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Master of Science in
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Strategic Distribution Network Design (DND): model and case studies in the Consumer Electronics Industry

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Abstract

This thesis has its foundations on the Logistics area, focusing specifically on the part related to the Distribution Network Design (DND). In order to have an efficient network, in terms of total logistics costs and service performance, designers need to match the drivers that influence the network with the type of solution that best delivers the company's products.

The objective of this work was to develop a model that describes a framework for the strategic phase of the distribution networks design process. It is intended to work for companies in the Consumer Electronics industry which operate, or plan to operate, in Italy.

First, a description of different network solutions and the factors influencing them is presented, and then an analysis of how these factors affect the logistics costs was followed. Successful companies in the field were interviewed in order to understand how the own company's drivers were related with the type of distribution network solution they adopted. Once all this information was collected and analyzed, it was established the network solutions according to the different distribution problems a company in the sector may have.

The normative model proposed consists on a list of drivers which are grouped in macrodrivers (Product, Service, Demand, Supply) that characterize the distribution problems presented by the firm. The information required by it is easy to be found and the units of measure must be converted to a unique scale of criticalities from 1 to 5.

Using the provided table of weights or levels of importance of each driver, there are calculated the values of "Market" and "Firm" associated to each distribution problem, which will be lastly positioned in a graphical representation with clusters corresponding to the distribution network types proposed. Finally, based on the previous decision, the number and location of the warehouses or transit points is also suggested.

The qualitative tool presented as the result of this thesis is applicable to the consumer electronics industry in Italy, easy to follow by distribution network designers, understandable to decision makers, and easy to adapt to changing requirements.

Executive summary

Reasons to develop the model

Existing models

The principal reason to develop this model was that there are no models in the literature trying to assess in a qualitative way the best distribution network solution according to a range of different factors affecting the network.

The different models and methods present in the literature that try to asses this objective, are quantitative tools very complex, not applicable to different scenarios, and not understandable to decision makers.

Impact on Company Performance

Distribution and Logistics have a variety of impacts on an organization´s financial performance. For companies, from 10 to 35 percent of gross sales are logistics cost, depending on business, geography and weight/value.

Since distribution cannot be avoided because it is essential for service level, the way in which it does not affect that much companies' performance, apart from understanding the implicated costs and how to reduce them, is to have an efficient distribution network that allows the delivery of products at the right place and time. The logistics decisions should also be made in order to decrease the level of inventories and the reduction of fixed capital.

There are many types of inventory held by companies including, raw materials, components, WIP (work-in-progress) and finished goods. The key logistics functions impact significantly on the stock level of all of these. This impact can occur with respect to stock allocation, inventory control, stock-holding policies, order and reorder quantities and integrated systems, among others.

There are many assets to be found in logistics operations: warehouses, depots, means of transportation, and material handling equipment. The number, size and extent of their usage are fundamental for an effective logistics planning.

Objective

The objective of this thesis is to present a Distribution Network Design Model useful for the Consumer Electronic industry in Italy, developed from the improvement and expansion of an existing model (Archini & Bannó, 2003), that provides the guide lines for selecting the most appropriate distribution network configuration for a certain distribution problem. The distribution problem is considered as the input for the model and it consists in a combination of different factors or drivers, internal or external to the firm. The aim of the model is to identify the distribution network that better satisfies the service level required by the customer at the lowest possible cost.

The model to be developed focuses only on the main strategic decisions, because these constitute the preliminary phase of the distribution network design and are the ones that define its performance and efficiency.

The decisions selected are:

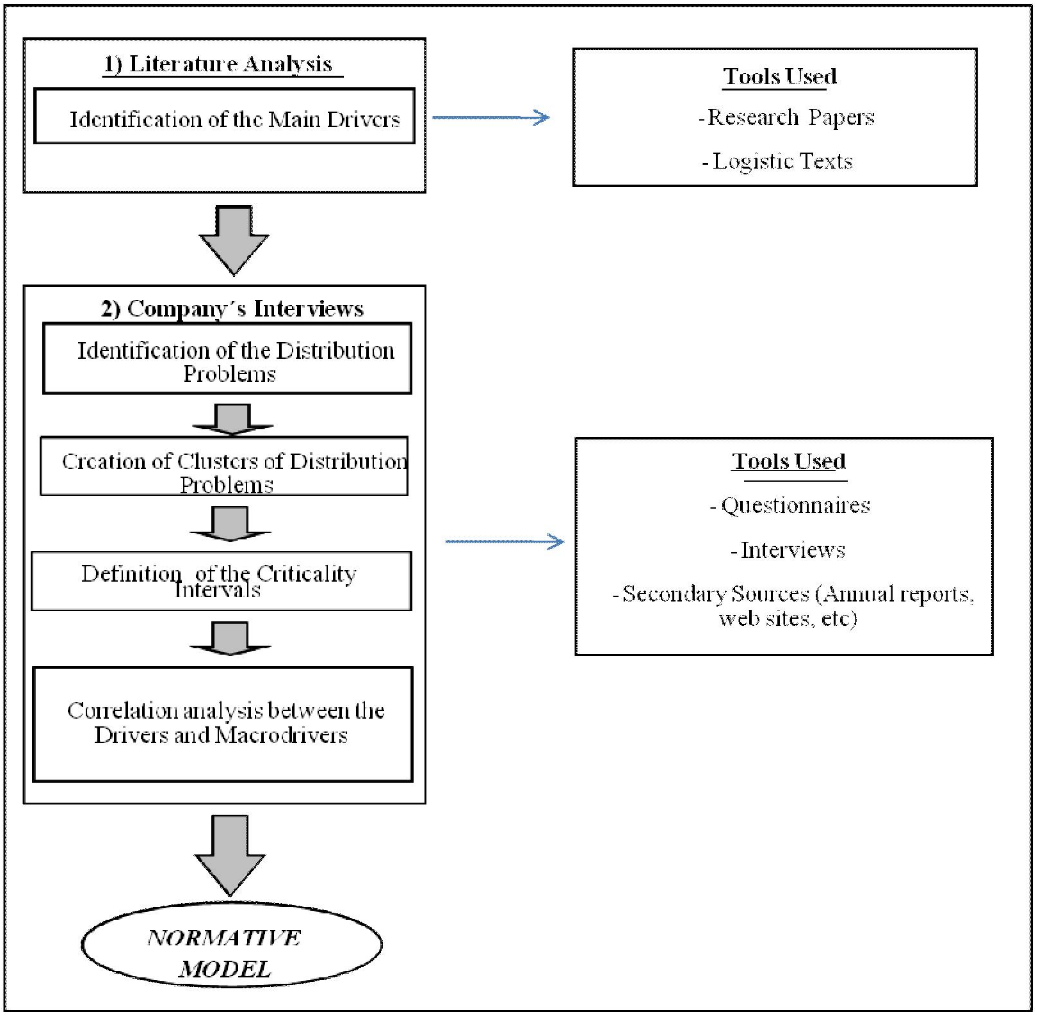
- Definition of the number of echelons of the distribution network
- Definition of the number of warehouses for each echelon
- Definition of the warehouse location
- Definition of the warehouse typology

The distribution network design has as objective the identification of the network structure that allows the minimization of total costs while maintaining a predefined service level. The costs that need to be considered during the network design are the ones that are affected by its configuration, which are: transportation costs, inventory costs, handling costs and order management costs.

The result of the work is intended to be a qualitative tool easy to use, applicable to actual cases, understandable to decision makers, easy to adapt to changing requirements and valid for a wide range of distribution problems.

Methodology

The sequence of steps used for the development of the different stages of the Distribution Network Design Model proposed by this work is presented in the following flow chart with a short explanation of each step.



Procedure for the literature analysis

The drivers taken into account by most authors in the past years were considered as a starting point to identify the founding set of drivers for a new model. The main sources of information considered to carry out the analysis were research papers. A total amount of 30 papers were analyzed and classified according to the distribution network choice that was intended to solve and the main drivers considered by each author as relevant.

In order to make a better analysis, the drivers mentioned in the papers were classified in four categories of macrodrivers: product, service, demand, and supply. Once identified the different drivers, different correlations between the drivers and the distribution network decisions (number of echelons, number of warehouses, warehouse location and typology of warehouse) were obtained taking in consideration the frequency of appearance of the driver among all the papers to make one decision. It was assumed that the frequency of appearance is directly proportional to the importance of that driver during the distribution network design. With this it was possible to obtain a list of drivers that must be taken in consideration.

Procedure for the interviews

A questionnaire was developed as a tool that could be used to obtain from companies operating in the consumer electronics industry, the characteristics of the four macrodrivers previously defined (product, service, demand and supply) and the distribution networks actually implemented by them.

The tool developed included the following main sections:

1) Data Context
2) Commercial Organization
3) Characterization of the actual Distribution Network
4) Flow Characterization
5) Managerial Logic

The 3 companies interviewed were: Hewlett-Packard, Sony and Samsung. These companies were considered to be a representative sample of the consumer electronics industry because the distribution problems presented in each one were diverse, as well as the network solution adopted.

Procedure to Identify Distribution Problems

The criteria proposed for the definition of distribution problems in the scope of each analyzed firm case, is composed by two principal steps.

1. First the flow diagrams have to be studied, in order to identify groups of products and clients characterized by a specific management.
2. Subsequently, the values of the drivers are analyzed for each individual group.

Procedure to make the clusters

The generation of the clusters was based on the number of levels and typology of the facilities at each level. Then, each group was characterized by specifying the number of nodes for each level, location and allocation of them, area covered by each one, area of the facility, types of clients served and variety of products managed.

Criteria for the definition of the criticality intervals

In order to get the synthetic representation of each distribution problem of the company cases, it is needed for the projection a scale of reference, composed by 5 intervals in order to find the criticality of each driver. The intervals have a growing scale of values from 1 to 5.

Using the scales of criticalities, all the drivers values were converted into a unique unit of measure. After this operation, it was possible to calculate the criticality values of each macrodriver (Product, Service, Demand and Supply), which were considered as the average of the drivers that compose each one.

Finally, with the objective of representing the distribution problems in a more aggregated way it was decided to define two new dimensions: Market, which is the combination of Service and Demand drivers, and Firm, which is the combination of Product and Supply Drivers. Therefore it is possible to obtain representative values by calculating the simple averages of the discussed pairs of macrodrivers. It is assumed, until this point, that the drivers pertaining to a macrodriver, and the macrodrivers that conform a group, have the same weight within it, which means that no differentiation of importance of the drivers and macrodrivers was considered.

Procedure for the correlation analysis

For the purposes of this thesis, the correlation analysis was done with the objective of identifying the relation between the drivers and between drivers and their correspondent macrodriver. It was used as input data the chart of distribution problems expressed with the drivers criticalities. Using the formula “CORRELATE” of a Microsoft Excel worksheet it was possible to obtain the Correlation Factors between all the drivers and macrodrivers. With the analysis of the result´s chart it was possible to determine whether or not different weights or level of importance of each driver within the macrodrivers should be assigned.

Results

Drivers Selected from the Literature Analysis

From the literature analysis (chapter 4), based on the frequency of appearance on the papers, 16 of a total amount of 28 drivers turn up to be significant for the distribution network design process, which are presented in the following table.

SELECTED DRIVERS		MACRODRIVER
1	Variety [SKUs]	Product drivers
2	Value [€/Kg]	
3	Density [Kg/m^3]	
4	Risk of obsolescence [days]	
5	Contribution Margin:	
6	Cycle Time [days]	Service drivers
7	Completeness [IFR]	
8	Returnability [%]	
9	Dimension of the order [%FTL]	Demand drivers
10	Number of customers	
11	Frequency of delivery [Deliveries per week]	
12	Seasonality	
13	Predictability of demand [%]	
14	Distance from plant to client	Supply Drivers
15	Number of plants	
16	Level of specialization	

Distribution Networks obtained

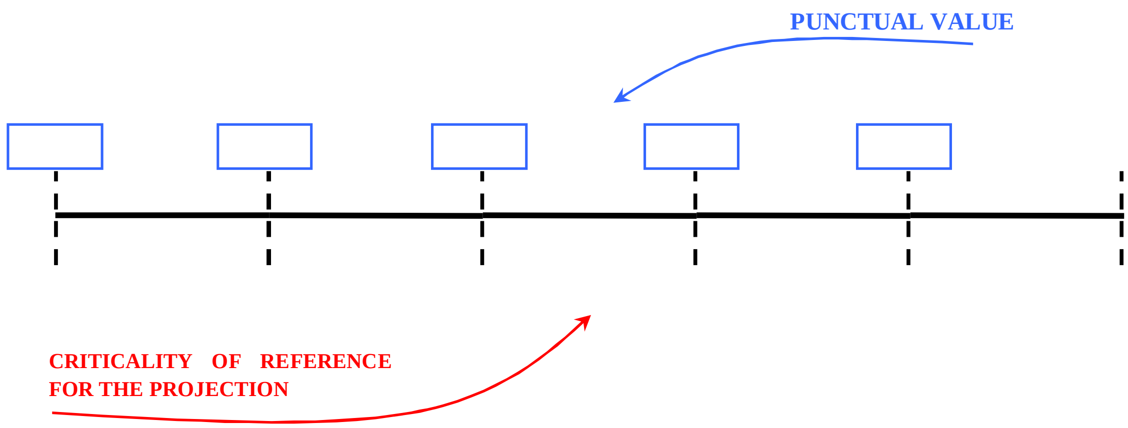
From the interviews done to the three companies, punctual values for each driver were obtained and it was possible to identify 16 distribution problems which adopted four different types of network solutions (presented in chapter 5):

- **Yellow: direct delivery from plants**
- **Green: 1 level of CWs**
- **Blue: 1 level of TPs**
- **Red: 2 levels, CWs and TPs**

Company	HP	Sony			Samsung				
Distribution Problem	HP1	SO1	SO2	SO3	SA1	SA2	SA3	SA4	SA5
		SO4	SO5	SO6	SA6	SA7	SA8	SA9	

Drivers Criticalities

In order to characterize each distribution problem using the list of drivers presented before, a scale of criticalities was done based on the impact of each driver over the logistics costs (analysis presented in chapter 7). The following graph corresponds to the general representation of the criticalities of the drivers, which was done for each one with the adequate values. On the upper part there are the punctual values of the driver obtained from the interviews and on the lower one, the correspondent value of criticality.



After the analysis done on this step, the drivers Returnability and Predictability of Demand were not considered for the future calculus of the macrodriver´s criticality because the values obtained did not present considerable differences that could be associated with one distribution network adopted or another.

Correlation Analysis

Using as input data a table with the characterization of the distribution problems with their respective driver´s criticalities, it was done a Correlation Analysis between drivers, and between the drivers and their correspondent macrodriver (Product, Service, Demand and Supply) with the objective of determining if the assumption of equal level of importance of the drivers within each macrodriver was correct or not.

As a result, it was obtained that not all the drivers influence in the same proportions their correspondent macrodriver, and for this reason different weights were assigned to each one of them.

Product	Variety	0.15
	Value	0.45
	Density	0.1
	Risk of obsolescence	0.25
	Contribution Margin	0.05
Service	Cycle Time	0.8
	Completeness	0.2

Demand	Dimensions of the order	0.4
	Number of customers	0.4
	Frequency of delivery	0.15
	Seasonality	0.05
Supply	Distance from plant to client	0.5
	Number of plants	0.25
	Level of specialization	0.25

It is possible to observe that for the macrodrivers that conform the “Firm” (Product and Supply), the drivers Value, Risk of Obsolescence and Distance from plant to client are the most important ones, while for the "Market" (Service and Demand) the Cycle Time, Dimension of the Order and Number of Customers, are the drivers that impact in a higher proportion their correspondent macrodriver.

The correlation analysis between the macrodrivers and their correspondent group (Market and Firm) was also done with the same objective as the previous case: assigning weights.

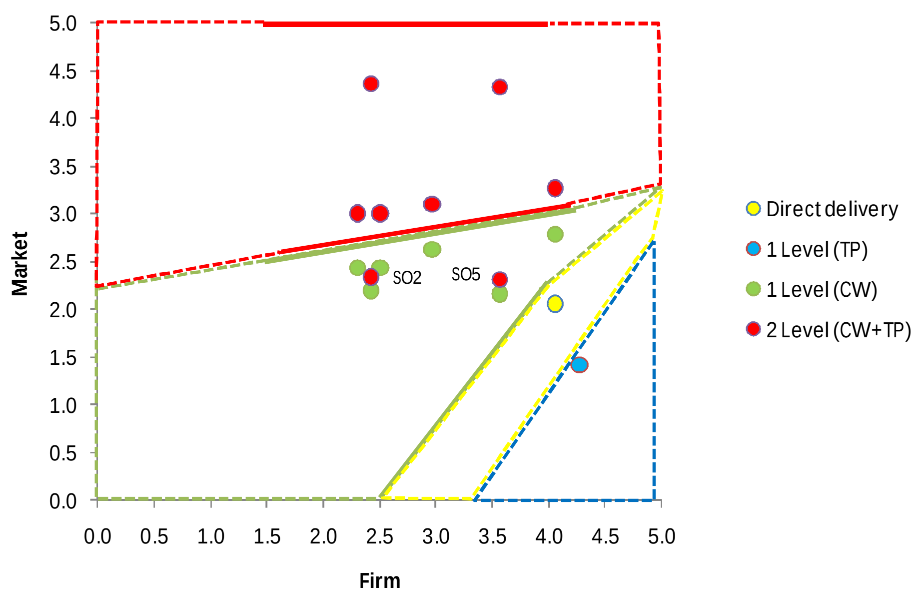
FIRM	
Product weight	0.65
Supply weight	0.35

MARKET	
Service weight	0.35
Demand weight	0.65

It can be observed that the Product and the Demand resulted to be the most important macrodrivers for the model to be proposed.

Analysis of the level and typology of network

The average values of "Market" and "Firm" obtained for each distribution problem, calculated with their correspondent weights, were used to place each distribution problem on a graphic representation as follows.



It can be observed that distribution problems with relatively similar characteristics of the Market and Firm adopted the same type of distribution networks forming clusters on the graph. Distribution networks of 2 levels with CW and TP are located in the upper part, 1 level of CW networks are situated in the center, and direct delivery and 1 level network with TP are placed in the lower-right corner. Further graphic representations of the impact of each macrodriver and the most relevant drivers were also done (chapter 9).

Normative Model

The Distribution Network Design (DND) model proposed by this thesis work presents the following 5 steps:

1. Company analysis and collection of data
2. Identification of the distribution problems and allocation of data for each distribution problem
3. Driver criticality analysis of the distribution problem
4. Individualization of the adequate network typology
5. Characterization of the network

The first step has the objective of obtain a complete and detailed vision of the logistic requirements and processes of each company. The tool used for this is the questionnaire (Appendix 1), specifically until the section 3.1 for the case of designing a new distribution network, and the complete set of questions for the re-design of an existing one, in order to compare the actual with the proposed by the model.

The second and third steps are very important because it is where the different distribution problems of each company are identified, by making a detailed analysis of the drivers and macrodrivers. The punctual values obtained in the second step will be then allocated within their correspondent scale of criticalities on the step 3, in order to have a unique and comparable unit of measure of the drivers. The scales of criticalities are different for each driver and are presented in the chapter 10.

Then, for the individualization of the adequate network typology, a previous calculus must be done. Using as input data the table of characterization of the distribution networks with the driver´s criticalities obtained in the previous step, and the table of driver´s weights presented before on the correlation analysis, it is possible to calculate the average criticality of the macrodrivers (Product, Service, Demand and Supply) and the group of macrodrivers (Market and Firm) by applying the corresponding formula.

$$C_i = \frac{\sum_{j}^{j_{\max}} Wj * c_j}{j_{\max}}$$

with: C_i = Macrodriver criticality i;

c_j = driver criticality j, with j = [1, …, j_{max}];

Wj = Weight of each driver

i = {product, service, demand, supply}

j = {variety, value, density, …., many products sources} = {all the drivers}

$$CF = \frac{Wp * Cp + Wl * Cl}{2}$$

$$CM = \frac{Ws * Cs + Wd * Cd}{2}$$

CF = firm criticality

CM = market criticality

Cp = product criticality

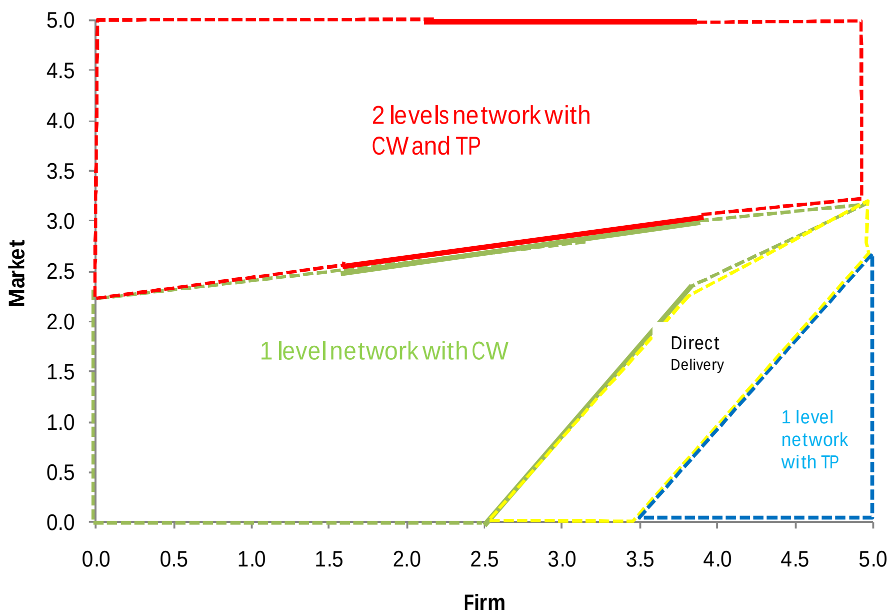
Cs = service criticality

Cl = supply criticality

Cd = demand criticality

W(p, l, s, d) = Weights (product, supply, service, demand)

The results of the Market and Firm criticalities that characterize a particular distribution problem, must be placed on the following graph to obtain the most adequate distribution network for it.



The last step consists in the characterization of the distribution network proposed by the model using the following suggestions:

- Networks with 1 level of CW should have one CW at National level.
- Networks with 1 level of TP should have at least 2 TPs at European level.
- Networks with 2 levels should have one CW at National level and at least 1TP every 1.5 Italian region.

Chapter 1. Objectives of the research

The objective of this thesis is to present a Distribution Network Design Model useful for the Consumer Electronic industry in Italy, developed from the improvement and expansion of an existing model (Archini & Bannó, 2003), that provides the guide lines for selecting, during the strategic decisions phase, the most appropriate distribution network configuration for a certain distribution problem. The distribution problem is considered as the input for the model and it consists in a combination of different factors or drivers, internal or external to the firm. The aim of the model is to identify the distribution network that better satisfies the service level required by the customer at the lowest possible cost.

The model focuses only on the main strategic decisions: number of echelons, number of warehouses per echelon, location and typology, because these constitute the preliminary phase of the distribution network design and are the ones that define its network performance and efficiency.

Once all these 4 choices have been set, subsequent operational decisions have to be made, for example: product optimization, vehicle routing, warehouse layout, automation level, transportation mode, inventory management, etc. These operational decisions are not considered in this work because are another topic beyond the limits of this study.

The result of the work is intended to be a qualitative tool easy to use, applicable to actual cases, understandable to decision makers, easy to adapt to changing requirements and valid for a wide range of distribution problems.

Chapter 2. Definition of the Distribution Network Problem

2.1 Historical Perspective of Logistics

The operations in the distribution and logistics fields have existed since the beginning of civilization and have been fundamental to the manufacturing, storage and movement of goods and products. However, it is only relatively recently, their recognition as vital functions within the business and economic environments. The role of logistics has changed and now it plays a major part in the success of many different operations and organizations.

