Decision Model for Transport Planning in the Glass Industry

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Abstract

With the globalization felt in the last decades, the complexity of the goods transport networks has grown, and with it, its impacts on the results of companies. Thus, the constant development of the departments responsible for the organization and planning of transport became crucial.

The decisions made in these departments will intervene in variables such as time, price, or environmental impact, intervening on the business performance.

In its turn, the organization of a certain transport is dependent on variables such as the model and type of transport used, the routes to be taken and the type of product to be transferred. Being the main objective of a company, in addition to customer satisfaction, the maximization of its profits, studying the previous variables in order to optimize them, becomes the main objective of the transport department.

Having in mind the fact that transport costs ascend to 10% of the company's total expenses, this project focused on improving the activities of this same department.

One of the potential improvements detected was the consideration of the distances between the final destination of a material and its production factory when the factory is selected to produce the same.

To develop it, a decision support tool was built in the allocation of factories. The way it works consists of the following: each material has been associated with a final destination, both information inserted by the user. The model places, in order of increasing distance, all the factories in the BA Glass universe and indicates the corresponding costs. In addition, it also indicates, in which it is possible to manufacture it, considering the production restrictions existing in each factory.

Subsequently, a study was carried out on the budget projected for the year 2021 for the transport department, based on the decision model previously built.

The main objective was to draw conclusions about the impact, changes in the manufacturing restrictions would have, both in the costs and in the total number of kilometers traveled.

The main conclusion was that, if all the materials were produced in the factory closest to their final destination, there would be an average reduction of 14% in the cost of each trip, an average reduction of 13,2 % in price per tonne transported, and a reduction of almost 40% in the total number of kilometers.

Resumo

Com a globalização sentida nas últimas décadas, a complexidade das redes de transporte de mercadorias cresceu, e com ela, os impactos desta nos resultados das empresas. Deste modo, tornou-se crucial o constante desenvolvimento dos departamentos responsáveis pela organização e planeamento dos transportes.

As decisões tomadas nestes departamentos intervirão em variáveis como: tempo, preço ou impacto ambiental, refletindo-se na performance do negócio.

Por sua vez, a organização de um transporte está dependente de variáveis como: o modelo e o tipo de transporte utilizados, as rotas a realizar e o tipo de produto a transferir. Sendo que o principal objetivo de uma empresa é, para além da satisfação do cliente, a maximização dos seus lucros, estudar as variáveis anteriores de modo a otimizá-las, torna-se o principal objetivo do departamento de transportes.

Atendendo a, que os custos dos transportes ascendem a cerca de 10% das despesas totais da empresa, este projeto focou-se na melhoria das atividades deste mesmo departamento.

Umas das potenciais melhorias detetadas, foi a consideração das distâncias entre o destino final de um material e o seu local de produção, quando selecionada a fábrica para produzir esse mesmo.

Para a desenvolver, foi construída uma ferramenta de apoio à decisão na alocação de fábricas.

O modo de funcionamento desta consiste no seguinte: cada material foi associado a um destino final, ambas as informações inseridas pelo utilizador. O modelo coloca assim, por ordem crescente de distância, todas as fábricas do universo BA Glass e os respetivos custos. Além disto, também indica, em quais é possível a fabricação deste, considerando as restrições de produção existentes em cada fábrica.

Posteriormente, foi realizado um estudo ao orçamento projetado para o ano de 2021 para o departamento de transportes, tendo por base, o modelo de decisão construído anteriormente.

O principal objetivo, era retirar conclusões sobre o impacto que teriam, alterações nas restrições de fabricação, tanto nos custos como no número total de quilómetros percorridos.

A principal conclusão foi o facto de, se todos os materiais fossem produzidos na fábrica mais próxima do seu destino final, haveria uma redução média de 14% no custo de cada viagem, uma redução media de 13,12% no preço por tonelada transportada e uma redução de quase 40% no número total de kilómetros.

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"To making living itself an art, that is the goal"

Henry Miller

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Acronyms and Symbols

KPI	Key Performance Indicator
PF	Finish Product
PA	Finished Product
BB	Blow Blow
PB	Press and Blow
NN	Narrow Neck
IWW	Inland Waterways Transport
TEU	Twenty-Foot Equivalent Units
AV	Avintes
AT	Athens
BU	Bucharest
GA	Gardelegen
JE	Jedlice
LE	León
MG	Marinha Grande
SI	Sieraków
SO	Sofia
PV	Plovdiv
VF	Vila Franca de los Barrios
VN	Venda Nova

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Chapter 1

Introduction

This project was developed within the scope of the Integrated Master in Mechanical Engineering at the Faculty of Engineering of the University of Porto. This took place in a business environment, in the Supply Chain department of BA Glass.

1.1 BA Glass

Ba glass started its history in 1912 as a Bottle commercialization company and by the name of Barbosa Almeida.

In 1930 started its industrial activity in Campanhã, Oporto and changed its name to Fábrica de Vidros Barbosa e Almeida, Lda.

In 1969, after going through some technological improvements, the Campanhã factory was deactivated and consequently, the Avintes factory, in Vila Nova de Gaia started its activity. In the following years, the factory suffered several improvements like the installation of the first automatic molding machine of the IS type in 1971, the installation of a new regenerative furnace as well as a new molding machine in 1983 and the construction of the forth furnace in 1988. By this time BA Glass was confirmed as the biggest production unit of glass containers in Portugal.

The year 1995 would be marked by the merge of BA and CIVE- a glass production company located in Marinha Grande, previously bought in 1993.

In 1998 "BA- fabrica de evases de vidrio Barbosa & Almeida, SA" was incorporated, making 90,15 % of the capital hold by BA. Also in the same year a new factory in Villa Franca de los Barros was built.

In 1999 the "Vidreira Leonesa", located in Leon, was acquired by BA and the name of the company was changed to "BA vidros".

In the following years, most of the industrial units suffered reconstructions. The first was Avintes in 2001, followed by Marinha Grande and Venda Nova in 2003 and 2008 respectively.

Simultaneously, the at the time called " BA glass I- Serviços de Gestão e Investimentos, SA" carried out acquisitions like Sotancro's group in 2008 which allowed the inclusion of the pharmaceutical and cosmetic sectors in BA's client portfolio and Warta's Glass group that allowed

the expansion of the company market to Eastern Europe. The expansion to Central Europe was made possible with the acquisition of HNG Global, a German glass packaging company located in Gardelegen, Germany. By this time BA group owned 8 factories and produced more than 14 million units of glass containers per day.

The last acquisition was made in 2017 with the Yioula Group. This acquisition added 4 plants in 3 countries (Greece (Athens), Bulgaria (Sofia and Plovdiv) and Romania (Bucharest)) and allowed the BA group to start producing more than 20 million units a day (BA Glass, 2018).

In Figure 1.1 BA's network of factories is represented.

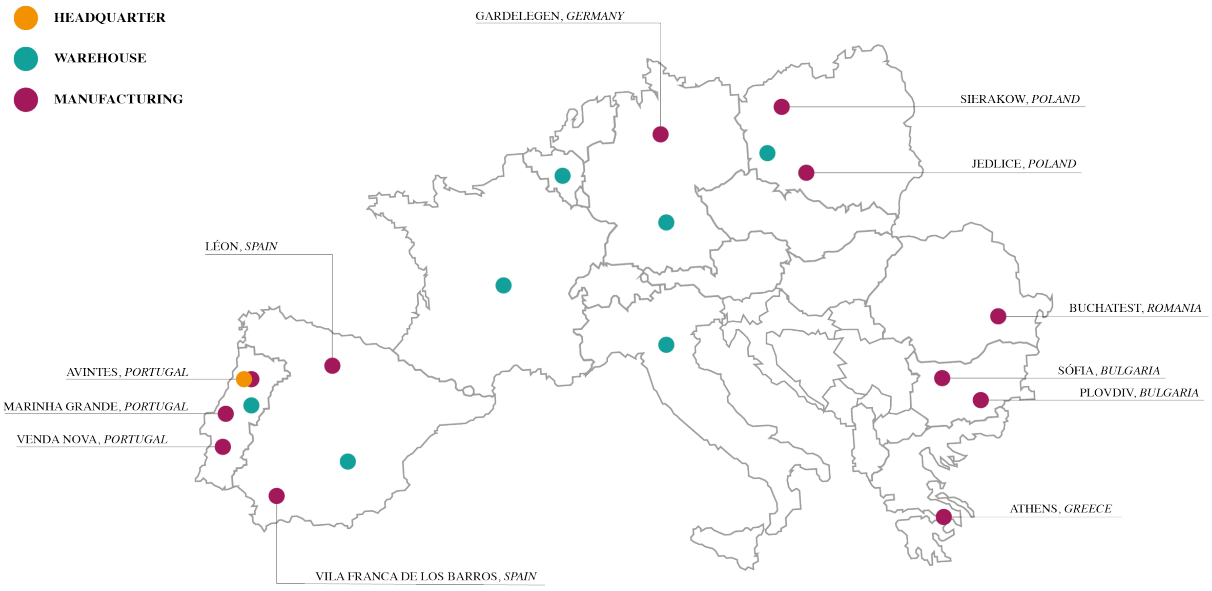


Figure 1.1: BA Glass Plant's location (BA Glass, 2018)

1.2 The project at BA

The extreme globalization felt in the last decades led to the increasing importance of the Supply Chain departments in companies. Raw materials can now arrive from any part of the world and final products can be delivered all around the globe. This is very positive for any company, as it will certainly encourage the growth of its profits.

However, it will also increase the complexity of its Supply Chain network.

As that complexity increases, so does the importance of transport planning. In a firm like BA, where the transport department represents more than 10 % of the total annual cost, the optimal planning of this sector is crucial. The department is responsible for, among other things, the monthly forecasting of sales, weekly forecasting of deliveries and slot management.

This expansion was very positive to not only grow the international client network but also to consolidate BA's competitive leadership.

However, the evolution of this industry also led to an increasing in the awareness regarding transportation cost and the fact that it is affected by a large number of variables. It is important to understand how each of them can influence the transport in the long and in the short term.

1.3 Main aim of the project

Currently, one of the main concerns of the department is the lack of interaction of the transports division in the early stages of the Supply Chain, more specifically when the plant to produce a certain product is allocated.

There is a long list of restrictions to have in mind when the location of manufacture is chosen, however, considering the distance that separates this location and the customer is still not a priority.

That is why the main goal of this project, developed in the transport department, was to create a decision tool to, along with all the restrictions already existing, make the use of the smallest distance possible for the delivery's travel a priority.

The purpose for that tool is to be later used internally by the department, not only to optimize the plant allocation process but also to draw conclusions about the possible alteration of this restriction between plants to minimize the transports sector impact on the final profit.

1.4 Metodology of the project

The first weeks of the internship were spent at the departments relevant for the project such as Production Planning or Logistics. It was a training period to understand how each department is involved with the transport planning and try to recognize possible improvements in them.

After settling at the transports department, corrections were performed in some of the existing databases to make sure that the information used in the decision model was the most accurate possible. Some of the alterations involved the transport zones and the routes definition.

The next step taken was collecting the restrictions involved in the plant allocation process as well as understanding how each of them affected the materials. This part involved different departments such as the IT department or the Business Development department.

After having all the information needed the next step was the building of the decision tool and subsequent testing and improvement.

Finally, that same decision model was used to analyze previous taken decisions regarding plant allocation at BA.

The goal was to understand how each restriction impacted that allocation and how, by alternating or changing some of those, the kilometers traveled and consequently the cost of traveling could be reduced.

1.5 Dissertation's structure

This dissertation is divided into five chapters. The project and its main goals as well as the company and its principal characteristics were explored in the first chapter.

In the second chapter, it is made a literature review in order to better understand the context of the referred project.

