FACULDADE DE ENGENHARIA DA UNIVERSIDADE DO PORTO

Dynamic Stock Management

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MASTER'S DISSERTATION

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Dynamic Stock Management

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To my parents and sister.

To my friends and colleagues.

To Mafalda.

Abstract

This is a study regarding the global stocks' optimization of the company Unicer Bebidas, S.A., after a large restructuring of the industrial and logistic platforms.

This study discusses the development of an adaptive, while dynamic, Safety Stock calculation methodology, based on historical records of Sales and Forecasting, using Microsoft Excel's Goal Seek tool.

The beginning of the analysis reveals that the company's strategy, to define their Safety Stocks, depends on a time value - the Coverage Time, establishing that the results will have the same format.

To add value to the analysis' results, the production's restrictions are taken into account, and represented as the Company Lead Time, a representation of both the materials' (Materials Lead Time) and production's (Production Lead Time) requirements. Alternatively, the traditional Safety Stock calculation method, extracted from the literature, is introduced, and is then transported into a time value.

The results are then validated, by presenting the Stock Service Level, for each of the studied finished product's segment, in the ABC-XYZ classification resulting matrix.

In a latter stage, the proposed methodology is subjected to a set of scenarios, presenting the relative, and absolute improvement in €, as well as the scenarios' real life applicability.

The suggested improvements have an yearly saving potential of over 500.000€.

Resumo

Este é um estudo sobre a otimização de stocks da empresa Unicer Bebidas, S.A., após uma reestruturação profunda das plataformas industriais e logísticas.

Neste estudo, é discutido o desenvolvimento de uma metodologia de cálculo de Stocks de Segurança, adaptativa, enquanto dinâmica, baseada em dados históricos de Vendas e Previsões, utilizando a ferramenta Goal Seek do Microsoft Excel.

O início da análise revela que a estratégia da empresa, para definir os seus Stocks de Segurança, depende de um valor temporal - o Tempo de Cobertura, estabelecendo que os resultados também terão o mesmo formato.

Para trazer valor aos resultados da análise, as restrições do ponto de vista da produção são tidas em conta, e representadas pelo Lead Time da Empresa, uma representação de ambos os requisitos de materiais (Lead Time dos Materiais) e da produção (Lead Time de Produção). Alternativamente, o método tradicional de cálculo de Stocks de Segurança, extraído da literatura, será introduzido, e será transportado para um valor temporal;

Os resultados são então validados, ao apresentar Nível de Serviço de Stock, para cada segmento de produto acabado em estudo, na matriz resultante da classificação ABC-XYZ.

Numa fase posterior, a metodologia proposta é sujeita a um conjunto de cenários, apresentando a melhoria relativa e absoluta em €, assim como a sua aplicabilidade na vida real.

As melhorias sugeridas têm um potential de poupança anual superior a 500.000€.

Acknowledgements

To my girlfriend, for motivating me to work harder, and harder, every day.

To my parents and sister, for criticizing my failures and celebrating my successes.

To my friends and colleagues, for the support over the years. A special thank you to Bruno, for the daily ideas' debate.

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To the company's professionals, for the time spent sharing their technical knowledge and personal sympathy. A special thank you to Benjamin Herbin, Jorge Gomes and Pedro Ribeiro, for the possibility to develop the project beyond all of my expectations.

In memoriam

Minnie

“If we keep doing what we’re doing, we’re going to keep getting what we’re getting.”

Stephen R. Covey

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Abbreviations and Symbols

CLT	Company Lead Time
CT	Coverage Time
KPI	Key Performance Indicator
LT	Lead Time
MLT	Material Lead Time
PLT	Production Lead Time
RCT	Resulting Coverage Time
ROP	Reorder Point
SKU	Stock-Keeping Unit
SS	Safety Stock
SSL	Stock Service Level
SSAlt	Alternative Safety Stock

Chapter 1

Introduction

This document is a dissertation for the Electrical and Computers Engineering Master's Degree at the Faculty of Engineering, University of Porto. It was developed in an industrial environment for Unicer Bebidas, S.A..

This Chapter will be devoted to: the company's presentation, the motivation of the project, along with the problem description, the project's development strategy, and the dissertation's structure.

1.1 Unicer Bebidas, S.A.

Unicer Bebidas, S.A. is the largest Portuguese beverage company with a multi-brand, and a multi-market strategy based on the operations of the beer and bottled-water business.

The company is also present in the segments of soft drinks and wines; in the production and commercialization of malt; and in the field of tourism, through the management of the developments: Parque de Vidago and Parque de Pedras Salgadas.

Figure 1.1: Unicer's logo

Unicer Bebidas, S.A. is currently held by the Portuguese group, Viacer, made up of the Violas, Arsopi and BPI groups with 56% of the shares and the remaining 44% by the Danish group, Carlsberg.

With 1,350 employees, Unicer is present in the North and South of the country in 15 locations, in which are included beer, soft drinks, and wine producing centres; water collection and bottling centres; sales and operations offices.

A continuous investment in innovation and human assets, and a management rooted for the quality put into their brands and service, is their *modus operandi* in the market. This quality is certified by the ISO 9001, ISO 14001, ISO 22000 and OHSAS 18001 norms, in all of their vastly diverse product portfolio.

1.2 Motivation & Objective

For Unicer Bebidas, S.A., which is completing a great transformation cycle[1], industrially and logistically, providing the perfect opportunity to study the company's internal procedures, from an unbiased perspective, in order to understand which may be considered problematic, and put forward an alternative set of measures through an analysis of the company's historical records.

This will present the company with the opportunity to revise their concepts, strategies, and the reality of their approach towards its most important products, which, in the midst of the every day activity, can be a strenuous task.

Having this difficulty in mind, an analysis of the company's Stock Management strategies and historical records of Sales and Forecasts is done, in order to provide a result which is identical to the current strategies.

1.3 Project Development

To perform the proposed task over the project's duration, through a series of meetings and presentations with both company professionals and university professors, the project evolved according to the following stages:

- Company presentation and introduction to its management strategies;
- Bibliographic research;
- Data gathering and pilot selection;
- Methodology development;
- Validation of the methodology's results and Scenario analysis;
- Study and suggestion of implementation strategies;

[1] The construction and integration of the automatized warehouse, which will be at the core of the company's operations, changing its whole logistic structure.

1.4 Structure

Besides the introduction, this dissertation contains,

- In Chapter 2, a description of the State of the Art, along with the mentioning of related and relevant works. In this Chapter, important concepts will be brought up and explained.
- In Chapter 3, a detailed view over Unicer's current Stock Management methodologies and strategies, facing the concepts that were approached in Chapter 2.
- In Chapter 4, the proposed Safety Stock methodology, which is explained in great detail.
- In Chapter 5, a graphical and mathematical validation of the methodology's results, taking into consideration daily records.
- In Chapter 6, a testing of set of scenarios, whose results are monetized and compared.
- In Chapter 7, a set of conclusions and suggested implementation strategies. Possible improvements to the methodology are also presented.

Chapter 2

State of the Art

In the upcoming Chapter, the State of the Art is described. In it, subjects regarding Stock Management will be detailed, with the specific purpose of being applicable when transported into Unicer's current footing.

In the words of Grewal et al. (2015) - "Managing inventory and service levels in a capacitated supply chain environment with seasonal demand requires appropriate selection and readjustment of replenishment decision variables."

2.1 Stock Management

The concepts of stock and its management are meaningless without a grasp of the environment where they are considered: the supply chain.

A supply chain is a whole network of activities that delivers a finished product to the customer - all the way back from the supplier of raw materials. Its efficiency depends on systems that allow relevant information to be shared among the supply chain, Reid and Sanders (2013).

Before approaching the fundamental concepts of stock management, it is necessary to classify and understand the definition of stocks and what is their purpose. According to Stevenson and Hojati (2007) and Vasconcelos (2008), inventory can be seen as:

- Raw Materials/Components;
- Products/Work in Process;
- Final Product;
- Supporting/Maintenance Materials, Tools, Packages[1].

[1] Goods destined to production that are not a direct part of the product

These various inventories share the objective to:

- Meet anticipated demand;
- Respond to unexpected variations in demand;
- Maintain the operations' independence;
- Minimize ordering costs.

The purpose of stock management is to strike a balance between material and production investment, and customer service, Heizer and Render (2011).

Demand is influenced by both external and internal factors, i.e, independent and dependent demand, respectively. These demands are balanced by purchase order requests, in order to keep inventory at a reasonable, or prescribed level.

According to Stevenson and Hojati (2007), effective inventory management strategies take into account:

- Inventory Tracking Systems;
- Classification Systems;
- Reliable Demand Forecasting;
- Knowledge of Lead Times;
- Reasonable Cost Estimates;
- Performance Measurement;

2.2 Inventory Tracking Systems

In order to maintain a correct inventory counting, tracking systems were designed. Initially, inventory tracking/counting had to be done manually. It was either one person's exclusive assignment, or a team effort after each operation. This was called permanent inventory counting.

A reasonable alternative to this approach is periodic counting, which is done according to a perceived ordering rhythm or cycle. This way, variations are detected in a sporadic fashion, Stevenson and Hojati (2007).

More technologically advanced tracking systems are able to permanently monitor the inventory levels with very little human effort, such as SAP's, or Primavera's, Warehouse Management System. To optimize such tracking efficiency, identification systems for all sorts of items are used, such as RFID tags (Logistic control in Penttilä et al. (2006)), GPS (Location techniques in Gupta and Sutar (2014)), QR codes (Su et al. (2014)) and Bar Codes (Ecological samples in Copp et al. (2014)).

2.3 Classification Systems

Counting systems, as presented in 2.2, are imperfect, i.e., when unexpected events, which disturb the natural flow of the supply chain[2], occur, the system does not automatically update the inventory level. This is why traditional counting is still required.

However, if this was done on a daily basis, in exchange for accurate information, there would be an enormous man-power cost. On the other hand, if inspections are less frequent, the risk of inaccuracy increases.

Faced with this information limitation, classification systems were developed to define which items' availability should be prioritized, depending on their value or market behaviour, Heizer and Render (2011), Jacobs and Chase (2010).

2.3.1 ABC Classification

The ABC approach, as seen in Jacobs and Chase (2010), divides the product portfolio in three groups according to their value to a company/business. This value is seen as the product's overall profitability:

- A items which constitute roughly 15% of the item list (a small minority), portraying the most valuable items as the highest sources of income;
- B items which represent the following 35%, with items of medium value and demand;
- C items which are the remaining 50% of the product list, presenting the ones that are the least valuable.

The segmentation may not be as precise as described, but its objective is to understand the importance and priority of each item, thus simplifying the focus of the counting efforts[3], Jacobs and Chase (2010).

Figure 2.1 portrays an example of an item segmentation based on an ABC Classification.

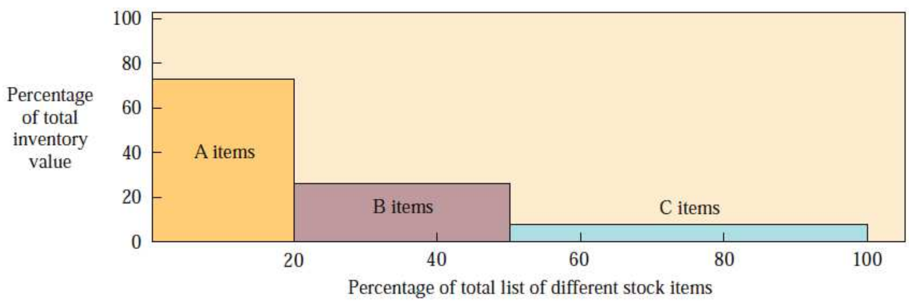

Figure 2.1: An ABC classification example, Jacobs and Chase (2010).

[2]Thefts, damages or natural disasters, among others.
[3]The most valuable items, must be counted more frequently than the remaining items.

2.3.2 XYZ Classification

The XYZ approach, as seen in Hoppe (2006), segments the product list in three groups depending on their sales variability:

- X items present slight fluctuations around a constant level of demand. The demand forecasting for these items is usually very accurate.
- Y items' demand is neither constant nor sporadic. They may present a trend or have a heavy cyclical or seasonal behaviour.
- Z items either have a very sporadic or erratic usage pattern. In some cases, these items may present absolutely no demand, making it extremely difficult to forecast their actual demand.

In Figure 2.2, an example of an XYZ Item Classification is visible, based on the fluctuation of items usage.

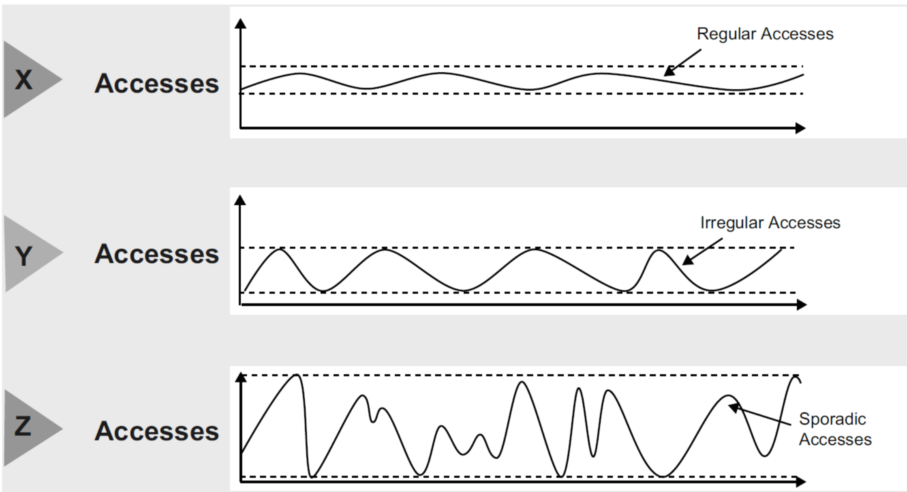

Figure 2.2: An XYZ classification example, Hoppe (2006).

2.4 Demand Forecasting

Forecasting is the process of predicting future events. This process allows companies to organize their planning regarding production, ordering and human resources, among others.

According to Stevenson and Hojati (2007), forecasting depends on the following factors:

- Availability of data, time, and resources;
- Sophisticated methods involving mathematical models;
- Forecasting Horizon;
- Type of Demand.

As Heizer and Render (2011) state, demand forecast can be purely deterministic and based on mathematical models, as well as a result of experience and/or intuition, or a combination of both.

Different methods are more efficient for different forecasting horizons. Heizer and Render (2011) classify them as:

- Short-Term - Ranging from one day to one year, it presents a high reliability, and so it supports the production activity. Normally associated with operations with the duration of three or less months;
- Medium-Term - Ranging from three months to three years[4]. Its focus is in the company's global production and supply capacity;
- Long-Term - For operations taking longer than three years. It has direct implications on the future of the company. And it is mostly used to study the introduction of brand diversity, new products, and unit location;

Depending on the Forecasting Horizon, a representation of Demand makes it clear that the evolution of Demand can be dissected into smaller, more predictable, components. Therefore enabling the more distinct observation of the various types of Demand. As Jacobs and Chase (2010) states, Demand can be seen as a sum of the following components, among others:

- Average Demand
- Trend
- Seasonality
- Random Variability

2.5 Knowledge of Lead Times

According to Stevenson and Hojati (2007), Lead Time (or LT) is the time interval between ordering a product and receiving it.

Knowing the LT is important to determine other service parameters. These parameters, according to Vasconcelos (2008), are:

- Safety Stock (or SS) - Stock level that should be maintained at all times in order to prevent stock-outs in case of unexpected variability.
- Reorder Point (or ROP) - Stock level at which an item needs to be reordered, in order to respect the Safety Stock.

