Study about Beirabaga's Distribution Network

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Abstract

Perishable agri-food products must be sold to the final consumer in a short period of time, as this type of product has a short lifetime and after being hand-picked, it gradually starts degrading. This means that every single operation carried out throughout the supply chain has to present high efficiency levels, and all infrastructures that support the whole chain should be well located, in order to reduce transportation times between producers and final consumers.

The present dissertation focuses on Beirabaga, a company that produces and commercializes soft fruits, such as: raspberries, blackberries, blueberries, among others. This work analyses Beirabaga's current distribution network - which is composed of several national and international producers, three production centres in Tavira, Fundão and Alpedrinha, and two packaging centres in Alpedrinha and Tavira (although this last centre is only used for exportation purpose) - and aims to redefine it in order to minimize the overall distribution times and costs associated with the supply chain.

In order to respond to this challenge, a thorough study about the company and their whole supply chain was required. Therefore, a literature review was made to characterize this chain and find some similar authors' studies; after that, two mathematical models were developed in order to find the optimal solutions in terms of costs and time. The solution that minimizes the total costs allows to reduce current costs in 12%, with a network configuration with two packaging centres; the solution that minimizes the time allows to reduce the current distribution time in 44%, with a network configuration with three packaging centres.

Key words: Perishable food, Supply Chain Management, Fruit Supply Chain, Food Supply Chain, Infrastructures' Location Problems

1. Introduction

Due to the steady growth of the world population and the market globalization, the demand for agri-food products is increasing. Therefore, it became fundamental for all the companies operating in agricultural sector to improve and develop their operations throughout the entire supply chain, making them more efficient.

In addition to the world population growth and the market globalization, there are other factors which demand a detailed study about the agri-food supply chain, such as: continuous climate changes, food safety, frequent changes in consumer trends and the perishability of certain products. The perishable agri-food products increase the complexity of supply chain management due to the short lifetime and the gradual loss of quality that these products have over time (Bowman et al., 2009).

In the case of perishable goods, it is important to have different infrastructures properly located throughout the entire supply chain, in order to reduce the transportation and storage time (Tong et al., 2012; Morganti & Gonzalez-Feliu, 2015).

Decisions related with infrastructures location are critical, because can ensure, or not, the supply chain efficiency, moreover for perishable goods. A bad location can lead to a higher cost, as well as to a product with inferior quality when sold to the final consumer.

The problem that will be addressed in this paper is related to the previously mentioned issues. It was proposed by Beirabaga, a company that produces and commercialises soft fruits (blackberry, blueberry, raspberry and gooseberry), products highly perishable (most of them have a lifetime of around 4 days). Beirabaga seeks to research and analyse how the current location of its infrastructures (packaging centres and cold stores) could affect, its national distribution network, in terms of costs and time. These two factors are fundamental for the distribution of these products. Furthermore, Beirabaga also intends to analyse new potential location to reduce costs and time.

This problem, involving perishable agri-food products, is a theme which presents enormous challenges in such a way that recently new studies have emerged in this field (Ahumada & Villalobos, 2009).

2. Problem Description

The present work will focus on analysing the actual distribution network and the possibility to reconfigure packaging centres location that serve the national

market, which represents around 70% of the all market, with the purpose of reducing cost and time.
The actual supply chain has suppliers (Beirabaga production centres, national producers and international producers), packaging centres, STEF's logistical platforms and clients.

2.1. Suppliers and Production

Beirabaga has soft fruit production centres located in Alpedrinha, Fundão and Tavira. Furthermore, Beirabaga commercializes fruit from other national producers spread across different districts. Beirabaga defines weekly purchase prices for each type of fruit. Every Friday, these prices are reported to the national suppliers, so that they can decide to sell the fruits (or not).
Occasionally, Beirabaga imports soft fruits from Spain and Holland. Usually, these imported berries are sold in the national market.
For Beirabaga to be able to meet the demand from different sources, it is important to do a good plan in order to avoid financial losses. This plan is disclosed every year and is decided based on historical data.

2.2. Order Fulfilment Process

The national customers' orders are received every day by fax in Alpedrinha's packaging centre between 12:00h and 14:00h to be delivered on the following day.
The packaging centre prepares the orders early on, even before receiving them. Consequently, when the orders arrive, the Alpedrinha's packaging centre will know how many pallets have to prepared per client. Each pallet can support a variable quantity that depends on each order and, has an ordering guide that contains information about: place of loading, place of delivery, customer name, and other information.
In addition to the daily orders, Beirabaga sometimes receives extraordinary orders from some clients when they want to do some promotional campaigns. In these cases, orders must be done in time and clients try to reach an agreement about price and quantity to be purchased.
Product prices, in a normal situation, are sent to all national clients every Wednesdays. Prices are valid during the following week.
International customers' orders are handled differently. Order plans are combined weekly. Every Monday, order plans between Wednesday and the following Wednesday are realized. These orders are packaged mostly in Tavira, because the major part of Tavira's production is exported. Only 30% is shipped to Alpedrinha to satisfy the national market needs.

