TAMPEREEN TEKNILLINEN YLIOPISTO
TAMPERE UNIVERSITY OF TECHNOLOGY

ELSA MONTOYA SANAVIA
OPTIMIZATION OF SUPPLIER PORTFOLIO OF A WATER BOT-
TLING PLANT

Master of Science Thesis

ABSTRACT

Suppliers are important nowadays since they are involved in every part of the business and that is why they are key elements of an organization.

This thesis focuses on the optimization of supplier portfolio of a specific company. The aim of the study is to analyze the supplier base of a company and proceed with a supplier selection elaborated by three different methods. The objective is to see if the actual contracts achieve the company's priorities by comparing our solutions with the real one and find the differences between the three methodologies that can be applied. The company's main business area is water bottling therefore the study focuses in the food and drink industry.

The research question is: What is an optimal supplier portfolio for a water bottling plant? Which lead us to know how a water bottling plant could optimize it. The optimal supplier portfolio has been overall defined by some criteria about supplier features and company requirements; and it is reachable thanks to the scientific selection methods provided by several authors.

Based on the literature, a survey instrument was developed to collect data, which allowed us to provide a reliable analysis and subsequent recommendations. This survey collects information about three main groups of suppliers: Equipment, services and raw materials. This data is about 34 suppliers that belong to these three buckets. All suppliers are scored according to the ten selected supplier characteristics: Proximity, post- sales services, quality, lead times, flexibility, financial status, communication, past experience, technical capacity and delivery. In addition, the supplier features have been also ranked in these questionnaires for each group since it is considered that the dimensions may have not the same importance according to the supplier function.

The methods used for reaching the final recommendations are AHP (Analytic Hierarchy Process, Checklists and portfolio maps. The aim of using several tools is to compare the different solutions they provide.

The results show us similarities and differences between the company solution and the obtained by applying the methodologies. These allowed us to make some recommendations in order to optimize the portfolio. In addition, some conclusions about methods are included based on the results we obtained.

PREFACE

This Master Thesis has been developed in the Industrial Management department, Tampere University of Technology, Finland as an exchange student. The task has been done as a mandatory work for graduating in the Master in Industrial Engineering, Polytechnic University of Valencia, Spain.

I would like to thank both Professor Miia Martinsuo and assistant professor Tuomas Ahola for giving me this opportunity and, for the examination and mentoring throughout this whole process. I would like to give thanks also to the target organization for its actively collaboration in this research.

Finally, thanks to my friends and all people who have encouraged and supported me during this entire adventure; especially my family, who always believed in me and helped me to overcome the toughest times.

Tampere, July 8th, 2016

Elsa Montoya Sanavia

CONTENTS

LIST OF FIGURES

LIST OF TABLES

List of Symbols and abbreviations

AHP	Analytic Hierarchy Process
CI	Consistency Index
CR	Consistency Ratio
KPI	Key Performance Indicator
λmax	Eigen Value
PET	Polyethylene Terephthalate
RI	Random consistency Index

1. INTRODUCTION

1.1 Background

Suppliers are the core of activities and processes in most of companies. They take part in every part of the business and play an essential role in how a company works since they are directly involved with the constant flow of goods and services. Supplier selection has become one of the key elements for businesses to improve product quality and productivity (Ansari and Modarress, 1988). Ansari and Modarress also state that outsourcing activities are as important as financial activities, marketing, human resources, manufacturing control or quality. This clarifies that in most industries a 57, 8% of the total manufacturing value belongs to purchases (Ansari and Modarress, 1988). This is caused by the globalization of the value chain and information thanks to the new technologies and new transportation possibilities (Moser, 2007). Moser also states that this is a clear competitive advantage for a company since allows it to look for the best suppliers at the lower cost worldwide which will be turn into a profit increment for the business.

On the other hand, according to Kraljic, the competition between companies has been intensified because of raw materials shortage and political interventions in markets, among other factors (Kraljic, 1983). So, companies have been becoming more and more dependent of external sources to ensure the availability of resources in the long- term and this is what made the definitive change: Purchasing is not anymore just an operation in the whole manufacturing process, but it has become a strategic function (Kraljic, 1983). The more dependent a company is regarding the components of its products and the risks they take in their relationships; the more important supply chain management is for that business.

1.2 Research context

Use of suppliers in a water bottling plant

Many activities take place in a water bottling plant. There are all the complex processes for bottling water, all the activities and machinery for packaging and the organizational activities to monitor and run the whole production plant among others.

Those are just some examples of activities developed in a water bottling plant. But let us take a look to all the activities and possible suppliers the company could need to achieve them successfully:

- Bottling water activities: To carry out these activities the main item the company need is the machinery for the production lines and all the raw materials which include: pre- shaped bottles, glue, labels, caps, cardboard boxes…

- Maintenance: This involves the purchase of all the spare parts for the machinery and probably also some maintenance services from outside for the specialized machinery for water bottling. The basic maintenance of the building is included here as well.
- Quality controls: Since we are talking here about a product for human consumption, the quality controls must be especially rigorous. The product needs to be controlled from the water is taken out of the natural spring to it has been transported to its destination. There is a danger in getting plagues, fungus or other problems that could be harmful for health and they need to be analyzed and controlled.
- Transportation: The spring water may be transported from the natural spring to the production plant in case the plant is not placed in the same location. Besides, the final packages need to be transported in order to deliver them in the different locations where are going to be sold.
- Cleaning services: Those services are in charge of the whole plant. They can be the regular ones for toilets and offices, or special ones allocated to sanitize the production lines and machinery when there is some maintenance or breakdown intervention.
- Chemical products: The water needs treatments to avoid getting infected so those chemical products are provided also by a supplier.
- Industrial vehicles: They include all the vehicles utilized to move heavy loads and loading up and down the trucks for transportation.
- General services: Those could be the internet connection, mobile network, printing service, computers and all the services related with the office work.
- Risks prevention: They include all the required installations to make the place safe against fire hazards and work accidents.

1.3   The case company

The study is going to focus in a soft drinks company from Spain, which is located in the central- east area of the country. The main activity the company develops is high volume bottled water standard manufacturing. Their product is present in several countries like Portugal, Czech Republic, Taiwan, Arab Emirates and Japan; its main customers being individuals and restaurants. It counts with 200 employees approximately, and is the fourth largest company in the area and holds the 11th place in the Spanish Non- alcoholic beverages sector. Its sales were over 54M € in 2014 and the assets value was over 168M €.

Regarding how they work with suppliers, the company has an overall preference of characteristics that they must achieve successfully: Prices and payment policies, Lead times, Quality, Reliability, Financial status, Flexibility and Capacity of adaptation. Each outsourced item is provided by a minimum of three suppliers. The quality KPIs are revised at the end of each year and there are changes if the results are not satisfactory.

All suppliers are registered in the company's supplier portal where some data from suppliers is required such as the value added tax identification number (VATIN) and the corporate name.

In addition, when the company contracts a new supplier, a "Decalogue of good practices" is signed, i.e. do not employ children; the company works with suppliers from China where human rights are not always respected.

1.4　Research question and objectives

How could we deal with all these suppliers? Which ones are better for the company and why? By merging these questions, the research question could be summarized all in one sentence: **"What is an optimal supplier portfolio for a water bottling plant?"**

The optimal supplier portfolio is a remarkably good group of suppliers that promotes sustainable supply chain management and means a competitive advantage for the company. It is not just to select the best suppliers; it must be aligned with company strategy, taking into account specific targets and constraints by integrating and balancing objectives. But, the aim it is not just to develop a strategic partner selection; we want to count on "sustainable considerations" too, i.e. technical capacity or financial status of the supplier (Neumüller, Lasch and Kellner, 2016)

1.4.1　Scope

The thesis focuses on the study of standard high volume bottled water manufacturing. We will evaluate 34 suppliers that belong to the supplier base of the company, regarding ten supplier features on the basis of three methodologies: AHP, Checklists and Portfolio maps. Those 34 suppliers are split in three main groups: Raw materials, services and equipment and they provide different types of product: Pre- shaped bottles, labels, caps and wooden pallets from the raw materials group; transport and cleaning services from the services group; and industrial machinery from equipment.

The four different raw materials suppliers and the industrial machinery ones are all used to elaborate all sizes of bottled water products from the case company. These sizes are 330 ml, 500 ml, 750 ml, 1.5L, 3L and 5L.

The company elaborates also more types of soft drinks products but they do not have been taken into account since they are manufactured out of the water bottling plant we are referring this study.

1.4.2 Objectives

The objectives of this research are:

- ❖ Determine if the present supplier selection is effectively aligned with top management priorities and company strategy, and identify the possible improvement needs in order to balance the portfolio.
- ❖ Find a suitable tool that supports the decision making process (Neumüller, Lasch and Kellner, 2016) and gain experience in supplier selection supportive methods. The methodology should help to evaluate several decision criteria based in the top management preferences.
- ❖ Possible extrapolation to other companies or industries (Neumüller, Lasch and Kellner, 2016). The methodology used in this research could be used in other type of businesses and for future further research and possible development of a general tool to deal with general supplier portfolio issues.

1.4.3 Potential business implications

- ❖ Reduce costs (Chen, Lee and Wu, 2008) and increase profit (Moser, 2007). Working together as a whole will allow the company to optimize the split of spent in outsourcing by avoiding unnecessary investments or the involvement of the governmental organizations.
- ❖ Alignment with company strategy (Chen, Lee and Wu, 2008). The optimal supplier portfolio selection should share the strategic goals of the company and forge an alliance in order to be in a win- win situation.

1.5 Information gathering

- ❖ Survey instrument

All the data from company utilized in the present investigation has been primarily collected by a survey instrument. This survey is made up of two main questionnaires. The first one is about basic information about 30 suppliers, gathering data about how solid are they regarding the criteria and their main strengths and weaknesses. The second part of the survey is about the importance of criteria when partnering different type of suppliers.

- ❖ Interviews

The company provided us a contact in case additional data was needed. This contact allowed us to get information about 4 extra suppliers required for the study besides of general information about the organization and the professional profiles from the respondents.

1.6   Structure of the thesis

The thesis is coherently divided in five chapters. Specifically:

1. Chapter1 includes the background, the context in which the thesis has been developed, a brief introduction about company and how they treat with suppliers and an overall view about the aim of the thesis, the scope and what we want to achieve with the results.
2. Chapter2 presents the potential areas in which the thesis is based on and the directives that guided us throughout the whole paper.
3. Chapter3 explains the tools and methods that have been used to develop this study. There are further descriptions about the industry context, the main information gathering method and how the methodologies were used.
4. Chapter4 shows the main findings from the investigation and the subsequent discussion about them, including at the end some conclusions about the research.
5. Chapter5 includes conclusions from the whole thesis and links our study with the previous research question and proposed goals.

2. LITERATURE REVIEW

This section includes a literature review about the potential areas that are relevant for the study. Those areas are:

- ❖ Supplier portfolio: This is the main area in which the thesis focuses on. The definition of a supplier portfolio and one of the principal methods to manage it are shown in this section.
- ❖ Supplier relationships: This is highlighted by several authors as one of the most important characteristics of a supplier portfolio. The articles will show us how to manage several supplier relationships at the same time, depending on the purchased item.
- ❖ Supplier selection: It is the second part in which the thesis focuses on. Several criteria for supplier selection and their characteristics are collected in this chapter.
- ❖ Optimization: One of the aims of the thesis is to balance the portfolio. Some goals for optimizing are directly linked with project portfolios.

2.1   Supplier portfolio

A supplier portfolio is a collection of providers of an organization that are all grouped together in order to manage the company resources to achieve the strategic objectives of the business. It is inevitable to think about how the management of this portfolio could affect the overall company. Breakdowns, the changing environment, changing economies and the development of new technologies are directly involved with supplier portfolio and they allow a company to take advantage of new opportunities as well as dealing with new constraints and risks.

This becomes important in the moment that a manufacturer outsources a relevant number of items; then, the company must deal with all those issues (Kraljic, 1983). Kraljic introduces in his article two main goals to achieve by managing the supplier portfolio:

- ❖ Pay special attention to the critical items of our supply chain. Critical materials must be available in the long- term and must be purchased at a competitive cost since they are non- substitutive products for the organization.
- ❖ It is no longer just an activity but a strategic function. Therefore, the company must monitor the purchasing processes as well as leading them in a way that benefits itself.

In order to enhance these two principal goals in managing the supplier portfolio, the author also includes some assessment questions that must be taken into consideration by top managers in charge of this task (Kraljic, 1983):

1. Is the organization taking advantage of all the actual opportunities among the available suppliers?
2. Are we able to mitigate or avoid bottlenecks and breakdowns that may appear?
3. How much risk can we run?
4. Which is the best cost- flexibility balance in making- buying policies?
5. How could we strengthen the long- term supply relationships with our suppliers or competitors or take advantage of resource- sharing?

According to the article, some European companies use a four- step approach to set up the supply strategy. Following this stages, the company collects data from the market and corporations, elaborates different possible scenarios, identifies potential suppliers, and develops individual strategies for critical materials in order to minimize their vulnerabilities and enhance their potential as a buyer. Besides, Gelderman and Semeijn in their article also state that global sourcing is to integrate and coordinate "procurement requirements" by taking into account R&D, manufacturing and marketing within business units (Gelderman and Semeijn, 2006).

Kraljic's four- stage process

Kraljic's four step approach is as follows:

1. Classification (Kraljic, 1983):
   In this stage all the items are classified in four different buckets. These are:
   - Strategic products: They are the most critical ones for the business. There are no alternative products and no many providers have the required certifications and quality. They have high profit impact and are very risky.
   - Bottleneck products: Those materials or products are the most complex ones. They have complicate specifications, and there are no many options to purchase them. They have a direct impact in the business. Low profit impact and high risk.
   - Leverage products: Those are the products that are a routine purchase for the company. High profit, low risk.
   - Noncritical (routine) products: They are not expensive items, and there are many substitutive products. They do not have much impact on the business. Low profit and low risk.
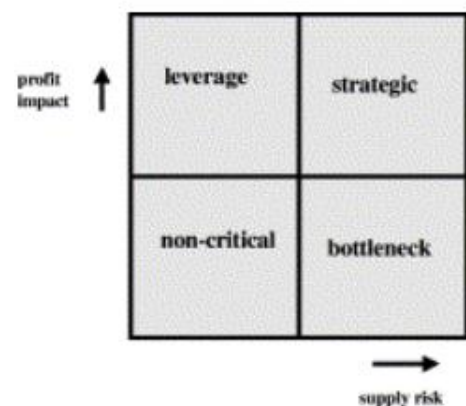
Figure 1 Kraljic's matrix for items classification (Gelderman and Van Weele, 2003)

In Figure 1, there is an example of Kraljic's matrix for classifying the purchased products.

2. Market analysis:
   Here the company analyses its suppliers and their bargaining power. This stage helps the organization to review the market and the strength of its providers.

3. Strategic positioning:
   Here the company maps the strategic items (classified in the first step) in a matrix whose axes are X- Market strength and Y- company strength. After this, the strategies are elaborated and the company makes the decision of exploiting, balancing or diversifying every material in the matrix depending on their position. Figure 2 shows the strategies layout.
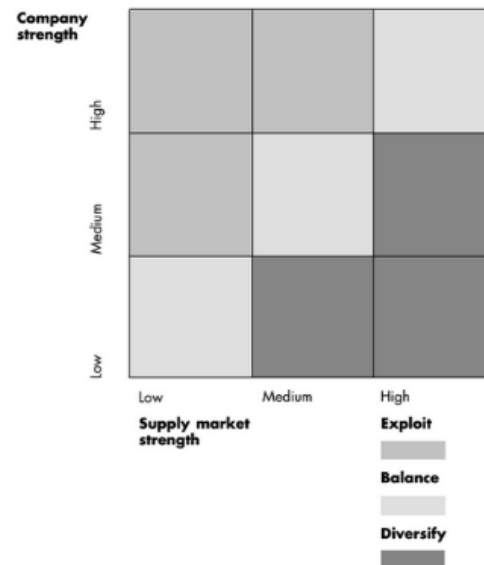
Figure 2 Purchasing portfolio matrix (Kraljic, 1983)

4. Action plans:
   Here the company analyses the different scenarios that could happen in regards of the position of the items in the stage three, and develops strategies and mitigation strategies for risks.

In the next image, it is shown a summary of the classification of purchased items and the strategies to follow depending on their position:
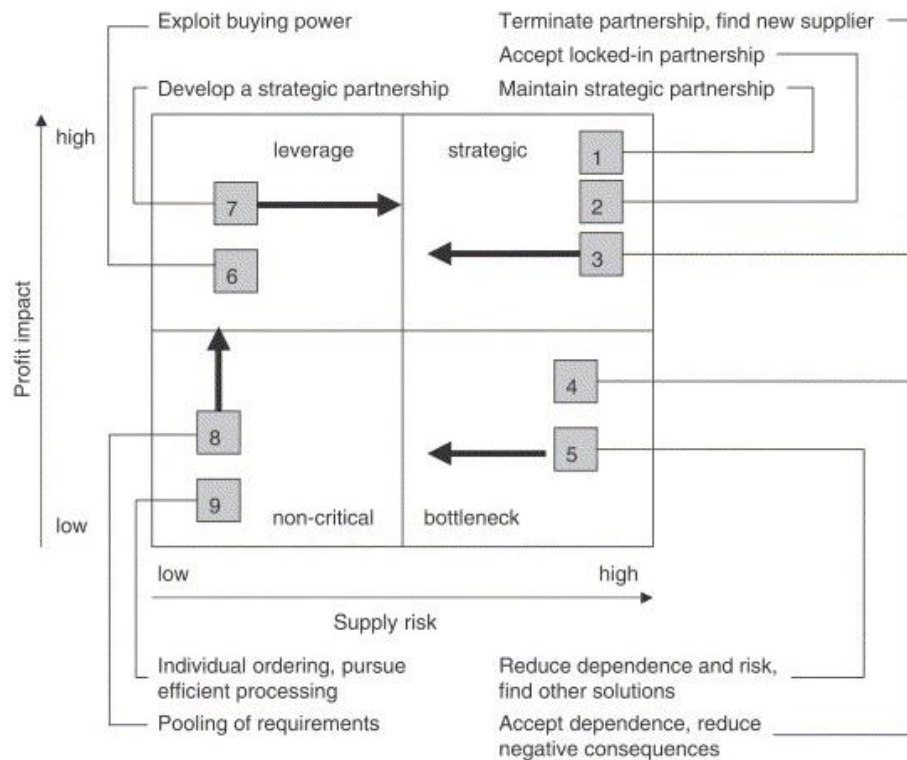
Figure 3 Summary of items classification and strategies to follow (Gelderman and Van Weele, 2003)

Gelderman and Semeijn apply Kraljic's matrix in their article in order to develop a portfolio analysis.

A portfolio model is "a tool that combines two or more dimensions into a set of heterogeneous categories for which different recommendations are provided" (Gelderman and Semeijn, 2006) and this is what the matrix allows us to analyze. The main purposes are to detect risks, elaborate mitigation actions, and identify the items that cause problems: those are the bottlenecks and the strategic products.