The concept of logistics has evolved through several stages of development. From being an unplanned and unformulated process in the 50s, to being related just to the physical distribution of finished products during the 60s – 70s, then passing to an integrated perspective of production activities and distribution in the 90s, and nowadays it is considered as a part of the supply chain, which is a broader concept that includes the suppliers and customers of the company (Rushton, Croucher, & Baker, 2006).

2.2 Importance of Logistics

Logistics follows the Dual Nature of Value Theory: "Create value to the customers and suppliers of the firm and value for the firm´s stakeholders". It is generally recognized that business creates four types of value in products and services, which are: form, possession, time and place. Manufacturing creates form value as raw materials are converted to finished goods. Possession value is often considered the responsibility of marketing, engineering and finance, where the values is created by helping customers acquire the product through such mechanisms as advertising, technical support and term of sale. While value in logistics, is primarily expressed in terms of time and place. Products and services have no value unless they are in the possession of the customer when (time) and where (place) they wish to consume them, and by doing so, the economic value for the firm is generated. (Ronald Ballou, 2004).

Distribution and Logistics can have also a variety of different impacts on an organization´s financial performance. This particularly applies when the whole of a business is considered. Traditionally seen as an operational necessity that cannot be avoided, taking into consideration that, for companies, from 10 to 35 percent of gross sales are logistics cost, depending on business, geography and weight/value ratio a good logistics operation, it can also offer opportunities for providing financial performance. (Nansi)

For many companies, a key measure of success is the Return on Assets (ROA): the ratio between the operating income and the capital employed, as it can be observed in the following graph.

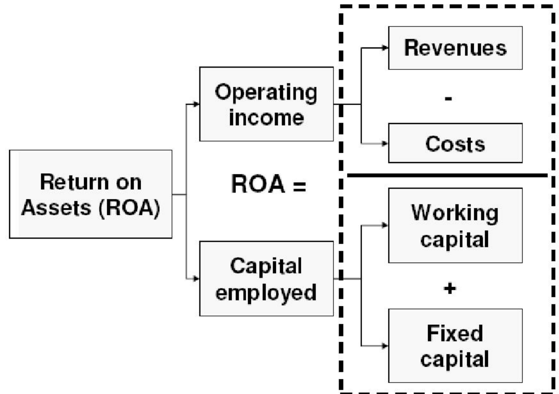


Figure 1 Impact of Logistics costs over ROA

In order to improve the business performance, the operating income should increase, and the capital employed decrease. Income can be enhanced through increased sales, and sales benefits from the provision of high and consistent service levels (On time deliveries, customer relationships, after-sales services), or by minimizing costs through efficient logistics operations (reduction in transport, storage and inventory holding costs, as well as maximizing labor efficiency).

On the other hand, the amount of capital employed can also be affected by the different logistics components. The working capital can be divided in inventories and cash and receivables. There are many types of inventory held by companies, including raw materials, components, WIP (work-in-progress) and finished goods. The key logistics functions impact very significantly on the stock level of all of these. This impact can occur with respect to stock allocation, inventory control, stock-holding policies, order and reorder quantities and integrated systems, among others. Cash and receivables are influenced by cash-to-cash and order cycle times. The logistics decisions should be made in order to decrease the level of inventories and to obtain faster payments.

Capital employed can also be decreased by reducing the fixed capital. There are many assets to be found in logistics operations: warehouses, depots, means of transportation, and material handling equipment. The number, size and extent of their usage are fundamental for an effective logistics planning.

Based on the model presented above it can be said that the main trade-off for logistics is between the expected customer service level and the costs that the company incurs in order to achieve it.

2.3 Factors influencing the logistic process

In recent years there have been very significant developments in the structure, organization and operations of logistics, notably in the interpretation of logistics within a broader supply chain. Major changes have included the increase in customer service expectations, the concept of compressing time within the supply chain, the globalization of industries, in terms of global brands and global markets, and the integration of organizational structures.

It is possible to view these different influences at various points along the supply chain and the factors can be clustered in 5 main categories: (Rushton, Croucher, & Baker, 2006)

The External Environment

One area of significant change in recent years has been the increase in the number of companies operating in the global marketplace. In the past, although companies may have a presence across a wide geographic area, this was supported on a local or regional basis through local or regional sourcing, manufacturing, storage and distribution. Nowadays, companies are truly global, with a structure and policy that represent a global business: global branding, global sourcing, global production, centralization of inventories and centralization of information, but with the ability to provide for local or regional requirements.

To service global markets, logistics networks become, necessarily, far more expansive and more complex, particularly for those companies that want to achieve a global strategy but providing a just-in-time service, fact that adds more importance to the design of the distribution network. The major logistics implications of globalization are:

- Extended supply lead times
- Extended and unreliable transit times
- Multiple break-bulk and consolidation options
- Multiple freight mode and cost options
- Production postponement with local added value

One key influence that has become increasingly important in recent years has been the development of a number of different economic unions (European Union, ASEAN, NAFTA, etc). Although the reason for the formation of these unions may be political, experience has shown that there have been significant economic changes, most of these beneficial ones. Within the European Union, for example, there have been significant advances in: transport deregulation, the harmonization of legislation across different countries, the reduction of tariff barriers, the elimination of cross-border customs requirements and tax harmonization. These changes had led many companies to reassess their entire logistics strategy and move away from national approach to embrace a new cross-border/international structure.

Another external factor affecting logistics is the rise in importance of “green” or environmental issues has had a particular impact in Europe. This has occurred through an increasing public awareness, but also as a result of the activity and pressure of international organizations. The consequences for logistics are important, including:

- The banning of road freight movements at certain times and days of the week
- The attempted promotion of rail over road transport
- The recycling of packaging
- Modifications on the product characteristics
- The outsource of reverse logistics flows
- Manufacturing and Supply

With respect to the manufacturing and supply processes, there have been many important developments which have resulted from both technological and organizational changes, like for example:

- New manufacturing technology: which can accommodate more complex production requirements and more product variations
- New supplier relationships: with the emphasis on single sourcing and lean supply, thus enabling suppliers and buyers to work more closely together.
- Focused factories: with a concentration on fewer sources but necessitating longer transport journeys.
- Global sourcing: emphasizing the move away from local or national sourcing.
- Postponement: where the final configuration of a product is delayed to enable reduced stock-holding of finished goods in the supply chain.

Some impacts of the factors mentioned above include the shortening of product life cycles, the wider product range expected by customers and provided by companies, and the increase in demand for time sensitive products, especially for the food and the consumer electronics industries. These may all add logistic problems with respect to the impact on stock levels and in particular the speed of delivery required.

Distribution

Related with distribution, fewer changes have been observed. Most of them are technology-based and are mainly focused in the operational context, like for example, new vehicles systems, stockless depots operating cross-docking arrangements, paperless information systems (implementations of RFID technology) and interactive routing and scheduling for road transport operations.

Retailing

In Europe as a whole there have been several trends in the retail sector that have had and will continue to have impact on logistics and supply chain development. In general, there have been a growth in multiple stores and a decline in independents ones. Multiple stores refer to those “one-stop” superstores and hypermarkets mainly located out of towns. Some of the changes observed in this field are the followings:

- The maximization of retail selling space, at the expense of retail stockrooms
- The reduction in DC stock-holding due to cost saving policies
- The reduction in the number of stock-holding DCs
- Just-in-time philosophies and concepts

Vendor Managed Inventory (VMI) policies: which tries to reduce or eliminate stocks in retail stores in favor of continuous flow of products needing more responsive delivery systems and more accurate and timely information.

The Consumer

As it was mentioned before, the customer service is considered as one of the key topics for the distribution network design and operation, and companies should take into consideration for decision making some evidences that their behavior is changing, for example, the fact that brand image is becoming less strong, and the dominant differentiator is changing to the availability.

Another important change in consumer´s behavior during the recent years is the non-store shopping or home shopping phenomenon that has been relatively common in the USA and Europe, and takes advantage of the access of clients to computers and internet in order to offer them electronic catalogues and direct selling services.

2.4 Description of the Network choices

The reasons why warehouses are required vary in importance depending on the nature of a company’s business. The main reasons are:

- To hold inventory that is produced in lean manufacturing
- To hold inventory and decouple demand requirements from production capabilities, helping to smooth the flow of products in the supply chain and assists in operational efficiency, enabling an agile response to customer demands.
- To hold inventory to enable large seasonal demands

- To hold inventory to help provide good customer service
- To enable cost trade-offs with the transport system by allowing full vehicle loads to be used.
- To facilitate order assembly

For the best possible customer service, a warehouse would have to be right next to the customer and would have to hold adequate stocks of all goods the customer might require; this would be an expensive, unmanageable and inefficient solution. The opposite alternative, which is the cheapest solution, would be to have just one warehouse and to send out a large truck to each customer whenever his orders are sufficient to fill the transport vehicle. The optimal solution lies somewhere between the two extremes (Lovell, Saw, & Stimson, 2005).

It is possible to classify distribution networks on the basis of choices that have to be made during the distribution network design or redesign:

- Number of echelons: direct shipment, 1-echelon, 2-echelon, 1 echelon + transit point, 3-echelon, mixed network. Some authors referred to this classification in different words, but basically are the same, for example:
    - (Payne & J. Peters, 2004):
        - Dispersed stock model. Finished goods stock held in more than one European distribution center
        - Central stock model: finished goods stock held in only one European distribution center.
        - Finished to order: no finished goods held in stock anywhere.
    - (Eero & Holmström, 2009): transit point is the same as country buffer.
    - (Chopra, 2003):
        - Manufacturer storage with direct shipping.
        - Manufacturer storage with direct shipping and in-transit merge.
        - Distributor storage with package carrier delivery.
        - Distributor storage with last mile delivery.
        - Manufacturer/distributor storage with costumer pickup.
        - Retail storage with customer pickup.

- Number of warehouses in each echelon: narrow distribution networks or wide distribution networks
- Location of warehouses
- Typology of warehouses in each echelon: central warehouse, regional warehouse, transit points, etc.

These choices have been considered, by many authors in the field, as the most important and strategic ones when designing a distribution network. Others might be considered as operational decisions, like for example the routing of vehicles, transportation mode, layout of the warehouse, among others, which are required for the subsequent refining of the design.

Next, the previous choices or decisions that have to be made are explained in detail.

Number of echelons

- Direct shipment: goods are delivered from the suppliers straight to the customers

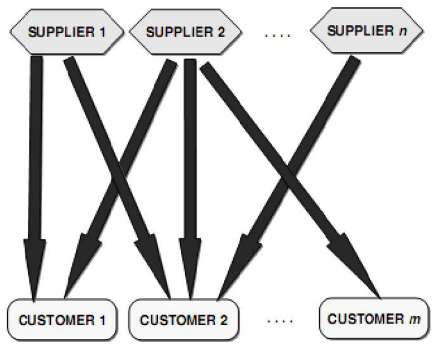


Figure 2 Scheme of Direct Shipment configuration

This type of situation is present when some conditions are present: the dimension of the expedition is big enough to guarantee low transportation tariff, the region considered is small enough to guarantee an adequate service level.

- 1-echelon: the central warehouse (one or many) fulfill all the assignments of the logistic channel. These warehouses provide the following functions:

- Product mixing: if suppliers only focus on a small part of the product range
- Reduction of the order cycle time: warehouses are nearer the market than the plants
- Optimization of transports: from plants to delivery points, thanks to the reduction in the number of arcs and the ensuing increase in the trucks utilization
- Centralization of safety stocks

The disadvantages respect to the direct shipment option could be an increment of handling costs due to additional activities of control movement and increase in maintenance costs due to a greater level of inventories.

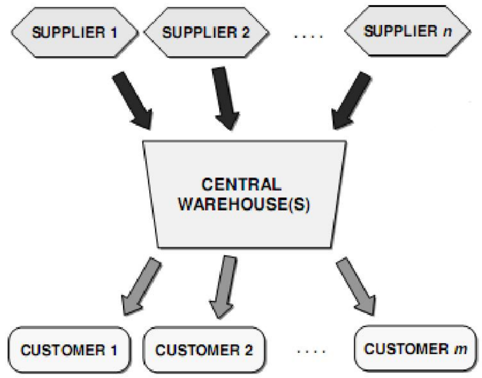


Figure 3 Scheme of the 1-echelon configuration

- 2-echelon: goods pass through two different levels of the distribution network from points of origin to the customers. The second tier of warehouses in a 2-echelon distribution network provides the following supplementary functions:

- Higher service level in terms of both cycle time and punctuality (thanks to the inventory in the regional warehouses)
- Optimization of transport to the end customers (local distribution)

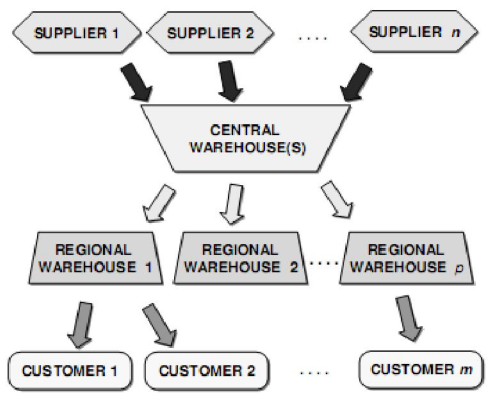


Figure 4 Scheme of the 2-echelon configuration

- 1 echelon + transit point: goods pass through one inventory echelon and one transit echelon with no inventories. The role of transit points aims at optimizing transports to the end customers by accepting a longer cycle time (+1 or 2 days on average) than the 1-echelon distribution network. It is usually used when clients are small and are spread on the area.

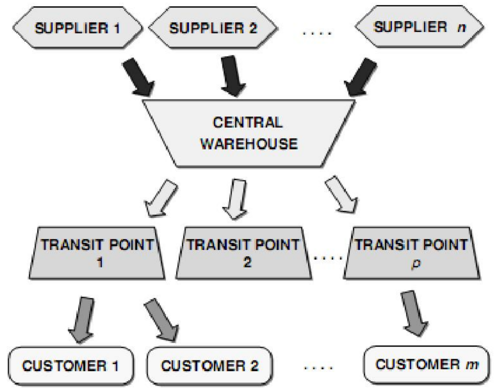


Figure 5 Scheme of the 1-echelon + transit point configuration

- Mixed network: this network allows direct shipment as well as deliveries through 1 or 2 echelons. Give the flexibility that allows the management of more than one distribution problem at the same time.

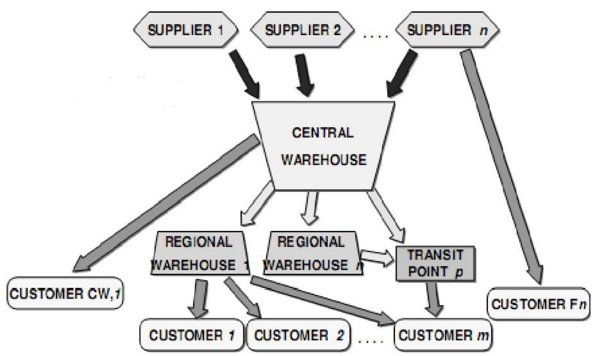


Figure 6 Scheme of the Mixed configuration

- 3-echelon: goods pass through three different levels of the distribution network from points of origin to the customers. It is composed of central warehouse, regional warehouse and transit point.

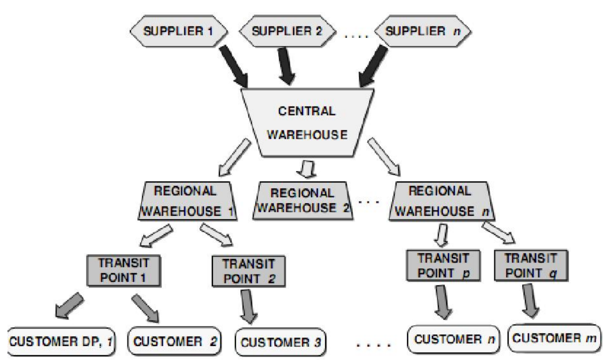


Figure 7 Scheme of the 3-echelon configuration

Number of warehouse in each echelon

Assuming the number of echelons has been set, the number of warehouses has to be determined in order to minimize the overall distribution cost for a given service level. In order to determine the number of warehouses, several factors have to be taken into account, for instance, costs trade-offs. The relationship of these costs will vary under different circumstances (industry, product type, volume throughput, regional location, age of building, handling system, etc).

The understanding and control of the trade-offs that exist between these different costs is a key element of supply chain management and design.

First, we describe the 5 cost components.

1. Stocks cost:
    - Maintenance cost:
        - § Storage cost (employment and conditioned space facilities , goods insurance)
        - § Borrowing costs on capital equipment
        - § Inventories depreciation
        - § Inventories obsolescence
    - Order costs:
        - § Management of stocking systems (stock control, communication, update activities).
2. Inbound transport cost or Primary cost:
   Cost due to the transport from establishments of the distribution network to the nodes (compressive tariff of the extra, administrative costs, no legal responsibility on the carrier)
3. Outbound transport cost or Secondary cost:
   Cost due to the transport from the nodes of the distribution network to the clients (compressive tariff of the extra, administrative costs, no legal responsibility on the carrier)
4. Handling cost:
   Movement of materials and packaging in the nodes of the distribution network (unload merchandise, control, put into stock, picking, order consolidation, loading to transport vehicle)
5. Order management cost:
   Order transmission, insertion, formal and credit verification, availability, scheduling deliveries, order confirmation)

The effect of different number of warehouses in a given distribution network can be seen by developing the economies of scale argument. If a distribution network is changed from one site to two sites, then the overall warehouse/storage costs will increase. The inbound and outbound transports are also affected by the number of warehouses in the distribution network, because the cost of delivery is essentially dependent on the distance that has to be travelled.

With an increasing level of decentralization (increased number of warehouses) the warehouse costs increase and the primary transport costs increase. In contrast, with increasing decentralization, the secondary transport (or local delivery) costs decrease. The total cost is assessed and this will usually lead to preferred level of centralization. In some cases, there can be a certain amount of uncertainty as to where the optimum lies (Lovell, Saw, & Stimson, 2005).

Cycle stocks and in transit stocks will not vary with an increase in the number of warehouses. Instead safety stocks will increase with the number of warehouses because the more the demand is split in the system warehouses, the more safety stocks.

Handling costs of course increase by incrementing the number of warehouses, although is subject to economies of scale.

The next graph summarizes the costs explained before. It is obtained by adding together the individual cost curves of the key distribution elements that correspond to each number of sites. It can be seen from the graph that the least expensive overall logistics cost occurs at the minimum point in the graph.

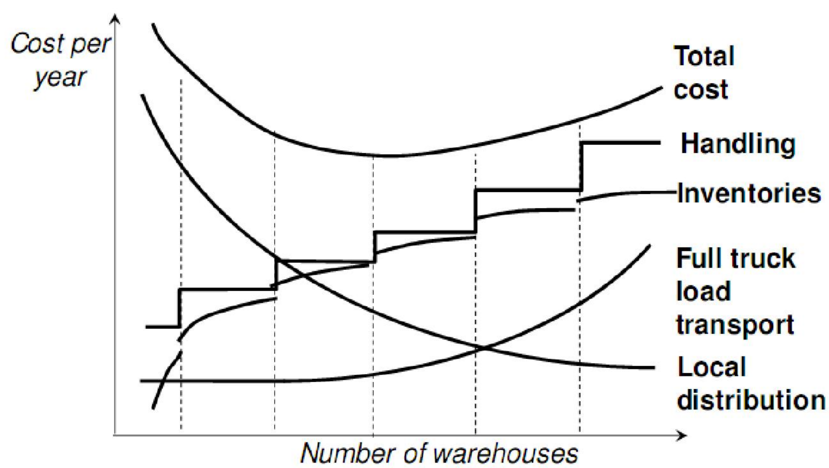


Figure 8 Logistics cost distribution

Location of warehouses

Locating fixed facilities throughout the supply chain network is an important decision problem that gives form, structure and shape to the entire supply chain system.

Optimizing the location of facilities within an existing network frequently can save between 5 to 15 percent of logistics costs (Ballou 1995).

Many logistics modeling techniques used in logistics concentrate on the detailed representation of specific parts of the logistics operation, for example: product optimization, warehouse location and vehicle routing. Suitable techniques do not exist to consider simultaneously all the possible alternatives. The problem of considering all products, made at many plants, shipped via all modes, to all the customers, via all warehouses is simple not possible. If the techniques did exist, solutions would require uneconomic runtimes on high capacity computers.

Linear programming is a mathematical technique that finds the minimum cost or maximum revenue solution to a distribution network problem. Under any given demand scenario the technique is able to identify the optimum solution for the sourcing of products. A typical sourcing model equation operates under the following constrains (Rushton, Croucher, & Baker, 2006):

- The availability of each plant for production
- The customer demand should be met
- The least-cost solution is required

The objective of a typical sourcing model equation is to minimize the following, given the run rate of each product at each plant:

- Raw material cost
- Material handling cost
- Production variable cost
- Logistics cost from plant to client

The output of the linear programming study is the optimized major product flows from point of origin to final destination. The next stage is to take these flows and to develop the most cost-effective logistics solution in terms of the most appropriate number, type, and locations of warehouses. Cost trade-off analysis can be used as the basis for planning and reasoning the planning of distribution systems. The models trying to address this (Ballou, 1995) are:

- Mathematical programming or exact methods which includes, multiple center of gravity, linear programming, integer programming and mixed integer programming
- Heuristics methods which use exact methods with heuristic procedures to guide the solution process
- Simulation

Types of warehouses

(Rushton, Croucher, & Baker, 2006):

- Finished goods warehouses: hold inventories from factories
- Distribution centers, which might be central, regional, national or local: all of these will hold stock to a greater or lesser extent
- Trans-shipment sites or stockless, transit or cross-docking DCs-by and large: these do not hold stock, but act as intermediate points in the distribution operation for the transfer of goods and picked orders to customers.
- Seasonal stock holding sites
- Overflow sites

In order to solve the previous problems it is important to understand what a distribution problem is, which main factors characterize it and how it influences or affects the flow of goods. Next section gives a broad definition of distribution problem and the next chapter individualizes the drivers.

2.5 Objective of the network design

The distribution network design has two main objectives:

a) Identify the network structure that allows the minimization of total costs while maintaining a predefined service level.

b) Identify the network structure that better manages the trade-off between the cost minimization and revenue maximization derived from the increase of the service level, guaranteeing the profit maximization.

Usually the first option is the one considered because it is simpler than the second one. The profit maximization objective requires estimating the potential gains resulting from the improvement of the service provided.

It is important when designing the distribution network to understand which are the costs that impact the most and the main trade-offs between them, in order to find the most efficient distribution solution.

Identification of the most relevant costs

The costs that need to be considered during the network design are the ones that are affected by the network configuration, these are: transportation costs, inventory costs, handling costs and order management costs (Chopra, 2003).

Transportation costs

Primary transportation costs: transportation from suppliers to the central warehouses and from central warehouses to the regional warehouses or transit points.

Secondary transportation costs: transportation from the distribution network nodes to the end customers.

Inventory costs

These costs refer to the four types of stocks that can be found within the logistic system: cycle stock, safety stocks, in-transit stocks and work in progress-stock. It is possible to group the main elements that compose the inventory costs in two categories:

Maintenance costs

- Storage Costs: generated by the used and equipped space and the insurance costs paid for the goods stored.
- Cost of Capital
- Goods depreciation
- Goods obsolescence

Order costs

Cost of the storage system management: generated by the revision of the stock, warehouse accountancy, communication and updating activities.

Handling costs

Costs generated by the handling activities in the warehouses and transit points of the distribution network, which include: loading/unloading activities, picking, order consolidation, etc.

Order management costs

These include all the costs related to personnel and information systems required for the process of the orders (data entry, credit verification, goods availability control, delivery scheduling, order confirmation, etc.).

2.6 Consumer Electronics Industry

This thesis will adapt the model of (Archini & Bannó, 2003) to the consumer electronics sector; thus changes in the structure of the model will be required, for example: change of relevant drivers and change of network solutions. It is the purpose of this thesis to understand in a greater depth the mechanics of distribution networks in this industry, to propose better changes and redesign approaches in order to save costs.