Chapter 3 explains the actual process of selecting a plant to produce a certain product, as well as the transport process from the moment the request is made and the transport planned, until the moment it arrives at its destination.

Chapter 4 explores the proposed improvements at the company: the decision model. It explains how it was built and how it works. It is also exposed the analysis done with the help of this tool and the conclusions withdrawn from it.

Finally, chapter 5 concludes and synthesizes all the above chapters as well as all the conclusions taken.

Chapter 2

Theoretical Contextualization

Globalization was one of the main responsible for making Transports Department a big source of expenses when analyzing a Business Supply Chain (Paulo Guedes, 2017). That globalization, felt in the last decades, led to an increase in the importance of logistic decisions, like transportation, in detriment of internal ones, such as, product quality improvement (Ghasemy Yaghin and Darvishi, 2020). For that matter, it is crucial to ensure the correct planning of transports.

When planning a transport, there are several aspects to consider, such as the transportation model in use, the type of transport chosen, the route and or the production planning restrictions.

2.1 Transportation models

Transportation models or Incoterms are a standardized set of rules brought together by the International Chamber of Commerce and recognized by the United Nations Commission on International Trade Law (Internation Chamber of Commerce, 2020).

The existing types of transportation models are:

- **Ex Works (EXW):** The seller isn't responsible for the loading or the delivery of the goods;
- **Free carriage (FCA):** The seller makes the delivery of the goods to a customer appointed entity and the risks of the delivery pass to the buyer;
- **Carriage paid to (CPT):** The seller makes the delivery to an entity; designated by him and is responsible for the delivery of the goods to the destination place
- **Carriage and insurance paid to (CIP):** It is the same as CPT but in this case the seller is not responsible for the conditions the goods will arrive in at the destination;
- **Delivered at Place (DAP):** The Seller is responsible for the delivery and the buyer is responsible for the unloading of the goods at the destination;
- **Delivered at place unloaded (DPU):** The seller is responsible for the delivery and the unloading of the goods and only after that, the risk is transferred to the buyer;

- **Delivered Duty Paid (DDP):** The seller bears all costs and risks till delivery but has also the responsibility of clear the goods both for export and import as well to formalized all customs formalities (DHL, 2020).

The first two models presented are preferred over the remaining. On these models, the firm is free from any responsibility over the transport.

2.2 Types of Transport

One of the most important decisions concerning transport planning is to decide which kind of transportation method to use: air, road, sea or rail.

Multimodal transport may be the best option since it maximizes the advantages and minimizes the disadvantages of each kind, however, there is a large range of restrictions to take into consideration when deciding the type of transport to use:

- **Final location:** due to their destination, some deliveries are impossible to be made by land as well as others that are unreasonable to be made by sea;
- **Supplier/warehouses location:** due mostly to production restrictions, some products can only be manufactured in certain plants, which will also limit the route options;
- **Deadline:** sometimes, the urge of delivering restricts the type of transport to use as some of them are slower than the others;
- **Product restrictions:** Some products demand particular transport conditions that only some types of transport can guarantee;
- **Costumer's restrictions:** Some clients may not allow the use of certain transportation methods.

In the Table 2.1, each transportation method was evaluated according to its performance in different variables, being red the worst classification possible and green the best:

- Lead time;
- Green gas emissions;
- Cost;
- Availability;
- Load dimensions;
- Routes flexibility;
- Distance of the transport.

Table 2.1: Transports Characteristics (Source: (Paulo Guedes, 2017))

Characteristic	Road	Sea	Railway	Air
Lead time	🟢	🔴	🔴	🟡
Emissions	🟡	🟢	🟡	🔴
Cost	🟡	🟢	🟢	🔴
Availability	🟢	🟢	🟡	🟡
Load dimensions	🟡	🟢	🟢	🟡
Routes flexibility	🟢	🟡	🔴	🟢
Distance	🟡	🟢	🟡	🟢

Lead Time

"Lead time is the elapsed time between placing an order and receiving it" (Jian et al., 2015). Lead time can be divided in:

- **order preparation:** the time required since the purchase request is made until the transport is booked;
- **order transit:**
  - **supplier lead time:** manufacturing time;
  - **delivery time**: necessary time to go from the supplier to the place of delivery;
  - **setup time:** preparation of the delivery (Song et al., 2013).

Transportation made by sea generally takes the longest leading time, because not only the fact that the waiting times at the ports are long, boats are by far, the slowest mode of transport.

In contrary, trains have considerably higher speeds. Nonetheless, it is usually necessary to allocate the goods in the railway terminals, which requires extra time. The same happens with airplanes.

Transportation by road normally deals with speed limitations and traffic, however, because the delivery can be done directly to clients, makes it a relatively fast transportation mode (W., 2003).

Emissions

Globalization allowed the delivery of goods to more distant costumers, however, that also meant longer distances and higher greenhouse gas Emissions. This emissions can affect the climate in four different ways:

- Direct greenhouse gases (mainly C02);

- Indirect greenhouse gases (such as tropospheric Ozone, mono-nitrogen oxides (NOx), carbon monoxide (CO) and Volatile Organic Compounds (VOC);
- Particles (black carbon (BC), organic carbon (OC) and sulfur compounds);
- Indirect effect of vaporizers that change the distribution and the properties of clouds (Tesfay, 2014).

Figure 2.1 shows the impact of greenhouse emissions from several industries and it's clear how much greater is the impact of Transport's sector.

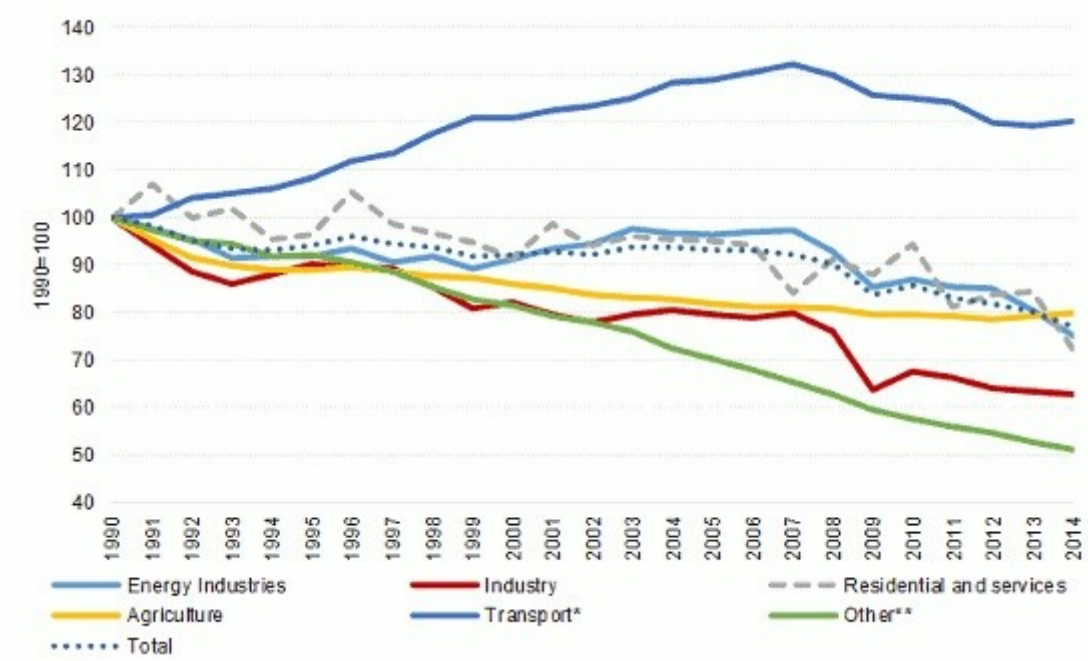


Figure 2.1: Greenhouse emissions by industry (Source: (Commission, 2016))

Concerns about greenhouse gas emissions have significantly increased in the last few years. Not only have customers become more aware of the importance of making environmentally friendly decisions, but the governments have also implemented more restrictive rules and taxes about this topic.

Regarding these rules, the Commission's low-emission mobility strategy, adopted in July 2016, wanted to make sure that Europe remained competitive not only in the transportation of goods but also people (Comission, 2016).

By the year 2017, the transport sector was responsible for 27% of the European Union total greenhouse emissions (Agency, 2017).

Table 2.2 represents the estimated values for grams of C02 emitted per tonne-Km for each freight transport type.

Table 2.2: C02 emissions per Transport Mode (Source: motorways of the sea Digital Multichannel Platform (2020))

Transport Mode		**Grams of CO2 per tonne-Km**
Sea freight	Bulk vessel	2.5
	Container Vessel	12.8
	Short sea vessel, general cargo	15.8
	Short sea vessel,container	36.3
Railway	EU average	81
Air freight	Boeing 747 F (most used)	435-474
Road freight	Truck	80

As is possible to conclude from the previous table, sea transport is the type of transport that is considered less pollutive. It has also been proved that measures have been taken and that the carbon efficiency of this freight transport method has been significantly improved in the last decade (Rehman Khan et al., 2018).

However, by 2015, maritime transport was responsible for 2.5% of the global greenhouse emissions and 13% of the EU's. For that reason, in 2013 was set a strategy by the European Commission, in order to reduce these emissions. This strategy incorporated three steps:

- Monitoring, reporting and verification of CO2 emissions from large ships using EU ports;
- Imposition of a greenhouse gas reduction target for the maritime transport sector;
- Adoption of further measures, including market-based measures, in medium to long term.

Some measures taken to mitigate air pollution were the development of European air pollutant standards, the introduction of low emissions zones or alternate traffic circulation in European city centers, the introduction in some countries of stronger speed limitations on highways when pollutant thresholds are reached, or the development and encouragement to use alternative transportation modes like rail or IWW (Inland Waterways Transport) (Commission, 2016).

From the graphic present in Figure 2.2, it is possible to visualize how much the greenhouse gas emissions have increased in international maritime transport and transports in general (including aviation). It also shows the European Commission targets for the years 2030 and 2050.

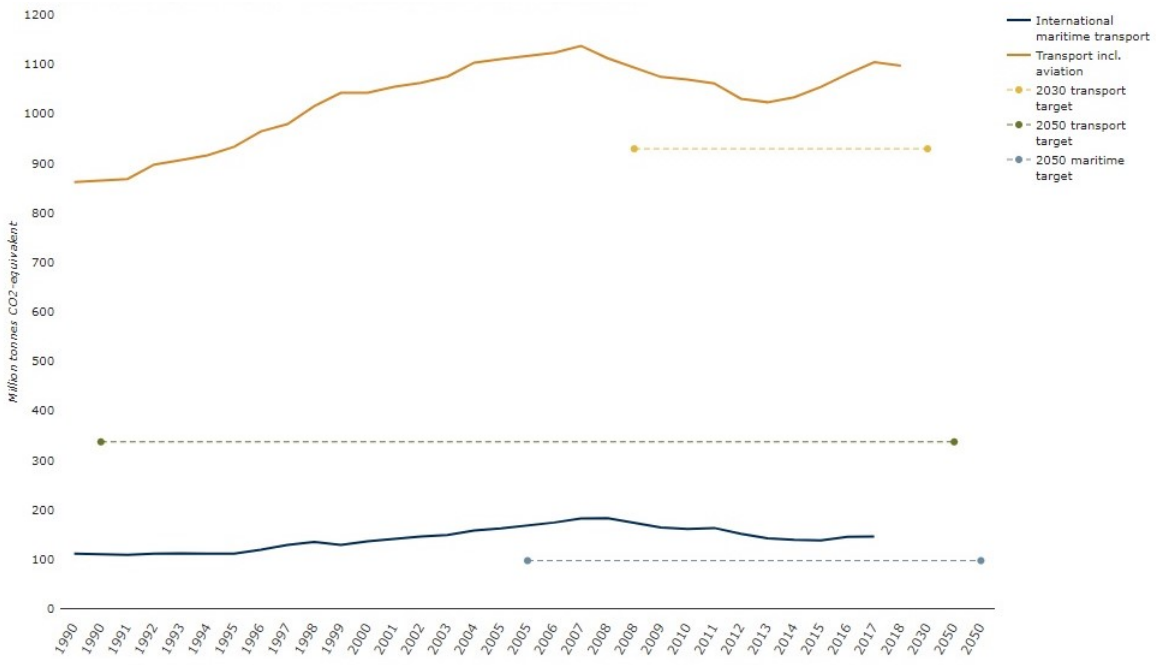


Figure 2.2: Greenhouse emissions and targets (Source: (Commission, 2016))

Availability

For this particular variable, it is clear to understand why road and sea transportation is preferred over the remaining two. Road transportation allows a connection from any point A to a point B at practically at any time and when compared to other types of transport the circulation limitations are very low. Sea is highly available due to the large number of ports existing in the world. The last count declared that in 2014 there were 835 ports in the world, detaining more than 99 % of the sea trade. (VED, 2014).

