Retail Transshipment Modelling

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Masters Dissertation

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Abstract

In an economy that is more and more consumer driven, the demands of the consumer in terms of service level, availability of product and price increase each day. Retail stores interact directly with consumers and, in order to cope with these demands, they need solutions that enable them to increase availability and maintain the level of investment. Transshipments are stock movements between locations at the same echelon. Usually, in retail, these are used in an *ad hoc* way. However, transshipments can become a powerful tool in inventory management to increase service level by preventing lost sales and maintaining or even reducing the investment in inventory.

This work aims to develop a model that can automatically detect imbalances of stock between stores and suggest transshipments to rectify those imbalances. The model developed can perform on inventory management systems with different characteristics, such as different replenishment systems and review schemes, and considers transshipment lead time, and can consider both bidirectional and unidirectional transshipments. The model was developed in order to deal with any number of stores and products under a centralized inventory management system.

The model divides the problem in three different phases, and then solves each of them using a set of heuristics. First there is a Detection Phase, in which the system predicts and determines imbalances in the stock levels of the different stores in the form of quantities of inventory needed and quantities available for transshipments. After determining needed and available quantities, the Ranking Phase begins. In this phase, the stores with need of stock and the stores with stock available are ranked and paired in order to define the transshipments of different SKU that will be suggested. After transshipments on a SKU level are defined, the Grouping phase occurs. In this phase the transshipments of different SKU's determined on the Ranking Phase are grouped together in pairs of sending/receiving stores in order to save transportation costs. In this phase undesirable or unwanted transshipments are filtered out and not suggested

A simulation study was developed in order to test the model. Two measures were created in order to evaluate the risk of transshipments and their efficiency. The main conclusions of the tests indicate that the model has potential to reduce costs in varying degrees, and that the profitability of the model application depends mainly on the profit margin of the products considered and the logistic cost of transshipments.

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Acronyms

CAS – Consistent Appropriate Share Rationing

LS/NT - Lost Sales Recovered per Transshipment

RUT – Receiver's Useless Transshipments

SKU – Stock Keeping Unit

SLA – Service Level Adjustment

SLRP – Probability of a stock-out occurring in the following period

SLS – Sender's Lost Sales

SL_{inf} – Lower Service Level

SL_{sup} – Higher Service Level

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1 Introduction

The retail sector has the complexity of multi-layer supply chain processes. This complexity keeps increasing as the global economy becomes more and more consumer oriented, with an increase of the service level requested, product quality, customization, speed of delivery and product availability. This urges for the development of logistics solutions that can promote higher service levels. Transshipments are stock movements between locations that can be used to suppress unexpected needs in a certain store or warehouse. Furthermore, transshipments can be used as an important and integrated tool of an inventory management system. This dissertation presents a model that can automatically detect imbalances of stock between stores and suggest transshipments to rectify these situations. This model enables stores to achieve a higher service level with the same level of investment in stock, leading to important savings. The model developed can be applied in numerous situations, and can be integrated with any inventory replenishment system. Furthermore, the model proposed enables the determination of the situations where transshipments have more potential for cost reductions. This dissertation provides further research and insight on the topic of transshipments and tries to satisfy, even if a little, the urge for logistic solutions that can improve operations in retail.

The rest of this section displays the framework and motivations that lead to the development of this project, its objectives and the structure of this dissertation.

1.1 Project's Framework and Motivation

This project has origin in a request by a client of InovRetail, who owns a fashion retail chain. With a focus on service level, this client sought a way of improving the availability of their products, and saw transshipments as a way for accomplishing this. Although transshipments were already allowed between stores, this process was informal and *ad hoc*, triggered by emergency needs in stores and managed by those stores. This client requested a system that would support the decision making process regarding transshipments. Modelling the problem and centralizing the decision may lead to improved results, and as such this project attempts to take advantage of this, by creating a generic model that is able to help not only in this specific case, but in others as well.

1.2 Retail transshipment Modelling project in InovRetail

InovRetail is a retail Research and Development company created in 2011 and has headquarters in UPTEC's. The company develops innovative solutions that help their clients (the retailers) to improve the attractiveness and efficiency of their stores. This leads not only to better store and business performance, but also to an improved experienced by the customers of the clients' stores. InovRetail presents a highly differentiated offer, sustained in technological solutions with measurable returns, custom tailored to each client. InovRetail's vision, mission and values are the following:

Vision:

"Become a reference as a provider of innovative, state of the art solutions for the retailers."

Mission:

"Improve the customers' retail experience, making store environments more appealing, dynamic and efficient, with measurable return to our clients."

Values:

"We are truly committed to our clients, partners and technology; to deliver measurable results, with quality, on time and on budget. We are always open to others and new ideas. We respect our commitments and thrive to excel every time, because good is just not enough!"

InovRetail presents itself as a demanding and ambitious project, composed by a team with a mix of experience and youth, with multidisciplinary competences and client oriented.

Concerning the company's organization, InovRetail has two main teams:

- A Business Consultancy team, which develops technical solutions (e.g. mathematical and statistical modelling, business analysis, etc.) that meet client's needs.
- A Software Development team which further develops the solutions created by the first team into fully developed software - the final product for the client.

The two teams have a continuous and strong integration with each other, and always work in close proximity in order to create state-of-the-art solutions with a high level of excellence.

This dissertation was promoted by the first team aiming at developing a model that would be able to satisfy a client's emergent need.

1.3 Objectives

The objective proposed for this dissertation is to develop and specify a model that can automatically detect imbalances of stock in stores and produce a list of suggested transshipments to rectify these imbalances. This model should be flexible, i.e. it should be adaptable to most of the situations, namely different inventory replenishment systems and review schemes. It is also an objective to make the model possible to be implemented in the short term.

1.4 Project Structure

The project that lead to this dissertation was organized in four general phases (see Figure 1). The first phase was the exploratory one, where the problem was probed in order to gain a reasonable understanding of it. With the same objective, articles about the topic were analyzed. After reaching a proper understanding of the problem, the second phase consisted of designing the model to solve the problem and designing a way of testing it (a simulation study was chosen). The third phase was to construct a prototype based on the results of the previous phase in order to test the model. In reality, the process of designing (second phase) and building (third phase), although separate in theory, could be considered as one phase. In fact, as the knowledge of how the system works, gained by building the prototype, leads to changes in design, which lead to changes in the prototype. It could be said that these two phases (second and third) are developed iteratively. The fourth and final phase consisted of using the prototype to test the model in different situations and measure its performance. Throughout the project, required documentation was produced for the development of this dissertation and the future implementation and application of the model. The milestones used to ensure the timely completion of the project were: a literature review, as a result of the first phase; a description of the model after the second phase, the prototype after the third phase, a discussion of the results and a specification at the end of the last phase.

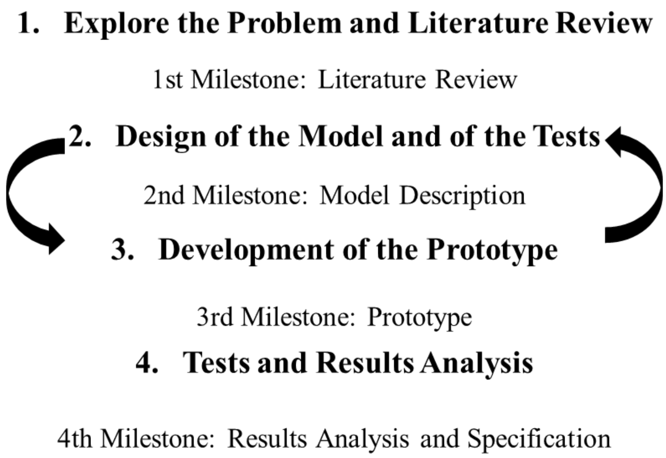

Figure 1 - Project Organization

1.5 Dissertation Structure

This dissertation has 6 sections. Section 1 is an introductory section. In section 2, the problem to be solved is defined and presented in more detail. In section 3, the main concepts required to understand this dissertation are presented, and a review of the literature on the topic is made. Section 4 presents the methodology used to solve the problem, such as the model developed during this dissertation and the simulation model used to test it, as well as the evaluation criteria used. In section 5, the tests used to evaluate the performance of the model are described and their results presented. In section 6, the main conclusions are summarized, and an outlook for future work is presented. Managerial implications of this dissertation are also presented in this last section.

2 Problem Presentation

The problem that originated this dissertation emerged from a request of a client, which is responsible for a nation-wide fashion franchise chain. This client requested a solution that could help the managers have a better grasp and control over their transshipments.

In store chains, transshipments are commonly used to handle stock shortages in one store, when another store of the same chain has excess stock. These imbalances of stock between stores have several reasons to occur. The first reason is related to the shortcomings of the replenishment systems, which due to costs (cost of continuous review, cost of holding stock, etc.) usually cannot avoid all stock-out situations. Even systems with greater complexity and that require the use of forecasts do not have perfect service level, or have the tendency to overstock if the required service level is very high. Variability in demand cannot be predicted and it affects both the replenishment systems in use and the forecast in which these systems are based. Transshipments can act as a way to compensate these shortcomings by correcting stock imbalances faster than a replenishment system could, reducing stock in all stores and diminishing the amount of lost sales due to stock-outs.

But even if we take into consideration a perfect replenishment system (i.e. a system that leads to zero stock-outs, with reasonable stock levels), there are situations in real world practice in which transshipments present advantages. It is a common practice to, in certain situations, order more than the suggested by the replenishment system. This could be either to take advantage of a commercial bulk discount, or simply because the supplier only accepts orders larger than a certain quantity. These situations where there is an imbalance in power between supplier and retailer is common in franchising, since the franchisees have limited supplier choice (sometimes no choice at all) due to the common standardization procedures in franchising. Transshipments can become an effective way to deal with this type of situations, since it allows stores with inventory shortcomings to receive stock from stores that have large amounts of stock due to a recent order, possibly reducing the number of orders made, and diminishing the stock levels throughout the chain. Therefore, companies can retain the advantages of commercial discounts without compromising the efficiency of the replenishment system and may even improve sales efficiency.

Currently, most transshipments occur when a certain item is requested in a store and this store does not have it in stock. The store employees then communicate with the other stores using the information system or the phone in order to find if there is an available item in a nearby store. If there is the possibility of transshipment, the customer is asked if he/she accepts to wait for a certain period (hours or days) and if he/she accepts, the transshipment is then made. This method (usually called an emergency transshipment) tries to prevent the lost sale, but leads to backordering. If the client is unwilling to wait, the sale is effectively lost, which makes this method poor in terms of performance.

However, the method described is very limited, and it does not showcase the true potential of transshipments. Another way to use transshipments is to use them to prevent stock-outs before they happen. These are called preventive transshipments. In this context, this dissertation developed a model which detects stock imbalances between stores and suggests transshipments to correct them, in order to prevent stock-outs. This model should be implemented in parallel with an existing replenishment system, i.e. the replenishment system should run separately and its workings remain unchanged and independent of the application of the transshipment model.

In order to enhance the comprehension of the problem, a black box diagram of the problem that the model has to solve was created (see Figure 2).

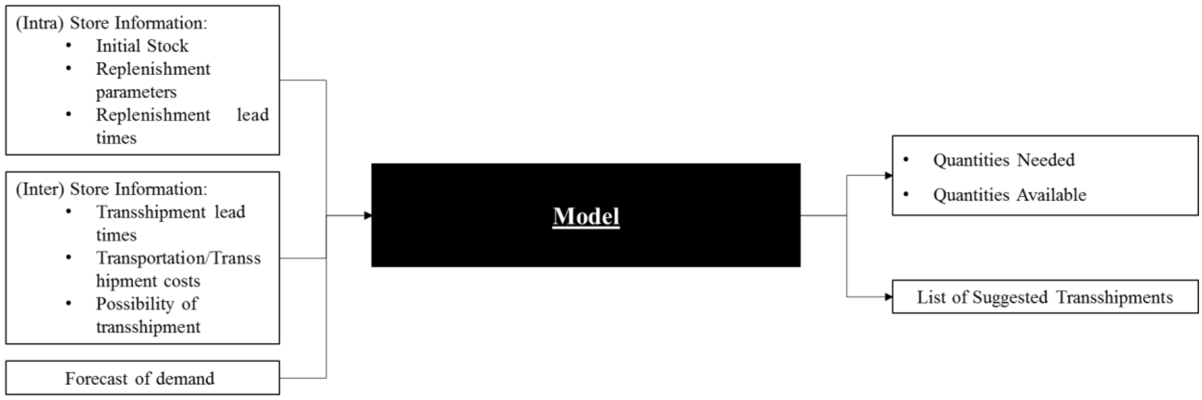

Figure 2 – Problem's Black Box Diagram

Figure 2 shows the problem's black box diagram, with the expected inputs and outputs of the model. As previously said, the objective is to detect imbalances of stock between stores. These imbalances come in form of quantities needed by each store in each period and the quantities available for transshipment in each store under the same conditions. The model should be capable of, based on the previous quantities, produce a list of suggested transshipments. This list includes the period when the transshipment occurs, the quantity transshipped and the indication of the store which sends and the store which receives the transshipment.

In order to solve this problem, three types of inputs are required: intra-store information, inter-store information, and demand's forecast. Intra-store information consists of information that is inherent and independent to each store. The required information is the initial stock, the replenishment parameters (order point and order-up-to point, for example) and replenishment lead times. Inter-store information pertains the information that depends on the relation between stores. It includes the transshipment lead time between stores, the cost of such transshipment and the indication if that transshipment is allowed or not (some transshipments may only occur in one direction or may not occur at all for strategical/business/logistic reasons). The last information needed is the forecast of demand, which is required in order to make decisions pertaining preventive transshipments.

Having defined what is requested by the problem and which information is necessary to obtain the required results, it is necessary to clarify the type of supply chain that comprises the problem where the model will work, as such is necessary for its development.

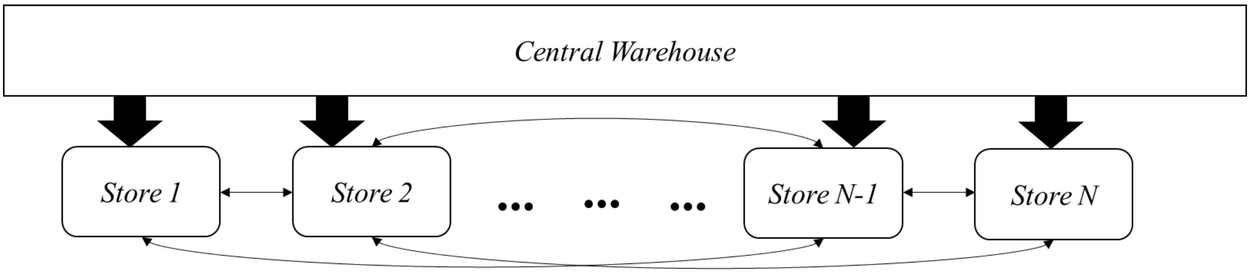

Figure 3 - System used for the model development.

The problem is a system similar to the one presented in Figure 3. *N* stores face customer demand. They are replenished from a central warehouse according to a certain replenishment policy (the same for all stores). The central warehouse exists as a way of coordinating inventory management among all stores. The stores can be heterogeneous, i.e. their inventory management parameters can be different. In case of periodic review in replenishment, the review period is the same for all stores. Besides the replenishment policy, transshipments between stores are also allowed. These transshipments may differ in lead time and cost for different stores. Some stores may not be able to transship between them or the transshipments may only occur in one direction (i.e. they can be unidirectional or bidirectional). If the transshipment review scheme is periodic, the review period is the same for all stores.

3 Literature Review

The global economy is becoming increasingly competitive, and consequently companies are forced to improve their operations in order to survive and seek growth. Furthermore, consumers' expectations and needs keep growing, both in terms of price and in terms of quality, which leads to reduced profit margins. Sometimes, the only way for companies to keep their margins at a compatible level with economic growth is to reduce costs. In addition to greater pressure from the consumer side, companies also face restrictions imposed by their suppliers, regulators and other players in the market, increasing the complexity of their decisions and reducing their leeway. The complexity is even greater when the integration of both strategical and operational decisions is a must in order to draw the full potential of the existent resources. This leads to the need of models that allow companies to face these issues.

One particular sector where these problems are noticeable is the retail sector, as, in one hand, it deals directly with the customer, and on the other hand it is at the end of the supply chain, usually facing coordination difficulties with suppliers. These difficulties gain prominence when retailers are small in size compared to their suppliers. In this context, the importance of operations management and logistics is at its peak since their genesis.

Logistics, as defined by Delaney, 1996, is the management of inventory in motion and at rest. The goal of the logistics manager is to achieve the lowest level of investment in inventory consistent with ensuring customer service and maintaining efficient production.

This dissertation will focus on inventory management, one of the dimensions of logistics. Inventory encompasses the goods and materials that an organization holds physically. Organizations hold stock for various reasons: to respond to customer demand on time (as a safety against demand variation), and to harmonize the seasonality of demand and suppliers production cycles. They may also hold stock to take advantage of commercial discounts and reduce transportation costs. However, having and handling inventory also involves costs. Holding costs, which are proportional to the quantity of inventory held, consist of the cost of having physical space occupied, taxes and insurances, obsolescence (loss of utility of a product), and the cost of opportunity. The last example of holding costs represents a larger part of this type of costs, as the capital used in purchasing inventory could have been invested in an alternative way. There are also fixed costs for ordering inventory, which encompass administrative and handling costs. The last type of costs come from not having enough stock to satisfy demand, such as: lost sales, administrative costs when backordering and loss of customer's goodwill, which may lead to permanent customer loss (as in Axsäter, 2007).

Two important concepts in inventory management are net inventory and service level.

Net inventory, see expression (1), is equal to the on hand stock (stock physically available) plus the stock in transit (from impending orders and/or transshipments) and customer returns, to which are subtracted sales and returns to supplier. Then adjustments from other occurrences may be made (obsolescence, thefts, etc.).

$$\begin{aligned} Net\ Inventory \\ &= (On\ Hand\ Stock + In\ Transit\ Stock \\ &+ Customer\ Returns) - (Sales + Supplier\ Returns) \\ &\pm Adjustments \end{aligned} \tag{1}$$

Service level measures the performance of a system, and its definition may vary on different levels of the supply chain and from sector to sector. In retail, service level may be generically defined as the amount of demand that a given agent is able to satisfy, and it is usually defined by the organization as a strategical objective (e.g. for high-end stores it is more critical to achieve a high service level than for stores which compete with low prices). One of the most used way of defining service level is the one used by Sürie and Wagner, 2002, which is presented in the following table.

Table 1- Service level measures.

Type	Description
α-service level	The probability that an incoming order can be fulfilled completely from stock.
β-service level	The proportion of incoming order quantity fulfilled from on-hand inventory.
γ-service level	$1 - \frac{mean\ demand\ not\ fulfilled\ per\ period}{mean\ demand\ per\ period}$

One of the components of inventory management is the definition of the replenishment policy. Replenishment is the cyclical process for the creation of orders that allow organizations to have the correct amount of stock, i.e. to have enough stock to satisfy demand in a given period and to minimize the amount of stock held and orders made, thus reducing costs.

Replenishment policies have two dimensions: when should stocks be reviewed, and the decision criteria for deciding when to order and in what quantity.

Regarding the first dimension, replenishment policies can have a continuous review, i.e. inventory is continuously being monitored and an order is placed as soon as the conditions for ordering are fulfilled. Another possibility is to review the inventory periodically, where inventory is monitored on several predefined moments (which have a certain periodicity). The first one enables a more rigorous control, but is more expensive and harder to implement, especially when compared to the periodic review, which is more economical and easier to implement.

Concerning the second dimension, replenishment policies can have several inventory control policies. These will be listed as follows (based on Chiou, 2008):

- (s, S) policy:

  This is a mixed review policy, i.e. it can be used with continuous review and periodic review. An order is placed if the inventory is below a predefined level *s*, called order point.

The order quantity is defined as *S* minus *s*, in which *S* is the order-up to point, i.e. the Maximums value of stock. If this policy is used with periodic review, it is usually called *Min-Max*.

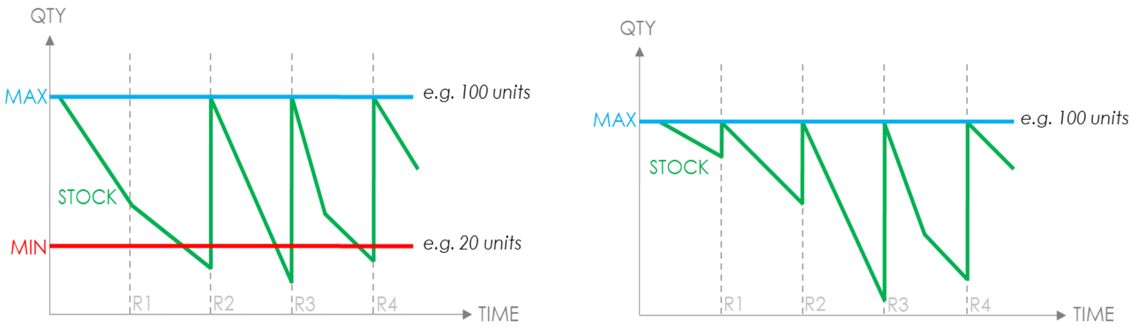

Figure 4- (s, S) [left] and (S-1, S) [right] inventory control policy.

- (S-1, S) policy:

This policy is a particular case of the previous one. In this one, whenever a sale is made, an order is placed equal to the quantity sold at the review moment. This is made in order to achieve inventory equal to *S* (hence *s* = *S-1*). This policy with a periodic review is called an *immediate policy*. This type of policy can achieve very high levels of service but has very high costs due to high inventory quantity (holding costs) and high number of orders (fixed costs).