2.3. Transport and Distribution

The transport along their supply chain has been done by other companies specialized in refrigerated transport. Nowadays, Beirabaga has transportation and distribution agreements with STEF, ServiRoad and GTO.
ServiRoad is the distributor that assures the connection between Alpedrinha and international clients. It is also responsible for the transportation from producers located in central Spain to Lisbon. From Lisbon to Alpedrinha, the transportation is handled by STEF.
GTO is the distributor responsible for delivering products from Tavira to international clients, and from Holland's suppliers to Alpedrinha packaging centre.
Finally, STEF is the company that handles the transport and distribution between Tavira and Alpedrinha, between most national producers and Beirabaga (some national suppliers manage their own deliveries to Alpedrinha), and also between Alpedrinha and other national clients scattered across the country.
The transportation between Tavira and Alpedrinha is carried out frequently. Whenever it is demanded, Beirabaga informs STEF, during the morning, about the number of pallets that are needed to be transported in the end of that same day. Regarding this mode of transportation, there is a one-day stop in STEF's logistics' platform, located in Póvoa de Santa Iria, in order to perform cross-docking before the cargo is delivered in Alpedrinha the day after.
In the packaging centre, after the clients' orders are received, Beirabaga informs STEF about the necessary number of pallets to transport to each national client. During the afternoon, between 17:00 and 18:00 p.m., STEF collects the pallets in Alpedrinha. Once the pallets are collected, the orders will be transported to one of STEF's platforms in order to be delivered to the respective clients in the end of the next day. If the clients' location is in the north of Portugal, then their orders will first go through STEF's logistics' platform located in Porto. On the other hand, if they are located in the centre or south, the orders will go through the logistics' platform in Póvoa de Santa Iria (Lisbon).
The transportation prices are presented every year by the companies that provide that service. The price associated with the transport of goods between the suppliers and the packaging centre (Alpedrinha) and between the packaging centre and STEF's logistics' platforms are presented in euros per pallet (€/pallet). The transportation price between STEF's logistics' platforms and the national clients can vary. If the client's order has less than 300kg, then the price to be applied is presented in euros per kilogram (€/kg). On the other hand, if the order has more than 300kg, then the price to be applied will be in euros per pallet (€/pallet). Lastly, in case the client is specifically the client 1 in Azambuja, then the price to be applied will always be in euros per pallet (€/pallet), regardless the order's size/weight.

3. Literature Review

3.1. Agri-food Supply Chain Management

Due to the continuous growth of the world population, a good agri-food supply chain management is becoming even more important. In developed countries, agricultural production is expected to grow in order to respond to the demand growth, it is expected to reach an increase of 70% until 2050 (FAO, 2006, 2007; Nelson et.al, 2010). European Commission is promoting extensive reforms in their agricultural politics, in order to respond adequately to various challenges that agri-food supply chains will have to face in the near future (European Commission, 2010).

The Agri-food supply chain consists of a set of activities that form a “farm-to-fork” sequence, which passes through the cultivation, processing, testing, packaging, storage, transportation, distribution and marketing (Iakovou et al., 2012). What differentiates this chain from others is the importance that some factors have, such as quality, safety and climate variability (Salin, 1998). Other factors, such as the variation in demand, price, perishability of many products, make this supply chain even more difficult to manage.

3.2. Cold Supply Chain

The cold supply chain can be defined as a refrigerated chain, where there is a continuous movement of fresh products from production until the final consumer, passing through various storage locations by different modes of transport, without changes in optimum conservation temperature and relative humidity levels (Dodd, 2013) (see figure 1).

These chains, where temperature control is a foundational component, are more complex than “normal” supply chains, because, as is defended by Smith and Spark (2004):

- Products require a tight temperature control.
- Most of these products have seasonal demand.
- Products have a short lifetime so factors such as speed, transport and handling reliability are even more important.
- Products require a specific transport and storage equipment.
- Transportation companies of this kind of products must comply with specific requirements. These companies incur in higher costs compared with the other carriers.

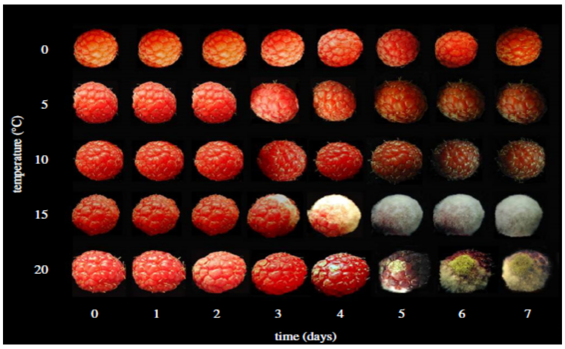

Figure 1 - Temperature impact on raspberries.

3.3. Supply Chain Network Design of Perishable Products

The network configuration that defines a supply chain is a long-term decision, which tries to establish how many infrastructures are necessary along the whole network and, as well, the transport connections that have to be established among them (Akkerman et al., 2010).

Perishable products’ supply chains also have network configuration decisions to take. According to Chen and Notteboom (2012), these decisions should consider the following issues:

1) Expiration Date - Cold chains of products with a longer shelf life should have a centralized distribution network, which allows a cost and risk reduction. Products with a shorter shelf life should have a decentralized distribution network, which allows an approximation to the customers and a distribution with more frequency.

2) Product Value - The most expensive products require a better quality control and a better product presentation. Products with a higher profit margin require a better service level and a stronger connection with their customers.

3) Demand Variability - It is a fundamental factor when defining warehouse locations, because, for example, unstable or unpredictable demand requires a decentralized distribution in order to be closer to its clients and, therefore, be prepared to act quickly when demand changes.

4) Flexible Answer - A centralized distribution is slower to respond if something changes in the market, in comparison with a decentralized distribution, which is closer to the final costumer.

5) Packaging - The packaging process can be different between markets. If the packaging process results in a higher variety of products to be distributed, then it is preferable to be close to the customers. Consequently, this will reduce costs and quantity transported.