First an insight of the industry is presented, in order to understand better the basics.

Consumer electronics industry includes electronic equipment for everyday use. For example: personal computers, telephones, televisions, cameras, mp3 players, calculators, GPS, DVD’s and camcorders. This industry is largely dominated by Japanese and Korean companies, such as Sony, Toshiba, Panasonic, Samsung, and LG.

Every year the Consumer Electronics Association, which is a sector of the Electronic Industries Alliance (EIA), makes a worldwide exhibition, where manufactures present their new products and consumers can see and try the most recent innovations.

Delivering innovative new products quickly and at competitive prices requires an efficient and effective supply chain (Hammel, Keuttner, & Phelps, 2002).

Consumer Electronics market

According to the Consumer Electronics Unlimited the European market as a whole in 2009 contracted by five percent. The members of Europe's biggest buying group have so far been affected by the recession to widely differing degrees. While 2009 turnover growth in Germany, France and Italy was actually slightly higher than the previous year's, Spain, the United Kingdom and some East European members, for example, suffered marked setbacks. Not all European countries are affected equally and simultaneously by the consequences of the economic crisis. The reasons for this are the significant differences in local market structures and consumer preferences. Despite this, intense competition persists in the European market for consumer electronics and household appliances while pressure on prices and margins is strong.

Eurostat has an interesting publication where compares price levels in consumer electronics using purchasing power parities. It concludes that price levels in EU countries lie very close together at the exception of Iceland which is far away from the average. Italy is slightly above the average (Borchert, 2008).

e-commerce

Nowadays the Internet has become a very important resource to sell consumer electronics equipment. The Internet is already the world's largest shopping mall, and is in a position to grow considerably over the foreseeable future (McQuitty & Peterson, 2000). With the Internet consumers can get great deals in less than 10 minutes of searching and comparing prices; it eliminates the need of going physically from one store to another. It has been stated that shoppers visit first the retailer and then buy through the Internet; this is because they want to see first physically the product and then benefit from the Internet purchase.

The electronics market is different from the markets of books, music and movies, due to the after sales service. The success of the firms in the e-commerce market depends on the efficiency of their distribution networks (Jay, Ozment, & Sink, 2007). This new approach is characterized by small order size, increased daily order volumes, small parcel shipments and same day shipments.

Environment

A very important issue to take into account is the environmental waste that is generated every year by electronic equipment. Since 2003 there is an EU legislation that restricts the use of hazardous substances in electrical and electronic equipment and promotes the collection and recycling of such equipment. It also provides schemes where consumers can return their used e-waste to the manufacturer free of charge.

Despite such rules on collection and recycling only one third of electrical and electronic waste in the European Union is reported as separately collected and appropriately treated. A part of the other two thirds is potentially still going to landfills and to sub-standard treatment sites in or outside the European Union.

Network redesign examples

It has been realized that by redesigning the distribution network of this type of industry, companies can save a lot in costs. For instance, the reengineering of HP's CD-RW Supply Chain and the design of a supply chain for innovative products of Nokia has lead to a significant costs reduction.

HP

Hewlett Packard was one of the pioneers of the re-writable CD-RW industry. Initially this product was targeted to business users but then the consumer market exploded with the digital revolution and the Internet, so revenues were doubling annually. On the other hand, the industry experienced accelerated product life cycles and the average selling price continued to drop 50% per year, due to competition.

Due to the previous facts, HP was forced to create a new business model that could deliver consistent profits in a market with significant price drops. The previous supply chain model was slow (126 days Cycle Time), expensive, unresponsive and with increasing inventory-driven costs.

After the implementation of the new supply chain, the results were savings from $50m a year, realizing total investment in less than a month. One world wide- distribution center in Asia, (instead of 3 regional locations) and 90% reduction in supply chain cycle time (from 126 days to 8 days).

Nokia

Many businesses deal with the problem of designing supply chains for diverse customer's needs; this is the case of Nokia. Nokia's networks division wrestled with a challenging problem: how to deliver its mainstay product, the base station that is the back bone of mobile communications, from a few days for some customers to a couple of weeks for others, and do so at an acceptable cost (Eero & Holmström, 2009).

Nokia understood that in order to support sales growth of its innovative products, its supply chain should be responsiveness, which is able to fill orders quickly, instead of efficient, which Fisher recommends for functional products. At a first try, Nokia configured a supply chain with country warehouses of finished products located close to the customers in order to fulfill orders in a matter of days. This configuration did not work, because it gave rise to inventory increasing costs (100 days of inventory), obsolescence and they realized that often a needed product configuration was not available at a specific location.

After analyzing what went wrong, the company determined that its customers fell into 3 categories and each needed a different supply chain. Three different supply chains were implemented and an inventory reduction of 40-45 days of supply was achieved and satisfaction improved significantly.

Chapter 3. General Methodology for the Development of the Model

In the previous chapter it was explained the characteristics and importance of the distribution networks and the different possible configurations that can be obtained during the design phase by combining the number of echelons, the number of warehouses in each echelon, the location of the warehouses and their type. Also, it was described the different types of costs that are involved in the logistic activities which demonstrate the high level of complexity of the problem.

In this chapter, it is presented the methodology used for the development of the different stages of the Distribution Network Design Model proposed by this work, starting with the proper identification of the main factors or drivers that affect the first stages of the distribution network design, data that was collected from the literature. Followed by the identification and analysis of different distribution problems presented within firms pertaining to the consumer electronics industry in Italy, for which some interviews were done, and finally the identification of correlations between the distribution problems observed and the distribution networks adopted by those companies in order to satisfy the requirements of the clients in terms of service and at the same time reducing the total costs.

It has been decided to analyze Italian companies because as described in the section 2.3 there have been important changes in Europe during the last years that led to reconfigurations of the distribution networks (Hammel, Keuttner, & Phelps, 2002).

The following flow chart presents the sequence of steps described above.

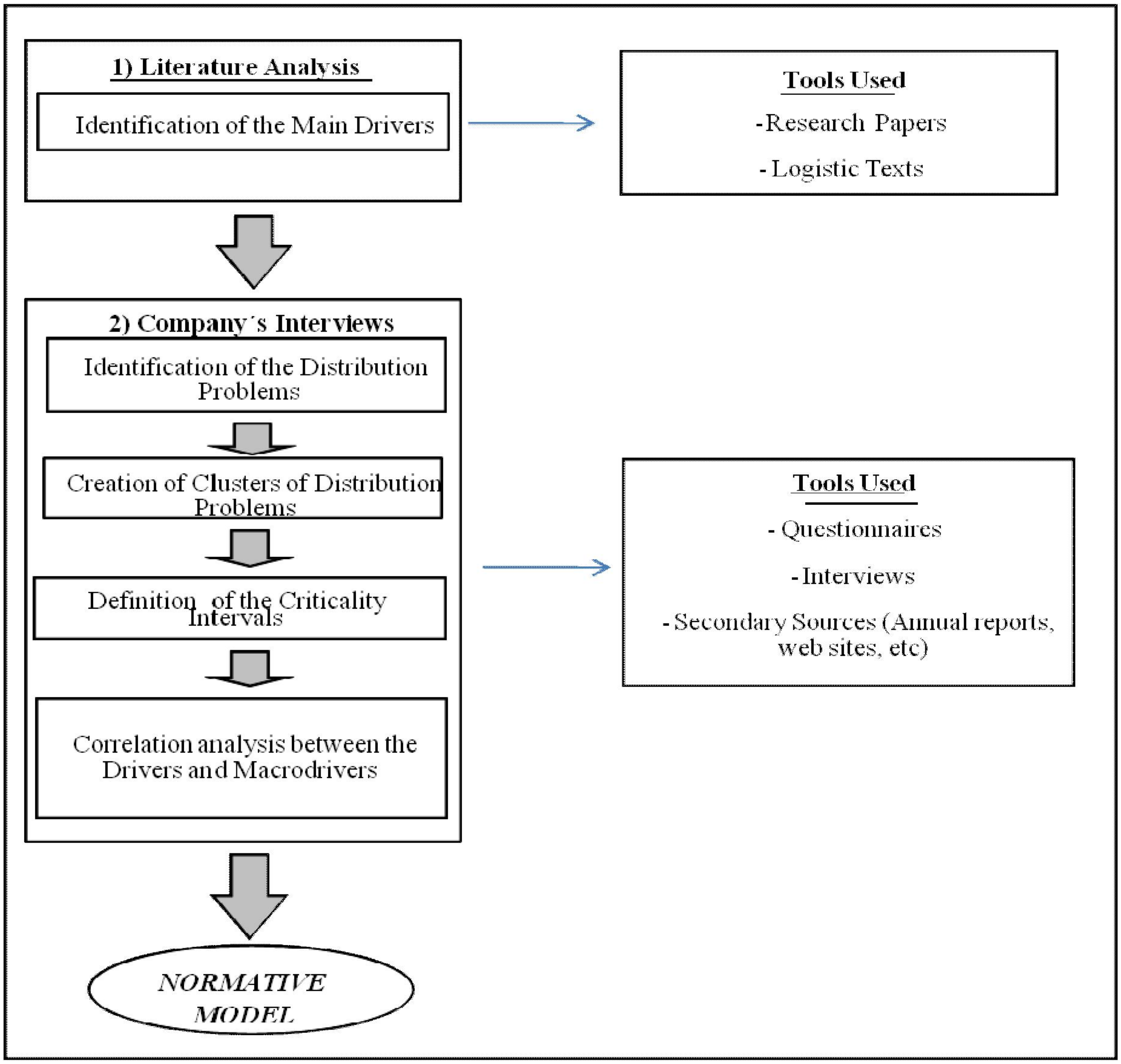


Figure 9 Flowchart for the development of the Distribution Network Design Model

3.1 Procedure for the literature analysis (chapter 4)

It has been studied and proved that some drivers have an impact on the main strategic decisions when designing a distribution network. In other words, the drivers taken into account by most authors in the past years were considered as a starting point to identify the founding set of drivers for a new model.

The main sources of information considered to carry out the analysis were logistics texts and research papers. Also, further information was provided by companies interviewed and it was used to tune the identification of the most important drivers.

Several methodologies which are related to the distribution network design problem have been presented by different authors. From those, it was possible to identify two types of approaches: the “complete” ones that try to solve both strategic (structure of the network, types of warehouses, etc) and operational issues (flow management, delivery policies, etc); and other methods that are focused in a part of the problem, like for example the location and allocation of the warehouses. For the purposes of this thesis, it has been decided to consider only the researches of the first group, because they present the problem as a combination of different factors.

In the case of the research papers, a total amount of 30 papers were analyzed and classified according to the distribution network choice that was intended to solve and the main drivers considered by each author as relevant in order to achieve an optimal solution.

Among the papers found, different distribution network choices were tackled but for the driver analysis only four of those were considered since they are the relevant ones according to the objective of the current thesis. The network choices selected, as it was mentioned in the section 2.4, were:

- Definition of the number of echelons of the distribution network
- Definition of the number of warehouses for each echelon
- Definition of the warehouse location
- Definition of the warehouse typology

It can be distinguished two types of papers, the ones that face the problem using a quantitative approach and the ones that are qualitative oriented.

- **Quantitative papers**: quantitative research refers to the systematic empirical investigation of quantitative properties or variables, and their relationships. The objective of quantitative research is to develop and employ mathematical models, theories and/or hypotheses pertaining to a phenomenon. The analysis in the quantitative research proceeds by using statistics, tables, or charts. In the case of logistics, this type of papers usually intends to solve a specific problem of the network configuration, for example the warehouse location.

- **Qualitative papers:** qualitative research involves gathering information that is not based on empirical data accumulation. The focus is on the expert opinion of people who are knowledgeable about the explored question and can give insights about the area. It relies more on the authentic opinion of fewer subjects, and is hardly presented in the form of numerical data. In-depth analysis can be carried out on the base of this type of research. On the other hand, to some extend it suffers from subjectivity and bias. For logistics, this second category of papers aims at solving the problem from a wider perspective and not focusing only in one part of the distribution network configuration (W.L & Neuman, 1997).

Both types were considered for the main drivers' identification since ultimately all the papers intent to solve the same problem despite the fact that the methods used are different. To carry out their analysis with a methodological approach, a table was designed and all the information considered relevant was registered. Its purpose was to have a synthesized view of the main problems that were discussed in the papers and the main drivers that were taken into account in order to solve those problems.

In order to make a better analysis, the drivers mentioned in the papers were classified in four categories that are called macrodrivers, or group of drivers that have a direct impact on a specific element of the distribution network. These macrodrivers influence directly the logistics costs, but mostly the physical distribution, reason why they can guide the designer to the best network. The macrodrivers are:

- **Product Drivers**: characteristics of the product
- **Service Drivers**: characteristics of the service provided to the customer and the process performance
- **Demand Drivers**: spatial and temporal characteristics of the demand
- **Supply Drivers**: characteristics of the supply chain

Once identified the different drivers, different correlations between the drivers and the distribution network decisions (number of echelons, number of warehouses, warehouse location and typology of warehouse) were obtained taking in consideration the frequency of appearance of the driver among all the papers to make one decision.

At the end, it was assumed that the frequency of appearance of the drivers in the papers analyzed, and that are used to take one distribution network decision, is directly proportional to the importance of that driver during the distribution network design. With this it was possible to obtain a list of drivers that must be taken in consideration during the design or re-design of a distribution network.

3.2 Procedure for the interviews (chapter 5)

Once having identified and analyzed the main drivers that must be taken in consideration for the distribution network design, the next step was to develop a tool that could be delivered to several companies operating in the consumer electronics industry in Italy in order to obtain from them the characteristics of the four macrodrivers previously defined (product, service, demand and supply) and the distribution networks actually implemented by them.

The tool developed was a Questionnaire which includes the following main sections (Appendix 1):

1) Data Context: Corresponds to general data of the interview (Name of the company, Date, Interviewee) and general data of the company (Sector, Market Share, Business units to consider)
2) Commercial Organization: which is referred to the type of clients of the company,
3) Characterization of the actual Distribution Network:
    a. Drivers for the design of the distribution network: the different drivers obtained during the literature analysis were grouped in macrodrivers (product, service, supply and demand) and presented in the questionnaire with their respective units of measure.
    b. Characterization of the Supply chain: includes a chart with the number, location and characteristics of each node of the actual distribution network.
    c. Actual Distribution Network: includes a graphic representation of the different distribution network types where it can be selected the used one, and also an European map were it can be placed the different plants, warehouses and transit points that conforms the distribution network of the company
4) Flow Characterization: corresponds to a graph were it can be placed the different flows that the company´s products follow from the plants the final clients. It is asked to present also the percentage of each flow.
5) Managerial Logic: corresponds to the inventory policy used by the company, the kind of transportation implemented and the strategic decision of give in outsource or not some of the logistics activities.

For the implementation of the questionnaire, different companies of the consumer electronics industry were contacted. Some prerequisites were established in advance in order to obtain a representative, coherent with the objectives of this thesis and uniform sample for the analysis, which were:

- Products manufactured: Personal computers, digital imaging, televisions, mobile phone, sound and peripherals, and white goods.
- Multinational firms operating in Italy
- Interviewee: Logistic or Operations Manager

Three companies of the industry which satisfied the requirements mentioned above accepted to be interviewed: Hewlett-Packard, Sony and Samsung. Although the limited number of them, it was considered to be a representative sample of the consumer electronics industry because the distribution problems presented in each one were diverse, as well as the distribution network adopted. A wide range of problems and solutions was obtained with the sample used.

Due to the availability of time of the Managers interviewed, a personal interview was not possible, but a phone call appointment was fixed with each of them with duration of approximately one hour. During the phone interview, several questions were asked and the questionnaire was used as a supporting tool; it was not directly filled by the interviewees.

3.3 Procedure to Identify Distribution Problems (chapter 5)

The information collected during the interviews was used to fill the questionnaires in order to have in the form of charts, graphs and maps all the information given by the managers in charge of the logistics of their company.

For each company case it was possible to identify at least one distribution problem, or groups of products and clients characterized by specific values of the drivers that project the network, and that justify a specific flow management. The individuation and description of these problems is very important to understand the factors that affect and influence the strategic decisions of the network design.

In “Global operations and logistics text and cases” (Dornier, Fender, & Kouvelis) distribution problems are defined as “logistic families”, stressing that identifying diverse families within an organization demonstrates a mature level in the flow management. These approach permits to implement distribution processes differentiated according to the regrouping characteristics, rather than only one for all the products and clients. For each family a logistics route has to be established with the objective of minimizing total costs guarantying the service level requested by the clients. The authors propose characterization criteria:

- The cycle time, conditioned strongly by the choice of transportation and the allocation of inventories in the system, and the
- Order dimension

A firm should in this way characterize its distribution problems only on the base of 4 groups that derive on the combination of cycle time (high/low) and the dimension of the order (high/low). The adopted matrix for the definition is the following:

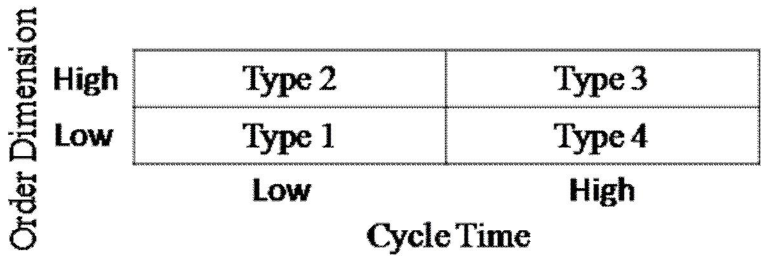


Figure 10 Distribution problem matrix of Dornier et all.

To describe the distribution problems based only in these two drivers, is not complete, because there are other drivers that impact considerably over the firm strategic choice: for example the high value of the product pushes over the centralization of the stocks in order to reduce the costs related to the financial charges, the security and its inventories.

In this point of the chapter it is explained the criteria followed by this model and applied to the firm cases in order to define completely the distribution problems.

Adopted procedure

The criteria proposed for the definition of distribution problems in the scope of each analyzed firm case, is composed by two principal steps.

First the flow diagrams has to be studied, presented in the paragraph 5.3 of each firm case in the chapter 5, in order to identify groups of products and clients characterized by a specific management of flow.

Subsequently, the values of the drivers are analyzed for each individual group, in order to provide a complete description.

It is important to underline that, once the groups of products and clients with a determined logistic route are identified, it corresponds always to precise values of service, demand and supply, while the product drivers are not valuable in a univocal way.

This is because inside one logistic family individualized it can be found a wide range of codes, each with specific characteristics. For example a firm can adopt one distribution network for 5000 products belonging to diverse sectors and characterized by different properties. To describe this problem in terms of product drivers, it was therefore calculated the average of all the products distributed with one unique network.

The following diagram illustrates in a synthetic way the procedure exposed for the definition of the distribution problems.

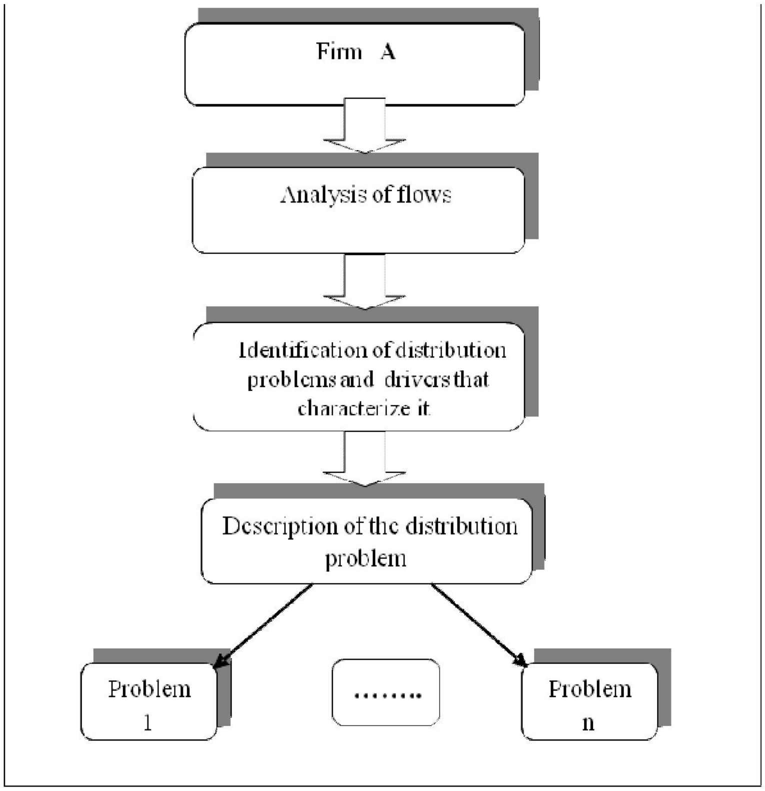


Figure 11 Diagram for the definition of Distribution Problems

3.4 Procedure to make the clusters (chapter 6)

After the identification of the distribution problems explained in the previous section, the next step is to form groups of them based on the distribution network adopted.

First, it is studied the number of levels and typology of the facilities at each level, secondly it is characterized the network at one level with transit points or with central warehouses, and then networks with two levels of central warehouses and transit points. The characterization consisted in the specification of number of nodes for each level, location and allocation of them, area covered by each one, area of the facility, types of clients served and variety of products managed.

These clusters will be part of the results analysis conducted in chapter 9, from which the normative model presented in chapter 10 will be formed.

3.5 Criteria for the definition of the criticality intervals (chapter 7)

In order to get the synthetic representation of each distribution problem of the company cases, it is needed for the projection a reference scale, composed by 5 intervals in order to find the criticality of each driver. The intervals have a growing criticality value from 1 to 5.

The objectives of this operation are two:

- Obtain an absolute reference system that permits the confrontation between drivers with different units of measure.
- Put in evidence the different intensities with which the value of a driver can influence the costs, or identify the criticality that the particular driver has in the company case.