- (R, Q) policy:

In this policy (which usually follows a continuous review scheme), whenever the inventory goes below the level *R* an order of fixed quantity *Q* is placed. It is a very straightforward and easy to implement policy, but does not fare well with demands of appreciable magnitude (Chiou 2008).

These inventory control policies are the most frequent in literature and in practice as they do not involve demand forecast. Next it is presented a list of more complex, forecast driven inventory control policies:

- *Time Coverage*: Orders stock cover on hand instead of net inventory, i.e. it is based on the number of days which the current on hand stock can cover when faced with the forecasted demand.
- *Dynamic*: This is a service level oriented method and has the biggest impact on stock reduction and service level improvement, and it is based on the risk of stock-out on given period.
- *Self-Adaptive Min-Max*: This is a policy based on Min-Max policy and uses forecast in order to automatically adapt *Min-Max* parameters.

The literature on replenishment is vast. For example, Silver, Naseraldin, and Bischak, 2007 attempt to determine the optimal parameters of an (s, S) policy (order point *s* and order-up-to point *S*) that follows a periodic review scheme. This means it tries to determine the parameters that lead the system to achieve the desired fill rate (fraction of demand satisfied without backordering). This should be attained to improve market performance and achieve strategical goals. In addition to the fill rate, it also tries to respect the average time between two replenishments, which is a common restriction that as origin on the supplier side. The main difficulty in determining these two parameters, in previous studies, comes from the fact that, in periodic review, orders are not made immediately when the order point is reached, but after, on the following review point. This study addresses this issue taking in consideration this fact on its calculations. The method developed produces positive results and it is simple to implement.

Zheng and Federgruen, 1991 present an algorithm capable of evaluating several (s, S) policies (both periodic and continuous review) and calculating the optimal policy (cost wise). It is simple and easy to implement, with a relatively low computational complexity.

Fisher, Rajaram, and Raman, 2001 try a different approach from the usual inventory control policy in order to develop a model able to manage the inventory of products with very short lifecycle, such as fashion products. As these type of products have very short life cycles, they only have one replenishment after the initial allocation, and the usual methods are not very effective. This paper develops a two-phase model that can duplicate profits compared to previous methods. The model can also be used to choose optimal order time and quantify benefits of lead time reduction.

3.1 Transshipments

One area of inventory management that has received more attention in recent times concerns transshipments, which complement traditional replenishment policies. This will be the main focus of this dissertation, therefore it is important to present the main concepts, as well as the literature on the topic.

Transshipments (or lateral transshipments) are stock movements between locations of the same echelon (as in Paterson and Kiesmüller, 2010).

Transshipments are commonly used in practice to offset stock shortages in retail stores, often involving backordering. There are several reasons why transshipments play a crucial role in a correct inventory management, and consequently modelling these situations is required. The aforementioned stock shortages usually come from difficulty in correctly forecasting demand. Even the most powerful forecasts will not be 100% correct due to variability (or white noise) in demand. By using transshipments, stores can pool their resources and share risk (also called variability pooling) therefore reducing costs associated with risks (Tagaras, 1999). Another reason for transshipments come from strategical, political and commercial issues. During procurement process, ordering large quantities in order to obtain bulk discount is common practice, and most of the times the savings from this sort of discount outweigh the increase in operational costs incurred. Other times the imbalance in stocks may not be voluntary but imposed by difference in powers, e.g. suppliers may have much more power than the retailer and impose minimum quantities per order. Transshipments are a very efficient way of handling these kind of situations, as it allows companies to retain the benefits of commercial discounts or keep ordering from a specific supplier and keep operational expenses in check, therefore achieving greater profit.

Transshipments can be divided according to two dimensions: type of pooling and transshipment timing.

Concerning the first dimension, transshipments can have complete pooling and partial pooling. In complete pooling, if a store requests a transshipment, another store in the system may send all stock it has (except the stock used to satisfy short term demand), i.e. it will not consider their own risk of stock-out when sending a transshipment to another store. In partial pooling, a store will take into account their own risk of stock-out and will keep some stock as safety for their own.

About the second dimension, there are preventive transshipments and emergency transshipments. The ones most used in practice are emergency transshipments, which happen only when a store has a stock-out. They often involve backordering client orders. Preventive transshipments try to prevent potential stock-outs by acting before they occur. This type of transshipment is not so frequent in practice, as it requires some form of prediction (e.g. forecasts) for them to be effective. However, this kind of transshipment holds the greatest potential for service level improvement.

The literature on transshipments is quite extensive. Chiou, 2008 and Paterson and Kiesmüller, 2010 develop literature reviews on this topic, classifying the literature according to several dimensions (two of them referenced above), making suggestions for future research.

Jönsson and Silver, 1987 attempts to define a global policy of inventory management (i.e. both replenishment and transshipment policy) for a two-echelon system (one warehouse and *N* stores). This policy has periodic review cycle and transshipment lead times are not considered negligible, which is not common in literature (both at the time of publishing and now). In terms of replenishment, the policy behaves in a similar way to an (S-1, S) policy with periodic review, since at the review period, all stores inventory level is brought up to a certain level . This paper tries to maximize service level, which is considered to be inversely proportional to backorders. It is considered that stock-outs have a much higher chance of occurring in the period immediately before the replenishment cycle, and is therefore more likely that a transshipment is needed during or immediately before that phase. This paper draws the conclusion that, with transshipments, it is possible to obtain the same service level with less investment in inventory (compared with a system without transshipments). It is also concluded that transshipments are more advantageous in high demand variability situations, a long planning horizon, high required service levels and short lead times. The main limitations of this article are the assumption that replenishment (delivery) occurs at the same time for all stores, which does not answer to a number of practical situations, and that all stores are homogeneous.

Robinson, 1990 examines the effects of emergency transshipments, using a model that considers multiple locations and in more than one period. It considers backorders and transshipment lead times as negligible. However, it can only provide an optimal solution for two non-identical locations or several identical locations, i.e. it cannot find the optimal solution for several non-identical locations. It concludes that transshipments can reduce costs considerably.

Diks and Kok, 1996 attempts to define a global policy with periodic review, but here transshipments occur at reorder moments (after the arrival of a replenishment order but before a new order is placed). It defines a transshipment criteria named *Consistent Appropriate Share Rationing* (CAS), whose objective is to balance stock among all stores. CAS consists of keeping the fraction of inventory of each store (comparatively to the system as a whole) constant, using preventive transshipments. The fraction of each store is chosen in order to achieve pre-determined service levels (measured in lost sales). The conclusions are similar to those of Jönsson and Silver, 1987, but add that transshipments are more advantageous when the average demands of each store are similar. The main limitation of this paper is the timing of transshipments, which is restrictive.

Tagaras, 1999 studies a situation with a central warehouse and three stores with emergency transshipments and complete pooling (stores share all stock among themselves). A model is developed to determine which quantity to transship and from which store to which store. This study suggests that, for complete pooling, the policy used to decide from which store and to which store to transfer has not a significant impact on costs. Another conclusion is that investment in inventory is lower and service levels are higher if stores are coordinated and pool their resources. The final conclusion is that groups of stores with similar demand (in terms of variance) have less costs than asymmetrical groups (especially when transshipment costs are low). The limitation of this article is the fixed number of stores it considers.

Archibald, 2007 develops a model of a periodic review, multi-location inventory system, considering emergency transshipments and negligible transshipment lead times. It also develops three heuristics in order to solve this problem. The article concludes that all three heuristics, which follow a partial pooling policy, perform better than complete pooling or no pooling (no transshipments). The less conservative heuristic has better results when compared to the other two.

Lee, Jung and Jeon, 2007 propose a transshipment policy (or rule) named *Service Level Adjustment* (SLA) that considers both emergency transshipments as preventive transshipments. It is a proactive policy that uses the service level to decide which quantity to transship during each period, and from which store to which store. The service level measure used in this article (named SLRP) indicates the probability of a stock-out not occurring in the period following the one being analyzed. Three service levels are previously defined for each store (lower, target and upper) and a store requests a transshipment when their service level measure is below the lower level, and only stores with SLRP above the upper level can transship to it. It assumes that demand follows a normal distribution. The conclusions of this article suggest that this this transshipment policy has a better performance than a policy which considers only emergency transshipments or preventive transshipments. However, this policy does not perform well for high transportation (transshipment) costs, and assumes that the necessity for transshipments is reviewed at each period.

Tiacci and Saetta, 2011 attempts to address the problem of preventive transshipment by creating a heuristic that minimizes costs. It assumes that demand follows a normal distribution and that transshipment lead time is the same for all stores (the goods are transshipped overnight). For a system with two stores it presents a preventive transshipment heuristic (PTH). This heuristic is effective in both high rotation and low rotation items. Although effective and easy to implement, the limitations regarding the use of only two stores and the overnight nature of the transshipment should not be overlooked.

Olsson, 2015 considers a single-echelon continuous review inventory system for spare parts with two locations. The replenishment policy is a (S-1, S) policy. The system has transshipments with positive and constant lead time. It has a transshipment rule base on the time the product has been in stock (this requires that information about the age of product is available). Although the model performs well (according to the results of the article), it is limited to a continuous review scheme and two locations.

Hochmutha and Köchelb, 2012 present a very different approach from the usual in literature about this topic. The authors consider that existing models are only analytically solvable under simplifying conditions. Furthermore, the heuristics available find approximate solutions, but interdependencies between ordering and transshipment decisions for continuous time are not addressed. Therefore this paper proposes the use of simulation optimization. It describes a very adaptable simulation model that can fit in most practical situations. This simulation model is then coupled with a genetic algorithm. An interesting conclusion is drawn from this study: a flow of transshipments is developed, i.e. some locations star to act as hubs (although the article does not answer why). Despite being a highly adaptive model, it is complex to implement and optimize.

Although the vast research on this topic, most of the existing models and heuristics are only analytically solvable under simplifying conditions, which make their use in practice limited. Hochmutha and Köchelb, 2012 tries to surpass this using simulation optimization, but the method proposed is difficult to implement.

The objective of this dissertation is to create a set of rules in order to detect imbalances in inventory system (need for transshipments and availability to transship) and decide what quantity should be transshipped, from where and to which store. These rules should work in parallel with an existing replenishment system and should be easy to implement. They should be adaptable to a number of practical situations (different review schemes, unidirectional/bidirectional transshipments, heterogeneous stores and positive constant lead times dependable on sender and receiver store). After defining these rules, a simulation study will be developed to perceive the advantages of the implementation of these rules in an inventory management system.

4 Methodology

After an extensive analysis of the problem, the study of the existing literature and the type of system in which the model has to perform, it was designed the methodology to approach the problem. The first step of the methodology was to divide the model in three phases, as shown in Figure 5. Then, after the division of the model in phases, a set of rules/heuristics was created in order to solve each phase's problem. This methodology was chosen due to its ease of application and its capability of achieving results at a reasonable speed. In order to test the model developed, a real situation was simulated.

4.1 Model's Phase Division

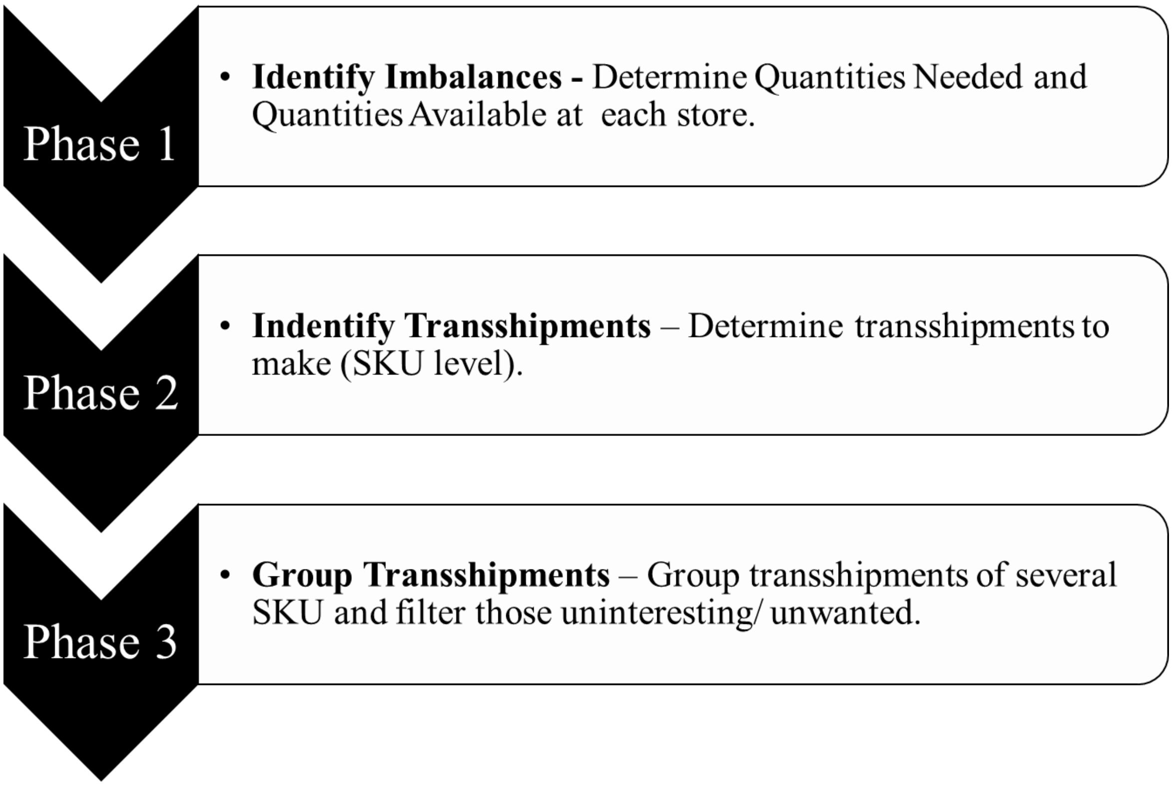

Figure 5 - Model's Phase Division.

On the first phase, the model identifies imbalances between stores. These imbalances come in the form of quantities needed, for stores with less stock than they need to satisfy demand and therefore need a transshipment, and available quantities, for stores with more than enough stock to satisfy their demand, and are consequently available to make a transshipment. These quantities are computed through detection rules/heuristics created with this purpose (for more detail, see section 4.2.1).

On the second phase, the model identifies the transshipments that are possible, by ranking the quantities determined on the previous phase and grouping a store which has a need for a transshipment with a store that has availability to transship. This is achieved through the use of ranking rules/heuristics (see section 4.2.2). Both this phase and the previous one occur at the SKU level.

The third phase occurs after the previous phases have been completed for all SKU's of the system. This phase groups the transshipments obtained previously for all SKU's in order to save in transportation cost. It groups transshipments that are sent from the same sending store to the same receiving store. It may also filter transshipments that are deemed undesirable by the model's user. This filter eliminates the transshipments that have a quantity below a certain level, defined by the user.

4.2 Rules/Heuristics Used

As one of the objectives of this dissertation is to produce a model with ease of implementation, it was decided to use heuristics in the development of the model. This method allows for good results in reasonable time. Several heuristics were created for the different phases of the model. The model will consist of the combination of three heuristics, one for each phase.

4.2.1 Phase 1 – Detection Rules

The detection rules were created in order to detect imbalances of inventory between the stores. Imbalances means that some stores will not have enough stock to face demand until replenishment, while other will have more than enough. The stores in the first situation are considered to need a certain quantity to be transshipped to them, while the ones in the second situations have a certain quantity to transship. It is then the objective of the detection rule to discern the stores which require transshipments and those which have stock available to supply others.

The detection rules developed are the following:

4.2.1.1 Base

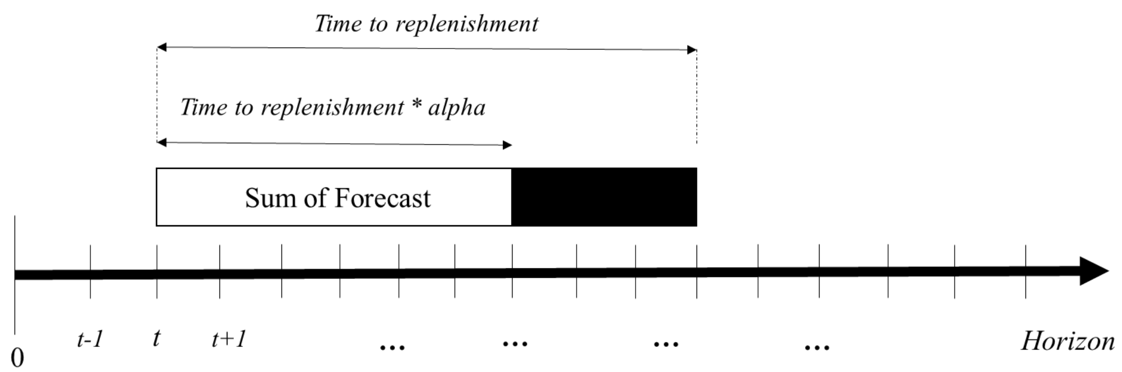

Figure 6- Schematics of the Base Detection Rule.

The base detection rule (the first one to be developed) determines the quantity needed by making the difference between the on-hand stock of the store at given period with the forecasted demand for a defined number of periods ahead.

$$Needed\ (or\ Available)\ Quantity = On\ Hand\ Stock_t - \sum_{t}^{t+time\ to\ replensihment*alpha} Forecast \quad (1)$$

If the quantity is positive, the store has quantity available, and if it is negative the store has needed quantity. If the quantity is zero, then the store does not order nor transships any quantity.

One detail that requires clarification is the parameter alpha, referred in expression (1). To avoid transshipments when the replenishment is too close (and for such considered dispensable), this parameter alpha was created so as to create an evaluation period that is limited to a certain percentage of the time left to replenishment. This evaluation period is the same for all rules.

4.2.1.2 Cover

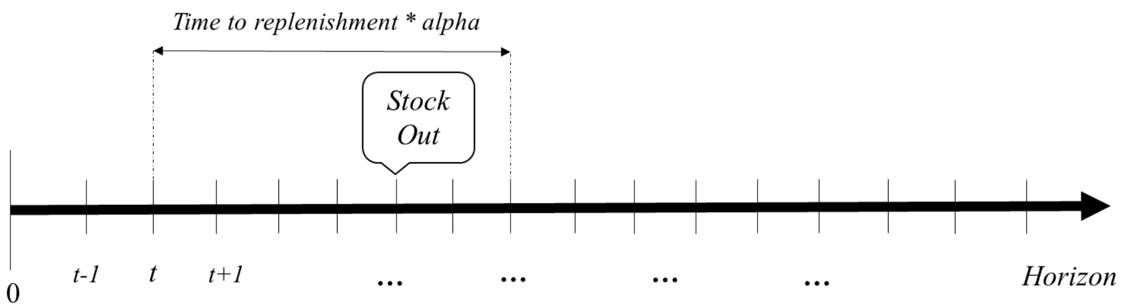

Figure 7- Schematics of the Cover Detection Rule.

The cover detection rules tries to detect stock-outs in the evaluation period. If there is a stock out during the evaluation period, the needed quantity is equal to the sum of forecasted demand from the day of stock out to the end of the evaluation period. If there is no stock out during the evaluation period, the available quantity for transshipments is equal to the on hand stock at the end of the evaluation period.

$$\begin{cases} Needed\ Q. = \sum_{stock\ out\ day}^{t+time\ to\ replenishment*alpha} Forecast \\ Available\ Q. = On\ hand\ stock_{t+\ time\ to\ replenishment*alpha} \end{cases} \quad (2)$$

4.2.1.3 Service Level Adjustment (I and II) (SLA)

This detection rule is based on the one proposed by Lee, Jung and Jeon 2007. The service level adjustment is a lateral transshipment policy based on service level presented on the aforementioned paper. The service level measure used in this article is named SLRP, and consists of the probability of not having a stock out in the following period. In the article, a confidence interval was made in order to determine which stores need a transshipment and the availability to transship (assuming that demand follows a normal distribution). These confidence intervals were compared with the target service levels stores had previously defined, i.e. upper and lower service levels, and needed and available quantities were computed based on this comparison.

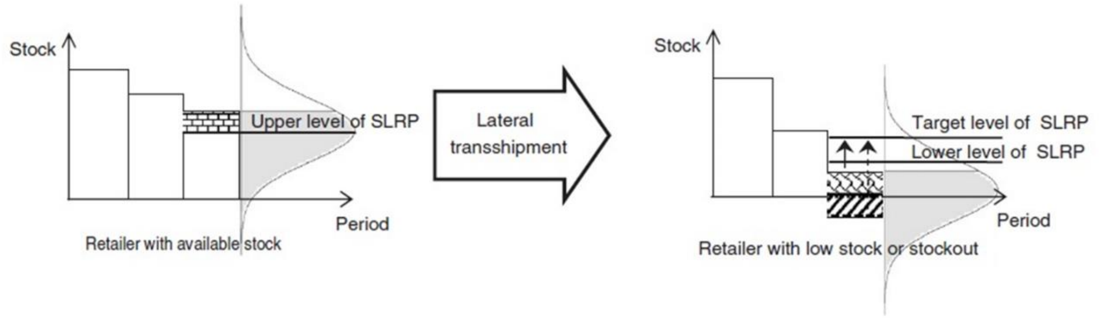

Figure 8- Decision to transship based on Service Level Adjustment (SLA) (based on Lee, Jung and Jeon, 2007).

