two products are being sold in the same average amount, but the forecasts for the first are much farther from the reality than for the second, why should the same safety stock be maintained for both?

To surpass this issue, it was used the Probability Approach, which has as an assumption that all the time series follow the normal distribution (Jacobs, 2002). With that being assumed, it is possible to calculate what the probability of running out of stock is, looking at previous demands and actual sales, and thus statistically analysing the forecast errors. After this, it is “easier” to predict what should be the level of safety stock in order to ensure the company provide a certain service level.

Having this approach, the thoughts of Chopra and Meindl (2007) that believed safety stocks should by influenced by the following factors were followed:

- The uncertainty of both demand and supply
- The desired level of product availability

Apart from demand variability, there are breakdowns, emergencies or lack of capacity that restrain every echelon of the chain, which can result in lost sales and, thus, negatively impacting service level.

Service Level

In the most recent literature, there are three different types of service level that are measures to characterize the service the firm is providing its customers, either if they are final customers or intermediate firms in the supply chain. Those are the α (alpha), β (beta) and γ (gamma) service levels. To briefly describe these, α measures the number/frequency of shortages over a time period, β measures the deepness of the stock out, that is, the quantity of product that was demanded but not provided during the studied period and finally the γ that combines quantity and time, hence these measures the quantity of the shortage and the time the company takes to replenish that demand, to use the latter figure the possibility of backordering must be assured (Tempelmeier, 2011).

2.2 Inventory Management

Inventory is the stock of every product, raw material, work-in-process held by an organization and an inventory system is a "set of policies and controls that monitor levels of inventory". The act of monitoring the inventory includes determining what is the level maintained, when should it be replenished and what should be the size of the order (Jacobs, 2002).

A great way to create leaner supply chains is to implement inventory management and to develop these systems continuously. All inventory items must be distinguished by a specific code and the common term used is stockkeeping unit (SKU). This code identifies the item whilst ascertaining its cost and manufacturer if needed.

Holding inventory, despite entailing extra costs, brings more stability to the whole supply chain. The main functions of inventory are the following (Stevenson & Hojati, 2007):

- To meet anticipated demand;
- To smooth production requirements;
- To protect against stock-outs;
- To take advantage of order cycles;
- To permit operations.

On another topic, the efficiency of every supply chain can be evaluated with two common measures:

$$Inventory\ Turnover = \frac{Cost\ of\ goods\ sold}{Average(Aggregate\ inventory\ value)} \qquad (1)$$

$$Weeks\ of\ supply = \frac{Average(Aggregate\ inventory\ value)}{Weekly\ sales} \qquad (2)$$

It is important to notice that the Average Aggregate Inventory Value includes raw material, WIP, finished goods and also goods on transit considered owned by the company (Jacobs, 2002).

These two inventory measures are closely related to the dimensions of supply chain success: Risk and service level. There has to be a balance in the efficiency of supply chain in order to be able to get good results in Service Level reducing supply risk.

It is important to remember that inventory record accuracy is, at great extent, a critical factor to the success of inventory management systems. As Kok and Shang (2007) confirm, “The direct effect of inventory record inaccuracy is losses resulting from ineffective inventory orders decisions” that could lead to “backorder penalties or lost sales”.

Just to notice that, inventory systems are normally developed for one of the following cases: Complete backordering – When the warehouse is out of stock, all the exceeded demand can be filled in following replenishments; Complete lost sales – Instead of being backordered, exceeded demand is lost because the customer gets what he wants elsewhere (Silver et al., 1998). None of these cases is always true in an organization - The real situation is a mixture of both, however because of the extra difficulty of modelling a hybrid method, companies tend to set one of these as a dogma.

There are four main types of processes in the production of goods and services that are often correlated with the type of product/service delivered: Job Shop (Small batches, many products); Batch Shop (Big batches, few products); Assembly Line (Parts moving from workstation to workstation at a controlled rate) and Continuous Flow (Process of undifferentiated materials). Batch Shop, “generally employed when a business has a relatively stable line of products” and when production is made “either to customer order or for inventory” is the type of process used in the studied industry (Jacobs, 2002).

The objective of all companies is to be part of a Lean Supply Chain. This is a flourished term to describe an efficient chain that uses Lean techniques. This approach can lead to efficiency gains throughout all the companies involved.

Just-In-Time (JIT)

One of the most important techniques in the logistics field is the JIT (Just-in-Time). This was a technique developed by Toyota founders and workers, the most known are Sakichi Toyoda and Taiichi Ohno, that have been replicated all over the world in all types of companies. It is nothing more than having the right thing, at the right place, at the right time, with the professional inputs needed to apply it in an industrial environment. Its goal is “The total elimination of inventory at all stages in the process.” (Hutchins, 1999).

Managing JIT systems requires more flexibility and willingness to face risks, though, it is a great way to find the “hidden” problems of current processes and therefore, triggers the necessary actions for improvement.

Despite being created to apply in manufacturing processes, these methods are becoming more and more used in other fields of business, one really important is in logistics where “The goal is to drive all inventory queues to zero, thus minimizing inventory investment and shortening lead time” (Jacobs, 2002).

Forecasts

To set up an inventory management system, forecasts and the inventory policy that is more beneficial to the company are needed. Take for beneficial the balance between easiness of implementation and effective improvements.

So, what is a forecast? A brief way of explaining it is saying that a forecast is a prediction of what someone thinks will occur in the future based on previous data. To calculate it there are many procedures and different approaches that will be explained afterwards.

Another wise question is why there is the need to have forecasts. In the majority of the businesses, the demand is not constant neither deterministic, that is, there is always a component of randomness that can not be controlled such as market conditions, economic trends, substitute products entrance, customers problems, etc.

Woolsey and Maurer (2000) assert that "The Forecast is wrong! And it will CHANGE!" .However, it could be wise to follow Henri Poincare belief that "It's far better to foresee even without certainty than not to foresee at all."

As was said before, the forecasts may be based on time series analysis that reflect previous demands of certain variable (anything can be forecasted, not only demand. There is the usual example of climate). About the demand itself, there are two types of demand: The Dependent Demand, which is caused by the demand for other products or services (Example: Tires that go to OEM of cars) and the Independent Demand (Tires everybody buy in the replacement market) that can not be extrapolated by the demand of other products or services, this is related to the actual demand from the market, what customers really want to buy (Jacobs, 2002).

The most widely used forecasting methods are the following: Simple Moving Average; Weighted Moving Average; Exponential Smoothing and Holt-Winters Method. The most complex is the Holt-Winters that takes into account the trend, level and seasonality of the time series while the others leave out any possible seasonality of the events.

A common way to define safety stocks is analysing the forecast errors with several measurements as the MAD (Mean Absolute Deviation) and the Tracking Signal. More detailed information about used forecasting methods will be provided during the report.

Having safety stocks is a must whenever the cost of a lost sale is higher than the cost of holding that extra inventory. And even if accurate forecasting could lead to reduced safety stocks, calculations can not relied in with 100% confidence because as Warren Buffett said "If past history was all there was to the game, the richest people would be librarians".

ABC Analysis

A real need when starting the implementation of inventory management system is to categorize the inventory. This is, to wisely define which are the most important SKUs for the company, which of them can not enter in disruption and those which value is residual and do not justify waste of time and resources in taking a look at, at least in the first stage of analysis.

A commonly used framework to segment inventory items is the ABC Classification. This routine is based on the Pareto principle being applied to inventory management whereas the latter was developed within quality control (Ramanathan, 2006).This theory states that 20% of the SKUs accounts for 80% of the revenues. And this is the basis for the ABC analysis where the items are disposed in a list, from the one that generates more revenues to the last and set these limits of percentages as below:

A item: 20% of SKUs ➔ 80% of sales volume

B item: 30% of SKUs ➔ 15% of sales volume

C item: 50% of SKUs ➔ 5% of sales volume

Of course it is not probable that these percentages will match at the unit, however, for the majority of businesses the approximation is very precise. Note that, the clustering of items can be altered by the inventory manager if there is the need of considering a low-volume product an A item, for example, if the client of that product is really important and if bad service in that particular article could affect the whole perceived service-level of the company.

After performing this breakdown, it will be possible to define how to tackle each group in terms of inventory management. The focus should begin with A SKUs and these have to be assigned more complex and consequently costly inventory systems since these are the most valuable inventories.

Inventory Policies

There are two general methods to manage inventory in terms of review: the continuous and the periodic. Continuous review should be used in A items, when necessary, because it gives more accurate levels of inventory at the moment, hence being possible to react faster. This type of review requires much more complex database systems and human resources so the system cost will automatically rise. Periodic review will work for many organizations, even for A items, and in this system, it is necessary to decide which will be the review period, daily, weekly or monthly. This choice depends on the processes before and after the inventory, the transportation and production frequency, etc.

After defining the review type, there is a pending decision about the frequency and quantity of the replenishment order. There are four important replenishment systems that will be explained next:

- Order-Point, Order Quantity (s,Q) System
- Order-Point, Order-Up-to-Level (s,S) System
- Periodic-Review, Order-Up-to-Level (R,S) System
- Periodic-Review, Order-Point, Order-Up-to-Level (R,s,S) System

When analysing these different approaches in terms of inventory management, measurements should be on the inventory level or position, this is, taking into account all the available stock including the On Order stock and subtracting the stock that can not be used. The usual calculation formula is presented below.

$$Inventory\ position = (On\ hand) + (On\ order) - (Backorders) - (Committed) \quad (3)$$

The usage of this measure brings to the simulations more accuracy and efficiency than using just the On-hand stock or the Net Stock (On hand – Backorders). Thus the trigger to the order in all the following presented methods will be the inventory position whenever the replenishment activation is quantity-based.

The major purpose why it should be used the inventory position is because it will prevent the system for ordering a replenishment today when a large shipment was scheduled for tomorrow. Although the first two systems are based in a continuous review, the characteristics of the reality of the company changed the focus to the systems with periodic review, along the report the reasons for that will be presented, but, simplifying, it is because this will be applied for the needs of the warehouse that will influence production. These production orders are done on a weekly-basis and not continuously.

The first to be presented is the Order-Point, Order-Quantity (s,Q) System. This is similar to the two-bin system, which is a physical analogy where you can define two bins as being your storage, the first bin would contain the s quantity while the second contains the Q.

A method like this could only be beneficial in specific situations and when demand has not a high variability/seasonality however it is easily implemented and manageable by any person.

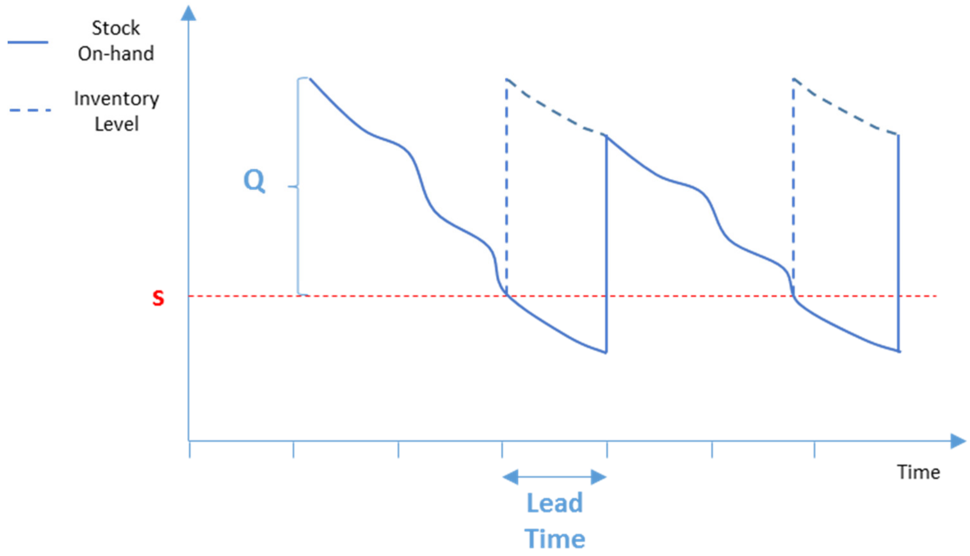

Figure 5 - Order-Point, Order Quantity (s,Q) System illustration

The following is the Order-Point, Order-Up-to-Level (s,S) System. The main principle is similar to the previous method, so the trigger is set whenever the inventory level goes below the s level, the reorder point whereas the S, Order-Up-to-Level, is dynamic and redefined in every time level s is reached.