High- volume standard manufacturing supplier portfolio examples

Some supplier portfolios from high- volume standard manufacturing industry have been already studied. These researches shown beneath are based in some similar context than the water bottling plant and the methodologies applied are very useful for our investigation.

Tahriri et al. in their article (Tahriri et al., 2008) investigate the supplier portfolio of a standard steel manufacturing company from Malaysia and it focuses in evaluating and selecting suppliers by AHP method.

The case company in this article consists of steel design, engineering, procurement, fabrication, installation and commissioning. The criteria are selected depending on how each criterion could affect the manufacturing process; they lay emphasis on raw materials and point out the nature of the problem: multiple criteria decision making.

On the other hand, the article from Yadav and Sharma (Yadav and Sharma, 2016) studies the supplier portfolio of an automobile company from India. This article proposes a supplier selection by means of applying Analytic Hierarchy Process. It stands out the importance of suppliers when the amount of "supply chain trading partners and stakeholders" becomes large; and the relevance of ensuring uninterrupted supply of items.

Our research is focusing on supplier evaluation and subsequent selection as well, taking into account raw materials suppliers among others. The case company also belongs to the manufacturing industry, specifically, standard high- volume.

However, there is one difference among the contexts. Automobile industry and steel manufacturing industry in India and Malaysia, respectively, seem to be not very important ones in those countries, belonging those products to the main importations. On the other hand, the food and drink industry is one of the main economic activities in Spain.

2.2 Supplier relationships

Continuing with Gelderman and Semeijn article (Gelderman and Semeijn, 2006), they also tell us that nowadays, most of the articles about supplier portfolio are about supplier relationships and the knowledge flow from multinational companies to headquarters and makes emphasis in how important is also this flow from headquarters to local units. This makes us think about the importance of relationships between the whole company and the supplier.

That Is why Olsen and Ellram in their article (Olsen and Ellram, 1997) create a model to manage supplier portfolio relationships. They make emphasis in the needed existence of a tool that allows the company to focus in all their contractual relationships and by taking into account all the factors and not just taking care of them in a single way.

They propose a three-step approach:

1. Analysis of the company's purchases:

In this first step, Olsen and Ellram focus on analyzing al the items the company has to outsource. The Kraljic's matrix is applied in order to classify the purchased materials and subsequently strategic recommendation. These are the four dimensions and suggestions:

❖ Leverage items: Having mutual respect between supplier and company is the goal. System contracting should be a good way to establish this relationship.

- ❖ Noncritical items: This relationship should be managed by itself. It is a standard procedure that could be carried out by using system contracting, blanket order or small purchase order charge card.
- ❖ Strategic items: The company should establish a close relationship with the supplier by establishing a joint venture, for instance.
- ❖ Bottleneck items: The company should be involved with the supplier in developing the product in order to reduce operational costs.

2. Analysis of current relationships:

The current relationships are going to be evaluated regarding to different criteria: the relative supplier attractiveness and the strength of the relationship. Each of this two factor have different factors to count on when evaluating the relationships. Some of them are for instance: Financial and economic, performance, technological and organizational factors for the supplier attractiveness; and economic, character of the exchange relationship and cooperation and distance between buyer and supplier for measuring the strength of the relationship.

Once this has been evaluated, all the relationships with each supplier are mapped in two axes: X- Strength of relationship and Y- Relative supplier attractiveness.

3. Action plans development:

In *Figure 4*, extracted from the article we have been going through (Olsen and Ellram, 1997), there is an example of supplier relationships mapping. The authors name before some strategies depending on the position the relationships has in the map:

- ❖ Cells 1, 2 and 4: the relationship can be made stronger by improving communication, mutual involvement in development or increasing the volume of the order.
- ❖ Cells: 3, 5 and 6: The recommendation here is to reallocate resources in order to in order to keep the relationship strong.
- ❖ Cells: 7, 8 and 9: The company must think
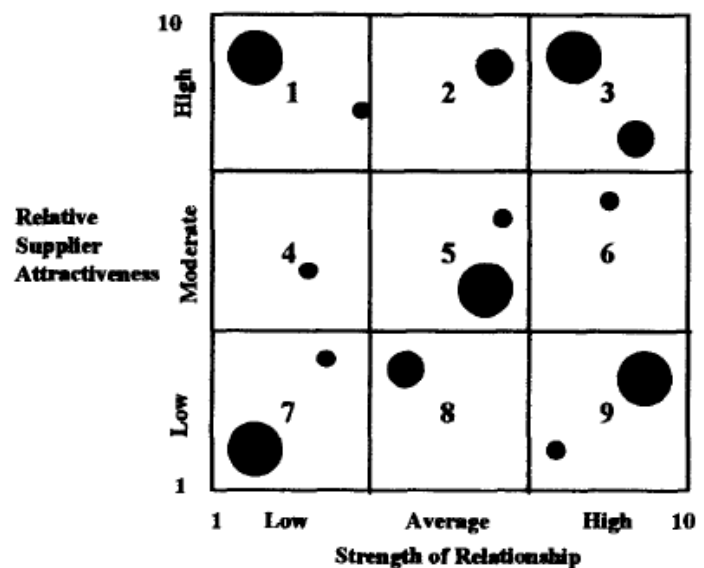
Figure 4 Example of supplier relationships mapping

about changing the supplier here. But first, they have to study the relationship network, that is, how the relationship with this supplier is affecting the others. This might be a good excuse to not to change the supplier.

Now the action plans can be developed. The authors split them in three different groups:

- ❖ Group 1: This group includes cells 1, 2, and 4; and the aim is to make the relationship with supplier stronger than before.
- ❖ Group 2: This one includes cells 7, 8, and 9; the purpose of this plan is "to improve the supplier attractiveness or the performance of the relationship" (Olsen and Ellram, 1997).
- ❖ Group 3: This group covers all cells in the figure. The strategy recommends to reduce the resources allocated to a relationship.

The final recommendation is that the company should choose a balance mix of action plans in order to ensure they have a solution for problems in the short- term and focus the work on the long- term relationships.

2.3 Supplier selection

This subject has been understudy by many practitioners since the 1960's (Ly`es Benyoucef, Hongwei Ding and Xiaolan Xie, 2003).

Several authors of the articles named beneath have carried out studies about supplier selection criteria in several industries and companies worldwide.

- **Article 1**: (Çebi and Bayraktar, 2003). They apply the AHP method to a supplier selection process. According to the article, in the food industry in Turkey, the most important features that suppliers need to fulfil are quality, delivery and cost.
- **Article 2**: (Choi and Hartley, 1996). This study is referred to the automotive industry in US. They state that the most important factors are quality and delivery; and the least important one is the financial dimension, which means also that price is not a very important characteristic.
- **Article 3**: (Verma and Pullman, 1998). They make a study about supplier selection process regarding how managers establish priorities among four particular features. The study is focused in metal processing and producers of small machine tools and tooling in the western US.
- **Article 4**: (Kraljic, 1983). He includes several criteria when evaluating purchasing portfolio. Some of them are not just related with supplier features but also with the market and the environment in which the business takes place such as market size, market growth and entry barriers. The study is carried out regarding several companies that belong to different industries.

- **Article 5**: (Dickson, 1966). He carried out a study to ask managers for supplier selection criteria. Later, he elaborated a list, which includes the most important supplier characteristics. The study includes several companies from US and Canada.
- **Article 6**: (Plebankiewicz and Kubek, 2016). They have been through studies from several authors in order to collect the most important supplier features. The study is focused in the construction industry.

The next table (Table 1) summarizes the variables that authors have taken into account. The cells colored in yellow show the factors pointed out as the most important ones by authors.

Articles:	1	2	3	4	5	6
Lead time	X	X				
Supply lots	X					
Flexibility	X	X	X			
Delivery	X	X	X		X	X
Technological Capacity	X	X		X	X	
Involvement	X				X	
Capacity of adaptation	X	X		X	X	
Quality	X	X	X		X	X
Cost	X	X	X	X	X	X
Reputation	X	X			X	
Market position	X			X	X	X
Financial status	X	X		X	X	X
Communication	X	X			X	X
Past experience	X				X	X
Post- sales services		X			X	X
Suppliers representative competence	X	X			X	
Reliability		X				
Competitive structure				X		
Uniqueness of product				X		
Situation				X	X	X
Warranties and policies					X	X
Trainee programs					X	X
Organizational structure					X	X

Table 1 Supplier selection criteria in different articles

Most relevant criteria

Finally, regarding this literature, we are able to elaborate a list with all the most important criteria to count on when selecting supplier portfolio. It has been selected those that have been mentioned in two or more articles:

a) Lead time
b) Flexibility
c) Delivery
d) Technological capacity
e) Involvement
f) Capacity of adaptation
g) Quality
h) Cost
i) Reputation
j) Market position
k) Financial status
l) Communication
m) Past experience
n) Post sales services
o) Supplier representative competence
p) Situation
q) Warranties and policies
r) Trainee programs
s) Organizational structure

In addition, we would like to count on company´s preferences when selecting suppliers. Those are financial status, quality, lead times, flexibility, capacity of adaptation and price.

The next table (Table 2) shows a table summarizing all these criteria. It has been done according to the articles in which they are cited and the company's preferences. The aim of this table is to remark which ones are more important in regards to make a subsequent selection to develop the investigation.

	Financial status	Quality	Delivery	Lead times	Flexibility	Involvement	Capacity of adaptation	Communication	Past experience	Technological capacity	Post-sales services	Cost	Reputation	Situation	Market position	Supplier represent.	Warranties and policies	Trainee programs	Organizational struc.
Çebi and Bayraktar	X	X	X	X	X	X	X	X	X	X		X	X		X	X			
Choi and Hartley	X	X	X		X		X	X		X	X	X	X			X			
Verma and Pullman		X	X		X							X							
Kraljic	X						X					X		X	X		X	X	X
Dickson	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X
Plebankiewicz and Daniel Kubek	X	X	X					X	X		X	X			X	X			
Company	X	X		X	X		X					X							

Table 2 Summary of supplier features present in the cited articles

2.4   Optimizing the supplier portfolio

Real problems are reduced to a single list of objectives because it is difficult to summarize them just in one single issue. Defining several objectives helps to have a better concept of the problem. That is called Multi- objective optimization (Abraham, Jain and Goldberg, 2005). We are talking about multi- objective optimization in the moment two objectives are in conflict (i.e. best quality and lowest cost).

Specifically, Feng, Wang and Wang article focuses in two similar areas (Feng, Wang and Wang, 2001). This research is about developing an optimization model that selects suppliers and tolerances between minimum manufacturing cost (including the quality issue) and the required level of manufacturing yield. The model consists of a stochastic integer programming approach.

On the other hand, Ben-Tal et al. in their article (Ben-Tal et al., 2005) propose a Robust Optimization approach to the issue this thesis is focused on: suppliers. That research lays emphasis on the uncertainties supply chain contains. Those uncertainties "concern production, inventory, scheduling and distribution decisions". Retailers look for keeping a low inventory and adjust the production to customer's demand, although the shortage of materials forces them to keep always available some inventory.

All those factors reinforce the Abraham, Jain and Goldberg's Multi- objective definition thanks to the multiple issues to deal with, and the contradictions between some of them.

Optimization has many implications in a business. It has been observed that supplier portfolio management has many common goals with project portfolio management. That is why it is considered useful to include some literature about project portfolio that could be connected with supplier portfolio.

Portfolio management is the management of one or more portfolios through all the levels of the organization. That includes identification, prioritization, selection, administration and control which makes it a decision process constantly up-dated and revised (Cooper, Edgett and Kleinschmidt, 2001).

Portfolio management is a quite important issue in companies since it is linked with key characteristics of a company. In the next lines those characteristics are going be linked with supplier portfolio since most of them are cited in the utilized articles. According to Cooper, Edgett and Kleinschmidt article (Cooper, Edgett and Kleinschmidt, 2001), these characteristics are:

1. Financial: Portfolio management always helps to maximize return. Referred to suppliers' portfolio management, the benefit would be increased because of the optimal split of spend among suppliers while achieving the best product possible.

2. Competitiveness: It helps the company to maintain a competitive position in the market. Partnering with the most suitable suppliers for the company means having a competitive advantage (Moser, 2007).

3. Allocate scare of resources: Olsen and Ellram tell us in their article how important is to allocate resources properly when managing supplier relationships (Olsen and Ellram, 1997).

4. Strategy of the company: The portfolio has to support the strategy. Kraljic states how managing suppliers becomes a part of the strategy in the moment the number of purchased items represents a significant volume.

5. Achieve focus: Also connected with supplier relationships. The Olsen and Ellram article establish a model to know in which relationships the company has to be more focused on.

6. Achieve balance: By managing suppliers' portfolio the company will achieve a balance between long and short- term. Olsen and Ellram write in their article about this balance when managing supplier relationships.

7. Improve communication: Communication will help to clarify the priorities of the company and the information flow will be improved both vertically and horizontally.

8. Objectivity: Portfolio management will provide a better objectivity in supplier selection.

3. RESEARCH METHOD

3.1   Context

3.1.1   Food and drink industry

The food and drink industry is the sector of the industrial production that transforms and preserves diverse materials and products used for the human feeding.

In this industrial sector the raw materials are products obtained from farming activities, ranching and fishing farms and from semi- prepared products which are previously prepared by other food industries.

Transformation and production processes for food products have as a goal to satisfy the necessities created by the customers' habits (pre- cooked meals, frozen products…) and to extend as much as possible the expiration date of the foodstuff.

The food and drink industry of the European Union is an essential part of the EU economy, beyond some other manufacturing sectors. It is the biggest manufacturing industry regarding the turnover, value added and employment.

Here comes a table (Table 3) with the recent developments in turnover, value added and employment (Fooddrinkeurope.eu, 2016) a.

	2012	*2013*	*%Change 2012-2013*
Turnover (€ billion)	1,062	1,244	17.1
Value added (€ billion)	206	-	-
Number of employees (million)	4.25	4.22	-0.6
Number of companies (1,000 units)	289	-	-

Table 3 Turnover, value added and employment

3.1.2   Bottled water industry

Bottled water is included in the bottled alimentary products and it is one of the most acquired products among beverages. In the food and drink industry, the bottled water market is one of the most growing sectors due to the increasingly health awareness and the new bottling technologies but it is also one of the most monitored.

The growth of income, the availability of different types of flavored water, the right preservation of the bottled water, the hygiene of the bottle and the launch of new innovative products play an essential role in the growth of this industry (Transparencymarket-research.com, 2016).

The water bottled market is the least affected regarding the fluctuations of raw material prices since water is an essential raw material and is plentiful; however, the plastic materials utilized for the bottles fluctuate affecting directly to companies' profit (Transparencymarketresearch.com, 2016). The volume of this market is driven by customer demand so, the consumption varies depending on the location. Asia Pacific was the largest market for bottled water followed by Europe and North America in 2013. Asia Pacific is expected to lead the global market over the next years on account of growing consumer demand for bottled beverages (Grandviewresearch.com, 2016).

Now, it follows some European data is included in order to show the actual potential of this industry (Efbw.eu, 2016):
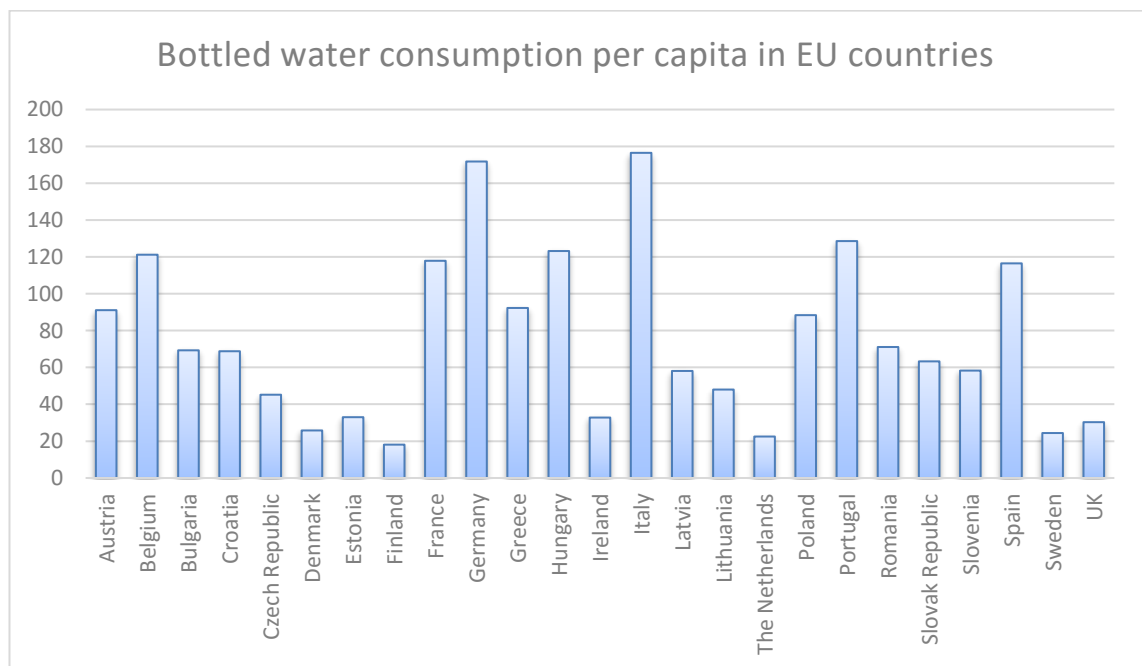
Figure 5 Consumption per capita 2014 (Efbw.eu, 2016).