The decision rule presented by Lee, Jung and Jeon 2007 was as follows: if a store had enough stock to surpass the upper service level, it would be available to transship; if a store was below the lower level of service level, it would need enough to reach the target service level.

In this dissertation, this particular aspect of the SLA lateral transshipment policy was adapted in order to create a rule used in detection of imbalances. The main difference is that the needed quantity is computed to achieve the low service level, and not the target service level. The reason for this difference was to reduce the number of inputs by the user, in order to increase the models usability. Also the evaluation time is not the time to replenishment (as in the original article), but the evaluation time used for the other detection rules (see expression (3) and (4)).

$$Needed\ Q. = int\big(average\ forecast * evaluation\ time + Z_{SLsup} * Std.Dev.forecast * evaluation\ time + 0.5\big) - On\ hand\ stock_t \quad (3)$$

$$Available\ Q. = On\ hand\ stock_t - int\big(average\ forecast * evaluation\ time + Z_{SLinf} * Std.Dev.forecast * evaluation\ time + 0.5\big) \quad (4)$$

Z_{SLsup} and Z_{SLinf} are the inverse normal functions values with the inputs of the upper service level and the lower service level, respectively. This first version of the detection rule is the one closest to the one presented in the mentioned paper (in the article it is considered demand instead of forecast). As one of the inputs for this model is a forecast, a second version of this rule was created where instead of using the average of demand for the evaluation period, we use the sum of forecast for the same period. From this results expressions (5) and (6).

$$Needed\ Q. = int\left(\sum_{t}^{t+time\ to\ replenishment*alpha} Forecast + Z_{SLsup} * Std.Dev.forecast * evaluation\ time + 0.5\right) - On\ hand\ stock_t \tag{5}$$

$$Available\ Q. = On\ hand\ stock_t - int\left(\sum_{t}^{t+time\ to\ replenishment*alpha} Forecast + Z_{SLinf} * Std.Dev.forecast * evaluation\ time + 0.5\right) \tag{6}$$

It is expected that the second version (SLA II) to perform better than the first one (SLA I), since it based on actual forecast for the period instead of an estimate based on the average forecast. However, both will be tested in order to achieve proper conclusions. If there is a case in which there is no forecast available, SLA 1 may be used with an average of historical data, making this rule usable.

4.2.2 Phase 2 – Ranking Rules

This section describes the main ranking rules used in the model. These ranking rules are used after determining the quantities needed and available to pair stores with needed quantities to stores with available quantities at the same period. These pairings are made after ranking the stores according to a number of criteria. After the pairing, the quantity transshipped is equal to the minimum between the quantity needed and the quantity available of the pair of stores. A flow diagram of an example of a Ranking rule (Maximums rule) can be consulted in annex A.

The ranking rules developed are the following:

4.2.2.1 Maximums

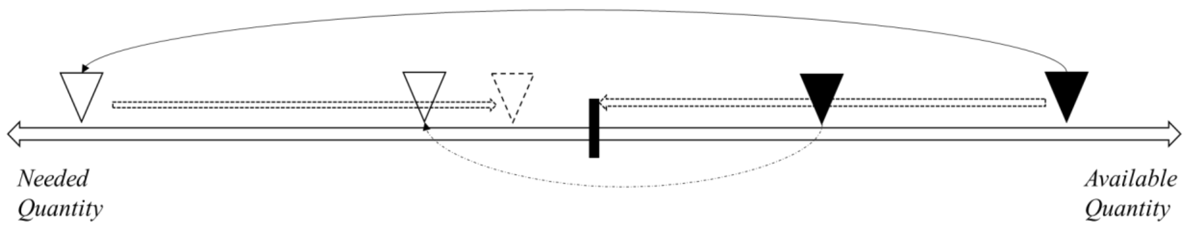

Figure 9- Schematics of Maximums Ranking Rule

The reasoning behind the Maximums ranking rule is to pair first the stores with the largest need (in quantity) with the store which has more stock available for transshipments. After pairing the largest need with the largest availability, the quantities needed and quantities available are updated. Next, the new maximum need is paired with the new maximum availability. This process is repeated until there is no more quantity required and/or quantity available, or if it is not possible to transship among those that still have need or availability. The logic for the creation of this rule is straightforward: the stores that would suffer a more severe stock out are served first, and the stores less likely to suffer a stock out are the first ones to send.

4.2.2.2 Minimums

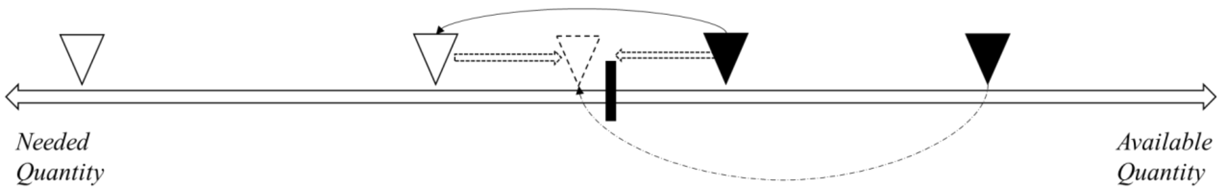

Figure 10- Schematics of the Minimums Ranking Rule

The Minimums ranking rule pairs the stores with the least needs, with the ones with least availability. The reasoning behind this rule comes from giving the option to users to use transshipments for smaller quantities, and leave the largest need to an emergency order. This may be the case for transshipping big items, when the transportation fleet in charge of transshipments cannot carry more than a certain quantity, while the replenishment fleet has more capacity. The stopping conditions for this rule are the same than for the Maximums rule.

4.2.2.3 Stock Out

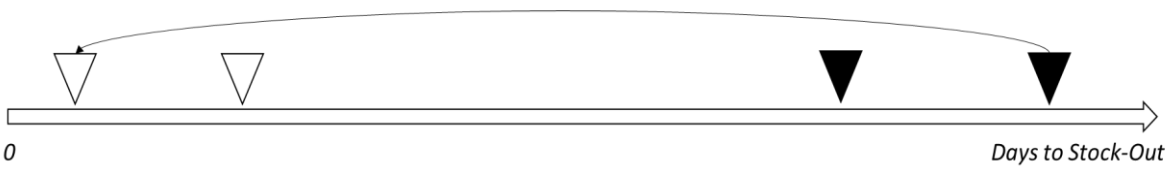

Figure 11- Schematics of the Stock-Out Ranking Rule

The stock out rule pairs, not according to quantity, but according to the number of days left to a predicted stock out. The store with needed quantity and with the least number of days to stock out is paired with the store with quantity available for transshipment and the highest number of days to stock out. After this pairing the needed and available quantities are updated, and this reasoning is repeated until there is no store with availability and/or needed quantity, or if it is not possible to transship between those which have. The underlying logic for the creation of this rule is to first serve the stores which have a stock out sooner, sending the transshipment from stores which would have their stock outs later (if they had – in case of no predicted stock out, that store is chosen).

4.2.2.4 Cost

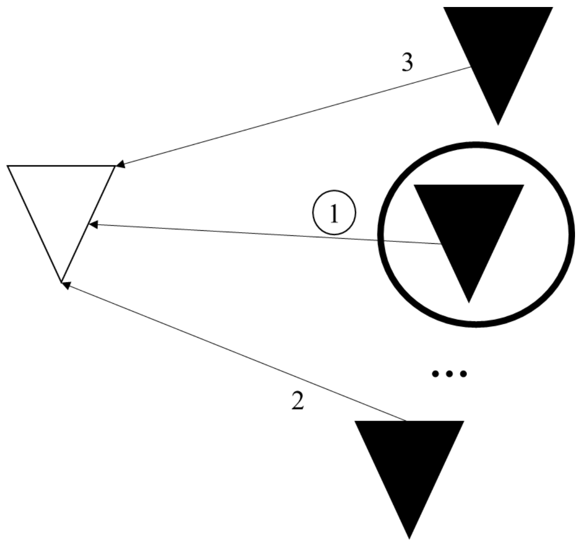

Figure 12- Cost Ranking Rule illustration. The cost of transshipment is represented near the arrows.

The idea behind the cost ranking rule is to reduce the cost of transshipping. This rule consists of pairing one store which needs a transshipment with the one which is available to send a transshipment and has the least cost for transshipping to the store in need. This rule has the particularity of not being able to decide both store trough this criteria. Transshipment costs depend on the location of the sending store and the receiving store. To select the cheapest transshipment to a certain store, it is first needed to select the origin store using one of the rules mentioned previously. Therefore there is no cost ranking rule, but several hybrid cost rules that are a mix of the cost rule with one of the rules mentioned previously (e.g. Cost Maximums rule, Cost Stock Out rule, etc.). The logic behind the creation of this rule is to minimize the cost of the transshipments.

4.2.2.5 Inverse

All the ranking rules mentioned previously assumed that, during the pairings of stores, the store with need was selected first. However it is possible to create inverse rules, where the store with availability is selected first, and then it is paired with a store in need. By ranking and selecting first the stores with availability to transship, it is being given priority to lowering the risk of stock-out in the sending store (which may happen due to sudden change in demand relative to forecast).

With the Inverse and Cost variations, the three base rules (Maximums, Minimums and Stock-Out) are expanded into 12 rules (3 base, 3 cost hybrid only, 3 inverse hybrid only and 3 inverse cost hybrid).

The following table presents a summary of the ranking rules introduced.

Table 2- Summary of Ranking Rules

Base Rule	Cost	Inverse	Inverse Cost
Maximums	Cost Maximums	Inverse Maximums	Inverse Cost Maximums
Minimums	Cost Minimums	Inverse Minimums	Inverse Cost Minimums
Stock Out	Cost Stock Out	Inverse Stock Out	Inverse Cost Stock Out

4.2.3 Phase 3 – Transshipments Grouping

The grouping of the transshipments obtained on the previous phases occurs on phase 3. The heuristic developed is quite simple. First, all transshipments from all SKU's are sorted out by sender store and receiver store, and transshipments with the same sender and receiver are grouped together. The second step is to check the quantity of these groups of transshipments and filter them. Those group of transshipments which are below the minimum limit defined are eliminated and not performed. If the quantity of the group of transshipments are above the limit, the transshipments occur and the group of transshipments has a single cost, since they share the cost of transportation.

4.3 Simulation

Having developed the model, it was necessary to test it. In order to do this, a simulation model was created. The next paragraphs first describe the simulation parameters and then the structure of the simulation. Afterwards it is described the evaluation criteria. This simulation was based on a (s, S) replenishment system, as it is the one currently used by the client who requested the model. The simulation model was programmed in Visual Basic for Applications (VBA) in Microsoft Excel. On sub-section 4.3.3, it is described the evaluation criteria used to analyze the behavior of the model across the simulation runs.

4.3.1 Simulation Parameters

To add more flexibility to the simulation model and to increase the range of tests made to the transshipment model developed, several parameters were created. These parameters are as follows:

- Replenishment Review Recurrence and Transshipment Review Recurrence: With these parameters it is possible to define when and at which frequency a review will happen, for both the replenishment and the transshipments. These parameters are independent from each other. The reviews may happen every day, any number of days per week, any number of days every two weeks, three weeks and four weeks. It is also possible to define in which day of the week the reviews will occur. If the decision maker chooses to review every day, it is considered a continuous review policy.

- The Alpha Parameter: this parameter, as described on the Detection rules section (4.2.1), defines the evaluation period used on the heuristics created. Alpha is equal to the proportion of the time to replenishment that will be used as the heuristics' evaluation time.

- The Lower Service Level (SL_{inf}) and the Upper Service Level (SL_{sup}): as described on the detection rule section (4.2.1), the Lower service level and Upper service level are used in the SLA 1 and SLA 2 detection rule in order to determine the quantities needed and available at each store.

- Transshipment Limit: this parameter defines the minimum quantity a transshipment of a single SKU must have in order to occur.

- Transshipment Group Filter: this is a parameter that defines the minimum quantity that a group of transshipments has to have in order to occur.

4.3.2 Simulation Structure

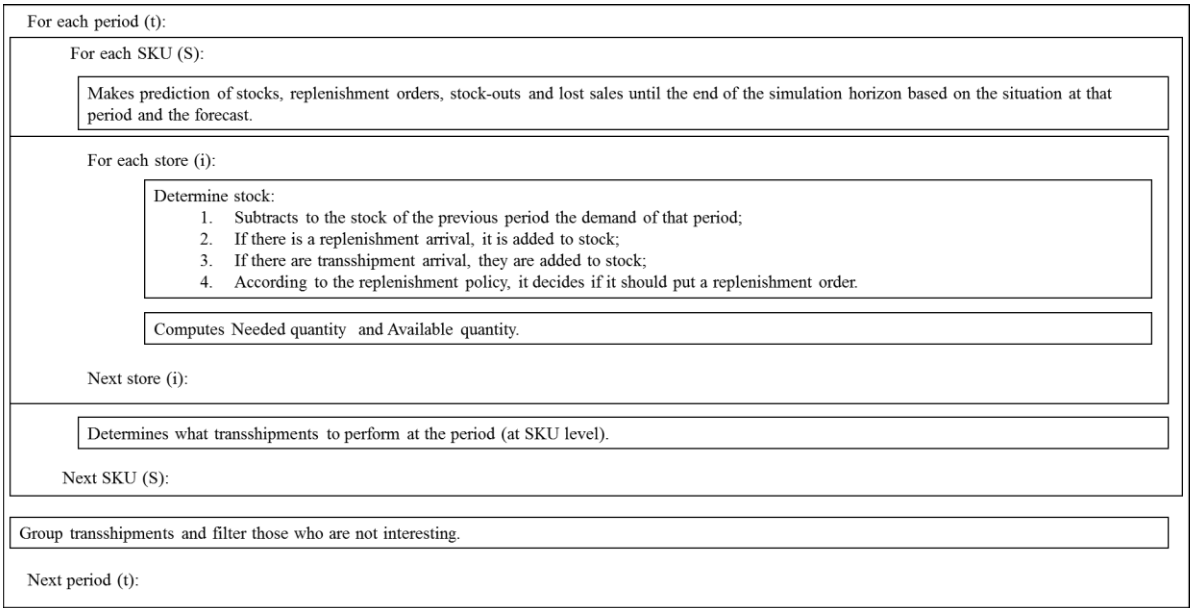

Figure 13- Simulation Structure

Figure 13 summarizes the simulation's structure used to test the model. For each period (with index *t*) and each SKU (with index S), first it is created a prediction of stock-outs for all periods from the current *t* to the end of the time horizon of the simulation. These predictions are based on the current state of the system at that point in the simulation and the forecast of demand. These predictions will be combined with the rules created for the model in order to decide which transshipments to make.

Then, and for each store (with index *i*), it is determined the stock of the current period. For this, first it is subtracted to the stock of the previous period the demand that occurred on the previous period. Then, lost sales and stock-outs are computed. It is assumed that replenishment orders and transfers only arrive at the end of the day. Afterwards, if there is a replenishment order arriving, it is added to stock. Likewise, if there are any transshipments arriving, its quantity is added to the store's stock. As a last step in determining the stock level, a replenishment order may be requested, if the conditions established by the replenishment policy for ordering are fulfilled (in case of periodic review, if the current period is a review period and if the order-point has been reached).

After determining the stock level, the quantity required and the quantity available for transshipment at each store are computed based on one of the detection rules defined.

Upon completion of the previous steps for each store, the simulation determines the transshipments to perform at SKU level. The final output of the model is to provide a list of suggested transshipments to the decision maker. In reality, the decision maker may choose not to perform the transshipment, but, during the simulation, it is assumed that all the suggested transshipments are made. These transshipments are determined based on one of the ranking rules defined.

When all transshipments at SKU level at the end of the period are known, transshipments are grouped, i.e. different SKU's that are transshipped from the same store to the same store are grouped together in order to save in transportation costs. These transshipments are also filtered by quantity, i.e. the user of simulation may define a minimum quantity, and the transshipment only occurs if it surpasses that quantity of products.

4.3.3 Evaluation Criteria

In order to evaluate the performance of the different systems different criteria were used. These criteria will be used to compare the system with transshipments with the one without transshipments (a control system). Furthermore, they will be used to assess the performance of systems with different transshipment rules.

The basic criteria used for evaluation were the number of orders, the quantity of lost sales, the average stock, and the cost of transshipments. The number of orders is the number of replenishment orders (per SKU) that all stores create during the horizon of the simulation and is related with ordering costs. The quantity of lost sales is the sum of the quantity not sold, due to stock-out for all stores, during the horizon of the simulation and is related to service level (a type β service level, according to Table 1). The average stock is the average on hand stock for all stores during the horizon of the simulation and is related with holding costs. The cost of transshipments is the sum of transshipment for all stores during the horizon of the simulation that result from transshipments and is related to extra transportation costs incurred from transshipments. The main focus is to compare systems with transshipments using different rules.

Another criteria was developed based on the basic criteria, named Lost Sales Recovered per Transshipment (LS/NT). This represents the average of lost sales recovered by a transshipment, and is computed using expression (7):

$$LS/NT = \left|\frac{Difference\ in\ Lost\ Sales}{Number\ of\ Transshipments}\right| \qquad (7)$$

During the development of the model, it arose the need to evaluate specific behaviors of the system when using the transshipment rules created. It is of particular relevance for retailers to know the likelihood of having a stock out when sending a transshipment. It is also important to know the likelihood of receiving a transshipment that will not cover any lost sales, and is therefore useless. This motivates the creation of two additional measures to evaluate these particular issues.

The first one is the Senders Lost Sales (SLS), and it is the number of transshipments that created lost sales in sender stores (when compared with a system with no transshipments) divided by the total number of transshipments.

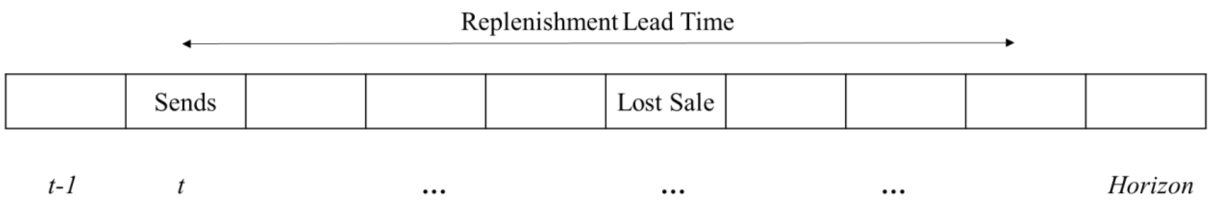

Figure 14- How to determine if there was a lost sale in sender (SLS). Example of a Lost Sale in Sender.

To determine the number of transshipments that lead to lost sales in sender we check the lost sales of the sender for an evaluation period equal to the replenishment lead time of the store that sent. If there are extra lost sales during that period when compared to the situation without transshipments, it is assumed that the lost sales were caused by the transshipment. The sum of all this cases is the dividend of expression (8).

$$SLS = \frac{Nº\ of\ Transshipments\ that\ lead\ to\ lost\ sales\ in\ sender}{Total\ nº\ of\ transshipments} \tag{8}$$

The second one, Receivers Useless Transshipments (RUT), is the number of transshipments that did not prevent any lost sales on the receiver (when compared with a system with no transshipments).

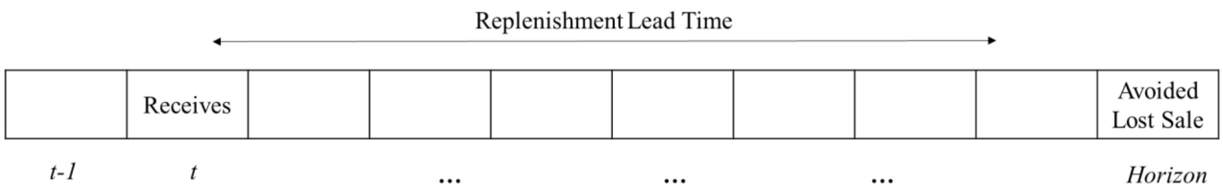

Figure 15 - How to determine if the transshipment was useless to the receiver (RUT). Example of a useless transshipment.

$$RUT = \frac{Nº\ of\ Transshipments\ that\ do\ not\ prevent\ lost\ sales\ in\ receivers}{Total\ nº\ of\ transshipments} \tag{9}$$

To determine the number of transshipments that do not prevent lost sales in receiver, we check the stock outs of the receiver for an evaluation period equal to the replenishment lead time of the store that received. If there are no lost sales avoided (i.e. the number of lost sales is the same) during that period when compared to the situation without transshipments, it is assumed that the transshipment was useless. The sum of all this cases is the dividend of expression (9).

5 Simulation Results

In this section, the results obtained in the simulation tests of the model developed are discussed. This section is structured as follows: first, a description of the methods used for validation of the simulation model; second, a description of the samples used on performance testing; third, an explanation of the tests performed; fourth, a discussion of the test results

5.1 Validation

During the development of the simulation model, it was necessary to perform model verification and model validation in order to ensure that the results obtained are correct. According to Sargent, 2011, model verification is defined as "ensuring that the computer program of the computerized model and its implementation are correct". From the same source, model validation is defined as "substantiation that a computerized model within its domain of applicability possesses a satisfactory range of accuracy consistent with the intended application of the model".

Verification of the program that implements both the transshipment model and the simulation model occurred throughout its development process using several test inputs (such as partial samples, single product samples and three product samples). The manual of the prototype developed can be consulted in annex B.