The 5 intervals are:

- 1: low criticality
- 2: medium low criticality
- 3: medium criticality
- 4: medium high criticality
- 5: high criticality

The criteria proposed for the definition of the intervals has the following steps:

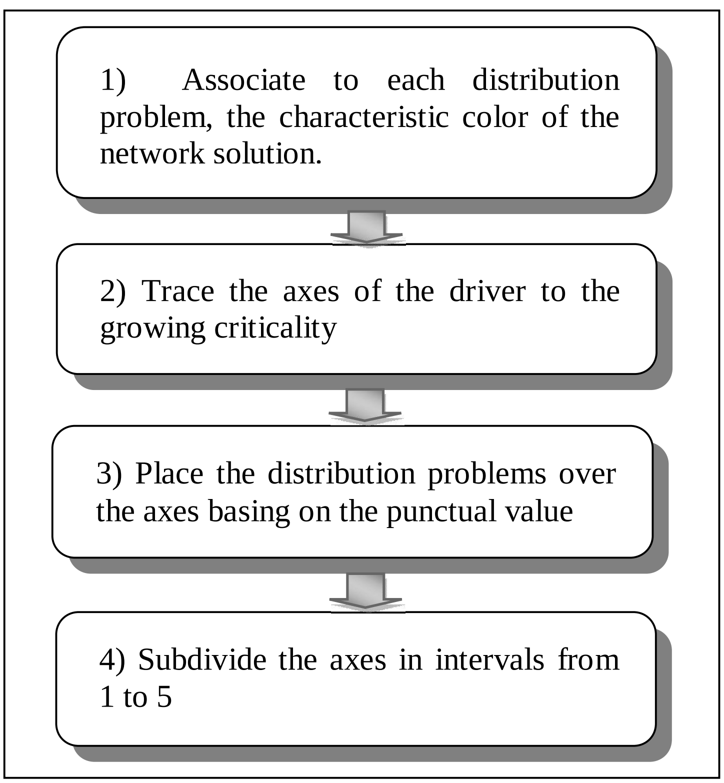


Figure 12 Diagram for the definition of the Criticality Intervals

1. Each driver is represented with different colors depending on the cluster that it belongs to. In particular the colors are the following:

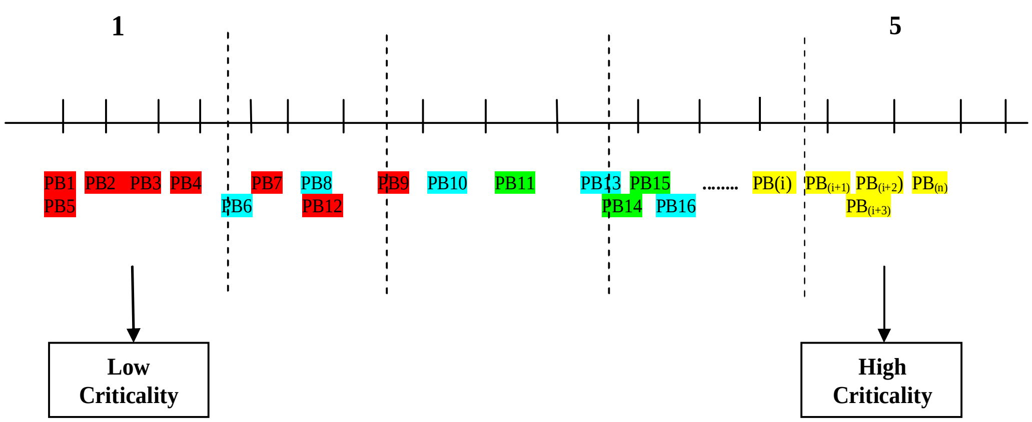
   - Yellow: direct delivery from plants
   - Green: 1 level of CWs
   - Blue: 1 level of TPs
   - Red: 2 levels, CWs and TPs

2. Trace the axes of the driver to the growing criticality

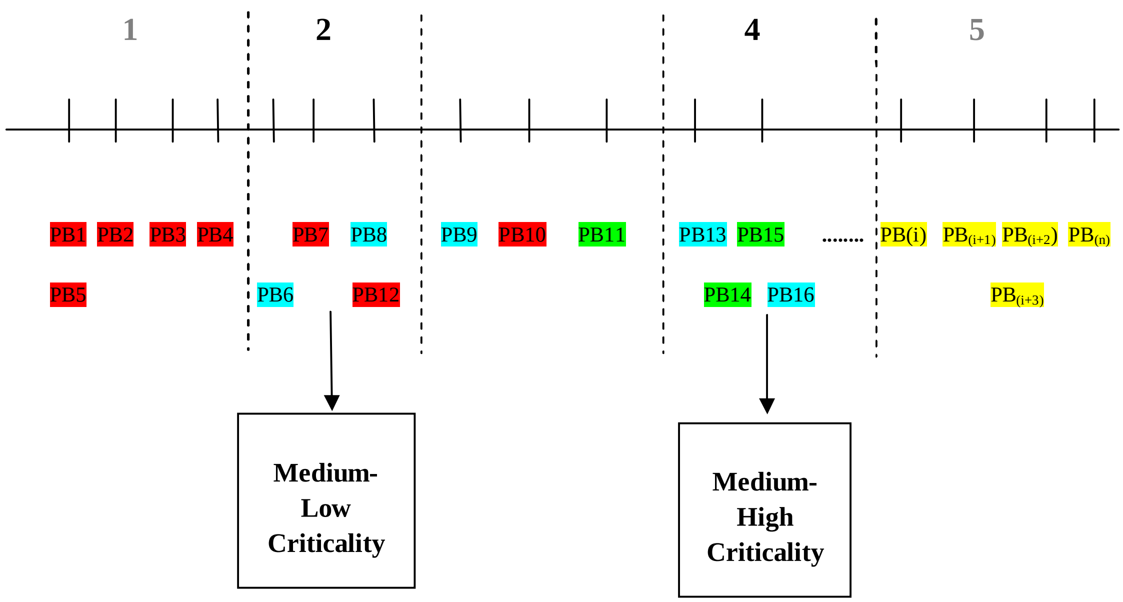
3. Each distribution problem is represented with its particular color over the axes basing on the punctual value. For the representation, refer to the tables defined in chapter 5.

4. The identification of different zones of criticality for each driver is done analyzing the distribution of the colors of the different distribution problems over the axes:

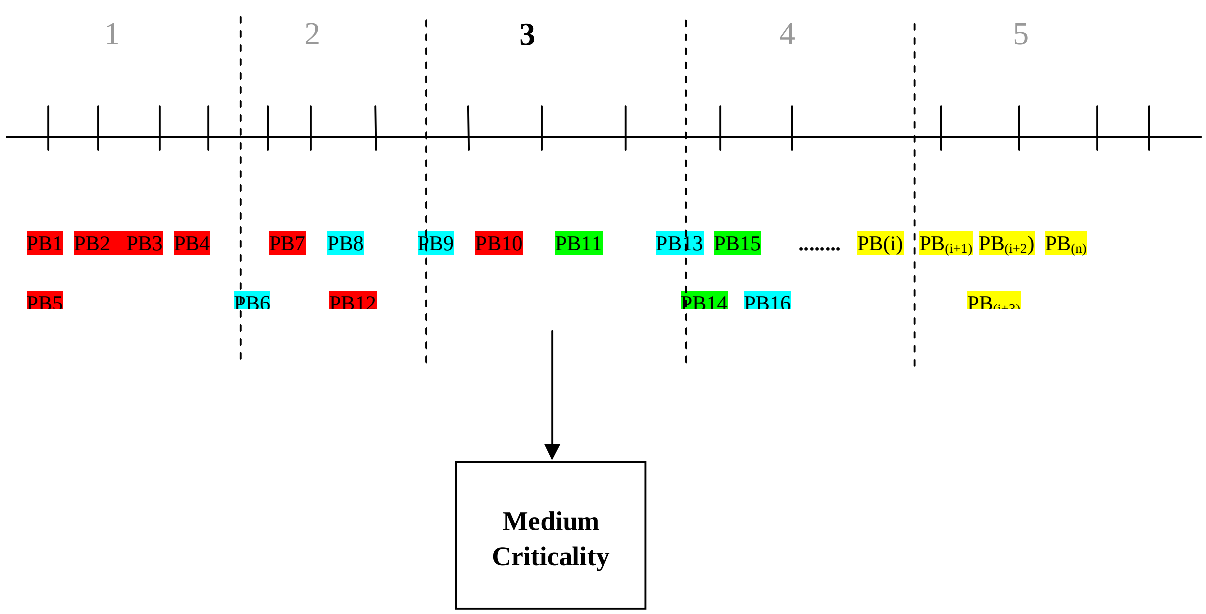
   - The intervals of high and low criticality are characterized of specific colors that identify network solutions well defined. For example, considering the following figure that examines a generic driver: at a higher level of criticality the degree of centralization augments. In this case the interval definition of high criticality (5) is at the extreme right characterized by distribution problems with direct delivery; the interval of low criticality (1) would be instead the one at the extreme left characterized by decentralized solutions.



   - The zones of criticality medium low or medium high are identified instead of one or two colors representing solutions of gradual passing of one strategic choice (centralization) to the opposite (decentralization). Considering the preceding example, a medium high criticality (4) it's characterized of networks of one level with CW, one level with TP or networks of two levels with CW and TP. Similarly will be indicated the medium low criticality (2) characterized by distribution problems with networks of two levels with CW and TP or 1 level with TP.



- The medium criticality (3) is characterized by the presence of all or almost all the colors meaning that in this interval can be found almost every network solution and therefore the driver has no particular influence in determining the solution.



It is opportune to emphasize that the preceding example is an ideal case, because in reality in the different zones could appear exceptions. Hence, never is a single driver which determines the network choice, but rather the combination of more factors. The objective is to get for each driver the reasonable intervals that are comparable between them and characterized by the presence of distribution problems that fall on it.

Using the scales of criticalities, the conversion of all the driver´s values of the distribution problems obtained during the interviews to a unique unit of measure was done. After this operation, it was possible to calculate the criticality values of each macrodriver (Product, Service, Demand and Supply), which were considered as the average of the drivers that compose each macrodriver.

$$C_i = \frac{\sum_{j}^{j_{max}} c_j}{j_{max}}$$

with: c_j = driver criticality j, with j = [1, …, j_{max}];

C_i = Macrodriver criticality i;

i = {product, service, demand, supply}

j = {variety, value, density, …., level of specialization} = {all the drivers}

Finally, with the objective of represent the distribution problems in a more aggregated way it has been decided to define two new dimensions: Market, which is the combination of Service and Demand drivers, and Firm, which is the combination of Product and Supply Drivers. The decision on grouping the data in this form derives from 2 hypotheses.

In the first place, it is considered that product and supply drivers are strongly conditioned to the internal decisions of the firm, while demand and service is determined by the market, or by exogenous elements of the firm. In reality, the limits between internal and external decisions are not so clear. The characteristics inherent to the product, for example, are not completely attributable to the firm's will, but are in part determined from the market needs; analog considerations can be made to the service level.

The other hypothesis is based on the fact that product and supply drivers influence more over maintenance and handling costs, while the drivers of service and demand influence more on transport costs.

Therefore it is possible to obtain representative values by calculating the averages of the discussed pairs of macrodrivers.

$$CF = \frac{Cp + Cl}{2} \qquad\qquad CM = \frac{Cs + Cd}{2}$$

CF = firm criticality;

Cp = product criticality;

Cl = supply criticality;

CM = market criticality;

Cs = service criticality;

Cd = demand criticality.

In the way that are expressed the formulas above, it is assumed that the drivers pertaining to a macrodriver, and the macrodrivers that conform a group, has the same weight within it, which means that no differentiation of importance of the drivers and macrodrivers is considered. A further analysis of Correlations was done in order to prove if this assumption was correct, or if the formulas needed to be adjusted by assigning levels of importance to each element.

3.6 Procedure for the correlation analysis (chapter 8)

The correlation analysis is a statistical method that defines the variation in one variable by the variation in another, without establishing a cause-and-effect relationship. The coefficient of correlation is a measure of the strength of the relationship between the variables; that is, how well changes in one variable can be predicted by changes in another variable (Business Glossary, 2010).

For the purposes of this thesis, the correlation analysis was done with the objective of identify the relation between the drivers and between drivers and their correspondent macrodriver. It was used as input data the chart of distribution problems expressed with the drivers criticalities (Tables 19 and 20). Using the formula “CORRELATE” of a Microsoft Excel worksheet it was possible to obtain a symmetric and diagonal chart of Correlation Factors between all the drivers and macrodrivers.

With the analysis of the result´s chart it was possible to determine whether or not different weights or level of importance of each driver within the macrodrivers should be assigned.

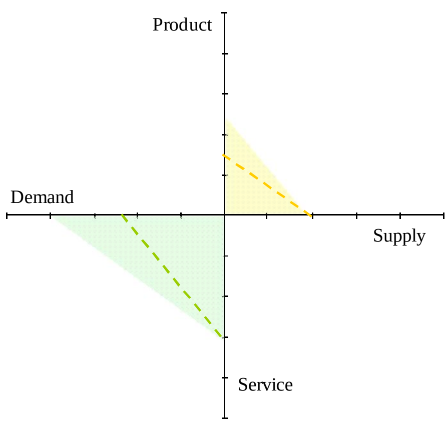
3.7 Synthetic representation of the firm cases (chapter 8)

With the objective of representing in a synthetic way the company cases, it was opportune to build a form that permits to underline on one side the characteristics of the identified distribution problem within each company case and on the other side the solution of the correspondent network.

All data is reported in a structured and precise way. The form, in fact, is a document that permits to observe the most significant information to deal with the analysis of correlation between the complexity of the distribution problem and the spatial network.

Next, it is reported the structure of the form.

<table>
<tr><td colspan="2">COMPANY NAME

General data</td></tr>
<tr><td colspan="2">Distribution problem</td></tr>
<tr><td>

Synthetic representation of data

Punctual values and criticality of drivers

Legend: Na= not available

Criticalities of drivers and macrodrivers</td><td>Solution of the network

- Decision on the number and typology of the levels
- Characterization (decision on the number, location and allocation) of the nodes</td></tr>
</table>

The sheet is divided in 3 major sections; which contain significant data for the development of the research.

General data

First, general data, in order to identify and characterize the company context in test:

- Sector
- Categories of products
- Turnover

Synthetic representation of the data

Initially the distribution problem is represented graphically, in a way to immediately provide the information of which are the more relevant drivers. Aggregation was carried out using two broken lines to connect the values of product and supply and service and demand. The two areas generated, colored different, provide immediately the idea of which ones are the more critical drivers for each distribution problem considered. Green area indicates market and yellow area indicates firm.

Afterwards, a summary table of the drivers is reported, completed with data obtained during the meeting with the company. In the adjacent column to the punctual values are the respective criticalities. The average is next reported, for each macrodriver, following the table just described.

Solution of the network

Based on the solution adopted by the firm, it is first reported the graphical representation of the network that describes the levels, then follows a representation that characterized, in terms of number, location and allocation of the nodes of the network. Followed by a short description.

Chapter 4. Identification of the main drivers that describe a distribution problem

In this chapter is carried out the literature analysis in order to identify the main drivers that describe a distribution problem and that will conduct the core of the analysis of the company cases. First are described the total amount of drivers presented in the work of "Archini and Bannò" in order to understand better what each one means and how they are measured. The drivers are grouped in macrodrivers: Product, Supply, Demand and Service. Then, the literature analysis was carried out by analyzing 30 papers. Graphs and tables are shown in order to understand better which the most important drivers are and which most of them authors have considered in their investigations.

4.1 Description of the Drivers presented by "Archini and Bannó"

Product Drivers

Density (kg/m^3) The density of a product is defined as its mass per unit volume.
Value (€/kg) It's the ratio between the price of the product and its weight.
Risk of Obsolescence (days) Every product has a specific life cycle, time that can be measured in days, weeks, months, etc. The risk of obsolescence can be considered either as perishability (time from the date of production to the date of expiration), for example for fresh goods or it can be seen as the period of time that a product can be offered to a market which is determined by changes in the customer's needs or due to the launch of a new version of the product, for example for consumer electronics goods.
Variety (number of products) Amount of different product codes that a company has. It is measured according to the number of codes commercialized by the company during a year.
Substitutability (qualitative) In the case that the product is out of stock the company could supply another product to satisfy the same customer need.

Product complexity (qualitative) Level of technology and innovation involved in developing the product, also includes the level of services involved in supporting the product from production through distribution and after sales support.
Contribution margin (%) Contribution margin equals price minus variable cost divided by price and is expressed as a percentage.

Service Drivers

Cycle Time (days) Number of days it takes to deliver an order from the moment it was placed by the customer.
Accuracy (%) Represents the capacity of the firm to fulfill orders in the exact way as it was placed by the customer. It can be calculated by dividing the number of correct orders delivered by the total number of orders placed.
Completeness (item fill rate) It is the probability of having a product in stock when a customer's order arrives.
Tracking (qualitative) Capacity of the firm to provide relatively accurate information about the state of the order in progress.
Returnability (qualitative) Ease with which a customer can return unsatisfactory merchandise and the ability of the network to handle such returns.
Customer experience (qualitative) Ease with which the customer can place and receive the order.

Demand Drivers

Number of Customers Total number of customers the company has.
Spatial density (number of customers/km^2) The quantity delivered on each shipment is directly related with the amount of Point of Sales (or customers) that a company has by square kilometer.
Dimension of the order (typology) The dimension of the order can be classified from the point of view of the quantity, in different levels: single product, packages, boxes, pallets, truck loads.
Frequency of delivery (deliveries/week client) Corresponds to the amount of deliveries for unit of time (days, weeks, months)
Seasonality (qualitative) Any predictable change or pattern in a time series that recurs or repeats over a specific period of time can be said to be seasonal.
Predictability of demand (%) Average margin of error in the demand forecast at the time production is committed.

Supply Drivers

Number of Plants Total number of plants the company has.
Exclusivity of production in a plant It is the exclusivity of realization of a product in one plant.
Distance from plant to client (km) The location of customers and the location of the plants have to be known in order to calculate the distance.
Level of specialization Plants producing only one family of products

4.2 Classification of the papers by distribution network decisions and drivers

The first table details the paper reference number, author and year, and the second one specifies the reference number of the paper that considers a driver relevant for each decision.

In the following tables are listed the four distribution network decisions and their relation with the drivers according to each author.

Reference number	Title	Authors	Journal	Year
1	What is the right supply chain for your products?	T. Payne and M. J. Peters	Journal of Logistics Management	2004
2	Assessing International Allocation Strategies	B.t Vos and E. van den Berg	International Journal of Logistics Management	1996
3	How to design the right supply chain for your customers	E. Eloranta and J. Holmström	Supply Chain Management: an international journal	2009
4	Designing a Distribution Network in a SC	S. Chopra	Transportation Research Part E	2003
5	Reformulating a Logistics Strategy: A concern for the Past, Present and Future.	R. Ballou	International Journal of Physical Distribution	1993
6	Distribution/Logistics Network Planning	D. Ratliff	Georgia Tech	
7	Product value-density: managing diversity through supply chain segmentation	A. Lovell, R. Saw and J. Stimson	The Internationl Journal of Logistics Management	2005
8	Distribution Network Design an Integrated Planning support framewor	Mourtis and Evers	International Journal of Physical Distribution & Logistics	1995
9	Logistics Network Design: Modeling and Info considerations	R. Ballou	International Journal of Logistics Management	1995
10	Location/allocation and routing decisions in in supply chain network design	S. H. Lashine, M. Fattouh and A. Issa	Journal of Modelling in Management	2008
11	Distribution network design: New problems and related models	D. Ambrosino, M.G. Scutell	European Journal of Operational Research	2005
12	International Logistics: A diagnostic Method for the Allocation of Production and Distribution Facilities	Van de Ven and Ribbers	International Journal of Logistics Management	1993
13	Achieving agility in SC through simultaneous design of and design for SC	H.Sharifi, H.S. Ismail and I. Reid	Journal of Manufacturing Technology Management	2006
14	A taxonomy for selecting global supply chain strategies	M. Christopher	International Journal of Logistics Management	2006
15	Distribution system Design with two level routing considerations	Jenn-Rong Lin and Hsien-Ching Lei	Department of Transportation and Navigation Science, National Taiwan Ocean University	2009
16	Linking Products with Supply Chains: Testing Fisher's Model	E. Selldin and J. Olhager	Supply Chain Management: An international Journal	2007
17	Distribution network design under uncertain demand	I. Ferretti, S. Zanoni, and L. Zavanella	Universita degli Studi di Brescia	2009
18	An integrated model for logistics network design	J.F. Cordeau and F. Pasin	HEC Montreal	2006
19	De Novo Programming Model for Optimal DND	R. Thomas	A Proposal for the Faculty of Research Grant	2002
20	Column generation: Application in distribution network design	T. Chung-Piaw	(NUS)	2002
21	What is the right supply chain for your products? (1997)	M. Fisher	Harvard Business Review	1997
22	Optimization models for the dynamic facility location and allocation problem	R. Manzini and E. Gebennini	International Journal of Production Research	2006
23	Transportation, facility location and inventory issues in distribution network design - An investigation	V. Jayaraman	International Journal of Operations & Production Management	1998
24	Inventory, transportation, service quality and the location of distribution centers	L. K. Nozick and M. A. Turnquist	European Journal of Opeartions Research	2000
25	On assessing the sensitivity to uncertainty in distribution network design	C.S. Lalwani, S.M. Disney and M.M. Naim	International Journal of Physical Distribution & Logistics Management	2006
26	Evaluating logistics network configurations for a global supply chain	A. Creazza; F. Dallari; M. Melacini	Supply Chain Management: An international Journal	2007
27	Strategic design and operational management optimization of a multi stage physical distribution system	R. Manzini and F. Bindi	Transportation Research Part E	2008
28	Supply Chain design in the food industry	J. van der Vorst, S. van Dijk and A. Beulens	International Journal of Logistics Management	2001
29	Analytic hierarchy process to assess and optimize distribution network	M. J. Sharma, I. Moon and H. Bae	Applied mathematics and Computation	2008
30	Central Distribution in Europe	J. Ashayeri and J. Rongen	International Journal of Logistics Management	1997

Table 1 Papers reference

	Product drivers						
Distribution Network Decisions	Density	Value (euro/kg)	Risk of obsolescence	Variety	Substitutability	Product complexity	Contribution Margin
Number of echelons	[1],[2],[26],[30]	[1],[2],[4],[26],[30]	[2],[3],[17]	[3],[4],[6],[9],[10],[18],[26],[29]	[1]		[3]
Number of WH for each echelon	[7],[30]	[4],[7],[30]	[3],[7],[17]	[3],[4],[6],[7],[9],[10],[18],[27],[29]		[7]	[3],[7]
WH location	[5],[30]	[4],[5],[30]	[5],[17]	[4],[6],[9],[10],[18],[27]			[5]
Typology of WH	[1],[7],[26],[30]	[1],[4],[7],[26],[30]	[3],[7]	[3],[4],[6],[7],[26],[27]	[1]	[7]	[3],[7]

Table 2 References related to the Product Drivers

	Service drivers					
Distribution Network Decisions	Cycle time	Accuracy	Completeness	Tracking	Returnability	Customer experience
Number of echelons	[4],[8],[29],[30]	[3]	[3],[4],[6]	[4]	[4],[17]	[4]
Number of WH for each echelon	[4],[8],[29],[30]	[3]	[3],[4],[6],[7]	[4]	[4],[17]	[4]
WH location	[4],[5],[8],[30]		[4],[6]	[4]	[4],[17]	[4]
Typology of WH	[4],[30]	[3]	[3],[4],[6],[7]	[4]	[4]	[4]

Table 3 References related to the Service Drivers

Distribution Network Decisions	Demand drivers					
	Number customers	Spatial density	Dimension of the order (typology)	Frequency of delivery	Seasonality	Predictability of demand
Number of echelons	[1],[9],[15],[18],[30]		[1],[4],[8],[15],[17],[18],[26],[30]	[1],[8],[15]	[1],[3]	[3]
Number of WH for each echelon	[9],[15],[18],[27],[30]	[7]	[4],[8],[15],[17],[18],[20],[27],[30]	[8],[15]	[3],[7]	[3],[7]
WH location	[5],[9],[15],[18],[24],[27],[30]	[5],[24]	[4],[8],[15],[17],[18],[20],[27],[30]	[8],[15]		
Typology of WH	[1],[27],[30]	[7]	[1],[4],[26],[27],[30]	[1]	[1],[3],[7]	[3],[7]

Table 4 References related to the Demand Drivers

Distribution Network Decisions	Supply drivers				
	Number of plants	Exclusivity of production in a plant	Distance from plant to client	Locations of plants and DC	Level of Specialization
Number of echelons	[10],[15],[18],[26],[29]		[2],[6],[9],[10],[17],[18],[29],[30]	[2],[6],[9],[10],[17],[18],[26],[29],[30]	[4],[29]
Number of WH for each echelon	[10],[15],[18],[29]	[7]	[6],[9],[10],[17],[18],[29],[30]	[6],[7],[9],[10],[17],[18],[27],[29],[30]	[4],[29]
WH location	[5],[10],[15],[18],[22]	[5]	[5],[6],[9],[10],[17],[18],[22],[30]	[6],[9],[10],[17],[18],[22],[27],[30]	[4]
Typology of WH	[26]	[7]	[6],[30]	[6],[7],[26],[27],[30]	[4]

Table 5 References related to the Supply Drivers

Then it was considered the frequency of occurrence of each driver in each of the four distribution network decisions to understand how they are related and also to identify the most relevant ones.