According to the data the five countries that consume more bottled water are: Italy, Germany, Portugal, Hungary and Belgium meanwhile the five that consume the least are: Finland, The Netherlands, Sweden, Denmark and United Kingdom.
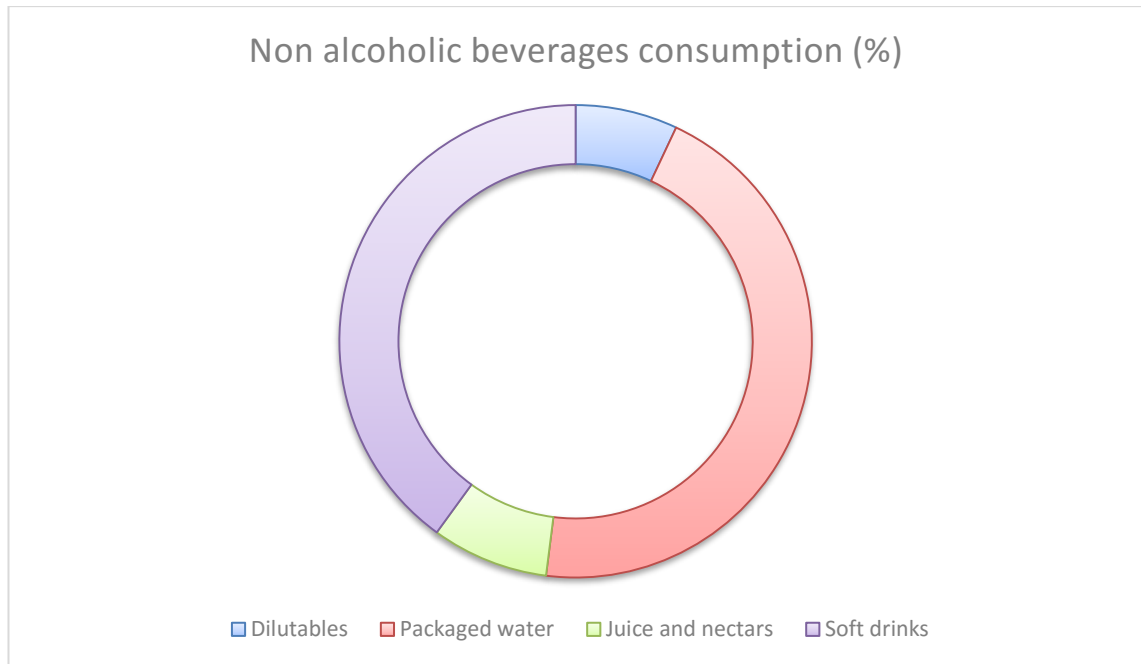
Figure 6 Non -alcoholic beverages consumption 2014(Efbw.eu, 2016)
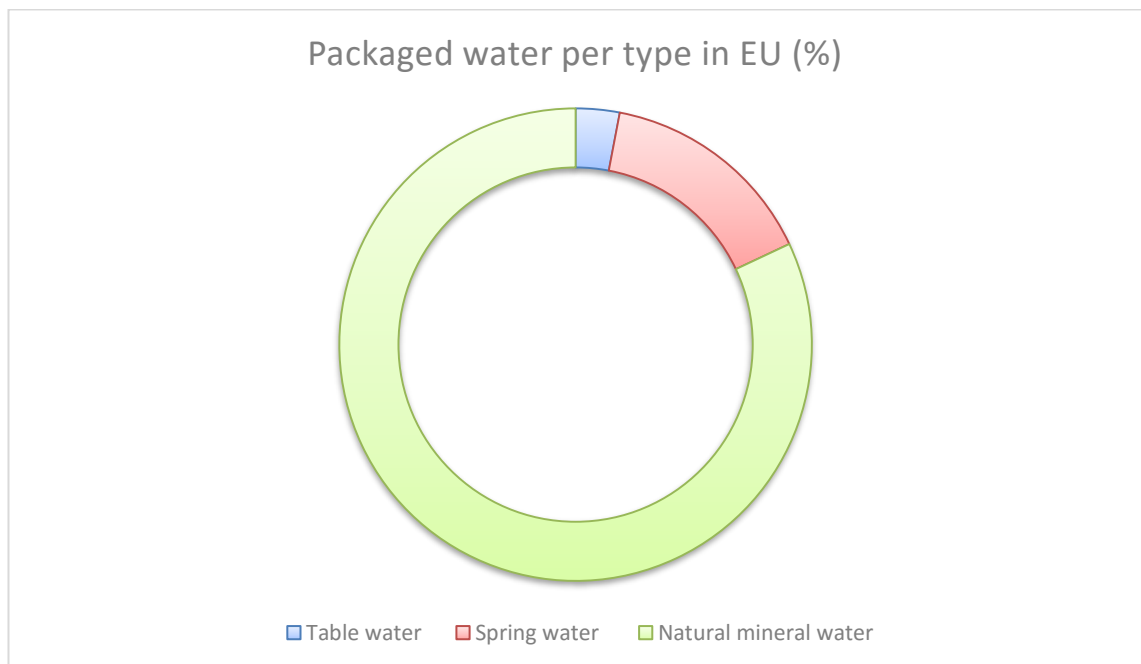
Figure 7 Packaged water per type consumption 2014 (Efbw.eu, 2016)

Sparkling water vs still water in EU (%)

Sparkling water   Still water
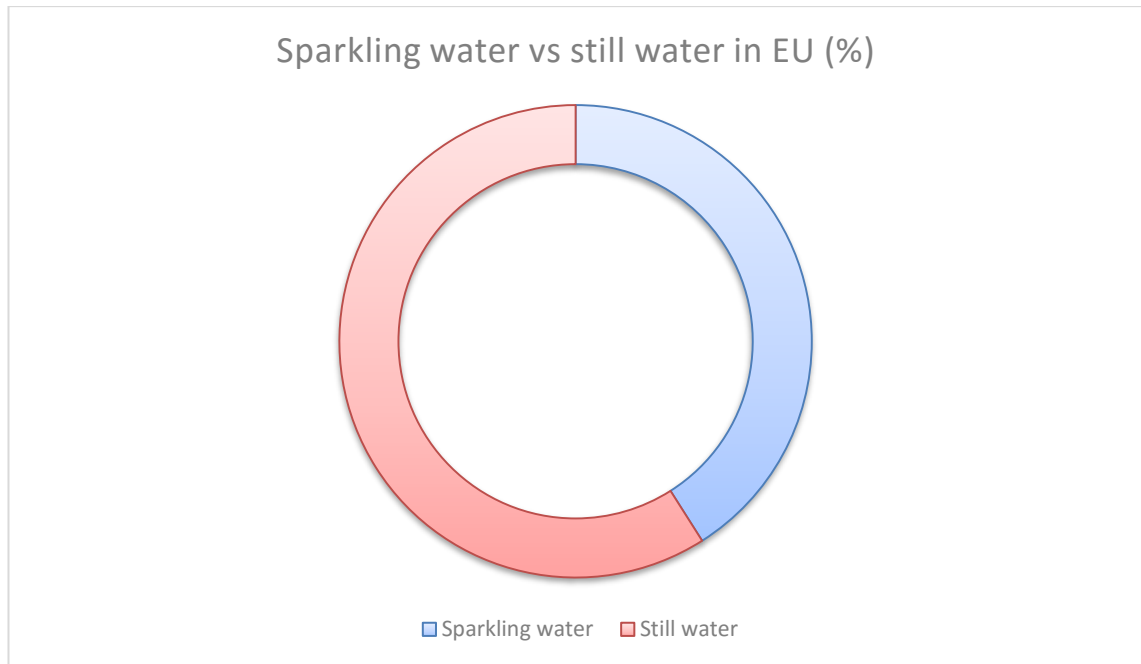
Figure 8 Sparkling vs still water consumption 2014 (Efbw.eu, 2016)

According to the three graphics above bottled water is the most sold product among beverages exceeding soft drinks consumption in a 5% (45% and 40% respectively).

3.1.3 Water bottling plant: Functioning

Regularly a water bottling plant receives the pre- shaped plastic bottles shaped by an outsourced company that elaborates the bottles. From this company, the pre- shaped bottles are transported by trucks to the different bottling companies. The packed and labelled pre- shaped bottles are received in the plant and the stored on the storage. In this area, they are selected and moved to the different bottling zones according to the volume of the bottle. There, operators place the pre- shapes in the respective lines and get them ready to go through all the process. Firstly, they go to the blowing machine in which we will obtain the plastic bottle by blowing inside the pre- shaped one. Then, the bottles go to the rinsing machine in order to eliminate the dust that may be inside. Once this process has been done, the bottles are directed to the filling machine where the water is poured into them at the correct level. At the end of this process, there is the capping machine which seals the bottled with a cap in order to avoid that the water is poured out or some polluting element goes inside. Now, the product goes again to the conveyor belt and is carried to the packing process.

After this stage, the product is codified by an injector that inscribes in each bottle the production date and the expiration date of the product.

Subsequently, the product is carried to the packing machine where the bottles are gathered in sets. Afterwards, these sets are directed to the palletization machine. This machine

covers the group of packages with a plastic film and afterwards is sealed with heat (Nadia Villa, 2016).

All along this process there are operators and multiple inspectors installed in all the lines in order to detect the defects that may appear.

3.2 Survey instrument

Due to the topic is very wide and the impossibility of carrying out such a large study, ten characteristics have been selected of all ones named above (section 2.3) in order to study them in such reliable and actual way.

The existing literature has been used in developing the survey. It was a crucial part in determining which factors are more important when evaluating suppliers and which information was needed in order to apply the existent supplier evaluation methods.

We merged all the characteristics selected by the authors, and ten of them have been chosen in order to set up a suitable list of supplier features to develop our study.

The selection is:

	Financial status	Quality	Delivery	Lead times	Flexibility	Involvement	Capacity of adapt.	Communication	Past experience	Technological capacity	Post-sales services	Cost	Reputation	Situation	Market position	Supplier represent.	Warranties and policies	Trainee programs	Organizational struc.
Çebi and Bayraktar	X	X	X	X	X	X	X	X	X	X		X	X		X	X			
Choi and Hartley	X	X	X		X		X	X		X	X	X	X			X			
Verma and Pullman		X	X		X							X							
Kraljic	X						X					X		X	X		X	X	X
Dickson	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X
Plebankiewicz and Daniel Kubek	X	X	X					X	X		X	X		X	X				
Company	X	X		X	X			X				X							

Table 4 Selected supplier features

1. Financial status
2. Quality
3. Delivery on time and good condition
4. Lead time
5. Flexibility
6. Communication
7. Past experience
8. Technological capacity
9. Post- sales services
10. Proximity

The following criteria is the one used for the selection:

- Price and costs have not been included since they are not very important according to the articles mentioned above (Choi and Hartley, 1996) and (Verma and Pullman, 1998). The Verma and Pullman one mentions a disruption between managers' opinion and actual practice but does not goes further in the study.
  We are aware of the importance of the price when purchasing products, but we decided to see how other factors can also affect the decisions and demonstrate that price is not the most important one despite that it seems to be.
- Financial status is supposed to be the least important according to the article (Choi and Hartley, 1996), but since prices are not being taken into account, we consider important to count on this factor. As we can see in Table 4, it is considered important by many authors and the company as well.
- Quality and delivery are ranked as two key factors by five articles (Choi and Hartley, 1996), (Verma and Pullman, 1998), (Çebi and Bayraktar, 2003), (Dickson, 1966) and (Plebankiewicz and Kubek, 2016) so these dimensions are essential in the study. Delivery includes the evaluation of lead- times as well. Quality and lead times have been pointed out as very important characteristics too.
- Relationships include past experience and the ability of easy communication. This characteristic has been selected considering that Choi and Hartley article (Choi and Hartley, 1996) states that relationships are very important when selecting suppliers since they are one of the most powerful obstructions to competitors and avoid them to entry in the market. Past experience and communication are included in 3 and 4 articles respectively out the 6 that have been analyzed.
- Flexibility is not considered a really important one in comparison with quality, delivery and cost but the article written by Verma and Pullman (Verma and Pullman, 1998) includes it inside the four factors they used and also it is important for the company, so we consider that it must be included among the ten dimensions.
- Proximity is just considered by Kraljic, Dickson and Plebankiewicz and Kubek but we consider that it may be important regarding some services that the company might need and that is why is being taken into account in the study.
- Post- sales services has been selected because post- sales relationships is considered an essential part of the buying- selling process between businesses.
- Technological capacity has been selected considering that in the article (Choi and Hartley, 1996) a disruption was found in scoring this dimension depending on the type of supplier so it is an interesting approach since this study also considers different type of suppliers.
- We decided to select 10 dimensions that include all authors' opinion and the company's one.

The survey instrument is made up of two main questionnaires. Both of them have been asked for being responded by 4-10 respondents in order to be filled by the person that has the best information.

In questionnaire 1 the respondents are asked for evaluating 30 suppliers individually in regards of the 10 selected factors in a scale from 1 to 5 (sample of survey in Appendix I). Those 30 suppliers are split in three main groups: Raw materials, services and equipment.

We have obtained feedback about basic information such as name, item provided, evaluation regarding the ten selected characteristics and main strengths and weaknesses.

In questionnaire 2, those three main groups are evaluated according to the criteria. That is, the respondents have to evaluate which are the most and least important criterion to count on when partnering suppliers that belong to each one of these three buckets (samples of survey in Appendix I).

After contacting with the company, we obtained information about 34 suppliers that were selected by the organization: 19 belong to "Raw Materials" group, ten belong to "Services" group and five to the "Equipment" one; besides of one copy of "questionnaire 2" evaluating the importance of the selected dimensions in each of the three groups.

The questionnaires where responded by one main person in charge of the purchasing department from the company. This person has the capacity of leading and managing teams, he/she keeps updated his/her knowledge about the market and has an overall technical understanding about company processes. The achievement of a win- win situation between the company and supplier is one of the main goals, as well as increasing quality and being environmental- friendly.

3.3 Data analysis

The following sections contain the explanation of the design used for this research. The description of the methodologies that have been used to analyse the data from the company have been also included, as well as the process how we went through it.

3.3.1 Research design

We are carrying out a **mixed- method procedure** in this investigation by employing the application of three different approaches: Analytic Hierarchy Process, Checklists and Mapping.

These procedures apply qualitative and quantitative approaches in order to address complex problems successfully. However, they may be a little bit challenging for the researcher since it requires the availability of extensive data, "the time- intensive nature of analysing both text and numeric data" and to be familiar with both quantitative and qualitative techniques (Creswell, 2003).

According to this article (Creswell, 2003), there are six major mixed- method models. Specifically, we are developing a **Concurrent Triangulation Strategy** and then a **cross-validation model**. This model regularly uses different qualitative and quantitative methods in order to make a comparison among them and point out their main weaknesses and strengths.

3.3.2 Analytic Hierarchy Process

The first method that is going to be applied is the Analytic Hierarchy Process (AHP). The AHP is the most famous multi- criteria method. It is an optimization methodology (Ly`es Benyoucef, Hongwei Ding and Xiaolan Xie, 2003). These tools have been developed to give people a hand in decision- making processes. They play an essential role when a group of workers is deciding among several tangible and intangible criteria (Dolan, 2008).

This author also tells us in his article about the two main strengths this method has: It is very sensible and user friendly. This means that it is very easy to use thanks to its design.

Vaidya and Kumar in their article describe 7 key basic steps to follow in order to carry out this method. Adapted from (Vaidya and Kumar, 2006), these ones are:

1. Define the problem.
2. Take into account all the potential parts that participate in this problem, which are the objectives and the pursued goal.
3. Selection of the criteria.
4. Organize the problem as a hierarchy.
5. Proceed with the pairwise comparison in each level according to the scale.
6. Calculate Eigen value, consistency index CI, consistency ratio CR.
7. Check out if these values are meeting the requirements. If not, repeat this procedure until the values are satisfactory.

Now, let us apply these steps to analyze our data.

We start from the supplier portfolio of the company. Our main objective is to verify if the organization is currently working with the most suitable suppliers. Therefore, the analysis is taking into account suppliers the company is working with at the moment and, other ones that belong to the supplier base but do not have a contract with them anymore.

As it was stated before, a survey was sent to the company with the purpose of obtaining some basic information about their suppliers. Now, we have data from 34 suppliers that belong to the supplier base. All of them have been evaluated according to the established criteria, which has been already named in the previous chapter (3.2) in Table 4. Tables 44, 45, 46, 47, 48, 49 and 50 in Appendix II, chapter 1 summarize the evaluation of the suppliers according to the results obtained in the questionnaires.

Now the problem must be structured as a hierarchy. According to Saaty (Saaty, 1987) a hierarchical model starts with the focus of the problem, and then descends through criteria, and finalizes with the different available options. The author also includes an extra level between criteria and the alternatives: the sub- criteria; but this it is not our case though.

Therefore, the hierarchy model of this research looks like as follows:
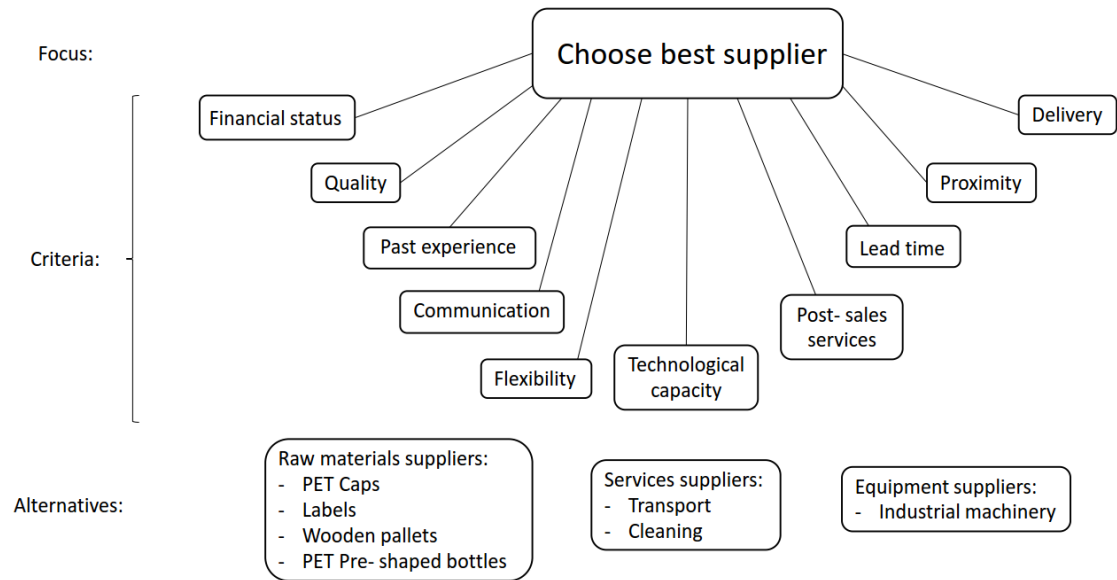
Figure 9 Hierarchy model. Adapted from (Saaty, 1987)

We are going to choose the best supplier for each product. The number of alternatives for each group of suppliers is:

- PET Caps: 7
- Labels: 3
- Wooden pallets: 5
- Pre- shaped bottles: 4
- Transport: 6
- Cleaning: 4
- Industrial equipment: 5

In the next step takes place the pairwise comparison between the 10 different criteria. According to James G. Dolan's article (Dolan, 2008) every input in the pairwise comparison matrix comes from comparing two criteria. The scale to compare the elements in pairs is:

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance of one over another	Experience and judgement strongly favour one activity over another
5	Essential or strong importance	Experience and judgement strongly favour one activity over another
7	Very strong importance	An activity is strongly favoured and its dominance demonstrated on practice
9	Extreme importance	The evidence favouring one activity over another is of the highest possible order of affirmation

Table 5 Scale for pairwise criteria. Adapted from (Saaty, 1987)

Table 5 shows the fundamental scale established by Saaty. The author also includes some intermediate values in the original table that have not been taken into consideration in this study.

Here is when the second part of the survey comes out. In order to establish the importance of each element over the others, a second questionnaire was elaborated to establish a prioritization of the 10 criteria in regards of each group. Table 51 in Appendix II shows us the 10 dimensions evaluated on a scale from 1 to 5 according to the importance they have when partnering a supplier that provides raw materials, services or equipment for the company.

The selected scale for establishing the importance of factors in Table 51 (from 1 to 5) has been establish with two main purposes. Firstly, it is a scale by which the respondent can easily answer the questions and secondly, it will allow as establishing the preferences of one element over another in an easy way.

However, the standard scale for AHP method (Table 5) differs from ours. So, we created an equivalence between both in order to be able to compare the elements with the Saaty scale by using our results from survey.