For model validation, a sample of the six fashion products with the highest rotation of the store chain was used. First, tests with extreme parameters were performed, one test with alpha = 0 and another with initial stock S_0 in each store extremely high (10 times more than supposed). These two situations produced no transshipments, as expected. For alpha = 0, the evaluation period was inexistent and therefore there could not be any need or availability for transshipments detected. With very high initial stocks in all stores, no transshipments were performed, since there were no stock-outs (also no replenishment orders were performed, for the same reason). Second, the sample was tested using different parameters and the behavior of the model was presented to experts (senior business consultants) on this domain in order to perform face validation. The tests were similar to those described on section 5.3 (Test Description). Having conducted this validation, the system behavior was approved.

5.2 Samples Description

The samples used to test the performance of the model can be divided according to three dimensions: Business Sector, Season and Product Group, resulting in seven data samples.

5.2.1 Business Sector

In order to obtain meaningful results that attest the flexibility of the model, it was decided to have samples from more than one retail sector. Two sectors were chosen: the Fashion sector, and the Pharmacy sector. The Fashion sector was selected as it is the one in which the client that requested the model operates. Therefore this is the first real world application in which the model will be used. Thus it is critical that the model is tested using this sector. The Pharmacy sector was selected due to their differences relative to the Fashion sector: higher rotation products, in higher quantities. Testing these two very different sectors provides general view of the applicability of the model.

Based on the demand scenarios and product group (see next sections) different data samples were used. Each data sample from the Fashion sector includes 21 stores, while the data samples from the Pharmacy sector include 5 stores each.

5.2.2 Demand Scenarios

In order to observe how the model reacts under different demand scenarios, samples from different seasons were tested. On the Fashion sample two season were tested: a sample from January (2^{nd}) to March (2^{nd}) (with less demand) and a Christmas sample (from November 1^{st} to December 31^{st}) (with higher demand). Regarding the Pharmacy sample, one season was tested, from January (2^{nd}) to February 28^{th}.

The Jan.-Mar. Fashion sample had a total time horizon of 60 days, the Christmas Fashion sample had a time horizon of 61 days, and the Pharmacy sample had a total of 58 days. The Christmas fashion sample is one day longer due to the fact that on Christmas day stores are closed, having one day where no sales are made. The Pharmacy sample is slightly shorter in terms of time horizon due to a data base size constraint, which made handling more than 58 days of data too time consuming.

5.2.3 Product Group

In order to produce significant results to managers, other samples are based on the product groups (P.G.). For Fashion, there are three samples sets: Highest rotation product (trousers), all sizes (an SKU is defined not only by product style, but also size and finishing touches), Medium rotation product (trousers), all sizes, and an amalgam of other groups of products (e.g. shorts, sweaters, etc.), which have lower rotations. The Pharmacy sample consisted of the 50 products with highest rotation.

The sample of high rotation trousers had 304 SKU’s, the sample of medium rotation trousers sample had 158 SKU’s, and the Amalgam had a total of 137 SKU’s, divided in the following groups: Shorts - 24; Shirts - 19; Coats - 5; Knitwear - 12; Sweatshirts - 4; T-shirts/Polo-shirts - 73).

In order to make it easier to perceive the samples tested, they are summarized in the following tables:

Table 3 - Samples used for testing – Fashion (number of SKU's in sample)

Fashion (21 stores)	Demand\P.G.	High rot. Trousers	Medium rot. Trousers	Amalgam
	Jan. – Mar. (60 days)	304	158	137
	Christmas (61 days)	304	158	137

Table 4 - Samples used for testing –Pharmacy (number of SKU's in sample)

Pharmacy (5 stores)	Season\P.G.	50 Highest
	Jan. – Feb. (58 days)	50

5.3 Test Description

In order to test the model in a variety of situations, the multiple samples were tested using different simulation parameters (as defined in subsection 4.3.1). Three groups of tests can be defined: Base tests, Continuous review tests, Periodicity tests, and Alpha parameter tests.

For all these tests, the number of combinations of Detection and Ranking heuristics used is four: the Detection heuristics used are the Base and the Service Level Adjustment 1 (SLA 1), and the Ranking heuristics used are the Maximums and the Cost Maximums. In order to obtain results in a more efficient way, first a battery of tests using all the heuristic combinations were performed using a smaller sample of the 6 SKU with the highest rotation. This was the same sample used on the face validation of the simulation model. A report with the results from this first round of tests can be consulted in annex C. The main conclusion of these tests was that the heuristics with the best performance were the Base, the SLA 1 Detection heuristics and the Maximums Ranking heuristic and its variants. It was also concluded that the Inverse variant had no significant difference from their original counterparts. Given these results, the four combinations aforementioned were chosen to perform the tests with larger samples.

5.3.1 Base Tests

The Base tests, which are used as a basis for comparison, have the following parameters:

Table 5 - Base Tests Parameters

Tests: Base	
Replenishment Review Recurrence	1
Transshipment Review Recurrence	1
Alpha	0.5
Lower Service Level (SL_{inf})	0.6
Higher Service Level (SL_{sup})	0.99
Transshipment Limit	0
Transshipment Group Filter	0

The Service Levels chosen were the ones that guaranteed a balance between risk (SLS values) and potential lost sales recovered. This test was named Base due to using the replenishment system which is expected to be the most used in practice. The use of alpha equal to 0.5 is due to being the median of the possible values that this parameter can take.

5.3.2 Continuous Review Tests

The continuous review tests, are used to measure the performance of the model under a system with continuous review policy. Two cases were tested: a full continuous review, where both replenishment and transshipments are reviewed continuously, and a semi continuous review, where the replenishment review is once a week and the transshipment review is continuous.

Table 6 - Continuous Tests Parameters

Tests: Continuous		
	Full	**Semi**
Replenishment Review Recurrence	0	1
Transshipment Review Recurrence	0	0
Alpha	0.5	0.5
Lower Service Level (SL_{inf})	0.6	0.6
Higher Service Level (SL_{sup})	0.99	0.99
Transshipment Limit	0	0
Transshipment Group Filter	0	0

5.3.3 *Periodicity Tests*

The periodicity tests assess the performance of the model when replenishments review are more spaced in time, namely once every two weeks and once every month (4 weeks).

Table 7 - Periodicity Tests Parameters

Tests: Periodicity		
	2 weeks	**4 weeks**
Replenishment Review Recurrence	2	4
Transshipment Review Recurrence	1	1
Alpha	0.5	0.5
Lower Service Level (SL_{inf})	0.6	0.6
Higher Service Level (SL_{sup})	0.99	0.99
Transshipment Limit	0	0
Transshipment Group Filter	0	0

5.3.4 *Alpha Parameter Tests*

With the alpha parameter tests, it was analyzed the performance of the model when the evaluation period changed. This was achieved by changing the alpha parameter. The values chosen were 0.3, 0.75 and 1, which represent a value lower than the one used on the basis model, a higher value, and a special case where the complete time for replenishment is used as evaluation period.

Table 8 - Alpha Tests Parameters

Tests: Alpha Parameter			
	0.3	**0.75**	**1**
Replenishment Review Recurrence	1	1	1
Transshipment Review Recurrence	1	1	1
Alpha	0,3	0,75	1
Lower Service Level (SL_{inf})	0,6	0,6	0,6
Higher Service Level (SL_{sup})	0,99	0,99	0,99
Transshipment Limit	0	0	0
Transshipment Group Filter	0	0	0

5.4 Test Results

The results from the simulation tests will be presented in this section. With a processor Intel I7 -720 QM (6M Cache, 1,60 GHz) and 8 Gb of RAM memory available, the simulation run time varied according to the samples' size: for a sample with around 300 SKU's and 4 scenarios (heuristics combinations) it took about 1h15min to be completed; for a sample with around 150 SKU and 4 scenarios it took about 0h30min to be completed.

The detailed results may be consulted in annexes D and E.

5.4.1 Fashion

5.4.1.1 Fashion - Base Tests

Regarding demand scenarios, the Christmas samples involve more transshipments, greater potential lost sales recovery and better average stock. However they have a bigger increase in replenishment orders than the Jan. - Mar. samples, and involve higher risk, with higher SLS and RUT values. Overall, LS/NT values are lower on the Christmas season. As the Christmas season has more stock movements (e.g. sales), more transshipments were expected. In this case, the higher risk and lower LS/NT may hint that the system is less efficient on very reactive systems (i.e. systems with high number of stock movements).

When comparing Detection rules, the Base Detection rule has greater lost sales recovery and better average stock. In terms of risk, the Base rule has slightly higher SLS values, but the SLA 1 Detection rule has very high RUT levels. In fact, SLA 1 presents overall worse performance (except on SLS values) due to a high number of useless transshipments, which leads to low values of lost sales recovered per transshipment (LS/NT).

In what concerns the Ranking rules, the Cost Maximums rule has, as expected, less transshipment costs. Although SLS lost sales recovery is higher using the Maximums Ranking rule, this rule has also more transshipments, which leads to worse LS/NT values than the Cost Maximums. The Cost Maximums also promotes an increase in the number of replenishment orders. When comparing the results of these two Ranking rules combined with the Detection rules, the Maximums rule is more resilient, i.e. it presents less variation using different Detection rules. The Cost Maximums performance is a lot worse when combined with the SLA 1 Detection rule than with the Base Detection rule.

Concerning the different samples, all of them presented the same behavior regarding seasonality, Detection rules and Ranking rules. The amalgam sample was tested with all the SKUs' groups together and separately. Results were the same, except in terms of number of transshipments and cost, which were less when all groups were together. Therefore, the amalgam sample will be tested with all the SKUs' groups together for the following tests.

5.4.1.2 Fashion - Continuous Tests

As a reminder, the continuous tests consisted of two scenarios: one where both the replenishments and the transshipments were reviewed continuously, called full, and another where only the transshipments were reviewed continuously, called semi. The results of these tests will be compared with the results of the Base tests, the basis for comparison.

In the semi scenario, increasing the number of transshipment reviews leads to more transshipments, which in turn leads to more lost sales recovered and lower average stock. However, the cost of transshipment increases, and the increase in number of replenishment orders is very high. Furthermore, SLS and RUT values increase as well, with the LS/NT decreasing, which indicates that the increase on the number of transshipments is greater than the increase in lost sales recovered. The increase in SLS and RUT values may be due to an increase in stock movements.

The number of replenishment orders increases with the increase in transshipments. As stores send their stock in transshipments, they accelerate their replenishment cycle, leading to an increase in their number of orders. Receiving stores, on the other hand, receive just enough to avoid lost sales having no interference on the speed of their replenishment cycle. The increase in the number of replenishments in the sending stores and the neutral impact on the receiving stores lead to an increase in the number of orders. In simpler words: stores sell more, they order more.

In the full scenario, different behaviors were revealed during the tests depending on the demand scenario used. In the Jan.-Mar. period, the number of transshipments is reduced, as are the costs. The average stock, however, increases significantly. The increase in the number of orders decreases. The potential lost sales recovery is lower in absolute (when compared with the basis for comparison) but greater in relative terms, meaning that there are less lost sales recovered in a system with continuous review. The reduced number of transshipments and lost sales recovered, together with the increase on average stock indicate that in a continuous replenishment review system, transshipments have less recovery potential during seasons with less sales, which makes sense, since replenishment orders are more flexible and can suppress lack of stocks faster. However, in the Christmas period there are more potential for recovery of lost sales. This indicates that, in high rotation environments, an increase in the speed of replenishment system may not be enough to satisfy demand, and that transshipments may play an important role in fulfilling part of this demand.

5.4.1.3 Fashion - Periodicity Tests

In order to test the performance of the model when the replenishment reviews are more spaced, the model was tested for replenishments occurring every two and every four weeks.

The increase in the spacing between replenishment reviews leads to an increase in the number of transshipments (when compared to the basis of comparison), as well as the number of replenishment orders. The average stock decreases greatly. In absolute, more lost sales are recovered, but they decreased relatively. The only situation where lost sales recovery is lower than the standard of comparison is when the replenishment review occurs every four weeks on Christmas, for the High rotation trousers. Since Christmas is a season of high rotation and the group of products presents high rotation, a replenishment review every four weeks may not be adequate. Therefore, it can be concluded that an inadequate replenishment system may hinder the model's performance. However, within certain limits, it is possible to say that the greater the difference between the recurrence of replenishment and transshipments, the greater the benefits of the model, namely in terms of lost sales recovered and average stock.

These results indicate that for products with spaced replenishments, the main advantage of transshipments is the reduction of the average stock levels, even more than the recovery of lost sales.

5.4.1.4 Fashion - Alpha Parameter Tests

To test the influence of the heuristics' evaluation time on the performance of the model, a test with different alphas (0,3; 0,75; 1) was performed.

The tests revealed that, when increasing alpha, and therefore increasing the evaluation time, the number of transshipments and lost sales recovered increased, as well as the RUT levels. The average stock and SLS levels variation depended on the group of products being analyzed and the heuristic combination used (no pattern was found).

It can be concluded that increasing the evaluation time leads to an increase in the number of transshipments, which was expected, and that increasing too much the evaluation time lead to more useless transshipments.

5.4.2 Pharmacy

5.4.2.1 Pharmacy - Base Tests

The results on the Pharmacy data sample were similar to those obtained with the Fashion sample, albeit Pharmacy sample had relatively less lost sales recovered. However, these results present some differences that require attention.

In this sample, RUT and SLS levels were similar when using the Base Detection rule and the SLA 1 Detection rules. However less transshipments were made on the scenarios with SLA1 as the Detection rule, and therefore less lost sales were recovered. On the Fashion samples, the number of transshipments and lost sales recovered were similar in both Detection rules (Base and SLA 1), but the SLA 1 scenarios had higher levels of RUT. The situation is the same in both cases, but presents itself on opposite manners: either transships a lot, recovering a lot of lost sales but making lots of useless transshipments in the process, or transships less, recovering less sales, but making less useless transshipments. It appears that for high rotation products (Pharmacy) this situation manifests in the latter form (less transshipments), while for low rotation (Fashion) it manifests with more transshipments and higher RUT.

As in the Fashion samples, LS/NT is better when using the Base Detection rule.

Concerning the Ranking rules, although in Fashion samples the difference between them was clear, on the Pharmacy sample there were no pronounced differences between the two rules (Maximums and Cost Maximums), namely in the number and cost of transshipments. It could be said that the higher the rotation, the less pronounced become the differences between Ranking rules. For the Detection rules, the differences show the same, but may appear in a different form.

In all tests, SLS values are higher on the Pharmacy sample than in the Fashion sample, indicating higher risk. This might be due to the reduced number of stores and SKU. When using the SLA 1 Detection rule, the SLS values go down when compared with the Base Detection rule.

5.4.2.2 Pharmacy - Continuous Tests

The results for this test on the Pharmacy sample are generally the same than those of the Fashion sample, with one important difference to notice. In the Full case (continuous review for both replenishment and transshipments), the average stock is lower, behaving in the exact opposite way than the Fashion sample, except when the SLA 1 Detection rule is used.

5.4.2.3 Pharmacy - Periodicity Tests

On the periodicity tests, the results were once again similar to those on the Fashion sample, especially with the group of High rotation trousers and when the replenishment recurrence is 4 weeks (as the Pharmacy sample includes high rotation products).

5.4.2.4 Pharmacy - Alpha Parameter Tests

The behavior of the model during these tests using the Pharmacy sample was the same as when using the Fashion sample.

6 Conclusions and Future Research

6.1 Managerial Implications

In order to improve perception of the advantages of the model and to determine when its use is the most profitable solution, a cost analysis for the Fashion samples was conducted. The results of this analysis can be consulted in annex F.

The costs were determined using real data. The cost of lost sale was considered to be equal to the profit margin of the product (sale price minus acquisition cost). Transshipment cost was considered to be equal to the transportation cost and was already included in the model, with one of its outputs being the total transshipments cost. It was assumed that every replenishment order represents 10 minutes of handling (employee time) per SKU, meaning that every extra replenishment (per SKU) would lead to an extra 2,10€ cost. The cost of stock was considered to be the opportunity costs of investing in inventory (given the small dimension of the items, they would be stocked in the store, and so, space renting costs were considered sunken costs). This lead to 0,22€ per extra unit of product for the two months period that the simulation occurred. Given the low decreases in average stock, and considering that the magnitude of the values obtained in the other cost components (thousands of euro), the cost of stock was deemed insignificant.

The results of this analysis show that, for most cases, transshipments lead to a reduction in cost. The magnitude of this reduction varies with a number of factors. Perhaps the most important is the profit margin of the product relatively to the transportation cost. It was possible to conclude that the use of the model with products which have higher profit margins results in higher cost reduction. In the scenarios tested, costs of transportation between stores are the same for all products, and profit margins become the main factor in determining the profitability of transshipments. Another factor is the number of SKU's and the rotation of the SKU group, which lead to more transshipments, which in turn lead to greater potential to recover lost sales. The high rotation trousers have a much more substantial reduction in cost than the medium rotation (7 to 8 times using the Base detection rule) because they have around twice the number of SKU's, a 22% of increase in profit margin and a higher rotation. Due to greater margins, Coats can have a better profitability than Shorts and Shirts, despite having lower number of SKU (86% increase in relation to Shirts and a 178% increase relatively to Shorts). However, Coats have a lower total cost reduction than the medium rotation trousers, even if they have higher margin, because they have a much lower number of SKU's and those have lower rotation, which means less lost sales to recover.

The cases where the model increases costs instead of reducing them occur with the T-shirt/Polo group of products, and when considering an alpha equal to 0.75 and 1 in the medium rotation trousers and the amalgam sample. The T-shirt/Polo group of SKU's has the lowest profit margin of all groups (15€). Therefore the transportation costs (that range from 12,04€ to 25,53€) makes transshipments of one unit cost more than what they save. For the increased alpha case, the number of transshipments increase more than the number of lost sales recovered, increasing useless transshipments (RUT), as it happened on the Fashion alpha parameter tests (section 5.4.1.4). This increase in useless transshipments leads to an increase in costs with no consequences in lost sales, resulting in loss. In this last case, reducing alpha solves the problem. In the T-shirt/Polo group of SKU's, the problem can be solved by applying a filter of 1 to the group of transshipments, preventing all group of transshipments with less than 2 units. This means that the sum of the profit margins would be greater than the maximum transshipment cost (30€ profit vs. 25,53€ cost), which makes the model with the Base detection rule and the Cost Maximums ranking rule return a profit of 223,20€ in Jan. to Mar. period and a profit of 213.15€ on the Christmas season.

Summarizing, profitability of the model depends mainly on the profit margin of the products and the cost of transportation. For situations where there are very high transportation costs and/or very low profit margin, the model should not be used. The greater the number of SKU's chosen and the higher the rotation of the products is, the greater the impact of the model on costs. As the cost of transshipments get lower, more products are viable for transshipping. This makes the Maximums Cost Ranking rule the one generally more profitable, due to achieving a high potential of lost sale recovery and minimizing costs at the same time.

In this case, these savings can represent up to 3% of the clients turnover for each product category.

6.2 Literature Comparison

From the results obtained, it is possible to infer some important conclusions. First and foremost, it can be perceived that transshipments can lead to important cost savings, as stated in Robinson, 1990. Transshipments may also lead to an improvement in the service level with the same investment in inventories, or the same service level with less investment in inventories, as concluded in Jönsson and Silver, 1987.

It is also noted that the ranking/pairing of the stores appears to have less impact on the effectiveness of transshipments than the detection of the need and availability of transshipments, which is also a conclusion of Tagaras, 1999.

As in Lee, Jung, and Jeon, 2007, transportation costs negatively impact the performance of the model. The SLA model adapted from this article had very high transportation costs and RUT levels (useless transshipments) which might explain why the model performs worse when transportation costs are high. In some scenarios, especially on the Pharmacy samples, where some stores have much higher stock and sales than others, it is possible to identify a flow of transshipments, with some stores (the ones with higher stock) behaving like hubs. This was also observed in Hochmutha and Köchelb, 2012.

6.3 Contributions

The results of the tests done in this dissertation provide evidence that transshipments have a lot of potential in reducing costs of an inventory system. This potential can be exploited by modelling transshipments. As seen in the Literature Review (section 2.1), many efforts have been done in order to study and develop this area. This dissertation contributes by developing a model with a very high flexibility, i.e. which can be applied in a myriad of situations (e.g. different review schemes, different transshipment restrictions, etc.). Dividing the problem in three separate phases (Detection, Ranking, Grouping), allowed to create a model using heuristics, which are easy to apply in practice. This modularity of the model also allows it to be easily improved or customizable to certain situations, as improvements and specifications may be introduced in one of the phases without affecting the others. This dissertation also develops and presents two measures that can be used in the study of transshipments – Senders' Lost Sales (SLS) and Receiver's Useless Transshipments (RUT). The first one measures the risk of making a transshipment and the other the efficiency of transshipments. These two measures, if used as evaluation tools, have the potential to bring new perspectives to research on the topic.

However, this model has some disadvantages. In case the transportation costs increase, it becomes more difficult to find products with a profit margin high enough to make transshipments economically viable. When the products have low profit margins, it is hard to find transportation costs low enough for the transshipments of these products to be viable. In this case, it is possible to use a filter quantity, and only make transshipments with a quantity above that limit. This may reduce the number of lost sales recovered, but makes sure the transshipments made are economically viable. It was also noted that using the model on few SKU's increases the risk of a lost sale in sender (SLS). This difficulty can be surpassed by aggregating several SKU groups together, or by using the SLA 1 Detection rule, which has lower values of SLS (it has however relatively higher values of useless transshipments – RUT).

6.4 Future Work

Given the model's shortcomings and potential for improvement, it is important to define possibilities of future work and research.