3.4. Network Design Models

In the last decade several authors and researchers have contributed to the literature through the development of mathematical models, but few were those who studied and developed mathematical models to improve the network design of perishable products supply chain, such as vegetables and fresh fruits. In these chapter, only two models will be presented.

The authors Gong et al. (2017) developed a mathematical model to be applied in Chinese perishable food supply chain. The purpose of this model is to define how many distribution centres (DCs) are necessary to build in Beijing and in which location, so that the costs related to transportation between DCs and the final consumer, inventory and spoiled fruit can be decreased. This model does not consider transportation costs between production and distribution centres, because 90% of the production centres are located out of Beijing.

The authors Orjuela-Castro et al. (2017) developed a mathematical model, which intends to define where are the most suitable locations to build collection centres and processing centres, along a perishable fruit supply chain. This study takes into account suppliers' location, geographical area and, temperature and humidity transport conditions. The reasoning behind these considerations is the fact that this model was developed taking in consideration the Colombian highlands, where humidity and temperature vary with altitude. This developed model considers costs that are associated with construction, transportation and with fruit that becomes spoiled during the transportation.

4. Mathematical Models

4.1. Description of the Mathematical models' Structures and Objectives

In this paper will be presented two MILP models with different objective functions:1) Cost Minimization; 2) Time Minimization.

Both models only consider the national structure of Beirabaga's supply chain.

The cost minimization model (Model 1) considers different expenditure levels, costs related with: purchase/production of fruit (their own production centres, national and international suppliers), transportation, investment and disinvestments related with packaging centres, and finally, labours and the material needed for packaging.

The time minimization model (Model 2) considers the transportation and processing time along the supply chain, in days, since the harvest until the delivery to the final consumer. Each connection that is established between the network entities, has an associated time, represented in days.

The decision to be modelled, in both models, is the determination of the optimal national network configuration, taking into account the different perspectives present in both models, the possibility to open/close packaging centre(s) and a purchased/production replanning. These models consider a temporal horizon of one year, which is subdivided into twelve periods of time (representing the twelve months of the year).

The parameters were obtained based on information collected through the company's CFO. The data collected and used in the problem resolution are relative to the year of 2017. The models' solution will be obtained through GAMS language.

4.2. Model 1

Indices and Sets

i - suppliers, $i \in F = \{1, 2,...,NF\}$

j - packaging centres, $j \in J = \{1, 2,...,NJ\}$

k - STEF's Logistics platforms, $k \in K = \{1, 2,\dots,NK\}$

c - clients, $c \in C = \{1,2,...,NC\}$

t - time period, $t \in T = \{1, 2, ..., NT\}$

Parameters

A^t_i - Soft fruits' average acquisition cost from supplier i, in the time period t (€/kg);

Q^t_i - Maximum quantity of soft fruits that can be purchased from supplier i, in the time period t (kg);

E_j - Maximum packaging capacity in the packaging centre j (kg);

I_j - Investment cost to open/preserve the packaging centre j (€/year);

D_j - Disinvestment cost in packaging centre j (€/year);

N^t_c - Customer demand c in the time period t (kg);

PM^t_c - Average weight per pallet delivered to the customer c in the time period t (kg/pallet);

$CTF^t_{i,j}$ - Transportation cost between supplier i and the packaging centre j in the time period t (€/pallet);

$CTJ_{j,k}$ - Transportation cost between packaging centre j and the logistic platform k (€/pallet);

$CTA^t_{k,c}$ - Transportation cost between logistic platform k and the customer c in the time period t (€/kg);

$CTB^t_{k,c}$ - Transportation cost between logistic platform k and the customer c in the time period t (€/pallet);

$CTE^t_{k=1,\ c=1}$ - Transportation cost between logistic platform k and the client 1 in Azambuja, in the time period t (€/pallet);

$TPF_{i,j}$ - Potential connection between supplier i and the packaging centre j (binary parameter where $TPF_{i,j} = 1$ if the connection exists, and $TPF_{i,j} = 0$ otherwise);

$TPJ_{j,k}$ - Potential connection between packaging centre j and the logistic platform k (binary parameter where $TPJ_{j,k} = 1$ if the connection exists, and $TPJ_{j,k} = 0$ otherwise);

$\mathrm{TPK}_{k,c}$ - Potential connection between logistic platform k and the customer c (binary parameter where $TPK_{k,c} = 1$ if the connection exists, and $TPK_{k,c} = 0$ otherwise);

$XM^t_{k,c}$ - Evaluates whether the average delivery's weight transported between logistic platform k and the customer c in the time period t, is higher than 300 kg ($XM^t_{k,c}$ = 1 if the delivery's weight exceeds 300 kg, and $XM^t_{k,c}$ = 0 otherwise);

$XN^t_{k,c}$ - Evaluates whether the average delivery's weight transported between logistic platform k and the customer c in the time period t, is lower than 300 kg ($XN^t_{k,c}$ = 1 if the delivery's weight is lower than 300 kg, and $XN^t_{k,c}$ = 0 otherwise);

PP - Average weight of each pallet that is transported between suppliers and the packaging centre(s) (kg/pallet);

O - Labour cost in the packaging centres (€/kg);

CM - Cost of packaging material (€/kg);

M - Very high positive number;

m - Positive number very close to zero;

Binary Variables

EA_j - Equal to 1 when investing in the opening/persevering the packaging centre j, 0 otherwise;

Non-negative Continuous Variables

QF^t_i - Quantity of soft fruit purchased from supplier i in the time period t (kg);

$XF^t_{i,j}$ - Quantity of soft fruits transported between supplier i and the packaging centre j in the time period t (kg);