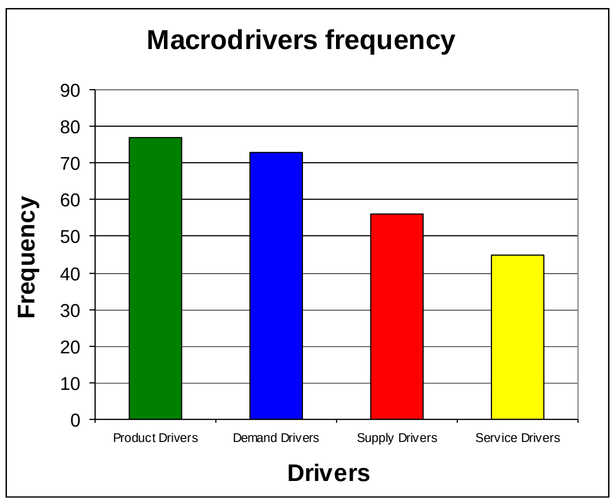
4.3 Analysis of the collected information

On the previously shown tables are represented the connections between drivers and decisions of the distribution network design problem. By considering these relationships and their frequencies of occurrence the importance of the drivers can be weighted. The first step is to consider the most aggregated level which is the macro groups of drivers identified: Product, Service, Demand and Supply. In order to create a model that evaluates all the tradeoffs existent when a decision is made, these four clusters should be carefully considered.

The analysis of the collected data (Table 6) indicates that the Service cluster has been less considered in the papers analyzed, while the Supply and Product drivers are the ones in which the most effort has been placed. This conclusion is coherent with the fact that most of the papers found are focused in the quantitative optimization of the system and Service Level variables are much more difficult to translate into a variable in a mathematical model.

Driver	Frequency	Incidence (%)
Supply Drivers	56	22%
Product Drivers	77	31%
Demand Drivers	73	29%
Service Drivers	45	18%
Total	**251**	

Table 6 Frequency of each cluster of drivers



Graph 1 Frequency of each cluster of drivers

When focusing in the decisions for the distribution design problem the results indicate that the previous authors focused more in determining the ideal number of echelons and warehouses for the structure while giving less importance to which type of warehouse suited best the network.

Decision	Frequency	Incidence (%)
Number of echelons	69	27%
Number of WH for each echelon	69	27%
WH location	59	24%
Typology of WH	54	22%
Total	**251**	

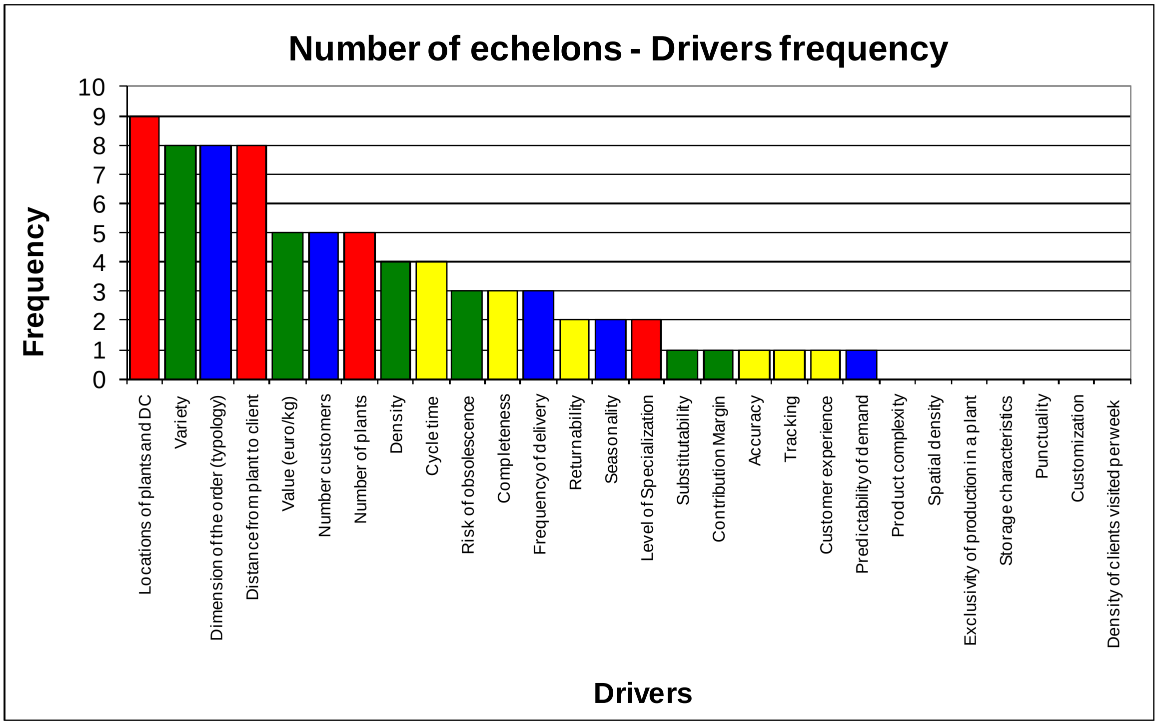
Table 7 Occurrence of each type of decision

The second level of analysis consists in finding which are the drivers that represent better each decision of the distribution design problem and then choosing a balanced set of drivers. This can be achieved through the graphical representation of the amount of times that each driver was considered to model the decisions.

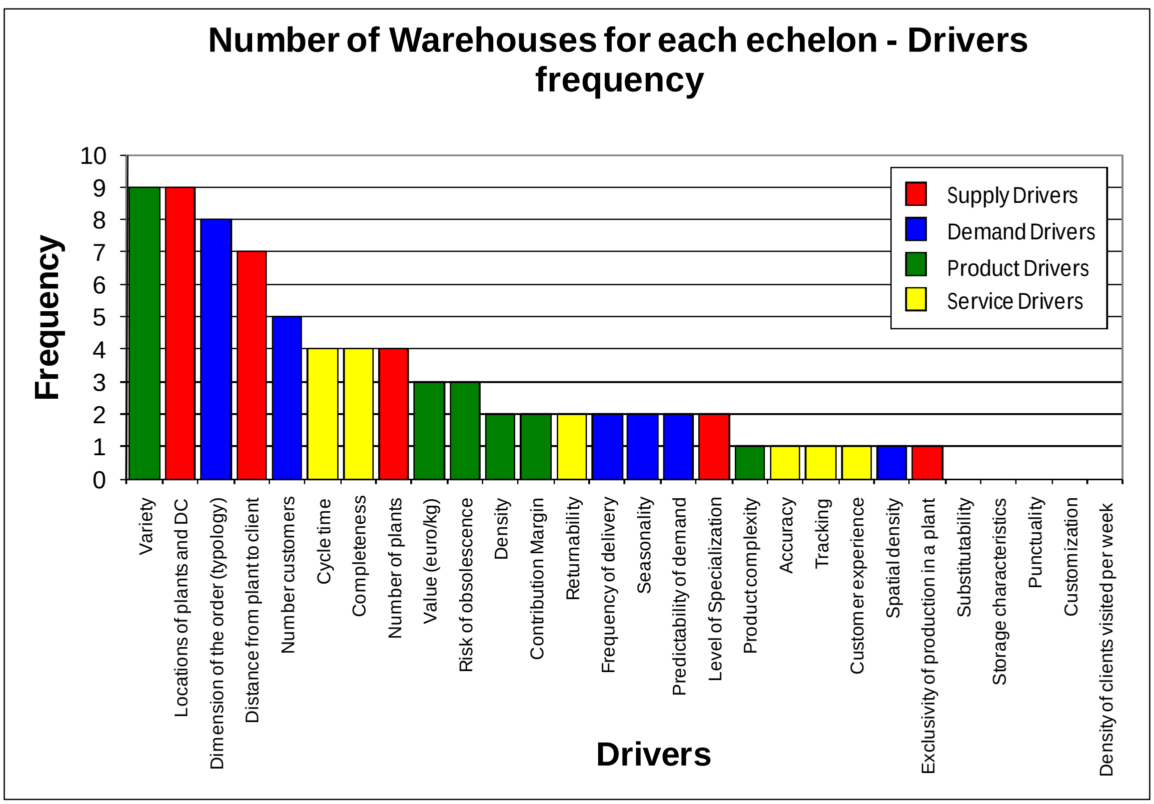
It could be argued that the frequency analysis leads to unfounded conclusions, since it considers the amount of times and not the focus and deepness applied to the research in each paper.

Since the objective is to determine what is considered by logistic experts as key indicators for the distribution design problem, it is the frequency of occurrence rather than other aspects that has to be studied in order to identify the starting group of drivers for the model.

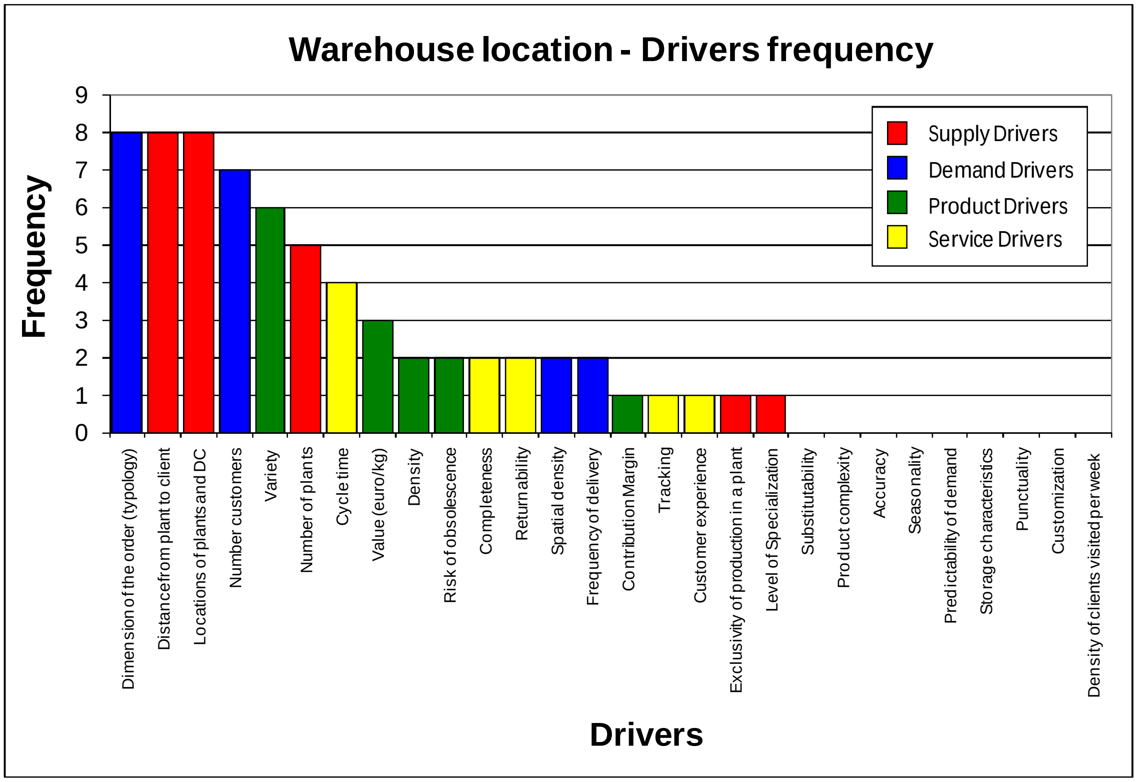
In the following graphs are represented the choices for distribution network design against the amount of times that each driver was considered to explain them:



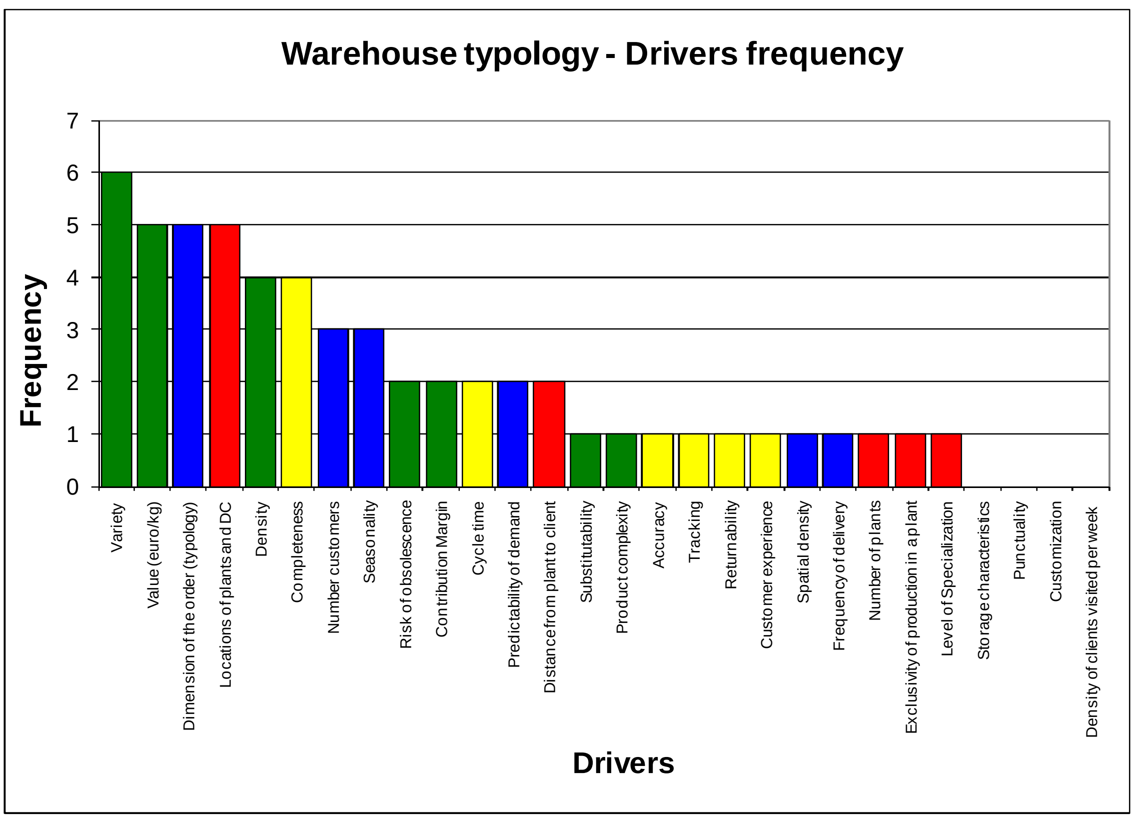
Graph 2 Drivers frequency for the decision: "Number of echelons"



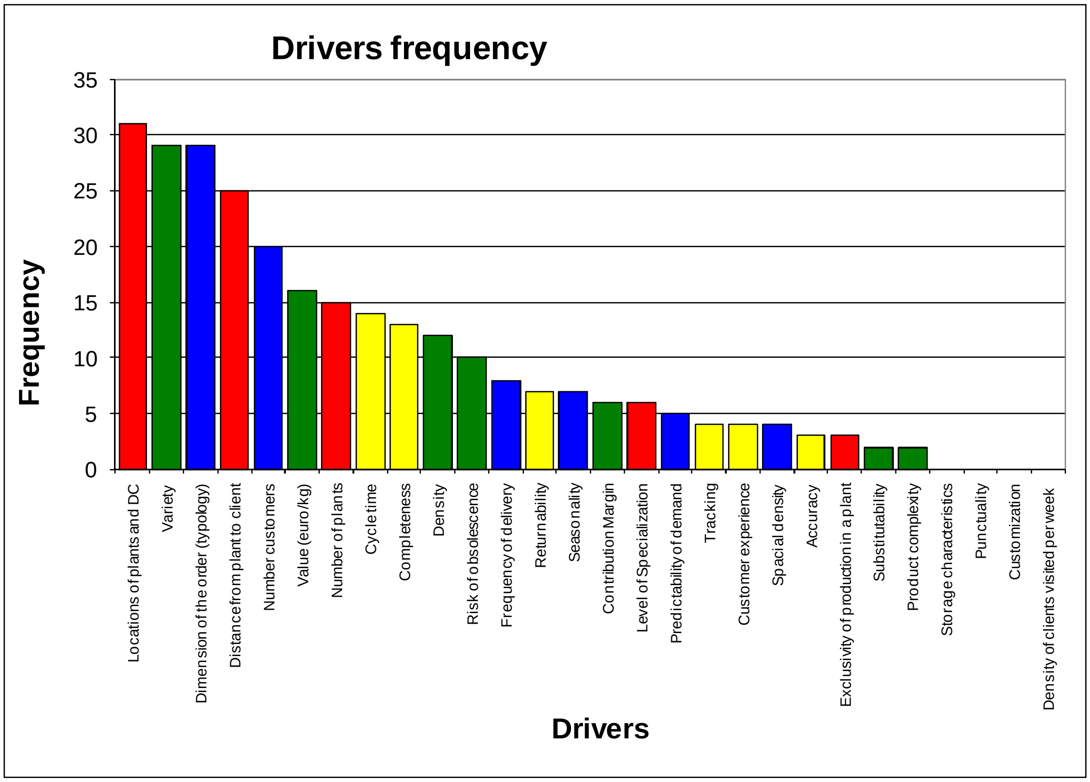
Graph 3 Drivers frequency



Graph 4. Driver's frequency for the decision "Warehouse Location"



Graph 5 Drivers frequency for the decision "Warehouse typology"



Graph 6 Total Drivers frequency

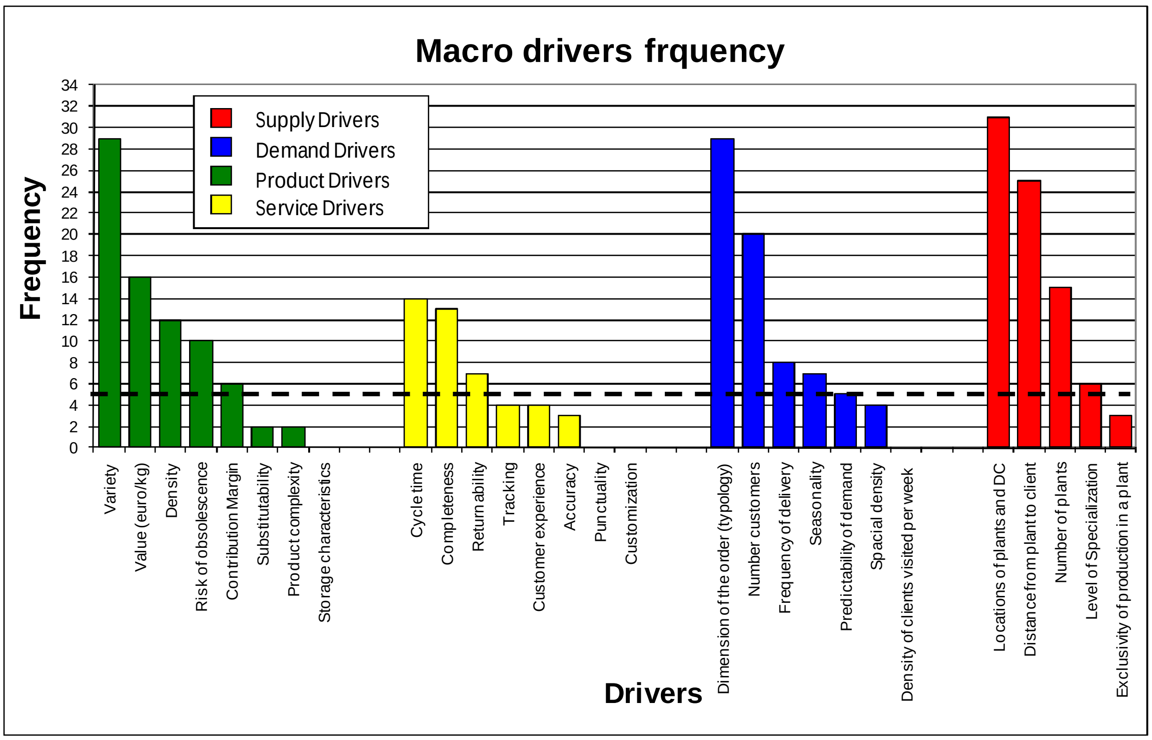
From the graphics some interesting conclusions can be extracted:

- Even though the most frequently used drivers can be found in the first three clusters (Supply, Demand, and Product) there is not a predominant one, which indicates that for the distribution network design decision a global approach has to be taken.
- Service drivers appear to be less used for modeling decisions, not only due to a smaller global number of references but also because in all cases the services drivers are found in a second or third level of importance.
  This is a key point to improve since Service Drivers play a strategic role in distribution network design despite the fact that their impact is difficult to include in a mathematical model.
- There are eight drivers that have high frequencies for all the four decisions, these are:
  - Variety
  - Dimension of the order
  - Distance from plant to client
  - Number of customers
  - Cycle time

- o Value
- o Completeness
- o Density

According to the literature analyzed and the findings previously mentioned it is clear that the eight drivers highlighted are the cornerstones of every model considered and therefore they should be the base of the future model. The model will have to be completed with other drivers that deal with more specific parts of the problem.

The rest of the drivers needed were found by studying cluster by cluster, considering those drivers that presented at least five or more references, and that the use the authors gave them was coherent with the focus of this thesis, the complete list can be seen in the following graphic:



Graph 7 Macro drivers frequency

As the driver of “location of plants and DC” cannot be measured it was considered the same as the driver called “distance from plant to client” since both refer to the same problem.

Analyzing the results from a global perspective, only 16 of the 28 drivers turn up to be significant for the distribution network design process.

	SELECTED DRIVERS	MACRODRIVERS
1	Variety	Product drivers
2	Value	
3	Density	
4	Risk of obsolescence	
5	Contribution Margin	
6	Cycle Time	Service drivers
7	Completeness	
8	Returnability	
9	Dimension of the Order	Demand drivers
10	Number of customers	
11	Frequency of delivery	
12	Seasonality	
13	Predictability of demand	
14	Number of plants	Supply Drivers
15	Distance from plant to client	
16	Level of specialization	

Table 8 Selected drivers from the literature analysis

It is important to highlight that at this point only three Service drivers have been included due to the already discussed fact that the literature analyzed consisted in a higher proportion of quantitative methods rather than qualitative.

Nevertheless, it is considered that Service drivers play a key role in the design of the distribution network and that this fact will be reflected during the case studies and interviews process.

For the **Product Drivers** group, the relevant drivers are:

- **Variety**

Several authors point out this driver as an important element for the network design. Its main impact is related to the number of echelons decision and the typology of the warehouse (Chopra, 2003). The effect over these two decisions has to do with the fact that a wide range of products implies a higher level of stocks and then a higher maintenance cost.

- **Value**

This driver is highlighted as a key determinant of the level of centralization since as its value increases the cost of holding inventory also increases (Lovell, Saw, & Stimson, 2005), causing the need of inventory centralization and also faster transport modes to reduce the level of stock in transit.

Geographic proximity to major markets is often an important consideration for products with a low value density, since the share of transportation costs in total costs will become too high with increasing distances (van den Berg & Vos, 1996). It is often essential for low-value products to have an inexpensive distribution system. Low values to weight ratio products, for example ore or sand, incur relatively high transport unit costs compared with high value to weight products, such as computer equipment.

- **Density**

Different authors have pointed out product density as one of the determinants for the design problem. The main reason is that products of low density offer poor utilization of the storage and transportation system (Ballou, 1993). The impact of product density is related to number of echelons since in case density is either very high or very low it is relatively easy to achieve transport saturation (weight or volume) with fewer orders. A low volume/high weight product, such as sheet steel, books, etc) will fully utilize the weight-constrained capacity of a transport vehicle; also will best utilize the handling cost component of storage. A high volume to weight ratio, tends to be less efficient for distribution, for example paper tissues; these products use a lot of space and are costly for both transportation and storage.

- **Risk of obsolescence**

Even though this driver is not among the group of the most mentioned drivers (the first nine), the risk of obsolescence it is considered an important factor for the design since this product characteristic may affect the number of echelons within the network and also the typology of the warehouses. Products with a short shelf life tend to have low levels of inventories and require faster transportation modes (Lovell, Saw, & Stimson, 2005).

- **Contribution Margin**

High profit margin products increase the cost of shortages, instead low profit margin products force to minimize the physical costs: costs of production, transportation and inventory storage. These two types of costs determine the decision about where in the chain to position inventory (Fisher, 1997).