Load dimensions

This is another important characteristic to consider when trying to choose the right transportation method. Contrary to what our common sense makes us think, the transportation capacity of an airplane is low when compared to a boat or even a freight train.

Even though trucks are a good option, there are weight limitations in the EU. There is a limitation of 44 tonnes to all three-axle motor vehicles with two or three-axle semi-trailers. In two-axle motor vehicles with three-axle semi-trailers, the weight limit is 42 tonnes. Both rules apply to vehicles with a length equal or inferior to 45 feet (13,72 meters) (EUR, 2015).

One of the best options would be ship transportation. Even though the containers used in ships are slightly smaller than the ones used in trucks, an average cargo ship can ship up to 4120 TEUs (Twenty-Foot Equivalent Units) (Inc., 2020).

Routes flexibility

This is possibly one of the best points to prove the importance of multimodal transportation since it is the only type of transfer that allows the connection between the origin point and any destination.

The railway is for sure the less flexible freight transport method since there is a limited number of fixed terminals and it is not possible to make intermediate stops (W., 2003).

On the other hand, road transport is a highly recommended choice. Besides the fact that there is an infinite number of routes that a truck can do when going from point A to point B, this type of transportation can reach any location, unlike sea transport. In Europe alone, there are more than 300 ports, however, when using this mode of freight there is always the necessity to use trucks to travel from the supplier to the origin port and from the destiny port to the client.

Distance

When the subject of discussion is the distance of travel, none of the options is significantly limited. However, sea and air transports could be the best decisions. This is because they are the only ones that allow intercontinental transfers of goods and are capable of travel longer distances than the others. Road and Railway are not bad options, however, distance and lead time is directly proportional on this types of transports. Lead time increases as the distance grows.

Cost

To study this variable, it is necessary to have in mind all the points featured previously.

For example, even though one of the objectives of freight transport is the improvement of the delivery speed (decrease of lead time), that will, most likely, increase significantly the price of delivery (Minken and Johansen, 2019).

Another example of these interconnections is load dimensions in sea transportation. Regardless of ships being considered the cheaper mode of transportation and the best in terms of load dimensions, increasing the container ship size will affect the cost efficiency and, consequently, make it less affordable (Cho and Lee, 2020).

The same happens when the Emissions of greenhouse gases increase. Taxes will be higher and transport price too.

Railway presents a very low price per unit cost, however, unlike road transportation, there is a need for investments in terminals, tracks and rolling stocks (W., 2003).

Air transport, on the other hand, has both high variable cost and fixed cost. Airplanes are expensive to buy, as well as fuel staff and airport maintenance (W., 2003).

As it is clear to conclude now, every characteristic explored before is influenced by all others.

Longer distances normally mean prolonged lead times and additional greenhouse gas emissions. Increasing the size of the ships will increase the fares indexes as well as affect the efficiency of the cost (Cho and Lee, 2020). The cost of a transfer will also increase on longer distances and on transport methods where the ratio between availability and demand is small.

After strictly analyzing these facts, the importance of multimodal transports becomes obvious.

2.3 Multimodal transport

Multimodal transport or **pipelines** is the carriage of goods with more than one type of transport. The idea of multimodal transportation is to do most of the carrier by rail or sea and use road only as a complementary transport mode (Kurtuluş and Çetin, 2020).

There are two types of multimodal transportation:

- **Intermodal transport** is defined as the movement of goods belonging to the same loading unit using various modes of transport without manipulating the goods themselves when changing modes (Ministers, 1997);
- **Combined Transport** is a type of intermodal transport where the majority of the journey is made by rail, inland waterways or sea and connections made by road are as short as possible (Commission, 2016);

The main goal of this type of transport is to use the main advantages of each transport such as:

- High capacity over long distances;
- Lower risk of damage, loss or robbery of the goods (use of close containers from beginning to end);
- Less environmental impact and fewer accidents (less use of road transport mode);
- Cost reduction (Change, 2020).

This mode is a competitive alternative to unimodal transport and that is why in the last decades, the European Union has been dedicating a lot of resources to develop and improve legislation and rules regarding intermodal freight transport (Bontekoning et al., 2004).

Like it was referred before, road transport owns a high quota of the freight transport mode, mostly in Europe. This type of transport brings a lot of disadvantages such as road traffic, accidents and high carbon emissions, so it is no surprise when we admit that one of the main purposes of using multimodal transport is to compete positively with road transport (Liedtke and Carrillo Murillo, 2012).

Road transport has been continuously increasing and is expected to be around 40% of the total freight transport by 2030 and around 80% by 2050. That is why the aim of the European Union Transport Policy (in 2011) was to achieve "a modal shift of 30% of road freight over 300 km by 2030, and more than 50% by 2050" (Commission, 2016).

There is still, a long way to go, since using combined transports decreases the flexibility of a route and requires extra lead time and extra money for handling the transport shifts (Altuntaş Vural et al., 2020).

For this reason, the European Commission made, in 2016, the "REFIT EX-POST EVALUATION of Combined Transport Directive 92/106/EEC". This was created to improve the Combined Transport Directive.

The previous Directive was created in 1992 due to the increasing impact of road transport in the European Union. Between the years of 1970 and 1990 freight transport has increased, in the European Union, by more than 50%. Road transport was about 40% of that total. Also in 1991, more than 30% of environmental costs were due to road transport, when only 3% was caused by rail and 1% by inland shipping. Road transport was also responsible for 22,7% of the total C02 emissions in the EU, while rail and inland waterways freight transport were responsible for 1,1% and 0,7% respectively.

By then, the cost of the environmental impact of freight transport was 54.4 billion euros, 95% of those, road transport's responsibility (Comission, 2016).

The Directive aimed to encourage the use of combined transports over the use of road transport. Laws like easy access to transport markets, improvement of the Trans-European Networks and promotion of fair prices were created to help choose the optimal combination of transport modes (Commission, 2016).

2.3.1 Rail-Road Combination

Rail-Road transport plays a very important role in the transportation sector since it allows a significant price decrease. However, some limitations arise such as the route to take since this type of transport can only be used in continental transfers.

Particularly in Europe, there is a dense infra-structure for this effect even though it is mostly condensed in a limited number of countries in the Northwest of Europe as represented in Figure 2.3.

On the other hand, the United States of America owns the longest railway network playing a significant role in the transportation of goods (over 30 %) (Wiegmans et al., 2018).

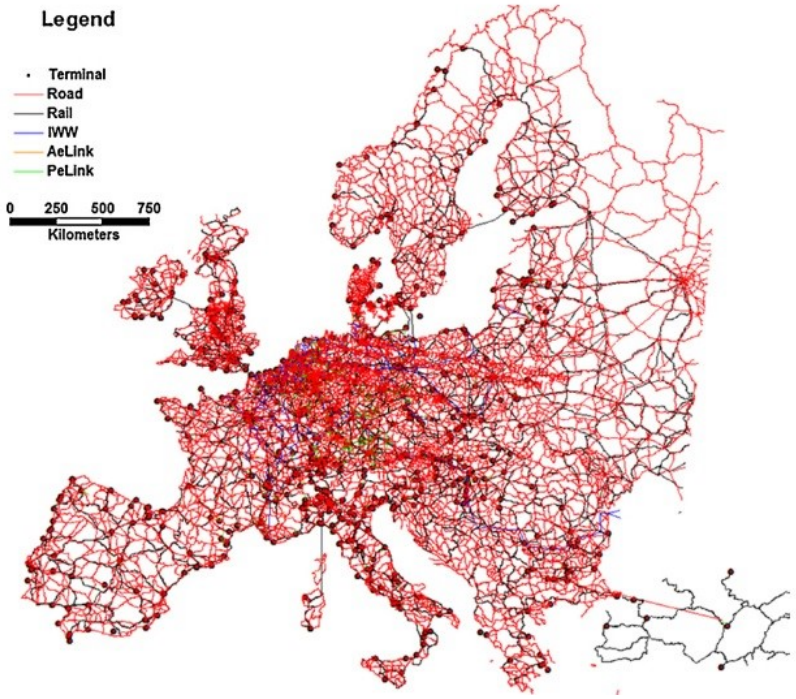


Figure 2.3: Rail Network in Europe (Source: (Zhang et al., 2013))

Since 2001, a long list of measures has been taken by the European Environment Agency such as:

- Financial support to projects whose purpose was the transfer of loads from the road to rail and waterways;
- Opening of the internal rail freight market to eradicate operational barriers (Transport, 2017).

2.3.2 Sea-Road Combination

Throughout the previous section, it became clear why sea transportation was the best option, when possible and when analyzing all variables.

In 2003 over 70% of the freight transport was made by containers (W., 2003). Using sea over road allows the improvement of transport cost, the increasing of the distances traveled and of the loading dimensions and the improvement of the environmental damages done.

2.4 Routes

The main purpose of transport logistics is to optimize the routes.

Routes are defined by everything that involves going from point A to point B. This includes the transportation mode used, the path chosen, the distance traveled and so on.

Two types of optimization are used more often when studying routes development:

- maximization of vehicles utilization (minimum number of vehicles possible);
- minimization of the distance traveled (Paulo Guedes, 2017).

There are two methods to achieve the optimization of this: Heuristics and Linear Programming.

2.5 Production Planning

Supply Chain improvement is crucial when trying to optimize a company. That is why the proper planning of each department is critical for a business to succeed.

Production planning is the department responsible for deciding when and how much of a certain product will be produced. That production time is defined as the planning horizon. This planning also involves the controlling of inventory levels and resources (Nalepa, 2014).

Besides everything that goes into the management of a factory, such as the workers and all of the elements that take part in it, production planning specifically can have a huge impact on transport planning. The location of plants takes a direct impact on all the elements that qualify the quality of a transport. There are two ways to plan the location of a company's plants: centralizing and decentralizing.

Centralizing

This method means installing each activity at a few locations only. On average, companies using this production scheme have an average cost of production 3% lower (Today, 2020). This way is possible to take advantage of the economies of scale in which the production cost decreases with the increasing of the production volume since the same equipment produces a large and wide range of products (De Vries et al., 2018).

Decentralizing

This type involves an organization with multiple facilities or locations and the main goal is for the company services to cover a large area (Fishbowl, 2018).

In general, decentralization will mean a loss of efficiency, however, every case is different and there are advantages in both choices (Nalepa, 2014).

Table 2.3 describes the most notable differences between these two methods of plants locations.

Table 2.3: Centralizing vs Decentralizing (Source:(Paulo Guedes, 2017); (Fishbowl, 2018); (Today, 2020))

Centralization	**Decentralization**
Better forecasting, more local jobs	Possibility to take advantages of areas with lower wages
Lower maintenance cost	High initial investment
Proximity to the source (cheaper raw materials)	Closeness to costumers (competitive transport prices
Product change is costly and time consumer	Production flexibility
Economy of scale	Better adaptation to market requirements
Possibility of better negotiation and constant production prices	Possible reduce of the delivery times

So, generally, decentralization is more suitable for companies that aim to develop their business and reach different and new markets.