$XJ^t_{j,k,c}$ - Quantity of soft fruits transported between the packaging centre j and the logistic platform k, which will have as final destination the customer c in the time period t (kg);

$XK^t_{k,c}$ - Quantity of soft fruits transported between logistic platform k and the customer c in the time period t (kg);

$NP^t_{i,j}$ - Number of pallets transported between supplier i and the packaging centre j in the time period t (units);

$NPE^t_{j,k,c}$ - Number of pallets transported between packaging centre j and the logistic platform k, which will have as final destination the customer c in the time period t (units);

$NPC^t_{k,c}$ - Number of pallets transported between logistic platform k and the customer c in the time period t (units);

CAP^t_j - Quantity of soft fruits packed in the packaging centre j in the time period t (kg);

Mathematic Formulation

$$\begin{aligned} Min\, Z &= \sum_{i\in F}\sum_{j\in J}\sum_{t\in T} NP^t_{i,j}\,.\,CTF^t_{i,j} \\ &+ \sum_{j\in J}\sum_{k\in K}\sum_{c\in C}\sum_{t\in T} NPE^t_{j,k,c}\,.\,CTJ^t_{j,k} + \sum_{k\in K}\sum_{c\in C}\sum_{t\in T}(XK^t_{k,c}\,.\,CTA^t_{k,c}.\,XN^t_{k,c} \\ &+ NPC^t_{k,c}.\,CTB^t_{k,c}.\,XM^t_{k,c} + NP^t_{k=1,c=1}.\,CTE^t_{k=1,c=1}) \\ &+ \sum_{j\in J}\sum_{t\in T} CAP^t_j.\,(O+CM) + \sum_{j\in J}(EA_j.\,I_j + (1-EA_j).\,D_j) \\ &+ \sum_{i\in F}\sum_{t\in T} QF^t_i.\,A^t_i \end{aligned} \quad (3.1)$$

$$\sum_{j\in J} XF^t_{i,j} \le Q^t_i \quad \forall\, i \in F, t \in T \quad (3.2)$$

$$QF^t_i = \sum_{j\in J} XF^t_{i,j} \quad \forall\, i \in F, t \in T \quad (3.3)$$

$$\sum_{i\in F} XF^t_{i,j}\,.\,TPF_{i,j} = \sum_{k\in K}\sum_{c\in C} XF^t_{j,k,c}\,.\,TPK_{k,c} \quad \forall\, j \in J, t \in T \quad (3.4)$$

$$\sum_{i\in F} XF^t_{i,j} \le E_j \quad \forall\, j \in J, t \in T \quad (3.5)$$

$$\sum_{i\in F} XF^t_{i,j} = CAP^t_j \quad \forall\, j \in J, t \in T \quad (3.6)$$

$$\sum_{j\in J}\sum_{c\in C} XJ^t_{j,k,c}.\,TPJ_{j,k} = \sum_{c\in C} XK^t_{k,c}\,.\,TPK_{k,c} \quad \forall\, k \in K, t \in T \quad (3.7)$$

$$\sum_{j\in J}\sum_{c\in C} NPE^t_{j,k,c} = \sum_{c\in C} NPC^t_{k,c} \quad \forall\, k \in K, t \in T \quad (3.8)$$

$$\sum_{j\in J} XJ^t_{j,k,c} = XK^t_{k,c} \quad \forall\, k \in K, c \in C, t \in T \quad (3.9)$$

$$\sum_{j\in J} NPE^t_{j,k,c} = NPC^t_{k,c} \quad \forall\, k \in K, c \in C, t \in T \quad (3.10)$$

$$\sum_{k\in K} XK^t_{k,c} = N^t_c \quad \forall\, c \in C, t \in T \quad (3.11)$$

$$\sum_{t\in T} CAP^t_j \le EA_j.\,M \quad \forall\, j \in J \quad (3.12)$$

$$\sum_{t\in T} CAP^t_j \ge (1-EA_j).\,m \quad \forall\, j \in J \quad (3.13)$$

$$NPC^t_{k,c} = \frac{XK^t_{k,c}}{PM^t_c} \quad \forall\, k \in K, c \in C, t \in T \quad (3.14)$$

$$NP^t_{i,j} = \frac{XF^t_{i,j}}{PP} \quad \forall\, i \in F, j \in J, t \in T \quad (3.15)$$

$$NPE^t_{j,k,c} = \frac{XJ^t_{j,k,c}}{PM^t_c} \quad \forall\, j \in J, k \in K, c \in C, t \in T \quad (3.16)$$

$$EA_j \in \{0,1\} \quad (3.17)$$

$$QF^t_i, XF^t_{i,j}, XJ^t_{j,k,c}, XK^t_{k,c}, NP^t_{i,j}, NPE^t_{j,k,c}, NPC^t_{k,c}, CAP^t_j \ge 0 \quad (3.18)$$

The objective function, equation (3.1), aims to minimize the supply chain global cost. The first three terms refer to the transportation cost between the different entities present in the network. The first term expresses the transportation cost between suppliers and packaging centres, the second between packaging centres and the logistic platform, and the third between logistic platforms and customers.

The fourth term expresses the variable costs considered in the problem: labour cost and packaging material related with the quantity to be packed in each centre.

The fifth term expresses the fixed costs related to the opening or maintenance (if the centres already exist -Alpedrinha's packaging centre) of the packaging centres, or disinvestment in them. Finally, the sixth term expresses the acquiring fruit cost.