In the detection phase, it might be worthy to extend the analysis of the Service Level Adjustment (SLA) detection rules. The SL_{inf} and SL_{sup} values used were the same for all stores and SKU's, and it could be useful to understand how giving individual and optimized values to each store could affect the performance of the system. Finding how to determine these optimal values for a combination of store-product could also be a topic for further research. The paper in which this rule was based assumed that demand followed a normal distribution, and so did the rule developed. It could be interesting to test if this method works with different distributions for specific demand scenarios. The SLA rules had the lowest SLS values, but the highest RUT values, and it showed that it was possible to manipulate risk by changing SL_{inf} and SL_{sup}, which makes this method very malleable, and with a lot of potential for improvement.

Although the ranking phase had the least impact on the performance of the system (when compared with the impact of the detection phase), for products with very high margin, small improvements may lead to great profits, and so improvements in this phase should also be considered. One way to improve the results of this phase is to apply a metaheuristic (e.g. Simulated Annealing, Neighborhood search with Taboo list) using one of the ranking rules developed as an initial solution.

The results of the cost analysis indicated that a transshipment is profitable if the margin of the products transshipped are higher than the cost of transshipment/transportation. When the margin of the products was low, this was counteracted using the filter option used in the grouping phase to prevent transshipments with less quantity than desirable. However, by incorporating this conclusion directly in the grouping phase, it is possible to automatically detect when a transshipment is going to be profitable or not. By adding the profit margins of each product as inputs of the model, it is possible to produce a rule such as: if the sum of the profit margins times the product quantity, minus the transshipment cost is greater than a minimum profit that each transshipment should provide (defined by the user), the transshipment is made. This rule would allow to make sure that all transshipments are profitable, and that all transshipments have at least a minimum profit. It could lead to better performances in terms of cost reduction.

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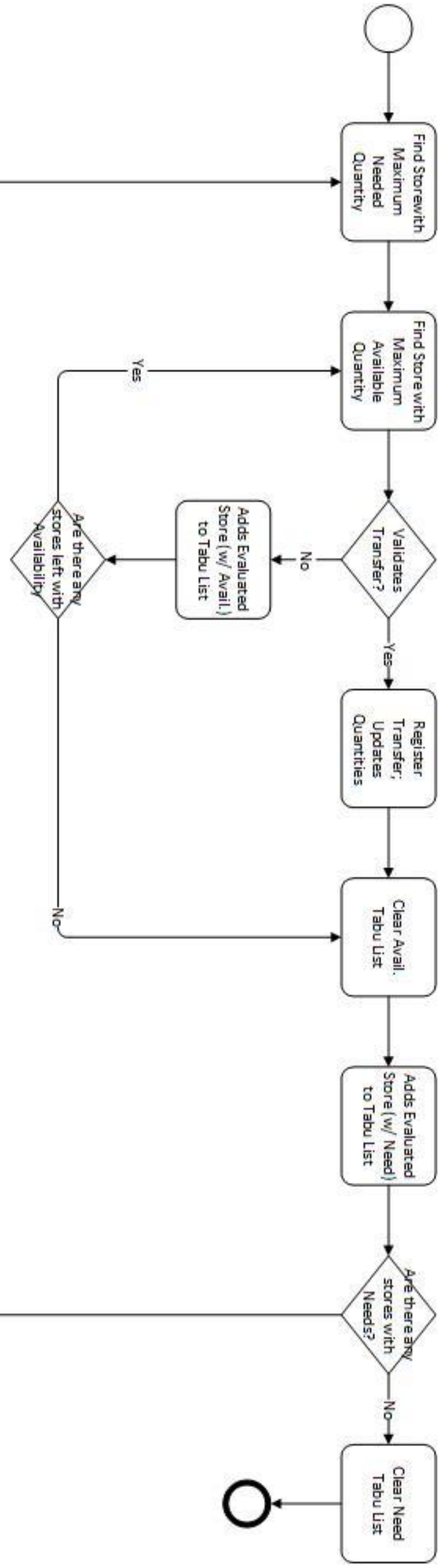
ANNEX A: Flow Diagram of an example of a Ranking Rule (Maximums)



Flow diagram of the Maximums ranking rule. This diagram represents one iteration (of period *t*)

ANNEX B: Prototype User's Manual

5/12/2015

SIMULADOR and SIMULADOR_F User's Manual

Retail Transshipments Modelling Prototype

Eduardo Oliveira, April 2015

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1

Prototype Overview

Prototype Overview

Objectives and Model Summary

- SIMULADOR (currently in version 8.3) and SIMULADOR_F (currently in version 3.3) are prototypes created to test the Retail Transshipment Model developed. These prototypes run simulations of the model applied to different scenarios.

- The aforementioned model has the objective of identifying imbalances of stock between stores in a retail chain, and suggest transshipments to correct these imbalances.

- The model is divided in three phases:
    1. Identify Unbalances (using Detection Rules)
    2. Identify Transshipments (using Ranking Rules)
    3. Group Transshipments (of different SKU's)

Prototype Overview

Prototype Overview

Model's Inputs and Outputs

- In order to achieve the intended outputs, the model requires inputs. Both the inputs and outputs are summarized on the following diagram:

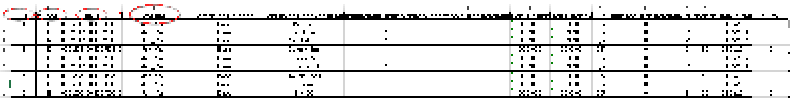
- The simulation has also an output Evaluation Criteria, which is used in order to gauge the performance of the system, which will be described later in the manual.

Worksheet Description – "Cenarios"

Worksheet Description

"Cenarios"

- In this worksheet are defined the different scenarios that will be simulated:
  - **ID**: Scenario ID, when doing multiple simulation runs, the program runs until the first blank cell in this column.
  - **N_SKU**: Defines the total number of SKU of the scenario.
  - **SKU**: A string consisting on the SKU codes of the products in the scenario separated by a semicolon(;). If the number of SKU in this string exceeds the *N_SKU*, only the first *N_SKU* are considered.
  - **Amostra**: Defines the sample used. In Fashion there are two alternatives: "*Jan_Mar*" and "*Natal*". In Pharmacy there is one alternative implemented, "*Jan_Fev*"*.



*For more information, see the "Additional Notes" section of this manual.

Worksheet Description – "Cenarios"

Worksheet Description

"Cenarios"

- **Critério de Deteção:** This defines the Detection Rule used. There are a total of 4 Detection rules:
  - "*Base*"
  - "*Cobertura*"
  - "*Service Level Adjustment 1*"
  - "*Service Level Adjustment 2*"
- **Critério de Ranqueamento:** This defined the Ranking rule used. There are a total of 14 Ranking Rules available:
  - "*Máximos*"
  - "*Mínimos*"
  - "*Stock-Outs*"
  - "*Custos Max.* "
  - "*Custos Min.* "
  - "*Custos SO* "
  - "*Inv. Máximos* "
  - "*Inv. Mínimos* "
  - "*Inv. SO* "
  - "*Inv. Custos Max.* "
  - "*Inv. Custos Min.* "
  - "*Inv. Custos SO* "
  - "*Neo Mínimos* "
  - "*Inv. Neo Mínimos* "

Worksheet Description – "Cenarios"

Worksheet Description

"Cenarios"

- **Recorrencia Replenishment:** It defines the periodicity the replenishment reviews will be made: 0 – daily; 1 – *N* times per week; 2 – *N* times every two weeks; 3 – *N* times every three weeks; 4 – *N* times every four weeks.
- **Recorrencia Transferência:** It defines the periodicity the transshipment reviews will be made: 0 – daily; 1 – *N* times per week; 2 – *N* times every two weeks; 3 – *N* times every three weeks; 4 – *N* times every four weeks.
- **Rep. Review:** It defines which days of the week will have a replenishment review. This input consists on a string with seven digits, either 0 or 1, where if there 1 means there is a review and 0 that there is not.
- **Trans. Review** : It defines which days of the week will have a transshipment review review. This input consists on a string with seven digits, either 0 or 1, where if there 1 means there is a review and 0 that there is not.

The conjugation of these criteria defines completely the review policy. E.g.: If there are two 1's in *Trans. Review* and a 1 in *Recorrencia Transferência*, it means there are two transshipments review every week.

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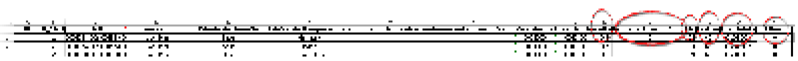
Worksheet Description – "Cenarios"

Worksheet Description

"Cenarios"

- **Alfa:** This is a simulation parameter that defines the size of the evaluation time that is used on the Detection and Ranking rules.
- **Limite nas Transferências:** This defines a limit on transshipments at the SKU level. A transshipment with quantity below this limit does not occur.
- **Data Inicial:** Defines the initial date of the simulation. In SIMULADOR, it should be 01/01/2014 for "*Amostra*" values of "*Jan_Mar*" and 01/11/2014 if the value is "*Natal*". In SIMULADOR_F, it should be 02/01/2010 for "*Amostra*" values of "*Jan_Fev*".
- **Filtro:** This defines a limit on transshipment groups of several SKU (applied at the model's third phase). A group of transshipments with quantity below this limit does not occur.



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Worksheet Description – "Cenarios"

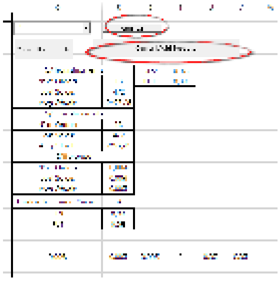
Worksheet Description

"Cenarios"

- **Button "Atualiza"**: This button refreshes the combo box to its left. That combo box selects the scenario to run. It should be pressed when scenarios are changed, or when a scenario is added or removed from the worksheet.

- **Button "Correr Multi-Produto"**: This button runs the simulation selected in the combo box.

- The **button "Correr Uni-Produto"** was used during development, when the prototype was only able to run one SKU at a time. It is now obsolete, and should not be used (unless there is only one SKU on the scenario supposed to run).
- The cells below the buttons were used to retrieve outputs on previous versions. Unless using the button "Correr Uni-Produto", there will be no change. These outputs are now presented on the worksheet "Multi_outputs".



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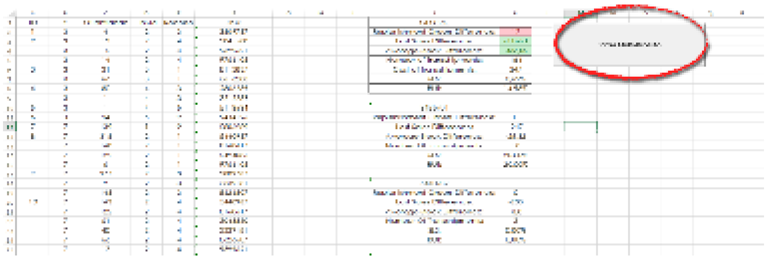
Worksheet Descriptions – "Multi_Outputs"

Worksheet Description

"Multi_Outputs"

- In this worksheet appear the outputs of a single simulation run. When running several scenarios automatically, only the last scenario will be displayed after all the simulation runs are completed.
- On the far right, there is the "**Correr Multi-Produto**" button, which runs the simulation for the scenario that is selected on the combo box of "cenarios".



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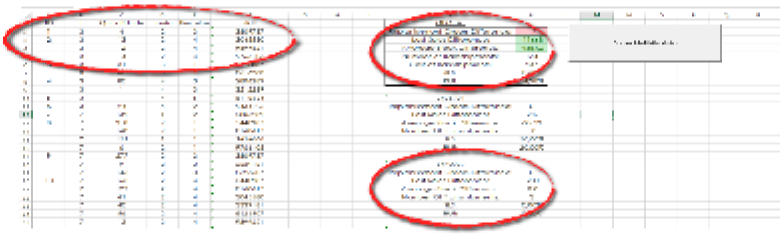
5/12/2015

Worksheet Descriptions – "Multi_Outputs"

Worksheet Description

"Multi_Outputs"

- On the left there is the list of transshipment that occurred during the simulation. Each group of transshipments has an ID. Then each group has line for each SKU transshipped, stating the period it occurred, the quantity transshipped the sender and the receiver store, as well as its SKU code.
- On top in the center we have the global results for all SKU, presented in the form of the evaluation criteria defined (more information on "Res_cenarios" description).
- Below the global results, it is presented the results divided by SKU.

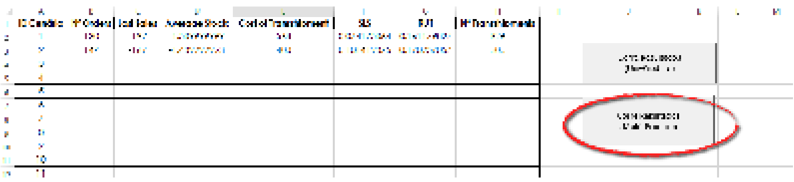


Worksheet Description – "Res_cenários"

Worksheet Description

"Res_cenarios"

- This worksheet has the function of running several scenarios automatically and register the Evaluation criteria of each scenario for performance analysis of the model.
- To run these simulations, the **button "Corre Resultados (Multi-Produto)"** should be pushed. The other button was used on previous versions of the prototype and should not be used (runs only for one SKU scenarios).



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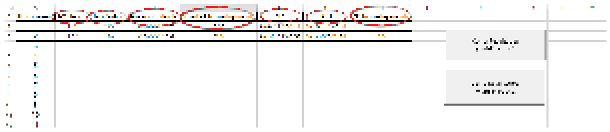
5/12/2015

Worksheet Description – "Res_cenários"

Worksheet Description

"Res_cenarios"

- The Evaluation Criteria is as follows (all criteria represent the difference between a system using the model and a system that does not use the model (without transshipments):
  - **Nº Orders:** This represents the difference in the number of replenishment order made. The values presented are the sum of this value for all scenarios.
  - **Lost Sales:** This represents the difference in quantity of lost sales. The values presented are the sum of this value for all scenarios.
  - **Average Stock:** This represents the difference in average stock in stores. The values presented are the sum of this value for all scenarios.
  - **Cost of Transshipments:** This is the sum of the cost of all transshipments (after being grouped).
  - **SLS** (Sender's Lost Sales): This represents the percentage of transshipments that originated lost sales on sender store. The values presented are the average of this value for all scenarios.
  - **RUT** (Receiver's Useless Transshipments): This represents the percentage of transshipments that recovered no lost sales for the receiving store. The values presented are the average of this value for all scenarios.
  - **Nº Transshipments:** This is the sum of all transshipments (already grouped) made in the scenario.

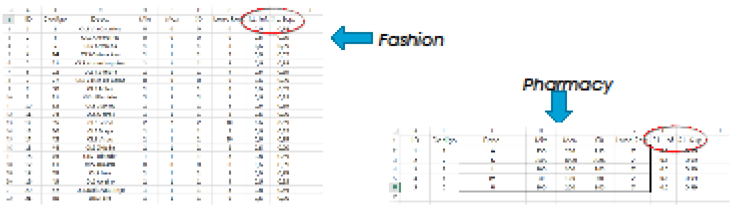


Worksheet Description – "lista_lojas"

Worksheet Description

"lista_lojas"

- This worksheet holds intra-store information. The first seven columns are automatically filled by the prototype while running the simulations. The last two columns define the Low Service Level (S.L. Inf.) and the Higher Service Level (S.L. Sup.).
- These two values affect the performance of the Detection Rules Service Level Adjustment 1 and 2 (SLA 1 and SLA 2). It can be different for each store. According to the first tests, the S.L. Sup. should be 0,99 (or SLS values become very high). S.L. Inf. Values can vary, but the lower this value, the lower the SLS and RUT values, but it also diminishes the lost sales reduction.



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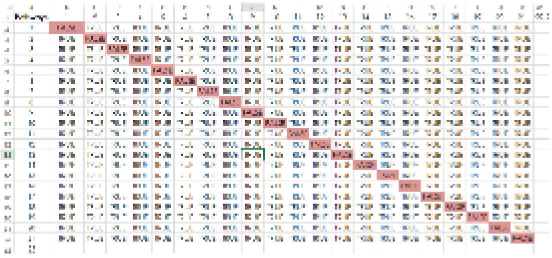
Worksheet Descriptions – "path_ways"

Worksheet Description

"path_ways"

- In worksheet "path_ways", it is saved the information on whether the transshipments from a certain to store to another is allowed or not. If the value is "TRUE", a transshipment is allowed from a certain store (column) to another store (line). If the value is "FALSE", the transshipment is not allowed. For the example in the picture, store 13 is allowed to tranship to store 9.



Running a Single Scenario

Running a Single Scenario

- In order to run a single scenario:

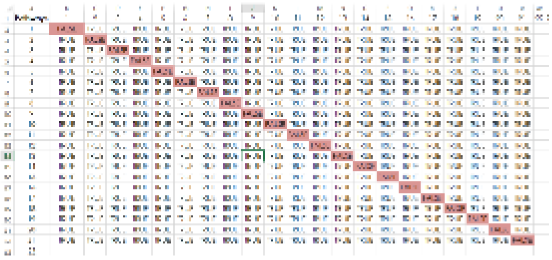
1. Go to worksheet "lista_lojas" and fill the S.L. Inf. and S.L. Sup. Columns with the desired values;
2. Fill worksheets "l_time_trans", "Custos_trans" and "path_ways" with the desired values (it should be a square of N (total number of stores) side);
3. Go to worksheet "cenarios" and fill a line on the table with the parameters desired (do not forget to add an ID to the line);
4. In "cenarios" press the button "Atualiza" and select the number corresponding to the ID of the scenario you want to run on the combo box;
5. Go to worksheet "Multi_Outputs" and press the button "Correr Multi-Produto".

Worksheet Descriptions – "path_ways"

Worksheet Description

"path_ways"

- In worksheet "path_ways", it is saved the information on whether the transshipments from a certain to store to another is allowed or not. If the value is "TRUE", a transshipment is allowed from a certain store (column) to another store (line). If the value is "FALSE", the transshipment is not allowed. For the example in the picture, store 13 is allowed to transship to store 9.



Running a Single Scenario

Running a Single Scenario

- In order to run a single scenario:

1. Go to worksheet "lista_lojas" and fill the S.L. Inf. and S.L. Sup. Columns with the desired values;
2. Fill worksheets "l_time_trans", "Custos_trans" and "path_ways" with the desired values (it should be a square of N (total number of stores) side);
3. Go to worksheet "cenarios" and fill a line on the table with the parameters desired (do not forget to add an ID to the line);
4. In "cenarios" press the button "Atualiza" and select the number corresponding to the ID of the scenario you want to run on the combo box;
5. Go to worksheet "Multi_Outputs" and press the button "Correr Multi-Produto".

Running Multiple Scenarios

Running Multiple Scenarios

- In order to run a multiple scenarios automatically:

1. Go to worksheet "lista_lojas" and fill the S.L. Inf. and S.L. Sup. Columns with the desired values;
2. Fill worksheets "l_time_trans", "Custos_trans" and "path_ways" with the desired values (it should be a square of N (total number of stores) side);
3. Go to worksheet "cenarios" and fill a line on the table with the parameters desired for each scenario (do not forget to add an ID to the line);
4. Go to worksheet "Res_cenarios" and press the button "Corre Resultados (Multi-Produto)".

Differences between SIMULATION_8.3 and SIMULATION_F_3.3

Differences between SIMULATION_8.3 and SIMULATION_F_3.3

- The instructions above will work in both files. However, some differences exist in both models' inner workings, resultant from the information about parametrization having different origins, namely databases. No further information is required about this to use the model's, but it should be noticed that simulation runs for Pharmaceutics cases should be made with SIMULATION_F_3.3, and simulation runs for Fashion cases should be made with SIMLATION_8.3.

Additional Notes

Additional Notes

- If the value of N for any given scenario is lower than the side of the matrix of filled cells on worksheets "l_time_trans", "Custos_trans" and "path_ways", only the first N stores will be taken into account during the simulation. If N is greater, the stores that go beyond N will have parameters of transshipments' lead time of 0, cost of transshipment equal to 0 and "path_ways" equal to "FALSE", which means the stores will have no transshipments.

- As seen in "cenarios", the possible samples are fixed and identified using a string. This was done this way to incorporate a safety measure that ensured that the initial date, first week and time horizon had no errors during the testing that could compromise the veracity of the results. In the future, it can be implemented a system where it is given an initial and a final date instead of using defined samples.

ANNEX C: 1st Result Analysis Report

Analysis: 1st Round Report

For this first round there were three samples of data used: Fashion from 2nd of January to 2nd of March (2014), Fashion from 1st of November to 31st of December (Christmas) (2014) and a Pharmacy sample from 1st of January to 28th of February (2010). For both Fashion samples and the Pharmacy sample, a group of six high rotation products was used (the same 6 for the Fashion samples). First the samples were tested under standard conditions. Next, the samples were tested under different conditions: different periodicities of replenishment review, continuous review and changes in alpha value (parameter between 0 and 1 that regulates the evaluation time of the heuristics). Each of these conditions involved 48 runs, corresponding to all the combinations between detection and ranking heuristics (4x12=48). Each set of 48 runs for six products took approximately 30 minutes for Fashion samples and 15 minutes for Pharmacy samples. This was mainly due to the connection to the databases (Fashion’s database is located externally and Pharmacy’s database is located in the computer).

1 Fashion

The parameters for the standard comparison were: replenishment review recurrence of once a week; transshipment review recurrence of twice a week; alpha equal to 0,5 and no transshipment limit or filter of transshipment groups. The Low service level was equal to 0,8 and the High service level was equal to 0,99.