[4] The horizons overlap, because there isn't a dry cut definition of these time intervals.

In a scenario where a product's demand is constant and known, and the orders are simultaneously delivered, in perfect conditions, knowing the LT, it's possible to periodically place orders (with a period of T), with the anticipation of LT, to the instant when stock (Q) will run out. This scenario presents a perfect service level, without the need for a safety stock due to the strictly periodic reordering points.

Figure 2.3 is a representation of this scenario.

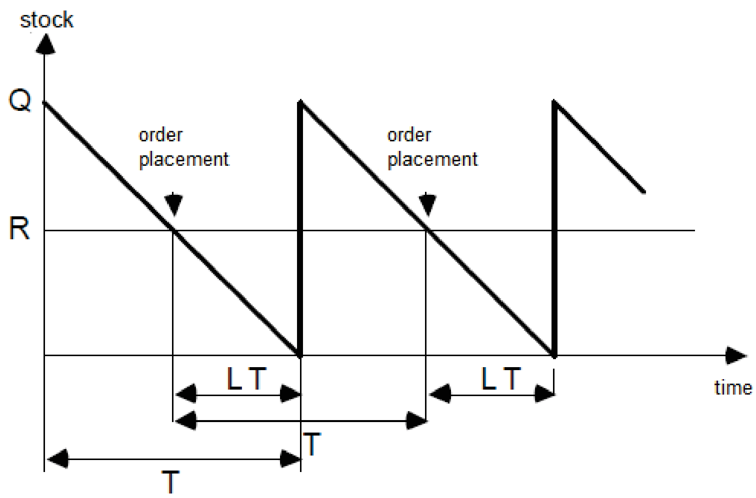

Figure 2.3: Representation of a predictable stock evolution, Vasconcelos (2008).

However, in reality, this theoretical approach has no application. This is why a safety stock is required.

2.5.1 Safety Stock & Reorder Point

The Safety Stock is the stock level corresponding to a desired minimum stock. To calculate SS[5], the Average Demand (μ_D), Demand Variability (σ_D), Average LT (μ_{LT}), LT Variability (σ_{LT}) and the acceptable stock-out risk (or the service level), need to be taken into account.

According to King (2011), to calculate the Safety Stock, equation 2.1 is used:

$$SS = z * \sigma \tag{2.1}$$

Where,

$$\sigma = \sqrt{\sigma_D^2 * \mu_{LT} + \sigma_{LT}^2 * \mu_D^2} \tag{2.2}$$

In equation 2.1, z is the value extracted from the standard normal distribution table, using the desired Service Level (Srinivasan (2010)), corresponding to the amount of necessary standard deviations needed to assure the designated stock-out rate.

[5] The Safety Stock calculation assumes that the data taken into account follows a normal distribution.

The Reorder Point should be set in order to satisfy demand, above the SS level. It follows the same principle as the scenario depicted in Figure 2.3; however, accounting the minimum stock level as the SS. Vasconcelos (2008) states that equation 2.3 is used to calculate the ROP.

$$ROP = \mu_{LT} * \mu_D + z * \sigma = \mu_{LT} * \mu_D + SS \tag{2.3}$$

These concepts are visible in Figure 2.4, where a comparison between a deterministic and the real stock evolution is depicted, including the SS level.

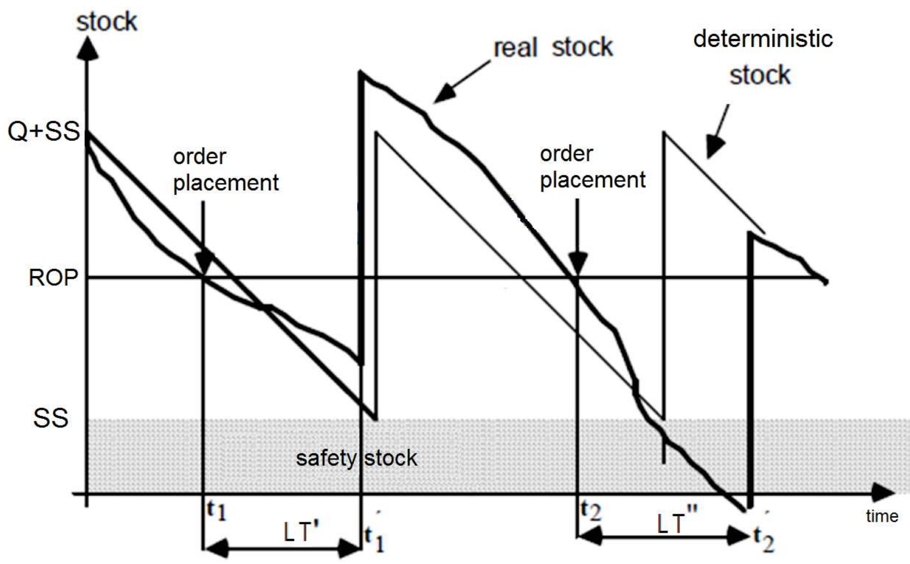

Figure 2.4: Comparison between predictable and real stock evolutions, Vasconcelos (2008).

In a real stock evolution, demand is not constant. Even when placing orders according to the ROP, there is the possibility of having stock-outs (as in the second order placement in Figure 2.4). What is left to understand is if having a stock-out is more expensive than increasing the SS level. To reach a conclusion, one must be able to calculate the various costs.

2.5.2 Cost Estimates

According to Stevenson and Hojati (2007) and Vasconcelos (2008), there are three types of inventory management costs:

- Ordering Costs - Ordering and receiving inventory costs.

  Depending on the forecasting horizon, calculating the ordering cost may be done differently:
  Ordering Cost per order[6]:

$$F_0 + C * Q \tag{2.4}$$

[6] Appropriate for shorter forecasting horizons.

Ordering Cost per year[7]:

$$F_0 * d/Q + C * d \tag{2.5}$$

Where, F_0 stands for independent order cost, C for unitary product cost per unit, Q for ordered amount, and d for yearly demand, Vasconcelos (2008).

- Holding Costs - Cost to hold an item in inventory, for a certain period of time[8];

  The holding costs includes financial expenses, maintenance expenses, and product depreciation, among others. According to Vasconcelos (2008), the equation for calculating the holding costs is:

$$F_1 * C * S \tag{2.6}$$

  Where, F_1 stands for yearly possession rate, and S[9] for average physical stock. $F_1 * C$ is a percentage of the unitary product cost.

- Shortage costs - Costs when demand exceeds supply;

  The shortage cost is exclusively dependent and proportional to the frequency of stock-out occurrences and the equation to calculate it is:

$$F_2 * n_r \tag{2.7}$$

  Where, F_2 stands for fixed cost per shortage, and n_r for number of stock-outs, Vasconcelos (2008).

From a managerial point of view, the most important value is the aggregated cost (K), which includes the three discussed costs:

$$K = F_0 * d/Q + F_1 * C * S + F_2 * n_r \tag{2.8}$$

Here, the objective is to minimize its cost, while keeping a pre-defined service level, Vasconcelos (2008). The way to do this is to find the adequate level of Q (Q_w).

Assuming that we want to maintain the highest possible service level, the portion of equation 2.8 becomes null. With the aim to minimize the result (K), one must derive the sum of equations 2.5 and 2.6, and solving in order of Q, to obtain Q_w as seen in equation 2.9,

$$(F_1 * C * \frac{Q}{2} + F_0 * \frac{d}{Q})' = 0 \Longleftrightarrow F_1 * \frac{C}{2} - F_0 * \frac{d}{Q^2} = 0 \Longleftrightarrow Q_w = \sqrt{\frac{2 * F_0 * d}{F_1 * C}} \tag{2.9}$$

[7] Appropriate for longer forecasting horizons.
[8] The standard time unit is one year.
[9] For simplification and calculation purposes, S is equal to $Q/2$, which is a rough approximation to reality.

Figure 2.5 has a representation, which better explains the optimization of costs. In it, a balance between them is visible, Vasconcelos (2008).

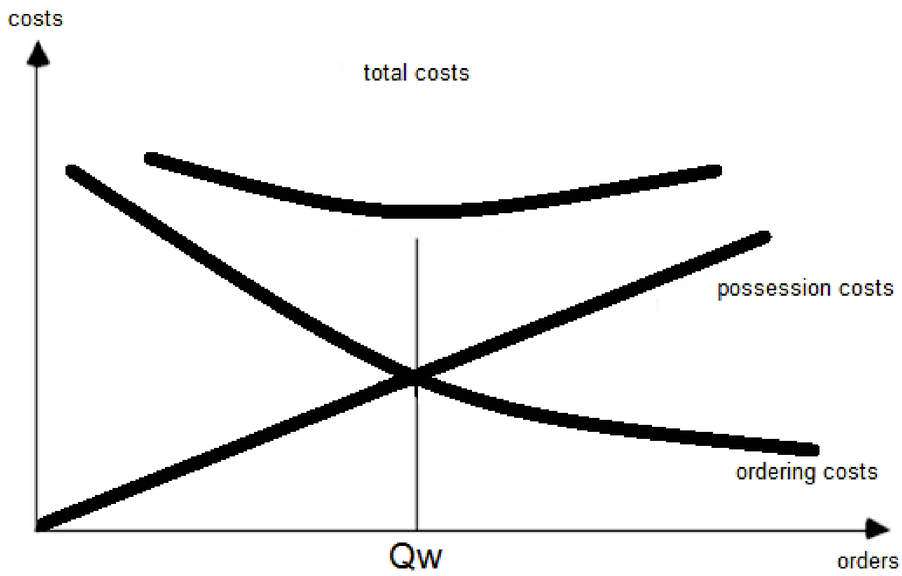

Figure 2.5: Contrast between the amount of orders and its respective costs, Vasconcelos (2008).

As seen in Figure 2.5, Q_w corresponds to the optimal order quantity, which levels the costs for equations 2.5 and 2.6, as seen in equation 2.10:

$$F_1 * C * \frac{Q}{2} = F_0 * \frac{d}{Q} \Longleftrightarrow Q^2 = \frac{2 * F_0 * d}{F_1 * C} \Longleftrightarrow Q_w = \sqrt{\frac{2 * F_0 * d}{F_1 * C}} \tag{2.10}$$

2.6 Performance Indicators

To assure that the supply chain is not wasting resources, or to understand its most fragile links, Key Performance Indicators (or KPI) are used. These KPI can be applied to the entirety of the supply chain, or to individual elements, in order to understand absolute and relative performances, respectively.

According to Heizer and Render (2011), there are KPIs of different natures, such as:

- Knowledge and interpretation of values with direct implication, such as LT (detailed in section 2.5).

- Resource profitability, such as:

  Turnover Rate:

$$TR = CQ/AS * 100 \tag{2.11}$$

  Where CQ stands for Consumed Quantity per Year and AS for Average Stock Quantity. The greater the TR, the greater the expected profitability of the finished product's stocks will be, since their warehousing expenses will be lower.

Coverage Rate:

$$CR = AS/CQ * 100 \tag{2.12}$$

This value gives an estimate on the stock holding duration, as a percentage of the year, or time period. With an appropriate conversion this value can be turned into Coverage Time.

- Other KPI are used to measure quality level, as follows:

  Client Service Level:

$$CSL = FO/TO * 100 \tag{2.13}$$

Where CSL stands for Client Service Level, FO for Yearly Fulfilled Orders and TO for Total Yearly Orders. It represents the percentage of fulfilled orders. The first and foremost objective of stock management is to maximize this parameter. After all, the client is the target of all activities in the supply chain.

Stock-Out Rate:

$$F_2 = UO/TO * 100 \tag{2.14}$$

Where F_2 stands for Stock-Out Rate (as seen in 2.5.2), UO for Unfulfilled Orders per Year. This KPI is the complement of the Service Level.

Chapter 3

Unicer's Management Strategies

The software used by Unicer Bebidas, S.A. - SAP - performs tasks such as Inventory Tracking, Demand Forecasting[1], and KPI Calculation deeming their mentioning unnecessary in this upcoming chapter.

The cost estimates defined in section 2.5.2 are always taken into consideration, however they are virtually unvarying. Strategic partnerships[2] and company ownerships[3], set by Unicer Bebidas, S.A., assure the stability of those costs.

On the other hand, Unicer uses a set of strategies resulting from the adaptation of the concepts mentioned in the previous Chapter. Onwards, the strategies which were considered relevant for the development of the project will be presented and detailed.

3.1 Inventory Tracking

Unicer Bebidas, S.A. uses a functionality of SAP - SAP's Warehouse Management System (or WMS) - to track its products. The products themselves are identified through their Stock-Keeping Unit (or SKU), which is a distinct unique item code to distinguish it from others.

Unicer's SKUs provide information, stored in SAP's WMS, which is structured according to three maintenance levels:

1. A managerial level - used for the company's management procedures, i.e. for KPI calculation, realease date. This level contains the most information regarding a product's attributes, including, but not limited to, product description, classification, material requirements' lists, pallet layout, lot size, expiration date (in months), product capacity (in centilitres), deposit fee (in €), among others.

[1]Deamnd Forecasting obtained using SAP takes into account all of the Demand's components mentioned in section 2.4

[2]BA Vidro has a close partnership with Unicer Bebidas, S.A.. They guarantee most of the bottle needs, as long as Unicer maintains a minimum value of orders.

[3]Maltibérica, a malt supplier, is held in 51% by Unicer.

2. A distribution centre level - where the information regarding: the existing product quantities in each centre, and the logistic movements is registered.

3. A sales organization[4] level - in which the sales are registered, along with retail price, sold quantity, among others.

Unicer's Stock Keeping Units are kept in clusters[5] to simplify their tracking and information maintenance.

3.1.1 Inventory Classification

Unicer Bebidas, S.A.uses an ABC-XYZ classification system to prioritize its stock management efforts. This system segments the different SKU clusters according to their demand volume and variability. Figure 3.1 details Unicer's product segmentation.

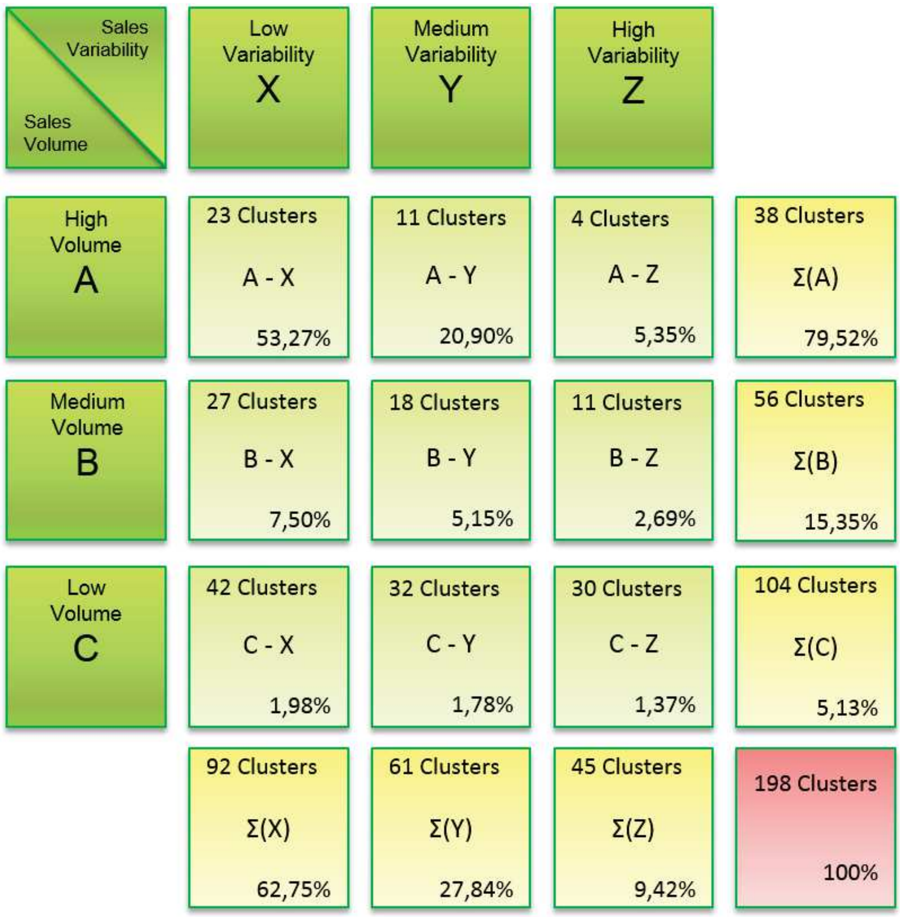

Figure 3.1: Segmentation of the project's ABC-XYZ matrix.