Centralization, on the other hand, should be used in companies with a local customer base and unique products. So, in the end, it all depends if the company wants to use a manufacturing strategy or a marketplace strategy (Fishbowl, 2018).

From the previous sectors, it is clear how complex a logistic structure can be. For that reason, and in certain activities, companies resort to logistic externalization to help them in this.

2.6 Logistic Externalization

While in the last decades, manufacturers evolved from "vertically integrated" to "globally decentralized", logistic industry unfolded from "insourcing" to "outsourcing" and then to "integrated" (Qian et al., 2021).

The constant globalization, previously mentioned, made firms more aware of the importance of gaining competitive advantage in ways such as reduction of lead time, creating unique and innovative products and making the customer the main focus of the business. New firms are emerging and forcing older ones to involve and have new services to offer (Hertz and Alfredsson, 2003).

The outsourcing of logistic operations relief the company from some of its services and allows the company to:

- Focus on its core business;
- Invest less in warehouses facilities and transport vehicles;
- Deliver a better operation performance due to the use of specialists of specific areas;
- Reduce the complexity of the supply chain;
- Have a better geographic coverage;

- Present competitive prices;
- Better adaptation to market changes (Paulo Guedes, 2017).

However there are some disadvantages that come from it, such as:

- Less operation control;
- Less efficient stock management;
- Risk of lower quality of services (Paulo Guedes, 2017).

Due to the previous fragility, sometimes third-party logistics (3PL) fail to satisfy some of the client's requirements and service needs. This inconsistency led to the appearance of fourth-party logistics (4PL) (Qian et al., 2021).

The 4PL is normally formed by a variety of long-term contracts between a client and one or more partners, being an interface between the client and multiple logistic services providers. Ideally, it manages all aspects of the client's supply chain. It is important to note that it is possible for a 3PL to form a 4PL organization within its previews structure (Management, 2020).

The utilization of outsourcing in companies in Europe, USA and Asia Pacific has been increasing drastically. By 2007 more than 70% of these companies were using it (Hsiao et al., 2010). There are two important types of outsourcing: Core Business outsourcing and non-core business outsourcing.

Core Business outsourcing refers to manufacturing operations, and it shows a great response to volume flexibility in production. However, it also doesn't seems to really help the innovation power of the companies since the product development follows the manufacturing plan (Hsiao et al., 2010).

Non-core business outsourcing, on the other hand, shows a great response in the innovation, cost efficiency, profitability and flexibility of a business (Gilley et al., 2004).

Outsource logistics should be divided into different levels. This will help not only developing strategies but also to easily achieve the company goals. Those levels are shown in Table 2.4.

Table 2.4: Levels of outsourcing (Source: (Hsiao et al., 2010))

Level		**Activities involved**
Execution Level	**Level 1**	Transportation or Warehousing
	Level 2	Value-added activities that previously belonged to production
Planning Level	**Level 3**	Inventory or transportation management
	Level 4	Distribution network management

Logistic whise, one of the most important characteristic of a transport is the distance that composes it.

This variable is defined when the plant allocation for the production of the material to be transported is done.

That process will be analyzed and optimized in the next chapters of this dissertation.

Chapter 3

Plant Allocation Process at BA Glass

BA uses a decentralized production process with a large network of plants distributed around Europe, each of them facing different concerns, restrictions and production capacities. Deciding when and where to produce a certain product is, for that reason,a very complex process.

This chapter focuses on the plant allocation process as it currently is. By understanding how the actual decision process works, it will be possible to draw conclusions on how the transport department is affected by it.

The transport's Key Performance Indicators will be analyzed as well as the outputs that are aimed to be maximized in this department.

The goal of this chapter is to find possible points of improvement for the decision process of plant allocation.

3.1 Product Flow

Market and Planning is the first department to have an active role in product development.

Figure 3.1 shows how the two departments work simultaneously at this unit: Business Development and Planning and Customer Service. Each of them is subdivided into other departments.

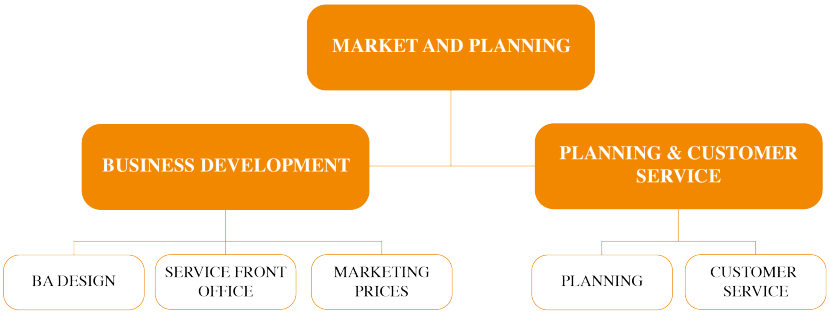


Figure 3.1: Route definition in BA Glass

Business Development

When a new order for delivery is placed, if the desired product has been produced before, the order will go directly to the Service Front Office department, otherwise, it will first go through the BA Design department.

The **Design** department analyzes the possibility of accepting a new product, taking into consideration the type of product and its design. This step generally does not happen since most of the products are decided even before the beginning of the year.

At this point, **Service Front Office** department takes actions and negotiates with the client details such as the delivery date and quantities.

In parallel, the **Marketing and Consumer** department is responsible for the pricing of new products as well as monitor possible campaigns that may affect the stocks levels of the costumers.

In this department, a very important part of the process also happens: sales forecasting.

Sales forecasting is a prediction of the future sells and it can affect several parts of a company, such as planning, marketing, management or logistics (Sohrabpour et al., 2020). Since BA works under a philosophy of make to stock, these forecasts are crucial for the maintenance of the client's stock at a safe level.

Furthermore, after the product request is authorized, the order to produce is allocated to one of the 12 possible plants.

This allocation decision is made based on a long list of restrictions such as:

- Design specifications: size, neck and design of the bottle;
- Colour;
- Type of pallet;
- Maximum height of the pelleted;
- Type of production.

Currently, the distance between the customer and the plants is not a priority, however, the influence of this variable on transport planning is undeniable. That is why plant allocation is a very important point of improvement.

Planning and costumer Service

When the order gets to this stage, the **Planning** department works constantly, in order to, not only maintain the clients stock at a minimum level, as well as to use, as best as possible, the production capacity.

The decisions made here become crucial to the quality of the delivery, however, before the order goes through the **Transport Planning** the **Planning Department** must still take action.

Planning

BA produces under a philosophy of Make to Stock, using the sales plan and controlling the material stocks for every client. In order to do so, the Planning Department manages the production lines changing and switching productions between these, but still considering all the restrictions imposed at each one of them. It all starts with a 3 month production plan that is updated weekly.

Ultimately, this department is responsible for managing the production lines, being that its decisions override all previous ones.

The work at the **Supply Chain** department begins after the decision about what and where to produce as well as the delivery details related to the customer are finalized.

3.2 Transport planning

The transport department has a big impact not only on the quality of the customer service but also on the total cost of a product, since it represents more than 10% of the annual total costs.

This department is divided into Iberia Operations, Central Europe Operations, Southeast Europe operations, Reverse Logistics and most recently transport planning.

The Transport Department work starts, as well as for other departments, with the annual **Budget**. This document contains important information regarding the quantity of finished product (PA) that it will be delivered to a certain customer in that year and also the place where that delivery will take place.

Then, along with the Business Development department, the transport division participates in the sales monthly forecast. This document collects important information regarding the quantity of each product that will be sold to each client.

As well as for the budget, this information is updated monthly and will help to plan the transport for that month by identifying peak sales and critical routes.

These sales peaks are normally due to special campaigns done by the customer that will most likely affect the costumers stock levels. Critical routes are routes that, for several reasons, arise concerns among the transport managers of each division. This concerns can be due to holidays that decrease the number of suppliers available or by the order of a large volume of product.

Alongside the previous task, the sales forecast is updated weekly. With this document, the department is able to predict the number of trucks necessary for each plant and for each day of the week.

As transport planning can be very unpredictable and unstable, strategies are used to support the delivery of goods and ensure the best customer service possible.

One of these strategies is the use of warehouses, allowing the maintenance of product in a bigger scale and closer do the costumer. The location of these warehouses is decided based on:

- Lack of space on the production spaces;

- Necessity of building safety stocks.

BA owns a large network of warehouses, mostly close to its plants. Besides those, the firm also uses **External Warehouses**. These are normally not permanent and change according to the company necessities.

Figure 3.2 features the current support network, as of 2020.

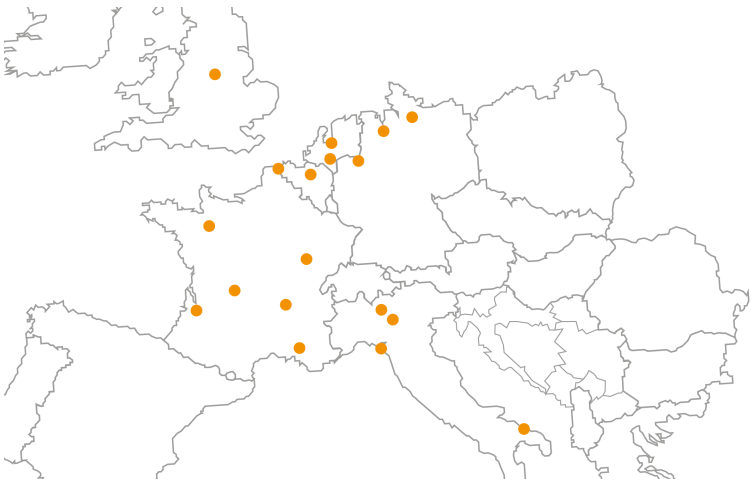


Figure 3.2: Map of the 2020 External Warehouses

The decision to acquire an external warehouse is decided alongside the budget and, besides the purposes mentioned before, the reasons for it are:

- Necessity detected by the Transport department due to the distance or the difficulty of acquiring suppliers in a certain location;
- Costumer's stipulation: some clients require the proximity of a large amount of product to compensate possible low stock levels;
- Pipeline: moving PF from containers to trucks.

To guarantee the correct management of these, it is necessary to maintain the storage capacity of these updates. This calculation is done annually and updated monthly. These calculations are represented, respectively, in Figure 3.3 and Figure 3.4.

Transport performance is dependant on several variables, one of them the loading of the goods, being the management of these also a responsibility of the transport planning division. To do so, it is used a platform named Transporeon that works as an interface of information between suppliers

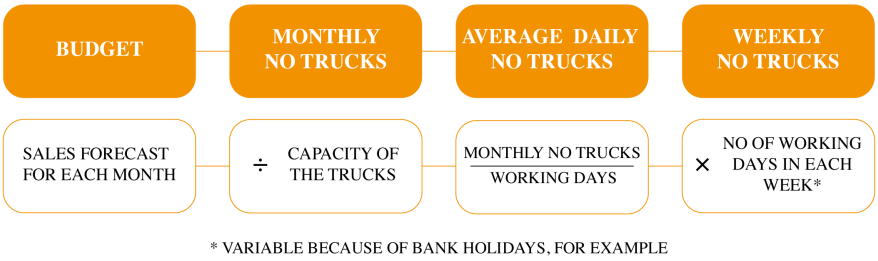


Figure 3.3: External Warehouses capacity's annual calculation

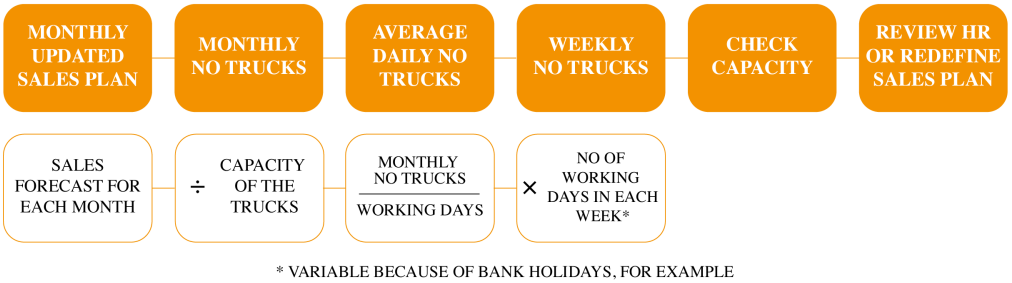


Figure 3.4: External Warehouses capacity's monthly calculation

and BA. With the use of this platform, it is possible to do an online follow up and management of the planned loadings.