The inequality (3.2) limits the amount of soft fruits that can be purchased from each supplier. In each time

period, it is not possible to acquire from each supplier more than its maximum capacity.
The inequality (3.3) aims to ensure that the quantity of soft fruits acquired to each supplier, in each period of time is equal to the quantity of soft fruits that is transported between each supplier and the packaging centres.
The equation (3.4) ensures that the quantity of soft fruits transported to a particular packaging centre must be equal to the amount of soft fruits that comes out from the same packaging centre. In addition, this equation ensures that there is no flow of soft fruits between entities that don't have possible connection.
The inequality (3.5) assures that the maximum packaging capacity, in each packaging centre, is not exceeded, so the quantity of soft fruits entering in a packaging centre cannot be greater than its capacity.
Equation (3.6) ensures that the all quantity of soft fruits that enters in a packaging centre is packed.
The equations (3.7) - (3.10) are related with the packaging and delivery processes to a given customer. These equations mainly aim to ensure that an order, specifically prepared in a packaging centre for a given customer, arrives in fact to the customer.
The equation (3.7) ensures that the amount of soft fruits that enters in a given logistic platform is equal to the quantity that comes out.
The equation (3.8) certifies that the number of pallets entering in a logistics platform is equal to the quantity that leaves that same platform. The equations (3.9) and (3.10) ensure that each packaged order to a specific customer, is firstly transported to a packaging centre, and only then transported to the customer.
The equation (3.11) guarantees that the demand of each client in each period of time is met.
The inequalities (3.12) and (3.13) ensure that the opening/maintenance of a particular packaging centre occurs, if it is necessary to pack in that centre. If there is no packaging at that location, these equations also ensure that, in this case, there is no investment in a new centre, or if a centre already exists, it is closed.
The equations (3.14) - (3.16) guarantee that the number of pallets that is transported between the entities present in the equations is equal to the flow amount of soft fruits divided by the average weight that each pallet is able to withstand.
Finally, the variables domains are defined in (3.17) and (3.18).

4.3. Model 2

The indices and sets are equal to model 1. In relation to the parameters present in the previous model, the model 2 also use: Q^t_i, E_j, N^t_c, $TPF_{i,j}$, $TPJ_{j,k}$, $TPK_{k,c}$.
In this model, in addition to the parameters mentioned before, the following are added:

$TTF_{i,j}$ - It represents, on average, the time interval, in days, since soft fruits' harvests in the supplier *i* until the arrival to the packaging centre *j*;

$TTJ_{j,k}$ - It represents., on average, the time interval, in days, since the beginning of an order's packaging process in the packaging centre *j* until the order's entering in the logistics platform *k*;

$TTK_{k,c}$ - It represents, on average, the time interval, in days, since the order's entering in the logistics platform *k* until reach the customer *c*;

Regarding to the previous model only continuous positive variables are used, which are: QF^t_i, $XF^t_{i,j}$, $XJ^t_{j,k,c}$, $XK^t_{k,c}$, CAP^t_j.

Mathematic Formulation

$$Min\ D = \frac{\sum_{i\in F}\sum_{j\in J}\sum_{t\in T} XF^t_{i,j}.TTF_{i,j}}{\sum_{c\in C}\sum_{t\in T} N^t_c} + \frac{\sum_{j\in J}\sum_{k\in K}\sum_{c\in C}\sum_{t\in T} XJ^t_{j,k,c}.TTJ_{j,k}}{\sum_{c\in C}\sum_{t\in T} N^t_c} + \frac{\sum_{k\in K}\sum_{c\in C}\sum_{t\in T} XK^t_{k,c}.TTK_{k,c}}{\sum_{c\in C}\sum_{t\in T} N^t_c} \quad (3.19)$$

The objective function (3.19) minimizes the average time between the suppliers' harvest and the customer's delivery.
In relation to the previous model (model 1) only the equations and inequalities (3.2) - (3.7), (3.11), (3.17) and (3.18) were used.

5. Results and Discussion

5.1. Introduction

In this sector, firstly, the current scenario will be presented in the period under analysis (2017), in terms of current costs but also the average time interval between harvests and the arrival to customers.
Therefore, the results from the mathematical models, implemented in GAMS language, will be analysed. In model 1 (cost minimization) it is intended to obtain the optimal network configuration, while model 2 (time minimization) considers the time factor. In both scenarios will analyse the possibility to invest in a packaging centre in Lisbon and/or in Tavira, and also the possibility to close the actual packaging centre in Alpedrinha.

5.2. Current Scenario

The current scenario includes all the production operations, distribution and packaging present in the supply chain considered in this study. The current results were obtained through the application of the model 1 and 2 (restricting them to the current situation). In the current scenario, as it was possible to understand from chapter 2, the only packaging centre that serves the national market, is located in Alpedrinha.

Table 1 - Incurred costs in the current scenario

	Transport	Packaging	Fruit Purchase/Production	Total
Cost	196.943 €	567.542 €	3.382.067 €	4.146.552 €
Weight	5%	14%	81%	100%

Through the table 1, it can be seen that the soft fruits' acquisition costs (purchase price and production costs) were those who weighted more in the final total costs incurred to satisfy the national demand. Then, were the packaging costs and, finally, the transportation costs.

In 2017, to satisfy the national demand, 41% of soft fruits came from national producers, 38% from international suppliers, and lastly, 21% from Beirabaga's production centres.

Table 2 - Average time interval that, on average, soft fruits take between the different processes.

	Harvest - Beginning of the packaging process	Beginning of the packaging process - Entry in a logistic platform	Entry in a logistic platform - delivery to the client	Total
Average time interval (days)	2,8	1	1	4,8

In table 2, it is possible to observe the average time that soft fruit takes to cover the current supply chain from the harvest until reaching the final consumer.