For the **Service Drivers** group, the relevant drivers are:

- **Cycle time**

As mentioned in the glossary the cycle time is the number of days it takes to deliver an order from the moment it was placed by the customer, firms that target customers who can tolerate a large cycle time require few locations that may be far from the customer and can focus on increasing the capacity of each location. On the other hand, firms that target customers that value short cycle times need to locate close to them. These firms must have many facilities, with each location having a low capacity. Thus, a decrease in customer's desired response time increases the number of facilities required in the network (Chopra, 2003).

- **Completeness**

An increase in the required completeness (item fill rate) will lead to additional inventory holding at the decoupling point in the network. This increase in inventories will translate in additional costs that have to be weighed against the increase in profits. This trade-off is an important relationship in selecting the most appropriate supply chain for a given situation. Diversity between products or customers in terms of completeness can, therefore, influence the most appropriate supply chain selection (Lovell, Saw, & Stimson, 2005).

- **Returnability**

For some type of products the possibility to return them becomes very important, for example, for electronic goods with parts that have to be disposed through specific processes or in the case of defective products.

By implementing returnability to their products the company becomes responsible of the recollection of all non usable products and their recycling either to re use them or to sell as raw material to other companies

Even though Returnability could be associated with other clusters, it's included here because customers are every day more concerned about the impact disposed products have on the environment and therefore this type of measures are perceived by them as an additional services.

From a logistics point of view returnability is the capability of the network to handle returns depends on the number of levels of the network. In the case of direct shipments reverse supply chain will be expensive and difficult to implement (Chopra, 2003).

For the **Demand Drivers** group, the relevant drivers are:

- **Dimension of the order**

If the dimension of the order is such that it can saturate the transport unit, the direct delivery from a central warehouse or factory will be mandatory. The inclusion of intermediate levels on this case will produce an increase of handling and inventory costs without a reduction in transport costs.

For smaller order sizes a second echelon will be required to allow the firm to reach the clients with transport mediums with high saturation. This way the local delivery costs will be optimized. The most critical scenario is represented by very small orders with high density of clients; in this case a three echelon network must be applied (Archini & Bannó, 2003).

- **Number of customers**

The higher the number of customers the higher the logistics costs, since it implies a higher number of deliveries causing an increase in the transportation costs, also in the handling and order management costs (Archini & Bannó, 2003).

From another perspective this driver may be used to try to assess the risk of obsolescence, the fewer customers the higher the risk due to customer turnover (Payne & J. Peters, 2004).

- **Frequency of delivery**

The frequency of delivery affects the different logistics costs mainly due to the fact that higher frequencies would imply higher levels of stock causing an increase in the cost of maintenance. Besides in order to be able to deliver the products more frequently to the customer is reasonable to think that the product should be closer to the client, causing also an increase in the stocks.

It is important to point out that usually the volume of the order is lower for high levels of frequency of delivery, impacting also in the handling and transportation costs (Archini & Bannó, 2003).

- **Seasonality**

Seasonality affects stocking costs by increasing its levels in the seasons it occurs, also increases the information requirements and the need of flexibility in order to cope with the demand variations in those periods. If seasonality increases or the product has a high seasonality there is a tendency of moving towards customers to ensure short delivery times in periods of maximum requests.

- **Predictability of the demand**

The effect of demand predictability on supply chain design (which includes inventory levels and locations) are widely discussed in the supply chain literature (Lovell, Saw, & Stimson, 2005) (Fisher, 1997).

The predictability of the demand has an impact on inventory holding policies in relation to the level of inventory centralization within a supply chain. The higher the level of unpredictability the more centralized should be the inventories (Lovell, Saw, & Stimson, 2005).

For the **Supply Drivers** group, the relevant drivers are:

- **Distance from plant to client**

The distance from plant to client affects total logistic costs since with the increase of distance there is a direct increase of transport costs being one of the drivers that define fares. Network design models that use mathematical methods are prone to include this driver due to its impact over the transportation cost (Lashine, Fattouh, & Issa, 2008) (Pasin & Cordeau, 2006).

Also the cost of maintenance of inventories varies since with distance increments the stocks tend to grow due to decentralization. Moreover safety stocks depend on lead times which depend on the distance to the client.

- **Number of plants**

The number of plants has an effect over the location of warehouses and the level of centralization of the warehouses (Lin & Lei, 2009). A large number of plants imply a larger number of links between the manufacturing point and the warehouses or the customer in case of direct distribution. This has a major impact over the transportation costs since finished goods are delivered from production plants to a set of DC's with trucks of larger capacity (first level of transportation).

From another perspective in the case that the number of plants can be defined (for Greenfield problems) it's important to consider that when the fixed costs are high, the volume is critical and large plants can produce products at significantly lower prices (Lovell, Saw, & Stimson, 2005).

- **Level of Specialization**

As the level of specialization of the plants in a supply chain decrease, the inventory and resulting inventory costs raise due to decentralization and loss of economies of scale, on the other hand if the level of specialization increase, total transportation cost will also rise by increasing the distances from plant to clients or warehouses.

Facility costs decrease as their number is reduced because consolidation allows the firm to exploit economies of scale (Chopra, 2003).

Chapter 5. Company cases

Hewlett Packard

HP is a technology company that operates in more than 170 countries around the world. HP explores how technology and services can help people and companies address their problems and challenges, and realize their possibilities, aspirations and dreams. HP applies new thinking and ideas to create more simple, valuable and trusted experiences with technology, continuously improving the way our customers live and work.

No other company offers as complete a technology product portfolio as HP, provides infrastructure and business offerings that span from handheld devices to some of the world's most powerful supercomputer installations. HP offers consumers a wide range of products and services from digital photography to digital entertainment and from computing to home printing. This comprehensive portfolio helps match the right products, services and solutions to the customers' specific needs.

5.1 Context Data of HP

General data of the interview

Date of the interview: 15 June 2010

Name of the company: Hewlett Packard

Address: Headquarters in Palo Alto, California. USA

Italy Central Office: Via G. di Vittorio, 9. Cernusco sul Naviglio, Milano.

Web Site: www.hp.com

Interviewee: Luciano Cesaroni, Operations Manager for the indirect channel for Europe

Company general data

Member of a Group: HP

Sector: Electronics

Multinational: Yes

Net revenues (2009): $114,552 million dollars

Market Share: worldwide leader in personal computers

N° Employees: approximately 304,000 worldwide

Business Unit to consider: The Personal Systems Group and The Imaging and Printing Group.

5.2 Commercial Organization of HP

Organization of the commercial function

HP is a leading global provider of products, technologies, software, solutions and services to individual consumers, small and medium-sized businesses (''SMBs'') and large enterprises, their offerings span:

- multi-vendor customer services, including infrastructure technology and business process outsourcing, technology support and maintenance, application development and support services and consulting and integration services;
- Enterprise information technology infrastructure, including enterprise storage and server technology, networking products and resources, and software that optimize business technology investments;
- Personal computing and other access devices; and
- Imaging and printing-related products and services

HP has 3 business units, the Personal Systems Group (PSG), the Imaging and Printing Group (IPG) and the Enterprise Business. Their customers are organized by consumer and commercial customer groups, and distribution is organized by direct and indirect channel. The direct clients usually correspond to the Enterprise Businesses while the indirect clients refer to Wholesalers and Retailers.

Types of clients

The clients in Europe can be divided in:

- Indirect channel clients: are around 400 and 32 of those are located in Italy
    - 5 big distributors that distribute to 1,000 Authorized resellers
    - Retailers: Many, for example, Mediaworld, Saturn, etc.

- Direct channel clients: Particular B2B cases
    - Consultancy
    - Projects

There are no direct deliveries from plants, because all the deliveries to the clients are managed through the European transit points, usually with loads of full truck.

5.3 Actual Distribution Network of HP

Drivers for the Design of Distribution Network

Product Characteristics

- Variety: HP has 20,000 product codes commercialized in Europe, taking into consideration all the configurations a product may have to satisfy specific markets, for example: batteries, keyboards, etc. For Italy, a quantity of 4,000 codes is commercialized.
- Value (€/Kg): considering the wide range of products that HP has, an average value of 1,000 €/Kg can be estimated.
- Density (Kg/m^3): Including Notebooks, Desktops and Printers, the average density is 7,6 Kg/m^3
- Risk of obsolescence: the obsolescence of HP consumer products is of 3 months and that of the commercial products 6-9 months.
- Contribution Margin: considering the return on equity 10-12%

Service Characteristics

- Cycle Time: it takes 15 days to deliver an order from the moment it is received.
- Completeness (item fill rate): the company has 100% of service level in their orders due to the very well known market and predictability of demand.
- Returnability: the return flow is not very important since it consists of only 1% of the total flows.

Demand Characteristics

- Dimension of the order (typology): usually the deliveries are of full truck load (FTL) since the majority of customers are big and make big purchase orders. Orders of more than one FTL might be also present. The value is presented as percentage of FTL from 0 to 1.
- Number of customers: 400 in Europe, from which 32 are in Italy.
- Frequency of delivery: 1 FTL/ customer/ day; thus 5 times per week.

- Seasonality: sales increase in the last quarter of the year, but as is only this period it can be said that the level is low-medium.
- Predictability of demand: it must be high (around 95%) in order to satisfy the service level and follow a zero inventory policy.

Supply Characteristics

- Distance from plant to client: since there are many plants located all over the world, we can consider 6,000 km in average.
- Number of plants: 50 located all over the world, from which 17 supplies Italy
- Level of specialization: although manufacturing plants are very dynamic and flexible in changing product configurations, one product can be manufactured in more than one plant in order to supply different markets; so the level of specialization is medium.

Macrodriver	Driver	Value
Product	Variety [SKUs]	20,000 (Europe); 4,000 (Italy)
	Value [€/Kg]	1,000
	Density [Kg/m^3]	7,6
	Risk of obsolescence [days]	120
	Contribution Margin [%]	10-12
Service	Cycle Time [days]	15
	Completeness [%]	100
	Returnability [%]	1
Demand	Dimension of the order [%FTL]	1
	Number of customers	400 (Europe) 32 (Italy)
	Frequency of delivery [Deliveries per week]	5
	Seasonality	Low – Medium
	Predictability of demand [%]	95
Supply	Distance from plant to client [Km]	6,000
	Number of plants	50 (17 supplies Italy)
	Level of specialization	Medium

Table 9 Summary of HP drivers

Characterization of the Supply Chain

There are 17 plants all over the world producing HP products that supply the Italian market, some of them are own establishments and some of them are outsourced in order to obtain cost efficiency and reduce time to market for certain products. The plants are not exclusive, so products can be produced in more than one plant.

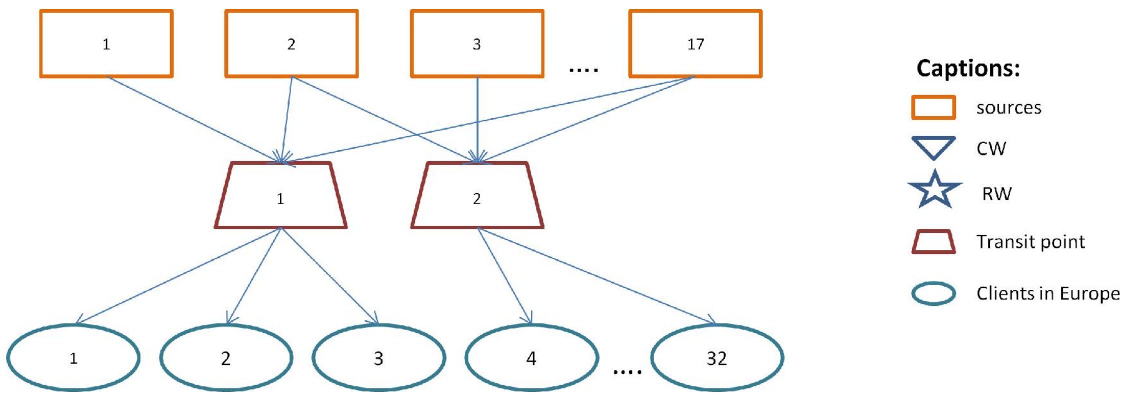


Figure 13 HP Distribution Network

The European Transit Points receive products from plants all over the world. The loads are consolidated and packaged in delivery loads, then are forwarded to the clients via the transit points.

Network classification

As seen in the diagram above the distribution network consists of one echelon with two transit points that distribute to all the clients in Europe. These transit points are outsourced through a 3PL provider.

Node characterization: (location and allocation)

The transit points are located in Luxemburg and The Netherlands. This network permits HP not to have inventories and be very flexible. The two transit points serve all customers in Europe.

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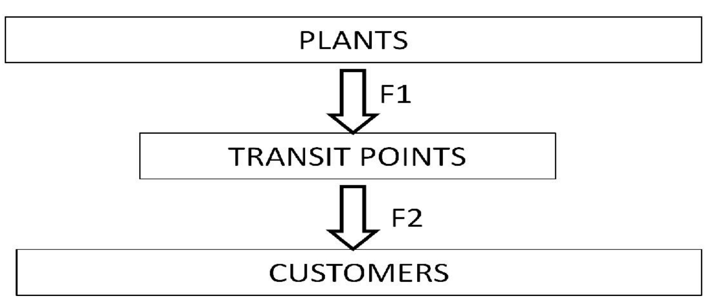


F1: from plants to Transit Points, 100% of the volumes.

F2: from Transit Points to customers all over Europe, 100% of the volumes.

Managerial logic

Stocks

- Safety Stocks: no safety stocks due to the zero inventory policy
- Service Level: (K utilized): With the logistic strategy implemented by HP, they have been able to reach 100% of service level.
- Logic of the material flow planning: The logic that HP uses is Assembly to Order. The order is placed electronically by the customer and is received by the establishment in charge of the production. It takes around 15 days to produce and deliver the order.

Transport

- Organization of primary transport

The primary transport from Plants to European transit points is done mainly by air because short cycle times are needed to satisfy the service level. The transit time for this operation is around 8 days.

- Organization of secondary transport

The secondary transport from transit points to the customers is done by road, using full truck loads.

Outsourcing

- Activities in outsourcing: the logic of HP regarding outsourcing is that each one has to do what it does best, so HP contracts the best 3PL providers to do the transportation and forwarding.
- Companies that handle the outsourced activities: the 3PL providers are different from each country in Europe, depending on the covering capacity. For example: CEVA, DHL and DMM.

Reverse Logistics

Reverse logistics constitutes 1% of the volumes, it is not really important for the logistics activity but instead it is important for the customer service.

5.4 Distribution Problems of HP

It can be observed only one distribution problem.

- HP1: All HP products follow the same flow, come from plants from all over the world and stop in a transit point in Europe to be assembled in orders and forwarded to clients in Italy. Despite there is a wide range of products, they all follow the same logistics path.

		HP1
Macrodriver	**Driver**	**Value**
Product	Variety [SKUs]	4,000
	Value [€/Kg]	1,000
	Density [Kg/m^3]	7,6
	Risk of obsolescence [days]	120
	Contribution Margin [%]	10-12
Service	Cycle Time [days]	15
	Completeness [%]	100
	Returnability [%]	1
Demand	Dimension of the order [%FTL]	1
	Number of customers	32 in Italy
	Frequency of delivery [Deliveries per week]	5
	Seasonality	Low Medium
	Predictability of demand [%]	95
Supply	Distance from plant to client [Km]	6,000
	Number of plants	17
	Level of specialization	Medium

Table 10 Summary of HP distribution problem

SONY

Sony is a leading manufacturer of audio, video, communications, and information technology products for the consumer and professional markets. Its motion picture, television, computer entertainment, music and online businesses make Sony one of the most comprehensive entertainment and technology companies in the world. It is a company with 1,006 consolidated subsidiaries worldwide.

5.1 Data Context of Sony

General data of the interview

Date of the interview: 29 June 2010

Name of the company: Sony

Address: Minato, Tokyo, Japan

Italy Central Office: Via Galileo Galilei, 40. Cinisello Balsamo – Milano.

Web Site: www.sony.com

Interviewee: Claudio Mirelli and Salvatore Paparelli: Logistics Directors of Sony Italy

Company general data

Member of a Group: Sony

Sector: Electronics

Multinational: Yes

Net revenues (2009): ¥7,214.0 billion

N° Employees: approximately 167,000 worldwide

Business Unit to consider: Sony Electronics that include IT and consumer electronics

5.2 Commercial Organization of Sony

Organization of the commercial function

Sony has 8 Business Units, from music and motion pictures to 3D Televisions. The business units of consumer electronics constitute the bigger part of total sales, which are:

- The Consumer Products & Devices Group (40.5%)
- The Networked Products & Services Group (21.0%)

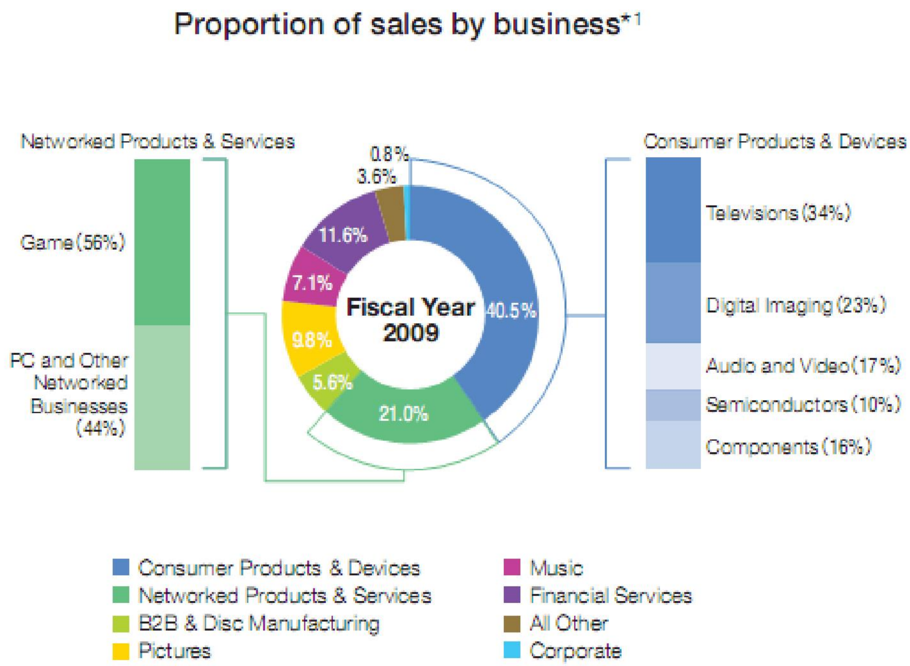


Figure 15 Sony Businesses

Types of clients

There are 1600 clients in Italy, from which 32 are big clients and the rest small retailers or specialized stores; and a total of 2700 Delivery Points.

Depending on the volume DHL can deliver directly to the client, without passing through the Transit points. If the volume is big enough to saturate the truck then it is delivered directly from the central warehouse; instead if the volume is not big, the order is delivered through transit points using a percentage of the truck load or using DHL express if the order is of some boxes, serving mainly to small clients.

5.3 Actual Distribution Network of Sony

Drivers for the Design of Distribution Network

Product Characteristics

- Variety: between all the products managed by Sony from headphones to televisions, there are 1,200 SKUs. Europe supplies 33% and Asia 66%.

- Value (€/Kg): a range of 55 €/Kg for televisions to 800 €/Kg for photo cameras.
- Density (Kg/m^3): a range of 160 Kg/m^3 for photo cameras to 643 Kg/m^3 for home theaters.
- Risk of obsolescence: it is medium for all the range of products varying from 180 to 240 days
- Contribution Margin: since it is not possible to calculate this for each type of product, a range from 10 to 14% is considered.

Level of Service

- Cycle Time (order-delivery): 2 days to the north of Italy and 3 - 4 working days to the south.
- Completeness (item fill rate): they have been able to reach 100% due to the backlog management policy.
- Returnability: the return flow is not very important since it consists of only 1% of the total flows.

Demand Characteristics

- Dimension of the order (typology): for direct deliveries to big customers the dimension of the order is FTL; for customers ordering less volume the transport managed by DHL is shared with Samsung so the dimension of the order is LFTL; for small customers ordering small quantities of products, DHL express provides the service, so the dimension of the order is some boxes.
- Number of customers: 1,600 invoicing points and 2,700 delivery points in Italy
- Frequency of delivery: 1 - 3 times per week
- Seasonality: for audio-video and informatics products the seasonality is well known and is strong in some periods of the year, so the seasonality can be said to be medium. For specialized products there is not a strong peak of sales so it can be said that is low -medium.
- Predictability of demand: based on the stock levels that Sony manages, it can be estimated an approximate percentage of predictability of the demand. Taking in consideration that 85% of the flow of products come from plants located in Europe reducing the transport times from plan to warehouse, Sony still manage high levels of inventory: 12 days for Televisions and 1 month for the rest of the products. This fact indicates that the predictability of the demand is not 100% but a 90% might be adequate.

Supply drivers

- Distance from plant to client: for plants located in Europe 1,000 km and for plants located in the Far East 9,000 km in average.

- Number of plants: 5 in Europe (Poland, Spain, Turkey, Slovakia, and Austria) and around 7 in Asia that supplies Italy.
- Level of specialization: there is high specialization of the plants located in Europe and medium for those located in Asia.

Macrodriver	Driver	Value
Product	Variety [SKUs]	1200
	Value [€/Kg]	55 – 800
	Density [Kg/m^3]	160 – 643
	Risk of obsolescence [days]	180 – 240
	Contribution Margin:	10 - 14%
Service	Cycle Time [days]	2 – 4
	Completeness [IFR]	100%
	Returnability [%]	1
Demand	Dimension of the order [%FTL]	From 0,2 to 1
	Number of customers	2,700 delivery points
	Frequency of delivery [Deliveries per week]	1 – 3
	Seasonality	Low Medium - Medium
	Predictability of demand [%]	90
Supply	Distance from plant to client	1,000 km - 9,000 km
	Number of plants	5 in Europe and 7 in Asia
	Level of specialization	Medium – High

Table 11 Summary of Sony drivers

Characterization of the Supply Chain

The manufacturing plants that supply the European market are located in: Poland, Turkey, Barcelona, Slovakia, Austria and 7 more located in the Far East. The European plants are highly specialized, each one focuses on a type of product; while plants in Asia produce very sophisticated products that can be produced in very few locations.

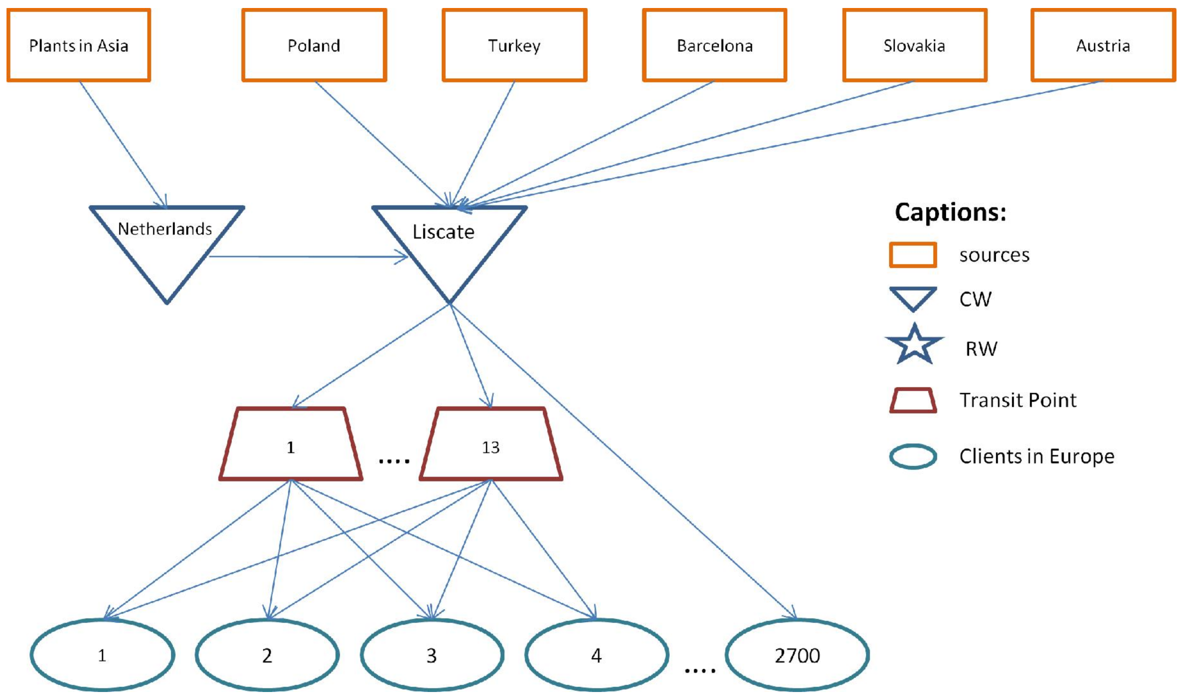


Figure 16 Sony Distribution Network

Network classification

As seen in the diagram above the distribution network consists of two echelons. The first level consists of Central Warehouses, 1 in The Netherlands and the other one in Italy; located in Liscate, Milano. Sony Logistics Europe B.V. (SLE) in Tilburg, The Netherlands is the European Distribution Centre (EDC) of Sony Europe. It stores all product ranges of Sony Electronics, which are shipped in by truck, sea and air freight from plants in Europe, Japan and Asia. SLE, which has a 'footprint' of about 80,000 m^2, distributes directly to local Sony warehouses across Europe, Middle East and Africa.