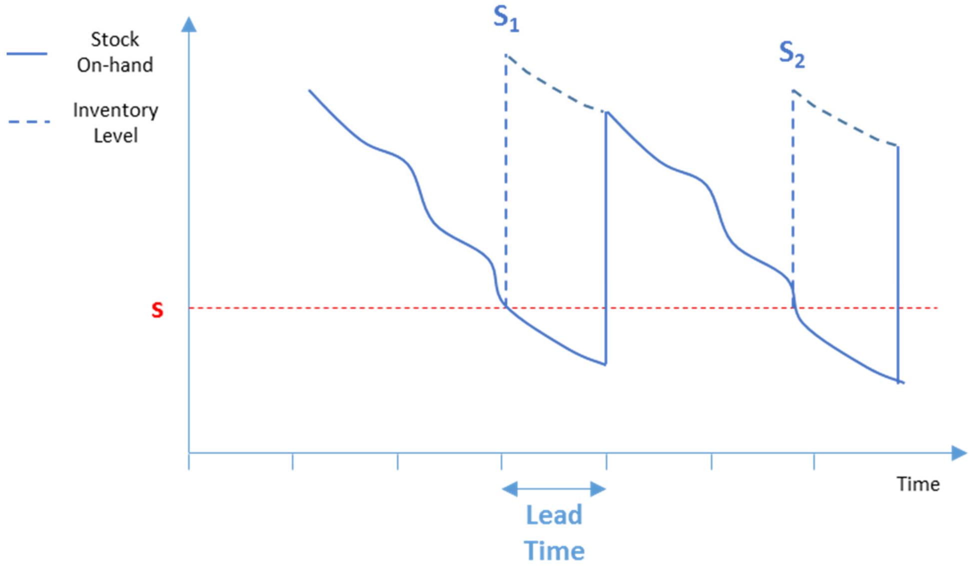

Figure 6 - Order-Point, Order-Up-to-Level (s,S) System illustration

The system that can be more easily implemented in the targeted company is the Periodic-Review, Order-Up-to-Level (R,S) System. Like was said before, this type of system is "much preferred to order point systems in terms of coordinating the replenishments of related items" (Silver et al., 1998), which is the case of production planning.

This ability to coordinate replenishments can bring great savings for the companies, possibly not according to inventory itself, but possibly savings in transportation and setup times when looking at production. An important advantage of this method is that the S level will be constantly changed according to demand pattern alterations and consequently influencing the requirements and replenishment orders. As said before, the main disadvantage could be the higher carrying costs when comparing with continuous review systems. The presented illustration below is related to a static Up-to-level, however the used system will have dynamic S levels.

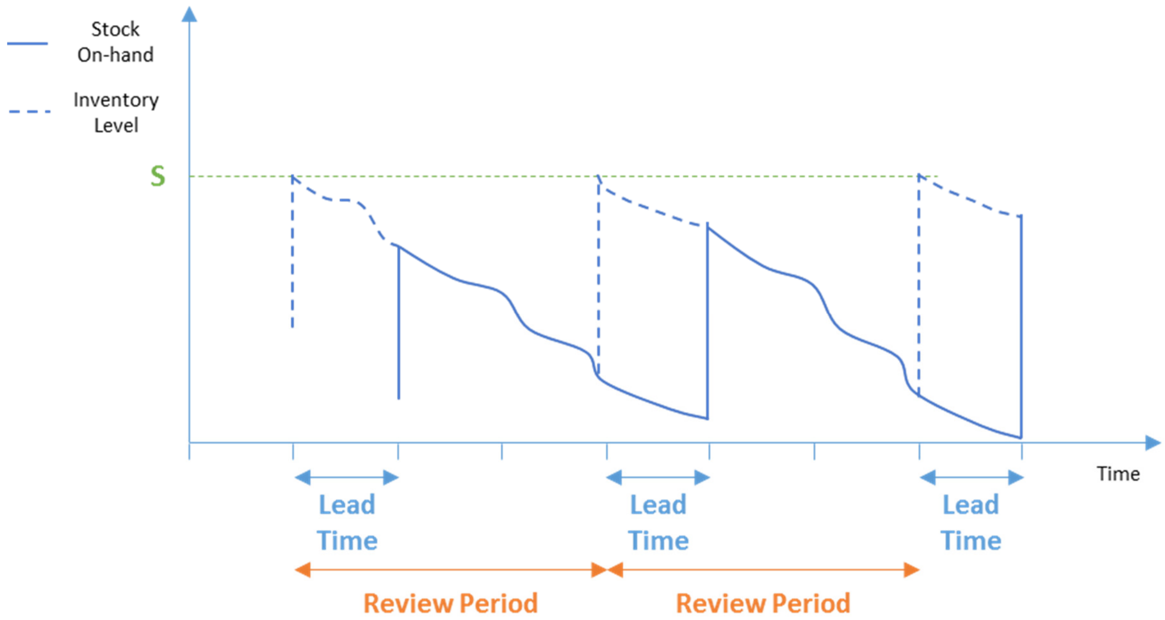

Figure 7 - Periodic-Review, Order-Up-to-Level (R,S) System illustration

After doing this theoretical review, all the main theories and methodologies used throughout the project can be more easily understood and even questioned.

3 Raw Materials Safety Stock Definition

In this chapter, the whole problem of raw materials safety stock definition is addressed. Beginning with the current situation at the company, the most important problems, the proposed solution and finally the results and discussion.

3.1 Current Situation

In terms of raw materials the biggest problem will stand with the ones that are supplied by Asian companies. In those cases, the transportation lead time can easily exceed one month and the delays in customs are frequent. Because of these facts, there is already held a certain quantity of safety stock for each of these items.

The definition of the stock levels has been done based on the know-how from people working in the field for decades, which are altered whenever the perception of disruption risk increases. Having a target level nearer the optimum is the objective being the statistical analysis of previous events the main tool to accomplish the assignment.

Even if these employees are really aware of the supply risks and holding costs, trying to have a safer system is natural if there is not a really incentive to reduce the inventory on hand. This is a natural behaviour, says Tomlin (2006), when there is an “unreliable supplier” with a “finite capacity or the firm is risk-averse”, which is the case of C-ITA for some of the reasons presented before. Therefore, there is the need to have a “methodology that is cost-effective as well as scientifically based rather than only being based on rules of thumb or ‘guestimates’” which often in periods of shortages, tends to raise safety stocks, but afterwards it is difficult to decrease them because people become afraid that its shrinkage will lead to recurrent shortages (Derrick & Giacobbe, 2012).

Being the textile reinforcement for tires the centre of the whole project, the raw materials to analyse are the different types of yarn needed to produce the several products C-ITA supply to internal clients (From Continental Group).

As said before, the process begins with the reception of yarn that is twisted into cord, which generates textiles by the process of weaving, ending in dipped fabric which is textile that is dipped in a chemical bath and dried. These chemicals are also a raw material, however the project was focused on the textile raw materials because the quantity is much more important in terms of warehousing costs as well as the cost of holding these materials.

All the suppliers are linked to the company through the SAP system. Therefore, the orders can be placed, almost automatically, at the time the system advises that there will be the need of replenishment somewhere in the future.

MRP is the acronym to Material Requirements Planning and having this system implemented, like at C-ITA, makes it possible to control “not only what item is purchased and in what quantities, but also the timing of its arrival” being a precious inventory management tool (Muller, 2011).

The MRP system projects inventory levels throughout time, using expected consumptions and present inventory levels. When it is expected that the raw material is going into disruption, a Purchase Requisition is defined. The employee that is responsible for purchasing each raw material, looks at the system for the purchase requisitions that are generated at a weekly-basis, when the MRP calculations are finished. The person can adapt these Purchase Requisitions, because in terms of transportation anticipating or postponing the shipments can be beneficial.

After this revision, the order is placed and the Purchase Requisition turns into a Purchase Order that is automatically transferred to the system of the particular supplier. Note that each Purchase Order can contain several Purchase Requisitions, for the same supplier, of different materials and with different expected arrival dates.

The yarn comes from various suppliers spread all over Europe and Asia. The major problems today arrive from these supplier that are farther from C-ITA’s plant. The usual transportation used in the Asian replenishments is by ship.

Since the transportation lead time is higher, the inherent variability also rises. Adding to this, the fact that problems in customs and consequently delays are not sporadic, it is understandable that managing these specific raw materials is a real need.

The present definition of safety stock takes these factors into account, however there is not a clear and statistical analysis of these events. Setting up a calculation method to calculate raw materials safety stock, will make it possible to distribute the inventory more wisely to mitigate the risk of shortage in raw materials and possibly reducing the global holding cost. It is essential to notice that these shortages could lead to stock-outs at tire plants. Usually these events trigger emergency meetings to look for alternatives of C-ITA’s products. This substitution lets the tire plants to run smoothly using a similar textile until C-ITA has the authorization to restart the supply of that particular product.

Typically when there is the need to search for an alternative to substitute a product C-ITA is supplying, the Corporate Purchasing Department forces the tire plant to continue using that new product for a defined period of time. This requirement brings deeper problems to C-ITA, not only for interrupting the supply which results in lost sales, but also because there is the possibility that this gain in production capacity is not filled in the short-term, not being able to distribute fixed costs in a more balanced way. Adding to this the fact that, when a shipment is late and triggers a shortage situation it will continue travelling ending at C-ITA’s warehouse, there will be an increase on the level of unnecessary inventory until that production restarts.

It is known that holding stock is costly and that the “combination of excess inventory and falling prices hurt many companies”, however this brief explanation brings out all the costs of supply disruption in this supply chain, being extremely important to hold safety stock to prevent it (Chopra & Sodhi, 2012).

3.2 Proposed Solution

Presently, there was not a clear study of what was the variability in transportation lead time from the suppliers. SAP is the best tool to use in order to get this type of information and there was already a query that gathered some information about the selected purchase orders. As Davis (1993) affirms “Over time, the vagaries of each supplier’s delivery performance can be tracked. Each supplier’s on-time performance, average lateness when late, and degree of inconsistency (as measured by the standard deviation of lateness) are the data to maintain.” this was the first goal in order to define, accurately, the safety stock of raw materials.

Nonetheless, a critical information was missing, the arrival date at C-ITA to measure the transportation lead time and its variability. There was the need to develop another query that would provide the needed information. A problem in connecting the Posting Date: Date of arrival at C-ITA, with the existent query was sidestepped by the creation of an auxiliary query that with the purchase order and the item returned the pretended date of arrival. The organization of the information in SAP is illustrated in figure 8. The table "Purchase Requisition" is related to the result of the existing query while the table "Purchase Requisition Check" returns the information about the arriving date at C-ITA that was missing:

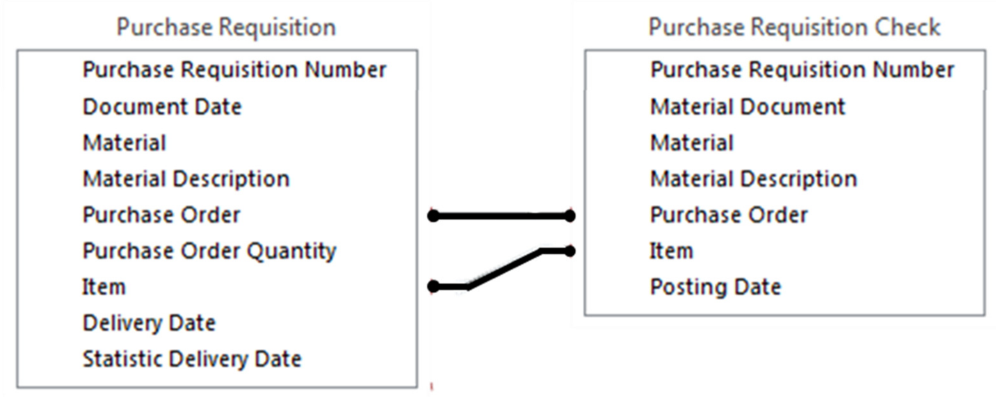

Figure 8 - Illustration of the queries used to collect required information

The safety stock of raw materials could be calculated from the transportation lead time variability through the following formula (4):

$$Safety\ Stock = Stdev(Lead\ times) * Norm.Inv(SL; 0; 1) * Expected\ Demand \qquad (4)$$

Note that, the expected demand, will always be determined by the MRP results, however, since there was no access to this information, historical consumptions were adopted as forecasts. The service-level used would be 95% which results in acceptable values of safety stock. The formula of the Sample Standard Deviation used is presented in (5):

$$Stdev = s = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2} \qquad (5)$$

However, as it is shown in Figure 8, a purchase requisition is a combination of the purchase order and the item, that is, a purchase order has several purchase requisitions merged, and the date of creation is related to the order. The problem that arises is that, a purchase order can combine purchase requisitions of different materials distributed for 2 months for example, therefore, when measuring the transportation lead time, it will vary for the first to the last requisition in two months, not representing a real variation in the lead time from delays or transportation problems. The only requirement is that the Purchase Order must consolidate Purchase Requisitions for the same supplier.

Another factor that could lead to the need of holding safety stock is the normal variation in consumptions at C-ITA's plant. However, MRP defines what should be the level of stock of each raw material at every moment and advices the person responsible for purchasing them to reschedule the arrivals whenever there is a change upwards in the system.

Since there is a MRP implemented and fully functional, the problem of consumption variations that usually takes place when safety stock is being calculated, is not an issue. Assuming the forecasts will be similar to actual sales, any growth in customers' demand, will lead to an increase in C-ITA's raw material consumption, however, this rise would have been predicted by the MRP which had asked for correspondent replenishments.

The literature states that safety stock must be defined influenced both by uncertainty in demand and supply (Chopra & Meindl, 2007). These two sources of variability are going to be handled differently. Raw material safety stock will be influence by supply variability whereas finished product are related to demand. Holding raw material safety stock for demand variation would result in duplicated inventory since final product inventory is already held with that purpose.

Also experts such as Beamon and Chen (2001) state that safety stocks must have external demand variability and the transportation time variability in consideration when defined. The calculation of raw material safety stocks must be done with direct sources that have impact in the usage of raw materials this inventory, this is the transportation demand variability from suppliers.