Applying this to Table 51, by comparing all the 10 dimensions by pairs, the steps to go from one scale to another and being able to compare the dimensions are:

- If the difference between the two numbers that define the importance is 0: the importance between the two factors is equal, so it must be defined with a 1 according to the basic scale in Table 5.
- If the difference between the numbers is 1: one element has moderate importance over another, so the proper number to make the comparison is 3.
- If the difference between the numbers is 2: one element has essential or strong importance over another, so the proper number to make the comparison according with the basic scale is 5.
- If the difference between the numbers is 3: one element has very strong importance over another, so the comparison between the two factors is defined with a 7 according to the basic scale.
- If the difference between the numbers is 4: one element has extreme importance over another, so the proper number to compare the two factors is 9 according to the basic scale.
- "The reciprocal values are then automatically entered for the transpose." (Saaty, 1987).

Taking into account this process named above in carrying out the pairwise comparison through the three groups, we obtained the tables 52, 53 and 54 included in Appendix II.

In the next step, the calculations of the Eigen Value, Consistency Index CI and Consistency Ratio CR take place (Appendix II, section 2.2). These values will help us to know if the prioritization list between suppliers we are going to elaborate is reliable.

We have to check if the CR values are meeting the requirements. There is just one requirement that was established by Saaty and it is that the value of CR must be smaller than the 10% of RI (Saaty, 1987).

So checking our values, we have:

	Raw materials	*Services*	*Equipment*
RI	1,49	1,49	1,49
10% of RI	0,149	0,149	0,149
CR	0,03011	0,02202	0,0764
CR≤0,149?	**Yes**	**Yes**	**Yes**

Table 6 Verification of reliability of the study

Therefore, once we have verified that our study is reliable, we can proceed to calculate the final evaluation of the supplier. This is shown in Tables 64, 65 and 66 in Appendix II, section 2.3.

3.3.3 Checklists

Checklist is the second method we are going to apply to analyse the data. It is very well known that one of the simplest ways of evaluating something is going through the characteristics and verify if our requirements are met or not; so this method consist of elaborating a list of questions/requirements the suppliers need to achieve and they are answered regularly with Yes/No answers. It is used as a supporting tool in order to make Go/Kill decisions (Cooper, Edgett and Kleinschmidt, 2001).

Ly`es Benyoucef Hongwei Ding and Xiaolan Xie present in their article also the "Elimination method". Here, the decisors establish a minimum mark in each criteria and the suppliers that do not achieve it, are automatically eliminated from the list (Ly`es Benyoucef, Hongwei Ding and Xiaolan Xie, 2003).

It may be sound very simple but we consider interesting the approach this method can provide. Our objective by applying this method is to see if it provides reliable results by comparing them with the ones from AHP, which is supposed to be one of the best.

Besides, it is considered one of the most widely used tool by companies when managing project portfolio. Cooper, Edgett and Kleinschmidt included it in their article and defined it as one of the most popular.

Let us see how we applied this method to the data.

We have 34 suppliers that belong to three different groups. These 34 suppliers have been evaluated regarding how strong they are fulfilling the criteria we set up in the Chapter 3.2 (Table 4). In addition, these criteria have been evaluated in each group in regards of its importance when contracting suppliers that belong to them.

Since this method is based in Yes/No answers, we established these criteria to evaluate the data:

- Groups: If the dimension is rated with less than 3 in Table 51 (Appendix II, section 1), it means that this dimension is not important and it does not matter if the supplier is strong on it or not.
- Suppliers: If a supplier is rated in some criteria with less than 3 in Tables 44, 45, 46, 47, 48, 49 and 50, it means that it is weak in that aspect and, it does not satisfy the requirement.

According to Table 51, all dimensions have been rated with a 3 or more but one: proximity in the equipment group. If we apply the criteria we set up for the numbers, this means that proximity is not an aspect to count on when partnering a supplier that provides equipment.

Tables 67, 68 and 69 in Appendix II, chapter 3 show as the application of this method. If supplier meets the requirement in some factor (rated ≥ 3) it is written a 1 as a YES and if it does not, it is written a 0 as a NO.

3.3.4 Portfolio Maps

The last third method we are going to apply it is based in the Kraljic's matrix included in the literature review. Firstly, Kraljic classifies items in regards of profit impact and supply risk. And then, the ones classified as "Strategic" are mapped regarding supply market strength and company strength.

So that, as we have the weights of each criterion in each group (calculated in AHP method previously and represented as Matrix B in Table 55, Table 56 and Table 57), we can determine which are the most important ones. The objective is to map the suppliers in a chart in which the axes X and Y are going to represent the most valuable two factors for the company in each group. Tables 70, 71 and 72 show us the prioritization of these factors in Appendix II, Chapter 4.

Therefore, the suppliers that belong to **raw materials** group will be represented concerning **Quality** and **Flexibility**. There are other dimensions with the same punctuation but we decided to go with quality because it is always in the first place when authors rank suppliers' features and flexibility because we think it is essential that a raw materials supplier is capable of satisfying the sudden orders of the foundation of the product.

Suppliers from **services** group will be represented according to **Quality** and **Lead Time**. We decided for quality and lead time over delivery because quality is one of the most important ones, as we said before; and, since we have more suppliers in this group for transport services, we consider lead time is more important that delivery because it is something essential for managing logistics and transportation.

Suppliers from **equipment** group are going to be map regarding **Flexibility** and **Post-sales services**; as it is shown in Table 72 (Appendix II, chapter 4) they are ranked the firsts one clearly over the rest.

4. KEY RESULTS AND DISCUSSION

This chapter shows the outcomes we got by applying the three methods described in section 3.3 and the discussion about them.

We have three buckets of suppliers: Raw materials, Services and Equipment. The first idea was to analyze the data using these three main buckets as the unique division of suppliers but, the information we received from company contained the supplier sorted by types of product or service. Therefore, we decided to present the results according to the group they belong and the product they provide since it has been considered that this approach is more reliable and accurate because the groups are more homogeneous.

These are the three buckets of suppliers and the products in which they have been divided according to the data:

1. Raw materials:
    a. Pre- shaped bottles
    b. Caps
    c. Labels
    d. Wooden pallets
2. Services:
    a. Cleaning
    b. Transport
3. Equipment:
    a. Industrial machinery

After the application of each methodology we have included the discussion of the results we got. The discussion makes reference to the correlations we obtained with company decision and also to the differences between our solution and the company's one trying to give and explanation to them and to understand why there is no similarity.

4.1   Selecting supplier portfolio based on AHP

The main goal we expect to achieve by applying this method is to make a list from the best supplier to the worst in which the supplier in first place is the best from the analyzed group since it satisfies the company requirements properly.

In the following pages the final results are shown. By applying a filter to Table 64, Table 65 and Table 66 (Appendix II), we obtain the result column by type of product that will allow us to make the ranking (Tables 7, 9, 13, 16, 18, 21 and 24). And then, Tables 8, 10, 14, 17, 19, 22 and 25 show us the final ranking of suppliers by product.

1. Raw materials:

Pre- shaped bottles	X1	X7	X8	X9	WEIGHTS
Financial status	0,059	0,029	0,057	0,059	0,058
Quality	0,067	0,084	0,033	0,085	0,155
Past experience	0,056	0,056	0,056	0,057	0,032
Communication	0,038	0,038	0,052	0,052	0,047
Flexibility	0,063	0,032	0,063	0,032	0,155
Technological Capacity	0,058	0,058	0,044	0,059	0,155
Post- sales services	0,054	0,054	0,054	0,036	0,155
Lead time	0,055	0,055	0,055	0,055	0,155
Proximity	0,062	0,031	0,031	0,031	0,026
Delivery on time and good condition	0,049	0,065	0,065	0,065	0,155
Result	0,063	0,061	0,058	0,060	

Table 7 Pre- shaped bottles suppliers' ranking numbers

Current contract?	Pre- shaped bottles supplier	AHP result	Ranking
YES	X1	0,063	1
NO	X7	0,061	2
NO	X9	0,060	3
NO	X8	0,058	4

Table 8 Pre- shaped bottles suppliers' final ranking

In Table 8 we can see that there is match between the selected supplier as the best one by applying AHP, and the one the company is working with at the moment: it is supplier **X1**. It satisfies the most important company requirements for raw materials (Table 70, appendix II: Quality, Flexibility, Technological capacity, Lead time and Delivery) with a 4, 4, 4, 3 and 3 respectively according to the survey results and Table 44 which shows all the individual supplier evaluation.

Caps	X12	X13	X14	X15	X16	X17	X18	WEIGHTS
F. status	0,045	0,029	0,075	0,059	0,059	0,059	0,059	0,058
Quality	0,051	0,067	0,067	0,034	0,034	0,034	0,057	0,155
Experience	0,057	0,023	0,023	0,057	0,057	0,045	0,057	0,032
Communication	0,065	0,052	0,052	0,052	0,052	0,052	0,052	0,047
Flexib.	0,063	0,08	0,079	0,032	0,063	0,032	0,047	0,155
Tech.Capacity	0,029	0,058	0,058	0,058	0,058	0,058	0,058	0,155
Post-sales s.	0,054	0,054	0,054	0,054	0,054	0,054	0,036	0,155
Lead time	0,037	0,055	0,055	0,055	0,037	0,055	0,055	0,155
Proximity	0,156	0,031	0,031	0,031	0,031	0,031	0,031	0,026
Delivery	0,049	0,049	0,049	0,065	0,065	0,065	0,049	0,155
Result	0,056	0,065	0,065	0,055	0,057	0,054	0,055	

Table 9 Caps suppliers' ranking numbers

Current contract?	Caps suppliers	AHP result	Ranking
NO	X14	0,065	1
NO	X13	0,062	2
NO	X16	0,057	3
NO	X12	0,056	4
NO	X15	0,055	5
YES	X18	0,055	6
NO	X17	0,054	7

Table 10 Caps suppliers' final ranking

Table 10 shows us that there is no match between the supplier the company is working with currently (**X18**) and the result we got from AHP method (**X14**). In order to understand why the company took this decision, we have gone through an individual study of suppliers **X14**, **X13**, **X16**, **X12**, **X15** and **X18** in order to know and understand why the company made that decision. It has been decided to study them regarding the most important factors for raw materials group (Table 70, appendix II: Quality, Flexibility, Technological capacity, Lead time and Delivery). Table 11 shows the individual evaluation of these 6 suppliers and if they have success achieving these requirements or not.

	Quality	Flexibility	Tech. Capacity	Lead time	Delivery
X12	3	4	2	2	3
X13	4	5	4	3	3
X14	4	5	4	3	3
X15	2	2	4	3	4
X16	2	4	4	2	4
X18	3	3	4	3	3
	Quality	Flexibility	Tech. Capacity	Lead time	Delivery
X12	√	√	×	×	√
X13	√	√	√	√	√
X14	√	√	√	√	√
X15	×	×	√	√	√
X16	×	√	√	×	√
X18	√	√	√	√	√

Table 11 Caps suppliers' evaluation. Focused study of most relevant requirements satisfaction

According to Table 11, the only suppliers that offer a good balance among the most relevant company requirements are **X13**, **X14** and **X18**. The others may be very strong in some characteristics but they do not satisfy all company necessities and that is why they have not been selected by them. So, let us focus the study now on suppliers **X13**, **X14** and **X18**.

Regarding **X13**, the only anomaly we find is that the organization has no good experience working with them (Past experience is rated with a 2 in Table 46, appendix II) and we found also, that this dimension is not rated as very important in the prioritized factors but definitely counts when partnering.

The next table show us the Past- experience factor grades for **current suppliers** in raw materials group:

Current contract?	Raw materials suppliers	Past experience
YES	X1	5
YES	X2	5
YES	X3	5
YES	X4	5
YES	X18	5
YES	X19	5

Table 12 Company experience with current raw material suppliers

If we take a look to Table 12, we can observe that all the company's experience with **current suppliers** is positive and that is why they probably decided to not to work anymore with supplier **X13**.

Regarding supplier **X14**, the company is not working anymore with them since they provide crown caps. The current products they are manufacturing do not require these type of caps so it makes sense that they are not working with this supplier.

So, going further in the analysis, applying extra information besides of the single method, we finally got **X18** as the solution.

Labels	X10	X11	X19	WEIGHTS
Financial status	0,060	0,030	0,060	0,058
Quality	0,051	0,051	0,034	0,155
Past experience	0,057	0,057	0,057	0,033
Communication	0,052	0,052	0,052	0,047
Flexibility	0,048	0,048	0,063	0,155
Technological Capacity	0,059	0,059	0,059	0,155
Post- sales services	0,073	0,0723	0,054	0,155
Lead time	0,055	0,055	0,037	0,155
Proximity	0,031	0,031	0,031	0,026
Delivery on time and good condition	0,033	0,033	0,065	0,155
Result	0,058	0,056	0,057	

Table 13 Labels suppliers ranking numbers

Current contract?	Labels suppliers	AHP result	Ranking
NO	X10	0,058	1
YES	X19	0,057	2
NO	X11	0,056	3

Table 14 Labels suppliers' final ranking

There is also no match between the supplier selected by the company (**X19**) and the one obtained from the AHP method (**X10**). Let us take a look to see why this is happening. We decided to make the study the same way as before: let us see how good suppliers **X10** and **X19** achieve company's necessities.

	Quality	Flexibility	Tech. Capacity	Lead time	Delivery
X10	3	3	4	3	2
X19	2	4	4	2	4
	Quality	Flexibility	Tech. Capacity	Lead time	Delivery
X10	√	√	√	√	×
X19	×	√	√	×	√

Table 15 Labels suppliers' evaluation. Focused study of most relevant requirements satisfaction

It seems that both suppliers are almost equal in comparing how they satisfy the most important factors for the company, and we do not have further information regarding their capabilities but, taking a look to the extra information included in the survey, we find in that supplier **X10** is located 650Km far away from the plant. Besides, there is an important constraint: because of this large distance, the supplier sends the product by means of a transport agency and, according to the answer we got in the survey, this agency is always late. That is possibly the definitive reason why the company is not working with them anymore since this constraint was pointed out as one of the main weaknesses despite proximity is not a relevant factor. They rather work with supplier **X19,** that is not better that the previous one but, they deliver the product by themselves and on time.

Wooden pallets	X2	X3	X4	X5	X6	WEIGHTS
Financial status	0,060	0,060	0,060	0,030	0,045	0,058
Quality	0,051	0,051	0,051	0,051	0,051	0,155
Past experience	0,057	0,057	0,057	0,057	0,057	0,033
Communication	0,052	0,052	0,052	0,065	0,065	0,047
Flexibility	0,048	0,048	0,032	0,063	0,063	0,155
Technological Capacity	0,059	0,030	0,074	0,030	0,030	0,155
Post- sales services	0,036	0,036	0,054	0,054	0,054	0,155
Lead time	0,055	0,055	0,055	0,055	0,055	0,155
Proximity	0,031	0,031	0,031	0,156	0,156	0,026
Delivery on time and good condition	0,049	0,050	0,050	0,049	0,033	0,155
Result	0,055	0,051	0,057	0,058	0,056	

Table 16 Wooden pallets suppliers' ranking numbers

Current contract?	Wooden pallets suppliers	AHP result	Ranking
NO	**X5**	0,058	**1**
YES	**X4**	0,057	**2**
NO	**X6**	0,056	**3**
YES	**X2**	0,055	**4**
YES	**X3**	0,051	**5**

Table 17 Wooden pallets suppliers' final ranking

In this case, the explanation of the no- match is not very difficult. The reason why company is not working anymore with suppliers **X5** and **X6** is that they are both suppliers that sell wooden pallets and the company decided that is was not profitable anymore for them to buy those materials. So, they decided to rent them, and that is the business of suppliers

X4, **X2** and **X3**. The reasons why they changed their mind in this operation are out of the thesis scope and we did not ask for them. We could recommend here to rescind the contract with supplier **X3**; it is not a strong one and we think it could be worthwhile to take other options into consideration.

2. Services:

Cleaning	X7	X8	X9	X10	WEIGHTS
Financial status	0,121	0,061	0,152	0,121	0,072
Quality	0,086	0,114	0,086	0,086	0,193
Past experience	0,083	0,083	0,083	0,083	0,072
Communication	0,083	0,083	0,083	0,083	0,032
Flexibility	0,063	0,063	0,063	0,063	0,072
Technological capacity	0,100	0,100	0,100	0,100	0,072
Post- sales services	0,097	0,097	0,097	0,097	0,072
Lead time	0,100	0,100	0,100	0,100	0,193
Proximity	0,053	0,053	0,053	0,053	0,029
Delivery on time and good condition	0,103	0,102	0,103	0,103	0,193
Result	0,093	0,094	0,095	0,093	

Table 18 Cleaning services suppliers' ranking numbers

Current contract?	Cleaning services suppliers	AHP result	Ranking
NO	**X9**	0,095	**1**
NO	**X8**	0,094	**2**
NO	**X7**	0,093	**3**
YES	**X10**	0,093	**4**

Table 19 Cleaning services suppliers' final ranking

According to Table 19, the selection made by AHP (**X9**) does not match with the current company selection (**X10**). We went through a deeper analysis to see how good **X9**, **X8**, **X7** and **X10** satisfy the company requirements: according to Table 71 in Appendix II, those are Quality, Lead time and Delivery.

	Quality	Lead time	Delivery on time and good condition
X7	3	3	4
X8	4	3	4
X9	3	3	4
X10	3	3	4
	Quality	Lead time	Delivery on time and good condition
X7	√	√	√
X8	√	√	√
X9	√	√	√
X10	√	√	√

Table 20 Cleaning services suppliers' evaluation. Focused study of most relevant requirements satisfaction

In Table 20 it is shown that all suppliers satisfy properly the most important requirements for company so, coming back to the extra information in the survey, something interesting was found in it. The lack of resources was written as a main weakness of supplier **X8** and the distance to the plant was also pointed out as a constraint for supplier **X9**. This information was highlighted in the survey so probably; they are reasons why the company decided to not to work with those two suppliers anymore despite they are the strongest ones according to the grading.

Regarding suppliers **X7** and **X10** both have the same punctuation in the result of the AHP method (Table 65 in Appendix) and it has been remarked how good are them in implementing the services as their main strengths, so either of them is perfectly qualified to make the job and we have no further information to make a decision between them.