The second level consists on regional transit points, which in the case of Italy are 13, one for each major region. The Warehouses and Transit Points are managed by DHL.

Node characterization: (location and allocation)

The Warehouse in The Netherlands stocks products coming from the different plants around the world and provides these products to the rest of Europe. In addition, the central warehouse in Italy stocks products coming from the European plants.

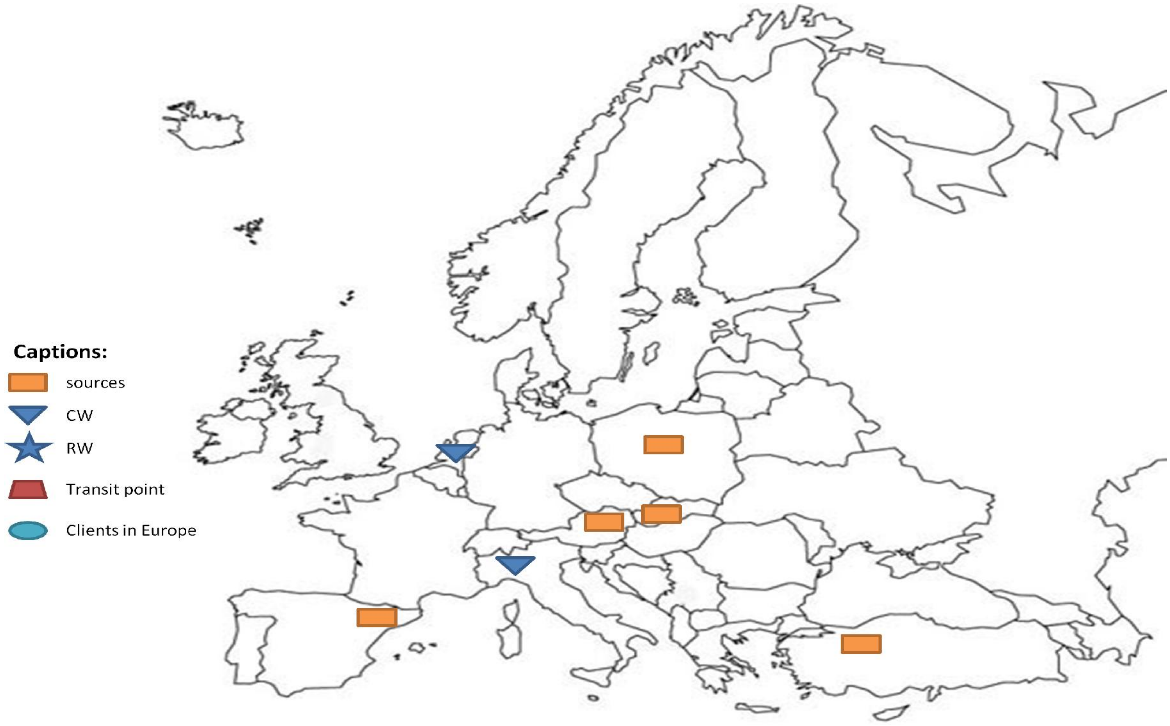


Figure 17 Location of Sony facilities

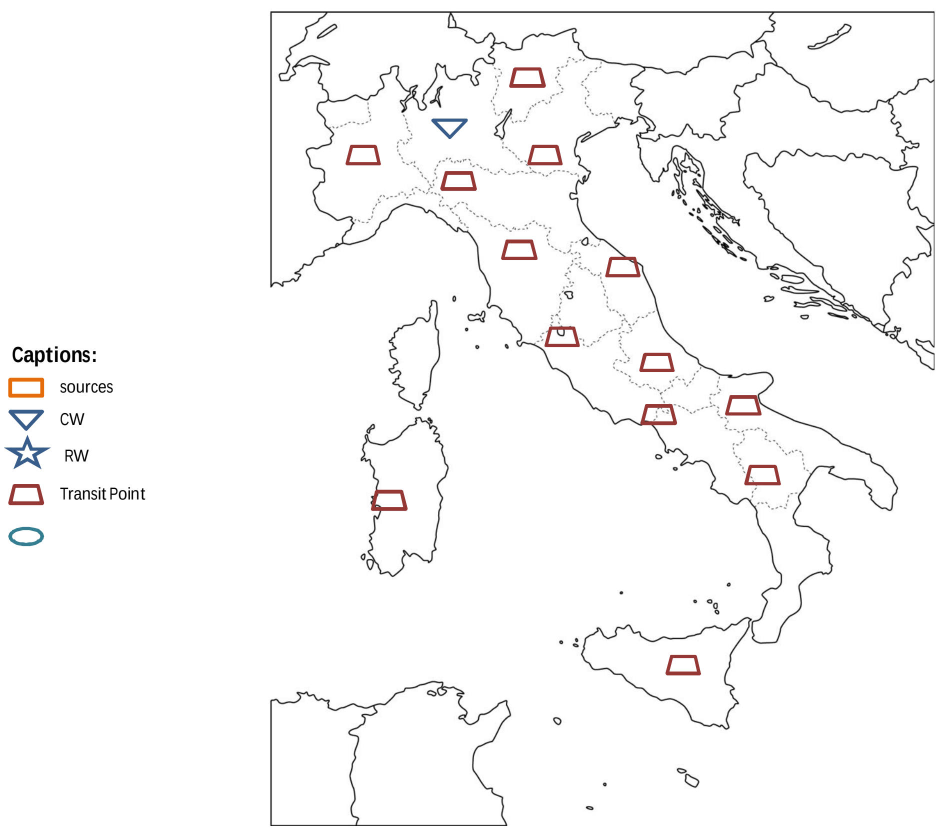


Figure 18 Location of Sony facilities

Activities, resources and capacity of each typology

The Central Warehouse located in Liscate has 80.000 m^2 and is mainly dedicated to picking activities, while in the transit points the orders are assembled using cross docking and are delivered to the clients located within a circular area in order to increase the OFR.

Flow Characteristics

Principal active flows:

F1: products produced outside Europe are delivered to the CW in The Netherlands, which corresponds to the 15%, and then are forwarded to the CW in Italy.

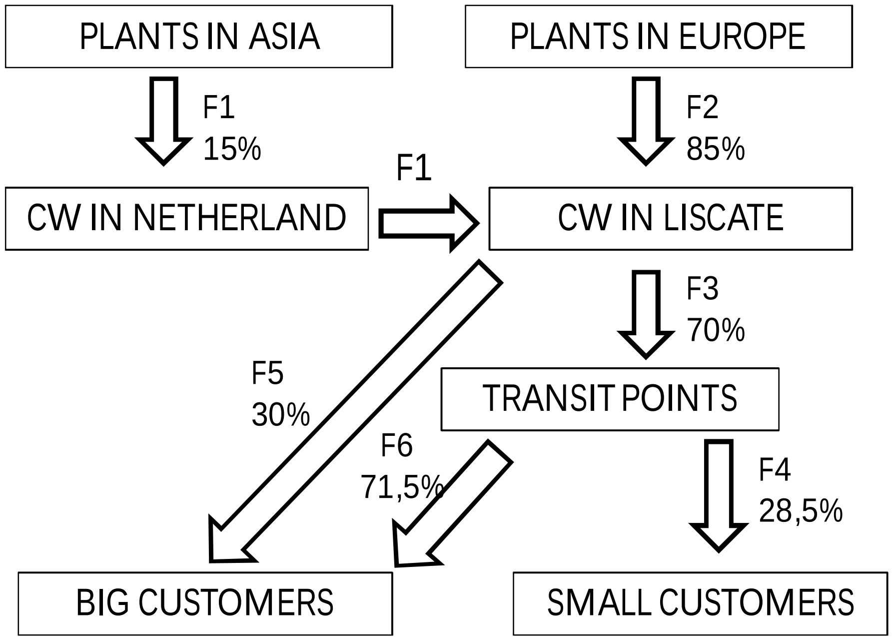
F2: products produced in European plants are delivered to the CW in Italy. This flow represents 85%.

F3: 70% of the products from CW in Italy to regional transit points.

F4: 28.5% of the 70% that uses transit points are delivered to small customers. This flow is managed by DHL express.

F5: 30% of products from CW in Italy to big customers managed directly by DHL without stopping at the transit points, depending on the volume ordered.

F6: 71.5% of the 70% of products that uses transit points are delivered to big clients which orders are of more than half truck load.



Managerial logic

Stocks

- Safety Stocks: the stocks vary upon the type of product. For the central warehouse in Italy (Liscate), TV stocks correspond to 12 days, while for the rest of products is approximately 1 month.
- Service Level: they have been able to reach 100% thanks to the backlog management policy.

Transport

- Organization of primary transport:
  From plants in Europe, the primary transport consists of road. From plants in Asia, consists in air.
- Organization of secondary transport:
  The secondary transport to clients or to transit points is done by road using FTL or LFTL depending on the client.

Outsourcing

- Activities in outsourcing: Warehouses, transit points and transportation are managed in outsourcing.
- Companies that handle the outsourced activities: Sony which shares the service of transit points and transportation with Samsung using DHL as 3PL, in order to saturate the mean of transport.

Reverse Logistics

The management of returned products is not a relevant factor for the distribution network, but it is considered as an internal organization problem at which Sony is making great efforts to understand the causes by implementing a prevention program.

5.4 Distribution Problems of Sony

There are 6 distribution problems. The first 3 distribution problems are characterized by the same supply and product drivers, but different demand and service requested by customers; representing 85% of the total flow of goods. The last 3 problems are characterized also by same supply and product drivers, which are more sophisticated in technology, and represent 15% of the total flow.

- SO1: provides direct delivery from the national CW to big customers, which orders are big enough in order to satisfy the saturation of the mean. The products come from the European plants and are stored in the national CW. These products are TVs, software and CDs demanded by the European clients. Another important characteristic is the appointment for delivery requested by the customer.

- SO2: the same products produced in European plants stop at 2 levels before being delivered to big customers, first at the national CW and then at the transit points of the logistics provider. By doing so a higher level of saturation of the means may be achieved, and therefore the reduction of costs. This second level adds 1 or 2 days for delivery.

- SO3: the same products produced in European plants are delivered using a 2 level network, first at the national CW and then at the transit points of the logistics provider. The difference between this distribution problem and SO2 is that the deliveries are done to small clients using DHL express. In this case there is no appointment requested by the customer.

- SO4: provides direct delivery from the national CW to big customers, which orders are big enough in order to satisfy the saturation of the mean. The products come from Far East plants and are stored in a European distribution center (EDC) located in The Netherlands that replenish the national CW of Italy (both warehouses are considered to be at the same level). Due to the level of specialization of these products, they can just be manufactured in the Far East in order to take advantage of economies of scale and technology. Another important characteristic is the appointment for delivery requested by the customer.

- SO5: the same products produced in the Far East plants stop at 2 levels, first at the EDC located in The Netherlands which replenish the national CW in Liscate and then on the regional transit points of the logistics provider. This second level adds 1 or 2 days for delivery.

- SO6: the same products produced in the Far East plants are stored at the first level at the EDC that replenish the national CW from where are delivered using the logistic service provider transit points to small clients using DHL express. In this case there is no appointment requested by the customer.

MACRODRIVER	DRIVER	VALUE					
		SO1	SO2	SO3	SO4	SO5	SO6
PRODUCT	Variety [SKUs]	400	400	400	800	800	800
	Value [€/Kg]	55	55	55	800	800	800
	Density [Kg/m^3]	160	160	160	643	643	643
	Risk of obsolescence [days]	180	180	180	240	240	240
	Contribution Margin:	10	10	10	14	14	14
SERVICE	Cycle Time [days]	3	4	2	3	4	2
	Completeness [IFR]	100	100	100	100	100	100
	Returnability [%]	1	1	1	1	1	1
DEMAND	Dimension of the order [%FTL]	1	0.6	0.2	1	0.6	0.2
	Number of customers	32	32	2668	32	32	2668
	Frequency of delivery [Deliveries per week]	3	2	1	3	2	1
	Seasonality	M	M	M	LM	LM	LM
	Predictability of demand [%]	90	90	90	90	90	90
SUPPLY	Distance from plant to client	1000	1000	1000	9000	9000	9000
	Number of plants	5	5	5	7	7	7
	Level of specialization	H	H	H	M	M	M

Table 12 Summary of Sony distribution problems

SAMSUNG

Samsung is comprised of companies that are setting new standards in a wide range of business, from electronics to financial services, from chemicals and heavy industries to trade and services. They share a commitment to creating innovative, high quality products and services that are relied on every day by millions of people and businesses around the world.

5.1 Data Context of Samsung

General data of the interview

Date of the interview: 30 June 2010

Name of the company: Samsung

Address: headquartered in Samsung Town, Seoul, South Korea

Italy Central Office: Via C.Donat Cattin, 5. Cernusco sul Naviglio – Milano.

Web Site: www.samsung.com

Interviewee: Danielle Farinella, Logistics Director

Company general data

Member of a Group: Samsung

Sector: Consumer electronics and home appliances

Multinational: Yes

Net revenues (2009): 138,994 (billions of KRW)

Market Share:

- LCD Monitor: 16.1%
- Hard disk drive: 9.5%
- Television set: 23%
- Printers: 16.4%
- Mobile phones: 23%
- Digital camera: 9.1%

N° Employees: approximately 164,000 worldwide

Business Unit to consider:

- Audio and Video
- Home Appliances
- Informatics
- Mobile
- Networking

5.2 Commercial Organization of Samsung

Organization of the commercial function

Samsung has 5 family products:

1. Audio and video: includes TVs, blue ray, Home Theaters and digital imaging (cameras and videos)
2. Home appliances: microwaves, washing machines, air conditioners
3. Informatics products: monitors, notebooks
4. Mobile phones
5. Networking: fix telephony, fixed and satellite decoders

Generally, clients buy only from one product family which is stored in one specific warehouse, so there is no order consolidation, Merge in Transit or Cross Docking activities are required to assemble one order.

Types of clients:

There are 400 clients in Italy that corresponds to 1,200 delivery points, which can be regrouped in:

- Mobile operators' clients provided in direct way.
- Specialized clients
- Non specialized clients
- Distributors

Direct clients: (Clients with direct shipment)

Direct deliveries from plant located in the Far East to customers in Italy are basically for the customized mobile phones that are delivered to the mobile operators. This flow represents 30% of the total Mobile flow. Also the decoders for satellite television are delivered directly to the customers, for example Sky.

5.3 Actual Distribution Network of Samsung

Drivers for the Design of Distribution Network

Product Characteristics

- Variety: there are 1,000 products from all the families which can be distributed in: 400 codes for audio video, 100 codes for home appliances, 150 codes for air conditioners, 50 for mobile phones and 300 for informatics products.
- Value (€/Kg): range of 13 €/Kg for home appliances to 1,000 €/Kg for mobile phones.
- Density (Kg/m^3): range of 110 Kg/m^3 for home appliances to 1,200 Kg/m^3 for mobile phones.
- Risk of obsolescence: from 3 months for mobile phones to 1 year for home appliances and air conditioners.
- Contribution Margin: varies depending on the type of product from 14% for audio-video to 30% for mobile phones.

Level of Service

- Cycle Time (order-delivery): 3-5 working days when appointments are not requested.
- Completeness (item fill rate): difficult to supply 100% because the orders are usually multiproduct within the same product family, so a 95% of completeness is considered. The only case with 100% corresponds to mobile phones that are delivered directly from the plants to the customers.
- Returnability: since the return flow is not very important it corresponds to only 1% of the total flows.

Demand Characteristics

- Dimension of the order (typology): 65% of the orders go directly from the warehouse to the client without passing through the transit point. From that 65%, 40% of the orders are 0,6FTL and the remaining 60% are of 0,4FTL or 0,2FTL. The 35% left, uses transit points and the average dimension of the order is 0,4FTL.
- Number of customers: 400 in Italy which correspond to 1200 delivery points.
- Frequency of delivery: depending on the product it goes from twice a week to once a month.
- Seasonality: is considered as low for home appliances, medium for audio-video and high for mobile phones.

- Predictability of demand: 95 %, it should be high because only the products that have a high probability of being sold are delivered to the warehouses.

Supply drivers

- Distance from plant to client: 1,000 km for the plants located in Europe and 9,000 km for the plants in the Far East.
- Number of plants: 10 plants that provide the Italian market.
- Level of specialization: there is high specialization of the plants that supply the warehouses in Italy.

Macrodriver	Driver	Value
Product	Variety [SKUs]	1,000
	Value [€/Kg]	13 – 1,000
	Density [Kg/m^3]	110 – 1,200
	Risk of obsolescence [days]	90 – 365
	Contribution Margin:	14% - 30%
Service	Cycle Time [days]	3 – 5
	Completeness [IFR]	95% - 100%
	Returnability [%]	1
Demand	Dimension of the order [%FTL]	0,2 – 0,6
	Number of customers	1,200 delivery points
	Frequency of delivery [Deliveries per week]	0,25 – 2
	Seasonality	From Low to High
	Predictability of demand [%]	95
Supply	Distance from plant to client	1,000 - 9,000
	Number of plants	10
	Level of specialization	High

Table 13 Summary of Samsung drivers

Characterization of the Supply Chain

The 3 plants in Europe, located in Hungary and Slovakia, produce products for the Audio-video and Informatics business units, while the plants in the Far East produce mobile phones, home appliances and air conditioners. The plants are highly specialized and the warehouses manage only one family of products because the training of personnel, the security of products and the flow management are different.

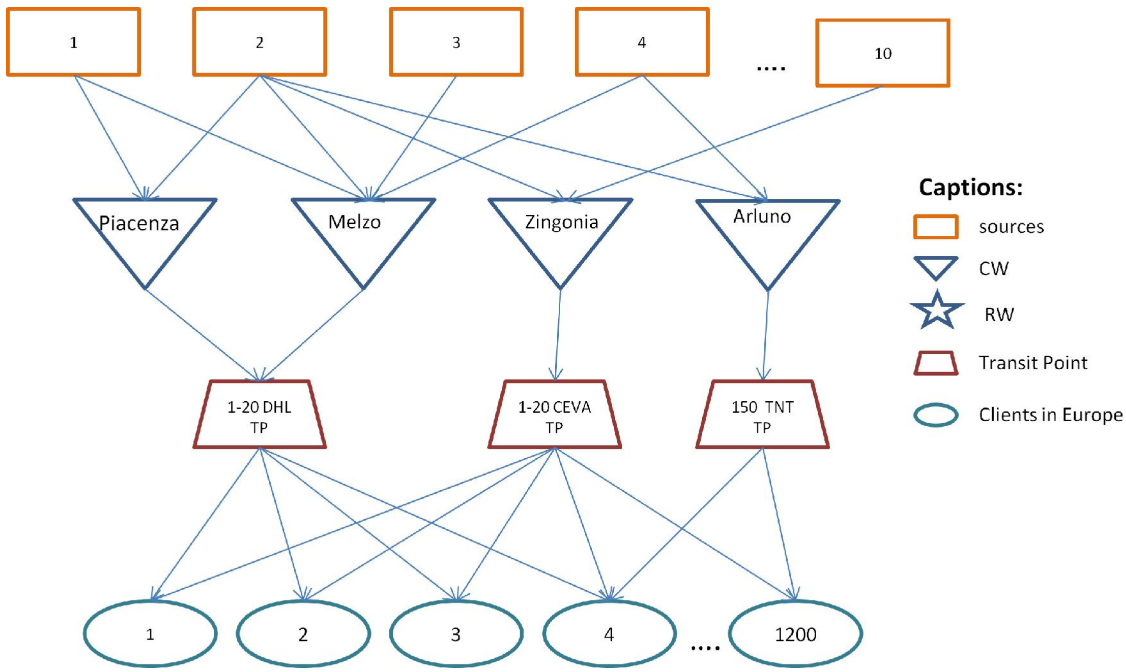


Figure 19 Samsung Distribution Network

Network classification

The network is of 2 levels; the first one consists of 4 CW in Italy, which are replenished by 10 plants located in Europe and the rest of the world. Each warehouse is managed by 3PLs providers. The second level consists of transit points of the 3PLs, distributed in the following way:

- DHL: 20 TP
- CEVA: 20 TP
- TNT Global express: 150 TP

Node characterization: (location and allocation)

The 4 CWs in Italy are located near Milan; instead the transit points are located in each region. Each warehouse is specialized in stocking one or two kinds of products:

- Piacenza: storages home appliances, managed by DHL
- Melzo: storages audio video and informatics products, managed also by DHL
- Zingonia: storages mobile phones, managed by Bertola Central Docks.
- Arluno: storages air conditioning systems, managed by CEVA

Figure 20 Location of Samsung facilities

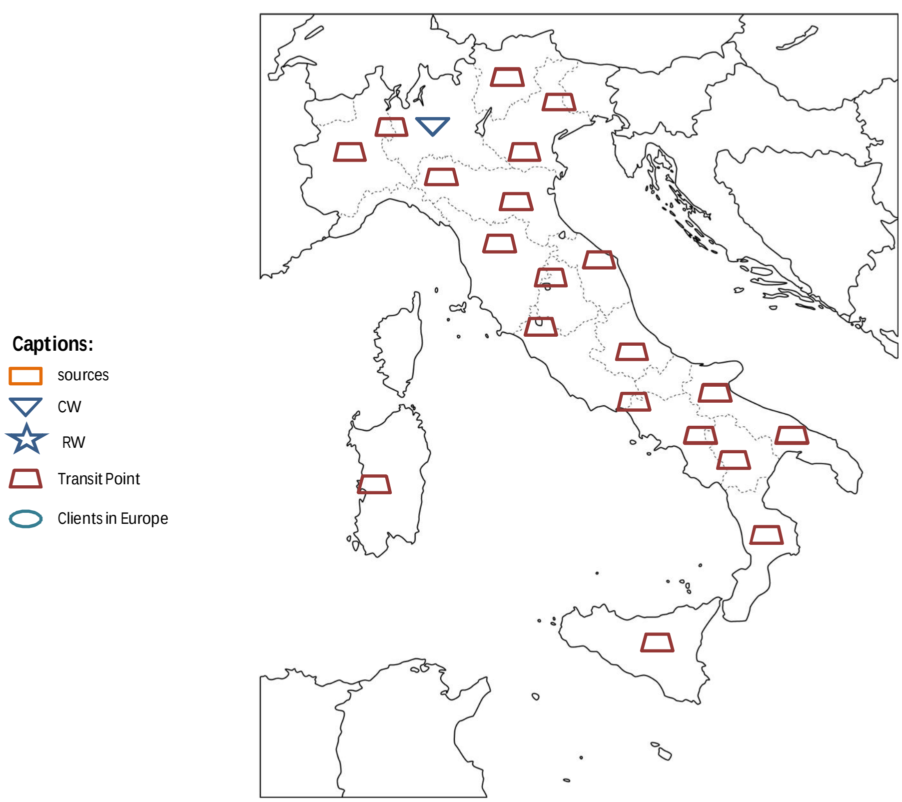


Figure 21 Location of Samsung facilities

Activities, resources and capacity of each typology

The 4 Central Warehouses are used for storage activities and have the following dimensions:

- Piacenza: 12.000 m^2
- Melzo: 20.000 m^2
- Zingonia and Arluno: the dimensions vary upon the time.