As said before, the methodology of measuring the lead time variation is impossible with the type of data available. For each Purchase Requisition there is information about the expected date of delivery and the actual day the shipment arrived. With this data, it was possible to calculate the deviations in delivery time.

Therefore, the calculation in terms of raw materials safety stock is based on the deviation between the statistic delivery date and the actual date when the raw material arrived at C-ITA, as said before, the most common measurement is based in lead time variability, although the data available made it impossible to follow this approach.

The statistic delivery date, is the date when MRP defines the replenishment should arrive, this proposal from the system can be not followed by the purchasing responsible person. Nowadays, empirically, the sense of delayed shipments is defined comparing the delivery date (date confirmed both by C-ITA purchasing and suppliers selling departments) with the actual arrival, nonetheless, in terms of safety stock definition, this can not be done because any postponement in arrival will have to be held with safety stock. Therefore the safety stock will be calculated as presented in (6):

$$Safety\ Stock = Average(Transportation\ Lead\ Time\ Variations) + Stdev(Transportation\ Lead\ Time\ Variations) * Norm.Inv(SL; 0; 1) * Expected\ Demand \qquad (6)$$

As explained during this chapter, the Transportation Lead Time Variation was measured with the date suggested by the MRP against the actual day of arrival as presented below:

$$Transportation\ Lead\ Time\ Variation = Statistic\ Delivery\ Date - Posting\ Date \qquad (7)$$

After some tests, to understand all the information received from those queries it was mandatory to filter the data in a way that could be further used in the target calculation. The cause of problems was the fact that for each Purchase Requisition there are multiple documents associated with it, as quality checks or the needed movement of reception of the raw material.

Having all the events, when the actual lead time was longer than expected, a statistical analysis was done, resulting in a number of days which, with 95% sureness would not be surpassed in terms of delays.

With the list of materials, the maximum number of days a delivery can delay and the average daily consumption in C-ITA's plant, it is easily calculated the desired level of safety stock that would be sufficient to respond to delays from suppliers against what was calculated from the MRP.

A study about how would the deliveries deviated from the expected during the year resulted in some interesting conclusions. The division was made into quarters which would be a reasonable time period to perform the safety stock revision. The results of the analysis, with the service-level of 95% are presented in figure 9:

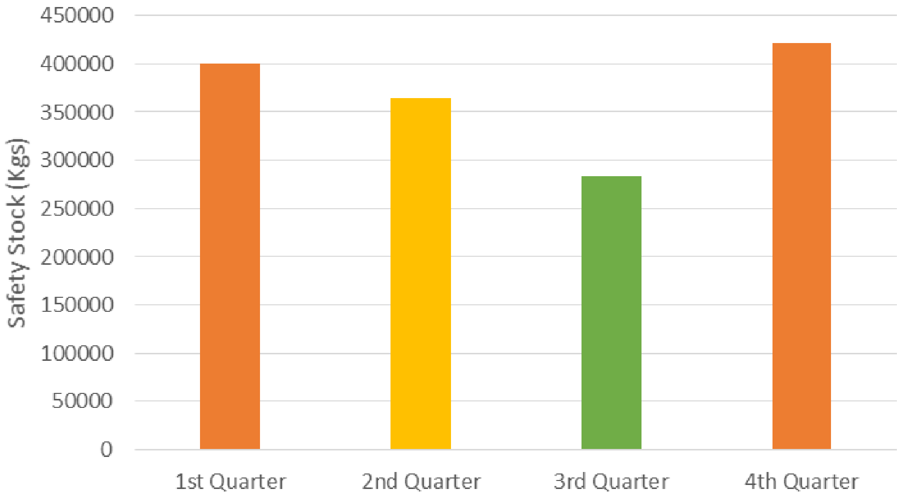

Figure 9 - 2013 calculated raw material safety stock per quarter

It can be seen that the overall calculated safety stock is higher in the first quarter and goes continually down along the year except for the last quarter. There is an explanation for this, in the beginning of the year, there are usual delays from Asian suppliers since the Chinese New Year' Eve celebrations bring problems in transportations.

Currently there is already a contingency plan for this period of the year, since these problems consecutively occur year after year, so when this period is coming, the safety stock levels are increased thus the possibility of having a shortage caused by delays is reduced.

Having this differentiated definition of safety stock in quarters can have an impact of roughly 6.000 € in holding cost a year against a situation where the calculated level of safety stock in the first quarter is maintained the whole year.

3.3 Results

Raw material safety stock calculations were based on historical delays and defining a confidence level in which the delays would be held by the safety stock resulting in production without problems. However, since it was impossible to gather information about past MRP results the possibility both of calculating the safety stocks based on the deviations between MRP results and actual consumptions vanished as well as the possibility to simulate what would have happened with those levels of safety stock.

Therefore, the delivering delays were the target of the analysis. When analysing the data of the delays, it was clear that some values were probably inaccurate. Roughly 2 % of the occurrences, from 2011 until 2014, resulted in delays higher than one month. It is possible that the arriving of the material at C-ITA was not immediately recorded in SAP therefore the supposed delay is much higher than the reality. In order to get the most real information from the gathered data, it was decided to remove those situations when the delay exceeded one month.

In figures 10 and 11 examples of the distribution of delays and the target stock calculated are presented in a more visual way. These were the safety stocks calculated with the records from the first five months of 2014.

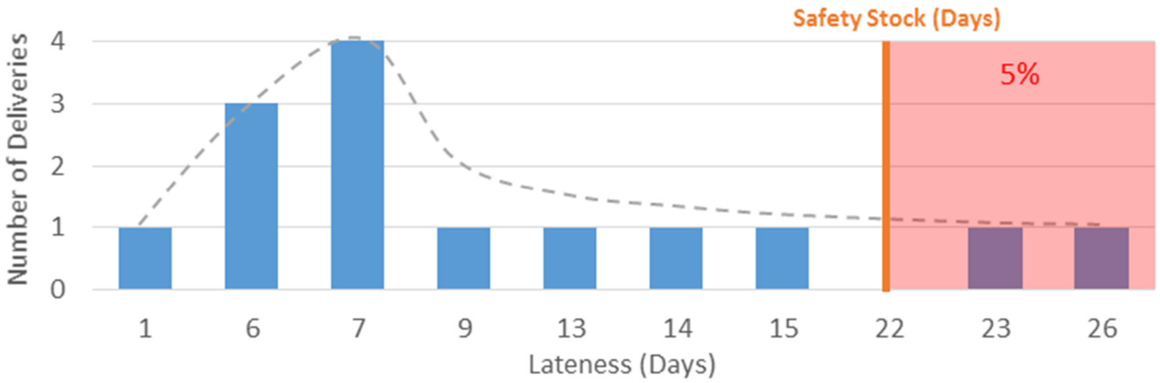

Figure 10 - Delaying occurrences distribution (Raw Material R074180101)

As presented in figure 10, if this was the target safety stock defined in the beginning of 2014, for two times there would have been problems of shortage. This happens because the confidence level used to calculate was 95% and because the distribution is approximated to a normal distribution which it is not in reality. The number of leftover occurrences is influenced by the distribution, to prove this, another raw material was analysed, distribution in figure 11; which resulted in just one shortage situation.

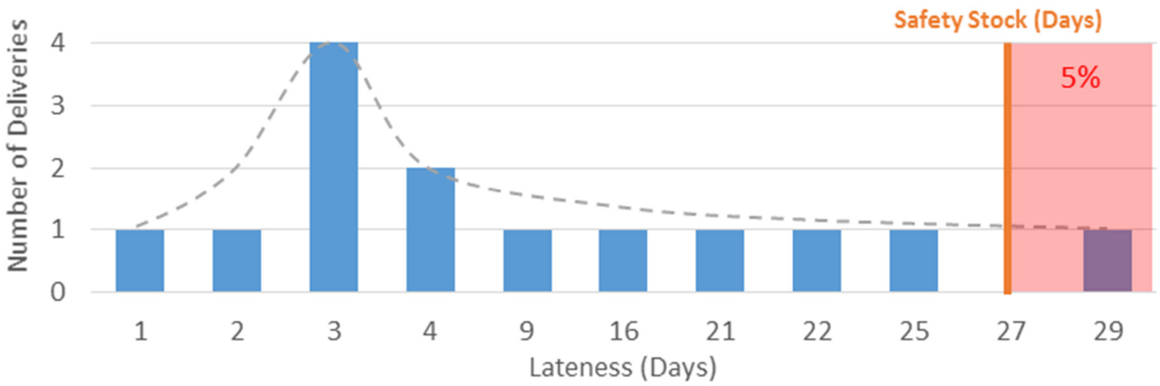

Figure 11 - Delaying occurrences distribution (Raw Material R072840101)

Having the target number of days that should be sustained by the safety stock, the program with the historical consumptions of each raw material will be able to convert days into weight. Using historical consumptions is not the best practice, this safety stock in days should be converted into weight with the forecasts of consumptions (MRP Results) that information was not available during the project as said before. However, the implementation on SAP could be done with the parameter of safety time instead of safety stock, this way, the calculated target delaying days would be directly used as an input and the system will automatically and dynamically calculate the level of safety stock. After performing all the analysis and calculations based on previous explanations for all the raw materials, the result of the proposed target safety stock for raw material is presented in Table 1.

Table 1 - Raw material target safety stock calculation (SL=95%)

Raw material	Target delaying days	Weekly consumptions (Kgs)	Target Safety Stock (Kgs)	Holding Cost
R072060102	4	3561	2035	- €
R072800101	1	10493	1499	515,65 €
R072830101	4	50936	29106	- €
R072840101	27	17616	67948	20.384,40 €
R073150101	8	546	624	- €
R073190101	9	5751	7394	2.380,99 €
R073350101	12	9937	17034	4.991,11 €
R073450101	14	8608	17215	- €
R073620101	1	5028	718	1.328,92 €
R074150101	17	532	1292	- €
R074160101	17	27721	67322	- €
R074180101	22	26199	82339	44.196,38 €
R074190101	13	39604	73550	- €

Note that the calculations were based in the creation of a new query on SAP that collected the events of delays in delivering from suppliers, being those values of safety stock statistically defined to hold delays within a certain confidence interval.

In terms of implementation, it is advised to define an extra safety stock calculated as certain days of consumptions in order to make the solution less subjected to distrust. As presented before, the costs of not delivering products to tire plants because of a shortage of raw material are so high that can not be faced With the evolution of times this extra safety stock could be diminished until achieving the target value that is enough to carry the deviations in supply for a certain confidence level.

However if the approach is decided to be starting with a similar volume of safety stock that should be continuously lessened until achieving the desired value, the service level could be settled as 99.85% firstly. This level of expected service level results in a similar overall value in terms of safety stock that is being held by the company presently. In table 2 are presented the global values of safety stock in kilograms defining different service-level and the current value. To ease the comparison, the values of calculated safety stocks will be added up the correspondent to the cycle stock. The cycle stock is defined by the consumptions of each raw material and defining that they will be replenished in order to optimize transportation costs. This is, if C-ITA consumes 5 tons of raw material A, since a truck transports approximately 20 tons, there will be replenishments in every 4 weeks. Having this assumption the cycle stock is equal to 210.591 = 420.682 / 2. This calculation is based on the sawtooth effect that is thoroughly explained in chapter 5

Table 2 - Overall value of raw material safety stock

	Currently	*Target (SL=95%)*	*Target (SL=99%)*	*Target (SL=99.85%)*
Safety Stock (Kgs)	517.400	368.234	446.301	514.699
Cycle Stock (Kgs)	?	210.591	210.591	210.591
Total Stock (Kgs)	702.666	578.825	656.892	725.290
Holding Capital	568.703 €	1.122.770 €	1.286.284 €	1.425.549 €
Holding Cost	56.870 €	112.277 €	128.628 €	142.555 €

The holding cost is calculated multiplying the holding capital with the interest rate. The interest rate used to analyse investments is 10%, therefore being this the used value throughout the whole project. All the other warehousing costs such as storage area opportunity cost or handling costs were not considered and require further analysis.

It is now possible to compare the proposal with an average value of the stock that is being held currently at C-ITA. It is noticeable that there is an important difference in the holding cost of the proposed situations against the current state. After a root-cause analysis it was possible to discover the source of this deviation. The problem was related to a single material, R074180101. This raw material is supplied by an Asian company and generally with considerable delays. Both in the proposed calculation and in the SAP current definition there is a great amount of safety stock appointed to this material. However, due to recurrent problems of the company in supplying what C-ITA is asking for, because of capacity limitations, the safety stock presently defined is constantly consumed. This is not a consignment material, therefore the holding costs of the proposed situation are comparably higher than the actual situation.

However since there are constant problems because of this specific raw material, the supply risk of the products based on this raw material is higher than it should, being the definition of a high value of this material safety stock proved as right. To attest that the mainly cause of the previous shown deviation was the R074180101 raw material, table 3 shows the values if the material was taken out of the equation. The values were calculated with a different cycle stock, according to the weekly consumptions without this specific raw material.

Table 3 - Target optimal stock levels without R074180101

	Currently	*Target (SL=95%)*	*Target (SL=99%)*	*Target (SL=99.85%)*
Total Stock (Kgs)	696.069	486.973	546.326	599.910
Holding Capital	533.293 €	630.583 €	693.650 €	752.559 €

Even if, the values without that specific raw material are much more similar there are still some deviations. This can be explained by the fact that naturally, the raw materials that are bought in a consignment contract, exist is higher quantity than supposed whereas for the other products, the reality is the opposing.