The comparison of the average results between Jan.-Mar. sample and the Christmas sample shows that the Christmas sample has less increase in orders, more lost sales recovery and a reduction on average stock. However, the Christmas sample had more transshipments (and consequently more transshipment cost). The change in SLS (Senders' Lost Sales) and RUT (Receivers' Useless Transshipments) values are not significant (there is a small change in values, but is also accompanied by an increase in variance).

Regarding the behavior of the detection rules, the Base rule and the SLA 1 rule resulted in the biggest lost sales recovery. The Base rule resulted in the smallest RUT values while SLA 1 had smaller SLS values. The increase in number of replenishment orders was greater in the SLA rules than in the Base rule. The cover rule had a relatively poor performance in lost sales recovery and an extremely poor performance in SLS, with very high values. The SLA 2 rule had similar behavior to the SLA 1 but had a more unpredictable behavior, sometimes with less lost sales recovery, others with less average stock recovery. SLA 1 performed better on the Christmas sample while the Base rule performed better on the Jan.-Mar. sample.

About the ranking rules, the Maximums rule (and its variations) had the greatest lost sales recovery, followed by the Minimums rules and the Stock-Out rules. The Maximums rules also had the smallest SLS values. The Cost variations had least costs (has expected). The Inverse variation had little or no variation when compared with their base counterparts.

1.1 Periodicity

The samples were tested for a replenishment review recurrence of every two weeks, every three weeks and every four weeks (every month).

As the time between reviews increases, the potential lost sales recovery diminishes, as does the number of replenishment orders increase (caused by transshipments). The average stock reduction increases with the time between reviews. SLS and RUT values remain unchanged. The number of transshipments and their cost decrease with an increase in time between reviews. This is probably due to an increase in the rules' evaluation period (resultant from the increased time to replenishment). As the rules' evaluation period increases the rules have the tendency to become more conservative, i.e. the quantity available for transshipment decreases.

The behavior of the detection rules and the ranking rules is the same as the standard sample, with the SLA rules (detection) and the Minimums rules (ranking) presenting slightly worse performance as the time between replenishment reviews increases.

These behaviors occur in both Fashion samples.

1.2 Continuous

While testing the behavior of the model for continuous review, two scenarios were considered: the first where both the replenishment and the transshipments were reviewed continuously and a second on where only the transshipments were reviewed continuously, while the replenishment review remained once per week.

The system with both review types performed worse than the standard. On the Christmas sample, there is an increase on average potential lost sales recovery, but this increase happens due to a relative increase in the more unstable rules, such as the SLA 2 and Cover. However this is accompanied with worse performance on average stock and transshipments' cost. The performance of the SLA 1 rule, the Base rule and the Maximums rule remain high and stable on all evaluation criteria.

The system in which only the transshipments are reviewed continuously present an improvement on the average performance. The rules behavior is the same as in the standard system, with the performance of all rules increasing at the same rate.

1.3 Alpha

In order to verify the effects of alpha's increase and decrease on the performance of the model, three variations of the standard system (alpha=0,5) were tested: alpha=0,3, alpha=0,75 and alpha=1 (equivalent to considering the evaluation period equal to the time to replenishment).

On average, as alpha increases, the number of orders increases, as does the average stock, the number and cost of transshipments and the RUT levels. There is a decrease on SLS values and number of lost sales. In summary, the system performs more transshipments, with an increased chance of useless transshipments but reduces lost sales and also decreases the risk of a lost sale in sender caused by a transshipment.

On the behavior of detection rules, SLA 1 and 2 have an increase in performance with lower values of alpha, while the Base rule had an increase in performance for higher values of alpha. The ranking rules have the same behavior as when using the standard system.

1.4 Service Level Adjustment (SLA)

As the tests progressed, it was found that the detection rules SLA 1 and SLA 2 had very high levels of RUT. As these two rules have two parameters that can be manipulated (Lower service level - SL_{inf} - and Upper service level – SL_{sup}), it was thought that these results could be improved. On the standard sample, the SL_{inf} was equal to 0,8 and the SL_{sup} was equal to 0,99. The Lower service level is very high, which can lead to detecting too much quantity needed at stores, leading to too many transshipments. It was decided to test the samples with different values of SL_{inf} and SL_{sup}. The values selected were (0,5; 0,99), (0.8; 0,999) and (0.5; 0,999). These values were selected in order to test the effect of both service levels on the rules performance, either separately and together.

On the (0,5; 0,99) case, two distinct situations happened. For SLA 1, the lost sales recovery decreased, while the RUT values and transshipment's number and cost decreased considerably. For SLA 2, the lost sales recover improved, with slight improvement on the average stock and on the RUT levels.

On the (0,8; 0,999) case, no significant changes occurred (overall performance had a very small decrease).

On the (0,5; 0,999) case, a similar situation to the (0,5; 0,99) case occurred. Since there were no significant changes in the (0,8; 0,999) case, it could be said that the effects of changing the service levels simply add up, i.e. there is no additional effect caused by changing both levels at the same time.

As a summary, decreasing the Lower service level leads to a reduction of number of transshipments and useless transshipments, but also leads to a decrease in the number of potential lost sales recovered.

2 Pharmacy

The parameters for the standard comparison were: replenishment review recurrence of once a week; transshipment review recurrence of twice a week; alpha equal to 0,5 and no transshipment limit or filter of transshipment groups. The Low service level was equal to 0,8 and the High service level was equal to 0,99.

The first thing to notice from the test results is that the SLS an RUT values on the Pharmacy sample are much lower than those of the Fashion samples.

The behavior of the detection and ranking rules is similar to the one on the Fashion samples, with the Base detection rule and the Maximums ranking rule (and its variants) achieving the best results. The SLA 1 and 2 result once again the highest values of RUT, while the highest SLS occurs on the Cover detection rule.

2.1 Periodicity

As in the case of the Fashion samples, the Pharmacy sample was tested for a replenishment review recurrence of every two weeks, every three weeks and every four weeks (every month).

In this sample, it was not possible do discern any particular behavior on the performance of the model. The overall performance of the model improved with a replenishment review every two weeks, but was worse with a review every three or four weeks. The only criteria which revealed constant behavior was the SLS values who kept decreasing as the time between reviews increased. The number of transshipments went up with the review every two and every three weeks, but it decreased greatly with the review period happening every four weeks.

The detection and ranking rules behave the same way as the standard sample, with the SLA 2 detection rule performance plummeting with the review period every four weeks.

2.2 Continuous

While testing the behavior of the model for continuous review, two scenarios were considered: the first where both the replenishment and the transshipments were reviewed continuously and a second in which only the transshipments were reviewed continuously, while the replenishment review remained once per week.

The system with both review types presents on average a better performance than the standard system. However the improvement occurred mostly on the SLA 2 detection rule, with the performance of the other staying the same or even getting worse (in lost sales recovery in particular). It could be said that in case the replenishment review policy is continuous, it should be considered the SLA 2 detection rule, as it performs the best in this type of situation. However, the reduction in average stock occurred for all the detection rules.

The behavior of the ranking rules is the same as in the standard system, with the Maximums rule achieving better results.

In the system in which only the transshipments are reviewed continuously, the number of orders decreases and the lost sales recovery increases, while the average stock performance is worse and the number of transshipments increases.

2.3 Alpha

In order to test the effects of alpha's increase and decrease on the performance of the model, three variations of the standard system (alpha=0,5) were considered, with alpha=0,3, alpha=0,75 and alpha=1 (equivalent to considering the evaluation period equal to the time to replenishment).

For alpha=0,3, the performance of the system is better on average, with slightly worse SLS values. As happened on the continuous case, the SLA 2 detection rule performs much better than in the standard case.

For alpha=0,75, the performance is similar to the standard system (with alpha=0,5) but with slightly better SLS values.

For alpha=1, the performance of the system is relatively worse on all criteria, but in particular on SLS and RUT levels.

The detection rules present the same behavior on these systems as they do on the standard one, with the aforementioned exception of SLA 2 for alpha=0,3.

The ranking rules present the same behavior for the systems with different alpha, with the exception of the Minimums ranking rule which is the best performer in for alpha=1.

2.4 Service Level Adjustment (SLA)

In what concerns the SLA 1 and SLA 2, the same situation as in Fashion occurred, with relatively high RUT values and number of transshipments. Therefore, the same testes on Lower service level and Upper service level were made. The behavior of the system is the same as the one with the Fashion samples: a decrease on the Lower service level leads to a reduction on the number of transshipments and useless transshipments, but also leads to a decrease in the number of lost sales recovered.

3 Conclusions

The conclusion to be retained for the next rounds of testing is that, when keeping the same parameters of the standard sample, the detection rules to be used should be the Base detection rule and the Service Level Adjustment (SLA) 1 detection rule. In what concerns the ranking rules, it should be used the Maximums ranking rules and its Cost variant, since little difference occurred using the Inverse variants.

ANNEX D: Simulation Results (Absolute)

			Fashion															
			Jan_Mar								Christmas							
			Base	Continuous		Periodicity		Alpha			Base	Continuous		Periodicity		Alpha		
				Full	Semi	2	4	0,3	0,75	1		Full	Semi	2	4	0,3	0,75	1
High rot. Trouser	Base - Maximums	Nº Orders	216	202	316	301	432	112	258	296	382	345	576	465	390	146	503	559
		Lost Sales	-360	-234	-499	-406	-455	-189	-421	-473	-567	-776	-874	-667	-478	-256	-758	-843
		Average Stock	-2,38	15,62	-3,62	-4,72	-7,41	-1,28	-2,67	-2,48	-4,00	-7,65	-7,31	-6,74	-6,58	-2,07	-4,59	-2,45
		Cost of Transshipments	7 307,10 €	5 858,10 €	15 214,50 €	9 004,50 €	9 677,25 €	4 719,60 €	7 990,20 €	8 994,15 €	12 771,90 €	17 905,50 €	27 168,75 €	15 266,25 €	11 146,95 €	6 572,25 €	16 177,05 €	19 551,15 €
		SLS	1,52%	0,67%	1,70%	1,35%	1,69%	1,48%	1,27%	0,87%	3,63%	0,97%	3,57%	3,82%	4,01%	5,53%	3,81%	3,33%
		RUT	8,67%	5,46%	10,01%	9,17%	15,79%	8,56%	9,29%	15,85%	13,18%	5,52%	13,64%	14,08%	14,40%	6,60%	17,16%	24,39%
		Nº of Transshipments	419	327	856	504	522	264	455	503	735	1015	1516	859	606	371	908	1072
		LS/NT	0,86	0,72	0,58	0,81	0,87	0,72	0,93	0,94	0,77	0,76	0,58	0,78	0,79	0,69	0,83	0,79
	Base - Cost Maximums	Nº Orders	294	393	408	348	435	154	351	383	423	577	603	472	379	163	554	591
		Lost Sales	-353	-232	-494	-396	-451	-186	-437	-453	-503	-720	-806	-598	-435	-208	-726	-758
		Average Stock	-2,84	11,88	-4,11	-4,69	-7,52	-1,99	-3,16	-2,33	-3,60	-2,21	-6,64	-6,58	-6,34	-2,21	-4,53	-1,48
		Cost of Transshipments	4 512,60 €	2 701,35 €	7 534,80 €	5 640,75 €	7 659,00 €	2 711,70 €	5 092,20 €	5 350,95 €	8 228,25 €	9 273,60 €	15 773,40 €	10 888,20 €	8 704,35 €	3 622,50 €	10 795,05 €	13 268,70 €
		SLS	2,11%	2,33%	2,01%	2,41%	1,85%	3,29%	1,65%	1,82%	6,09%	3,06%	5,89%	5,32%	4,96%	8,92%	4,97%	4,45%
		RUT	8,46%	4,89%	9,49%	9,65%	16,21%	5,65%	9,92%	15,50%	13,21%	4,93%	14,24%	14,81%	15,06%	4,62%	17,40%	24,63%
		Nº of Transshipments	364	227	588	433	487	223	399	420	616	753	1168	757	563	301	760	887
		LS/NT	0,97	1,02	0,84	0,91	0,93	0,83	1,10	1,08	0,82	0,96	0,69	0,79	0,77	0,69	0,96	0,85
	SLA 1 - Maximums	Nº Orders	210	78	399	464	465	56	604	725	423	541	706	600	520	144	760	909
		Lost Sales	-232	-97	-400	-380	-420	-69	-457	-506	-541	-640	-873	-693	-569	-208	-892	-1020
		Average Stock	-0,97	2,43	-3,04	-6,59	-9,00	-0,18	0,58	3,70	-0,59	7,77	-2,30	-4,98	-6,20	0,16	2,95	8,44
		Cost of Transshipments	7 089,75 €	3 860,55 €	17 853,75 €	13 061,70 €	9 325,35 €	1 645,65 €	20 172,15 €	23 918,85 €	15 421,50 €	22 169,70 €	33 378,75 €	19 302,75 €	13 620,60 €	4 709,25 €	27 644,85 €	30 284,10 €
		SLS	0,94%	0,21%	0,98%	1,51%	0,09%	1,26%	1,65%	1,63%	2,50%	1,04%	2,48%	3,19%	3,41%	2,31%	3,14%	2,48%
		RUT	15,59%	18,34%	23,55%	31,16%	37,96%	3,24%	39,11%	42,83%	29,71%	36,28%	29,22%	35,12%	38,33%	19,27%	42,70%	47,50%
		Nº of Transshipments	384	214	951	701	497	93	1086	1286	824	1193	1787	1035	722	252	1489	1618
		LS/NT	0,60	0,45	0,42	0,54	0,85	0,74	0,42	0,39	0,66	0,54	0,49	0,67	0,79	0,83	0,60	0,63
	SLA 1 - Cost Maximums	Nº Orders	238	164	434	506	470	60	643	790	436	648	705	630	535	137	787	964
		Lost Sales	-207	-92	-386	-385	-426	-60	-449	-519	-503	-538	-817	-663	-567	-169	-835	-980
		Average Stock	-1,27	3,27	-2,90	-6,59	-8,76	-0,41	-1,62	2,50	-0,59	10,53	-2,94	-4,76	-6,05	0,00	2,78	8,25
		Cost of Transshipments	4 885,20 €	2 266,65 €	11 892,15 €	9 956,70 €	7 731,45 €	1 179,90 €	14 738,40 €	18 640,35 €	11 353,95 €	13 330,80 €	25 264,35 €	15 638,85 €	10 525,95 €	3 187,80 €	21 321,00 €	24 653,70 €
		SLS	1,36%	0,95%	1,21%	1,52%	0,15%	1,99%	1,46%	1,33%	3,59%	2,22%	2,76%	3,73%	2,97%	2,56%	3,64%	3,00%
		RUT	16,16%	18,75%	24,34%	31,37%	38,11%	3,46%	38,98%	42,94%	29,66%	36,07%	30,55%	35,42%	38,31%	19,13%	42,67%	47,50%
		Nº of Transshipments	342	184	798	623	452	88	968	1155	733	950	1561	955	637	229	1306	1470
		LS/NT	0,61	0,50	0,48	0,62	0,94	0,68	0,46	0,45	0,69	0,57	0,52	0,69	0,89	0,74	0,64	0,67

			Fashion															
			Jan_Mar								Christmas							
			Base	Continuous		Periodicity		Alpha			Base	Continuous		Periodicity		Alpha		
				Full	Semi	2	4	0,3	0,75	1		Full	Semi	2	4	0,3	0,75	1
Medium rot. Trouser	Base - Maximums	Nº Orders	48	71	72	53	77	20	59	64	161	120	229	183	139	75	189	212
		Lost Sales	-60	-45	-91	-73	-87	-37	-74	-78	-205	-271	-289	-240	-173	-107	-252	-300
		Average Stock	-0,41	3,38	-0,58	-0,96	-1,55	-0,24	-0,48	-0,41	-1,57	-3,20	-2,16	-2,13	-2,36	-0,85	-1,45	-0,09
		Cost of Transshipments	1 386,90 €	1 604,25 €	2 639,25 €	1 873,35 €	2 049,30 €	921,15 €	1 438,65 €	1 759,50 €	4 740,30 €	6 882,75 €	9 170,10 €	5 858,10 €	4 688,55 €	2 442,60 €	5 682,15 €	7 358,85 €
		SLS	0,52%	0,97%	0,16%	0,37%	0,21%	0,91%	0,84%	1,10%	2,29%	0,55%	2,56%	2,52%	2,47%	1,83%	2,10%	1,47%
		RUT	7,99%	5,11%	6,81%	4,61%	10,47%	4,72%	4,86%	8,92%	11,84%	5,23%	12,45%	13,18%	12,37%	5,82%	14,95%	21,19%
		Nº of Transshipments	77	88	145	100	106	49	79	94	254	369	500	313	247	131	307	390
		LS/NT	0,78	0,51	0,63	0,73	0,82	0,76	0,94	0,83	0,81	0,73	0,58	0,77	0,70	0,82	0,82	0,77
	Base - Cost Maximums	Nº Orders	62	96	87	79	90	41	73	79	173	231	244	197	140	80	203	238
		Lost Sales	-61	-47	-92	-74	-89	-43	-78	-83	-182	-257	-271	-216	-161	-81	-234	-274
		Average Stock	-0,44	1,68	-0,67	-1,02	-1,78	-0,47	-0,53	-0,40	-1,30	-1,17	-2,10	-2,34	-2,24	-0,84	-1,41	0,38
		Cost of Transshipments	745,20 €	610,65 €	1 138,50 €	1 035,00 €	1 304,10 €	476,10 €	807,30 €	910,80 €	3 053,25 €	4 140,00 €	5 682,15 €	4 202,10 €	3 653,55 €	1 645,65 €	3 788,10 €	5 175,00 €
		SLS	0,31%	2,14%	0,60%	0,65%	0,72%	0,75%	0,00%	0,31%	4,22%	2,21%	4,17%	3,11%	2,75%	5,17%	3,08%	2,86%
		RUT	7,62%	3,66%	4,88%	4,61%	9,39%	4,11%	4,37%	9,11%	11,39%	4,68%	11,75%	13,38%	13,08%	5,15%	15,17%	20,80%
		Nº of Transshipments	60	55	93	82	89	39	66	72	217	299	400	286	231	122	265	347
		LS/NT	1,02	0,85	0,99	0,90	1,00	1,10	1,18	1,15	0,84	0,86	0,68	0,76	0,70	0,66	0,88	0,79
	SLA 1 - Maximums	Nº Orders	22	54	71	58	122	7	106	108	158	309	260	238	193	53	294	338
		Lost Sales	-24	-21	-66	-51	-103	-6	-77	-87	-193	-231	-298	-275	-216	-63	-330	-381
		Average Stock	0,02	0,91	-0,48	-1,16	-2,72	0,11	0,77	2,18	0,63	10,69	0,65	-0,85	-1,33	0,61	2,51	5,40
		Cost of Transshipments	910,80 €	807,30 €	3 229,20 €	2 815,20 €	4 036,50 €	155,25 €	4 999,05 €	6 592,95 €	5 816,70 €	8 538,75 €	12 885,75 €	9 045,90 €	7 627,95 €	1 697,40 €	12 544,20 €	14 748,75 €
		SLS	0,00%	0,00%	0,27%	0,86%	0,00%	0,00%	0,68%	0,68%	1,09%	0,29%	1,06%	1,38%	1,30%	0,24%	1,20%	1,02%
		RUT	10,84%	8,88%	13,65%	19,72%	23,27%	3,14%	27,37%	28,44%	27,36%	30,74%	28,11%	30,22%	34,19%	17,44%	38,87%	41,28%
		Nº of Transshipments	50	46	167	154	211	8	269	352	307	452	681	478	396	90	665	783
		LS/NT	0,48	0,46	0,40	0,33	0,49	0,75	0,29	0,25	0,63	0,51	0,44	0,58	0,55	0,70	0,50	0,49
	SLA 1 - Cost Maximums	Nº Orders	33	51	86	76	120	6	113	147	147	380	258	240	193	55	308	371
		Lost Sales	-22	-21	-66	-56	-99	-5	-80	-94	-160	-221	-278	-244	-207	-61	-298	-360
		Average Stock	-0,02	0,88	-0,35	-1,14	-2,72	0,12	0,34	1,78	0,75	11,58	0,17	-0,93	-1,12	0,80	2,29	5,32
		Cost of Transshipments	652,05 €	476,10 €	2 049,30 €	1 697,40 €	3 053,25 €	103,50 €	3 332,70 €	4 833,45 €	4 274,55 €	5 516,55 €	9 232,20 €	6 241,05 €	5 806,35 €	1 159,20 €	8 807,85 €	11 685,15 €
		SLS	0,26%	0,00%	0,14%	0,76%	0,09%	0,00%	0,47%	0,46%	2,61%	1,21%	1,45%	2,34%	1,47%	1,16%	1,99%	1,37%
		RUT	10,69%	8,40%	13,38%	19,44%	23,92%	3,14%	27,08%	28,68%	26,85%	30,02%	27,67%	29,77%	34,51%	17,62%	38,17%	40,95%
		Nº of Transshipments	49	38	137	129	193	8	241	321	274	369	571	396	360	81	569	723
		LS/NT	0,45	0,55	0,48	0,43	0,51	0,63	0,33	0,29	0,58	0,60	0,49	0,62	0,58	0,75	0,52	0,50