[4] Unicer's terminology for a market segment, i.e. internal market, external market, among others

[5] SKU clusters are groups of final products with different SKU, but the product's material requirements are the same. The difference between the SKUs may be something as simple as decoration, the product's destination, or a promotional price.

The ABC-XYZ Classification is a quantitative system, based on two complementary analyses: ABC (section 2.3.1) and XYZ (section 2.3.2). As previously seen, the ABC classification is based on sales volume, while the XYZ approach depends on the sales variability over time. The records' detail required for these analyses is different. The ABC analysis presents adequate results with monthly or yearly records. However, it is preferable to perform the XYZ analysis, with weekly, or even daily records, due to impossibility of studying variability in aggregate records.

The results of the joint analysis is a matrix, where the SKU clusters are grouped in one of the nine possible segments, combining the characteristics of the two analyses. Figure 3.1 presents a segmented view of Unicer's product clusters according to their quadrant of the resulting matrix. On the top left corner of each quadrant is the amount of corresponding product clusters. On the lower right corner is the sales volume of each segment, which is identified by the characters in the middle.

In Figure 3.1, it is visible that A items (high demand), are less likely to integrate the A-Z quadrant (high demand and variability), matching the description provided by the joint classification systems, where it is uncommon for products with great sales volume to be of sporadic consumption.

In Appendix A, the project's ABC-XYZ matrix is presented in greater detail.

3.2 Performance Indicators

Unicer evaluates, on a daily basis, the following KPI:

- Stock Service Level[6] (or SSL) - KPI regarding the existence of stocks in order to satisfy the orders received; It is calculated in volume, according to equation 3.1:

$$SL = SP/TO \tag{3.1}$$

  Where SP stands for stocked finished product, and TO for Total Daily Orders.

- Client Service Level - already described in section 2.6, calculated at the individual unit level, however, it takes into account product delivery delays and damages, as well as returns.

- Perfect Order[7] - The result of the decomposition of in smaller KPIs for each of the processes. Calculated at the level of the order, with a binary result: 1, if completely fulfilled; and 0, if any error is detected. The dimension of the error is irrelevant, qualifying this KPI as the most rigorous.

Unicer still calculates KPIs such as the Coverage Rate, however a "reverse engineering" of the concept, expressed in equation 2.12, is used as a Safety Stock calculation method, as seen in the

[6] Usually, this level is greater than the Client Service Level.
[7] Usually, this value is lower than the Client Service Level.

upcoming section 3.3.

3.3 Safety Stock

Because the inputs for equation 2.12 are both historical records, this KPI is only calculable post hoc. Instead, by following the next 3 steps, it's possible to understand Unicer's SS calculation approach:

1. Define a Desired Coverage Rate (or *DCR*), to replace the Coverage Rate, within the values of 0 and 1 (from 0% to 100% of a month's duration);

2. Replace the Sales portion of the equation by the monthly Forecast (or F_m) of an upcoming time period;

3. Now that two, of the three portions of the equation are known, the last is calculable. The result for equation 3.2 is a static SS value for a designated time period.

$$DCR = \underline{SS}/F_m * 100 \Leftrightarrow \underline{SS} = DCR * F_m * 100 \tag{3.2}$$

The most practical view of the Desired Coverage Rate is its time conversion. DCR must be multiplied by the amount of days in a month, obtaining a (Desired) Coverage Time (or CT[8]). And so, the calculation to obtain the SS, is detailed in equation 3.3:

$$SS = CT * F_m * 100 \tag{3.3}$$

However, this CT is a fixed constant for the whole year, for each SKU, granting it a reduced freedom to apply reductions. Even though the results for this approach are dynamic, it is inaccurate to qualify them as adaptive.

As seen in equation 3.3, the SS level depends on CT and Forecast. Since CT is constant, the only "variable" is the Forecast. This makes the results dynamic, because Forecast is very susceptible to variations from various sources. However, it is not an adaptive calculus, since the current methodology will still blindly follow the Forecast.

3.4 Production Capacity

In a scenario without production restrictions, orders are fulfilled as soon as they enter the system. However, setting up production lines is a very costly endeavour, consequently, there are

[8]The same CT values are different for each month, since 7 days are 22.6% of the 31 days in January, but 25.0% of the 28 days in February)

always minimum[9] and maximum[10] production restrictions.

The detailed mathematical model of the company's production capacity is dependant on a great variety of factors. Instead, a simplified representation of the production limitations is used - the Company Lead Time.

3.4.1 Company Lead Time

The Company's Lead Time it represents the restrictions imposed by its two components, in the productive process: the raw materials, and operation's tools' availability. It takes into consideration the description given in section 2.5. To quantify it, the maximum between two time components is chosen:

- Materials Lead Time (or MLT) - Time interval between ordering the raw materials for production and receiving them, while taking into account the materials ordering frequency.
- Production Lead Time (or PLT) - Necessary amount of waiting time required, in order to place two consecutive production orders, taking into account, production lines set-up time[11]

The maximum between these two components is chosen in a conservative approach. If a certain product's materials have an extremely high MLT, the production will be scheduled according to their arrival. On the other hand, if PLT is greater than MLT, the materials will be available for production, whenever PLT defines it. From this Chapter onwards, CLT will be used to represent the production restrictions .

[9] At times, changing the production lines set-up consumes more time than production itself, hence, minimum production lot sizes are implemented, presenting a production restriction.

[10] The production lines' output capacity are an obvious maximum production restriction.

[11] If a certain product requires the production lines to stop for several hours, in order to set them up, the product's PLT will be high. On the other hand, if a production line has a very reduced set-up time for a certain product, its PLT will be small.

Chapter 4

Safety Stock Optimization Model

The project's objective, described in section 1.2, led to the development of a methodology, based on historical records. Considering values from January 2013[1] and including the values of up to June 2015, the study encases 30 time periods.

In the upcoming chapter, a description of the proposed methodology's inputs, structure, processing and results is given.

Using the concept of CT (section 3.3), the methodology's results will be a set of time values[2] to act as CTs for every time period. The objective of these new CTs is to reduce the difference between the existing stocks, which are guided by the Forecast values, and the Sales, in order to avoid any unnecessary waste.

4.1 Analysis' Requirements

Before retrieving data records for the methodology, it is important that the user supplies the desired goals and limits, so it becomes possible to understand what the user considers waste. These parameters are:

- Desired remaining stocks at the end of each month;

  The case in study, in this dissertation, considers a desired remainder of 0%[3]. In other words, the optimal objective is not having any stock excess, at the end of each time period.

- Objective Stock Service Level;

  The case in study, in this dissertation, considers an objective SSL of, at least, 99.0%.

- Maximum and Minimum change limits;

[1] Older records present less reliable information, or the ABC-XYZ matrix is composed of products whose demand is of little relevance to the company's current scenario. Therefore, the sample is limited to the beginning of 2013.

[2] Time values have directly proportional stock levels by simply multiplying by a monthly Forecast value, as seen in 3.3.

[3] This value needs to be a percentage, in order to be usable between time periods, as well as between products.

The methodology's results are limited using this parameter, in case the user has a reduced capacity to perform modifications to its system. The change limits for the case in study, in this dissertation, were strategically set as extreme in order to study the full potential of the methodology's results.

4.2 Data Inputs, Stock and Remainder

The proposed methodology that was used relies on four data sets per SKU: Real Demand, Demand Forecast[4], Coverage Time (CT), and Company's Lead Time (CLT)s. CLT's application in the methodology will be explained in section 4.5.

With the first three inputs, it is possible to calculate Unicer's current values of:

- Initial Aggregate Monthly Stock[5] level.

  In order to calculate the Stock level, while taking into consideration equation 3.3, equation 4.1 is used:

$$Stock = F_m + CT * F_m \tag{4.1}$$

Then, by subtracting the Real Demand from the Stock, we obtain the:

- Initial Remainder , observed at the end of each month, as seen in equation 4.2:

$$Remainder = max\{0, Stock - Real\} \tag{4.2}$$

Figure 4.1, depicts the inputs of equations 4.1 and 4.2.

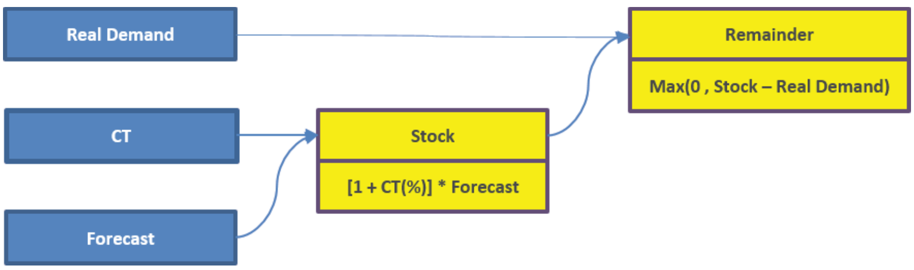

Figure 4.1: Flow chart representation of equation 4.1 and 4.2.

This initial Remainder will be the term of comparison towards the results presented by the methodology.

In the proposed methodology, the CT becomes a Monthly CT (or MCT). As the name implies, MCT has the potential to be different each month, and, as such, the SS level will may be adaptively calculated on a monthly basis.

[4]The used Forecast is obtained beforehand and then compared with the Real Demand of the respective time periods.
[5]The Stock level is non-linear, because the smallest production units are taken into account. Stock will always be a multiple of the smallest producible unit, which is the amount a pallet can hold.

4.3 Monthly Coverage Time

To obtain MCT, the first step is the generating an array of 12 MCTs equal to the original CT, according to equation 4.3.

$$MCT = CT * (1 - r) \tag{4.3}$$

Where r is a scalar[6] factor of multiplication, started with the value of 0. Resulting in the values on Table 4.1.

Table 4.1: Created MCT values from CT.

CT	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
7	7	7	7	7	7	7	7	7	7	7	7	7

Considering equation 4.1, the Monthly aggregate Stock (MStock) is calculated, using the MCT and Forecast values. Consequently, the Monthly Remainder (MRemainder) is calculated, as in equation 4.2, using MStock, instead of Stock.

At this point, the Remainder and MRemainder are the same, however the MCT values are susceptible to variations provoked by r, which will be modified, using Microsoft Excel's Goal Seek.

4.4 Goal Seek Analysis

Goal Seek is a Microsoft Excel's built in What-If Scenario Analysis tool. It is a numeric method used to find the zero of a function. By running the Goal Seek algorithm, upon r in equation 4.3, in order to reach the user's goals, set in section 4.1, a recommended set of scalars is obtained, and recorded separately, for each time period.

The Goal Seek tool runs twice for everyone of the 30 time periods per product, so a compariosn may be performed afterwards. Firstly, to satisfy the first goal of having no Remainder at the end of each month. The results provided by this method disregard the Demand Variability discussed in section 2.5.1. So, to account for this variability, Goal Seek runs once more, in order to reach the second, and most important, objective of the analysis, the SL of 99.0%. This is done by comparing the MCT stock level and the Sales records, on a daily basis.

However, the results provided the Goal Seek analysis need to be carefully handled. This process consists on filtering the results twice.

The first filter considers the acceptable change limits set by the user. If a recorded resulting scalar is considered disproportional according to the user's predefined limits, it will be restrained.

[6]This scalar should be interpreted as a reduction. As r increases, MCT decreases, as well as the opposite.

Once the new set of filtered scalars is obtained, a new filter is applied. Since our aim is 12 monthly CTs for future implementation, and, at the moment, there are 30 scalars, per product, for each of the time periods in study. So, the minimum reduction among the analogous months over the three years is assigned as the adequate r. This selection aims to be conservative, in order to never apply inadequate reductions.

The MCT values obtained from the Goal Seek Analysis are theoretical, disregarding any kind of production restrictions. As such the methodology's results need to be limited and, in case MCT is the same as CT, an alternative should be presented.

4.5 Company Lead Time & Alternative Safety Stock

Having the production restrictions in mind, and as described in section 3.4, CLT is used as the lower bound for the methodology's results.

With CT, CLT and MCT as the only inputs available in order to obtain the optimal value of the SS level, and knowing that CLT and CT are the bounds of the result, this can be seen as a rather incomplete approach, since the inputs are either constants, or based on a non-linear method (Goal Seek Analysis[7]). Presenting an alternative input is an advisable strategy, and the most adequate proposal is none other than the Safety Stock calculation method discussed in section 2.5.1.

The alternative Safety Stock (or SSAlt) is based on an average of the Real Demand, its variability[8], as well as the CLT, which is considered to be constant. SSAlt's inputs are depicted by the blocks in figure 4.2.

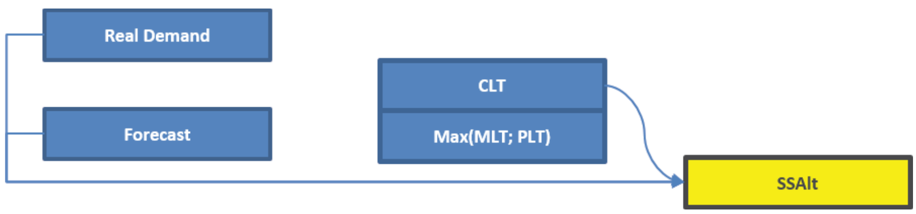

Figure 4.2: Alternative Safety Stock's inputs.

Consequently, once the static value of SSAlt is calculated, using an average of the Forecast values for the analogous months, one obtains a time conversion[9] of SSAlt's result.

[7]The Goal Seek Analysis' result is non-linear, because the MCT calculation is based on non-linear formulas.

[8]The average of Real Demand is calculated for the analogous months' Sales over the three years in study. The Sales' Variability is calculated as an average of the variability of the company's daily Sales records for each analogous month.

[9]Number of days or percentage of the month for the respective analogous months. Depending on the handled measurement unit, the adequate value is used. If handling a monthly value, it applies a percentage of the month, or else, if handling daily averages, it applies a number of days.

4.6 Resulting CT

Following the structure of this Chapter, once the SSAlt is calculated, all of the methodology's requirements have been met, to enter its final stage, where CT, CLT, MCT and SSAlt act as the inputs for the methodology's last process, as seen in figure 4.3.