3.4 Discussion

These values of raw materials safety stock are believed to be sufficient to run the plant smoothly without having problems to supply production. However, since some of the raw materials are bought in a consignment policy, which lower the overall cost of holding this extra inventory.

Nevertheless, the costs of handling these materials in excess and the cost of the warehousing space are not calculated but increase the need of managing this inventory wisely.

If the solution is adopted, rather than having “random” values of safety stocks based on historical know-how of an employee, the reduction in safety stock would be considerable, with a confidence level of 95 % being however the costs higher because of differences in contracts of materials (consignment policy).

This reduction will not predictably affect the “service-level” of the warehouse when providing material to production since the target values were calculated from historical data about delays in deliveries from C-ITA’s suppliers.

Analysing these results, it easily possible to infer that the safety stock for raw materials could be defined in a methodological way that will result in a more efficient allocation of inventory. Even if 95% of confidence is a great target, the company could begin with altering the safety stocks to a target which has 99.85% possibility of not being in shortage, with the same volume of inventory even if with slightly higher costs. These higher costs were already explained being important to notice that, if the safety stock defined on SAP really existed in the warehouse, as it was supposed to be, the difference would not be as important.

It is also important to know that, even if with 99.85 % of confidence level the overall target safety stock level is similar in quantity, there is a sizeable difference in its distribution. Of the overall 515 tons of target safety stock, the sum of positive differences between target and current definitions (the proposed value is higher than the presently defined on SAP) is around 184 tons while 186 tons should be taken off from current definition. Having 2/3 of the overall safety stock not according to the history of delays is a sign that these values should be revised as soon as possible.

It has to be noticed that for the time period used for this calculation, there were some raw materials that had zero kilograms of safety stock calculated, against positive quantities defined currently in SAP. This means that, in the 5 months of 2014 there was not even a single delay and even though safety stock is being held, validating the sense that this inventory have not been managed in the most proper way.

An important outcome of this study is that, some of the raw materials, don’t have great variability in terms of transport therefore being the need to hold safety stock reduced. Some of these materials are bought with a consignment policy that result in being more expensive, this range of raw materials are not critical so they can be purchased normally, being C-ITA responsible for the holding costs of those that should not be considerable because of the reasons presented. On the other hand, some raw materials should be considered to change to a consignment policy since the present variability increases the need to hold safety stock that is costly. That information was transmitted to responsible buyers at corporate purchasing department that will analyse the possibility of changing these contracts in order to reduce the holding costs in the most critical raw materials. It was also transmitted that the decision on the type of purchasing contract should be influenced by the required level of safety stock in order to calculate the trade-off between the price of the raw material and the possible savings in holding cost.

This calculation takes into account that some materials are bought in a consignment policy that do not have impact on the holding cost, this is, C-ITA would not pay for the inventory until consuming it. However, it does not make sense to hold material that will not be needed, there are other inventory costs, as warehousing space and handling costs that should be enough to convince the company to adapt this methodology even for the consignment stocks.

4 Finished Product Safety Stock Definition

The problem of finished goods target stock level definition was the first addressed in the project. The justifications for that are the holding costs involved as well as the direct impact in service level.

In the following chapter it is described the present situation in the beginning of the project in the field of finished products safety stock, the proposed solution as well as important results and expected benefits of the new solution.

4.1 Present Situation

Managers all over the world are getting more focused in the whole supply chain efficiency and looking for ways to maximize it. One of the first ways to do that is to look for inventory that is not being used wisely. The bullwhip effect is a reality and with the objective to be safer against demand variations from different echelons the orders are emphasized lowering the overall supply chain efficiency.

Developing a methodology to analyse inventory and trigger orders according to the actual needs of each echelon will avoid duplication of inventory in different parts of the supply chain.

Demand variations come from the willingness to buy tires from the final customers. This demand is them translated into demand of assemblies, components and raw materials along the supply chain which is named dependent demand.

Continental – Indústria Têxtil do Ave has been suffering from problems related to forecasting errors because the main system used is the make-to-stock, and even if the clients provide C-ITA forecasts, some of them with months in advance, those are, as expected, wrong. In addition, the long production lead time related to a machinery based production process, the low flexibility of the company to adapt easily and quickly to changes augments the problems.

Even if C-ITA has yearly sales to nearly 30 customers, some of them external to the Continental Group, the core business is to supply Continental tire plants with textile reinforcements. To prove this, an ABC analysis, figure 12, was done with the sales from 2013, note that the sales pattern will not predictably change from 2013 to 2014:

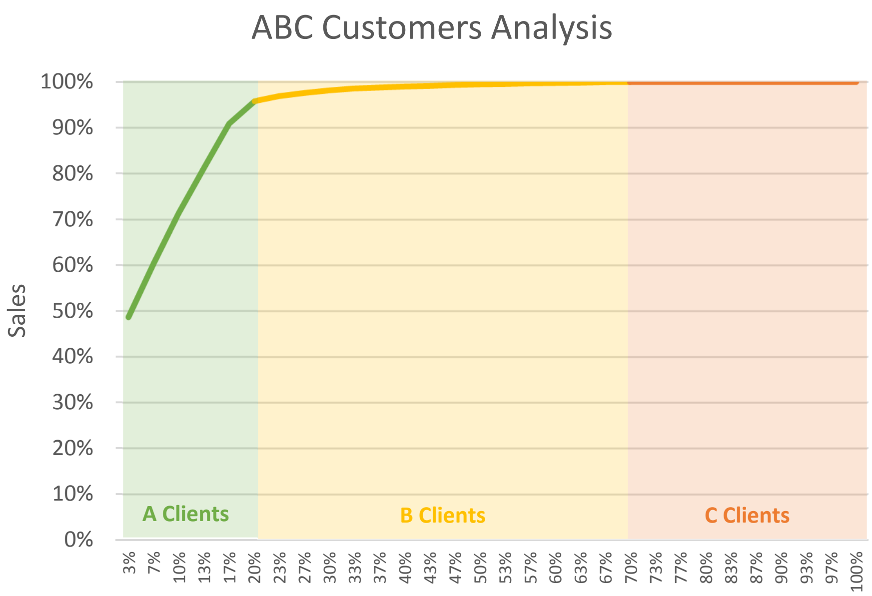

Figure 12 - ABC Analysis for C-ITA's customers

The 20% of customers that represent more than 95% of yearly sales are 6 internal partners are part of the Continental Group. This group of internal customers signifies approximately 30 different products which are result of the manufacture of 18 raw materials. C-ITA's production has a divergent (arborescent) structure, the opposite of an assembly line, thus resulting in more finished goods than raw materials (Beamon & Chen, 2001). An illustration of a raw material breakdown to related products through Work-In-Process, is presented in figure 13:

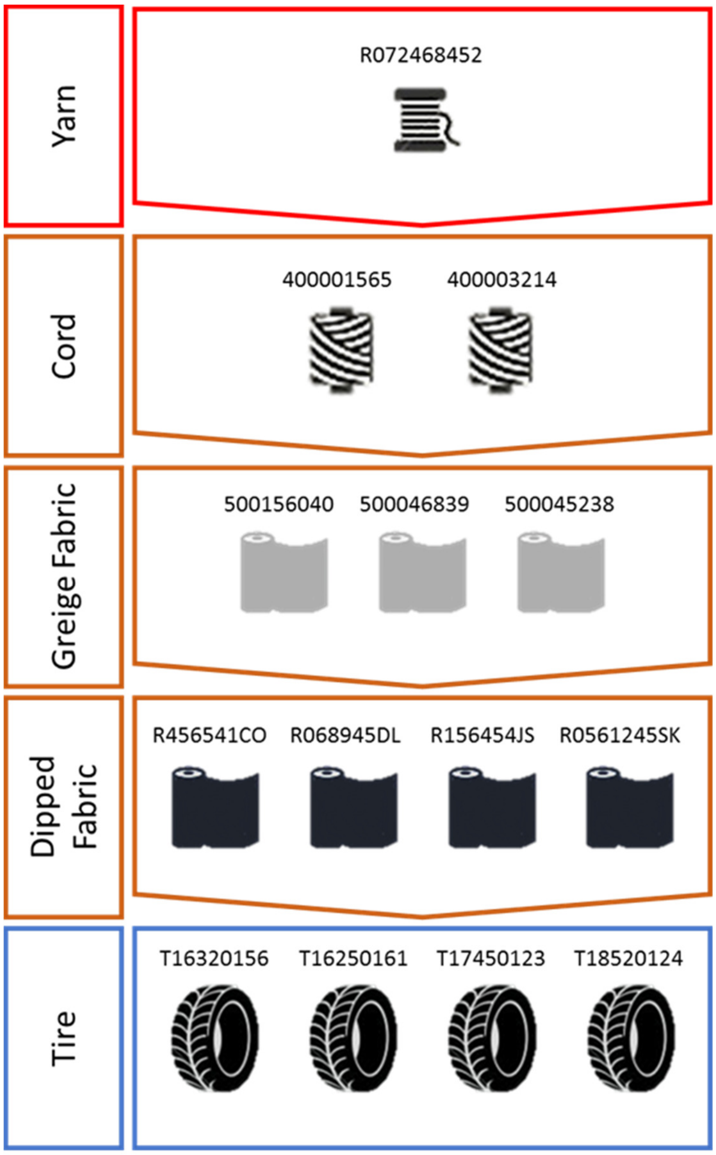

Figure 13 - Product breakdown illustration

Along the project, all the analysis was divided in two groups, one composed by Continental Mabor - Indústria de Pneus, and the other by the remaining 5 clients that correspond to the majority of C-ITA sales volume.

The main reason for the division is not only because of the proximity since CMIP is located across the road from C-ITA, but because the informational platforms from which the forecasts are received is different.

The type of data received from the customers also differs in terms of forecasts and orders. The plant from Lousado, CMIP, works in in a way similar to JIT (Just-in-time), this results in continuous replenishments on a daily basis which means that the tire plant does not hold inventory apart from the restricted needs for the short-term.

There is an agreement between C-ITA and CMIP that defines that all the safety stock should be held at C-ITA and the orders are placed in one day to the following one. Since the production time exceeds by far one day, this means that the two companies are working in a way similar to a VMI (Vendor Managed Inventory).

The production planning in tire plants is set up based on forecasts the customers provide. These are calculated by complex algorithms that link the markets orders and the stock in the supply chain and results in expected demand that is converted into production orders. Through the use of Material Requirements Planning systems, these production plans generate raw material needs, and some of those are products supplied by C-ITA.

The information about requirements is shared in different ways depending on the customer. The main client, Continental Mabor - Indústria de Pneus, the plant also located in Lousado, is using a new system called RMDP (Raw Material Demand Planning) which objective is to provide the suppliers, in the case C-ITA, with the right information Just-in-Time (JIT). The project, being developed by the Continental headquarters in Hannover, has the aim to make the flow of information more efficient, fast and error proof, minimizing human interaction along the process, this is a measure to reduce the bullwhip effect by doing what Silver advises to: “Instead of responding to unknown an highly variable demand, they share information so that the variability of demand they observe is significantly lower” (Silver et al., 1998).

Corporate purchasing department, is the responsible organization for the project development and is working closely with the Logistics Department of C-ITA, since the latter is one of the most interested party in the process. In the future, when the RMDP system is implemented in all the plants that are C-ITA’s clients, and working without problems, it will be possible to access the expected plants’ requirements in terms of textile reinforcements and use them as forecasts directly.

Continental Corporate Purchasing Office, has been developing a system named RMDP (Raw Material Demand Planning) which main objective is to automatically transfer the results from tire plants’ MRP (Material Requirements Planning), the requirements of raw materials according to planned production, into the SOP (Sales Operations Planning) system as forecasts.

This system is fully operational in CMIP, therefore its planned requirements are being used as forecasts in C-ITA. In addition to this, there are almost no problems in terms of transportation constraints because there is a daily supply, nearly JIT, and the extra stock from CMIP in stored at C-ITA’s warehouse.

The extra stock referenced before, that is stored at C-ITA’s warehouse, is going to be defined from now on as the emergency stock. This inventory is held to prevent stock disruption in case of machinery breakdown, or extraordinary transportation problems, for example. This value is defined from Corporate Purchasing and is usually equal to the production requirements during the response lead time from the supplier. However, since the transportation lead time from C-ITA to CMIP is less than a day, it was defined that the need of one week should be held at every moment in order to have this time to get an alternative supplier.

This has the potential to be a great improvement logistics-wise since, the rightness of the forecasts in the beginning of the chain will result in better forecasts in the end. Thus, C-ITA will be working based on real needs that are based on demand forecasts instead of forecasts of needs, based on forecasts. To sum up, theoretically, the errors will be lower, the bullwhip effect will diminish as the links of the chain will be sharing the handled information as easily and effectively as possible.

In order to make it possible to deliver the right amount, in the right place, at the right time, C-ITA has to rely in the results from the MRP that runs every week at CMIP and has as an output the raw material needs/requirements for the following weeks, according to the defined production plan (in 4 weeks), and in the mid-term according to sales forecasts with the help of an algorithm constructed and maintained by the headquarters of Continental, in Hannover.