The transport department is responsible for acting when there are red alerts about the load of goods in plants or when the capacity of the warehouses is being reached.

To organize transports and calculate the number of trucks needed per month the following mathematical formulas are used.

$$\frac{trucks}{month} = \frac{\frac{jars}{month}}{\frac{jars}{truck}} \quad \text{and} \quad \frac{jars}{truck} = \frac{\frac{jars}{pallets}}{\frac{pallets}{truck}}$$

The number of pallets/truck depends on the type of pallets:

- **Europalete:** 33 pallets per truck or 66 if pallet height >1,3 m;
- **Other pallets:** 26 pallets per truck or 52 if pallet height >1,3 m;

3.3 Transports and its Key Performance Indicators

Constant improvement is the main motivation of the transport department. To do so, the collection of information and data during the process becomes extremely important to find possible

improvement points for the business. Studying the Key Performance Indicators of the transports department of BA will help to better identify those.

3.3.1 Leading time

Leading time is one of the main concerns when preparing freight transport. It is composed by the loading and the delivery time, being the first the time required to prepare the goods for transportation, and the leading time the time of travel between the plant or warehouse and the final destination.

Due to the high demand for products, as well as limited production capacity in factories, sometimes the time available to deliver something to the client is very limited. That is why it is important to know the minimum lead time required to carry out a certain trip. The only lead time that can be more accurately calculated by the company is the lead time of road deliveries. The lead time of transportation made by train, airplane or boat is, normally, a lot more fickle. For that reason, BA created a formula to do it.

By stipulation, a truck moves at an average speed of 50 Kilometers per hour with a maximum limit of 9 hours per day.

The delivery time calculated as previously described, may not be exact due to some unpredictable variables such as:

- Border control;
- Traffic;
- Unforeseen by the carrier;
- Weather events.

For these reasons, a small adjustment is, most of the times, taken into consideration.

This lead time will also be used to define **routes**. To define these, BA uses a 5 number code preceded by the letter "R" as represented in Figure 3.5.

The first number represents the number of days required to schedule the transport and find a supplier. The remaining four numbers are the transit time: the first two being the number of "half" days and the last two the number of hours required for the transport.



Figure 3.5: Route definition in BA Glass

3.3.2 Loading time

The time required to prepare a load and if this load is done within the set time, influences the performance of transport.

To manage this variable, BA utilizes the platform Transporeon, which will work as an interface of information between the carriers and the transport department.

Whenever a specific transport is allocated to a supplier, the carriers have the chance to book a 2-hour interval in one of the "loading spaces" available at the intended plant. That "space" is denominated "Slot".

Once the transport is accepted an open booking is created. In it, the supplier is able to:

- **Book a Time Slot:** The carrier can select a free slot but only after the "Planned Loading Start" and if BA agrees with this loading. This planned time is a prediction on when the carrier should start the loading and consequently the travel, and it is based on the defined routes;
- **Edit the Time Slot:** From the booking until the "Check-in time", it is possible for the supplier to change the license plates of the vehicle or the trailer as well as the container number if it is sea transportation. It is also possible to change the information regarding the driver;
- **Rebook the Time Slot:** It is possible to change the booking to another Slot as long as there is another one available and only until 6 hours before the previous booking.

There is also a special alert denominated "last call". It is a one-hour advance notice given by the transport department team to the suppliers in order to avoid deadline delays.

Besides the daily tasks, this platform issues, every month, a "Time Slot Management Report". It aims to analyze the work of the carriers: if slots are being booked and if carriers are arriving at the loading place at the correct time.

To better understand the errors being made at this stage of the supply chain, it was carried out an analysis to a 2 month loading records.

The purpose was to identify the differences between the expected loading date and the actual day on which the load happened for each shipment. By taking conclusions on the errors committed, it may be possible to make some improvements on these.

The first stage involved an analysis by plant and as is possible to see in Figure 3.6, it is clear that the factories own a similar rate of delays. The green line represents the weighted average and the purple line the percentage of delayed loads of each plant. Each plant is mentioned by its correspondent code and is represented by an orange bar proportional to the number of shipments carried out during the period under analysis.



Figure 3.6: Loads per Plant

The meaning of these codes in the figure are:

- **AV:** Avintes;
- **MG:** Marinha Grande;
- **VF:** Vila Franca;
- **LE:** Leon;
- **VN:** Venda Nova:
- **SI:** Sieraków;
- **JE:** Jedlice;
- **GA:** Gardelegen;
- **AT:** Athens;
- **SO:** Sofia;
- **PV:** Plovdiv;
- **BU:** Bucarest;
- **EXW:** External Warehouses;

The next step was the analyze of the carriers from each factory separately and draw conclusions about whether these did or did not booked slots.

The next conclusion withdrawn was that when carriers book the slot, the delays are not as significant as opposed to the loadings done without bookings. Therefore, encourage the suppliers to schedule the slots is a way of getting more accurate loadings times and consequently meet the required delivery times.

It was performed a more thorough analysis in order to try to understand if there was a pattern in these delays. For that reason, it was performed a study to the suppliers and its percentage of delays.

The final conclusions and actions taken were:

- Some routes could be badly defined and, for that matter, there is an increasing need to redefine them in order to avoid delays;

- The suppliers that caused these delays for a certain origin-destination set were always the same and there was the need to understand why;
- Since most of the delays happened when there were not slot bookings, encourage the carriers to book "loading appointments" may be a good solution.

3.3.3 Costs versus Sales

To optimize profit is one of the most important things to consider in a business and since transport represents a considerable part of the annual costs (around 10%), the job of the transport planning is crucial.

The most influential decisions in the cost of transport are:

- Transport scheduling;
- The location of the plant or the warehouse;
- The location of the client;
- Type of transport used.

Transport scheduling

As seen before, preparing the transport ahead of time allows flexibility of most of the transport implications. This will definitely reduce the cost of travel as it will expand the possibility of choices.

Currently, this is one of the concerns at the firm and definitely one of the points to improve. Knowing earlier what and when to produce and actually do it would be a big development for the transport planning once it will allow a more economic transport type without worrying with the possibility of not delivering something to a customer on time.

Plants and Warehouses network

The decentralized production strategy followed by BA, allows the company not only to have its plants in the most economically advantageous places but also establishing its warehouses in strategic locations according to the client's locations and necessities.

Even though it is not possible to change the locations of either factories or clients, by strategically choosing the location of the warehouses, it is possible to reduce lead time and at the same time, as seen in the previous point, also reduce costs.

Type of transport

Even though it became clear in chapter two that using sea transportation brings a lot of economic advantages to a company, it is also true that each firm deals with its own limitations and because of these, the most used transportation mode in BA Glass is road, through the use of trucks.

Transportation via air is very expensive and it is not viable for this type of product. Regardless of the fact that airplanes are relatively small when the point is to transport freight and that glass containers are a heavy product, some routes are just too short to be worthy the involvement of airport logistics.

The European rail network still has a lot to improve before becoming relevant for this use. For example, the fact that in Iberia the gauge used for rail transportation is different makes it very unfavorable due to the extra cost and logistics necessary when traveling between Iberia and the rest of the Europe.

However, in countries like the United States of America, where the rail network is wide, the train is a very appealing transport, mostly when traveling from the ports to the final destinations.

Sea transportation is vital when doing intercontinental travels, and it is also very appealing when the cost savings is worth the extra lead time. When BA uses this type of transport it is always as an intermodal mode of transportation since it is always necessary the use of another type of transport to perform the transfers between the plant and the port or the port and the final destination.

3.3.4 Customer Satisfaction and Product Quality

Customer service is mostly affected by the product quality and by the quality of the transport. So, customer satisfaction is dependent on the way the client itself is treated, more properly the maintenance of its safety stock.

The transport division is not involved in product quality, since this is directly related with production. For that matter, it is not responsible for the quality of the final product. The transport department is, however, responsible for the maintenance of the product quality during the delivery to the customer. The only way to measure the performance of this sector is by controlling the performance of the suppliers and analyzing the costumer's complaints.

Obviously clients are always the main concern in a business and for that reason, the level of contentment of the clients and the quality of the product provided are very important to measure the performance of a business.

That is why the complaints done by them are a very important way to measure the performance of the transport. This complaints are managed by the Customer Service department.

At the end of every year, the clients are encouraged to fill a special form in order for BA to draw conclusions about the services provided.

That form is divided in several categories and the carriers are asked to give to each category a numeric classification:

- Logistics: deliveries, loadings, warehouses, etc;
- Costumer Service;
- Sales;

- Production.

The final classification will be an average of the classifications given. In the same form, there is also an "open field" to get a personal opinion about the pros and cons of BA Glass.

Even though Customer Service is mostly responsible for receiving the complaints and redirect them to the department in charge of it, it is directly involved with the transport department, since it can be affected by all the key performance indicators explored before.

The delivery leading time has to be exact enough to obtain the greatest margin of profit to the company while meeting the client's needs, requisitions and satisfaction.

To ensure the optimization of the variable time, it is necessary to deliver the product within the required time: choose the best type of transport and make it with the shortest possible distance while keeping the lowest cost possible.

The cost of transport has to be low enough to keep the total cost of a product competitive with equivalent companies and cover the expected profit of the company, while still meeting the quality and requirements demanded by BA.

Product quality is key when pleasing a customer. For that matter it is important that the suppliers used are trustful and reliable. To evaluate this, BA utilizes the platform mentioned before Transporeon.

3.4 Outputs to maximize & Possible improvements

The main aim when organizing a transport is to maximize profit while maintaining the customer satisfaction. After the previous sections, it is easy to understand why customer satisfaction is so relevant for the company's profit and, consequently, why the transport department plays such a big role in that satisfaction.

The main concerns found in the planning of transport were:

- Delay on loadings;
- Delay on deliveries;
- Lack of time to prepare a certain transport which leads to the obligation to make less profitable decisions.

Some of these concerns could be corrected mostly by improving the communication between the transport department and the early stages of the supply chain.

The main worry detected was the fact that when allocating a plant to a product production, the distance between the final destination and the plant is not considered. Consequently, the cost and the environmental impacts of that transport are not taken as a priority.

The suggestion is to make distance one of the restrictions when that decision is being taken.

A possible improvement to the actual system would be to create an updated decision model to support the factory allocation process. The proposed decision tool is aimed to, along with all the previous existing restrictions, indicate and encourage the use of the plant that is closer to the client and consequently constitute the lowest cost to BA.

Besides that, the decision tool will pilot an analysis to the next year budget in order to take conclusions about the decisions that will take place.

This decision had the main goal of:

- Understand the percentage of the plants chosen for the production of the materials that owned the shortest distance between them and the final destination of this material;
- When the plant chosen was not the closest to a certain material is major to know which restrictions were conditioning factors in this decision;
- Try to understand what would happen to the total distance traveled as well to the total cost if some of the existing restrictions changed or switched between factories;

Chapter 4

Decision Tool for Plant Alocation

This chapter will explore the solution proposed to the concerns exposed in chapter three.