5.2. Model 1 (Costs Minimization)

The main results that can be extracted from Model 1 is the fact that it recommends closing the packaging centre in Alpedrinha, to invest in the other two packaging centres, Lisbon and Tavira, and also to replanning their purchases to importers, national producers, and replanning their own production in Tavira, Fundão and Alpedrinha.

Table 3 - Incurred costs comparison between Model 1 and the current scenario.

	Transport	Packaging	Fruit Purchases/Production	Total Investment/Disinvestment	Total
Cost (€)	120.521	567.542	2.944.063	13.520	3.645.646
Weight	3%	16%	81%	0%	100%
Improvement	38,8%	0%	13%	-	12%

Through the analysis of table 3, it is possible to conclude that the Model 1 implementing costs permit a total improvement of 12 % compared to the current scenario. The new network configuration allows to reduce the transportation cost in 38,8% and small fruits' acquisition cost in 13%. The investment in new packaging centres in Tavira and Lisbon (279.000€ each one), and the disinvestment in packaging centre in Alpedrinha (287.600€ profit), originates an annual cost of 13.520 € (investment and disinvestment are amortised over 20 years).

The packaging cost are maintained, because the *CM* and *O* parameters are applied equally to any packaging centre under this study.

In Model 1, the annual offer from production centres would be more prominent, its participation in the national customer satisfaction would increase from 21% to 51%. Of these 51%, 43% would come from Tavira's production centre. This increase largely explains the reduction of soft fruit's acquiring cost, because, except during the month of June, it is cheaper for Beirabaga produce their own fruits instead to import or purchase to national producers. Beirabaga, with Model 1, would reduce its import rate from 38% to 18%. The national producers would have a weight of 31%.

Table 4 - Trasnport costs comparison between the current scenario and Model 1.

	Suppliers-Packaging Centre	Packaging Centre-Logistic Platforms	Logistic Platforms-Clients	Total
2017	86.611,7 €	40.233,1 €	70.098,2 €	196.943 €
Model 1	25.925,2 €	24.497,6 €	70.098, 2€	120. 521 €
Improvement	70%	40%	0%	38,8%

Through table 4, it is possible to observe the reasons that lead to a reduction of 38,8% in the transportation costs. It would be possible, with this scenario, to reduce 70% of transportation costs between suppliers and packaging centres and, in 40% between packaging centres and STEF's logistic platforms.

The new packaging centres, in Tavira and Lisbon, would improve, in almost all cases, the cost that is spent to transport soft fruits between suppliers and the new packaging centres. In this new configuration, 58% of soft fruits would not represent any cost for Beirabaga in this part of the transport, because 56% would be packaged in Tavira. This packaging centre would be supplied exclusively by Tavira's production centre, by importers from southern Spain and, finally, by national producers located in Faro. In these cases, Beirabaga would not have to pay directly for transportation costs. The remaining 2%, of the 58%, represent the amount of soft fruits that would be purchased to Lisbon's suppliers and will be delivered in the new packaging centre located in Lisbon. These situations mentioned before, contribute in 41% to improve the total transportation cost between suppliers and packaging centres.

In 2017, only 24% of the soft fruits, which were transported to the packaging centre located in Alpedrinha, did not represent any transportation cost. This scenario would lead to a reduction of 8%, in the soft fruits' importation from Netherlands and from centre of Spain. This would greatly contribute to the reduction of transportation costs between suppliers and the packaging centres (32%). This improvement occurs due to the fact that transporting a pallet from these destinations has a high cost compared to the any other connection from national producers or Beirabaga's production centres.

Table 5 - Comparison between the current scenario and the Model 1.

		STEF's Logistic Platform				
		P.Sta Iria		Porto		Total
	Packaging Centre	Quantity (kg)	Cost (€)	Quantiy (kg)	Cost (€)	
Model 1	Lisbon	142160,2	0	65978,5	8730,9	
	Tavira	210991,8	9191,9	53821,5	6574,8	
	Total	353152	9191,9	119800	15305,7	
2017	Alpedrinha	353152	28214,8	119800	12018,3	
Improvement			67%		-27%	40%

In table 5, it is possible to observe the main reason that lead to an improvement in transportation costs between packaging centres and logistic platforms. This derives from the fact that transportation cost to Póvoa de Santa Iria suffer in this new configuration an improvement of 67%. With the new packaging centre in Lisbon, 68% of soft fruits that would be packaged there, would be transported to Póvoa de Santa Iria, in order to after that be distributed by national clients.

The transportation cost between the new packaging centres and the Porto's logistic platform would increase compared with current situation. This represents a negative contribution of -27% in costs. This occurs because the soft fruits' pallet transportation between Tavira's packaging centre and the logistics platform in Porto has a higher cost compared with any other connections. However, in total transport costs between these entities (packaging centres and logistic platforms), the implementation of Model 1 would represent an improvement of 40%.

It is important to note that in this network configuration and with the purchases and production replanning, the soft fruits would take, on average, about 3.1 days from the harvest until the end customer, 1.7 days less than the current scenario.

5.3. Model 2 (Time Minimization)

After applying the model 2, a new network configuration is obtained. A solution that recommends keeping the Alpedrinha's packaging centre in operation and also recommends opening a new packaging centres in Tavira and Lisbon.

Table 6 - Comparison between the current scenario and the Model 2.