Emergency stock must not be used to deal with demand variations and is supposed to be intact until some extraordinary event happens, giving the plant some time to set up a contingency plan while smoothly producing without stopping the plant.

This division is also useful in terms of validating the RMDP system, CMIP accounts for 49% of the sales thus is a good customer to corroborate the new system advantages.

CMIP accounts for the majority of C-ITA's yearly sales being the perfect customer to validate the RMDP system. The other five customers, identified by the city where the plant is located: Aachen, Korbach, Puchov, Otrokovice and Timisoara are still sending the forecasts via e-mail which results in extra manual work in terms of imputing the data into the SOP system. In terms of production planning, short-term, C-ITA uses the orders from the clients through the SAP system that are usually placed one month in advance.

Knowing this, it could seem that C-ITA has an easy task in producing to the internal clients, since the data from the future needs is received with some weeks in advance. But, as Aaron (2000) says, the forecasts "usually are wrong" and all the customers, every week, end up asking for different amounts of products from the predictions some weeks before.

After receiving these forecasts, the sales and logistics department director is responsible person for approving this data, and sometimes, he actually changes the forecasts depending on past patterns such as situations when forecasting is always lower than the actual need of the customer.

When this plan is fixed, the Production Planning Department has the duty of translating it into a production plan. As it was said before, this industry is characterized as being capital intensive, thus being the maximization of capacity utilization and uptime the main goals. For that reason, it is normal that a machine is running the same product for several weeks being the time needed to change from one batch to another of the same product lower than was needed if the product was constantly being changed.

SOP is an individual module incorporated in SAP, the ERP system, where exists data about the customer's FC, C-ITA's FC, possible corrections and all of this different data have priorities. For example, if there is only a forecast from the customer, the system will act like it is the best figure therefore being used as forecast whereas if the Logistics Director makes a correction the used customer forecast is surpassed by this correction.

A good example of the situation of recurrent forecast errors coming from the RMDP system has been studied at Continental Mabor - Indústria de Pneus. There are some products supplied by C-ITA that are used as raw materials in UHP (Ultra High-Performance) tires at CMIP. Since the production plan at CMIP is “frozen” for 3 weeks, the present one plus the two following weeks, it is expected that the requirements for those weeks are near the reality.

However for the next weeks, here named +3 and +4, the plan is not fully defined being difficult to have precise requirements from RMDP. Figure 14 shows the discrepancies from the consecutive forecasts for the same week, and the actual sale. There is a clear gap from FC+2 to FC+3 error. That is justified from the frozen period in CMIP’s production plan.

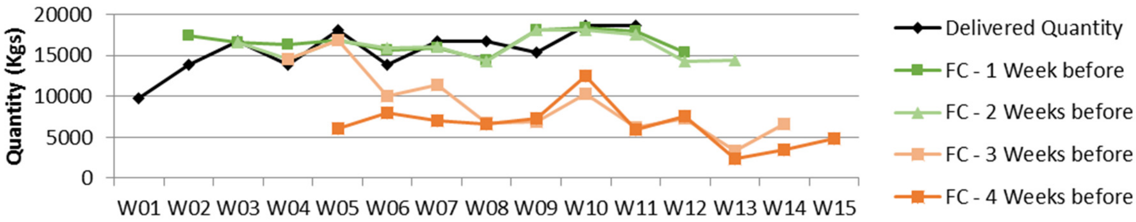

Figure 14 - Forecast Analysis (RMDP Results)

During the length of the project it was not possible to solve the problem, however this analysis was sent to the responsible department of RMDP development in Hannover, and the problem will expectedly be addressed during this period of improvement of the system.

The MRP runs according to the sales plan defined at C-ITA, that is constructed based on the forecasts received from customers. The MRP “explodes” these expected sales into requirements according to the BOMs (Bills of Materials) and the routings defined in the system, independently from the production plan that is done afterwards. This constitutes a source of problems because production does not exactly match sales, production and transportation constraints are responsible for this mismatch. Thus the requirements generated from the sales plan can diverge from the ones resulting from production plans.

A good example of the differences that occur from the sales plan to the production plan are exemplified in table 4:

Table 4 - Sales Plan vs. Production Plan

	Week 10	*Week 11*	*Week 12*	*Week 13*	*Week 14*
Sales Plan	0	20	0	20	0
Production Plan	10	10	10	10	10

The need to produce in batches or the preference for shipping in full trucks are influencing this difference which will bring problems both in Forecast analysis and in requirements results as explained before.

Nowadays, it is not defined a safety stock of finished goods to cope with demand variations. The production time is roughly 3 weeks, so to make sure the deliveries to customers will be done, C-ITA would need to have precise forecasts 3 weeks in advance so production could start with the exact quantities the customers will ask for in the future.

Sometimes there are problems and C-ITA would not be able to provide the demanded quantities if production was exactly what was forecasted. Since there is a production stage, the weaving where it is mandatory to produce in batches, the plant is constantly producing more than the forecasts represented. This is the reason why there are not so many supply disruptions as it could be expected while looking at the forecast errors and without having safety stocks.

Even if the extra produced quantity can not hold an increase in the forecast inside the production period, there is the possibility of altering the production plan and being able to produce the additional quantity to meet demand. This production plan alterations entails several problems as the increase in setup times and costs and the possibility of not delivering other orders because of this extra capacity utilization that was not planned.

All the project followed the assumption that the whole weekly sales should be produced on Monday so, despite any problems in production, C-ITA would be able to supply the clients that week. This is a strategic input for the present work that was taken as a hard constraint. The factor that defines this value is the production cycles in the last process of production. Dipping, the bottleneck process, is planned according to cycles defined for each of the raw material that is part of WIP. Nowadays, the cycle is repeated on a weekly basis which makes it mandatory to have one week of sales to be able to supply whatever is requested from customers. A carefully study should be performed on this matter however being the scope of the project the logistics associated with the business it wasn't addressed.

The other reason for this requirement is the fact that when the SAP system was implemented the minimum time unit used was the week. Therefore, in terms of planning, employees can not be sure of the real finishing date of production of a batch, being mandatory to establish this condition to compare the proposal to the present situation.

Although having weekly sales already produced on Monday is an internal requirement, it is not always met - After gathering all the needed data it was possible to measure this fact. The larger period possible to calculate it was from the calendar week 5 to 14, along this time only in 70% of the weeks, all sales were produced on Monday, being roughly 80% of the sales produced. These results will be compared to the proposed model as the α and β service-level.

After all, the plant is already holding safety-stock, it is the inventory that exceeds the demand each week. This happens recurrently because of the production batches and because sometimes the responsible people do not believe on the provided forecasts producing more than expected to prevent eventual order changings.

Since the policy is make-to-stock, the plant can not just produce what is "demanded" through forecasts because the customers can change order until the day of delivery incurring C-ITA in extra risks. If the production was based in a make-to-order strategy, the need of safety stock of finished goods would be lessened.

Nowadays, even if there is safety stock of finished goods at C-ITA, although not specifically calculated, all the other 6 bigger plants, except Lousado, also hold safety stock to diminish the risk. These quantities are not studied and there is not shared information about these levels, being probable the existence of some redundancies on the inventories held by both parts.

4.2 Proposed Solution

As said before, the safety stock calculation of finished goods is made from demand variability leaving out the lead time variability from suppliers to raw materials safety stock definition. Therefore service-level is influenced by the replenishment lead time (Production + transportation lead time) and the safety stock defined to cope with variations from clients' demand (Minner, 2001). To measure all these variables, a deep search for data and its analysis was performed that is going to be following described.

All the stock and forecasting analysis throughout the targeted customers will be different from Lousado plant, not only because of the proximity, the system of forecasting transfer and the just-in-time supply, but also because C-ITA is its only supplier when it comes to textiles. These facts make it easier to analyse consumption variations throughout the year because they will be mandatorily reflected on C-ITA's sales.

For all the other 5 customers, C-ITA is an important supplier but not the only one. This will lead to an unbiased examination because an increase in tire production could not influence positively the sales to those plants since they can be producing tires which are produced with C-ITA competitors' textile reinforcements.

Another purpose of this project is to set a level of safety stock that will cope with demand variations raising the possibility of having a more stable production plan to be more productive and have the highest capacity utilization to follow the company policy.

The first stage of the project stood for the collection of important data that would be possibly needed to set up a proposal. Since the objective was to calculate target safety stocks for both raw materials and finished goods, there were different types of compulsory data to analyse.

Essential data to define safety stock levels is divided in consumptions, both from customers and C-ITA plant, forecasts provided and the actual sales to tire plants as well as lead times of transportation.

As told before, the ERP used is the SAP system which was implemented back in 2011, from that time on, there is historical data that is static, such as consumptions, which did not represent a problem in collecting. Although, for data like forecasts, that are changed from week to week, there was the pursuit for periodic records of this data.

Ending up with optimum safety stock level for each raw material and finished good required the construction of a simulator in order to get proved data of what would happen differently with this inventory definition and compare it to what has been happening.

The simulator developed make it possible to extrapolate what would have been the inventory evolution pattern during the chosen period with the calculated safety stocks. In figure 15, there is an illustration of the inputs the algorithm needs and the outputs it delivers.

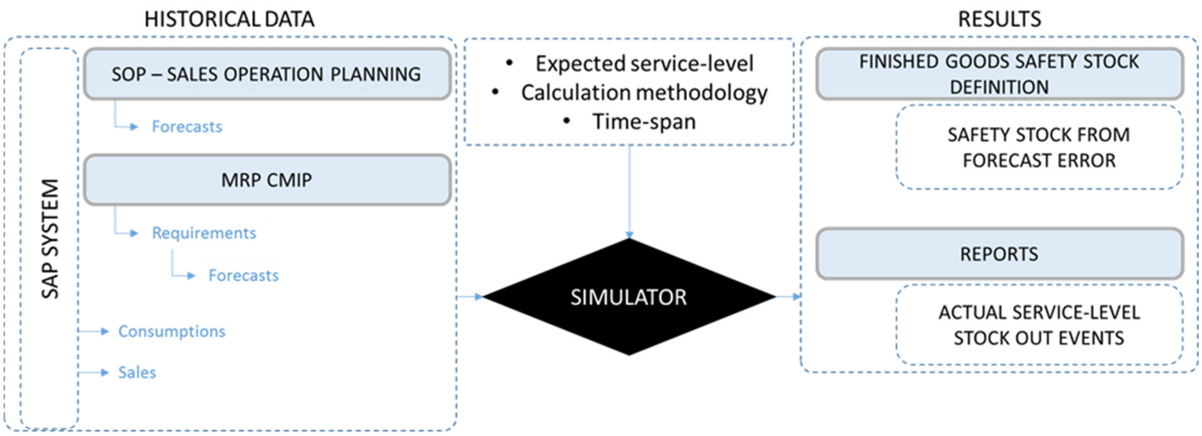

Figure 15 - Simulator structure

The project started by analysing what should be the safety stock level of finished goods. For the A items, which are related to the 6 biggest customers, the definition of an optimum level of this inventory and locating it where it is more beneficial will lead to the optimization of the supply chain.

Beginning with CMIP, as it was previously stated, the forecasts used are a result from the MRP, which calculates raw materials needs every week. Since the forecasts are also changed every week, there was the need to search for historical data according to the forecasts inputted in the SAP system every week. The file existed and there was a record of the evolution of forecasts used for Lousado plant.

After having the hands on this data, it was possible to analyse how precise were the values, the analysis is also better at CMIP because weekly needs are really replenished whereas in the other plants because of transportation constraints, this is not true.

The company follows the FTL (full-truck load) policy for transportation, which is understandable according to the transportation costs involved. This could be a problem because the replenishment can be equal to monthly needs because of shipping aggregations and the forecasts are not the plant requirements in terms of consumptions but there is the combination of other factors that can adulterate the forecast analysis.

Calculating the forecast errors is the first stage to define safety stocks. There are several methods to define this level of inventory which will be scrutinized afterwards.

The two main methodologies for calculating safety stocks are basing it in the forecasting errors, when they are available, and with consumption variation that is the most common choice.

Because of the forecasting problems specified before, the option could have been according to consumption variations, but that data must be compared with the expected consumptions, the results from the MRP, data that was not available. Therefore, since the expectations that forecasting accuracy is going to evolve because of the ongoing projects on this field, it was defined that this should be the choice.

However there are some problems when analysing this data as presented following. For example, there is the possibility that a plant asks for the anticipation of a delivery, for example 20 tons of the product A. The answer from the sales responsible employee at C-ITA, can be affirmative if there is extra stock of that product, because of lot-sizing production or just because the production planning defined that product will be available one week before. If product A is sold when requested, looking at the data after that, it will be seen that variation replicated. One week when it was supposed not to sell nothing, there was an increase of 20 tons, whereas in the following week the decrease was also by 20 tons.

These cases are difficult to deal with because the measurement of the forecast error would be inaccurate.

Because of this, the simulator is based in the forecasts to generate production orders but the safety stock can be calculated both from consumption variations or forecast errors, this would be a decision from the user that would be able to simulate and check which the best approach is.

One problem inherent to the method of consumption analysis is that, when there are people managing inventory there is the risk of getting orders that do not match expected consumptions, related to the bullwhip effect. Though, there could be weeks when the plant replenishments responsible employee will be asking for quantities that can not be supplied, but that would not be really consumed, according to historical patterns.