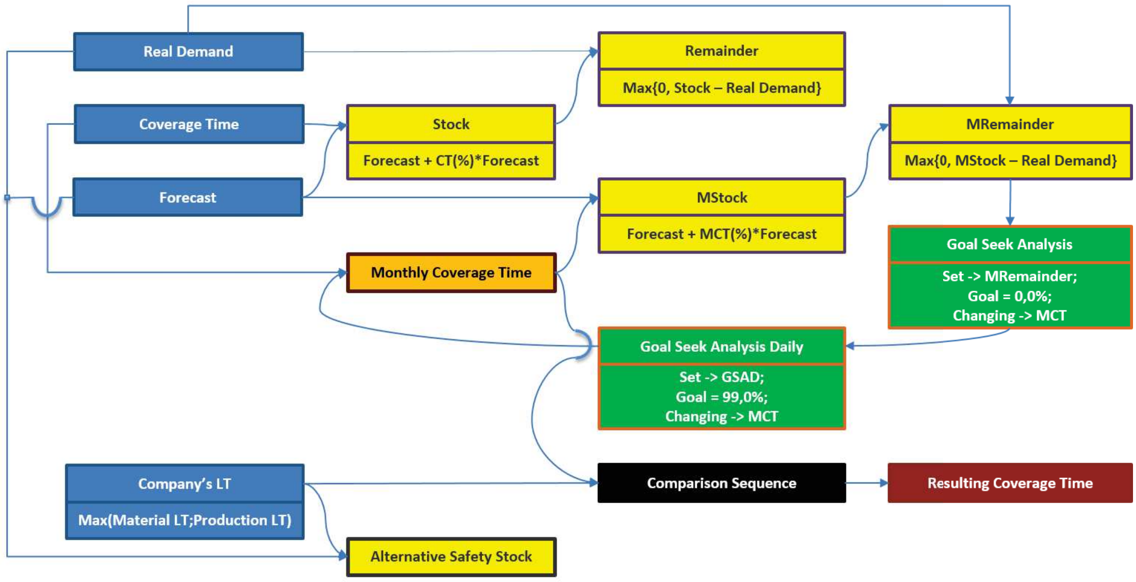

Figure 4.3: Flow chart representation of the proposed optimization methodology.

Figure 4.3 is the complete methodology's flow chart diagram. In it, all of the previously mentioned concepts are depicted, where:

- The blue-coloured blocks are the methodology's data inputs.
- The yellow-coloured ones are the result of formulas or equations.
- The green-coloured blocks represent the Microsoft Excel's Goal Seek tool algorithms.
- The orange-coloured block is the Goal Seek Analysis' result.
- The black-coloured block depicts the succession of comparisons in order to reach a Resulting CT (RCT), which is represented in Figure 4.4.

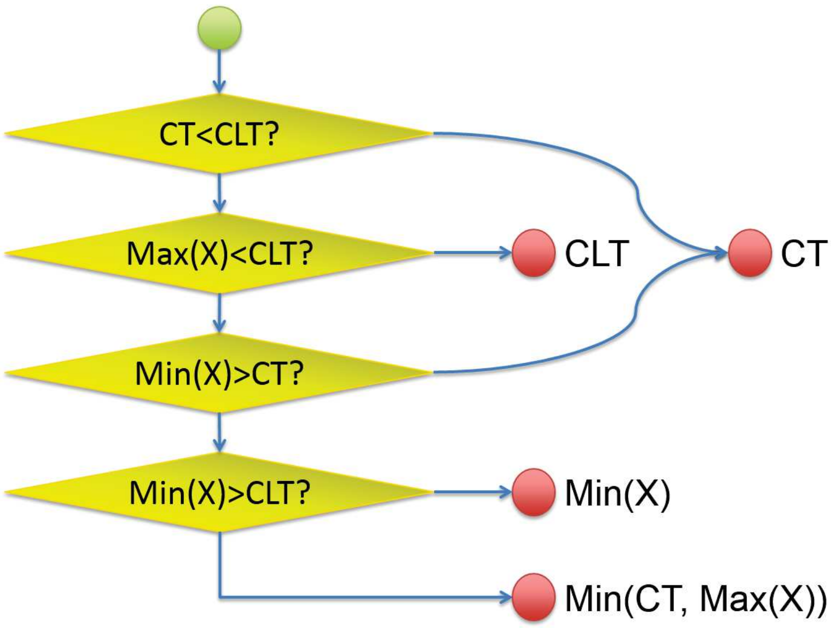

Figure 4.4: Flow chart representation of the comparison sequence to obtain the resulting CT.

The depicted comparison has the following sequence:

1. Is the Coverage Time smaller than the Company's Lead Time?

   If so, this is a great example of CT parametrization and RCT should remain as CT.

   If not, the next comparison is verified.

2. Is the maximum value among the Monthly Coverage Time and the Alternative Safety Stock smaller than the Company's Lead Time?

   If so, CLT should be assigned as the new RCT, otherwise, the production restrictions, would be disregarded.

   If not, the next comparison is verified.

3. Is the minimum value among the Monthly Coverage Time and the Alternative Safety Stock greater than the Coverage Time?

   If so, RCT remains as the initial CT, because there is no added value in increasing the SS level, as long as it presents the desired SSL.

   If not, the next comparison is verified.

4. Is the minimum value among the Monthly Coverage Time and the Alternative Safety Stock greater than the Company's Lead Time?

   If so, the minimum value among MCT and SSAlt is assigned as the new RCT, because there is a value that matches all previous criteria.

   If not, the minimum value among CT and the maximum value among MCT and SSAlt is assigned as the new RCT. Meaning that, as last resort, no change is done.

4.6.1 Lead Time vs Alternative Safety Stock

Although SSAlt is a function of CLT, and both are inputs for the comparison sequence, their results complement, instead of offsetting each other.

When comparing them, SSAlt suggests a time value based on the average and variability of a product's daily Sales records. While CLT is itself a time value, which corresponds to another independent stock level.

4.6.2 Additional Restriction

Based on the experience of Unicer's professionals, another restriction was added, in which the lowest acceptable time value (CLT) was that of 3 days. In other words, if MCT or SSAlt present an unexpectedly low time value, the lower bound always assures the minimum of 3 days of CT. This limitation was strategically set in order to cover the absence of workforce during weekends, when necessary.

4.7 Initial Results

The proposed methodology was initially tested in the A-X quadrant of the ABC-XYZ matrix (according to the classification mentioned in section 3.1.1). As soon as the methodology was complete, its application was expanded to the remaining A product groups (A-Y and A-Z).

The reason behind this choice is, as previously explained in section 2.3, besides their greater financial impact for the company, their variability's behaviour made their study more interesting and valuable to the project.

The methodology's initial results are in appendix B, in figures B.1 and B.2, for the A-X, A-Y, and A-Z quadrants, respectively.

Having CT and CLT, one can immediately observe the methodology's result range, and that all of the Resulting Coverage Times are within those bounds.

Chapter 5

Model's Results Validation

In this Chapter, the results, of the proposed methodology in Chapter 4, undergo a graphical and mathematical validation, in order to evaluate the quality of the methodology's results.

Initially, the stock levels mentioned in section 4.6 are graphically represented, in order to visually express RCT's behaviour in comparison with the actual stock levels, and then, in the following section the methodology's results are validated mathematically, along with a comment of the observable results.

5.1 Graphical Comparison

Since the amount of inputs for obtaining RCT is rather small, the graphical representation reveals all of them, therefore simplifying the identification of the RCT's determining factor, as seen in Figure 5.1, where MCT is visibly assigned as RCT.

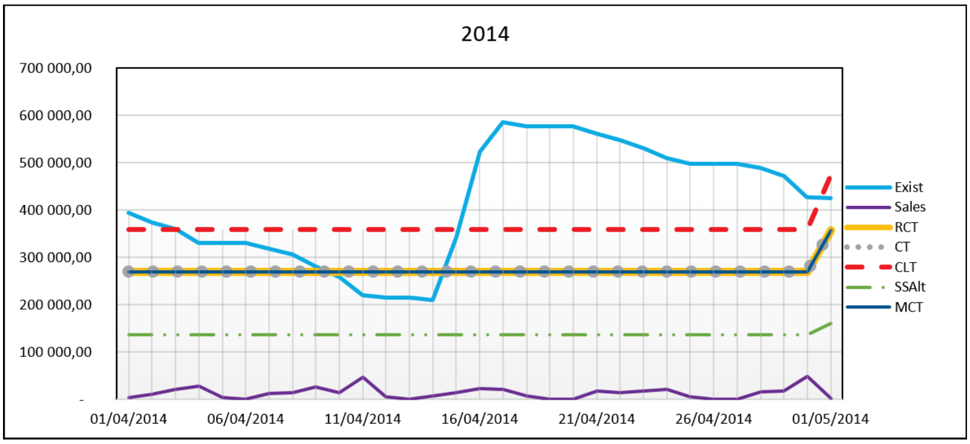

Figure 5.1: Example of a graphical representation of the methodology's results.

In Figure 5.1, the represented levels correspond to records of daily Existences, daily Sales, as well as RCT, CT, CLT, SSAlt and MCT.

The first assessment in the validation process is verifying if the Sales' value is greater than any stock level. Then, according to their different behaviours, it's possible to classify them. Appendix C, contains Figures[1] C.1, C.2, C.3 and C.4, which represent the four types of observed behaviours, which are:

1. No Improvement - as seen in Figure C.1, which is characterized by having a CLT greater than CT. Since CLT is our lower bound and CT is already lower than CLT, no changes are done and RCT remains as CT, as explained in 4.6. This situation is most likely witnessed in products with greater sales volume, which is commonly seen on A-X quadrant.

2. Clear Improvement - as seen in Figure C.2, where demand presents a reduced variability and when compared with the suggested stock level, there isn't a moment in which the Sales' value exceeds the original CT, or even the CLT level. So, an optimization presents virtually no risk, and has a clear impact on the stock levels.

3. Few Excesses - as seen in Figure C.3. This situation highlights a product in which the Sales' peaks are close to the lowest suggested SS levels. If the average stock level was in question, such behaviour would be worrisome. However, the stock level in question is the desired minimum.

4. Response to Orders - as seen in Figure C.4 the last type of behaviour is an example of a product with an extremely erratic variability. Therefore, an accurate forecast proves to be a difficult task. Optimizing the SS level is possible, however, the implementation of similar strategies must be a carefully monitored process.

[1] These Figures have a high amount of detail and are quite large, such they will not be transported to the middle of the Chapter.

5.2 Mathematical Comparison

The most practical way to calculate the efficiency of the proposed methodology's results is to perform a daily comparison of the Sales records and the RCT level, which will provide a ratio, previously described as SSL. Tables 5.1, 5.2 and 5.3 reflect the SSL, for each of the quadrants A-X, A-Y, and A-Z, respectively.

Table 5.1: Mathematical validation table for A-X quadrant.

SKU	Designação	SSL
100001130	SB ORIG. BARRIL 30L	99,56%
100001150	SB ORIG. BARRIL 50L	99,45%
100302020	SB ORIG. BARRIL TP 20L	100,00%
100304610	SB ORIG. TP 1Lx6 TB	100,00%
104304025	SB ORIG. TP 0,25x24 CX PULL OFF	93,08%
110204633	CRISTAL TP 0,33x6*4 SH	100,00%
110823020	CRISTAL TR 0,20x30 GR	100,00%
115004025	CRISTAL TP 0,25x24 CX PULL OFF	94,62%
900303010	VITALIS TR 1Lx12 GR NID	100,00%
900306005	VITALIS PET 5Lx3 SH NID	100,00%
900306015	VITALIS PET 1,5Lx12 SH NID	100,00%
900306033	VITALIS PET 0,33x24 SH NID	99,89%
900306050	VITALIS PET 0,50x24 SH NID	100,00%
900306105	VITALIS PET 5L NID	99,78%
900346615	VITALIS PET 1,5Lx6 SH NID	99,45%
900356105	VITALIS PET 5L ½PAL NID	100,00%
920704025	PS TP 0,25X24 TB BEST	99,78%
920704625	PS TP0,25X6*4 SH PT/FR/AL B	100,00%
940006015	CARAMULO PET 1,5Lx12 SH	100,00%
940006033	CARAMULO PET 0,33x24 SH	100,00%
940006050	CARAMULO PET 0,50x24 SH	100,00%
940006615	CARAMULO PET 1,5Lx6 SH	100,00%
940096105	CARAMULO PET 5Lx144	99,89%

On Table 5.1, a great majority of the products present a rate of 100%. As expected from a quadrant with low variability, the requirements for most of the cases will be completely satisfied even with a lower SS level.

It's important to point out that products 104304025 and 115004025 (the ones gravely below 99.0% level), are products for which the methodology has not proposed any changes. In other words, the RCT is the same as the initial CT, and such behaviour is the current reality.

On Table 5.2, the majority of the products does not present results as stable as in the previous quadrant. This agrees with the XYZ classification, since sales variability increases from an X to Y classification.

Table 5.2: Mathematical validation table for A-Y quadrant.

SKU	Designação	SSL
100308033	SB ORIG. LATA 0,33x24 SH	99,67%
100503020	SB ORIG. TR 0,20x30 GR SC	100,00%
100503033	SB ORIG. TR 0,33x24 GR SC	100,00%
100504120	SB ORIG. TP 0,20x10*2 SH SC	100,00%
100534633	SB ORIG. TP 0,33x6*4 SH SC	99,89%
100804025	SB ORIG. TP 0,25x20 CX SC	97,80%
100804520	SB ORIG. TP 0,20x15 CX SC	98,90%
105704625	SB ORIG. TP 0,25x6*4 SH EXP BP	99,89%
105714033	SB ORIG. TP 0,33x24 CX EXP PAL RET 60 BP	100,00%
105784025	SB ORIG. TP 0,25x24 CX EXP BP	99,12%
110423033	CRISTAL TR 0,33x24 GR	100,00%

In this quadrant, as previously explained in section 5.1 regarding the third type of behaviour, the SS level in question (RCT) is the desired, not the average, minimum.

And increasingly, the sales variability is reflected in the SSL, as seen on Table 5.3, where no product presents a SSL of 100%, and not all products present a SSL of 99.0%.

Table 5.3: Mathematical validation table for A-Z quadrant.

SKU	Designação	SSL
100004125	SB ORIG. TP 0,25x10*2 SH EC	96,71%
100804020	SB TP 0,20x24 CX SC	99,12%
100804033	SB ORIG. TP 0,33x24 CX SC	99,45%
105324033	SB ID TP 24x0,33 AFRICA	97,04%

A perfect maintenance of the Safety Stocks for a vast product portfolio is a difficult task, therefore maintaining the observed levels is a great achievement.

Chapter 6

Scenario Analysis

After the methodology's results propose a new set of CT (RCT) (Chapter 4) and they are validated (Chapter 5), there is a need to quantify these results. In the upcoming chapter, the methodology's results (both initial and the scenario's) are compared with the initial Remainder mentioned in section 4.2 and then monetized. This way, the results of all scenarios can be compared on equal footing.

After running the methodology, a Resulting Remainder (RRemainder) is obtained, while using the RCT values to obtain a Resulting Stock (RStock), similarly to equation 4.1 and then subtracting Real Demand to it, using the same logical process as in equation 4.2. Consequently, the Improvement is measured using equation 6.1.

$$Improvement = Remainder - RRemainder \tag{6.1}$$

Until now, all records have the same measurement unit: the litre. To perform the necessary calculations for the methodology, this unit is adequate. However, to universally quantify the proposed improvement, this unit is not the most useful, since a litre of water is not the same as a litre of beer, and their financial value reflects it. Using each product's internal production cost, every litre has a direct value in €. The monetization is done by averaging the overall improvement, over the amount of months with demand and then the average is multiplied by the respective internal production cost.