Mainly, it will be explained how the model was developed and built.

The initial situation will be analyzed as well as its restrictions and the conclusions withdrawn from it.

Then, the methodology followed to develop this solution will be explained and the necessary analysis will be performed.

4.1 Principal aim of the project

To optimize profit is crucial to reduce the main sources of spending.

This specific project will focus on the costs of the transport department. A way to reduce these is by reducing the number of kilometers traveled by the product.

Having that in mind, it was created a simulation tool with the aim of supporting the team responsible for the plant allocation, making the distance traveled a priority when choosing the factory to produce a certain product ordered.

This tool will define the best plant to produce, prioritizing the distance to the customer. It will optimize the distance between the plant and the destiny of the material while respecting the pre-existing restrictions.

The utilization of the smallest distance possible will positively affect several variables like lead time, cost of transportation or even the environmental impacts of the transport.

This will directly improve not only the company's profit, but also the client's level of satisfaction.

Later on, it was also noticed the importance of an extra study: analyzing the decisions already made regarding this matter.

The intention was to understand what is the percentage of the current productions that are taking place at the factories that are the closest to the final destination.

For the productions that are not, the goal was to understand why that happens: in which plants happened more frequently, which were the conditioning restrictions and what can be changed to reach better economic results.

4.2 Simulation Tool

The simulation tool was developed using Excel with the support of VBA programming in order to make the tool simple, intuitive, and user friendly. Its main function is to sort the factories by preferential order of production.

This ordering is set to optimize the actual process of choosing a plant to produce a certain material with the main focus of involving the distance between the origin (plant) and the destination (warehouse or client).

The Excel tool is composed of several sheets that provide different pieces of information. However, only two of them are relevant for use: "results" and "user".

The sheet "results" utilizes the information provided by the user to collect the necessary data regarding the material. It is built to inform about the possibility of producing a certain material, considering each restriction separately.

It also designates, for each production line, if it is possible to produce that same material, according to the set of restrictions for those.

The tool also orders all the factories in ascending order of distance to the final destination.

The second sheet, "user", is destined to be used for inserting the information regarding the material do produce, and to obtain the desired information regarding plant allocation.

When utilizing the tool, more properly this last interface, the user has access to a window like the one shown in Figure 4.1.

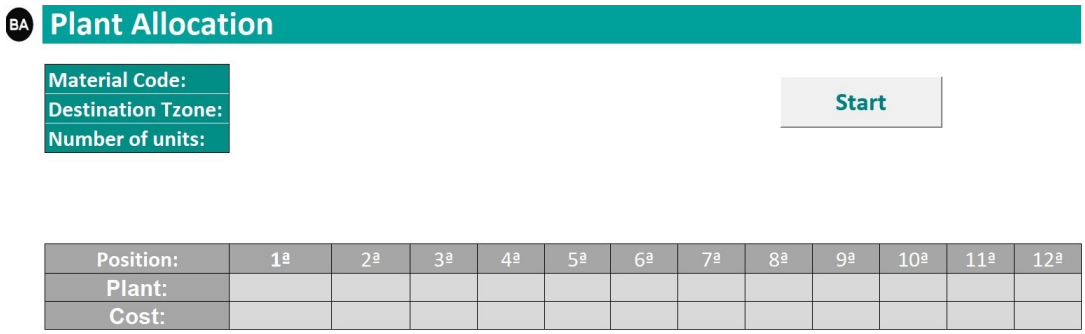


Figure 4.1: User's window

When the "Start" button is pressed, different pop-ups appear on the screen, as shown in Figure 4.2, and consecutive questions to the user must be answered:

- 1st: Material Code;
- 2nd: Tzone of destination;
- 3rd: Production dimensions.

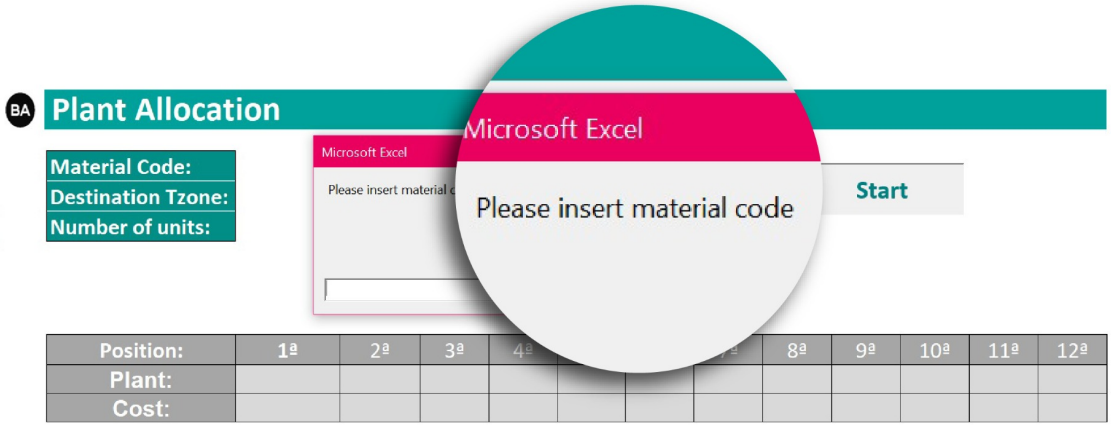


Figure 4.2: User's window

The tool will transfer the provided information to another sheet, named "results" and, then, transfer back the necessary results.

The tool will use the "material code" to get information regarding the production, and the "Destination Tzone" to obtain and sort the distances between that destination and every possible plant.

Even though the third and last question provides important information regarding the production, it is not mandatory, and it is possible to use the current database to obtain that same information, for most of the materials.

Figure 4.3 presents the final result.

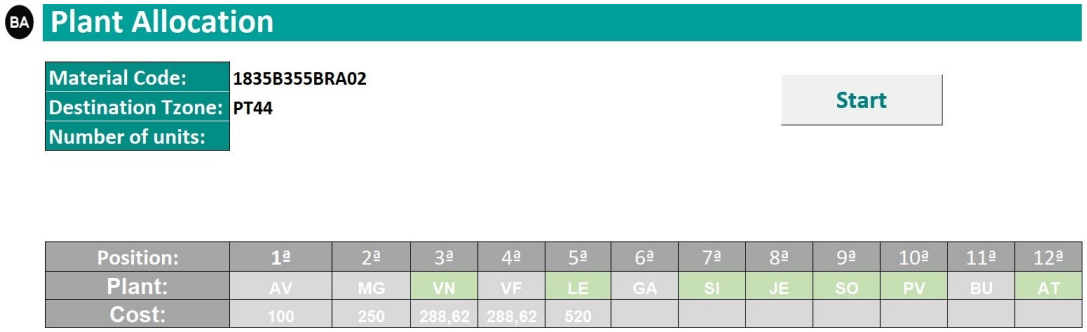


Figure 4.3: Final result of the model

The decision tool will return the plants ordered by their distances to the material in question.

Considering production lines restrictions, the plants in which is possible to produce will appear in green.

In the cases where this information is available, the tool will also return the cost of that particular travel.

At this point, the user is free to allocate the material as wished, having in mind the suggestions given by this decision model but also respecting the available productive capacity.

4.2.1 Model Restrictions

Even though the main goal for the use of this tool is to minimize the distance between the plant where a product is produced and the client for which it is intended, there is a list of restrictions that limit that choice.

Every plant has several production lines and each one of them owns a different set of restrictions. Those restrictions however have a different impact on production and that is what is going to be analyzed next.

Before being produced, each product is defined by its mold code like the one shown in Figure 4.4. That code contains important information about the characteristics of the product.



Figure 4.4: Mold Code Definition

The first letter, "M", indicates that, is indeed a mold's code. The 4 following numbers refer to the type of model that will be produced with this mold and, the next two, the "X's" in Figure 4.4, indicate the size of the product. Then there are four letters, where the first two indicate the kind of molding we are dealing with (primary mold or finish mold) and the other two the type of production in which that mold will be used (BB,PB,NN). The next letter indicates the type of cooling of the mold and finally, the last number is the batch number.

After the product is produced, there is a different nomenclature for it depending on its final state: Finish Product (PF) and Finished Product (PA). The difference between them is that while PF is the name given to each element produced like bottles, jars, and so on, PA refers to the set of PF packed and ready to ship to the customer.

When processing orders or deliveries, however, the subject of analysis is always the PA.

Figure 4.5 shows that code.



Figure 4.5: PA Code Definition

The first four elements refer to the type of material. The next four components of the code indicate the type of neck or "marisa" of the product. The following two letters are the color of the product and the next element is the type of finish given to the product. Finally, the last two elements represent the type of PA that the material is: the type of pallet and the separators used, etc.

Size

This restriction indicates the distance between the axes of the production machine. It indicates, for that reason, the maximum size that a product manufactured at a certain production line can have.

Sec

Sec is the diminutive of sectors, and it is directly related to the number of products in production. The greater the number of sectors the greater the ratio of product produced per hour. This particular restriction indicates the maximum number of sectors that a production machine can own.

For example, if a certain production line has a "maximum number of sectors" of 10, it can never produce a product that requires a bigger number of sectors in the production machine.

Color

The current existing colours are: **AM** (ambar), **AS** (strong amber), **BA** (light blue), **BR** (flint), BU (uv flint), CO (cobalt blue), FM (dead leaf), PR (black), **UV** (uv green), **VB** (antique green), **VG** (georgia green), VO (olivia green) and **VR** (green).

However, not all colors are available at every plant, much less at every production line. Only the ones in bold are constantly present in the company production process. Some of these colors are seasonal or reserved for special campaigns.

Type of production

The production process consists of five stages:

- **Composition of glass:** Mixture of all the raw materials;
- **Fusion of raw materials:** at a temperature of 1500-1600 ºC;
- **Treatment of the surface:** thermal process names re-firing;
- **Inspection and quality control:** insurance of the product specifications;
- **Packaging:** in layers, on pallets and protected with a plastic film (BA Glass, 2018).

Regarding types of production, BA utilizes three different kinds:

- **Blow and blow:**

  In this process, the "gobs" (heated liquid glass) are poured into a "blank mold". Then, using compressed air, the neck of the glass container is formed. Afterwards, another blast of air is applied in the existing form and the liquid is transferred to the walls of the parison ("blank mold"). Following, the transfer to a final mold happens, where the reheated glass takes its shape. The final molding is achieved with a combination of compressed air and vacuum. The process is illustrated in Figure 4.6 (Vetropack Group, 2021).

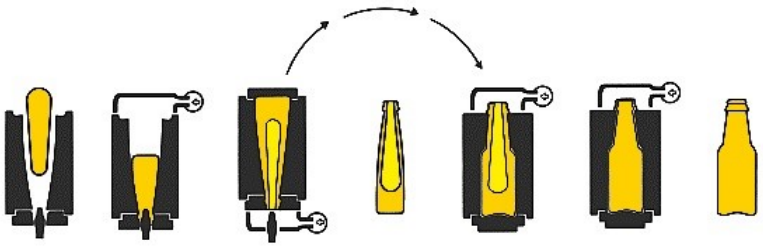


Figure 4.6: Blow and Blow process (Source: (in Glass, 2020))

- **Narrow Neck:**

  This process, also known as Narrow Neck Press and Blow, allows the saving of molten glass and the better distribution of glass in the finished product. A plunger is used to exercise strength on the side of the "blank mold", forming a bulb. This bulb is transferred to a finish mold by a roller, and the finished product is blown out (Canpack Group, 2013).

- **Press and blow:**

  In the first stage of this process, molten "gobs" of glass are delivered in the parison mold and a plunger presses the glass into the parison shape to give it a form. The next stages are similar to the equivalents in the Blow and Blow method where the blank shape is transferred into the blow mold to achieve the final shape. This process is represented in the Figure 4.7 (Eurotherm, 2021).