Since there is the existence of forecasts in the business, it is normal to use them to plan production and deliveries therefore being extremely important to define safety stocks. As referred before, safety stocks can be calculated from consumption variations or forecast errors. The first attempt was to use the forecast errors because it would expectedly result in better values of safety stocks.

For that calculation it was used the technique stated by Chockalingam (2007) which is:

$$Safety\ Stock = Norminv(Service\ Level) * Forecast\ Error * \sqrt{Lead\ Time} \quad (8)$$

The Forecast Error used is the Root Mean Squared Error and it is calculated as following:

$$RMSE = \sqrt{\frac{\sum(Actual - Forecast)^2}{N}} \quad (9)$$

As expected the results were good in terms of service level, nevertheless the excess of safety stock is notorious. In several items, the safety stock is sporadically used and not in all its quantity. One of the reasons why this could be happening is because this formula is measuring the "distance" between forecast and actual deliveries, no matter if in excess or lack.

After simulating scenarios in different periods, the conclusions in terms of the quantity of safety stock calculated were clear, they weren't adopted to the reality of the business.

To overcome this problem, based on the sense of what could be a good calculation of the safety stock, the next formula was constructed and was based on the setting of confidence levels in terms of safety stock which would cover the accumulated negative errors (Forecast lower than deliveries) for the period of the production lead time.

The base of the calculation stands for the assumption that the forecast errors follow a normal distribution. With that being said, it is possible to know, with a defined level of confidence, which should be the safety stock level to cope with forecast variations.

For that calculation, average of the accumulated errors, its standard deviation and the expected service level are needed.

From now on, the FC Error is defined as the difference between the forecast and the actual sale. A negative sign will indicate that the forecast was lower than the sale, being, in those cases, mandatory to hold safety stock.

$$FC\ Error = Actual\ Sale - Forecast \quad (10)$$

The forecast used to calculate this data can be different and simulated in the program. The options about what would be the used forecast are the following:

- Forecast given one week before (FC-1)
- Forecast given two weeks before (FC-2)
- Forecast given three weeks before (FC-3)
- Forecast given four weeks before (FC-4)
- The average of the four previous forecasts (Avg(FCs))

For the accumulated errors, the assumption was that the value to use in each week would be calculated differently according to the lead time. If the production lead time is two weeks:

$$Accumulated\ Error_{(Week\ i)} = Min\big(Error_i; Sum(Error_i; Error_{i-1})\big) \quad (11)$$

If the production lead time for one product is three weeks, the accumulated error will be:

$$Accumulated\ Error_{(Week\ i)} = Min\big(Error_i; Sum(Error_i; Error_{i-1}); Sum(Error_i; Error_{i-1}; Error_{i-2})\big) \quad (12)$$

This variation is intimately related to the fact that the production lead time will be critical to define which will be the forecasts used to start production according to the proposed inventory management system.

The usage of the minimum of these errors is important to be sure that do not exist positive errors that are jeopardizing the calculation of the negative accumulated error, since the negative errors are the important figures to calculate the safety stocks as explained before.

To calculate the safety stock the following method is applied:

$$Safety\ Stock = Average\ (Ac.Errors) + Stdev(Ac.Errors) * Norminv(SL; 0; 1) \quad (13)$$

After doing this calculation for the whole product line-up, the service-level results would be roughly the same as the methodology shown before (8) whereas the total safety stock level is considerably lower, giving the notion that this procedure is better than the one used by Chockalingam (2007).

The simulator developed is able to calculate the target safety stocks defining different parameters as the confidence level, the weeks that should be used to measure the errors or even the methodology used to calculate the target safety stock. Moreover, it would compute the service-level values for a simulation period of time, for each product.

There are various methodologies to calculate safety stocks, the simulator as three of them incorporated: One that calculate safety stocks from consumption variations from tire plants; another that is based in the distribution of the forecast errors (Chockalingam) and the last one that is based on the accumulated errors of forecasts. The results presented next are the results from the calculation with the negative accumulated errors of forecast that is believed to be the approach that fits best the business and its characteristics.

In terms of the location of the safety stock, even if the majority of the products are specific for a customer, it does make sense to hold that safety stock at C-ITA. The reason is that, despite any special relation between C-ITA and its clients, the service level is valuated according to the response it gives to demand and if successfully supplied. Any extra need for consumption at the customers' plants must be supplied immediately, and the solution for that is to hold the safety stock the nearest possible to the production site. For that, another study on how the MRP results, this is expected requirements diverge in relation to the actual consumptions as well as the variability in transportation lead time, from C-ITA to each tire plant, would be necessary.

Holding safety stock in stages before finished goods, for example, in greige fabric which is the WIP before the last process could also be a possibility. However, this last process is the production bottleneck, and since production is planned to achieve 100% machinery occupation, there would be problems when clients ask for extra quantities. If there is no safety stock of finished goods, at that time, the machine that is responsible for dipping the fabric will be assigned to produce this extra order. If so, possibly, other orders would not be satisfied since the production plan was not defined that way and the capacity of the machine is fixed.

4.3 Results

The simulator created has various approaches in terms of safety stock calculation incorporated. The parameters can be altered which will result in different values of targeted safety stock calculation. Two situations will be presented that will expectedly result in a service-level of 90% and 95% each. Note that the service-level measure is the β, which in measured in terms of quantity stock out.

To present the target safety stock of finished goods, the following parameters were settled:

- Analysis Period: 2014/W06 to 2014/W13
- Simulation Period (measuring of service-level): 2014/W14 to 2014/W18
- Methodology Used: Accumulated Negative Errors
- Forecast Used: Average of Forecasts
- Lot/Batch Production: Yes

Because of the methodology adopted to calculate the safety stocks, the statistical analysis of the accumulated errors, the expected service level used in the NormInv function is not equal to the real β Service-Level that is calculated after the simulation. Therefore, it is difficult to predict what will be the real service level when defining the expected value to start the calculations. Even if the safety factor is zero, according to (13), the safety stocks will be equal to the average of the accumulated errors, which will result in a good service-level after simulation. This difference between expected and actual service level is due to the production in batches and also because the error distribution is not normally distributed which is assumed in the calculations. These results demonstrate that just for producing in batches, there is already safety stock being held, that is not properly calculated but is sufficient to held a part of the demand variations. For this situation, target safety stock levels calculated are presented in table 7, in Appendix. A brief summary of those results is presented in table 5.

Table 5 - Result of finished goods safety stock calculation (SL=96%)

Overall Safety Stock (Kgs)	138.855
Holding Capital of Safety Stock	658.035 €
Holding Cost of Safety Stock	65.803 €

These target stock levels would result in a certain service-level that is presented in table 6. Having a proper look at the calculated safety stocks per material, it is possible to notice that in terms of consumption/sales days, the values are really dissimilar, that is the proof that demand variability is different from material to material, being important to analyse safety stocks separately. The safety stock definitions for the whole product line-up is presented in table 7 in Appendix.

However, this safety stock level and its cost cannot be analysed separately. There is the need to compare it with the average inventory being held at C-ITA because, as said before, there is already safety stock being held because of lot-size production that is not accurately defined. Table 6 shows the comparison between the present situation and the proposed situation.

Table 6 - Comparison Actual vs Proposed situation (Inventory On-Hand)

	Current Situation	Proposed Situation
α Service Level	85 %	91 %
β Service Level	88 %	96 %
Stock On-Hand (Kgs)	559.919	639.773
Holding Cost	223.968 €	255.909 €

As can be seen in table 6, the difference between the simulated stock on-hand and the actual value of inventory at C-ITA's warehouse is not equal to the calculated amount of safety stock. That is because, at the moment, there is safety stock already being held, even if it is not precisely defined. It is possible to see that the exceeded inventory is less than the calculated target value therefore being not as costly as in can be believed looking just at the calculated values.

The developed program will also make it possible to check what would happen in the past if those levels were adopted, admitting a (R,S) system is applied as can be seen in figure 16. It is also possible to choose if the production has lot sizes defined or not, therefore production orders will be placed accordingly. This (R,S) system, as can be seen in Chapter 2, will look at the following weeks' forecasts, depending on the production lead time will define the expected demand over this period, the S (up-to-level), and after comparing this value with the inventory level, a production order will be launched. Depending on the parameter defined, the model will adapt to lot-sizing production of flexible production. Figure 16 illustrates the evolution of both simulated and actual inventory for a specific product as well as the defined safety stock and the clients for whom the product is supplied.

Code	Plant 1	Plant 2	Plant 3
R0534701AU	Timisoara	Lousado	Korbach
	8354118	8354113	8329212

Values	2014/W01	2014/W02	2014/W03	2014/W04	2014/W05	2014/W06	2014/W07	2014/W08	2014/W09	2014/W10
FC+1	8217	8173	2043	2317	2478	2170	2333	20952	2352	8584
FC+2	8173	2458	2071	2478	9002	8607	20927	2336	8562	8288
FC+3	8110	187	2828	9190	9681	9788	2912	9498	9279	9240
FC+4	7018	2668	9259	9609	10044	8950	9391	9003	9538	9325
SS	5525	5525	5525	5525	5525	5525	5525	5525	5525	5525
DSS	0	0	0	0	0	0	0	0	0	0
DSS + SS	5525	5525	5525	5525	5525	5525	5525	5525	5525	5525
S	37043	19012	21726	29120	36731	35040	41088	47314	35257	40962
Actual Stock	-1911	13381	8897	10166	19718	14612	12707	13926	4388	11950
Stock OH	5525	2254	-1697	3858	11353	3753	8720	15596	3369	9604
WIP Twisting	8110	9424	0	9424	9424	9424	9424	9424	9424	9424
WIP Weaving	8173	8110	9424	0	9424	9424	9424	9424	9424	9424
WIP Dipping	8217	8173	8110	9424	0	9424	9424	9424	9424	9424
Total Stock	30025	27962	15838	22707	30202	32026	36994	43869	31643	37877
Sales	1911	11488	12124	2555	1930	7600	4457	2549	21651	3190
Order	9424	0	9424	9424	9424	9424	9424	9424	9424	9424

Values	2014/W11	2014/W12	2014/W13	2014/W14	2014/W15	2014/W16	2014/W17	2014/W18	2014/W19
FC+1	1972	2119	8432	2538	1508	8630	9089	8635	2361
FC+2	8226	8619	2401	1695	8709	8965	8635	2296	2284
FC+3	8865	3225	2094	8554	9611	9319	2296	2501	2351
FC+4	2689	1895	8289	9782	9050	2145	2501	2253	21031
SS	5525	5525	5525	5525	5525	5525	5525	5525	5525
DSS	0	0	0	0	0	0	0	0	0
DSS + SS	5525	5525	5525	5525	5525	5525	5525	5525	5525
S	27276	21382	26740	28094	34403	34585	28046	21211	33553
Actual Stock	10084	5695	10137	11998	15124	13937	10129	6989	-9523
Stock OH	10758	11370	18905	19426	16902	10012	5579	6128	6030
WIP Twisting	9424	0	0	0	9424	9424	9424	0	0
WIP Weaving	9424	9424	0	0	0	9424	9424	9424	0
WIP Dipping	9424	9424	9424	0	0	0	9424	9424	9424
Total Stock	39032	30219	28330	19426	26326	28861	33852	24977	15454
Sales	8270	8813	1889	8904	2524	6890	4433	8875	9523
Order	0	0	0	9424	9424	9424	0	0	18849

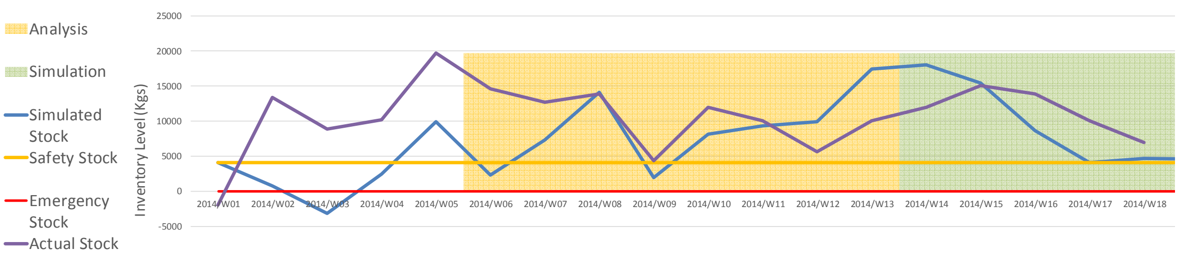

Figure 16 - Simulator information about product R0534701AU

The program can be easily adapted to analyse different products, even from different companies, the only requirement is that the inputted data about forecasts, consumptions and sales have the same layout, otherwise some adaptations will be needed. The construction of this tool was thought in order to be possible to do the same analysis along other supply chains of the Continental Group.

4.4 Discussion

Since there was not a clearly defined level of safety stock before, it is difficult to compare the inventory level before and after the project. Therefore, concrete conclusions will be possibly made after applying the algorithm outputs while improvements can be made to evolve the tool and make it more useful to the organization.

As presented previously, there is the possibility to change the calculation parameters therefore resulting in different target levels of safety stock. The usage of those levels must be validated by people with knowledge both of the production processes and also of the sales to check if the results match the real problem and its possible solution. Being a strategic decision, this level of safety stock can handle these variations with more or less risks or it can be stated that there was a shift in some variables according to the sources of variations hence being possible to reduce this safety stock in specific products. The tool will support strategic decisions however, human input can not be discarded.