6.1 Initial Results

The initial results encase the monetization of the overall improvement after applying the methodology over the three studied quadrants, as seen in Tables D.1 and D.2. The monetized improvement should be seen as an average yearly saving. The results of all scenarios will be detailed in the last section of this Chapter.

6.2 Scenarios

The upcoming scenarios follow the exact same methodology, but have different data inputs. In order to create plausible scenarios there's a need to understand which parameters are susceptible to change.

The user's input parameters and CT are the objectives of the methodology.

Real Demand and Forecast are invariable, since they are data records.

Therefore, CLT is the parameter under analysis during this project's stage. Since CLT is dependent on its two components (MLT and PLT), there is a possibility to create and analyse scenarios bi-dimensionally.

6.2.1 Material Restriction Scenario (MRS)

The following scenario regards changes done exclusively to MLT. In this scenario, the material requirements are always assured. Therefore, the restrictions fall over the production requirements (PLT).

The single selection criterion for this scenario is that MLT must define CLT. Assuming a product's materials are always available in the warehouse, their internal LT is one day. So, in this scenario, all selected product's MLT will be considered 1.

Taking into account every product of the three quadrants in study, only three products present different improvements as seen on table 6.1.

Table 6.1: Comparison of monetized savings between the Initial Scenario and MRS.

SKU	Description	Init	MRS
100302020	SB ORIG. BARRIL 20L	- €	14 453,23 €
900306005	VITALIS PET 5Lx3 SH NID	- €	6 977,26 €
920704625	PS TP0,25x6*4 SH PT/FR/AL B	27 916,67 €	68 484,86 €

On the other hand, in order to ensure the material requirements, additional costs would need to be accounted for. However, most of the material requirements' responsibility is up to the suppliers and when it isn't, the actual costs are unvarying as explained in the introduction of Chapter 3.

This scenario presents improvements in comparison to the initial results. So, it's safe to conclude that this scenario is applicable and Unicer can implement purchase politics to change these product's MLT.

6.2.2 Production Restriction Scenario (PRS)

In this scenario, the product selection is made according to the following criteria:

- LT needs to be defined by PLT.
- LT needs to be greater than the average of all product's LT.
- There are production lines with the adaptability potential to produce other items.

  This final criterion implies that the selected products are categorised as glass bottled beer, with returnable or one-way bottles.

Table 6.2 contains which products fit this scenario's criteria, and the initial and adapted amount of production lines, along with the corresponding PLT.

Table 6.2: Side by side representation of the changes made to PLT.

SKU	Description	IL	Init. PLT	AL	Adapt. PLT
100304610	ORIG. TP 1Lx6 TB	1	28	2	14
110204633	CRISTAL TP 0,33x6*4 SH	2	14	3	10
110823020	CRISTAL TR 0,20x30 GR	2	14	3	10
100503020	SB ORIG. TR 0,20x30 GR SC	2	14	3	10
110423033	CRISTAL TR 0,33x24 GR	1	14	2	7

Assuming that the output capacity of each production line is equivalent, the adapted PLT is the rounded up result of equation 6.2.

$$A.PLT = I.PLT * I.L./A.L. \tag{6.2}$$

Where $A.PLT$ stands for adapted PLT, $I.PLT$ for initial PLT, $I.L.$ for initial amount of production lines and $A.L.$ for adapted amount of production lines.

Table 6.3: Comparison of monetized savings between the Initial Scenario and PRS.

SKU	Description	Init	PRS
100304610	ORIG. TP 1Lx6 TB	- €	26 661,84 €
110204633	CRISTAL TP 0,33x6*4 SH	- €	16 382,17 €
110823020	CRISTAL TR 0,20x30 GR	12 370,78 €	21 173,17 €
100503020	SB ORIG. TR 0,20x30 GR SC	- €	28 527,25 €
110423033	CRISTAL TR 0,33x24 GR	9 851,02 €	26 078,84 €

Now, taking into account the necessary investment to adapt a production line, the last step is calculating the time required to obtain return on investment (or RoI).

The company accepts a maximum of 2 years for this type of investment to bear fruit, however, none of the products present such a quick return on investment. Besides, the fact that the improvements are seen as savings, makes the financial impact very different.

Table 6.4: Evaluation of the time required to obtain a return on investment.

SKU	Description	PRS - Init	Adapting Cost[1]	RoI (Years)
100304610	ORIG. TP 1Lx6 TB	26 661,84 €	150 000,00 €	5,63
110204633	CRISTAL TP 0,33x6*4 SH	16 382,17 €	40 000,00 €	2,44
110823020	CRISTAL TR 0,20x30 GR	7 550,38 €	180 000,00 €	23,84
100503020	SB ORIG. TR 0,20x30 GR SC	28 527,25 €	180 000,00 €	6,31
110423033	CRISTAL TR 0,33x24 GR	16 227,82 €	80 000,00 €	4,93

Seeing that the expected investment for any of the line adaptations presents a slow return, from a financial point of view, this scenario is not beneficial in comparison with the initial results, deeming this scenario inapplicable.

6.2.3 Material & Production Restrictions Scenario (MPRS)

This scenario is a combination of both the criteria and results of MRS and PRS. In other words:

- If their CLT is defined by MLT, consider it 1.
- If CLT follows the PRS criteria, evaluate the results upon the adaptation of a production line.

In this scenario, a greater amount of products is selected and the results have a much greater impact, as seen in Table 6.5. It is also possible to see that no product is affected by both scenarios, simultaneously.

Table 6.5: Comparison of monetized savings between the Initial Scenario and MPRS.

SKU	Description	Init	MPRS
100302020	SB ORIG. BARRIL TP 20L	- €	14 453,23 €
100304610	SB ORIG. TP 1Lx6 TB	- €	26 661,84 €
110204633	CRISTAL TP 0,33x6*4 SH	- €	16 382,17 €
110823020	CRISTAL TR 0,20x30 GR	12 370,78 €	19 921,16 €
900306005	VITALIS PET 5Lx3 SH NID	- €	6 977,26 €
920704625	PS TP0,25X6*4 SH PT/FR/AL B	27 916,67 €	68 484,86 €
100503020	SB ORIG. TR 0,20x30 GR SC	- €	28 527,25 €
110423033	CRISTAL TR 0,33x24 GR	9 851,02 €	26 078,84 €

Since no product is affected by both scenarios, the decision to apply any of the scenarios is independent, and, therefore, simpler. The results support the conclusions of sections 6.2.1 and 6.2.2, in which MRS is viable, and PRS is not.

6.3 Result Comparison

Each result comparison done so far regards only the selected products for each scenario and the initial scenario's results. The most appropriate comparison must be done including all products across all scenarios, as seen in Table 6.6, where for every scenario, the results of each quadrant are detailed in their absolute value, and in a relative proportion of the initial Remainder.

Table 6.6: Comparison of monetized savings between all scenarios.

		Δ MLT					
		Init			MRS		
Δ PLT	Init	A-X	178 284,00 €	19,04%	A-X	240 282,68 €	22,55%
		A-Y	370 962,37 €	22,66%	A-Y	370 962,37 €	22,66%
		A-Z	121 256,22 €	20,79%	A-Z	121 256,22 €	20,79%
		TOTAL	670 502,60 €		TOTAL	732 501,27 €	
	PRS	A-X	228 878,39 €	21,11%	A-X	290 877,07 €	24,56%
		A-Y	415 717,44 €	27,71%	A-Y	415 717,44 €	27,71%
		A-Z	121 256,22 €	20,79%	A-Z	121 256,22 €	20,79%
		TOTAL	*135 852,05 €		TOTAL	*197 850,73 €	

The marked results (*), represent the improvement, while accepting the required investment of approximately 630 000 €to adapt all of the production lines. Naturally, the grandeur of the investment takes a proportional toll upon the scenario's total results.

The optimal solution is to apply the Material Restriction Scenario, while disregarding any modifications to the PLT.

Chapter 7

Conclusions & Suggestions

In this last Chapter, a description of the project's methodology is given, along with the presentation of the project's resulting tool, suggestions towards the tool's implementations and recommended future works. Lastly, a brief conclusion is expressed.

7.1 Methodology

During the initial study of the company's Safety Stock calculation methodology, the concept of Coverage Time immediately became the focus of the project. A correct parametrization of this factor has direct effects over the company's operation.

In order to narrow the range of products in the study, a segmentation was put performed according to their sales' volume and variability, namely, the ABC-XYZ classification. To diagnose flaws in the current methodology, the most effective approach was to analyse data records, and, based on them, state which should have been the optimal coverage, while ensuring the user's defined SSL.

To maintain the proposed methodology's results' coherence, the production capacity is taken into account, and represented as the CLT (concerning both the Materials' and Production's requirements).

To add value to the presented results, an alternative SS is calculated using the normal distribution's Safety Stock calculation method.

The proposed methodology's results range from the Company Lead Time, acting as the lower bound, to the Coverage Time, acting as the upper bound and the starting point.

The results were then graphically and mathematically validated, expressing the result's contributing factor, according to the suggested levels, and the Stock Service Level, considering the daily Sales' records.

The methodology was then tested in a set of scenarios, presenting not only the relative and absolute improvement, as well as the scenario's applicability.

7.2 Project's Result

The project led to the development of a SS level calculation tool, based on historical records, designed to:

1. Modify the company's Safety Stock calculation method, making it adaptive, while dynamic;
2. Optimize the safety stock levels per time period;
3. Validate the methodology's results; and
4. Study a set of scenarios which can be combined, among them;

The tool was successfully completed taking into account the initial purposes of the project (1 & 2), as well as the additional objectives that were set along the way (3 & 4).

7.3 Implementation Suggestion

Products whose behaviour is identical the second situation described in section 5.1 should be parametrized accordingly, without hesitation.

Ignoring the first behaviour which suggests no changes in the parametrizations, the third and fourth behaviours' parametrization must be slowly implemented in the company's working environment, if at all, while analysing their impact upon the company's operation.

The most relevant distinction between the tested scenarios (MRS and PRS) is the implementation cost. The Material Restriction Scenario can be implemented at virtually no cost, directly providing advantages, while the Production Restriction Scenario has a high implementation cost, thus rendering the RoI unacceptable. Especially since the proposed improvement is seen as an average yearly saving.

This leads to the conclusion that only the MRS should be implemented along the usage of the proposed methodology.

Attempting to implement the MRS without the proposed methodology yields no benefits, as the improvements are directly related to the parametrization of CT and not the reduction of CLT.

7.4 Further Improvements

The treated problematic, described in section 1.2, considers the global chain as a unique production and distribution centre.

A possible improvement would be the structuring of the distribution network, and assign optimal Safety Stock levels per centre, linking the Stock Service Level and the Client Service Level.

To develop the proposed methodology, static periods of time were taken into consideration, in order to understand the evolution of each product's results. However, once the methodology was complete, it became possible to adapt the methodology to non-static periods of time.

The project's next step is a program whose inputs are the product's SKU, the desired time periods under study (ideally multiples of 12), CT, CLT (MLT & PLT) and the user's inputs that were mentioned in section 4.1. The output is a set of recommended RCT, while presenting result validations on a daily basis and the comparative results for the various scenarios. An example of an interface for the mentioned program is visible in figure 7.1.

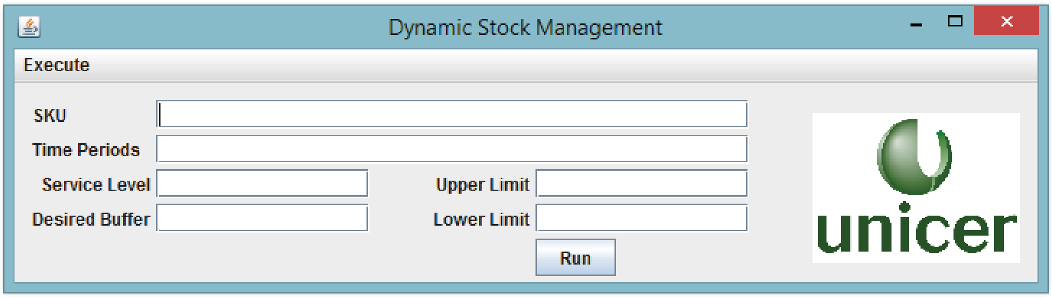

Table 7.1: Possible interface for a program version of the proposed methodology.

7.5 Conclusion

As long as the seemingly chaotic, industrial environment, remains unchanged, an unbiased perspective will always bring unexpected results. That was the fundamental teaching obtained through this experience.

Appendix A

ABC-XYZ Matrix

	X		Vol
A	CL0474 | A	104304025 - SB ID PULL OFF TP 24x0,25	16,03%
	CL0576 | C	115004025 - CRISTAL TP 0,25x24 CX POFF	7,59%
	CL0017 | A	100001150 - SUPER BOCK BARRIL 50 L	6,05%
	CL0013 | A	100001130 - SUPER BOCK BARRIL 30 L	2,96%
	CL0137 | A	920704625 - PS TP 0,25X6*4 PT/FR/AL	1,78%
	CL0175 | A	900006015 - VITALIS PET 1,5 L	1,67%
	CL0183 | A	940006015 - CARAMULO PET 1,5 L	1,53%
	CL0181 | A	940006033 - CARAMULO PET 0,33 L	1,52%
	CL0172 | A	900006050 - VITALIS PET 0,50L	1,47%
	CL0489 | A	900746615 - VITALIS PET 1,5Lx6 SH	1,37%
	CL0169 | A	900006033 - VITALIS PET 0,33L	1,18%
	CL0182 | A	940006050 - CARAMULO PET 0,50 L	1,16%
	CL0165 | A	900316105 - VITALIS PET 5 L Â½ PALETE	1,13%
	CL0178 | A	900306105 - VITALIS PET 5 L	1,07%
	CL0173 | A	900003010 - VITALIS TR 1 L	0,96%
	CL0066 | A	100304610 - SUPER BOCK ID TP 6x1L	0,93%
	CL0012 | A	100302020 - SB ORIG. BARRIL TP 20L	0,90%
	CL0186 | A	940096105 - CARAMULO PET 5L PAL 144	0,77%
	CL0179 | A	900006005 - VITALIS PET 5 L 3-P	0,75%
	CL0148 | B	920704025 - PEDRAS SALGADAS TP 0,25x24	0,67%
	CL0117 | B	110823020 - CRISTAL TR 0,20 C30	0,62%
	CL0042 | A	110204633 - CRISTAL NS TP 6 x 0,33	0,61%
	CL0185 | B	940006615 - CARAMULO PET 6x1,5L	0,54%
			53,27%

Figure A.1: A-X quadrant of the ABC-XYZ resulting matrix.

		Y	Vol
A	CL0083 | A	100503033 - SUPER BOCK ID TR 24x0,33	7,57%
	CL0089 | A	100503020 - SB ORIG. TR 0,20x30 GR	2,49%
	CL0061 | A	105704625 - SB TP 0,25x6*4 SH EXP BP	1,92%
	CL0480 | A	100804025 - SB ORIG. TP 0,25x20 CX SC	1,76%
	CL0047 | A	100534633 - SUPER BOCK ID TP 6x0,33	1,48%
	CL0100 | A	100504120 - SUPER BOCK ID TP 10x0,20	1,36%
	CL0351 | A	105784025 - SB TP 0,25x24 CX EXP BP	1,34%
	CL0087 | A	110423033 - CRISTAL TR 0,33	0,98%
	CL0058 | A	105714033 - SB TP 0,33x24CX EXP PAL60 BP	0,88%
	CL0299 | A	100804520 - SB TP 0,20x15 CX SC	0,61%
	CL0055 | B	100308033 - SUPER BOCK ID LATA 24x0,33	0,52%
			20,90%

Figure A.2: A-Y quadrant of the ABC-XYZ resulting matrix.