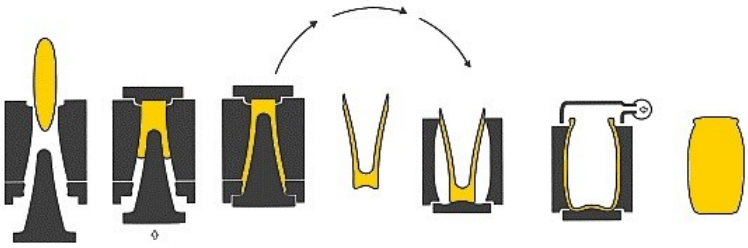


Figure 4.7: Press and Blow process (Source: (in Glass, 2020))

Type of pallet

Currently, there are two types of pallets in the PA's used by BA Glass:

- Euro pallet: 1,2 m x 0,8 m with a height between 0,144 m and 0,146 m;
- Standart pallets: 1,2 m x 1 m.

These dimensions will influence the quantity of products carried in each truck or container. The difference in loads was pointed out in chapter three.

The type of pallet used is decided by:

- Number of articles to be included in the PA;
- Costumers requirements.

Maximum Height

The maximum height is dependant on the number of elements that are set to be produced, and is calculated by adding:

- the height of the container produced, multiplied by the number of layers of the PA;

- the total thickness of the separators necessary between layers;
- the height of the pallet chosen.

The height of the final PA is associated with the material and it is an important restriction when plant allocating due to the machine responsible for placing the plastic casing. These machines have a height limitation and those limits define the maximum height impose by the production line.

Currently, the limits are between 2,15 meters and 2,6 meters.

Segment

The segment restriction is referent to the type of product to produce (the type of bottle or jar for example). Currently, there are 11 different types.

Number of Gobs

The type of forming machine used has a bank of 5-20 identical sections. These sections form a row and each gob lies into one of these sections with the help of a gob distributor.

Each section manufactures between one and four containers at the same time. This means that the higher the number of gobs possible in a certain production line, the higher the number of elements produced.

The minimum number of gobs necessary depends on the number of elements that are set to be produced. With the growth of the lot size, the number of gobs necessary increases proportionally.

This means that, for example, if a certain material has a production that requires double gob, it can only be produced in production lines that work with a number of gobs equal or superior to two. Currently, the type of gob is defined as follow:

- Less than 300.000 units: single gob;
- Between 300.000 and 10.000.000 units: double gob;
- More than 10.000.000 units: triple gob.

Cooling methods

There are two independent restrictions regarding the type of cooling: **BF** and **FM**.

These refer, to the type of cooling of the blank and the finished mold, respectively. The molds work as explained previously in the type of production section.

Distance

This project proposes to increase the company's profit by reducing the number of kilometers traveled.

For that reason, the main goal of this tool is to find, for each material, the closest factory to its destination point. To do so, it was necessary to add this restriction in the new decision model and consequently have a clear and practical list of all the possible distances.

In order to make it easier to create the necessary list of distances, and have a limited number of possibilities, every customer or "ship to party" was associated with a destination code denominated in BA as "Tzone".

The classification of the destinations does as follow.

Every country is divided into several zones, which, in general comprises the different postal codes for that same country.

Each zone is defined by two capital letters representing the country, followed by two numbers that represent the postal code division.

Figure 4.8 exemplifies the case of Bulgaria.

Bulgaria BG

TZONE	Postal Code	Description
BG01	all started by 1	Sofia
BG02	all started by 2	Blagevgrad
BG03	all started by 3	Montana
BG04	all started by 4	Plovdiv
BG05	all started by 5	Lovech
BG06	all started by 6	Stara Zagora
BG07	all started by 7	Ruse
BG08	all started by 8	Burgas
BG09	all started by 9	Varna



Figure 4.8: Tzones definition example

Some countries however are not divided due to a lack of interest to the company in doing it. In those cases, the country is represented by the duplication of its country code.

After that, and since the list of possible routes was very extensive, there was the need to optimize the way the distances were obtained.

Because of it, a VBA function was created. The functionality of it was to return the distance between two places.

This tool works, by getting the first result on a "google maps" search and, for that reason, and to obtain more accurate results, it was necessary to write the name of the city followed by a comma and the name of the country, as represented in Figure 4.9.

Origin	Destination	Distance (Km)
Porto, Portugal	Badajoz, Spain	359

Figure 4.9: Get Distance Function

In routes where sea transportation is an obligation or a very obvious choice, such as islands or intercontinental travels, it was made a different list.

In this cases, it was built a list containing the three distances used for transportation:

- the distance between the origin point and the closest port;
- the distance traveled by boat;
- the distance from the destination port to the client or sold to party.

Currently, the distance of that route is being considered as a whole (the sum of the three distances in Kilometers).

It was noticed, that when the travel is performed by sea, in most of the cases, this happened independently of the plant chosen. So, in those cases, the plant selection is not as relevant.

However, it should be found a fairly way to compare these distances since, like seen previously, kilometers done by road are not comparable with kilometers done by sea whether in terms of money, time spent or environmental impacts.

Price

To improve the comparison terms between the factories, besides sorting the plants by their distance to the destination point, it was also included in the model the price of those trips.

However, the price of a trip is very volatile. It is dependent on various factors such as time of the year, carrier used, or other unforeseen events. For this reason, it is impossible to predict, exactly, budgets for routes that have never been traveled before.

Consequently, the database is not very large and for that reason, despite being important when plant allocation, it does not work as a restriction in the decision model built but as an auxiliary variable.

4.3 Analysis of the production plan for 2021

Along with the transport budget for the following year, is done a prediction, for every material, of the possible factory of production. This plant allocation is based mostly on records from previous years.

It was conducted a study on the 2021 budget, using the model built, in order to draw conclusions on the production forecasts for the next year.

Since manufacturing has different limitations at each production line, the important thing to do is the discovery of the restrictions that limit those choices and the impact of these on the materials. This is, when predictions do not correspond with what would be the best allocation choice according to the decision tool built.

Knowing which of the materials are not set to be produced in one of the closest factories to their final destinations, will allow to understand, which conditions are responsible for that. What

would change in the total number of kilometers travel and in the total cost of transport, if some of these restrictions were changed.

To improve the accuracy of these decisions, it is necessary to know when these allocations fail in their predictions to choose the plant that leads to the shortest travel.

From a first analysis of the given data, it was noticed that the total number of kilometers to be travelled in 2021 would be 47.823.808 Km.

First, a list was made containing every finished product present in the budget.

Then, the 12 plants belonging to BA were placed by their ascending order of distance to the final destination of each material.

This way, it becomes known the ranking of factories for each product, considering the distances between those plants and the place of destination.

When comparing the previous ranking with the plant in which each material is set to be produced, the results obtained are present in Table 4.1.

Table 4.1: Rank of the plant set for production

Rank of plant's choices	**Percentage of materials**
1st	42,5 %
2nd	13,7 %
3rd	14,8 %
4th>	29 %
Total	100%

From the materials set to be produced in 2021, only 42,5% have their productions predicted to happen in the factory that is the closest to their final destination.

In 13,7% of the materials, the production will be held in the second-closest plant and in 14,8% in the third.

From the annual production, 29% are not predicted to be produced in any of the three closest factories.

Considering all the restrictions, if all the materials were manufactured at the plant that is the closest to the material place of destination, there would be an average reduction of 14% in the travel prices and an average reduction of 13,12% in the cost per tonne. The total number of kilometers traveled would also suffer a significant reduction of 39,63% to 28.870.043 Kms.

It could be mentioned the cost reductions, but as previously said, the price of transport is very volatile.

Attending to the fact that there is a lot of prices missing, mainly for the routes that are being proposed at this project and that has never been executed before, it would not be wise to consider the cost reduction in the transport department for this study.

Proceeding with the restrictions analysis, the focus was given to the materials that are not planned on being produced close to their final destination. This is, the 29% that are not allocated to one of the three closest factories. Considering only the travel distance, for the majority of the materials, plants B, D and F would be the first choice, as it is possible to conclude through Figure 4.10.

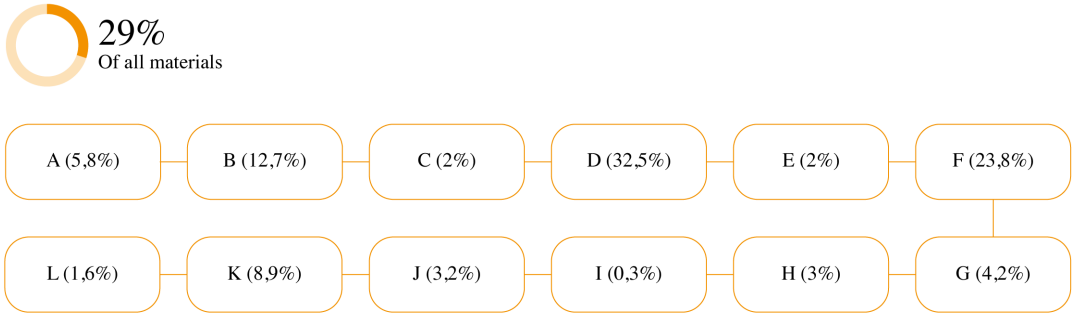


Figure 4.10: Percentage of materials for which each factory would be the first choice in terms of distance

With the goal of knowing why these allocations were being made this way, it was developed a deeper analysis to the three plants with the highest percentage in Figure 4.10.

Plant B

For 12,7% of the materials included in the figure 4.10, the nearest plant to its final destination is the factory B.

If these were produced in B, the average reduction of the price per trip would be 2,464%, the average reduction of price per tonne would be 2,24% and the number of total kilometers would suffer a reduction of 1,652%.

It is important to conclude which were the production restrictions that prevented this from happening.

As to color production restriction, from the 12,7% of the materials analyzed, only 2% could have been produced in this place. Regarding the remaining 98% the same would not be possible, due to non- availability of its colors at this plant.

Figure 4.11 represents the distribution per color of these materials.

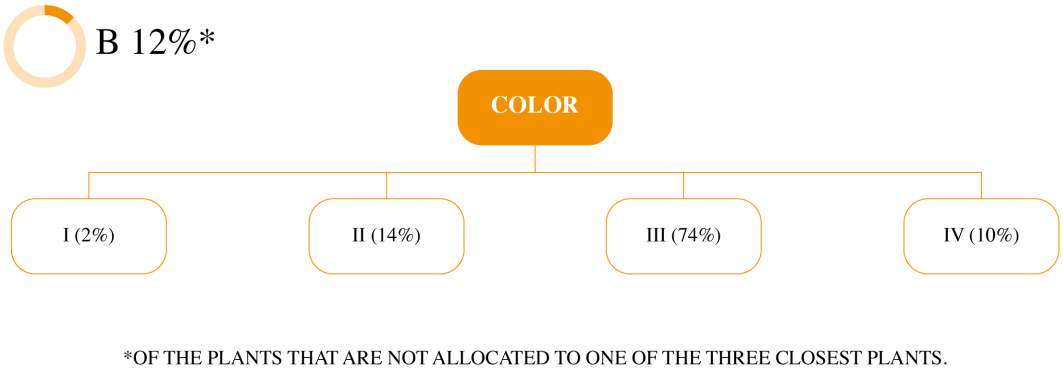


Figure 4.11: Percentage of colours for the plant B

It was concluded that 74% of the materials analyzed in Figure 4.11, have not been allocated to plant B due to the unavailability of its color, III.

By analyzing the impact of the production restrictions on this 74% it was concluded that none of them, apart from the color, is restrictive to this allocation choice. This is, all the necessary types of production, segment, sector or gobs were available for manufacturing at this plant.