Even if safety stock is needed to deal with other problems, just because manufacturing is not a deterministic and uncapacitated environment, like machinery breakdown, production process variability, the ability to supply demand that is higher than the plant capacity, it is believed that, those calculations, divided by category or function of the inventory, "would lead to inefficiencies from redundant stocks" (Stephen C Graves, 1987). Moreover, the probability that inventory for all these purposes is needed at the same time in infinitesimal, real-world has the great advantage of randomness and the stock can be aggregated benefiting from risk-pooling.

The main source of problems, demand variability, was chosen to be the calculation source of the safety stock and certainly the result of it will be enough to handle other minor sources of problems. Being C-ITA and its customers part of the same corporate Group, it could be debated if the cost related to this safety stock, that is needed due to demand variability, should or not be divided both by C-ITA and tire plants as Corbett (2001) assesses. This distribution of costs would comprise clients and C-ITA in the search for forecasting improvements, stable production, and information sharing that would result in increasing the efficiency of the supply chain.

It is also possible to notice that the evolution of service-level is not proportionally related to the evolution of safety stock. The increase on service-level forces the safety stock to increase exponentially, therefore being these decisions really important to the companies that must be made strategic-wise to follow the organization vision and mission.

This simulator aggregates the demands and orders of all clients per material which obligates the strategy of holding the safety stock at C-ITA. Even if, there are few products that are common to various customers, there are possible savings in terms of holding costs by aggregating demand thus reducing variability.

Having this tool fully function will help C-ITA to search for demand variations its patterns and causes and have a closer relation with customers to solve the existing problem therefore increasing the supply chain efficiency. Investing in this, it would be possible to contradict Davis's (1993) thoughts that "Most organizations are designed to create winners and losers; working together for system optimization receives little more than lip service".

The most important issue in this definition is the added cost related to holding safety stock. However, when the comparison is based on the stock on-hand, it is possible to notice that the excess is not so considerable because nowadays, because of production characteristics, there is already safety stock being held therefore being fair to use these values to compare current and proposed situation.

Moreover, it is believed that safety stock definition will make it possible to apply a “frozen-period” of 3 weeks in production. Therefore, it is likely that increased efficiency due to the reduction of setup times by diminishing the need of production plan changes had to be added to the equation of benefits and cons of the proposed solution. The profits derived from a minor increase of 1% in the uptime of machinery, due to production stability achieved, would be enough to surpass the costs of holding the excess of inventory. However, further analysis on this field is needed and possibly the savings in setup time would be difficult to calculate before implementation because it will be importantly influenced by the defined production plan.

5 Supply Chain Management

The final purpose of this project is to optimize the inventory management in the whole supply chain. This management will be a balance between capital invested in inventory and disruption risk. This optimum balance could be set with a higher level of inventory if avoiding supply risk is more important than having that extra cost. This is one of the expected achievements of supply chain management that "when planned, designed, and executed effectively, is the key to achieving high levels of operating performance which, in turn, drives shareholder value" (Tyndall, Gopal, Partsch, & Kamauff, 1998).

The problem of having exceeded inventory and still not diminishing the supply risk is an important issue to be taken care of by the company. To avoid this problematic, there is the need to implement an intelligent inventory management systems also at the customers' plants. This will lead to a better management of the inventory since it will be separated from human intervention being expelled all the disadvantages of human behaviours that amplify the bullwhip effect as referred before.

5.1 Current Situation

Presently, there is not a global view and analysis of the supply chain and the lack of information on the inventory and where is it being held at each moment consists in an opportunity to evolve and to develop methodologies to manage the supply chain more efficiently.

The definition of safety stocks of finished goods at C-ITA's plant will bring changes to the whole supply chain. An important study would be to know how the inventory is distributed and if that breakdown is static or if it is frequently changing. Through the SAP system it was possible to gather data about the inventory level both at C-ITA and at the customers' plants for a certain period of time. According to the sales from the previous week, with the help from the sales department, it was possible to know which would be the quantity of stock in transit at those moments. The results are presented in figure 17:

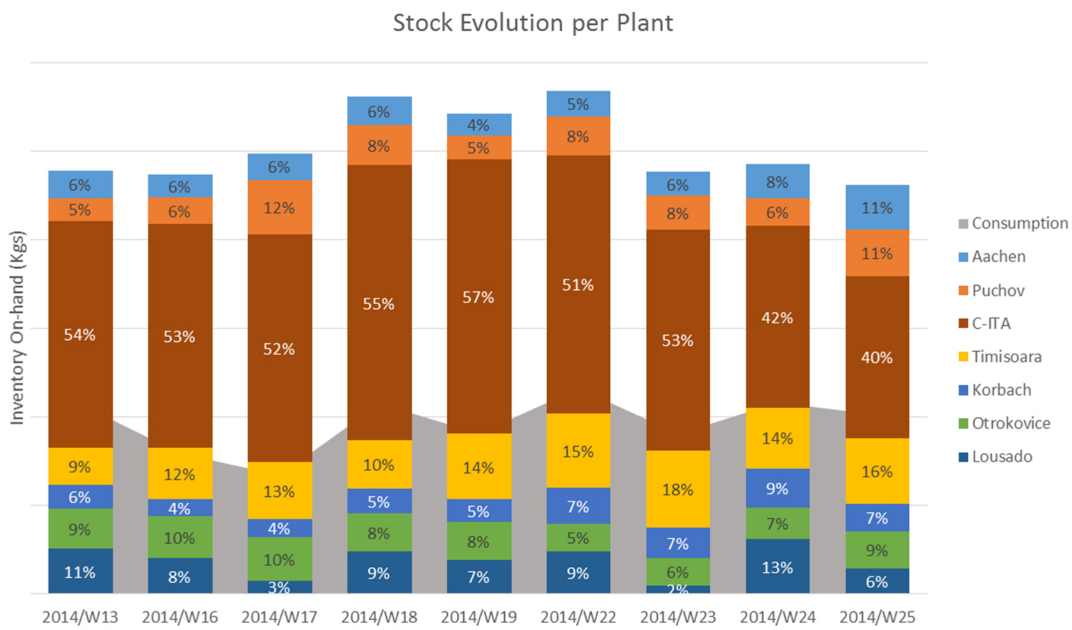

Figure 17 - Supply chain inventory evolution per plant

Knowing that CMIP accounts for almost half of C-ITA's sales, it can be noticed that the average quantity of inventory at CMIP is not proportional to its consumptions. This corroborates the thought that the analysis must be distinctive both because of the transportation lead time and the frequency of replenishments. It can not be said that the amount of overall inventory along the supply chain is related to the evolution of consumption because the available data is not conclusive, however it is possible to notice that the inventory in the supply chain is enough to hold more than two weeks of consumption (consumption values in the chart are related to weekly aggregate consumptions of all plants).

It is important to notice that this information was collected through the shared system that should be reliable and updated. However, the information was gathered on Monday mornings, being predictable that the weekend consumptions of raw materials at tire plants could not be updated at that time. This stock level would be used to compare the proposed and present situation. Yet, it is important to take in consideration that, in reality, this overall value of inventory will be lower. To collect more reliable information, it would be important to get a close relation with the customers in order to confirm these values.

The information was also gathered in terms of clusters: Stock at C-ITA, at customers and in-transit. Inventory disposal is shown in figure 18.

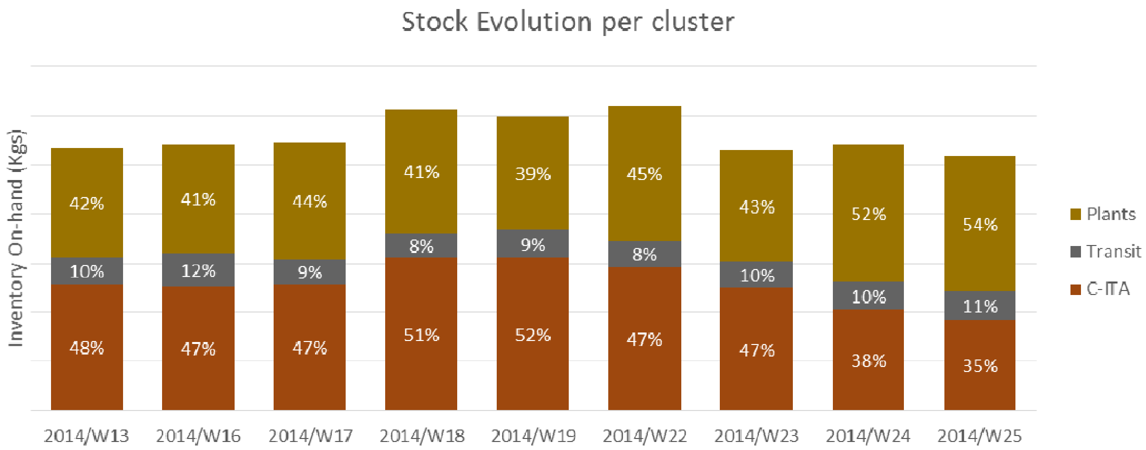

Figure 18 - Supply chain inventory evolution per cluster

As can be seen in the previous figure, the level of stock in the supply chain does not have major alterations neither in quantity nor in location along the time. Nevertheless, these quantities can be placed not in the most efficient and effective manner to deal with demand variations. It is therefore possible to control the supply risk while diminishing the holding cost creating a more efficient process.

Nowadays, there is not a specific review period on the clients' plants for each product. The products with more rotation, that is, that are consumed in great quantities and in a regular pace at the tire plants are shipped with more frequency, one or two times a week. On the other hand, less used products can be delivered in a monthly-basis.

In terms of inventory management, it would be better to have more frequent deliveries, "Multiple smaller quantity purchases of the same item certainly hold down your carrying costs"(Muller, 2011), therefore being possible to reduce the "sawtooth" inventory. However the overall cost of the logistics operation that should be analysed is the sum of the holding cost and the transportation cost. An illustration of the sawtooth effect, how average inventory is influenced by the frequency of delivering, is presented in figures 19 and 20.

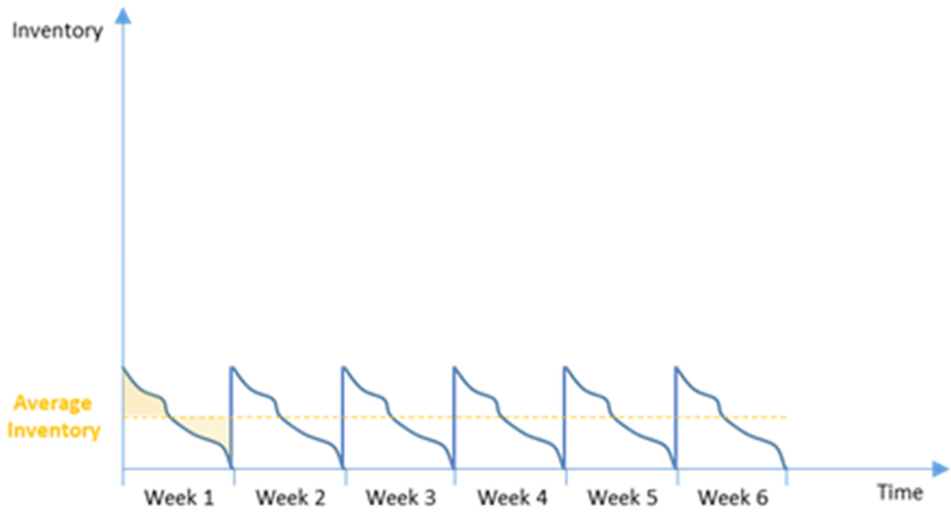

Figure 19 - Weekly replenishment "sawtooth"

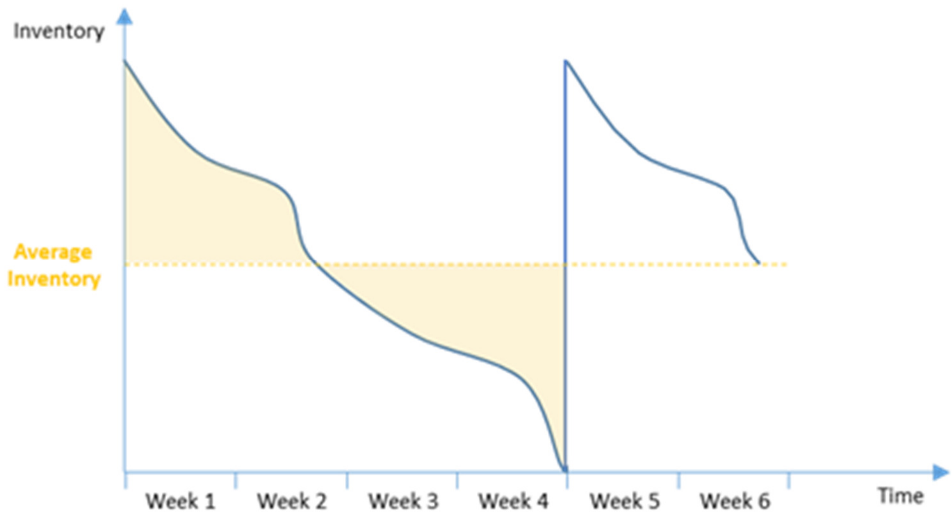

Figure 20 - Monthly replenishment "sawtooth"

Presently, the strategy is to ship full-truck loads (FTL) whenever it is possible, because, even if there is not a calculation of the relation between holding and transportation costs influenced by the replenishment period, the sense is that the transportation cost is more important thus being important to optimize it. Comparing to firms in higher demand environments as Silver describes, instead of the justification that "if the product does not sell today, it will almost surely sell tomorrow and, and the savings from shipping FTL outweigh any small inventory savings that could be gained by holding back inventory at the warehouse level", the tire plants can consume no textile reinforcement one day, but will consume it in the next one (Silver et al., 1998).