Transport	X1	X2	X3	X4	X5	X6	WEIGHTS
Financial status	0,121	0,061	0,121	0,061	0,121	0,061	0,072
Quality	0,114	0,114	0,114	0,114	0,114	0,058	0,193
Past experience	0,139	0,139	0,055	0,055	0,139	0,139	0,072
Communication	0,111	0,111	0,111	0,111	0,111	0,111	0,032
Flexibility	0,156	0,156	0,156	0,156	0,063	0,063	0,072
Technological capacity	0,100	0,100	0,100	0,100	0,100	0,100	0,072
Post- sales services	0,129	0,097	0,097	0,097	0,097	0,097	0,072
Lead time	0,100	0,100	0,100	0,100	0,100	0,100	0,193
Proximity	0,053	0,105	0,053	0,053	0,263	0,263	0,029
Delivery on time and good condition	0,051	0,128	0,128	0,077	0,103	0,103	0,193
Result	0,103	0,112	0,109	0,095	0,110	0,094	

Table 21 Transport services suppliers' ranking numbers

Current contract?	Transport services suppliers	AHP result	Ranking
YES	**X2**	0,112	**1**
YES	**X5**	0,110	**2**
YES	**X3**	0,109	**3**
YES	**X1**	0,103	**4**
NO	**X4**	0,095	**5**
YES	**X6**	0,094	**6**

Table 22 Transport services suppliers' final ranking

In transport services our solution is very similar to the one that the company adopted. There is just a discrepancy at the end of the final ranking where the supplier they are not working with, **X4**, goes ahead of the supplier **X6**. Let us try to find some explanation for that. First, we are going to see how well these two suppliers satisfy the most important factors for the company in this group:

	Quality	Lead time	Delivery on time and good condition
X4	4	3	3
X6	2	3	4
	Quality	Lead time	Delivery on time and good condition
X4	√	√	√
X6	×	√	√

Table 23 Transport services suppliers' evaluation. Focused study of most relevant requirements satisfaction

Still we can see that **X6** is worse than **X4**. But, coming back to the extra information in the survey, we found that one of the main weaknesses of **X4** is that the overall quality of the service is not good, so that is why they probably do not work with it. Instead of that, they contract a supplier that may not have the best characteristics but does its job properly. At this point, counting on the information we have, we would recommend to not have a contract with supplier **X6** and look for other options in the market that could satisfy the requirements better.

3. Equipment

Industrial machinery	X1	X2	X3	X4	X5	WEIGHTS
Financial status	0,308	0,154	0,154	0,154	0,231	0,138
Quality	0,250	0,100	0,250	0,250	0,150	0,111
Past experience	0,208	0,208	0,167	0,208	0,208	0,035
Communication	0,190	0,190	0,143	0,238	0,238	0,089
Flexibility	0,167	0,166	0,167	0,167	0,333	0,188
Technological capacity	0,235	0,235	0,176	0,235	0,118	0,089
Post- sales services	0,154	0,231	0,231	0,231	0,154	0,151
Lead time	0,111	0,111	0,111	0,111	0,555	0,089
Proximity	0,211	0,211	0,211	0,211	0,158	0,019
Delivery on time and good condition	0,211	0,211	0,211	0,211	0,158	0,090
Result	0,182	0,157	0,167	0,177	0,240	

Table 24 Industrial machinery suppliers' ranking numbers

Current contract?	Industrial machinery suppliers	AHP result	Ranking
YES	**X5**	0,240	**1**
NO	**X1**	0,182	**2**
NO	**X4**	0,177	**3**
NO	**X3**	0,167	**4**
NO	**X2**	0,157	**5**

Table 25 Industrial machinery suppliers' final ranking

In this case our solution is the same as the one the company adopted. Supplier **X5** is the best by far in the available options.

The main conclusions that can be pointed out from the application of this method is that it is a very accurate approach to carry out a supplier selection. We have obtained matches in most of the cases but there have been also some exceptions.

We have to consider that this is still a method that makes calculations but does not include the "personal touch". It is very good to make a first draft of the final decision but it is not reliable at 100%.

This has been figured out because of trying to find an explanation to the differences we found between the solution obtained from the method and the one adopted from the company. Finally, by applying some filters, combining other methods and counting on extra information we were able to understand why the company made the actual decision in most of the cases.

The evidence of this are the anomalies and discrepancies we have met in this study. They have appeared because the decision- maker of the company has taken into consideration experiences, other external factors (transport agency that was always delayed) and personal opinions.

The method by itself is very accurate but our final recommendation is to combine it with another tool in order to obtain the most optimal combination of suppliers.

The next table summarizes the solutions got by AHP:

	Current	*AHP*	*AHP + extras*
Pre- shaped bottles	X1	X1	X1
Caps	X18	X13	X18
Labels	X19	X10	X19
Wooden Pallets	X2 X3 X4	X2 X3 X4	X2 X4
Cleaning s.	X10	X9	X7 or X10
Transport s.	X1 X2 X3 X5 X6	X1 X2 X3 X4 X5	X1 X2 X3 X5
Industrial Machinery	X5	X5	X5

Table 26 Portfolio solution by AHP

4.2   Selecting supplier portfolio based on checklists

The checklists method has been applied as methodology 2. The main goal we expect to achieve by applying this method is to see which suppliers achieve the most of the company requirements and therefore which are the best ones.

This method and the previous set up criteria allowed us to count how many of these requirements the suppliers fulfil: they are written in the las row "sum" in Tables 27, 28, 30, 32, 33, 34 and 36. Starting from Tables 67, 68, and 69 the results we obtained are:

1. Raw materials:

PET Pre- shaped bottles	X1	X7	X8	X9
Current contract?	YES	NO	NO	NO
Financial status	1	0	1	1
Quality	1	1	0	1
Past experience	1	1	1	1
Communication	1	1	1	1
Flexibility	1	0	1	0
Technological capacity	1	1	1	1
Post- sales services	1	1	1	0
Lead time	1	1	1	1
Proximity	0	0	0	0
Delivery on time and good condition	1	1	1	1
Sum	9	7	8	7

Table 27 Pre- shaped bottles suppliers' satisfaction level

According with the number of satisfied requirements in last column, the best supplier is **X1** and it is the one the company is working with at the moment so there is a match in this result. In this case this method also provides a clear solution.

Caps	X12	X13	X14	X15	X16	X17	X18
Current contract?	NO	NO	NO	NO	NO	NO	YES
Financial status	1	0	1	1	1	1	1
Quality	1	1	1	0	0	0	1
Past experience	1	0	0	1	1	1	1
Communication	1	1	1	1	1	1	1
Flexibility	1	1	1	0	1	0	1
Technological capacity	0	1	1	1	1	1	1
Post- sales services	1	1	1	1	1	1	0
Lead time	0	1	1	1	0	1	1
Proximity	1	0	0	0	0	0	0
Delivery on time and good condition	1	1	1	1	1	1	1
Sum	8	7	8	7	7	7	8

Table 28 Caps suppliers' satisfaction level

In Table 28, the sum row shows us that the best suppliers are: **X12**, **X14** and **X18**. The company decision (**X18**) is still included in the solution we obtained but this method does not allow us to choose one of them, though. Let us see then which ones of these three satisfy the most relevant factors for raw materials (Quality, Flexibility, Technological capacity, Lead time and Delivery):

Caps	X12	X14	X18
Current contract?	NO	NO	YES
Quality	1	1	1
Flexibility	1	1	1
Technological capacity	0	1	1
Lead time	0	1	1
Delivery on time and good condition	1	1	1
Sum	3	5	5

Table 29 Caps suppliers' evaluation. Focused study of most relevant requirements satisfaction

Now the decision has to be made between **X14** and **X18** and, due to the current product the company is manufacturing at the moment, they do not need crown caps anymore, whose supplier is **X14**, the final decision would be **X18**.

Labels	X10	X11	X19
Current contract?	NO	NO	YES
Financial status	1	0	1
Quality	1	1	0
Past experience	1	1	1
Communication	1	1	1
Flexibility	1	1	1
Technological capacity	1	1	1
Post- sales services	1	1	1
Lead time	1	1	0
Proximity	0	0	0
Delivery on time and good condition	0	0	1
Sum	8	7	7

Table 30 Labels suppliers' satisfaction level

In this case, the best supplier we obtained is **X10**, the same we obtained with AHP method. There is no match with the company in this case. As we explained before, the company decided to withdraw the contract with **X10** because they do business by means of a transport agency and this agency delivers the product always late. So, that leaves us **X11** and **X19** as potential suppliers, both with 7 satisfied requirements. Let see how many of the most important requirements (Quality, Flexibility, Technological capacity, Lead time and Delivery) these suppliers fulfil:

Labels	X11	X19
Current contract?	NO	YES
Quality	1	0
Flexibility	1	1
Technological capacity	1	1
Lead time	1	0
Delivery on time and good condition	0	1
Sum	4	3

Table 31 Labels suppliers' evaluation. Focused study of most relevant requirements satisfaction

According to Table 31 the most qualified supplier is **X11**, which lead us to recommend the company to make business with supplier **X11** instead of **X19,** by using this method.

Wooden pallets	X2	X3	X4	X5	X6
Current contract?	YES	YES	YES	NO	NO
Financial status	1	1	1	0	1
Quality	1	1	1	1	1
Past experience	1	1	1	1	1
Communication	1	1	1	1	1
Flexibility	1	1	0	1	1
Technological capacity	1	0	1	0	0
Post- sales services	0	0	1	1	1
Lead time	1	1	1	1	1
Proximity	0	0	0	1	1
Delivery on time and good condition	1	1	1	1	0
Sum	8	7	8	8	8

Table 32 Wooden pallets suppliers' satisfaction level

According with Table 32, the best suppliers are **X2**, **X4**, **X5** and **X6**. The company does not have contract with **X5** and **X6** since they are renting wooden pallets instead of buying. That is why the company has contract with **X2** and **X4** that also are among the best supplier we selected by this method. **X3** satisfies one less requirement than the others so we would recommend here to look for other options.

2. Services

Cleaning services	X7	X8	X9	X10
Current contract?	NO	NO	NO	YES
Financial status	1	0	1	1
Quality	1	1	1	1
Past experience	1	1	1	1
Communication	1	1	1	1
Flexibility	0	0	0	0
Technological capacity	1	1	1	1
Post- sales services	1	1	1	1
Lead time	1	1	1	1
Proximity	0	0	0	0
Delivery on time and good condition	1	1	1	1
Sum	8	7	8	8

Table 33 Cleaning services suppliers' satisfaction level

Table 33 shows us that the best cleaning services suppliers are: **X7**, **X9** and **X10**, and we know from the last method that all of them satisfy the most important requirements. We have extra information in the survey to exclude **X9** because the distance to the plant has been pointed out as a main weakness. So, this leaves in the group suppliers **X7** and **X10** and the one the company is working currently is included in it (**X10**), but the lack of information and this method itself do not allow us to make a decision between them or justify the company decision.

Transport services	X1	X2	X3	X4	X5	X6
Current contract?	YES	YES	YES	NO	YES	YES
Financial status	1	0	1	0	1	0
Quality	1	1	1	1	1	0
Past experience	1	1	0	0	1	1
Communication	1	1	1	1	1	1
Flexibility	1	1	1	1	0	0
Technological capacity	1	1	1	1	1	1
Post- sales services	1	1	1	1	1	1
Lead time	1	1	1	1	1	1
Proximity	0	0	0	0	1	1
Delivery on time and good condition	0	1	1	1	1	1
Sum	8	8	8	7	9	7

Table 34 Transport services suppliers' satisfaction level

In this case, Table 34 shows us that the best supplier is **X5**, which the company is working with currently. So there is correlation so far between our solution and the present. The second group of best suppliers is: **X1**, **X2** and **X3**. The organization is also working with them at the moment so there is still match between solutions. The worst suppliers for

transport services are: **X4** and **X6**. The recommendation here would be to remove **X6** from our current suppliers and since it has been graded as the worst one.

Let us take a look to what happens if we evaluate them just regarding the most important factors for the services group. Those factors are, according to Table 71, Quality, Lead time and Delivery:

Transport services	X1	X2	X3	X4	X5	X6
Current contract?	YES	YES	YES	NO	YES	YES
Quality	1	1	1	1	1	0
Lead time	1	1	1	1	1	1
Delivery on time and good condition	0	1	1	1	1	1
Sum	2	3	3	3	3	2

Table 35 Transport services suppliers' evaluation. Focused study of most relevant requirements satisfaction

According to Table 35, the most suitable suppliers are **X2**, **X3**, **X4** and **X5** which matches almost 100% with company decision since **X4** has as a main weakness that the overall quality of the services is not good. The weakest suppliers are **X1** and **X6** again. The recommendation here would be to withdraw contracts with them.

3. Equipment

Industrial machinery	X1	X2	X3	X4	X5
Current contract?	NO	NO	NO	NO	YES
Financial status	1	0	0	0	1
Quality	1	0	1	1	1
Past experience	1	1	1	1	1
Communication	1	1	1	1	1
Flexibility	0	0	0	0	1
Technological capacity	1	1	1	1	0
Post- sales services	1	1	1	1	1
Lead time	0	1	1	1	0
Proximity	0	0	0	0	0
Delivery on time and good condition	1	1	1	1	1
Sum	7	6	7	7	7

Table 36 Industrial machinery suppliers' satisfaction level

Here, Table 36 show us that the best suppliers are: **X1**, **X3**, **X4** and **X5**. The one the company is working with at the moment **X5** belongs to that group, so there is correlation with the solution so far. Let see which of those suppliers satisfy the most important requirements for industrial machinery group. According to Table 72 in appendix II they are Flexibility and Post- sales services:

Industrial machinery	X1	X3	X4	X5
Current contract?	NO	NO	NO	YES
Flexibility	0	0	0	1
Post- sales services	1	1	1	1
Sum	1	1	1	2

Table 37 Industrial machinery suppliers' evaluation. Focused study of most relevant requirements satisfaction

So, by applying this method there is match between the solution and the company decision. Supplier **X5** is the most suitable one.

The main conclusion we can say about this method it is that it is not a decision- making method at all. It could help to discard some suppliers, the ones that obtain less punctuation (less satisfied requirements) but it is not able to select just one unless there is a really good one, like the selected one in pre- shaped bottles or industrial machinery-

AHP is capable of elaborate a ranking and the most of the time there is a clear first place that indicates us which is the best one but this method just can help to reduce the potential list of supplier and can be a really useful supporting- decision tool.

In order to justify and understand the company decisions, it has been not enough by applying the method by itself. As it happened in the AHP application, we have had to apply some filters, combine methods and extra information to reach specific points.

The next table shows the solution obtained by checklists:

	Current	*Checklists*	*Checklists + extras*
Pre- shaped bottles	X1	X1	X1
Caps	X18	X12 or X18	X18
Labels	X19	X10	X11
Wooden Pallets	X2 X3 X4	X2 X4	X2 X4
Cleaning s.	X10	X7 or X9 or X10	X7 or X10
Transport s.	X1 X2 X3 X5 X6	X1 X2 X3 X5	X2 X3 X5
Industrial Machinery	X5	X1 or X3 or X4 or X5	X5

Table 38 Portfolio solution by Checklists

4.3   Selecting supplier portfolio based on mapping

As third methodology, the suppliers have been mapped regarding the two most important factors of the group they belong according to Tables 70, 71 and 72.

The actual suppliers should be place in the **upper part on the right**; then the requirements would be satisfied according to company necessities.

Starting from Tables 44, 45, 46, 47, 48, 49 and 50 where the suppliers' strength was evaluated regarding each dimension, the maps result:

1. Raw materials:
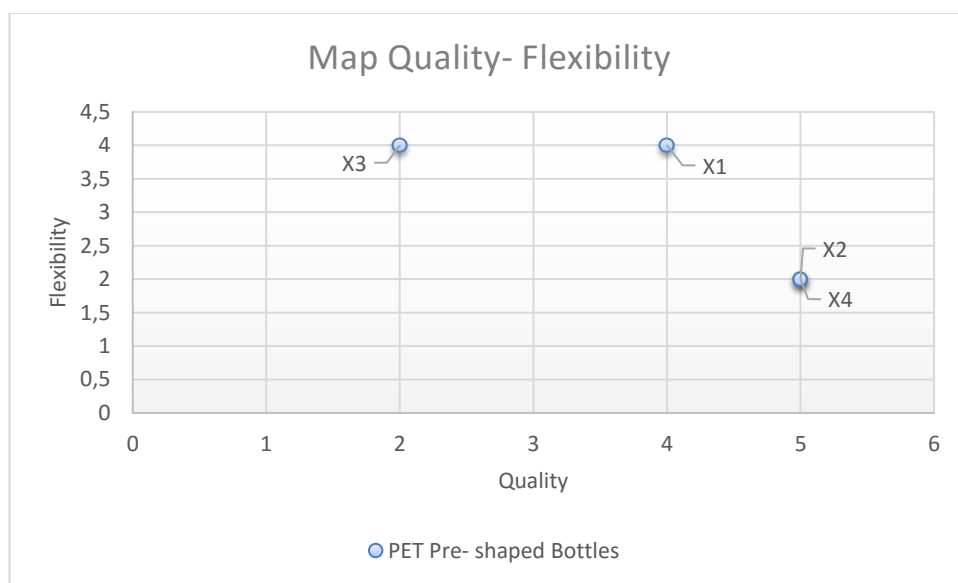
Figure 10 Map Quality-Flexibility: Pre- shaped bottles

The company has current contract with **X1**, which is the only one pre- shaped bottles supplier placed in the proper area of the chart. There is coincidence between company the decision and what we obtained applying the method.
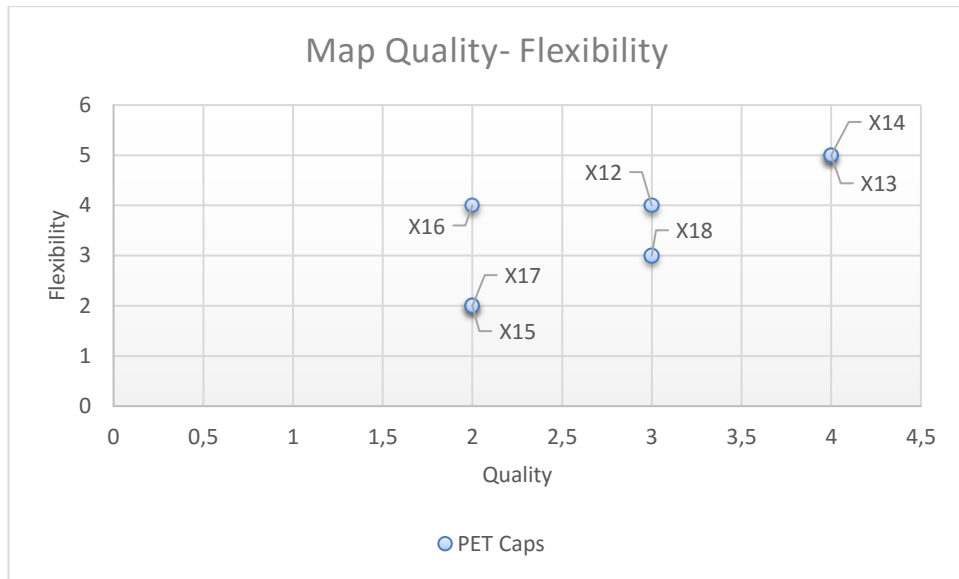
Figure 11 Map Quality-Flexibility: Caps