So, it is possible to conclude that if the color III, from which 74% of the previously analyzed materials are made, was added to the range of colors available for production in B, the average cost of transport would be reduced in 2,018% and the total number of kilometers travel would be less 1,288%.

Plant D

From the Figure 4.10, it is possible to conclude that 32,5% of the materials that have not been allocated to one of the three closest plants to their final destinations, had as the nearest factory the plant D.

By analyzing the restriction referring to the color, it was noticed that color II, to which 65% of the materials were associated, could have been produced in this plant. The remaining 35% were belonging to materials with diverse colors, none of them available for production in D.

Regarding the segment type of the materials produced in the color II, the results are as presented in Table 4.2.

Table 4.2: Percentage of each Segment for Plant D

Colour	Percentage
AA	63,8%
AB	8,7%
AC	6,7%
AD	1,7%
AE	9,4%
AF	9,7%
Total	100%

It was verified that segments AA, AC and AE are available for production in this plant. This means that from the material analyzed that own the color II, 79,9% could have been produced in D, and only the 20,1% that utilizes the type of segments AB, AD and AF are not possible to be produced in this plant.

Finally, by analyzing the 79,9% refered before, 72,7% of these are not set to be produced in D due to the absence of a certain production type: X.

By adding this type of production, and allowing the materials restricted by it to be produced in factory D, the average cost per travel would be reduced by 2,3%, the average reduction in the cost per tonne would be of 0,62% and the number of kilometers in 4,45%.

The previous analysis is represented in Figure 4.12

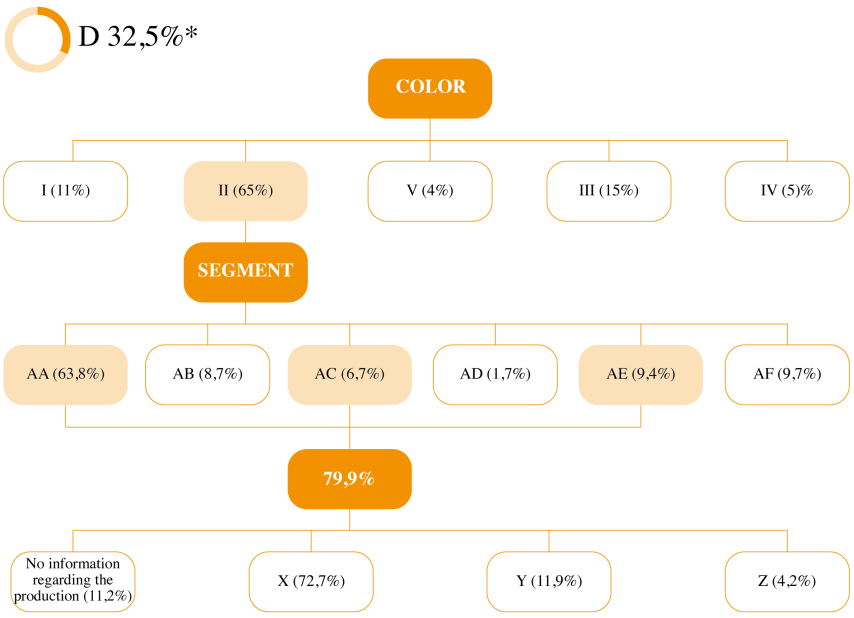


Figure 4.12: Plant D analysis

Plant F

From the materials present in Figure 4.10, 23,8% had as the closest factory to its final destination, plant F.

The review done to this plant is described in Figure 4.13.

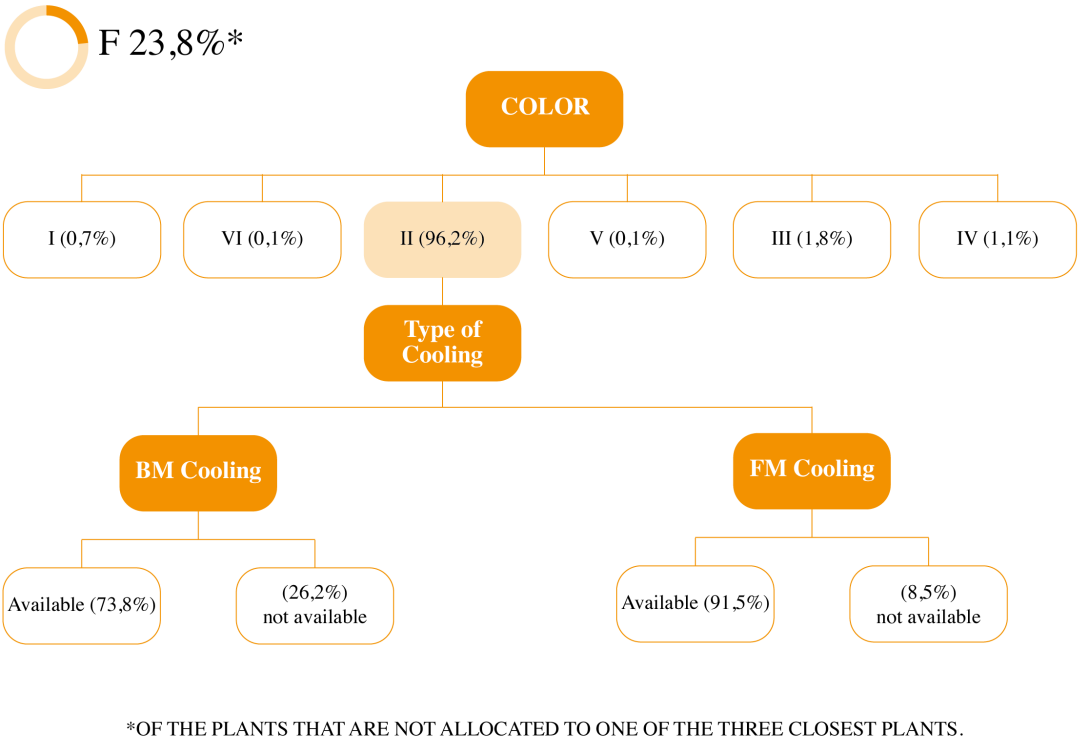


Figure 4.13: Plant F analysis

By analyzing the color of the materials analyzed in Figure 4.13, it was concluded that 96,2% of these could have been produced in factory F, since its color (II) is available for production. If all previous materials had their productions transferred to F, the cost per transport would suffer an average reduction of 1,51%, the cost per tonne would suffer an average reduction of 1,77% and the total number of kilometers traveled, would be shortened in 4,89%.

The remaining restrictions have not shown to be significantly restrictive since from the 96,2% of materials, produced with the color II, 100% of them had its segment type, its production type and its sections and gobs numbers available at the factory F.

The only production restrictions that could have limited the allocation of these materials to this particular plant are the type of cooling of the molds.

When analyzed the type of cooling of the blank mold, 73,8% of these materials had their type of blank mold cooling available at this plant and only 26,2% were limited by this restriction.

Alongside that, 91,5% were not limited by the finish mold type of cooling and only 8,5% of these did not have its type of finish mold cooling available at this plant.

Chapter 5

Conclusion and future works

This dissertation work was focused on the transport department activities of BA Glass. Being transports one of the greatest sources of expenses of the company, there is always the need of optimizing the way of working of these.

The focus chosen for this development was the communication improvement between the departments of Production Planning and Transports, more properly, the moment of factory allocation for production.

This way, the distances between the final destination of the materials and every BA factory were added to the existing production restrictions.

This development consisted on the building of a decision model, which main goal was to support the supply chain team, on the decision of choosing a factory to produce a certain material.

The excel program built was capable of, for each material inserted by the user, ordering all the BA factories by ascending order of their distance to the material final destination. Besides that, it also indicated in which of them was possible to produce a certain material, having in mind the production restrictions of each plant.

Furthermore, this tool was used to analyze previously made decisions, not only to evaluate this, but also to propose possible improvements or further studies about this particular activity.

During that analysis, the goal was to identify which improvements could be carried out, in terms of production restriction, to improve both the price per trip and the total number of kilometers traveled. Reducing the number of kilometers would mostly lead to a reduction in the environmental impacts of the company and in the lead time necessary to do the deliveries.

The most important conclusion to withdraw, was the savings in the previously referred variables if all the materials proposed in the 2021 budget were produced in the factory that is the closest to their final destination.

After a close examination of the document, it was concluded that not all the materials are set to be produced in the plant that is the closest to their final destination. The percentage of materials in which this happens is only 42,5%. From the remaining materials, 13,7% are set to be produced in

the second-closest plant and 14,8% in the third. The subject of analysis was the 29% of materials to which the plant allocation is one of the furthest plants possible.

If all the materials were produced in the plant that later leads to the shortest trip until their final destination, important savings could be verified. In terms of the total number of kilometers planned to be travel for the year 2021, these changes could mean a reduction of 39,63% since the number of kilometers would pass from 47.823.808 Kms to 28.870.043 Kms.

This reduction in kilometers would also mean an average reduction of 14% on the price per trip and of 13,2% on the cost per tonne.

After this first analysis, individual studies were performed to the top three plants that were the first option, in terms of distance. This was done only for the materials that are not set to be produced in one of the closest three factories to their final destination.

For each one, conclusions were drawn on how the average price per trip and per tonne as well the total number of kilometers would be reduced if some of the most conditioning production restrictions were removed.

Some of these conclusions were that by adding an extra material color in factory B production lines, it could be possible to reduce the average cost per trip by more than 2%, the average cost per tonne in 2,24% and the total number of kilometers in 1,18%.

When it comes to the plant located in D, it could be possible to achieve an average reduction of 2,3% in the cost of travel, an average reduction of 0,62% in the price per tonne, and a reduction of 4,45% in the total number of kilometers, if it was added the only type of production missing in it.

The last plant analyzed was factory F, from which was concluded that if all the materials that have plant F as their closest factory produced in it, the reduction felt in the number of kilometers would be 4,89%, in the average price per tonne would be of 1,77% and in the average price of travels would be of 1,51%.

Since the cost of transportation is very uncertain, and dependent of multiple factors such as the time of the year, the number of containers traded or the carrier used, the price for every possible route is not known.

For that reason, it is not possible to predict the total value saved for that year, with this change, and the only possible values to compare are the average reduction in the price of each one.

Finally, it was also noticed that it would not be correct to compare the reduction in the price per kilometer. For some trips, despite the price reduction being significant, the reduction in kilometers would also be high and for that reason, the price per kilometer would increase without meaning something negative.

During the execution of this work, there were several times in which there were detected not only possible points of improvement as well as proposals for future analysis and works.

The model will continue to be used in the company, to improve some of the already existing activities.

One example of that is the sales plan. With the use of the decision model on these, it is possible to find, monthly, improvements in the factory allocations.

The model will be updated and changed, whenever necessary, in situations like changes in the production lines restrictions, clients restrictions, or changes in the warehouse's network.

Apart from that, the model will be used by the Transports Department to communicate and discuss, with the Production division, possible production plans changes.

The main possible improvement to be made in the model's software, is to find a way to fairly compare the distances between the destinations and the plants.

Currently, there is no difference in comparing distances if they are either from maritime routes or routes done by road. Since the impacts of these two transportation modes, mostly environmental and in terms of lead time, are very different, it would be interesting to find a method to differently classify these. Apart from this, it would be also good to keep growing the database used by the decision tool, in order to improve the accuracy and the quality of the results obtained.

When it comes to more extensive and upgraded analysis, and since the main focus is the continuous improvement of the company profit and consequently reducing of the lead time, it would be good to keep the search for possible routes changes of the materials, since the correct changes could lead to reductions in the number of kilometers and in the cost of travels.

The changes that should be sought are the use of as many sea routes as possible.

When prepared in advance, this type of route is positively competitive. Despite the extra lead time necessary, it has shown positive impacts on the company's budget and on the reduction of environmental impacts.

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