		Z	Vol
A	CL0301 | A	100804020 - SB TP 0,20x24 CX SC	2,16%
	CL0065 | A	100804033 - SB ORIG. TP 0,33x24 CX SC	1,53%
	CL0361 | A	105324033 - SB ID TP 24x0,33 AFRICA	0,96%
	CL0602 | C	100004125 - SB ORIG. TP 0,25x10*2 SH EC	0,70%
			5,35%

Figure A.3: A-Z quadrant of the ABC-XYZ resulting matrix.

		X	Vol
B	CL0570 | B	100334033 - SB ORIG. TP 0,33x24 CX F	0,49%
	CL0171 | B	900003250 - VITALIS TR 0,50 (C20)	0,47%
	CL0147 | B	920303025 - PEDRAS SALGADAS TR 0,25	0,47%
	CL0146 | B	920006010 - PEDRAS SALGADAS PET 1,0L 4-P	0,45%
	CL0341 | B	940006005 - CARAMULO PET 5 L 3-P	0,41%
	CL0136 | B	920754625 - PEDRAS SALGADAS TP6 0,25 1/2	0,37%
	CL0213 | B	560016615 - FRUTIS LARANJA PET 1,5 L 6-P	0,35%
	CL0569 | C	115011130 - CRISTAL BARRIL 30L ESPANHA	0,35%
	CL0076 | B	290204633 - MARINA NS TP 6 x 0,33	0,30%
	CL0093 | B	240503033 - SB STOUT ID TR 24x0,33	0,29%
	CL0159 | B	920144425 - PEDRAS LIM/CHÃ TP 0,25 4-P	0,29%
	CL0070 | B	270504633 - SB SEM ALCOOL ID TP 6x0,33	0,29%
	CL0062 | B	240504633 - SB STOUT ID TP 6 x 0,33	0,26%
	CL0022 | B	120001130 - CARLSBERG BARRIL 30 L	0,24%
	CL0230 | B	570708033 - FRUTEA PES LATA 0,33x24 BP	0,23%
	CL0204 | B	480101120 - SNAPPY COLA BARRIL 20L COMP	0,23%
	CL0503 | B	110014610 - CRISTAL TP 6 x 1 L	0,22%
	CL0138 | B	920314625 - PED.SAL.TP 6 0,25 1/2PAL DUS	0,22%
	CL0229 | B	570108033 - FRUTEA LIMÃƒO LATA 0,33L COMP	0,21%
	CL0231 | B	570208033 - FRUTEA MNG/MAR LAT0,33L COMP	0,19%
	CL0149 | B	920103075 - PEDRAS SALGADAS TR 0,75 GN	0,19%
	CL0009 | B	100308633 - SUPER BOCK ID LATA 6x0,33	0,18%
	CL0144 | B	920606633 - PEDRAS SALGADAS PET 0,33 6-P	0,18%
	CL0118 | C	240503020 - SB STOUT ID TR 30x0,20	0,17%
	CL0168 | C	900506633 - VITALIS PET 0,33 6-P (1X6GF)	0,16%
	CL0095 | B	270503033 - SB SEM ALCOOL ID TR 24x0,33	0,15%
	CL0446 | B	110204120 - CRISTAL NS TP 10 x 0,20	0,15%
			7,50%

Figure A.4: B-X quadrant of the ABC-XYZ resulting matrix.

		Y	Vol
B	CL0298 | A	100814020 - SB TP 0,20x24 CX Â½PAL SC	0,52%
	CL0014 | B	105111130 - SUPER BOCK BARRIL 30L EXP (V	0,51%
	CL0092 | B	120323025 - CARLSBERG TR 0,25 C30 NI	0,47%
	CL0052 | B	105704633 - SB TP 0,33x6*4 EXP PAL60 BP	0,38%
	CL0338 | C	920354633 - PEDRAS PET 6x0,33 1/2 PAL	0,37%
	CL0056 | B	100308050 - SUPER BOCK ID LATA 24x0,50	0,36%
	CL0015 | B	105001130 - SUPER BOCK BARRIL 30 L FRANÇ	0,27%
	CL0201 | B	400051120 - SNAPPY LIMA LIMÃƒO BARRIL 20L	0,26%
	CL0496 | C	391034033 - SOMERSBY TP 0,33x24 CX	0,25%
	CL0152 | B	920704125 - PEDRAS SALGADAS TP 0,25X10*2	0,24%
	CL0205 | C	590006615 - GUARANA BRASIL PET 1,5 L 6-P	0,23%
	CL0568 | C	391004433 - SOMERSBY TP 0,33x4*6 TB	0,20%
	CL0208 | B	430516415 - FRISUMO LAR PET 1,5L 4P COMP	0,20%
	CL0495 | C	391021130 - SOMERSBY BARRIL 30L	0,19%
	CL0211 | B	430566415 - FRISUMO ANANÃS PET 1,5Lx4 SH	0,19%
	CL0533 | C	365004633 - SB NEGRA SIN ALCOHOL TP6x33	0,19%
	CL0040 | B	160204633 - CHEERS NS TP 6 x 0,33	0,18%
	CL0227 | B	430518033 - FRISUMO LARANJA LATA 0,33L C	0,15%
			5,15%

Figure A.5: B-Y quadrant of the ABC-XYZ resulting matrix.

		Z	Vol
B	CL0041 | A	115124033 - CRISTAL TP 0,33 EXP PAL 70	0,43%
	CL0082 | B	100804533 - SB TP 0,33x15 CX SC	0,42%
	CL0068 | C	250404633 - SB GREEN TP 6x33 SH SC NEW	0,25%
	CL0522 | C	120004525 - CARLSBERG TP 0,25x15 CX	0,24%
	CL0048 | B	100554633 -SUPER BOCK ID TP 6x33 1/2 PAL	0,23%
	CL0037 | A	120344025 - CARLSBERG TP 0,25 CLUB NI	0,22%
	CL0510 | B	100854533 - SB TP 0,33x15 CX Â½PAL SC	0,21%
	CL0534 | B	105324050 - SB ORIG. TP 0,50x12 CX XL	0,19%
	CL0099 | B	100564620 - SB ID TP 6x20 1/2 PAL PLAS 0	0,18%
	CL0109 | B	245324033 - SB STOUT ID TP 24x0,33 EXP	0,17%
	CL0609 | C	105314025 - SB TP 0,25x24 CX PULL MOÃ‡AMB	0,15%
			2,69%

Figure A.6: B-Z quadrant of the ABC-XYZ resulting matrix.

	X		Vol
C	CL0166 | C	900013225 - VITALIS TR 0,25 (C28) N	0,15%
	CL0085 | B	100553033 - SUPER BOCK ID TR 24x33 Â½ PAL	0,12%
	CL0215 | C	560036615 - FRUTIS MAÃ‡Ãƒ PET 1,5 L 6-P	0,10%
	CL0180 | C	900006075 - VITALIS PET 0,75 L SPORT CAP	0,10%
	CL0217 | C	560056615 - FRUTIS LAR/MAR PET 6x1,5L	0,10%
	CL0438 | C	240504120- SB STOUT ID TP 10 x 0,20	0,10%
	CL0216 | C	560156615 - FRUTIS LIMÃƒO PET 1,5Lx6 SH L	0,10%
	CL0198 | C	490516615 - RICAL GASOSA PET 1,5 L 6-P C	0,10%
	CL0077 | C	300504633 - SB ABADIA ID TP 6x0,33	0,09%
	CL0372 | C	900106350 - VITALIS LIM&MG PET8x3x0,5L C	0,09%
	CL0024 | C	240001130 - SB STOUT BARRIL 30 L	0,09%
	CL0214 | C	560026615 - FRUTIS ANANÃS PET 1,5 L 6-P	0,08%
	CL0551 | C	290014610 - MARINA TP 6x1L	0,08%
	CL0088 | C	110053033 - CRISTAL TR 24x0,33 Â½ PAL	0,08%
	CL0162 | C	920164425 - PEDRAS FRAMB/GIN TP 0,25 4-P	0,07%
	CL0505 | C	115008033 - CRISTAL LATA 0,33	0,06%
	CL0255 | C	130423033 - CRISTAL PRETA TR 33	0,06%
	CL0530 | C	270504120 - SB SEM ALCOOL TP 10x0,20	0,05%
	CL0096 | C	360543033 - SB SEM ALCOOL PRETA ID TR 33	0,05%
	CL0475 | C	930004425 - VIDAGO TP 0,25 4-P	0,04%
	CL0553 | C	290004225 - MARINA TP 12x0,25	0,04%
	CL0157 | C	920626633 - PS LEVÃSSIMA PET 0,33 6-P	0,04%
	CL0238 | C	500004025 - SNAPPY GINGER ALE TP 0,25L	0,03%
	CL0043 | C	130204633 - CRISTAL PRETA NS TP 6 x 0,33	0,03%
	CL0164 | C	920446433 - PEDRAS LIM/CHÃ PET 0,33 4-P	0,03%
	CL0371 | C	900246350 - VITALIS MAÃ‡Ãƒ/CHÃ PET 0,5 8X3	0,03%
	CL0218 | C	570106615 - FRUTEA LIMÃƒO PET 6x1,5L COMP	0,02%
	CL0219 | C	570006615 - FRUTEA PÃŠSS.PET 6x1,5L COMP	0,02%
	CL0220 | C	570206615 - FRUTEAMNG/MAR PET6x1,5L COMP	0,02%
	CL0577 | C	921004025 - PS TP 0,25x24 CX TAP	0,02%
	CL0476 | C	930004075 - VIDAGO TP 0,75 L	0,01%
	CL0527 | B	905006650 - VITALIS PET 240x6x0,5L MERCA	0,00%
	CL0528 | A	905656650 - VIT.PET120x6x0,5L MERC 1/2 P	0,00%
	CL0542 | C	790206015 - SUMO S/GÃS PET ANAN ITM 1,5L	0,00%
	CL0543 | C	790306015-SUMO S/GÃS PET LAR/MAR ITM 1,5	0,00%
	CL0544 | C	790406015 - SUMO S/GÃS PET MAÃ‡Ãƒ ITM 1,5L	0,00%
	CL0545 | C	790506015-SUMO S/GÃS PET FRU BOS ITM 1,5	0,00%
	CL0573 | C	701026015 - AMANHECER AN PET 1,5Lx12 SH	0,00%
	CL0580 | C	591006015 - GUARANA CONT PET 1,5Lx12 SH	0,00%
	CL0615 | C	700406015 - SUMO S/GÃS ANAN/COCO 1,5x12	0,00%
	CL0620 | C	986006015 - AGUA LISA GUIA PET 1,5Lx12	0,00%
	CL0623 | C	986006105 - AGUA LISA GUIA PET 5L	0,00%
			1,98%

Figure A.7: C-X quadrant of the ABC-XYZ resulting matrix.

<table>
<tr><th></th><th colspan="2">Y</th><th>Vol</th></tr>
<tr><td rowspan="33">C</td><td>CL0050 | B</td><td>100584633 - SB TP6 33 TB Â½PALDUS L6P5 SC</td><td>0,14%</td></tr>
<tr><td>CL0228 | C</td><td>430528033 - FRISUMO ANANÃS LATA 0,33L C</td><td>0,14%</td></tr>
<tr><td>CL0235 | B</td><td>430516015 - FRISUMO LARANJA PET 1,5 L C</td><td>0,13%</td></tr>
<tr><td>CL0060 | B</td><td>120204625 - CARLSBERG NS TP 6 x 0,25 CLU</td><td>0,12%</td></tr>
<tr><td>CL0101 | B</td><td>100524120 - SB ID TP 10x0,20 1/2PALRETZ</td><td>0,12%</td></tr>
<tr><td>CL0097 | C</td><td>360504633 - SBSA PRETA ID TP 6x0,33</td><td>0,12%</td></tr>
<tr><td>CL0237 | C</td><td>430566015 - FRISUMO ANANÃS PET 1,5Lx12</td><td>0,11%</td></tr>
<tr><td>CL0232 | C</td><td>590008033 - GUARANÃ BRASIL LATA 0,33L</td><td>0,10%</td></tr>
<tr><td>CL0199 | C</td><td>400006615 - SNAPPY LIMA LIMÃƒO PET 6x1,5L</td><td>0,09%</td></tr>
<tr><td>CL0239 | C</td><td>510004025 - SNAPPY ÃGUA TÃ“NICA TP 0,25L</td><td>0,07%</td></tr>
<tr><td>CL0135 | C</td><td>925704050 - PS TP 0,50x12 CX PT/IN/ES/FR</td><td>0,07%</td></tr>
<tr><td>CL0079 | C</td><td>160214633 - CHEERS PRETA NS TP 6 x 0,33</td><td>0,06%</td></tr>
<tr><td>CL0532 | C</td><td>365003033 - SB NEGRA SIN ALCOHOL TR24x33</td><td>0,06%</td></tr>
<tr><td>CL0133 | C</td><td>924104075 - PEDRAS NATURAL GAS VID750CC</td><td>0,05%</td></tr>
<tr><td>CL0140 | C</td><td>290008033 - MARINA LATA 24 X 0,33</td><td>0,04%</td></tr>
<tr><td>CL0200 | C</td><td>400008633 - SNAPPY LIMA/LIMÃƒO LATA 6x33</td><td>0,04%</td></tr>
<tr><td>CL0202 | C</td><td>480106615 - SNAPPY COLA PET 6x1,5L COMP</td><td>0,04%</td></tr>
<tr><td>CL0130 | C</td><td>925704625 - PS TP 0,25X6*4 SH IN/ES BEST</td><td>0,03%</td></tr>
<tr><td>CL0210 | C</td><td>430511120 - FRISUMO LARANJA BARRIL 20L C</td><td>0,03%</td></tr>
<tr><td>CL0203 | C</td><td>480108633 - SNAPPY COLA LATA 6x0,33 COMP</td><td>0,03%</td></tr>
<tr><td>CL0241 | C</td><td>430513025 - FRISUMO LARANJA TR 0,25 GN</td><td>0,03%</td></tr>
<tr><td>CL0207 | C</td><td>590008633 - GUARANÃ BRASIL LATA 6 0,33L</td><td>0,02%</td></tr>
<tr><td>CL0021 | C</td><td>120002020 - CARLSBERG BARRIL TP 20L</td><td>0,02%</td></tr>
<tr><td>CL0407 | C</td><td>430516625 - FRISUMO LARANJA PET 0,25x6 C</td><td>0,02%</td></tr>
<tr><td>CL0242 | C</td><td>430523025 - FRISUMO ANANÃS TR 0,25 GN</td><td>0,02%</td></tr>
<tr><td>CL0209 | C</td><td>430518633 - FRISUMO LARANJA LATA 6x33 C</td><td>0,02%</td></tr>
<tr><td>CL0212 | C</td><td>430528633 - FRISUMO ANANAS LATA 6x33 C</td><td>0,02%</td></tr>
<tr><td>CL0370 | C</td><td>900006350 - VITALIS AN/FIB PET 8x3x0,5L</td><td>0,01%</td></tr>
<tr><td>CL0578 | C</td><td>921006010 - PS PET 1Lx12 CX TAP</td><td>0,01%</td></tr>
<tr><td>CL0240 | C</td><td>400103025 - SNAPPY LIMA/LIMÃƒO TR 0,25 GN</td><td>0,01%</td></tr>
<tr><td>CL0016 | C</td><td>100302005 - SUPER BOCK BARRIL ID TP 5L</td><td>0,01%</td></tr>
<tr><td>CL0315 | C</td><td>172111130 - GRIMBERGEN DOUBLE BARRIL 30L</td><td>0,01%</td></tr>
<tr><td></td><td></td><td>1,78%</td></tr>
</table>

Figure A.8: C-Y quadrant of the ABC-XYZ resulting matrix.