			Fashion															
			Jan_Mar								Christmas							
			Base	Continuous		Periodicity		Alpha			Base	Continuous		Periodicity		Alpha		
				Full	Semi	2	4	0,3	0,75	1		Full	Semi	2	4	0,3	0,75	
Amalgam (join)	Base - Maximums	Nº Orders	79	54	124	105	164	38	91	106	279	270	415	307	238	117	389	459
		Lost Sales	-110	-75	-164	-130	-170	-65	-125	-136	-355	-543	-522	-397	-289	-163	-491	-578
		Average Stock	-0,78	3,35	-1,34	-1,42	-2,57	-0,62	-0,89	-0,61	-2,49	-3,63	-4,17	-3,92	-3,69	-1,26	-2,59	1,31
		Cost of Transshipments	2 359,80 €	2 183,85 €	4 781,70 €	3 384,45 €	3 922,65 €	1 511,10 €	2 773,80 €	3 487,95 €	10 039,50 €	14 107,05 €	21 114,00 €	12 502,80 €	8 714,70 €	4 968,00 €	12 885,75 €	15 804,45 €
		SLS	1,02%	0,42%	1,16%	1,04%	0,68%	0,47%	1,57%	0,43%	9,95%	2,93%	7,38%	7,93%	6,87%	10,76%	8,19%	6,98%
		RUT	4,61%	6,03%	7,47%	6,22%	15,35%	6,26%	5,44%	11,83%	23,66%	9,07%	26,61%	26,71%	30,94%	12,74%	29,24%	37,79%
		Nº of Transshipments	133	119	262	188	209	85	150	185	552	766	1143	673	460	275	694	842
		LS/NT	0,83	0,63	0,63	0,69	0,81	0,76	0,83	0,74	0,64	0,71	0,46	0,59	0,63	0,59	0,71	0,69
	Base - Cost Maximums	Nº Orders	104	120	142	134	161	60	126	138	297	445	434	338	241	139	411	481
		Lost Sales	-101	-76	-151	-135	-165	-65	-123	-137	-320	-493	-495	-389	-261	-148	-471	-561
		Average Stock	-0,89	2,34	-1,32	-1,55	-2,52	-0,62	-1,04	-0,73	-2,53	-1,74	-3,97	-3,89	-3,94	-1,36	-2,51	1,30
		Cost of Transshipments	1 417,95 €	890,10 €	2 225,25 €	2 059,65 €	2 784,15 €	786,60 €	1 749,15 €	2 163,15 €	7 276,05 €	8 725,05 €	14 107,05 €	8 994,15 €	6 323,85 €	3 312,00 €	9 749,70 €	11 830,05 €
		SLS	0,96%	0,10%	1,21%	1,09%	1,26%	1,12%	0,48%	1,12%	11,61%	6,40%	9,35%	8,26%	8,66%	12,57%	8,10%	7,54%
		RUT	4,28%	5,27%	6,96%	6,82%	15,06%	3,68%	5,22%	11,94%	24,53%	8,19%	26,36%	26,93%	30,34%	8,04%	30,68%	38,82%
		Nº of Transshipments	120	80	180	164	184	68	141	164	501	642	943	592	418	255	635	740
		LS/NT	0,84	0,95	0,84	0,82	0,90	0,96	0,87	0,84	0,64	0,77	0,52	0,66	0,62	0,58	0,74	0,76
	SLA 1 - Maximums	Nº Orders	80	28	178	181	184	27	244	287	308	499	438	387	314	147	507	585
		Lost Sales	-69	-44	-141	-140	-162	-32	-172	-195	-348	-437	-496	-439	-347	-179	-549	-596
		Average Stock	-0,31	1,24	-1,11	-2,36	-3,50	-0,12	0,61	2,48	1,97	13,06	1,64	-0,79	-1,90	1,97	4,85	6,88
		Cost of Transshipments	2 463,30 €	1 738,80 €	6 592,95 €	5 764,95 €	5 309,55 €	672,75 €	9 045,90 €	11 178,00 €	10 960,65 €	15 887,25 €	22 428,45 €	13 869,00 €	10 484,55 €	4 057,20 €	18 878,40 €	20 700,00 €
		SLS	0,83%	0,00%	1,06%	1,21%	0,00%	0,72%	0,85%	1,03%	7,09%	1,88%	5,43%	6,86%	6,12%	3,89%	6,22%	4,59%
		RUT	16,44%	20,78%	21,27%	26,92%	45,53%	3,14%	35,45%	46,80%	47,16%	51,60%	47,94%	48,51%	60,00%	34,33%	64,37%	69,58%
		Nº of Transshipments	136	92	363	313	274	37	490	595	577	828	1175	741	561	217	1007	1097
		LS/NT	0,51	0,48	0,39	0,45	0,59	0,86	0,35	0,33	0,60	0,53	0,42	0,59	0,62	0,82	0,55	0,54
	SLA 1 - Cost Maximums	Nº Orders	97	68	189	195	188	29	266	330	321	647	438	396	334	151	535	598
		Lost Sales	-62	-40	-143	-146	-162	-27	-178	-212	-336	-393	-480	-414	-347	-170	-542	-564
		Average Stock	-0,54	1,70	-1,23	-2,34	-3,39	-0,16	-0,05	1,98	1,96	16,73	1,39	-0,84	-1,89	2,17	4,25	6,63
		Cost of Transshipments	1 790,55 €	890,10 €	4 729,95 €	4 088,25 €	3 746,70 €	382,95 €	6 427,35 €	8 176,50 €	8 890,65 €	11 333,25 €	17 915,85 €	11 105,55 €	8 031,60 €	3 301,65 €	15 276,60 €	17 149,95 €
		SLS	1,31%	0,72%	0,75%	1,44%	0,00%	0,60%	0,95%	0,75%	7,45%	3,81%	5,79%	7,11%	6,11%	5,67%	6,52%	5,13%
		RUT	16,76%	20,27%	21,65%	26,90%	45,38%	2,78%	35,40%	46,54%	46,22%	51,50%	48,55%	48,72%	60,25%	34,17%	64,41%	69,60%
		Nº of Transshipments	128	75	319	273	237	32	442	537	546	735	1054	682	500	215	930	1013
		LS/NT	0,48	0,53	0,45	0,53	0,68	0,84	0,40	0,39	0,62	0,53	0,46	0,61	0,69	0,79	0,58	0,56

			Pharmacy							
			Jan_Feb							
			Base	Continuous		Periodicity		Alpha		
				Full	Semi	2	4	0,3	0,75	1
50 Highest	**Base - Maximums**	Nº Orders	28	9	38	41	10	7	32	34
		Lost Sales	-27201	-10140	-36294	-39710	-14688	-12888	-30652	-29637
		Average Stock	-798,61	-2958,63	-957,63	-849,18	-1690,66	-203,68	-696,50	-59,05
		Cost of Transshipments	273,00 €	273,00 €	708,00 €	287,00 €	184,00 €	149,00 €	247,00 €	237,00 €
		SLS	10,15%	6,50%	9,24%	11,61%	11,21%	14,35%	6,53%	7,39%
		RUT	14,02%	9,62%	16,48%	14,59%	36,73%	6,38%	19,04%	42,06%
		Nº of Transshipments	185	186	494	191	124	100	173	163
		LS/NT	147,03	54,52	73,47	207,91	118,45	128,88	177,18	181,82
	Base - Cost Maximums	Nº Orders	41	11	51	54	15	6	39	47
		Lost Sales	-26965	-9972	-35602	-34438	-15819	-12106	-29792	-30134
		Average Stock	-630,12	-4799,21	-994,98	-1012,53	-1352,70	-200,81	-799,24	-601,70
		Cost of Transshipments	282,00 €	241,00 €	743,00 €	294,00 €	206,00 €	163,00 €	279,00 €	246,00 €
		SLS	12,73%	7,97%	9,21%	13,08%	11,27%	19,94%	6,25%	8,19%
		RUT	14,95%	11,51%	17,07%	15,36%	37,86%	7,54%	20,05%	42,23%
		Nº of Transshipments	199	184	531	200	139	115	197	172
		LS/NT	135,50	54,20	67,05	172,19	113,81	105,27	151,23	175,20
	SLA 1 - Maximums	Nº Orders	17	17	21	20	5	7	20	1
		Lost Sales	-11668	-11668	-19441	-20358	-11130	-6264	-12503	-13230
		Average Stock	-436,02	-436,02	-456,08	-471,62	-761,03	-150,29	-395,06	-37,96
		Cost of Transshipments	247,00 €	247,00 €	700,00 €	293,00 €	157,00 €	119,00 €	264,00 €	304,00 €
		SLS	5,59%	5,59%	4,64%	7,68%	7,82%	4,29%	6,65%	4,72%
		RUT	14,98%	14,98%	14,21%	16,84%	12,15%	6,81%	27,37%	50,89%
		Nº of Transshipments	164	164	473	192	102	82	175	200
		LS/NT	71,15	71,15	41,10	106,03	109,12	76,39	71,45	66,15
	SLA 1 - Cost Maximums	Nº Orders	21	8	20	23	7	8	21	7
		Lost Sales	-11851	-3616	-18516	-20292	-11161	-6465	-11998	-12968
		Average Stock	-454,06	-70,35	-597,24	-576,80	-446,26	-110,12	-463,58	-121,68
		Cost of Transshipments	259,00 €	156,00 €	713,00 €	319,00 €	159,00 €	112,00 €	279,00 €	307,00 €
		SLS	6,31%	5,61%	5,30%	7,58%	9,27%	6,98%	6,28%	4,88%
		RUT	15,40%	17,63%	14,68%	17,13%	12,67%	6,98%	27,95%	49,69%
		Nº of Transshipments	179	112	494	209	105	80	186	202
		LS/NT	66,21	32,29	37,48	97,09	106,30	80,81	64,51	64,20

ANNEX E: Simulation Results (Relative)

			Fashion															
			Jan_Mar								Christmas							
			Base	Continuous		Periodicity		Alpha			Base	Continuous		Periodicity		Alpha		
				Full	Semi	2	4	0,3	0,75	1		Full	Semi	2	4	0,3	0,75	1
High rot. Trouser	Base - Maximums	Nº Orders	6,92%	3,48%	10,13%	10,81%	19,24%	3,59%	8,27%	9,49%	9,12%	6,32%	13,75%	11,69%	11,94%	3,49%	12,01%	13,34%
		Lost Sales	-32,88%	-43,90%	-45,57%	-27,19%	-19,50%	-17,26%	-38,45%	-43,20%	-22,77%	-46,41%	-35,10%	-24,27%	-13,05%	-10,28%	-30,44%	-33,86%
		Average Stock	-0,94%	4,05%	-1,44%	-1,93%	-3,21%	-0,51%	-1,06%	-0,98%	-1,62%	-2,53%	-2,96%	-2,77%	-2,82%	-0,84%	-1,86%	-0,99%
		Cost of Transshipments	7 307,10 €	5 858,10 €	15 214,50 €	9 004,50 €	9 677,25 €	4 719,60 €	7 990,20 €	8 994,15 €	12 771,90 €	17 905,50 €	27 168,75 €	15 266,25 €	11 146,95 €	6 572,25 €	16 177,05 €	19 551,15 €
		SLS	1,52%	0,67%	1,70%	1,35%	1,69%	1,48%	1,27%	0,87%	3,63%	0,97%	3,57%	3,82%	4,01%	5,53%	3,81%	3,33%
		RUT	8,67%	5,46%	10,01%	9,17%	15,79%	8,56%	9,29%	15,85%	13,18%	5,52%	13,64%	14,08%	14,40%	6,60%	17,16%	24,39%
		Nº of Transshipments	419	327	856	504	522	264	455	503	735	1015	1516	859	606	371	908	1072
	Base - Cost Maximums	Nº Orders	9,42%	6,76%	13,08%	12,50%	19,38%	4,94%	11,09%	12,28%	10,10%	10,56%	14,39%	11,86%	11,60%	3,89%	13,23%	14,11%
		Lost Sales	-32,24%	-43,53%	-45,11%	-26,52%	-19,33%	-16,99%	-39,36%	-41,37%	-20,20%	-43,06%	-32,37%	-21,76%	-11,88%	-8,35%	-29,16%	-30,44%
		Average Stock	-1,13%	3,08%	-1,63%	-1,92%	-3,26%	-0,79%	-1,24%	-0,92%	-1,46%	-0,73%	-2,69%	-2,71%	-2,72%	-0,90%	-1,84%	-0,60%
		Cost of Transshipments	4 512,60 €	2 701,35 €	7 534,80 €	5 640,75 €	7 659,00 €	2 711,70 €	5 092,20 €	5 350,95 €	8 228,25 €	9 273,60 €	15 773,40 €	10 888,20 €	8 704,35 €	3 622,50 €	10 795,05 €	13 268,70 €
		SLS	2,11%	2,33%	2,01%	2,41%	1,85%	3,29%	1,65%	1,82%	6,09%	3,06%	5,89%	5,32%	4,96%	8,92%	4,97%	4,45%
		RUT	8,46%	4,89%	9,49%	9,65%	16,21%	5,65%	9,16%	15,50%	13,21%	4,93%	14,24%	14,81%	15,06%	4,62%	17,40%	24,63%
		Nº of Transshipments	364	227	588	433	487	223	395	420	616	753	1168	757	563	301	760	887
	SLA 1 - Maximums	Nº Orders	6,73%	1,34%	12,79%	16,67%	20,71%	1,79%	19,36%	23,24%	10,10%	9,90%	16,85%	15,08%	15,92%	3,44%	18,14%	21,70%
		Lost Sales	-21,19%	-18,20%	-36,53%	-25,45%	-18,00%	-6,30%	-41,74%	-46,21%	-21,73%	-38,28%	-35,06%	-25,22%	-15,53%	-8,35%	-35,82%	-40,96%
		Average Stock	-0,38%	0,63%	-1,21%	-2,69%	-3,90%	-0,07%	0,23%	1,47%	-0,24%	2,57%	-0,93%	-2,05%	-2,66%	0,06%	1,20%	3,42%
		Cost of Transshipments	7 089,75 €	3 860,55 €	17 853,75 €	13 061,70 €	9 325,35 €	1 645,65 €	20 172,15 €	23 918,85 €	15 421,50 €	22 169,70 €	33 378,75 €	19 302,75 €	13 620,60 €	4 709,25 €	27 644,85 €	30 284,10 €
		SLS	0,94%	0,21%	0,98%	1,51%	0,09%	1,26%	1,65%	1,63%	2,50%	1,04%	2,48%	3,19%	3,41%	2,31%	3,14%	2,48%
		RUT	15,59%	18,34%	23,55%	31,16%	37,96%	3,24%	39,11%	42,83%	29,71%	36,28%	29,22%	35,12%	38,33%	19,27%	42,70%	47,50%
		Nº of Transshipments	384	214	951	701	497	93	1086	1286	824	1193	1787	1035	722	252	1489	1618
	SLA 1 - Cost Maximums	Nº Orders	7,63%	2,82%	13,91%	18,18%	20,94%	1,92%	20,61%	25,32%	10,41%	11,86%	16,83%	15,83%	16,38%	3,27%	18,79%	23,01%
		Lost Sales	-18,90%	-17,26%	-35,25%	-25,79%	-18,26%	-5,48%	-41,00%	-47,40%	-20,20%	-32,18%	-32,81%	-24,13%	-15,48%	-6,79%	-33,53%	-39,36%
		Average Stock	-0,50%	0,85%	-1,15%	-2,69%	-3,79%	-0,16%	-0,64%	0,99%	-0,24%	3,48%	-1,19%	-1,96%	-2,60%	0,00%	1,13%	3,34%
		Cost of Transshipments	4 885,20 €	2 266,65 €	11 892,15 €	9 956,70 €	7 731,45 €	1 179,90 €	14 738,40 €	18 640,35 €	11 353,95 €	13 330,80 €	25 264,35 €	15 638,85 €	10 525,95 €	3 187,80 €	21 321,00 €	24 653,70 €
		SLS	1,36%	0,95%	1,21%	1,52%	0,15%	1,99%	1,46%	1,33%	3,59%	2,22%	2,76%	3,73%	2,97%	2,56%	3,64%	3,00%
		RUT	16,16%	18,75%	24,34%	31,37%	38,11%	3,46%	38,98%	42,94%	29,66%	36,07%	30,55%	35,42%	38,31%	19,13%	42,67%	47,50%
		Nº of Transshipments	342	184	798	623	452	88	968	1155	733	950	1561	955	637	229	1306	1470

			Fashion															
			Jan_Mar								Christmas							
			Base	Continuous		Periodicity		Alpha			Base	Continuous		Periodicity		Alpha		
				Full	Semi	2	4	0,3	0,75	1		Full	Semi	2	4	0,3	0,75	1
Medium rot. Trouser	Base - Maximums	Nº Orders	5,62%	5,08%	8,43%	6,58%	10,83%	2,34%	6,91%	7,49%	10,22%	5,63%	14,53%	12,18%	10,77%	4,94%	11,99%	13,45%
		Lost Sales	-38,71%	-45,45%	-58,71%	-33,33%	-26,28%	-23,87%	-47,74%	-50,32%	-27,52%	-50,84%	-38,79%	-29,20%	-16,37%	-14,21%	-33,83%	-40,27%
		Average Stock	-0,37%	2,47%	-0,52%	-0,88%	-1,47%	-0,22%	-0,43%	-0,37%	-1,47%	-2,46%	-2,02%	-2,02%	-2,32%	-0,82%	-1,36%	-0,08%
		Cost of Transshipments	1 386,90 €	1 604,25 €	2 639,25 €	1 873,35 €	2 049,30 €	921,15 €	1 438,65 €	1 759,50 €	4 740,30 €	6 882,75 €	9 170,10 €	5 858,10 €	4 688,55 €	2 442,60 €	5 682,15 €	7 358,85 €
		SLS	0,52%	0,97%	0,16%	0,37%	0,21%	0,91%	0,84%	1,10%	2,29%	0,55%	2,56%	2,52%	2,47%	1,83%	2,10%	1,47%
		RUT	7,99%	5,11%	6,81%	4,61%	10,47%	4,72%	4,86%	8,92%	11,84%	5,23%	12,45%	13,18%	12,37%	6,03%	14,95%	21,19%
		Nº of Transshipments	77	88	145	100	106	49	79	94	254	369	500	313	247	134	307	390
	Base - Cost Maximums	Nº Orders	7,26%	6,86%	10,19%	9,80%	12,66%	4,80%	8,55%	9,25%	10,98%	10,84%	15,48%	13,11%	10,84%	5,08%	12,88%	15,10%
		Lost Sales	-39,35%	-47,47%	-59,35%	-33,79%	-26,89%	-27,74%	-50,32%	-53,55%	-24,43%	-48,22%	-36,38%	-26,28%	-15,23%	-10,87%	-31,41%	-36,78%
		Average Stock	-0,40%	1,23%	-0,60%	-0,93%	-1,68%	-0,42%	-0,48%	-0,36%	-1,22%	-0,90%	-1,97%	-2,22%	-2,20%	-0,79%	-1,32%	0,36%
		Cost of Transshipments	745,20 €	610,65 €	1 138,50 €	1 035,00 €	1 304,10 €	476,10 €	807,30 €	910,80 €	3 053,25 €	4 140,00 €	5 682,15 €	4 202,10 €	3 653,55 €	1 645,65 €	3 788,10 €	5 175,00 €
		SLS	0,31%	2,14%	0,60%	0,65%	0,72%	0,75%	0,00%	0,31%	4,22%	2,21%	4,17%	3,11%	2,75%	5,17%	3,08%	2,86%
		RUT	7,62%	3,66%	4,88%	4,61%	9,39%	4,11%	4,37%	9,11%	11,39%	4,68%	11,75%	13,38%	13,08%	5,15%	15,17%	20,80%
		Nº of Transshipments	60	55	93	82	89	39	66	72	217	299	400	286	231	122	265	347
	SLA 1 - Maximums	Nº Orders	2,58%	3,86%	8,31%	7,20%	17,16%	0,82%	12,41%	12,65%	10,03%	14,50%	16,50%	15,83%	14,95%	3,36%	18,65%	21,45%
		Lost Sales	-15,48%	-21,21%	-42,58%	-23,29%	-31,12%	-3,87%	-49,68%	-56,13%	-25,91%	-43,34%	-40,00%	-33,45%	-20,44%	-8,46%	-44,30%	-51,14%
		Average Stock	0,02%	0,66%	-0,43%	-1,06%	-2,57%	0,10%	0,69%	1,96%	0,59%	8,22%	0,61%	-0,81%	-1,31%	0,57%	2,35%	5,06%
		Cost of Transshipments	910,80 €	807,30 €	3 229,20 €	2 815,20 €	4 036,50 €	155,25 €	4 999,05 €	6 592,95 €	5 816,70 €	8 538,75 €	12 885,75 €	9 045,90 €	7 627,95 €	1 697,40 €	12 544,20 €	14 748,75 €
		SLS	0,00%	0,00%	0,27%	0,86%	0,00%	0,00%	0,68%	0,68%	1,09%	0,29%	1,06%	1,38%	1,30%	0,24%	1,20%	1,02%
		RUT	10,84%	8,88%	13,65%	19,72%	23,27%	3,14%	27,37%	28,44%	27,36%	30,74%	28,11%	30,22%	34,19%	17,44%	38,87%	41,28%
		Nº of Transshipments	50	46	167	154	211	8	269	352	307	452	681	478	396	90	665	783
	SLA 1 - Cost Maximums	Nº Orders	3,86%	3,65%	10,07%	9,43%	16,88%	0,70%	13,23%	17,21%	9,33%	17,83%	16,37%	15,97%	14,95%	3,49%	19,54%	23,54%
		Lost Sales	-14,19%	-21,21%	-42,58%	-25,57%	-29,91%	-3,23%	-51,61%	-60,65%	-21,48%	-41,46%	-37,32%	-29,68%	-19,58%	-8,19%	-40,00%	-48,32%
		Average Stock	-0,02%	0,64%	-0,31%	-1,04%	-2,57%	0,11%	0,31%	1,60%	0,70%	8,90%	0,16%	-0,88%	-1,10%	0,75%	2,15%	4,99%
		Cost of Transshipments	652,05 €	476,10 €	2 049,30 €	1 697,40 €	3 053,25 €	103,50 €	3 332,70 €	4 833,45 €	4 274,55 €	5 516,55 €	9 232,20 €	6 241,05 €	5 806,35 €	1 159,20 €	8 807,85 €	11 685,15 €
		SLS	0,26%	0,00%	0,14%	0,76%	0,09%	0,00%	0,47%	0,46%	2,61%	1,21%	1,45%	2,34%	1,47%	1,16%	1,99%	1,37%
		RUT	10,69%	8,40%	13,38%	19,44%	23,92%	3,14%	27,08%	28,68%	26,85%	30,02%	27,67%	29,77%	34,51%	17,62%	38,17%	40,95%
		Nº of Transshipments	49	38	137	129	193	8	241	321	274	369	571	396	360	81	569	723