		Harvest - Beginning of the packaging process	Beginning of the packaging process - Entry in a logistic platform	Entry in a logistic platform - Delivery to the client	Total
2017	Average time interval (days)	2,8	1	1	4,8
Model 2		1,3	0,4	1	2,7
Improvement		52%	60%	0%	44%

Regarding the obtained results (table 6), it can be observed that the Model 2 implementation would promote a substantial improvement (44%) in the average time between soft fruits' harvest and their arrival to the clients. This improvement would be possible through the substantial reduction (around 52 %) of the soft fruits' average time from harvest until the beginning of the packaging process, as well as through the reduction (around 60%) of the average time interval that soft fruits take from the beginning of the packaging process until the arrival to STEF's logistic platforms (Póvoa de Santa Iria and Porto).

With this new configuration, Beirabaga would meet 43% of the national demand using their own production centres, while 43% of soft fruits would come from national producers and, finally, around 14% would come from international producers.

In this scenario, more than half of the soft fruits would be packaged in Lisbon (60%), while 39% would be packaged in the new packaging centre in Tavira, and finally, 1% would be packaged in Alpedrinha. The average time reduction between harvest and the beginning of the packaging process happens, because with the new packaging centres in Tavira and Lisbon, and, with the purchases and production replanning, the following changes occur:

1) 64% of soft fruits, which begin the packaging process, have an average time less or equal to 1 day, while in 2017 only 11% of soft fruits had, on average, 1 or fewer days.

2) All the soft fruits arrive to the packaging centre within less than 2 days after their harvest. In the current scenario, 66% of the soft fruits that entered in Alpedrinha's packaging centre had, on average, more than 2 days.

In light of this analysis we can conclude that, with the implementation of Model 2, it is possible, to improve in 52% the days that, on average, each soft fruit accumulates between harvest and the beginning of the packaging process.

The reduction of the average time between the beginning of the packaging process and the entry in a logistics platform occurs, because in this scenario 60% of soft fruits, which satisfy the demand considered, would be transported from Lisbon's packaging centre to the logistic platform in Póvoa de Santa Iria. This would substantially reduce the time, since this is the only link that takes, on average, less than one day (0 days).

It is important to refer that the inherent cost in setting up Model 2 is about 3.779.637€

5.4. Sensitivity Analysis

The parameters analysed were those related to demand and supply, with investment and disinvestment in packaging centres, transportation costs and, finally, the average purchase price of soft fruits to national producers and international suppliers.

Demand and Supply

The parameters related to demand (N^t_c, MPC^t_c, MQ^t_c) were increased and decreased, respectively, by 20% and 40%. The total offer (national and international), corresponding to the maximum capacity of each supplier (Q^t_i) was changed. It assumed the values of the amounts that were provided exclusively to the national consumers in 2017, with the objective of understanding whether or not models 1 and 2 would still recommend the same opening/closure scenario for the packaging centres, in case Beirabaga could not reschedule its purchases and production.
The increase in demand by 20% and 40% could create a problem to Beirabaga, because suppliers (*i*) in certain months of the year would not be able to provide fruit to Beirabaga (Q^t_i), making it impossible to satisfy the national demand in those months of the year.
The demand variation in 20% and 40%, does not change the packaging centre opening/closing decisions in Scenario 1 and Scenario 2.
With regard to supply, even considering that it is not possible to replan the production and purchases origin, Beirabaga can improve its total costs, even if it is a reduced improvement (-1%). This improvement would maintain the Alpedrinha packaging centre in operation and recommend a new packaging centre in Lisbon. This new packaging centre, in this situation, will permit a transportation cost reduction (-26.2%) comparing with the current situation. Applying the model 2, maintaining the current offer to the national market, would be possible to improve the average time between harvest and delivery to the clients (-39.6%), because the application result determines the opening of the three packaging centres.

Investment and Disinvestment

Variations of 10%, 20% and 50% were applied to the parameters D_j and I_j, individually, assuming that the amortisation year remained (20 years).
The variation in investment and disinvestment costs does not cause a large variation on the total costs in relation to the Scenario 1, but if there is a variation of +20%, +50% and -50% in parameter I_j, the network configuration, recommended in scenario 1, changes. If the parameter increases 20% or 50%, then the recommendation would be to invest in a packaging centre in Lisbon and disinvest in the Apedrinha's packaging centre. If the investment cost in each packaging centre decreases 50%, then it is better to invest in all packaging centres.
Regarding the disinvestment costs, if Beirabaga is unable to receive 80% of what it expects to receive from the disinvestment in Alpedrinha's packaging centre, then this centre should not be closed and a new one should be opened in Tavira.

Transportation Costs

Transportation costs are presented annually and normally they increase each year. Therefore, a sensitivity analysis was performed, taking into account this situation, increasing the parameters related with the transportation costs ($CTF^t_{i,j}$, $CTJ_{j,k}$,$CTA^t_{k,c}$, $CTB^t_{k,c}$, $CTE^t_{k=1,\ c=1}$) in 10%, 20% and 50%.
After applying the model 1 with the respective variations, the results showed that the percentage increment applied to the transportation costs causes an insignificant variation in relation to the optimal total cost (scenario 1), something that was expected due to the reduced weight of this cost in the total cost.