The company has contract with supplier **X18**, which is place in the limit of the area, but still inside which makes it to coincide with company decision. Although, according to the map, the best suppliers to work with are **X14** and **X13**. We know the company does not have a contract anymore with **X14** because of the type of cap they manufacture (crown caps) and we know, because of survey, that **X13** is located far away from company and this was pointed out was one of the main weaknesses. Regarding **X12** and **X18**, we cannot make a decision with this method or the information we have so, both are suitable.
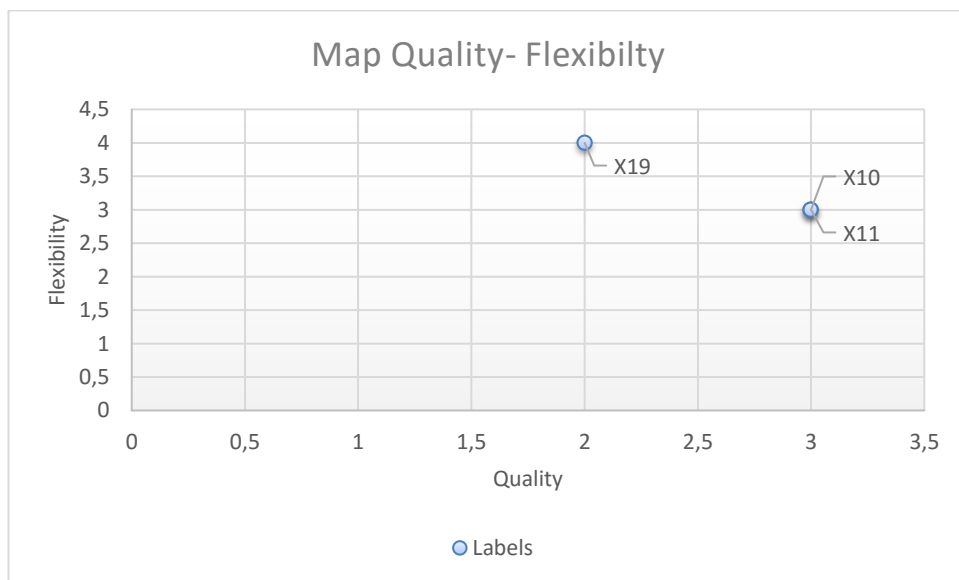
Figure 12 Map Quality-Flexibility: Labels

The two suppliers we have for Labels could possibly be in contract with the company are **X10** and **X11** since they are place in the correct area. We know the company discard **X10**

because they work with a transport agency that is always late in the deliveries. So, according to this method the most appropriate is **X11**. However, the company is actually working with **X19**.
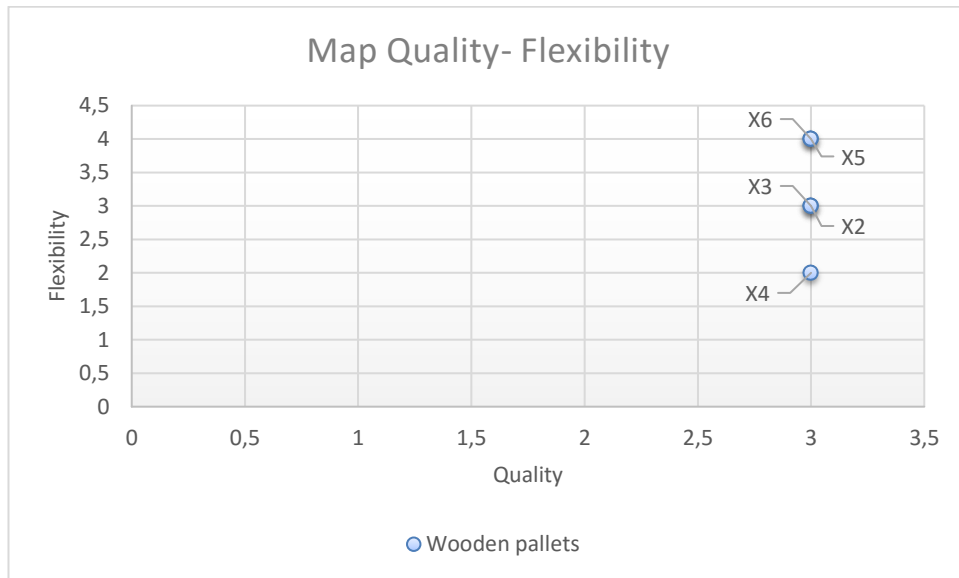
Figure 13 Map Quality-Flexibility: Wooden pallets

Figure 13 shows that the company could work with any of **X2**, **X3**, **X5**, and **X6**. All of them are placed in the right zone in the chart. The company has contract at the moment with: **X2**, **X3** and **X4**. **X5** and **X6** are excluded since the company is not buying wooden pallets anymore, they are renting them. **X2**, **X3** and **X4** are wooden pallets renting suppliers. According to this method the recommendation would be to work with **X2** and **X3** but not with **X4**.

   2. Services:
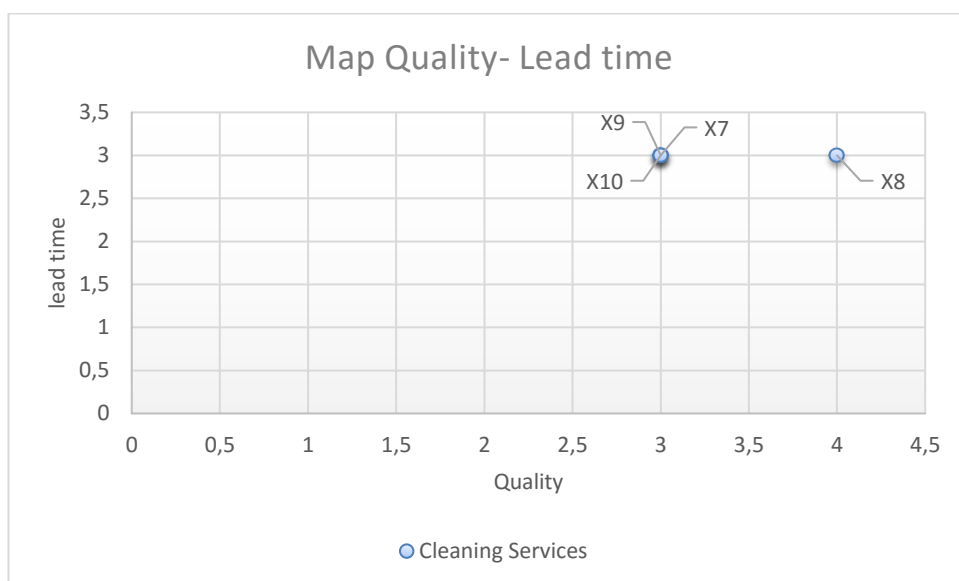
Figure 14 Map Quality-Lead time: Cleaning services

Figure 14 shows us that the company could partner with any of those represented in the chart, since all of them are included in the proper area, although the best place belongs to **X8**. But the additional info allows us to discard suppliers **X9** and **X8** because of the distance to the plant and the lack of resources respectively where pointed out as main disadvantages. This leaves us **X10** and **X7** as potential suppliers. Currently, the company has contract with **X10**.
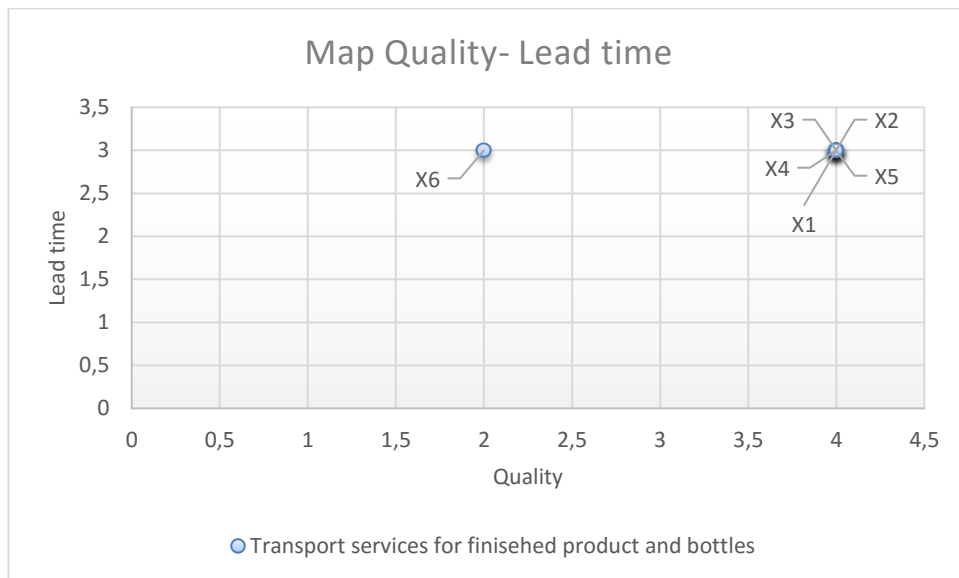
Figure 15 Map Quality-Lead time: Transport services

In Figure 15, we can see that suppliers **X1**, **X2**, **X3**, **X4** and **X5** satisfy the company requirements at the same level so, any of them could be appropriated for the job. However, the company has contract with **X1**, **X2**, **X3**, **X5** and **X6**. The organization does not have contract anymore with **X4** since they are not satisfied with the service they received; which limits our solution to **X1**, **X2**, **X3** and **X5**. Our recommendation here would be to withdraw the contract with **X6**.

3. Equipment:
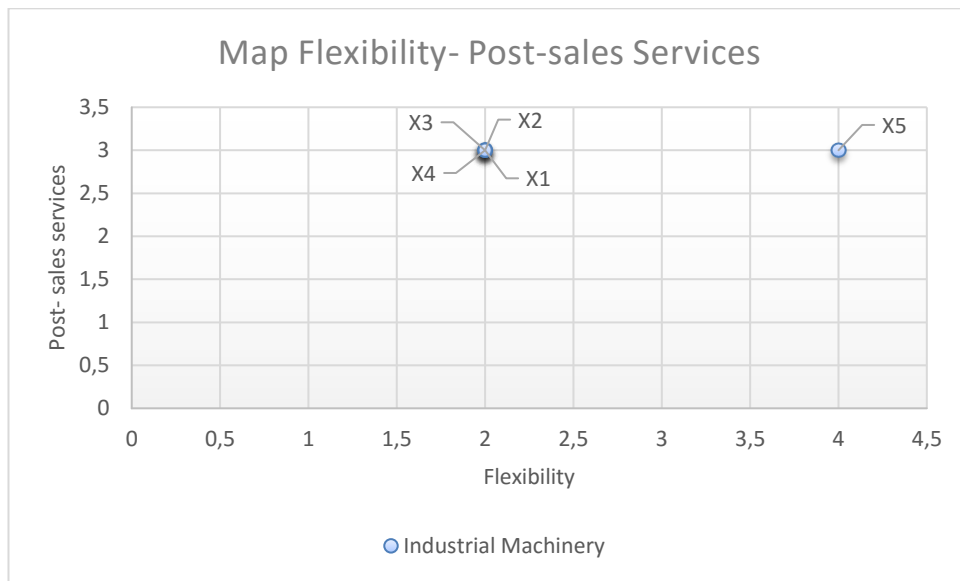
Figure 16 Map Flexibility -Post-sales services: Industrial machinery

In this case, there is a match between the solution obtained from the method and the company decision. According to Figure 16, the only suitable supplier is **X5** and it is the one the organization has contract with at the moment.

The main conclusion about this method is that, as the checklists one, is not a decision-making one. It is very helpful to support other methods but not to make specific decisions. It can help us to discard some suppliers and just consider the most suitable ones but it is necessary the application of other tools to make a clean and concise selection.

In this application we were not able to apply the filter we did in the other two methodologies since the maps themselves were already based on the most important characteristics for the company in each group. However, thanks to the extra information in the survey we were able to make some recommendations.

The next table shows the final solution obtained by mapping:

	Current	Mapping	Mapping + extras
Pre- shaped bottles	X1	X1	X1
Caps	X18	X13	X12 or X18
Labels	X19	X10 or X11	X11
Wooden Pallets	X2 X3 X4	X2 X3	X2 X3
Cleaning s.	X10	X8	X7 or X10
Transport s.	X1 X2 X3 X5 X6	X1 X2 X3 X4 X5	X1 X2 X3 X5
Industrial Machinery	X5	X5	X5

Table 39 Portfolio solution by mapping

4.4   Cross- method comparison

The next tables, Table 40 and 41, show a summary of the solutions we got from the three methodologies and the one the company adopted. The solutions obtained from the methods are shown the way we got them without applying any additional filter or taking into account any additional information.

Just **X14** from raw materials (Crown caps supplier) and **X5** and **X6** from raw materials (wooden pallets selling suppliers) have been discard since the business these suppliers are offering does not fit with current company activities.

	Current	AHP	Checklists	Mapping
Pre- shaped bottles	X1	X1	X1	X1
Caps	X18	X13	X12 or X18	X13
Labels	X19	X10	X10	X10 or X11
Wooden Pallets	X2 X3 X4	X2 X3 X4	X2 X4	X2 X3
Cleaning s.	X10	X9	X7 or X9 or X10	X8
Transport s.	X1 X2 X3 X5 X6	X1 X2 X3 X4 X5	X1 X2 X3 X5	X1 X2 X3 X4 X5
Industrial Machinery	X5	X5	X1 or X3 or X4 or X5	X5

Table 40 Comparison of solutions: the use of single methods vs current situation

	AHP	Checklists	Mapping
Pre- shaped bottles	√	√	√
Caps	×	√	×
Labels	×	×	×
Wooden Pallets	√	×	×
Cleaning s.	×	√	×
Transport s.	×	×	×
Industrial Machinery	√	√	√

Table 41 Matches and no matches between methods and company

The next table represents the solution we got applying he methods **plus additional information** and other methodologies:

X14 from raw materials (Crown caps supplier) and **X5** and **X6** from raw materials (wooden pallets selling suppliers) have been also discarded here.

	Current	AHP	Checklists	Mapping
Pre- shaped bottles	X1	X1	X1	X1
Caps	X18	X18	X18	X12 or X18
Labels	X19	X19	X11	X11
Wooden Pallets	X2 X3 X4	X2 X4	X2 X4	X2 X3
Cleaning s.	X10	X7 or X10	X7 or X10	X7 or X10
Transport s.	X1 X2 X3 X5 X6	X1 X2 X3 X5	X2 X3 X5	X1 X2 X3 X5
Industrial Machinery	X5	X5	X5	X5

Table 42 Comparison of solutions: the use of methods + extras vs current situation

	AHP	Checklists	Mapping
Pre- shaped bottles	√	√	√
Caps	√	√	√
Labels	√	×	×
Wooden Pallets	×	×	×
Cleaning s.	√	√	√
Transport s.	×	×	×
Industrial Machinery	√	√	√

Table 43 Matches and no matches between methods + additional tools and company

These four tables above show us something very curious. According with the results we got, if a company sets up its portfolio just using one single method, it will obtain almost the same results no matter which method they use. Table 41 shows that the three methods got just few matches each with the current company selection and two of them are the same. This probably means that in those two products (pre- shaped bottles and industrial machinery in this case) there is a really good supplier that stands out over the others.

However, by combining several methods and taking into account more factors and extra information, we can see that the solution reached through each method is very approximate to the current one. Specially, the AHP method has obtained almost a 100% of matches when we did a further investigation among the potential suppliers.

Also, the mapping, which counts with less factors to obtain the solution than the checklists, has obtained better results than them. This means that the company really gives priority to the 2 or 3 more important factors in the group, leaving the rest in a second place.

There are three groups of suppliers in conflict with the current solution (Table 43): Labels, wooden pallets and transport services suppliers.

The first recommendation for the company to optimize the supplier portfolio would be to withdraw the contract with supplier **X6** from transport services. It does not achieve the company requirements and it has been out of the final selection in each of the three methodologies.

Concerning wooden pallets suppliers, two methods pointed out that **X3** does not satisfy the requirements of the company and other obtained **X4** as the weakest one; so we would recommend here to investigate this area and make a decision in order to optimize this group of suppliers.

Regarding the labels group, AHP pointed out the same supplier as the most suitable one, but the other two methods do not support that decision; methodologies 2 and 3 identify **X11** as the most appropriate. Our final recommendation is that this area needs further investigation as well in order to balance the existing portfolio and check if the current supplier **X19** is indeed the best one.

The company stated that they need three suppliers for each item, as a minimum. Despite of this, Table 42 shows some solutions which do not include more than three suppliers (company's policy). We just knew, beforehand, one current supplier in some groups, so we are not able to recommend more suppliers because we do not have information about the other contracts. There are other solutions, in which we have reduced the number of suppliers because we considered two main findings: there are clear suppliers that do not satisfy company's requirements or, there are some suppliers that are included in some methods but are out of others, which means to us that this specific group needs further study and needs to be rebalanced.

5. CONCLUSIONS

The thesis focused on the main research question: What is an optimal supplier portfolio for a water bottling plant? The investigation started by going through the main areas connected with supplier portfolio. A literature review was elaborated about purchasing portfolio, supplier selection, supplier relationships and optimization. All these previous studies and philosophies leaded us to know what are the most important issues when managing a portfolio and how to deal with them. Those articles and books also included a wide variety of methodologies to make this management process easier. Three methodologies were chosen in order to apply them to a company case. The company is a water bottling plant located in Spain. Finally, we were able to identify the weaknesses of the portfolio and make some recommendations to optimize it.

Supplier portfolio makes special emphasis in the importance of managing suppliers carefully when the number of purchased items is large (Kraljic, 1983). The author insists in dealing with the amount of risk the company could run, the number of suppliers the company has, managing relationships with suppliers properly and also, in looking into the advantages the company could get some benefit and checking if all of them are being exploited. That is why Kraljic introduces a matrix in order to be able to classify the items considering external and internal characteristics at the same time. The aim of this matrix is to set up strategies to manage critical suppliers.

Then, Olsen and Ellram (Olsen and Ellram, 1997) make reference in their article to one of the main issues that were named by Kraljic: Supplier relationships. They say that relationships are the main issue of portfolio management. In their article they use an approach of Kraljic's matrix to manage relationships with suppliers.

The literature about supplier selection is about the criteria the authors claimed as the most important when partnering suppliers. Taking into account several articles and the company's preferences we selected 10 criteria to develop this study: Financial status, Communication, Technological capacity, Flexibility, Lead times, Delivery, Quality, Past- experience, Post- sales services and Proximity.

Finally, we wanted to take a look to literature about optimization. Some examples and approaches are shown in this section. In addition, the main implications it has to company are written. Some of them are related with portfolio management. For instance, they have in common that selected projects and suppliers both need to be aligned with company strategy and also, some methods could be used in both management processes.

In the company case a survey instrument was send to them. The survey included questions for the company about basic information from 30 suppliers and the evaluation from the three main groups in which they are included: raw materials, services and equipment. The

suppliers were evaluated according to 10 pre- defined dimensions and then, those 10 dimensions were prioritized inside each group. Finally, the company was collaborating actively and we got data from 34 suppliers by surveys and, extra information about the organization and the respondent by phone interviews with a contact they facilitated to us. Tables 44, 45, 46, 47, 48, 49 and 50 summarize the individual evaluation of suppliers and Table 51 shows the prioritization of factors in each main group. By having information about 34 suppliers from three different groups, all of them belonging to the supplier base, we are able to study the supplier portfolio as a whole and try to find an answer to our main research question.

The research was a success. Some supplier portfolio weaknesses were identified by applying the three methods. In addition, we were able to make some findings regarding the methodologies used as well. The data analysis was carried out by applying three different methods that were chosen because of their diversity: AHP, Checklists and Portfolio maps. Firstly, each methodology was applied to the data by following only and exclusively the theory and the results were visibly very different that the ones the company adopted. So, we went through the data again, but this time, further investigation was made. Starting from the results we got from the first application, the number of potential suppliers was reduced, and taking into account more dimensions and extra information, we got a second supplier selection (one from each methodology) and these ones were almost the same the company is using currently.