	Z		Vol
C	CL0595 | C	100104020 - SB ORIG TP 0,20x24 CX COROA	0,13%
	CL0603 | C	250004533 - SB GREEN TP 0,33x15 CX NEW	0,12%
	CL0575 | C	245004025 - SB STOUT TP 0,25x24 CX POFF	0,11%
	CL0547 | C	100514620 - SUPER BOCK ID TP 6x0,20	0,11%
	CL0618 | C	105404633 - SB TP 0,33X6*4 EXP PAL RET60	0,08%
	CL0601 | C	391004133 - SOMERSBY TP 0,33x10*2	0,07%
	CL0406 | C	730498833 - ALDI 1/2PAL MISLATA 33 75/25	0,07%
	CL0608 | C	105554633 - SB TP 0,33x6*4 TB UK PAL 70	0,07%
	CL0046 | B	100524133 - SUPER BOCK ID TP 10x33 ECON	0,06%
	CL0492 | C	281504633 - SB CLASSIC TP 0,33x6*4 SH SC	0,06%
	CL0596 | C	105444033 - SB ORIG. TP 0,33x24 CX UK	0,06%
	CL0473 | C	100564120 -SB ID TP 10x20 1/2 PAL PLAS 0	0,05%
	CL0552 | C	166004633 - CHEERS RADLER 6x0,33CL TP	0,04%
	CL0494 | C	281504120 - SB CLASSIC ID TP 10x0,20	0,04%
	CL0053 | C	105454633 - SB TP 0,33x6*4 TB UK PAL 84	0,04%
	CL0297 | C	100554133 - SB ID TP 10x33 ECON 1/2 PAL	0,03%
	CL0610 | C	925054625 - PEDRAS SALGADAS TP6 0,25 AFR	0,03%
	CL0408 | C	430526625 - FRISUMO ANANÃS PET 6x25 C	0,03%
	CL0567 | C	391054033 - SOMERSBY TP 0,33x24 CX Â½PAL	0,03%
	CL0020 | C	120308633 - CARLSBERG LATA 6 x 0,33 NI	0,03%
	CL0561 | C	270594633 - SBSA TP 0,33x6*4 TB PAL RET	0,02%
	CL0080 | C	100384033 - SB ID TP 24x0,33 ALUMINIO	0,02%
	CL0626 | C	392004433 - SOMERSBY BBERRY TP 0,33x4*6	0,02%
	CL0619 | C	365004625 - SB NEGRA SIN ALCOHOL TP6x25	0,01%
	CL0607 | C	240002010 - SB STOUT BARRIL TP 10L	0,01%
	CL0156 | C	970014025 - MELGAÃ‡O TP 0,25 CAIXA	0,01%
	CL0629 | C	920804125 - PS TP 0,25X10*2 SH L10P8	0,01%
	CL0625 | C	915704075 - PS TP 0,75x12 CX PT/IN/AL B	0,00%
	CL0627 | C	100334633 - SB TP6 0,33 SH L6P5 SC	0,00%
	CL0261 | C	170001130 - GUINNESS BARRIL 30 L	0,00%
			1,37%

Figure A.9: C-Z quadrant of the ABC-XYZ resulting matrix.

Appendix B

Initial RCT Results

		RCT											
CT	CLT	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
7	3	3,3	3,0	3,2	3,1	3,0	3,0	3,3	3,0	3,0	3,0	3,0	3,0
7	3	3,5	3,2	3,2	3,5	3,8	3,0	5,4	7,0	7,0	3,0	4,1	3,0
7	7	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0
21	28	21,0	21,0	21,0	21,0	21,0	21,0	21,0	21,0	21,0	21,0	21,0	21,0
3	4	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0
14	14	14,0	14,0	14,0	14,0	14,0	14,0	14,0	14,0	14,0	14,0	14,0	14,0
20	14	14,0	14,0	14,0	14,0	20,0	14,0	14,0	14,0	14,0	14,0	14,0	14,0
3	4	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0	3,0
12	10	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	12,0	12,0
14	28	14,0	14,0	14,0	14,0	14,0	14,0	14,0	14,0	14,0	14,0	14,0	14,0
12	10	10,0	12,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	12,0	10,0
12	7	7,0	7,0	7,0	7,4	7,0	7,0	12,0	7,0	7,0	7,0	7,0	7,0
12	7	12,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,5	7,0
12	4	4,0	4,0	4,0	4,0	4,0	4,0	4,1	4,0	4,0	4,1	5,0	4,6
10	4	4,0	4,0	4,0	4,3	4,3	5,7	4,1	4,2	4,4	4,0	4,0	4,0
12	10	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0
12	7	7,0	7,0	9,9	7,0	7,4	7,0	7,0	7,0	7,0	7,0	7,0	7,0
9	7	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0	7,0
11	7	7,0	7,0	7,0	7,0	7,0	7,0	8,4	11,0	7,0	7,0	7,0	7,0
12	10	10,0	10,0	10,0	10,0	12,0	12,0	10,3	10,0	10,0	10,5	10,0	10,0
12	10	10,0	10,0	10,0	10,0	10,0	12,0	12,0	12,0	10,0	10,0	10,0	10,0
15	7	15,0	15,0	7,0	7,0	7,0	7,0	7,0	14,3	7,0	7,0	15,0	10,7
13	4	13,0	13,0	4,0	13,0	4,3	4,0	4,0	4,0	4,0	4,0	4,0	4,6

Table B.1: Initial CT, LT and Resulting CT for A-X quadrant.

CT	CLT	RCT											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
14	14	14,0	14,0	14,0	14,0	14,0	14,0	14,0	14,0	14,0	14,0	14,0	14,0
14	14	14,0	14,0	14,0	14,0	14,0	14,0	14,0	14,0	14,0	14,0	14,0	14,0
11	7	7,0	7,0	7,0	7,0	7,0	11,0	7,0	11,0	7,0	7,0	10,0	7,0
14	10	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0	10,0
14	7	8,8	7,0	7,0	7,0	7,0	8,7	14,0	7,5	7,0	7,4	7,0	7,1
14	7	13,4	14,0	10,1	10,0	7,0	8,0	10,3	12,6	14,0	10,8	7,0	14,0
14	10	10,2	11,8	10,0	10,0	14,0	12,1	10,0	10,0	10,0	10,0	10,0	10,0
14	10	10,2	10,0	10,0	10,0	10,0	10,1	11,3	10,8	10,0	10,0	11,6	10,2
14	7	10,1	9,5	7,3	9,7	10,7	7,3	7,7	11,6	9,3	8,4	9,1	14,0
14	7	9,6	8,7	8,6	10,6	9,6	8,2	14,0	7,8	9,1	8,2	9,5	9,5
18	14	14,0	14,0	14,0	14,0	14,0	18,0	14,0	14,0	14,0	14,0	14,0	14,0

CT	CLT	RCT											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
14	14	14,0	14,0	14,0	14,0	14,0	14,0	14,0	14,0	14,0	14,0	14,0	14,0
14	7	11,6	9,7	10,0	8,4	10,9	14,0	7,0	11,6	7,3	10,7	7,0	8,7
11	7	9,1	8,9	7,1	8,1	7,9	10,2	7,9	9,6	7,0	9,2	7,0	7,0
14	7	9,8	14,0	9,0	7,8	7,7	14,0	9,2	14,0	14,0	14,0	14,0	14,0

Table B.2: Initial CT, LT and Resulting CT for A-Y and A-Z quadrant.

Appendix C

Validation Situations

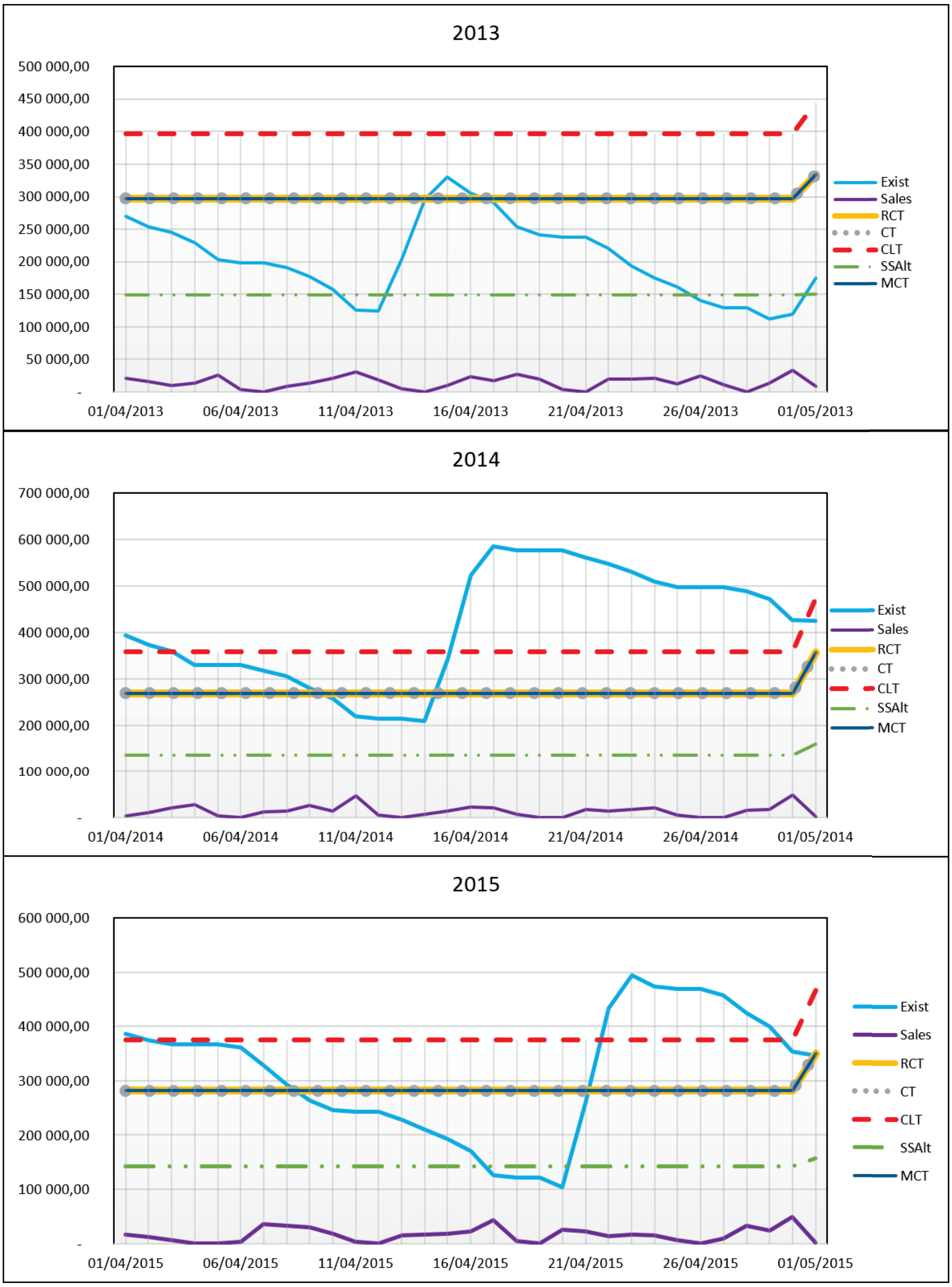

Figure C.1: Graphical representation of "SB ORIG. TP 1Lx6 TB"'s behaviour.

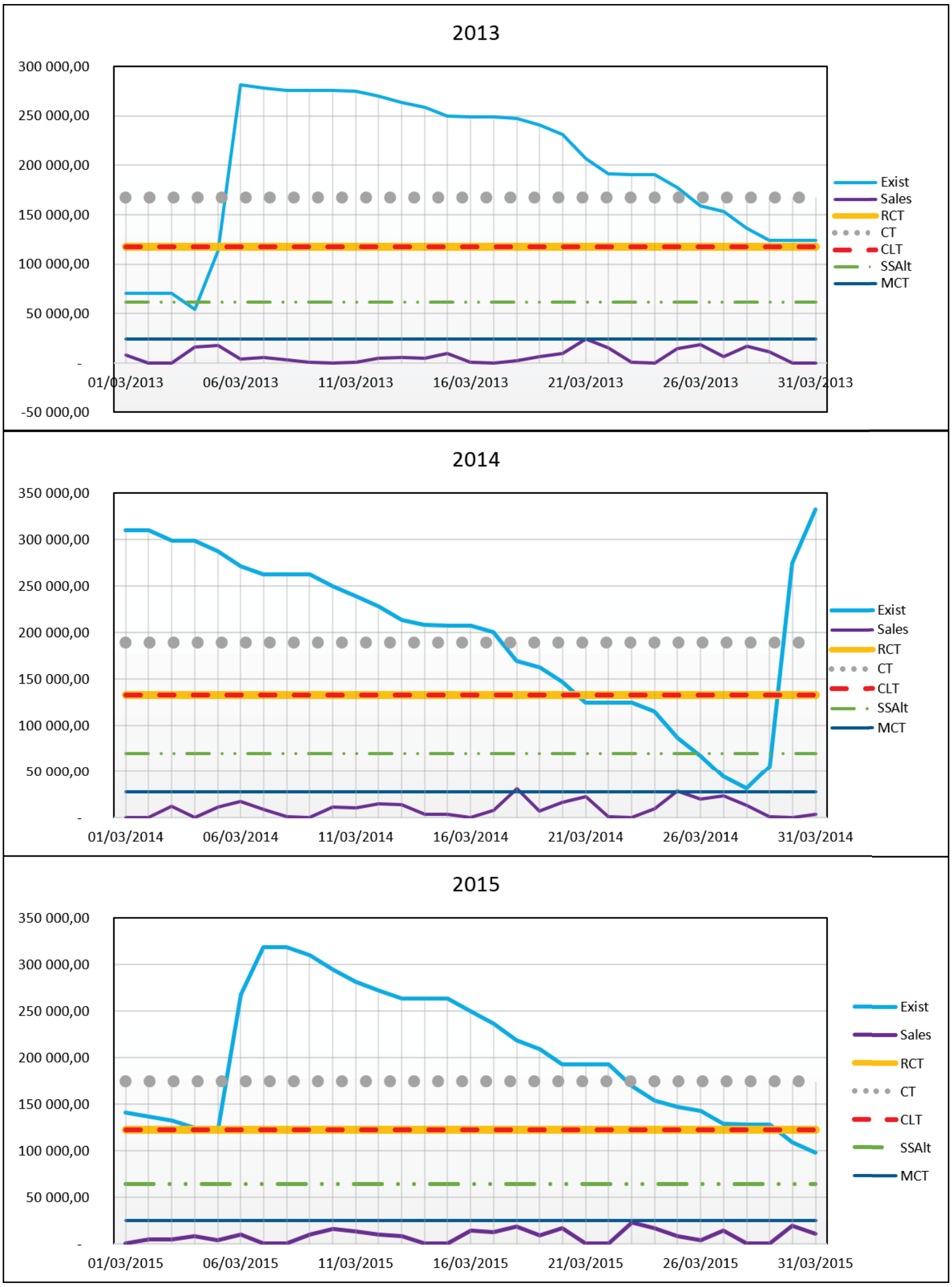

Figure C.2: Graphical representation of "CRISTAL TR 0,20x30 GR"'s behaviour.