Purchase Costs

The soft fruits production and purchase average costs represent a very high percentage of the annual total costs. The monthly soft fruits purchase prices have some uncertainty, because prices were defined based on a monthly average purchase price of one kilogram of soft fruits in 2017. Therefore, this sensitivity analysis was carried out to evaluate if some possible oscillations could change the investment/disinvestment decision in the packaging centres defined in scenario 1, assuming that the nationals and international producers would always be available to provide the same quantities. Consequently, a variation of 10%, 20% and 70% in A_i^t parameter values referring to the national and international suppliers was done.
After observing the results, it can be concluded that a possible change in purchase prices, even with implausible variations (70%), would not change the investment/disinvestment decisions that were recommended in scenario 1. Conversely, the production and purchase decisions change. The soft fruit's acquiring cost decreases if there is a reduction in average purchase prices. With this gradual decline, the scenario also changes gradually and begins to be more advantageous for Beirabaga to be supplied, in more quantity, with soft fruits from national and international suppliers. These decreases would lead to a little increase in transportation costs, unless there is an abrupt and implausible decrease in average purchase price (-70%).
The increase in purchase prices would lead to an insignificant decrease in transportation costs. However, the soft fruits' acquiring cost increases, because in scenario 1, the quantity of soft fruits which satisfy the national market is close to the maximum capacity of Beirabaga production centres, so it is not possible to be supplied more regularly by production centres. This led to an inevitable increase in total costs.

6. Conclusion

After applying model 1 and model 2, it was possible to obtain an optimal cost scenario (Scenario 1), and an optimal time scenario (Scenario 2).

Through the implementation of scenario 1, Beirabaga could save 12% annually comparing to the current situation. This scenario recommends closing the current packaging centre, and to open two new packaging centres in Lisbon and Tavira, taking into account the possibility of Beirabaga to be capable of replanning its own production and the purchases to satisfy the national demand. Beyond cost saving, with the application of this model, Beirabaga could reduce the average time that soft fruits take to reach the customer, taking about 3.1 days, instead of 4.8 days. A considerable improvement.

Scenario 2 represents the optimum time scenario. Through the implementation of this scenario, Beirabaga could reduce the average time between harvest until the arrival to the customers by 44%. This scenario recommends that Beirabaga opens the three packaging centres (maintaining the actual and opening the new ones in Tavira and Lisbon), taking into account, like in scenario 1, the possibility to replanning its production and purchases. The implementation of this scenario would result in a cost around 3.779.637 euros. This scenario would represent a significant time improvement.

Through the sensitivity analysis it was possible to realize that the optimal investment and disinvestment decisions in packaging centres for Scenario 1, change if there is a deviation in the investment and disinvestment costs, and if Beirabaga cannot replan its soft fruits production and purchases (to supply the national market). The sensitivity analyses performed on Scenario 2 show that the results are robust. Whereas in Scenario 1 it is necessary to have a certain rigor in the envisaged budget and to ensure that is possible to replan the offer for the domestic market, in order to guarantee that it is safe to move forward with the proposed network in Scenario 1.

Time and cost were the two main factors analysed in this dissertation. Scenario 2 presents an approximate cost to Scenario 1 (optimal cost), with an annual difference of +133,991€ (+3,7%). Scenario 2 also represents a significant time improvement in comparison with the current situation, (-44%) and also with Scenario 1 (-13%). Taking this into account, Beirabaga would benefit the most by having the three packaging centres working, even if this meant a slightly higher cost.

Moreover, considering the performed analysis and the received data, Beirabaga is advised to study the possibility of increasing its production in all its centres, for this would not only significantly reduce the costs, but would also allow Beirabaga to have a higher control over the quality and appearance of the fruits, which are both factors that are highly valued by the customer.

For future work, some improvements that can sustain the robustness of this analysis are indicated. The first suggestion is the execution of the same study, but now taking into consideration the differentiation of the soft fruits and products, since this would give a greater robustness to the work.

The second suggestion is the possibility of considering new locations for packaging centres, for example in Porto.

Another improvement suggestion to the present models would be to consider the stock costs that are not considered in these models. Finally, it would be interesting to consider, in these models, the costs associated with orders that are not matched and that are sent back, due to the lack of quality or other reasons.

To conclude, the work done in this paper is expected to be a useful tool for Beirabaga, without forgetting that these models have some limitations and do not predict all situations. Thus, it is expected that Beirabaga's investment/disinvestment decisions are made in light of their needs and their reality.

7.References

Aung, M.M., Chang, Y.S. (2014). Temperature management for the quality assurance of a perishable food supply chain. *Food Control*, 40, 198-207.

Orjuela-Castro, J.A., Sanabria-Coronado, L.A., Peralta-Lozano, A.M. (2017). Coupling facility location models in the supply chain of perishable fruits. *Research in Transportation Business & Management*, 24, 73-80.

Ahumada, O., Villalobos, J.R. (2009). Application of planning models in the agri-food supply chain: A review. *European Journal of Operational Research*, 196 (1), 1-20.

Tsolakis, K.N., Keramydas, C.A., Toka, A.K., Aidonis, D.A., Iakovou, E.T. (2013). Agrifood supply chain management: A comprehensive hierarchical decision-making framework and a critical taxonomy. *Biosystems Engineering*, 120, 47-64.

Florkowski, W.J., Shewfelt, R.L., Brueckner, B., Prussia, S.E. (2014). Postharvest Handling: A Systems Approach. Academic Press in an imprint of Elsevier.

Rong, A., Akkerman, R., Grunow, M. (2011). An optimization approach for managing fresh food quality through the supply chain. *International Journal of Production Economics*, 131 (1), 421-429.

Chen, L., Notteboom, T. (2012). Distribution and value-added logistics in the cold chain product market with application to the role of seaports. Asian Logistics Round Table Conference (ALRTC 2012).

Gong, W., Li, D., Liu, X., Yue, J., Fu, Z. (2007). Improved two-grade delayed particle swarm optimisation (TGDPSO) for inventory facility location for perishable food distribution centres in Beijing. *New Zealand Journal of Agriculture Research*, 50(5), 771-779.