The company's current supplier portfolio has been optimized and we have final recommendations: Firstly, the recommendation is to withdraw the contract with the **transport supplier** named as "**X6**" belonging to the services group. In both analytical studies, by single methodologies and the combined ones, this supplier has been pointed out as the weakest one of the group since is does not achieve company's requirements in most of the dimensions. The second recommendation is that the company needs to study the **wooden pallets suppliers** group. Two different results have been obtained regarding suppliers **X3** and **X4**. **X3** has been classified as one of the weakest one by two methods while **X4** has been classified as the weakest one by the third one; so, we consider that this area needs further investigation in order to optimize the whole supplier portfolio. Regarding the **labels suppliers**, two methodologies pointed out supplier **X11** as the best, instead of the current supplier **X19**. We also would recommend here to investigate if the current solution is the most suitable one.

Regarding the methodologies, we found that applying them just by themselves may not lead the decision- makers to achieve a proper solution. The results we obtained here with the single methods were not very similar to the ones the company adopted (Tables 40 and 41). But, by applying them in combination, the solutions we got are very similar to the company's one (Tables 42 and 43) which lead us to think that this is the correct way to carry out a decision- making process. So, here it is answered one of the future investigations named by Saaty. The author included in his article the question: "Can the general

optimization problem be solved using the AHP?" (Saaty, 1987); and the answer is clearly: No, it cannot.

Regarding the factors, we also found that, just taking into account the ones that are supposed to be the most important ones, could lead in making the wrong decisions. The accurate solution we got, was thanks to consider more factors that the ones marked as the most relevant. Experience and opinions are also important when selecting suppliers, mathematics and tools can help us but definitely, the "human touch" has a leading role in this process.

There are some future further investigations that could be done based on this study. Some of the were included in Saaty's article:

- Extrapolation of this process to be applied in more industries or businesses.
- Develop psychological studies to taking into account people's strength of feeling and represent them by numerical scales (Saaty, 1987).
- Relate AHP method with risk analysis (Saaty, 1987).
- Gather information about how satisfied are costumers with AHP solutions (Saaty, 1987).

REFERENCES

Abraham, A., Jain, L. and Goldberg, R. (2005). *Evolutionary multiobjective optimization*. New York: Springer.

Ansari, A. and Modarress, B. (1988). JIT purchasing as a quality and productivity centre. *International Journal of Production Research*, 26(1), pp.19-26.

Ben-Tal, A., Golany, B., Nemirovski, A. and Vial, J. (2005). Retailer-Supplier Flexible Commitments Contracts: A Robust Optimization Approach. *Manufacturing & Service Operations Management*, 7(3), pp.248-271.

Chen, S., Lee, H. and Wu, Y. (2008). Applying ANP approach to partner selection for strategic alliance. *Management Decision*, 46(3), pp.449-465.

Çebi, F. and Bayraktar, D. (2003). An integrated approach for supplier selection. *Logistics Information Management*, 16(6), pp.395-400.

Choi, T. and Hartley, J. (1996). An exploration of supplier selection practices across the supply chain. *Journal of Operations Management*, 14(4), pp.333-343.

Cooper, R., Edgett, S. and Kleinschmidt, E. (2001). Portfolio management for new product development: results of an industry practices study. *R&D Management*, 31(4), pp.361-380.

Creswell, J. (2003). *Research design*. Thousand Oaks, Calif.: Sage Publications.

Dickson, G. W. (1966) "An analysis of vendor selection: systems and decisions". *Journal of purchasing,* Vol. 1, N. 2, pp: 5- 17.

Dolan, J. (2008). Shared decision-making – transferring research into practice: The Analytic Hierarchy Process (AHP). *Patient Education and Counseling*, 73(3), pp.418-425.

Efbw.eu. (2016). *EFBW: Key statistics*. [online] Available at: http://www.efbw.eu/index.php?id=90 [Accessed 12 Apr. 2016].

Feng, C., Wang, J. and Wang, J. (2001). An optimization model for concurrent selection of tolerances and suppliers. *Computers & Industrial Engineering*, 40(1-2), pp.15-33.

Fooddrinkeurope.eu, (2016) a. [online] Available at: http://www.fooddrinkeurope.eu/uploads/publications_documents/Data_and_Trends_2014-20152.pdf [Accessed 2 Apr. 2016].

Gelderman, C. and Semeijn, J. (2006). Managing the global supply base through purchasing portfolio management. *Journal of Purchasing and Supply Management*, 12(4), pp.209-217.

Gelderman, C. and Van Weele, A. (2003). Handling measurement issues and strategic directions in Kraljic's purchasing portfolio model. *Journal of Purchasing and Supply Management*, 9(5-6), pp.207-216.

Grandviewresearch.com. (2016). *Global Bottled Water Market - World Bottled Water Market Size, Trends, Analysis And Segment Forecasts To 2020 - Bottled Water Industry Research, Outlook, Application, Product, Share, Growth, Key Opportunities, Dynamics, Analysis, Bottled Water Report - Grand View Research Inc*. [online] Available at: http://www.grandviewresearch.com/industry-analysis/bottled-water-market [Accessed 11 Apr. 2016].

Kraljic, P. (1983). *Purchasing must become supply management*. Boston, MA: Harvard College.

Ly`es Benyoucef, Hongwei Ding, Xiaolan Xie (2003). *Supplier Selection Problem: Selection Criteria and Methods*. [Research Report] RR-4726, INRIA. 2003, pp.38. <inria-00071860>

Moser, R. (2007). *Strategic purchasing and supply management*. Wiesbaden: Dt. Univ.-Verl.

Nadia Villa, M. (2016). *Planta embotelladora - Monografias.com*. [online] Monografias.com. Available at: http://www.monografias.com/trabajos82/planta-embotelladora/planta-embotelladora.shtml [Accessed 3 Apr. 2016].

Neumüller, C., Lasch, R. and Kellner, F. (2016). Integrating sustainability into strategic supplier portfolio selection. *Management Decision*, 54(1), pp.194-221.

Olsen, R. and Ellram, L. (1997). A portfolio approach to supplier relationships. *Industrial Marketing Management*, 26(2), pp.101-113.

Plebankiewicz, E. and Kubek, D. (2016). Multicriteria Selection of the Building Material Supplier Using AHP and Fuzzy AHP. *Journal of Construction Engineering and Management*, 142(1), p.04015057.

Saaty, R. (1987). The analytic hierarchy process—what it is and how it is used. *Mathematical Modelling*, 9(3-5), pp.161-176.

Tahriri, F., Osman, M., Ali, A., Yusuff, R. and Esfandiary, A. (2008). AHP approach for supplier evaluation and selection in a steel manufacturing company. *Journal of Industrial Engineering and Management*, 1(2).

"Toma De Decisiones En Dirección De Proyectos. Método AHP. Pasos Del Método". 2015. Presentation.

Transparencymarketresearch.com. (2016). [online] Available at: http://www.transparen-cymarketresearch.com/bottled-water-market.html [Accessed 11 Apr. 2016].

Vaidya, O. and Kumar, S. (2006). Analytic hierarchy process: An overview of applications. *European Journal of Operational Research*, 169(1), pp.1-29.

Verma, R. and Pullman, M. (1998). An analysis of the supplier selection process. *Omega*, 26(6), pp.739-750.

Yadav, V. and Sharma, M. (2016). Multi-criteria supplier selection model using the analytic hierarchy process approach. *Journal of Modelling in Management*, 11(1), pp.326-354.

APPENDIX I

Survey instrument

Suppliers' individual evaluation:

Questionnaire 1

General Supplier Information

1. Name of supplier:

2. What does it provide to the company?

3. Which group does it belong to?

☐ Raw materials   ☐ Services   ☐ Equipment

4. Current contract/deliveries with the company?

☐ Yes | ☐ No

Supplier Evaluation: how strong is the supplier in regard to the following aspects?

5. Financial status. Scale: from 1 (weak company) to 5 (strong company).

☐ 1   ☐ 2   ☐ 3   ☐ 4
☐ 5   ☐ N/A

6. Quality. Scale: from 1 (low quality) to 5 (high quality).

☐ 1   ☐ 2   ☐ 3   ☐ 4
☐ 5   ☐ N/A

7. Past experience. Scale: from 1 (bad references) to 5 (good references).

☐ 1   ☐ 2   ☐ 3   ☐ 4
☐ 5   ☐ N/A

8. Communication. Scale: from 1 (tough) to 5 (easy).

☐ 1   ☐ 2   ☐ 3   ☐ 4
☐ 5   ☐ N/A

9. Flexibility. Scale: from 1 (bad) to 5 (good).

☐ 1   ☐ 2   ☐ 3   ☐ 4
☐ 5   ☐ N/A

10. Technological capacity. Scale: from 1 (low) to 5 (high).

☐ 1   ☐ 2   ☐ 3   ☐ 4
☐ 5   ☐ N/A

11. Post-sales services. Scale: from 1 (missing) to 5 (total).

☐ 1   ☐ 2   ☐ 3   ☐ 4
☐ 5   ☐ N/A

12. Lead time. Scale: from 1 (long) to 5 (short).

☐ 1   ☐ 2   ☐ 3   ☐ 4
☐ 5   ☐ N/A

13. Proximity to the manufacturing plant. Scale: from 1 (far) to 5 (close).

☐ 1   ☐ 2   ☐ 3   ☐ 4
☐ 5   ☐ N/A

14. Delivery of the product on time and good condition. Scale: from 1 (never) to 5 (always).

☐ 1   ☐ 2   ☐ 3   ☐ 4
☐ 5   ☐ N/A

Main strengths and weaknesses of supplier

15. What are the main strengths of this supplier? (The strengths can differ from those asked in this questionnaire).

16. What are the main weaknesses? (The weaknesses can differ from those asked in this questionnaire)

Group's evaluation:

Questionnaire 2

When evaluating a supplier that belongs to "Raw Materials" group, how important are these dimensions?

1. Raw Materials. Scale: from 1 (irrelevant) to 5 (crucial)

	1	2	3	4	5	N/A
Financial status	☐	☐	☐	☐	☐	☐
Quality	☐	☐	☐	☐	☐	☐
Past experience	☐	☐	☐	☐	☐	☐
Communication	☐	☐	☐	☐	☐	☐
Flexibility	☐	☐	☐	☐	☐	☐
Technological capacity	☐	☐	☐	☐	☐	☐
Post- sales services	☐	☐	☐	☐	☐	☐
Lead time	☐	☐	☐	☐	☐	☐
Proximity	☐	☐	☐	☐	☐	☐
Delivery	☐	☐	☐	☐	☐	☐

When evaluating a supplier that belongs to "Services" group, how important are these dimensions?

2. Services. Scale: from 1 (irrelevant) to 5 (crucial)

	1	2	3	4	5	N/A
Financial status	☐	☐	☐	☐	☐	☐
Quality	☐	☐	☐	☐	☐	☐
Past experience	☐	☐	☐	☐	☐	☐

Communication	☐	☐	☐	☐	☐	☐
Flexibility	☐	☐	☐	☐	☐	☐
Technological capacity	☐	☐	☐	☐	☐	☐
Post- sales services	☐	☐	☐	☐	☐	☐
Lead time	☐	☐	☐	☐	☐	☐
Proximity	☐	☐	☐	☐	☐	☐
Delivery	☐	☐	☐	☐	☐	☐

When evaluating a supplier that belongs to "Equipment" group, how important are these dimensions?

3. Equipment. Scale: from 1 (irrelevant) to 5 (crucial)

	1	2	3	4	5	N/A
Financial status	☐	☐	☐	☐	☐	☐
Quality	☐	☐	☐	☐	☐	☐
Past experience	☐	☐	☐	☐	☐	☐
Communication	☐	☐	☐	☐	☐	☐
Flexibility	☐	☐	☐	☐	☐	☐
Technological capacity	☐	☐	☐	☐	☐	☐
Post- sales services	☐	☐	☐	☐	☐	☐
Lead time	☐	☐	☐	☐	☐	☐
Proximity	☐	☐	☐	☐	☐	☐
Delivery	☐	☐	☐	☐	☐	☐

APPENDIX II

1. Survey results:

- Raw materials:

Q	PRODUCT	CURRENT CON-TRACT?		Finan-cial sta-tus	Qu-al-ity	Past ex-peri-ence	Com-munica-tion	Flex-ibil-ity	Technologi-cal Capac-ity	Post-sales ser-vices	Lead time	Proxim-ity	Delivery on time and good condition
Q1	PET Pre- shaped bottles	YES	X1	4	4	5	3	4	4	3	3	2	3
Q13	PET Pre- shaped bottles	NO	X7	2	5	5	3	2	4	3	3	1	4
Q14	PET Pre- shaped bottles	NO	X8	4	2	5	4	4	3	3	3	1	4
Q15	PET Pre- shaped bottles	NO	X9	4	5	5	4	2	4	2	3	1	4

Table 44 Suppliers' evaluation: PET Pre- shaped bottles

Q	PRODUCT	CURRENT CON-TRACT?		Finan-cial sta-tus	Quali-ty	Past ex-peri-ence	Commu-nication	Flexi-bility	Technolog-ical Capac-ity	Post-sales ser-vices	Lead time	Proxim-ity	Delivery on time and good condition
Q3	Wooden pal-lets renting	YES	X2	4	3	5	4	3	4	2	3	1	3
Q4	Wooden pal-lets renting	YES	X3	4	3	5	4	3	2	2	3	1	3
Q5	Wooden pal-lets renting	YES	X4	4	3	5	4	2	5	3	3	1	3

Q	PRODUCT	CURRENT CONTRACT?		Financial status	Quality	Past experience	Communication	Flexibility	Technological Capacity	Post-sales services	Lead time	Proximity	Delivery on time and good condition
Q6	Wooden pallets	NO	**X5**	2	3	5	5	4	2	3	3	5	3
C7	Wooden pallets	NO	**X6**	3	3	5	5	4	2	3	3	5	2

Table 45 Suppliers' evaluation: Wooden pallets

Q	PRODUCT	CURRENT CONTRACT?		Financial status	Quality	Past experience	Communication	Flexibility	Technological Capacity	Post-sales services	Lead time	Proximity	Delivery on time and good condition
Q25	PET Caps	NO	**X12**	3	3	5	5	4	2	3	2	5	3
Q26	PET Caps	NO	**X13**	2	4	2	4	5	4	3	3	1	3
Q27	Crown Caps	NO	**X14**	5	4	2	4	5	4	3	3	1	3
Q28	PET Caps	NO	**X15**	4	2	5	4	2	4	3	3	1	4
Q29	PET Caps	NO	**X16**	4	2	5	4	4	4	3	2	1	4
Q30	PET Caps	NO	**X17**	4	2	4	4	2	4	3	3	1	4
Q31	PET Caps	YES	**X18**	4	3	5	4	3	4	2	3	1	3

Table 46 Suppliers' evaluation: PET Caps

Q	PRODUCT	CURRENT CONTRACT?		Financial status	Quality	Past experience	Communication	Flexibility	Technological Capacity	Post-sales services	Lead time	Proximity	Delivery on time and good condition
Q23	Labels	NO	X10	4	3	5	4	3	4	4	3	1	2
Q24	Labels	NO	X11	2	3	5	4	3	4	4	3	1	2
Q34	Labels	YES	X19	4	2	5	4	4	4	3	2	1	4

Table 47 Suppliers' evaluation: Labels

- Services:

Q	SERVICE	CURRENT CONTRACT?		Financial status	Quality	Past experience	Communication	Flexibility	Technological capacity	Post-sales services	Lead time	Proximity	Delivery on time and good condition
Q2	Transport services for finished product and bottles	YES	X1	4	4	5	4	5	4	4	3	1	2
Q8	Transport services for finished product and bottles	YES	X2	2	4	5	4	5	4	3	3	2	5
Q9	Transport services for finished product and bottles	YES	X3	4	4	2	4	5	4	3	3	1	5
Q10	Transport services for finished product and bottles	NO	X4	2	4	2	4	5	4	3	3	1	3

| Q11 | Transport services for finished product and bottles | YES | **X5** | 4 | 4 | 5 | 4 | 2 | 4 | 3 | 3 | 5 | 4 |
| Q12 | Transport services for finished product and bottles | YES | **X6** | 2 | 2 | 5 | 4 | 2 | 4 | 3 | 3 | 5 | 4 |

Table 48 Suppliers' evaluation: Transport services

Q	SERVICE	CURRENT CON-TRACT?		Finan-cial sta-tus	Qual-ity	Past ex-peri-ence	Commu-nication	Flexi-bility	Technolog-ical capac-ity	Post-sales services	Lead time	Prox-imity	Delivery on time and good condition
Q20	Cleaning	NO	**X7**	4	3	3	3	2	4	3	3	1	4
Q21	Cleaning	NO	**X8**	2	4	3	3	2	4	3	3	1	4
Q22	Cleaning	NO	**X9**	5	3	3	3	2	4	3	3	1	4
Q23	Cleaning	YES	**X10**	4	3	3	3	2	4	3	3	1	4

Table 49 Suppliers' evaluation: Cleaning services

- Equipment:

Q	PRODUCT	CURRENT CON-TRACT?		Finan-cial sta-tus	Qual-ity	Past ex-perience	Commu-nication	Flexi-bility	Technolog-ical capac-ity	Post-sales services	Lead time	Prox-imity	Delivery on time and good condition
Q16	Industrial Machinery	NO	**X1**	4	5	5	4	2	4	3	2	1	4
Q17	Industrial Machinery	NO	**X2**	2	2	5	4	2	4	3	3	1	4

Q18	Industrial Machinery	NO	**X3**	2	5	4	3	2	3	3	3	1	4
Q19	Industrial Machinery	NO	**X4**	2	5	5	5	2	4	3	3	1	4
Q33	Industrial Machinery	YES	**X5**	3	3	5	5	4	2	3	2	5	3

Table 50 Suppliers' evaluation: Industrial Machinery

- Importance of dimensions inside the groups:

Importance of dimensions in each bucket

Dimensions	Raw materials	Services	Equipment
Financial status	4	4	4
Quality	5	5	4
Past experience	3	4	3
Communication	4	3	4
Flexibility	5	4	5
Technological capacity	5	4	4
Post- sales services	4	4	5
Lead time	5	5	4
Proximity	3	3	2
Delivery on time and good condition	5	5	4

Table 51 Importance of dimensions in each group

2. AHP method calculations:

2.1 Pairwise comparison

RAW MATERI-ALS	Financial status	Quality	Past ex-perience	Commu-nication	Flexi-bility	Technologi-cal Capacity	Post- sales services	Lead time	Prox-imity	Delivery on time and good condition
Financial status	1	0,333	3	1	0,333	0,333	1	0,333	3	0,333
Quality	3	1	5	3	1	1	3	1	5	1
Past experience	0,333	0,200	1	3	0,200	0,200	0,333	0,200	1	0,200
Communication	1	0,333	0,333	1	0,333	0,333	1	0,333	3	0,333
Flexibility	3	1	5	3	1	1	3	1	5	1
Technological capacity	3	1	5	3	1	1	3	1	5	1
Post- sales services	1	0,333	3	1	0,333	0,333	1	0,3333	3	0,333
Lead time	3	1	5	3	1	1	3	1	5	1
Proximity	0,333	0,200	1	0,333	0,2	0,200	0,333	0,200	1	0,200
Delivery on time and good condition	3	1	5	3	1	1	3	1	5	1