			Fashion															
			Jan_Mar								Christmas							
			Base	Continuous		Periodicity		Alpha			Base	Continuous		Periodicity		Alpha		
				Full	Semi	2	4	0,3	0,75	1		Full	Semi	2	4	0,3	0,75	1
Amalgam (join)	Base - Maximums	Nº Orders	6,68%	2,59%	10,48%	9,64%	17,92%	3,21%	7,69%	8,96%	11,45%	8,48%	17,03%	13,24%	12,53%	4,80%	15,96%	18,83%
		Lost Sales	-31,79%	-45,18%	-47,40%	-27,66%	-23,22%	-18,79%	-36,13%	-39,31%	-20,51%	-43,68%	-30,16%	-21,15%	-12,14%	-9,42%	-28,37%	-33,39%
		Average Stock	-0,73%	2,24%	-1,25%	-1,36%	-2,60%	-0,58%	-0,83%	-0,57%	-2,53%	-2,82%	-4,24%	-4,06%	-4,02%	-1,28%	-2,63%	1,33%
		Cost of Transshipments	2 359,80 €	2 183,85 €	4 781,70 €	3 384,45 €	3 922,65 €	1 511,10 €	2 773,80 €	3 487,95 €	10 039,50 €	14 107,05 €	21 114,00 €	12 502,80 €	8 714,70 €	4 968,00 €	12 885,75 €	15 804,45 €
		SLS	1,02%	0,42%	1,16%	1,04%	0,68%	0,47%	1,57%	0,43%	9,95%	2,93%	7,38%	7,93%	6,87%	10,76%	8,19%	6,98%
		RUT	4,61%	6,03%	7,47%	6,22%	15,35%	6,26%	5,44%	11,83%	23,66%	9,07%	26,61%	26,71%	30,94%	12,74%	29,24%	37,79%
		Nº of Transshipments	133	119	262	188	209	85	150	185	552	766	1143	673	460	275	694	842
	Base - Cost Maximums	Nº Orders	8,79%	5,76%	12,00%	12,30%	17,60%	5,07%	10,65%	11,67%	12,19%	13,98%	17,81%	14,58%	12,69%	6,03%	20,80%	24,00%
		Lost Sales	-29,19%	-45,78%	-43,64%	-28,72%	-22,54%	-18,79%	-35,55%	-39,60%	-18,49%	-39,66%	-28,60%	-20,72%	-10,96%	-10,34%	-31,72%	-34,43%
		Average Stock	-0,83%	1,56%	-1,23%	-1,49%	-2,55%	-0,58%	-0,97%	-0,68%	-2,57%	-1,35%	-4,04%	-4,02%	-4,29%	2,00%	4,93%	7,00%
		Cost of Transshipments	1 417,95 €	890,10 €	2 225,25 €	2 059,65 €	2 784,15 €	786,60 €	1 749,15 €	2 163,15 €	7 276,05 €	8 725,05 €	14 107,05 €	8 994,15 €	6 323,85 €	3 312,00 €	9 749,70 €	11 830,05 €
		SLS	0,96%	0,10%	1,21%	1,09%	1,26%	1,12%	0,48%	1,12%	11,61%	6,40%	9,35%	8,26%	8,66%	3,89%	6,22%	4,59%
		RUT	4,28%	5,27%	6,96%	6,82%	15,06%	3,68%	5,22%	11,94%	24,53%	8,19%	26,36%	26,93%	30,34%	34,33%	64,37%	69,58%
		Nº of Transshipments	120	80	180	164	184	68	141	164	501	642	943	592	418	217	1007	1097
	SLA 1 - Maximums	Nº Orders	6,76%	1,34%	15,05%	16,62%	20,11%	2,28%	20,63%	24,26%	12,64%	15,68%	17,97%	16,69%	16,54%	6,20%	21,95%	24,54%
		Lost Sales	-19,94%	-26,51%	-40,75%	-29,79%	-22,13%	-9,25%	-49,71%	-56,36%	-20,10%	-35,16%	-28,65%	-23,39%	-14,57%	-9,82%	-31,31%	-32,58%
		Average Stock	-0,29%	0,83%	-1,04%	-2,27%	-3,54%	-0,11%	0,57%	2,31%	2,00%	10,15%	1,67%	-0,82%	-2,07%	2,21%	4,32%	6,74%
		Cost of Transshipments	2 463,30 €	1 738,80 €	6 592,95 €	5 764,95 €	5 309,55 €	672,75 €	9 045,90 €	11 178,00 €	10 960,65 €	15 887,25 €	22 428,45 €	13 869,00 €	10 484,55 €	4 057,20 €	18 878,40 €	20 700,00 €
		SLS	0,83%	0,00%	1,06%	1,21%	0,00%	0,72%	0,85%	1,03%	7,09%	1,88%	5,43%	6,86%	6,12%	5,67%	6,52%	5,13%
		RUT	16,44%	20,78%	21,27%	26,92%	45,53%	3,14%	35,45%	46,80%	47,16%	51,60%	47,94%	48,51%	60,00%	34,17%	64,41%	69,60%
		Nº of Transshipments	136	92	363	313	274	37	490	595	577	828	1175	741	561	215	930	1013
	SLA 1 - Cost Maximums	Nº Orders	8,20%	3,26%	15,98%	17,91%	20,55%	2,45%	22,49%	27,90%	13,17%	20,33%	17,97%	17,08%	17,59%	6,20%	21,95%	24,54%
		Lost Sales	-17,92%	-24,10%	-41,33%	-31,06%	-22,13%	-7,80%	-51,45%	-61,27%	-19,41%	-31,62%	-27,73%	-22,06%	-14,57%	-9,82%	-31,31%	-32,58%
		Average Stock	-0,50%	1,14%	-1,15%	-2,25%	-3,43%	-0,15%	-0,05%	1,85%	1,99%	13,00%	1,41%	-0,87%	-2,06%	2,21%	4,32%	6,74%
		Cost of Transshipments	1 790,55 €	890,10 €	4 729,95 €	4 088,25 €	3 746,70 €	382,95 €	6 427,35 €	8 176,50 €	8 890,65 €	11 333,25 €	17 915,85 €	11 105,55 €	8 031,60 €	3 301,65 €	15 276,60 €	17 149,95 €
		SLS	1,31%	0,72%	0,75%	1,44%	0,00%	0,60%	0,95%	0,75%	7,45%	3,81%	5,79%	7,11%	6,11%	5,67%	6,52%	5,13%
		RUT	16,76%	20,27%	21,65%	26,90%	45,38%	2,78%	35,40%	46,54%	46,22%	51,50%	48,55%	48,72%	60,25%	34,17%	64,41%	69,60%
		Nº of Transshipments	128	75	319	273	237	32	442	537	546	735	1054	682	500	215	930	1013

			Base	Continuous		Periodicity		Alpha		
				Full	Semi	2	4	0,3	0,75	1
50 Highest	Base - Maximums	Nº Orders	4,01%	0,87%	5,44%	7,21%	2,67%	1,00%	4,58%	4,87%
		Lost Sales	-18,27%	-9,62%	-24,38%	-21,27%	-5,07%	-8,66%	-20,59%	-19,91%
		Average Stock	-0,96%	-1,52%	-1,15%	-1,06%	-2,31%	-0,25%	-0,84%	-0,07%
		Cost of Transshipments	273,00 €	273,00 €	708,00 €	287,00 €	184,00 €	149,00 €	247,00 €	237,00 €
		SLS	10,15%	6,50%	9,24%	11,61%	11,21%	14,35%	6,53%	7,39%
		RUT	14,02%	9,62%	16,48%	14,59%	36,73%	6,38%	19,04%	42,06%
		Nº of Transshipments	185	186	494	191	124	100	173	163
	Base - Cost Maximums	Nº Orders	5,87%	1,06%	7,31%	9,49%	4,00%	0,86%	5,59%	6,73%
		Lost Sales	-18,11%	-9,46%	-23,92%	-18,45%	-5,46%	-8,13%	-20,01%	-20,24%
		Average Stock	-0,76%	-2,47%	-1,20%	-1,27%	-1,85%	-0,24%	-0,96%	-0,72%
		Cost of Transshipments	282,00 €	241,00 €	743,00 €	294,00 €	206,00 €	163,00 €	279,00 €	246,00 €
		SLS	12,73%	7,97%	9,21%	13,08%	11,27%	19,94%	6,25%	8,19%
		RUT	14,95%	11,51%	17,07%	15,36%	37,86%	7,54%	20,05%	42,23%
		Nº of Transshipments	199	184	531	200	139	115	197	172
	SLA 1 - Maximums	Nº Orders	2,44%	0,68%	3,01%	3,51%	1,33%	1,00%	2,87%	0,14%
		Lost Sales	-7,84%	-3,45%	-13,06%	-10,90%	-3,84%	-4,21%	-8,40%	-8,89%
		Average Stock	-0,53%	-0,01%	-0,55%	-0,59%	-1,04%	-0,18%	-0,48%	-0,05%
		Cost of Transshipments	247,00 €	165,00 €	700,00 €	293,00 €	157,00 €	119,00 €	264,00 €	304,00 €
		SLS	5,59%	3,28%	4,64%	7,68%	7,82%	4,29%	6,65%	4,72%
		RUT	14,98%	17,82%	14,21%	16,84%	12,15%	6,81%	27,37%	50,89%
		Nº of Transshipments	164	106	473	192	102	82	175	200
	SLA 1 - Cost Maximums	Nº Orders	3,01%	0,77%	2,87%	4,04%	1,87%	1,15%	3,01%	1,00%
		Lost Sales	-7,96%	-3,43%	-12,44%	-10,87%	-3,85%	-4,34%	-8,06%	-8,71%
		Average Stock	-0,55%	-0,04%	-0,72%	-0,72%	-0,61%	-0,13%	-0,56%	-0,15%
		Cost of Transshipments	259,00 €	156,00 €	713,00 €	319,00 €	159,00 €	112,00 €	279,00 €	307,00 €
		SLS	6,31%	5,61%	5,30%	7,58%	9,27%	6,98%	6,28%	4,88%
		RUT	15,40%	17,63%	14,68%	17,13%	12,67%	6,98%	27,95%	49,69%
		Nº of Transshipments	179	112	494	209	105	80	186	202

ANNEX F: Cost Analysis

			Jan_Mar							
			Base	Continuous		Periodicity		Alpha		
	Margin			Full	Semi	2	4	0,3	0,75	1
High rot. Trouser (304 SKU)	81,60 €	Base - Maximums	- 21 615,30 €	- 12 812,10 €	- 24 840,30 €	- 23 493,00 €	- 26 543,55 €	- 10 467,60 €	- 25 821,60 €	- 28 981,05 €
		Base - Cost Maximums	- 23 674,80 €	- 15 404,55 €	- 31 918,80 €	- 25 942,05 €	- 28 229,10 €	- 12 142,50 €	- 29 829,90 €	- 30 809,55 €
		SLA 1 - Maximums	- 11 400,45 €	- 3 890,85 €	- 13 948,35 €	- 16 971,90 €	- 23 970,15 €	- 3 867,15 €	- 15 850,65 €	- 15 848,25 €
		SLA 1 - Cost Maximums	- 11 506,20 €	- 4 896,15 €	- 18 694,05 €	- 20 396,70 €	- 26 043,15 €	- 3 590,10 €	- 20 549,70 €	- 22 051,05 €
Medium rot. Trouser (158 SKU)	66,71 €	Base - Maximums	- 2 514,90 €	- 1 248,60 €	- 3 280,16 €	- 2 885,18 €	- 3 592,77 €	- 1 505,12 €	- 3 373,99 €	- 3 309,48 €
		Base - Cost Maximums	- 3 193,91 €	- 2 323,12 €	- 4 816,12 €	- 3 735,64 €	- 4 444,09 €	- 2 306,33 €	- 4 242,78 €	- 4 460,23 €
		SLA 1 - Maximums	- 644,04 €	- 480,21 €	- 1 024,56 €	- 465,21 €	- 2 578,43 €	- 230,31 €	84,98 €	1 015,98 €
		SLA 1 - Cost Maximums	- 746,27 €	- 817,71 €	- 2 172,96 €	- 1 878,76 €	- 3 299,04 €	- 217,45 €	- 1 766,80 €	- 1 128,59 €
Amalgam (137 SKU)	47,66 €	Base - Maximums	- 2 716,90 €	- 1 277,25 €	- 2 774,14 €	- 2 590,85 €	- 3 835,15 €	- 1 507,00 €	- 2 992,60 €	- 2 771,21 €
		Base - Cost Maximums	- 3 177,31 €	- 2 480,06 €	- 4 673,21 €	- 4 093,05 €	- 4 741,65 €	- 2 185,30 €	- 3 848,43 €	- 4 076,47 €
		SLA 1 - Maximums	- 657,24 €	- 299,44 €	246,69 €	- 527,35 €	- 2 024,97 €	- 795,67 €	1 360,78 €	2 487,00 €
		SLA 1 - Cost Maximums	- 960,67 €	- 873,50 €	- 1 688,53 €	- 2 460,61 €	- 3 579,42 €	- 842,97 €	- 1 497,53 €	- 1 234,42 €
Shorts (24 SKU)	30,00 €	Base - Maximums	- €	-	-	-	-	-	-	-
		Base - Cost Maximums	- €	-	-	-	-	-	-	-
		SLA 1 - Maximums	- €	-	-	-	-	-	-	-
		SLA 1 - Cost Maximums	- €	-	-	-	-	-	-	-
Shirts (19 SKU)	45,00 €	Base - Maximums	- 312,30 €	-	-	-	-	-	-	-
		Base - Cost Maximums	- 399,75 €	-	-	-	-	-	-	-
		SLA 1 - Maximums	10,80 €	-	-	-	-	-	-	-
		SLA 1 - Cost Maximums	- 45,60 €	-	-	-	-	-	-	-
Coats (5 SKU)	83,50 €	Base - Maximums	- €	-	-	-	-	-	-	-
		Base - Cost Maximums	- €	-	-	-	-	-	-	-
		SLA 1 - Maximums	- €	-	-	-	-	-	-	-
		SLA 1 - Cost Maximums	- €	-	-	-	-	-	-	-
Knitwear (12 SKU)	38,50 €	Base - Maximums	- €	-	-	-	-	-	-	-
		Base - Cost Maximums	- €	-	-	-	-	-	-	-
		SLA 1 - Maximums	- €	-	-	-	-	-	-	-
		SLA 1 - Cost Maximums	- €	-	-	-	-	-	-	-
Sweat-Shirts (4 SKU)	54,00 €	Base - Maximums	- €	-	-	-	-	-	-	-
		Base - Cost Maximums	- €	-	-	-	-	-	-	-
		SLA 1 - Maximums	- €	-	-	-	-	-	-	-
		SLA 1 - Cost Maximums	- €	-	-	-	-	-	-	-
T-shirt/Polo (73 SKU)	15,00 €	Base - Maximums	769,05 €	-	-	-	-	-	-	-
		Base - Cost Maximums	152,85 €	-	-	-	-	-	-	-
		SLA 1 - Maximums	1 469,70 €	-	-	-	-	-	-	-
		SLA 1 - Cost Maximums	993,00 €	-	-	-	-	-	-	-

			Christmas							
			Base	Continuous		Periodicity		Alpha		
	Margin			Full	Semi	2	4	0,3	0,75	1
High rot. Trouser (304 SKU)	81,60 €	Base - Maximums	- 32 693,10 €	- 44 691,60 €	- 42 940,05 €	- 38 184,45 €	- 27 038,85 €	- 14 010,75 €	- 44 619,45 €	- 48 063,75 €
		Base - Cost Maximums	- 31 928,25 €	- 48 266,70 €	- 48 729,90 €	- 36 917,40 €	- 25 995,75 €	- 13 008,00 €	- 47 283,15 €	- 47 343,00 €
		SLA 1 - Maximums	- 27 835,80 €	- 28 918,20 €	- 36 375,45 €	- 35 986,05 €	- 31 717,80 €	- 11 961,15 €	- 43 546,35 €	- 51 039,00 €
		SLA 1 - Cost Maximums	- 28 775,25 €	- 29 209,20 €	- 39 922,35 €	- 37 138,95 €	- 34 617,75 €	- 10 314,90 €	- 45 162,30 €	- 53 289,90 €
Medium rot. Trouser (158 SKU)	66,71 €	Base - Maximums	- 8 597,15 €	- 10 943,66 €	- 9 628,19 €	- 9 768,00 €	- 6 560,38 €	- 4 537,87 €	- 10 731,87 €	- 12 208,95 €
		Base - Cost Maximums	- 8 724,67 €	- 12 519,37 €	- 11 883,86 €	- 9 793,56 €	- 6 792,76 €	- 3 589,86 €	- 11 395,74 €	- 12 603,74 €
		SLA 1 - Maximums	- 6 726,53 €	- 6 222,36 €	- 6 447,83 €	- 8 799,55 €	- 6 376,11 €	- 2 394,03 €	- 8 852,70 €	- 9 957,96 €
		SLA 1 - Cost Maximums	- 6 090,35 €	- 8 428,36 €	- 8 771,38 €	- 9 532,19 €	- 7 597,32 €	- 2 794,61 €	- 10 424,93 €	- 11 551,35 €
Amalgam (137 SKU)	47,66 €	Base - Maximums	- 6 293,90 €	- 11 205,33 €	- 2 893,02 €	- 5 773,52 €	- 4 559,24 €	- 2 554,88 €	- 9 698,41 €	- 10 779,13 €
		Base - Cost Maximums	- 7 351,45 €	- 13 836,83 €	- 8 573,25 €	- 8 835,79 €	- 5 609,31 €	- 3 449,78 €	- 11 835,06 €	- 13 897,11 €
		SLA 1 - Maximums	- 4 978,23 €	- 3 892,27 €	- 291,11 €	- 6 241,04 €	- 5 394,07 €	- 4 165,24 €	- 6 222,24 €	- 6 476,86 €
		SLA 1 - Cost Maximums	- 6 449,01 €	- 6 038,43 €	- 4 041,15 €	- 7 794,09 €	- 7 805,02 €	- 4 483,45 €	- 9 431,62 €	- 8 474,49 €
Shorts (24 SKU)	30,00 €	Base - Maximums	- 49,35 €	-	-	-	-	-	-	-
		Base - Cost Maximums	- 91,80 €	-	-	-	-	-	-	-
		SLA 1 - Maximums	- 103,05 €	-	-	-	-	-	-	-
		SLA 1 - Cost Maximums	- 95,85 €	-	-	-	-	-	-	-
Shirts (19 SKU)	45,00 €	Base - Maximums	- 758,55 €	-	-	-	-	-	-	-
		Base - Cost Maximums	- 970,95 €	-	-	-	-	-	-	-
		SLA 1 - Maximums	- 347,40 €	-	-	-	-	-	-	-
		SLA 1 - Cost Maximums	- 585,90 €	-	-	-	-	-	-	-
Coats (5 SKU)	83,50 €	Base - Maximums	- 1 268,25 €	-	-	-	-	-	-	-
		Base - Cost Maximums	- 1 210,35 €	-	-	-	-	-	-	-
		SLA 1 - Maximums	- 1 587,70 €	-	-	-	-	-	-	-
		SLA 1 - Cost Maximums	- 1 751,20 €	-	-	-	-	-	-	-
Knitwear (12 SKU)	38,50 €	Base - Maximums	- 4,60 €	-	-	-	-	-	-	-
		Base - Cost Maximums	- 534,30 €	-	-	-	-	-	-	-
		SLA 1 - Maximums	- 373,35 €	-	-	-	-	-	-	-
		SLA 1 - Cost Maximums	- 496,85 €	-	-	-	-	-	-	-
Sweat-Shirts (4 SKU)	54,00 €	Base - Maximums	- 249,75 €	-	-	-	-	-	-	-
		Base - Cost Maximums	- 280,80 €	-	-	-	-	-	-	-
		SLA 1 - Maximums	- 366,45 €	-	-	-	-	-	-	-
		SLA 1 - Cost Maximums	- 428,55 €	-	-	-	-	-	-	-
T-shirt/Polo (73 SKU)	15,00 €	Base - Maximums	3 196,80 €	-	-	-	-	-	-	-
		Base - Cost Maximums	1 943,70 €	-	-	-	-	-	-	-
		SLA 1 - Maximums	3 957,60 €	-	-	-	-	-	-	-
		SLA 1 - Cost Maximums	2 638,35 €	-	-	-	-	-	-	-