This requirement defines which is the delivering frequency of each product for each plant. Customers tend to require shipments of only one product in a truck so that the inbound logistics processes can be optimized and more efficient. Consequently, raw material with higher consumption will be shipped with more frequency than the others. However, shipping trucks with just one product will predictably lead to more stock on-hand on average, being important to define a calculation procedure to decide in the most beneficial way to the company.

5.2 Proposed Solution

Some assumptions had to be made in order to define which would be the best way to distribute the inventory both at C-ITA and its customers' plants.

First of all, the replenishment period has to be settled for all the products and customers. A brief analysis showed that the transportation costs are considerably higher than the holding the inventory during the working year. To deal with this fact, a program was set up to simulate how the costs (transportation and holding) would vary by the influence of the replenishment period.

The simulator is based on previous consumptions of the plants for each of the products and make it possible to notice how important it is to optimize transportation in this supply chain. After using the program, it will be possible to show customers' plants managers what is the importance of having this analysis and how the delivery of products could be done more frequently, if the truck could be shipped with a mixture of products, without increasing transportation costs.

The parameters that can be changed in the program are the replenishment periods that can be adapted for each product and customer. By altering these factors, the calculation in terms of needed inventory as well as the involved costs, both transportation and holding costs will be done. The aspect of the program in terms of inputting data is presented in figure 21:

Aachen	Puchov	Timissoara	Korbach	Otrokovice	Lousado
38715	35343	37148	33342	16752	19908
R0521703AE Weekly	R0620001AS Lead Time	R0620001AR Lead Time	R0534701AU Weekly	R0744301AZ Weekly	R0793501AL Daily
R0539701AM Weekly	R0552801AW Weekly	R0534701AU 2 in 2 Ws	R0589001AN Weekly	R0623301AA Weekly	R0534701AU Daily
R0552801AY Weekly	R0683101AF Weekly	R0589001AN Lead Time	R0793701AI Weekly	R0650101AH Weekly	R0620001AR Daily
R0620001AQ Weekly	R0685701AF Lead Time	R0623301BA 2 in 2 Ws	R0679901AI Weekly	R0686001AO Weekly	R0640901AK Daily
R0623101AJ Weekly	R0786401AF Lead Time	R0683101AG Lead Time		R0695301AC Weekly	R0649701AL Daily
R0679901AE Weekly	R0788401BB Lead Time				R0650101AL Daily
R0744301AZ Weekly					R0651401AL Daily

Figure 21 - Input data sheet (Supply chain inventory program)

As the replenishment periods are being changed, the calculation of trucks needed and the overall costs are done, being easier for the user to notice the impact each definition will have. Calculations about the consumptions that are going to be supply depending on the frequency are made being converted in the number of trucks needed. The objective will be to minimize the transportation capacity not used since, as it will be shown in the results, the transportation cost is more important than the holding cost. The calculated information about the demand (average consumption during replenishment period), the number of trucks needed to fulfil that demand and consequently the costs associated are presented in figure 22:

Aachen			Puchov			Timissoara			Korbach			Otrokovice			Lousado		
Repl. Per.	Weight	T	Repl. Per.	Weight	T	Repl. Per.	Weight	T	Repl. Per.	Weight	T	Repl. Per.	Weight	T	Repl. Per.	Weight	T
Daily	0	0	Daily	0	0	Daily	0	0	Daily	0	0	Daily	0	0	Daily	19908	1
Lead Time	0	0	Lead Time	19278	1	Lead Time	17641	1	Lead Time	0	0	Lead Time	0	0	Lead Time	0	0
Weekly	38715	2	Weekly	16064	1	Weekly	0	0	Weekly	33342	2	Weekly	16752	1	Weekly	0	0
2 in 2 Ws	0	0	2 in 2 Ws	0	0	2 in 2 Ws	19506	1	2 in 2 Ws	0	0	2 in 2 Ws	0	0	2 in 2 Ws	0	0
3 in 3 Ws	0	0	3 in 3 Ws	0	0	3 in 3 Ws	0	0	3 in 3 Ws	0	0	3 in 3 Ws	0	0	3 in 3 Ws	0	0
Monthly	0	0	Monthly	0	0	Monthly	0	0	Monthly	0	0	Monthly	0	0	Monthly	0	0

Extra Capacity					
1285	4657	2852	6658	3248	92
Transportation Cost					
195.120,00 €	335.957,14 €	253.722,86 €	217.131,43 €	154.285,71 €	36.000,00 €
Holding Cost					
70.123,84 €	66.814,16 €	63.322,34 €	51.931,09 €	30.278,18 €	128.536,06 €
Total Cost					
265.243,84 €	402.771,30 €	317.045,20 €	269.062,51 €	184.563,89 €	164.536,06 €

TOTAL TRANSPORTATION COST	1.192.217,14 €
TOTAL HOLDING COST	411.005,66 €
TOTAL COST	**1.603.222,80 €**

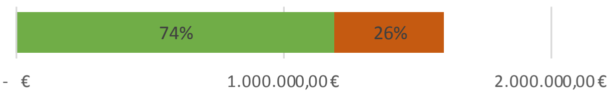

Figure 22 - Replenishment period changing impacts on supply chain inventory

Having this support, it will be easier to the sales responsible to convince the customers of which should be the replenishment periods and their impact on the overall cost of transporting and holding inventory for the supply chain.

5.3 Results

As said before, the main objective of the project is to optimize inventory along the supply chain, however this tool makes it easier to understand that just optimizing inventory will not result in the best situation for the company. The best situation in terms of inventory is to have the higher replenishment frequency possible. With the program, it is easy to check which would be the associated costs with this policy. The results of a replenishment policy that defines refills every lead time period are presented in figure 23:

Extra Capacity					
12346	9247	15392	16184	8034	92
Transportation Cost					
273.168,00 €	361.800,00 €	338.297,14 €	303.984,00 €	216.000,00 €	36.000,00 €
Holding Cost					
60.954,67 €	61.929,29 €	54.629,15 €	44.310,12 €	26.449,04 €	128.536,06 €
Total Cost					
334.122,67 €	423.729,29 €	392.926,30 €	348.294,12 €	242.449,04 €	164.536,06 €

TOTAL TRANSPORTATION COST	1.529.249,14 €
TOTAL HOLDING COST	376.808,34 €
TOTAL COST	**1.906.057,48 €**

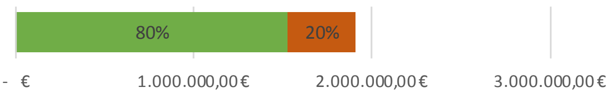

Figure 23 - Results for lead-time period replenishments

Another important situation is the one used today. The replenishment frequency for each plant and product were defined as currently and the results are presented in figure 24. Since the frequency is lower than the presented above, the transportation costs will be lower while the holding costs will predictably rise, remember the "sawtooth" effect.

Extra Capacity

1285	-3054	5549	1966	5157	92

Transportation Cost

195.120,00 €	310.114,29 €	338.297,14 €	184.561,71 €	190.285,71 €	36.000,00 €

Holding Cost

70.123,84 €	74.570,17 €	63.287,27 €	87.685,25 €	44.750,58 €	128.536,06 €

Total Cost

265.243,84 €	384.684,45 €	401.584,41 €	272.246,96 €	235.036,29 €	164.536,06 €

TOTAL TRANSPORTATION COST	1.254.378,86 €
TOTAL HOLDING COST	468.953,16 €
TOTAL COST	**1.723.332,02 €**

Figure 24 - Results for current replenishment policy

As can be seen in the previous figure, the transportation costs decreased because of the reduction in the replenishment frequency. However, there is an optimum stage that is achieved by the reduction of the extra capacity in the trucks that is not being used. Just doing some experiments, changing these replenishment periods to optimize transportation capacity utilization resulted in less costs as can be seen in figures 21 and 22.

5.4 Discussion

The previously shown results support the idea that, the best way to manage this supply chain would be to interact inventory and transportation management.

This overall analysis is important to demonstrate the potentialities for improvement in this field and combine efforts both from central management and from Continental and tire plants, C-ITA's customers, in developing an integrated decision methodology that balancing holding and transportation costs that would result in lower operational costs with the same level of service.

It is important to notice that, nowadays, deliveries are made according to customers' requirements, therefore if there is a product which monthly consumption equals a truck capacity, probably this product is being shipped in a monthly-basis. Tire plants, prefer to receive single-product shipments since the reception and following organization of the warehouse is eased. This tool makes visible the savings the organization would have if different products were shipped together, according to the best matches between consumptions and replenishment periods to optimize transportation utilization.

The firstly presented situation, figure 22, results in a better compromise than the used today. Those savings can be easily obtained if there is an agreement to redefine replenishments with all customers. Future developments to optimize this costs should be done if there is a possibility to replenish with different time-periods than the presented before, this will need the ability to replenish in different days from one week to another, something that will need further analysis in terms of costs and feasibility.

As stated since the beginning of this document, the purpose of the project was to set target levels of safety stock both for raw materials and finished goods, however it had been thought that this analysis would make sense in this reality and that it will sustain the future developments in this field.

6 Conclusions and future developments

The whole project of defining methodologies both for raw materials and finished goods safety stock calculation is of major importance to the company. Nowadays, there are problems, raised by the influencers of this calculation, such as demand and transportation lead time variability, that bring inefficiencies to the company.

Properly defining the safety stock levels will make it possible to have a smoother production, with a more stable production plan which will result in savings in setup times, warehousing occupation, advantages that could not be calculated in a quantitative basis during the project but there are commonly accepted as beneficial and valuable.

Moreover, the overall analysis in terms of the supply chain that made it possible to conclude how the replenishment policies (period) could affect the chain performance by optimizing the balance between inventory and transportation costs is also crucial for the long term success of the company and that could initiate other developments within this field.

A great thing of the project is that all the tools developed to create this document can be easily adapted to other industries and companies which could result in major savings to the Continental Group if applied throughout all the divisions and plants of the organization.

The develop work in the project made it possible to go to the headquarters of Continental to present the studied methodologies and conclusions in order to convince top management to invest resources in this field because there will be a payback. The future of the project will be then decided, after the publishing of this document.

To sum up, the project was important to gather important information, to carefully analyse it and to organize in the proper way to give insights of what could be done to improve the overall efficiency of the supply chain. The main focus was to decrease supply risk, however balancing it with the related costs and overall efficiency of the supply chain was a requirement.

The project was presented in the Continental headquarters to supply chain managers within the corporate purchasing department. The three approaches studied in terms of safety stock definition for raw materials and finished goods as well as the comparison between holding and transportation costs were appreciated and possibilities for developing them in other plants were raised.

In the short term, there is the need to apply these methodologies both for raw material safety stock definition, it is also important to reconstruct the tools that define those level to be more user-friendly and easily used by other employees more related to those specific fields. Deciding when is the best time to replenish each product in each plant can, in the future, be assisted by the developed tool.

In the medium-term it is important to study the possibility of calculating safety stocks from the deviations between the MRP results and actual consumptions that will be important to define the target levels to be held at the tire plants during the period when C-ITA can not respond to variations.

Trying to implement all these calculations and methodologies inside SAP to reduce manual working is also important in the future as well as developing the proposed tools in a more integrated way with the used ERP.

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Appendix

Table 7 - Finished products safety stock calculation (SL=96%)

Material	Safety Stock	Consumption Days	β Service Level
R0521703AE	2723	9	100%
R0534701AU	4123	4	100%
R0539701AM	992	2	100%
R0552801AW	905	2	69%
R0552801AY	172	1	100%
R0589001AN	3400	4	74%
R0620001AQ	5535	4	100%
R0620001AR	7714	4	100%
R0620001AS	0	0	62%
R0623101AJ	9275	4	100%
R0623301AA	3965	2	100%
R0623301BA	3582	2	86%
R0640901AB	3326	1	100%
R0640901AK	4731	2	100%
R0649701AL	2081	1	100%
R0650101AH	2760	2	100%
R0650101AL	5295	2	100%
R0651401AL	7213	2	100%
R0669302AZ	3178	3	100%
R0679901AE	7563	4	100%
R0683101AF	12997	8	98%
R0683101AG	3104	2	100%
R0685701AF	5238	4	100%
R0685701AK	4176	3	100%
R0686001AO	400	1	100%
R0695301AC	2371	1	100%
R0699701AS	3085	3	92%
R0744301AZ	202	7	100%
R0781601BA	659	3	100%
R0786401AF	1601	3	100%
R0788401BB	8720	3	93%
R0793501AL	13026	7	93%
R0793601AK	1224	1	97%
R0793701AI	2723	9	100%