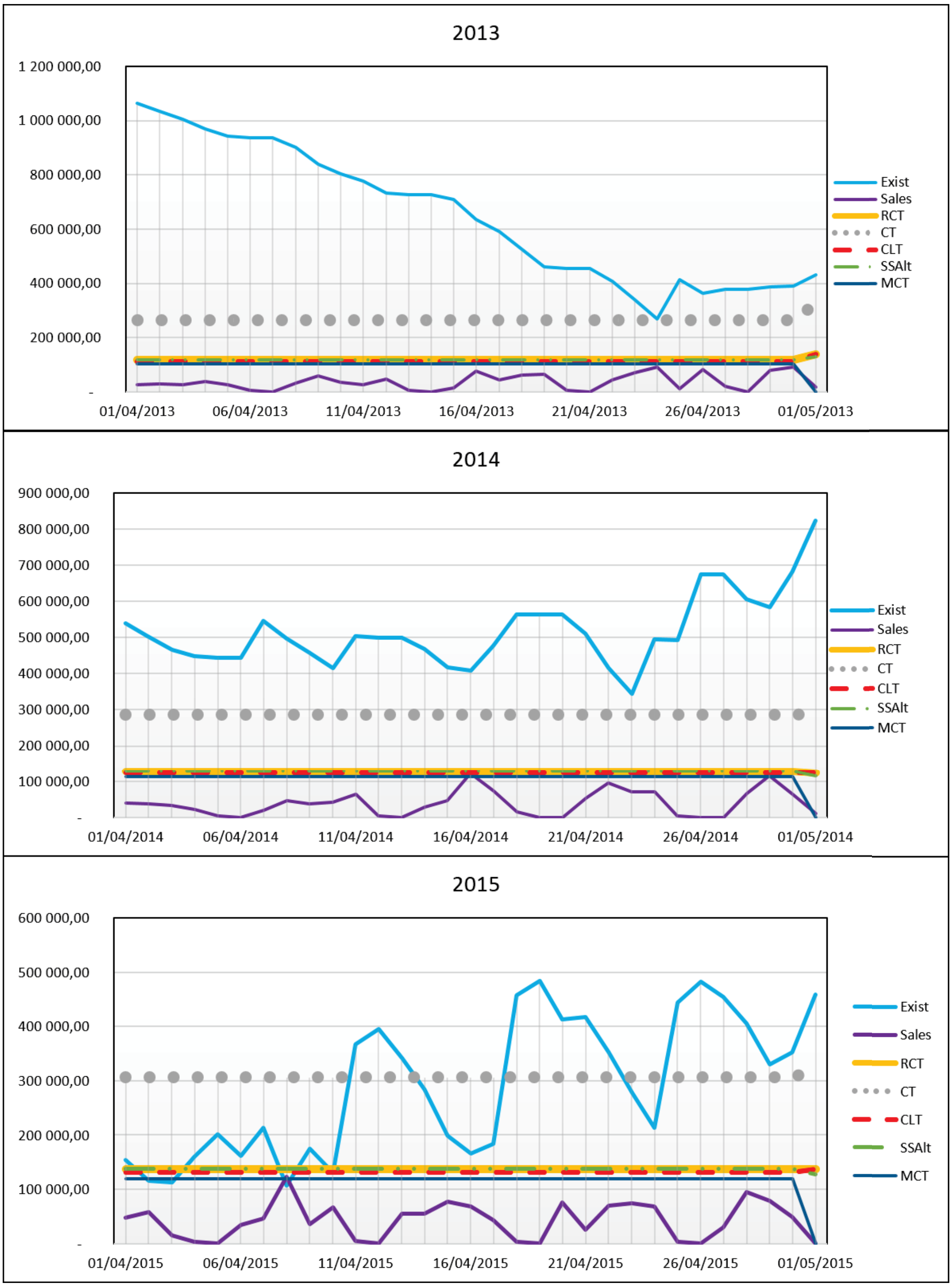

Figure C.3: Graphical representation of "SB ORIG. BARRIL 30L"'s behaviour.

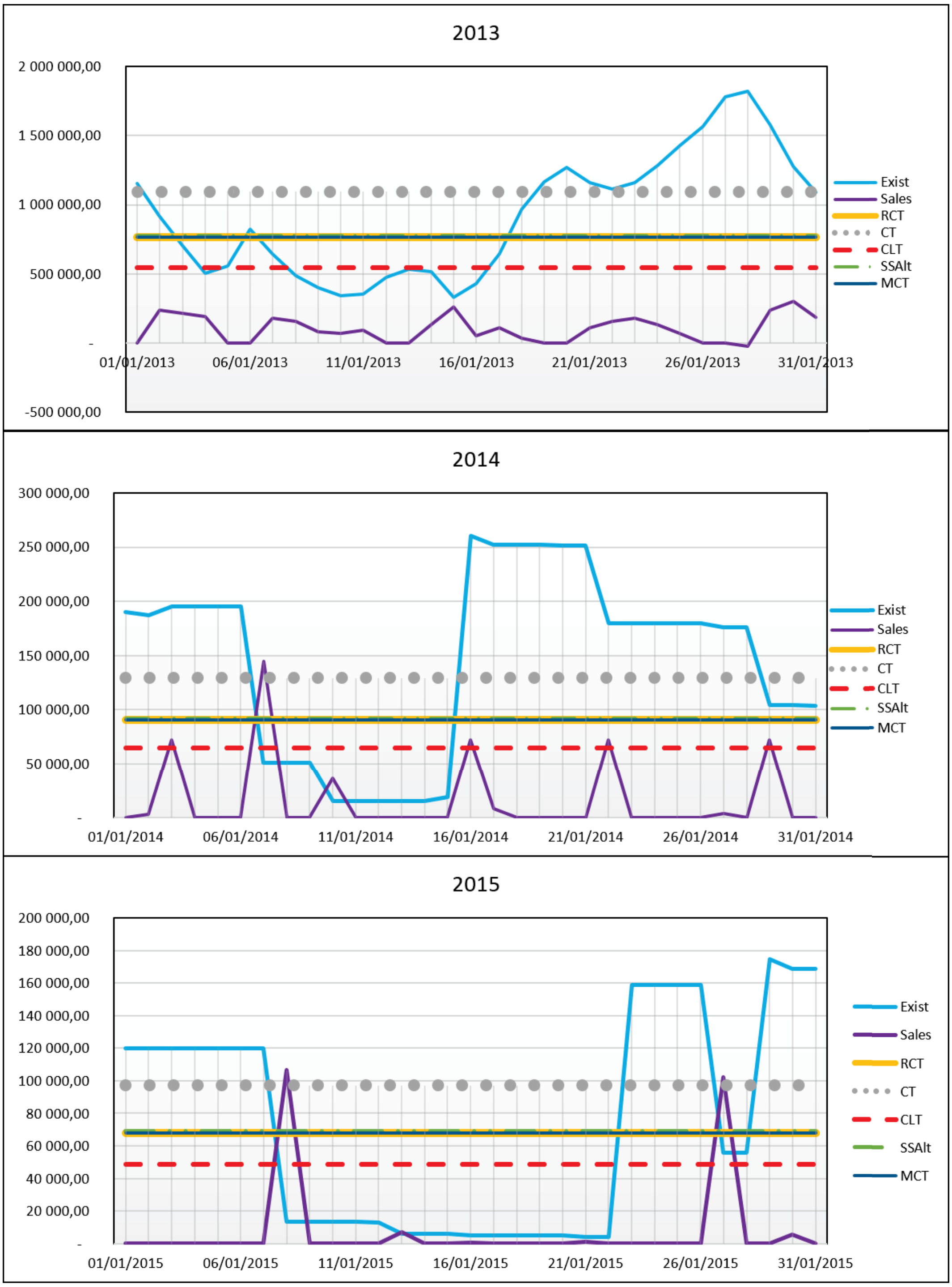

Figure C.4: Graphical representation of "SB ORIG. TP 0,33x24 CX AFRICA"'s behaviour.

Appendix D

Monetized Results

SKU	Designação	Init	MRS	PRS	MPRS
100001130	SB ORIG. BARRIL 30L	25 819,42 €	25 819,42 €	25 819,42 €	25 819,42 €
100001150	SB ORIG. BARRIL 50L	28 371,84 €	28 371,84 €	28 371,84 €	28 371,84 €
100302020	SB ORIG. BARRIL TP 20L	- €	14 453,23 €	- €	14 453,23 €
100304610	SB ORIG. TP 1Lx6 TB	- €	- €	26 661,84 €	26 661,84 €
104304025	SB ORIG. TP 0,25x24 CX PULL OFF	- €	- €	- €	- €
110204633	CRISTAL TP 0,33x6*4 SH	- €	- €	16 382,17 €	16 382,17 €
110823020	CRISTAL TR 0,20x30 GR	12 370,78 €	12 370,78 €	19 921,16 €	19 921,16 €
115004025	CRISTAL TP 0,25x24 CX PULL OFF	- €	- €	- €	- €
900303010	VITALIS TR 1Lx12 GR NID	1 465,67 €	1 465,67 €	1 465,67 €	1 465,67 €
900306005	VITALIS PET 5Lx3 SH NID	- €	6 977,26 €	- €	6 977,26 €
900306015	VITALIS PET 1,5Lx12 SH NID	3 407,86 €	3 407,86 €	3 407,86 €	3 407,86 €
900306033	VITALIS PET 0,33x24 SH NID	12 612,37 €	12 612,37 €	12 612,37 €	12 612,37 €
900306050	VITALIS PET 0,50x24 SH NID	11 427,29 €	11 427,29 €	11 427,29 €	11 427,29 €
900306105	VITALIS PET 5L NID	8 300,45 €	8 300,45 €	8 300,45 €	8 300,45 €
900346615	VITALIS PET 1,5Lx6 SH NID	9 603,63 €	9 603,63 €	9 603,63 €	9 603,63 €
900356105	VITALIS PET 5L ½PAL NID	2 815,72 €	2 815,72 €	2 815,72 €	2 815,72 €
920704025	PS TP 0,25X24 TB BEST	12 357,29 €	12 357,29 €	12 357,29 €	12 357,29 €
920704625	PS TP0,25X6*4 SH PT/FR/AL B	27 916,67 €	68 484,86 €	27 916,67 €	68 484,86 €
940006015	CARAMULO PET 1,5Lx12 SH	5 321,54 €	5 321,54 €	5 321,54 €	5 321,54 €
940006033	CARAMULO PET 0,33x24 SH	5 589,13 €	5 589,13 €	5 589,13 €	5 589,13 €
940006050	CARAMULO PET 0,50x24 SH	2 415,09 €	2 415,09 €	2 415,09 €	2 415,09 €
940006615	CARAMULO PET 1,5Lx6 SH	3 604,62 €	3 604,62 €	3 604,62 €	3 604,62 €
940096105	CARAMULO PET 5Lx144	4 884,65 €	4 884,65 €	4 884,65 €	4 884,65 €
		178 284,00 €	240 282,68 €	228 878,39 €	290 877,07 €

Table D.1: Monetized saving table for A-X quadrant across all scenarios.

SKU	Description	Init	MRS	PRS	MPRS
100308033	SB ORIG. LATA 0,33x24 SH	- €	- €	- €	- €
100503020	SB ORIG. TR 0,20x30 GR SC	- €	- €	28 527,25 €	28 527,25 €
100503033	SB ORIG. TR 0,33x24 GR SC	63 412,10 €	63 412,10 €	63 412,10 €	63 412,10 €
100504120	SB ORIG. TP 0,20x10*2 SH SC	49 068,29 €	49 068,29 €	49 068,29 €	49 068,29 €
100534633	SB ORIG. TP 0,33x6*4 SH SC	52 242,15 €	52 242,15 €	52 242,15 €	52 242,15 €
100804025	SB ORIG. TP 0,25x20 CX SC	28 321,25 €	28 321,25 €	28 321,25 €	28 321,25 €
100804520	SB ORIG. TP 0,20x15 CX SC	56 007,51 €	56 007,51 €	56 007,51 €	56 007,51 €
105704625	SB ORIG. TP 0,25x6*4 SH EXP BP	48 952,58 €	48 952,58 €	48 952,58 €	48 952,58 €
105714033	SB ORIG. TP 0,33x24 CX EXP PAL RET 60 BP	25 378,27 €	25 378,27 €	25 378,27 €	25 378,27 €
105784025	SB ORIG. TP 0,25x24 CX EXP BP	37 729,19 €	37 729,19 €	37 729,19 €	37 729,19 €
110423033	CRISTAL TR 0,33x24 GR	9 851,02 €	9 851,02 €	26 078,84 €	26 078,84 €
		370 962,37 €	370 962,37 €	415 717,44 €	415 717,44 €

SKU	Description	Init	MRS	PRS	MPRS
100004125	SB ORIG. TP 0,25x10*2 SH EC	- €	- €	- €	- €
100804020	SB TP 0,20x24 CX SC	62 535,53 €	62 535,53 €	62 535,53 €	62 535,53 €
100804033	SB ORIG. TP 0,33x24 CX SC	18 430,77 €	18 430,77 €	18 430,77 €	18 430,77 €
105324033	SB ID TP 24x0,33 AFRICA	40 289,92 €	40 289,92 €	40 289,92 €	40 289,92 €
		121 256,22 €	121 256,22 €	121 256,22 €	121 256,22 €

Table D.2: Monetized saving table for A-Y and A-Z quadrant across all scenarios.

References

Adam J Copp, Theodore A Kennedy, and Jeffrey D Muehlbauer. Barcodes are a useful tool for labeling and tracking ecological samples. *Bulletin of the Ecological Society of America*, 95(3): 293–300, 2014.

Chandandeep S Grewal, ST Enns, and Paul Rogers. Dynamic reorder point replenishment strategies for a capacitated supply chain with seasonal demand. *Computers & Industrial Engineering*, 80:97–110, 2015.

Priya Gupta and SS Sutar. Study of various location tracking techniques for centralized location, monitoring & control system. *IOSR Journal of Engineering (IOSRJEN) ISSN (e)*, pages 2250–3021, 2014.

Jay Heizer and Barry Render. *Operations Management Flexible Version with Lecture Guide & Activities Manual Package*. Pearson Higher Ed, 2011.

Marc Hoppe. *Inventory optimization with SAP*. Galileo Press Bonn, 2006.

F. Robert Jacobs and Richard B. Chase. *Operations and supply management: The core*. McGraw-Hill Irwin New York, NY, 2010.

PL King. Crack the code, understanding safety stock and mastering its equations. *APICS magazine*, 21(4):33–36, 2011.

Katariina Penttilä, Mikko Keskilammi, Lauri Sydänheimo, and Markku Kivikoski. Radio frequency technology for automated manufacturing and logistics control. part 2: Rfid antenna utilisation in industrial applications. *The International Journal of Advanced Manufacturing Technology*, 31(1-2):116–124, 2006.

R. Dan Reid and Nada R. Sanders. *Operations Management, an Integrated Approach*. John Wiley & Sons, 2013.

G. Srinivasan. *Quantitative Models In Operations And Supply Chain Management, 1/e*. PHI Learning Pvt. Ltd., 2010.

William J. Stevenson and Mehran Hojati. *Operations management*, volume 8. McGraw-Hill/Irwin Boston, 2007.

Chia-Rong Su, Ching-Ter Chang, Chih-Yung Chen, and Chang-Shu Tu. Qr codes & gps functions-new applications in taiwan. In *Machine Learning and Cybernetics (ICMLC), 2014 International Conference on*, volume 2, pages 638–642. IEEE, 2014.

Bernardo José Calafate de Vasconcelos. Gestão de stocks, 2008.