Table 52 Raw materials factors pairwise comparison (Matrix A)

SERVICES	Financial status	Quality	Past ex-perience	Commu-nication	Flexi-bility	Technologi-cal Capacity	Post- sales services	Lead time	Prox-imity	Delivery on time and good condition
Financial status	1	0,333	1	3	1	1	1	0,333	3	0,333
Quality	3	1	3	5	3	3	3	1	5	1
Past experience	1	0,333	1	3	1	1	1	0,333	3	0,333
Communication	0,333	0,200	0,333	1	0,333	0,333	0,333	0,200	1	0,500
Flexibility	1	0,333	1	3	1	1	1	0,333	3	0,333

Technological capacity	1	0,333	1	3	1	1	1	0,333	3	0,333
Post- sales services	1	0,333	1	3	1	1	1	0,333	3	0,333
Lead time	3	1	3	5	3	3	3	1	5	1
Proximity	0,333	0,200	0,333	1	0,333	0,333	0,3333	0,200	1	0,200
Delivery on time and good condition	3	1	3	5	3	3	3	1	5	1

Table 53 Services factors pairwise comparison (Matrix A)

EQUIPMENT	Financial status	Quality	Past experience	Communication	Flexibility	Technological Capacity	Post- sales services	Lead time	Proximity	Delivery on time and good condition
Financial status	1	1	3	1	3	1	3	1	5	1
Quality	1	1	3	1	0,333	1	3	1	5	1
Past experience	0,333	0,333	1	0,333	0,200	0,333	0,200	0,333	3	0,333
Communication	1	1	3	1	0,333	1	0,333	1	5	1
Flexibility	0,333	3	5	3	1	3	1	3	7	3
Technological capacity	1	1	3	1	0,333	1	0,333	1	5	1
Post- sales services	0,333	0,333	5	3	1	3	1	3	7	3
Lead time	1	1	3	1	0,333	1	0,333	1	5	1
Proximity	0,200	0,200	0,333	0,200	0,143	0,200	0,143	0,200	1	0,200
Delivery on time and good condition	1	1	3	1	0,333	1	0,333	1	5	1

Table 54 Equipment factors pairwise comparison (Matrix A)

2.2 Reliability of the results

The Eigen Value is calculated by a simple formula: $AxB = C \; and \; D = C/B$ where A is the matrix of pairwise comparisons from each group (Table 52, Table 53 and Table 54) and B is composed out of the normalized weights for each criteria regarding each group as well (column on the right in Table 55, Table 56 and Table 57 in Appendix II). D will give us three vectors with different values of λmax (Eigen Value) each of them belonging to each group. Then, by calculating the average of the elements of these three vectors we will obtain the λmax of each matrix of judgements from each group ("Toma De Decisiones En Dirección De Proyectos. Método AHP. Pasos Del Método", 2015).

Let us calculate first the vector column B:

Starting from the matrices of comparison (Table 52, Table 53 and Table 54), we have the factors compared with each other and the first step is to calculate the geometric mean of each row (dimension). Then, by normalizing these geometric means, this vector will correspond with the vector of weights which is representing the influence that each factor has in each group. We are going to name this vector: Matrix B.

RAW MATERIALS	WEIGHTS (Matrix B)	
	Geo. Mean	Geo. Mean Norm
Financial status	0,719	0,058
Quality	1,918	0,155
Past experience	0,401	0,032
Communication	0,577	0,047
Flexibility	1,918	0,155
Technological capacity	1,918	0,155
Post- sales services	0,719	0,058
Lead time	1,918	0,155
Proximity	0,322	0,026
Delivery on time and good condition	1,918	0,155

Table 55 Normalized weights for criteria in Raw materials (Matrix B)

		WEIGHTS (Matrix B)	
SERVICES		Geo. Mean	Geo. Mean Norm
Financial status		0,896	0,072
Quality		2,390	0,193
Past experience		0,896	0,072
Communication		0,390	0,031
Flexibility		0,896	0,072
Technological capacity		0,896	0,072
Post- sales services		0,896	0,072
Lead time		2,390	0,193
Proximity		0,356	0,0290
Delivery on time and good condition		2,390	0,193

Table 56 Normalized weights for criteria in Services (Matrix B)

		WEIGHTS (Matrix B)	
EQUIPMENT		Geo. Mean	Geo. Mean Norm
Financial status		1,633	0,138
Quality		1,311	0,111
Past experience		0,418	0,035
Communication		1,052	0,089
Flexibility		2,214	0,188
Technological capacity		1,052	0,089
Post- sales services		1,777	0,151
Lead time		1,052	0,089
Proximity		0,231	0,019
Delivery on time and good condition		1,052	0,089

Table 57 Normalized weights for criteria in Equipment (Matrix B)

Now, calculating AxB in each group (A is the pairwise comparison matrix and B is the vector column), we will obtain the vector column named as C. Table 58 shows us the vector C that corresponds to each group of suppliers.

	Raw Materials	Services	Equipment
Financial status	0,598	0,735	1,826
Quality	1,561	1,964	1,325
Past experience	0,393	0,735	0,364
Communication	0,512	0,354	0,924
Flexibility	1,561	0,735	2,103
Technological capacity	1,561	0,735	0,924
Post- sales services	0,598	0,735	1,807
Lead time	1,561	1,964	0,924
Proximity	0,269	0,296	0,201
Delivery on time and good condition	1,561	1,964	0,924

Table 58 Vector C for each group

The next step is to obtain matrix D by Calculating C/B. C are the vectors column we obtained for each group represented in Table 58 and B are the vectors column represented in Table 55, Table 56 and Table 57. Matrix D represents the Eigen Value in each row; that means, for each criterion in each group.

	Raw Materials (Matrix D)	Services (Matrix D)	Equipment (Matrix D)
Financial status	10,261	10,167	13,189
Quality	10,035	10,186	11,926
Past experience	12,110	10,167	10,264
Communication	10,932	11,246	10,353
Flexibility	10,035	10,167	11,203
Technological capacity	10,035	10,167	10,353
Post- sales services	10,261	10,167	11,989
Lead time	10,035	10,186	10,353

Proximity	10,300	10,312	10,261
Delivery on time and good condition	10,035	10,186	10,353

Table 59 Vector D and Eigen value average (λmax) for each group

Calculating now the average of each column, we obtain the value of the Eigen Value in each group:

	Raw Materials	*Services*	*Equipment*
λmax	10,404	10,295	11,024

Table 60 Eigen Value for each group

Now it is time to calculate the CR and CI, and get the value of the random consistency index RI.

$CI = \frac{\lambda max - n}{n-1}$ with n=dimension of the judgment matrix; in our case: n=10. So for each group the value of CI is:

	Raw Materials	*Services*	*Equipment*
CI	0,045	0,033	0,114

Table 61 CI value for each group

RI comes out from a table elaborated by Saaty (Saaty, 1987):

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,49

Table 62 Random consistency Index values by Saaty (Saaty, 1987)

In our case, as n=10: **RI=1, 49**

The next step is to calculate the consistency ratio CR: $CR = \frac{CI}{RI}$

So, for each group the value of CR is:

	Raw Materials	*Services*	*Equipment*
CR	0,030	0,022	0,076

Table 63 CR values for each group

2.3 Supplier evaluation

In the next tables the overall evaluation is shown and this is the last step of the method. The result column points out the number assigned for the suppliers regarding the importance of the criteria in the group they belong and how strong are they in each characteristic. This number also will allow us to rank them in order to know which the best ones are.

Here there is an example of how to calculate the result. For supplier **X1** from raw materials group, the result would be:

$$
\begin{aligned}
X1Result = {} & (0{,}060\text{x}0{,}058) + (\ 0{,}068\text{x}0{,}155) + (0{,}057\text{x}0{,}033) + (0{,}039\text{x}0{,}047) \\
& + (0{,}063\text{x}0{,}155) + (0{,}059\text{x}0{,}155) + (0{,}055\text{x}0{,}155) + (0{,}055\text{x}0{,}155) \\
& + (0{,}063\text{x}0{,}026) + (0{,}049\text{x}0{,}155) = \mathbf{0{,}063}
\end{aligned}
$$

RAW MATERIALS		Financial status	Quality	Past experience	Communication	Flexibility	Technological Capacity	Post-sales services	Lead time	Proximity	Delivery on time and good condition	Result
PET Pre-shaped bottles	X1	0,060	0,068	0,057	0,039	0,063	0,059	0,055	0,055	0,063	0,049	0,063
Wooden pallets renting	X2	0,060	0,051	0,057	0,052	0,048	0,059	0,036	0,055	0,031	0,049	0,055
Wooden pallets renting	X3	0,060	0,051	0,057	0,052	0,048	0,029	0,036	0,055	0,032	0,049	0,050
Wooden pallets renting	X4	0,060	0,051	0,057	0,052	0,032	0,074	0,055	0,055	0,031	0,049	0,058
Wooden pallets	X5	0,030	0,051	0,057	0,065	0,063	0,029	0,055	0,055	0,156	0,049	0,058
Wooden pallets	X6	0,045	0,051	0,057	0,065	0,063	0,029	0,055	0,055	0,156	0,033	0,056
PET Pre-shaped bottles	X7	0,030	0,081	0,057	0,039	0,032	0,059	0,055	0,055	0,031	0,066	0,061
PET Pre-shaped bottles	X8	0,060	0,034	0,057	0,052	0,063	0,044	0,055	0,055	0,031	0,0655	0,058
PET Pre-shaped bottles	X9	0,060	0,085	0,057	0,052	0,032	0,059	0,036	0,055	0,031	0,066	0,061
Labels	X10	0,060	0,051	0,057	0,052	0,048	0,059	0,073	0,055	0,031	0,033	0,058

Labels	**X11**	0,030	0,051	0,057	0,052	0,048	0,059	0,073	0,055	0,032	0,033	0,056
PET Caps	**X12**	0,045	0,051	0,057	0,065	0,063	0,029	0,055	0,037	0,156	0,049	0,056
PET Caps	**X13**	0,030	0,068	0,023	0,052	0,079	0,059	0,055	0,055	0,031	0,049	0,063
Crown Caps	**X14**	0,075	0,068	0,023	0,052	0,079	0,059	0,055	0,055	0,031	0,049	0,065
PET Caps	**X15**	0,060	0,034	0,057	0,052	0,032	0,059	0,055	0,055	0,031	0,066	0,055
PET Caps	**X16**	0,060	0,034	0,057	0,052	0,063	0,059	0,055	0,037	0,031	0,066	0,057
PET Caps	**X17**	0,060	0,034	0,045	0,052	0,032	0,059	0,055	0,055	0,031	0,066	0,055
PET Caps	**X18**	0,060	0,051	0,057	0,052	0,048	0,059	0,036	0,055	0,031	0,049	0,055
Labels	**X19**	0,060	0,034	0,057	0,052	0,063	0,059	0,055	0,037	0,031	0,066	0,057
	WEIGHTS	0,058	0,155	0,033	0,047	0,155	0,155	0,155	0,155	0,026	0,155	

Table 64 Raw materials: ranking numbers

SERVICES		Financial status	Quality	Past experience	Communication	Flexibility	Technological capacity	Post-sales services	Lead time	Proximity	Delivery on time and good condition	Result
Transport services for finished product and bottles	**X1**	0,121	0,114	0,139	0,111	0,156	0,100	0,129	0,100	0,053	0,051	0,103
Transport services for finished product and bottles	**X2**	0,061	0,114	0,139	0,111	0,156	0,100	0,097	0,100	0,105	0,128	0,113
Transport services for finished product and bottles	**X3**	0,121	0,114	0,055	0,111	0,156	0,100	0,097	0,100	0,053	0,128	0,110
Transport services for finished product and bottles	**X4**	0,061	0,114	0,055	0,111	0,156	0,100	0,097	0,100	0,053	0,077	0,095
Transport services for finished product and bottles	**X5**	0,121	0,114	0,139	0,111	0,063	0,100	0,097	0,100	0,263	0,103	0,110
Transport services for finished product and bottles	**X6**	0,061	0,057	0,139	0,111	0,063	0,100	0,097	0,100	0,263	0,103	0,094
Cleaning	**X7**	0,121	0,086	0,083	0,083	0,063	0,100	0,097	0,100	0,053	0,103	0,093
Cleaning	**X8**	0,061	0,114	0,083	0,083	0,063	0,100	0,097	0,100	0,053	0,103	0,094
Cleaning	**X9**	0,152	0,086	0,083	0,083	0,063	0,100	0,097	0,100	0,053	0,103	0,095
Cleaning	**X10**	0,121	0,086	0,083	0,083	0,063	0,100	0,097	0,100	0,053	0,103	0,093
	WEIGHTS	0,072	0,193	0,072	0,032	0,072	0,072	0,072	0,193	0,029	0,193	

Table 65 Services: ranking numbers

EQUIPMENT		Finan-cial sta-tus	Qual-ity	Past expe-rience	Commu-nication	Flexibil-ity	Techno-logical ca-pacity	Post-sales ser-vices	Lead time	Prox-imity	Delivery on time and good condition	Result
Industrial Machinery	**X1**	0,308	0,250	0,208	0,190	0,166	0,235	0,154	0,111	0,211	0,211	0,182
Industrial Machinery	**X2**	0,154	0,100	0,208	0,190	0,166	0,235	0,231	0,111	0,211	0,211	0,156
Industrial Machinery	**X3**	0,154	0,250	0,167	0,143	0,166	0,176	0,231	0,111	0,211	0,211	0,167
Industrial Machinery	**X4**	0,154	0,250	0,208	0,238	0,166	0,235	0,231	0,111	0,211	0,211	0,177
Industrial Machinery	**X5**	0,231	0,150	0,208	0,238	0,333	0,118	0,154	0,555	0,158	0,158	0,240
	WEIGHTS	0,138	0,111	0,035	0,089	0,188	0,089	0,151	0,089	0,020	0,089	

Table 66 Equipment: ranking numbers

3. Checklists method

RAW MATE-RIALS	CURRENT CONTRACT?		Financial status	Quality	Past ex-perience	Commu-nication	Flexi-bility	Techno-logical capacity	Post-sales services	Lead time	Prox-imity	Delivery on time and good condition
PET Pre-shaped bottles	YES	X1	1	1	1	1	1	1	1	1	0	1
Wooden pallets renting	YES	X2	1	1	1	1	1	1	0	1	0	1
Wooden pallets renting	YES	X3	1	1	1	1	1	0	0	1	0	1
Wooden pallets renting	YES	X4	1	1	1	1	0	1	1	1	0	1
Wooden pallets	NO	X5	0	1	1	1	1	0	1	1	1	1
Wooden pallets	NO	X6	1	1	1	1	1	0	1	1	1	0
PET Pre-shaped bottles	NO	X7	0	1	1	1	0	1	1	1	0	1
PET Pre-shaped bottles	NO	X8	1	0	1	1	1	1	1	1	0	1
PET Pre-shaped bottles	NO	X9	1	1	1	1	0	1	0	1	0	1
Labels	NO	X10	1	1	1	1	1	1	1	1	0	0

			Financial status	Quality	Past experience	Communication	Flexibility	Technological capacity	Post-sales services	Lead time	Proximity	Delivery on time and good condition
Labels	NO	**X11**	0	1	1	1	1	1	1	1	0	0
PET Caps	NO	**X12**	1	1	1	1	1	0	1	0	1	1
PET Caps	NO	**X13**	0	1	0	1	1	1	1	1	0	1
Crown Caps	NO	**X14**	1	1	0	1	1	1	1	1	0	1
PET Caps	NO	**X15**	1	0	1	1	0	1	1	1	0	1
PET Caps	NO	**X16**	1	0	1	1	1	1	1	0	0	1
PET Caps	NO	**X17**	1	0	1	1	0	1	1	1	0	1
PET Caps	YES	**X18**	1	1	1	1	1	1	0	1	0	1
Labels	YES	**X19**	1	0	1	1	1	1	1	0	0	1

Table 67 Raw materials suppliers' verification of requirements

SERVICES	CURRENT CONTRACT?		Financial status	Quality	Past experience	Communication	Flexibility	Technological capacity	Post-sales services	Lead time	Proximity	Delivery on time and good condition
Transport	YES	**X1**	1	1	1	1	1	1	1	1	0	0
Transport	YES	**X2**	0	1	1	1	1	1	1	1	0	1
Transport	YES	**X3**	1	1	0	1	1	1	1	1	0	1
Transport	NO	**X4**	0	1	0	1	1	1	1	1	0	1
Transport	YES	**X5**	1	1	1	1	0	1	1	1	1	1
Transport	YES	**X6**	0	0	1	1	0	1	1	1	1	1
Cleaning	NO	**X7**	1	1	1	1	0	1	1	1	0	1
Cleaning	NO	**X8**	0	1	1	1	0	1	1	1	0	1
Cleaning	NO	**X9**	1	1	1	1	0	1	1	1	0	1
Cleaning	YES	**X10**	1	1	1	1	0	1	1	1	0	1

Table 68 Services suppliers' verification of requirements

EQUIP-MENT	CURRENT CON-TRACT?		Financial status	Qua-lity	Past ex-perience	Commu-nication	Flexi-bility	Technologi-cal capacity	Post- sales services	Lead time	Prox-imity	Delivery on time and good condition
Industrial Machinery	NO	**X1**	1	1	1	1	0	1	1	0	0	1
Industrial Machinery	NO	**X2**	0	0	1	1	0	1	1	1	0	1
Industrial Machinery	NO	**X3**	0	1	1	1	0	1	1	1	0	1
Industrial Machinery	NO	**X4**	0	1	1	1	0	1	1	1	0	1
Industrial Machinery	YES	**X5**	1	1	1	1	1	0	1	0	0	1

Table 69 Equipment suppliers' verification of requirements

4. Portfolio maps method calculations

Raw materials	Prioritization of factors	
Quality	**0,155**	**1**
Flexibility	**0,155**	**2**
Technological capacity	**0,155**	**3**
Lead time	**0,155**	**4**
Delivery on time and good condition	**0,155**	**5**
Financial status	0,058	6
Post- sales services	0,058	7
Communication	0,047	8
Past experience	0,032	9
Proximity	0,026	10

Table 70 Prioritization of factors in Raw Materials group

Services	Prioritization of factors	
Quality	**0,193**	**1**
Lead time	**0,193**	**2**
Delivery on time and good condition	**0,193**	**3**
Financial status	0,072	4
Past experience	0,072	5
Flexibility	0,072	6
Technological capacity	0,072	7
Post- sales services	0,072	8
Communication	0,031	9
Proximity	0,029	10

Table 71 Prioritization of factors in Services group

Equipment	Prioritization of factors	
Flexibility	**0,188**	**1**
Post- sales services	**0,151**	**2**
Financial status	0,138	3
Quality	0,111	4
Communication	0,089	5
Technological capacity	0,089	6
Lead time	0,089	7
Delivery on time and good condition	0,089	8
Past experience	0,035	9
Proximity	0,020	10

Table 72 Prioritization of factors in Equipment group