The Transit Points are designated for sorting and re-palletization activities.

Flow Characteristics

Principal active flows:

F1: Mobiles produced in the Far East are delivered directly to the mobile operators, this flow corresponds 30% of all the mobiles delivered in Europe and corresponds 6% of the total outbound flow.

F2: House appliances produced in Asia are delivered in the Piacenza Warehouse corresponding 6% of the total inbound flow.

F3: Products from the audio-video and informatics family are produced in Europe and delivered in the Melzo Warehouse, representing 40% and 30% respectively.

F4: The rest of the mobile phones that are not delivered directly to the mobile operators are delivered to the Zingonia Warehouse, representing 70% of all the mobiles delivered in Europe and 14% of the total outbound flow.

F5: Air conditioners are produced in Asia and delivered to the Arluno Warehouse. This flow represents 4%.

F6: 60% of the products in the Piacenza warehouse are delivered to the clients without stopping in the transit points.

F7: 40% of the products in the Piacenza warehouse stop in one of the 20 DHL transit points, before final delivery.

F8: 40% of the products in the Melzo warehouse stop in one of the 20 DHL transit points, before final delivery.

F9: products delivered to final customers from the DHL transit points

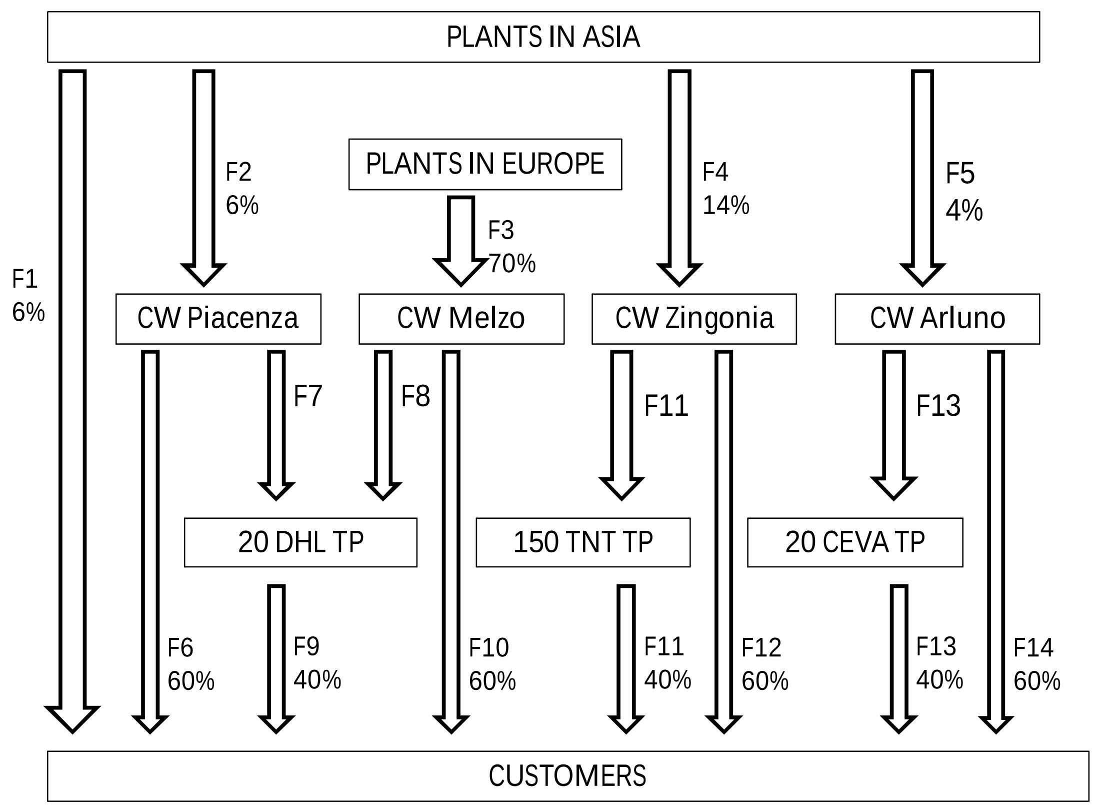
F10: 60% of the products in the Melzo warehouse are delivered to the clients without stopping in the transit points.

F11: 40% of the products in the Zingonia warehouse stop in one of the 150 TNT transit points and then these same products are delivered to final customers.

F12: 60% of the products in the Zingonia warehouse are delivered to the clients without stopping in the transit points.

F13: 40% of the products in the Arluno warehouse stop in one of the 20 CEVA transit points and then these same products are delivered to final customers.

F12: 60% of the products in the Arluno warehouse are delivered to the clients without stopping in the transit points.



Managerial logic

Stocks

- Safety Stocks: the stocks vary based on the type of product:
    - 1 week of stock for Mobile and Audio – Video products
    - 3 – 4 weeks for Home appliances
- Service Level: difficult to reach 100% due to multi product orders of one family.

Transport

- Organization of primary transport
    - Products manufactured in Europe (Audio – Video and Informatics) use Air and Road transportation
    - Products manufactured in the Far East (Mobile and Home Appliances) arrive by Air and Ship.
- Organization of secondary transport

  The secondary transportation is mainly done by road.

Outsourcing

- Activities in outsourcing: Warehouses, transit points and transportation are managed by 3PLs
- Companies that handle the outsourced activities: DHL, CEVA, Bertola Central Docks.

5.4 Distribution Problems of Samsung

Due to the wide range of products Samsung provides, the distribution problems have different product and supply drivers. It has to be underlined that each family of products has its own warehouse, this because each family of products requires different maintenance, personnel and also different channel for distribution.

- SA1: characterized by direct delivery of customized mobile phones and television decoders from Far East plants to mobile operators or TV providers.

- SA2: consist of one level of CW located in Piacenza that stores products from the home appliance family, produced in the Far East plants and are forwarded directly to clients which request a specific appointment for delivery.

- SA3: consist of two levels, the first is the CW located in Piacenza that stores home appliance products and the second level consists of 20 DHL transit points that manage this type of products.

- SA4: consist of one level of CW located in Melzo that stores products from the audio-video and informatics families produced in European plants and are forwarded directly to clients which request a specific appointment for delivery.

- SA5: consist of two levels, the first is the CW located in Melzo that stores products from the audio-video and informatics families produced in European plants and the second level consists of 20 DHL transit points that manage this type of products.

- SA6: represented by mobile phones, which are not delivered directly to mobile operators, but instead stop at one level of CW located in Zingonia and then are forwarded directly to clients that request a specific appointment for delivery.

- SA7: represented by mobile phones, which are not delivered directly to mobile operators, but instead stop at one level of CW located in Zingonia and then at a second level of 150 TNT transit points that manage this type of products.

- SA8: characterized by air conditioners produced in the Far East plants, stop at one level of CW located in Arluno and then delivered directly to clients that request a specific appointment for delivery.

- SA9: characterized by air conditioners produced in the Far East plants, stop at one level of CW located in Arluno and then at a second level of 20 CEVA transit points that manage this type of products and then forwarded to clients.

MACRODRIVER	DRIVER	VALUE								
		SA1	SA2	SA3	SA4	SA5	SA6	SA7	SA8	SA9
PRODUCT	Variety [SKUs]	50	100	100	700	700	50	50	150	150
	Value [€/Kg]	1000	13	13	370	370	1000	1000	90	90
	Density [Kg/m^3]	1200	110	110	170	170	1200	1200	170	170
	Risk of obsolescence [days]	90	365	365	180	180	90	90	365	365
	Contribution Margin:	30	24	24	14	14	30	30	14	14
SERVICE	Cycle Time [days]	5	3	5	3	5	3	5	3	5
	Completeness [IFR]	100	95	95	95	95	95	95	95	95
	Returnability [%]	1	1	1	1	1	1	1	1	1
DEMAND	Dimension of the order [%FTL]	0.4	0.6	0.4	0.6	0.4	0.4	0.2	0.6	0,4
	Number of customers	5	35	1160	32	1163	32	1163	35	1160
	Frequency of delivery [Deliveries per week]	0.25	0.5	1	2	2	1	1	0.5	1
	Seasonality	H	L	L	M	M	H	H	L	L
	Predictability of demand [%]	95	95	95	95	95	95	95	95	95
SUPPLY	Distance from plant to client	9000	9000	9000	1000	1000	9000	9000	9000	9000
	Number of plants	4	3	3	3	3	4	4	3	3
	Level of specialization	H	H	H	H	H	H	H	H	H

Table 14 Summary of Samsung distribution problems

Chapter 6. Clusters of distribution problems based on the network strategic choice

6.1 Projection elements

It has been said in chapter 2, that there are several types of solutions based in the choice of the distribution network. In this chapter, there are identified and grouped all the possible choices based in the strategic decision that has been chosen to consider in the path of experimental analysis.

6.2 Identification of clusters

Number of levels and typology for each level

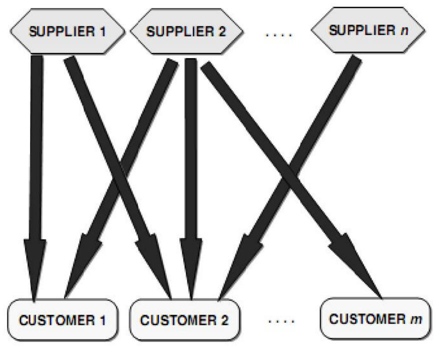
From the study of company cases, the proposed network solutions are: direct delivery, one level of CW, one level of transit points, and two levels composed of CW and transit points. Next, it has been compiled a table that reports all the possible solutions.

Distribution Problem	**Number and typology of levels of the distribution network solution**
HP1	Network of 1 level: transit points
SO1	Network of 1 level: central warehouse
SO2	Network of 2 levels: central warehouse and transit points
SO3	Network of 2 levels: central warehouse and transit points
SO4	Network of 1 level: central warehouse
SO5	Network of 2 levels: central warehouse and transit points
SO6	Network of 2 levels: central warehouse and transit points
SA1	Direct delivery from manufacturing plants
SA2	Network of 1 level: central warehouse
SA3	Network of 2 levels: central warehouse and transit points
SA4	Network of 1 level: central warehouse
SA5	Network of 2 levels: central warehouse and transit points
SA6	Network of 1 level: central warehouse
SA7	Network of 2 levels: central warehouse and transit points
SA8	Network of 1 level: central warehouse
SA9	Network of 2 levels: central warehouse and transit points

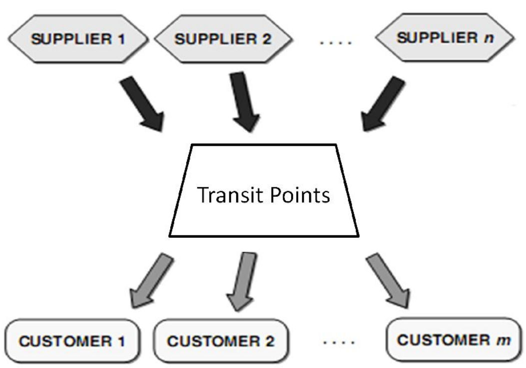
Table 15 Distribution Problems and Network Solutions

From the aggregated analysis of all the adopted possible solutions, emerged the next 4 clusters:

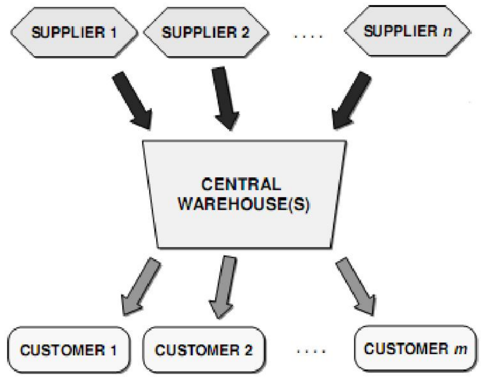
1. Direct delivery from manufacturing plants
   Distribution problems belonging here: SA1



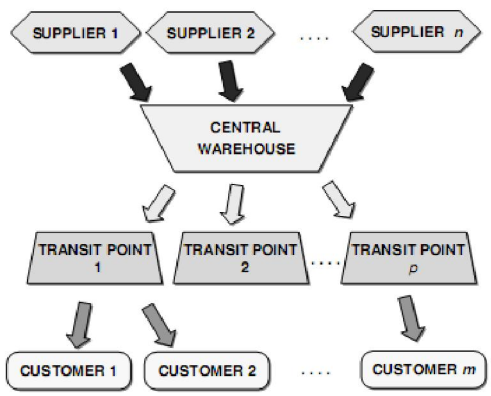
2. 1 level of t
   Distributio



3. 1 level of central warehouse
   Distribution problems belonging here: SO1, SO4, SA2, SA4, SA6, SA8



4. 2 levels of central warehouse and transit points
   Distribution problems belonging here: SO2, SO3, SO6, SO5, SA3, SA4, SA7, SA9



Characterization of nodes for the 1 level network with transit points

In the definition of the structure, as well as the decision of the number and type of level already analyzed, contribute in fact other choices that in this work are characterized as follows:

- Number of nodes at first level
- Average area served by nodes
- Location of nodes over the European surface
- Allocation of clients to the nodes
- Surface of the WH
- Variety of products for each WH

The HP1 distribution problem is the only one that implements this type of network. It consists of two transit points located in Luxemburg and The Netherlands that are used to satisfy the demand of clients from all over Europe and manage the complete variety of products of the company.

DP	Nodes	Area served	Location	Allocation	Surface	Variety
HP1	2	10,180,000 km^2	Luxemburg and Netherlands	All Europe	Unknown	Full mix

Table 16 Characterization of TP at first level

Characterization of nodes for the 1 level network with central warehouse

In the following table, it is presented the details for the distribution problems having one level of CW.

DP	Nodes	Area served	Location	Allocation	Surface	Variety
SO1	1	301,338 km^2	Liscate	Big italian customers	80,000 m^2	Full mix
SO4	1	301,338 km^2	Liscate	Big Italian Clients	80,000 m^2	Full mix
SA2	1	301,338 km^2	Piacenza	Big Italian Clients	12,000 m^2	Home appliances
SA4	1	301,338 km^2	Melzo	Big Italian Clients	20,000 m^2	Audio, video and informatics
SA6	1	301,338 km^2	Zingonia	Big Italian Clients	Variable	Mobile phones
SA8	1	301,338 km^2	Arluno	Big Italian Clients	Variable	Air conditioners

Table 17 Characterization of CW at the first level

As seen from the table above, all these distribution problems serve the national territory of Italy. The difference relies on the Company, for example Sony has one WH which stores all products, while Samsung has specialized warehouses that store only one family of products, each.

Figure 22 Location of CW

Characterization of nodes for the 2 level network with central warehouse and TP

The strategic decisions of the network to take into account, like in the preceding analysis, are number, location and allocation for each level and variety of products available in the CW. In order to group the alternatives of network proposed by the companies in solution clusters, are resumed in the next table for each distribution problem.

DP	1° level: Central Warehouse				2° level: Transit Points		
	Number	Variety	Location	Allocation	Number	Location	Allocation
SO2	1	Full mix	Liscate	Big italian customers	13 DHL	Principal Italian regions	1 TP for each 1.5 Italian region
SO3	1	Full mix	Liscate	Small italian customers	13 DHL	Principal Italian regions	1 TP for each 1.5 Italian region
SO5	1	Full mix	Liscate	Big italian customers	13 DHL	Principal Italian regions	1 TP for each 1.5 Italian region

SO6	1	Full mix	Liscate	Small Italian Clients	13 DHL	Principal Italian regions	1 TP for each 1.5 Italian region
SA3	1	Home appliance	Piacenza	Big italian customers	20 DHL	Italian regions	1 TP for every Italian region
SA4	1	Audio-video and informatic	Melzo	Big italian customers	20 DHL	Italian regions	1 TP for every Italian region
SA7	1	Mobile	Zingonia	Small italian customers	150 TNT	Principal Italian cities	7.5 transit points for each Italian region
SA9	1	Air conditioners	Arluno	Big italian customers	20 CEVA	Italian regions	1 TP for every Italian region

Table 18 Characterization of the CW and TP of the 2 level networks

With the information above it can obtain the following groups:

- Central Warehouse with one transit point every 1.5 Italian region: SO2, SO3, SO5 and SO6

Figure 23 Location of TP for SO2, SO3, SO5 and SO6

- Central Warehouse with one transit point every Italian region: SA3, SA4 and SA9

Figure 24 Location of TP for SA3, SA4 and SA9

- Central Warehouse with 7.5 transit points for each Italian region: SA7

Due to the complexity of this network, it is not possible to illustrate it.

Chapter 7. Relationship between distribution problems, drivers and logistic costs

Among the sixteen drivers selected in chapter 4, there are three new drivers that were added, and others that were removed from the work presented by "Archini and Bannò" after carrying out the literature analysis. The objective of the following analysis is to understand the impact of all these drivers over the logistic cost in order to see if each driver is critical for the different network choices. Each driver has a different impact over the network design process; this impact will be described by the criticality of the driver which will depend on the effects of the driver over the logistic costs.

After understanding the costs, the criticalities of the drivers will be defined, which consent to relate the factors characterized by different units of measure. The procedure followed to identify the intervals of reference is described in paragraph 3.5. And it was used the following legend:

Yellow: direct delivery from plants
Green: 1 level of CWs
Blue: 1 level of TPs
Red: 2 levels, CWs and TPs

Company	HP	Sony			Samsung				
Distribution Problem	HP1	SO1	SO2	SO3	SA1	SA2	SA3	SA4	SA5
		SO4	SO5	SO6	SA6	SA7	SA8	SA9	

Product drivers:

Variety

An increase in the variety of the products offered cause an increase in the total logistics costs due to the following reasons:

Transportation costs: a greater variety of products increases the transportation cost, both primary and secondary. Primary transport increases because different products could require different transport typologies creating the risk of not saturation of the transport means, while secondary transport increases because client orders may be of just few products and therefore there are more deliveries. However, by increasing the range of products, customers could make larger orders, making it easier the saturation of the transport mean, thus increasing the cost of primary transportation, but decreasing substantially the secondary transport, having as a result the reduction of the total cost of transport.

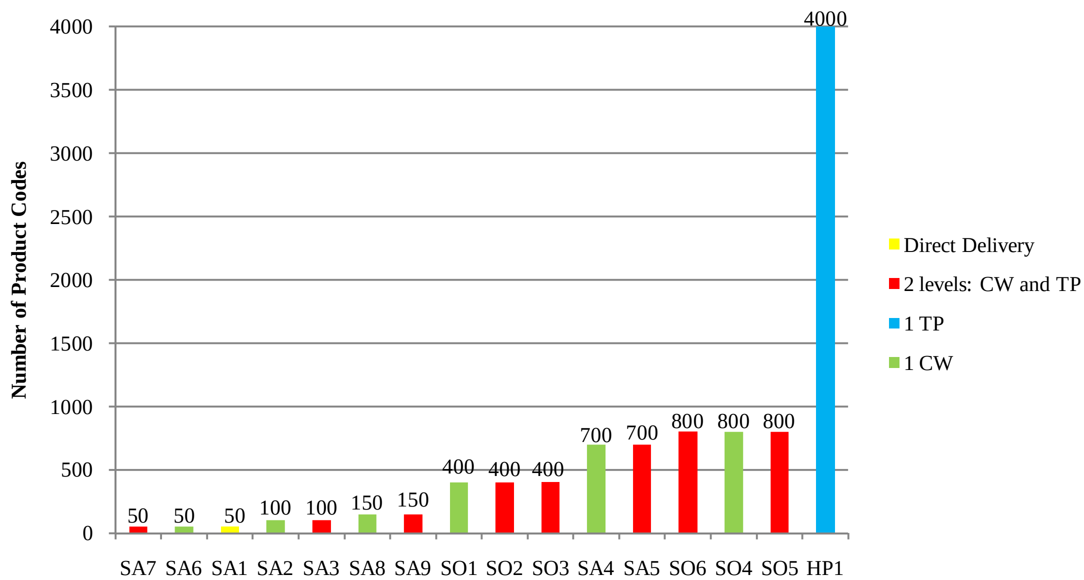
Inventory costs: with a great variety of products, the inventory costs tend to increase because it leads to an increase in the average level of stock and the level of safety stocks for the different products, having greater space occupancy and increasing the insurance costs.

Handling costs: these costs tend to increase because a greater variety could require, for an average volume order, a greater number of picking operations. Furthermore, since the product codes are large numbers, it would increase the risk of errors and might therefore need a control system and the allocation of more resources.

Cost of lost sale: this cost might be reduced because, in the presence of a greater variety of products, the needs of the clients could be satisfied with a substitutive product of the same company.

For the analysis of the distribution problems, the variety of products was measured in Number of Product Codes. Theoretically, it can be said that with a great variety of products, the criticality of the driver raises and the distribution network implemented should be centralized in order to avoid duplication and increase of the levels of stock.

From the graph below it can be observed that different values of variety were obtained, from 50 to 4000 SKUs, but it was not possible to correlate a specific variety with a type of distribution network implemented with the exception of the distribution problem HP1.

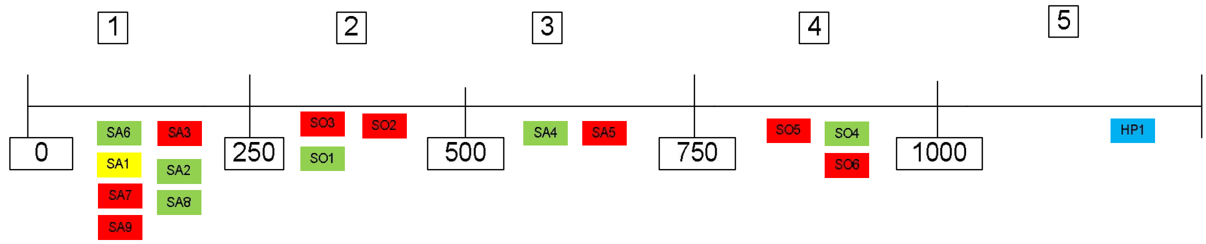


Graph 8 Relation between the variety of products, distribution problem and network applied

For the case of HP1, which is the distribution problem with more number of products, the solution adopted was a network of 1 level conformed by transit points. This design is coherent with the reasoning above because of the complete elimination of stocks, and therefore the reduction of logistics costs. While, for the rest of the variety values obtained, different distribution networks were applied no matter the number of SKUs. This behavior is because for the same type of products, like for example the distribution problems SA1, SA6 and SA7 which corresponds to mobile phones that are delivered directly, with one level of warehouses, or with 2 level network of warehouses and transit points, respectively, the distribution network adopted is based on other drivers, like number of clients or cycle time, and not on the number of products.

As a conclusion, it can be said that for extremely high variety of products, the implementation of a network that eliminates the products on inventory is recommended in order to reduce total logistics costs, while for lower variety different distribution networks might be applied.

The following graph presents the scale of criticality of the driver "Variety" were it can be observed in one axis the conclusion mentioned above.



Graph 9 Scale of Criticality of the driver “Variety”

Value

An increase in the value of the products, cause an increase in the total logistic cost.

Transportation costs: an increase in the value of the goods diminishes the incidence of the cost of transport, either primary or secondary over the product cost.

Inventory costs: these costs increase with the augment of the goods value, because the costs of insurance, the finance charges and the costs related to depreciation, are all directly proportional to the value.

Handling costs: the handling cost might increase if the value of the product augments due to specific handling requirements to avoid damages to the product, but it is not a rule.

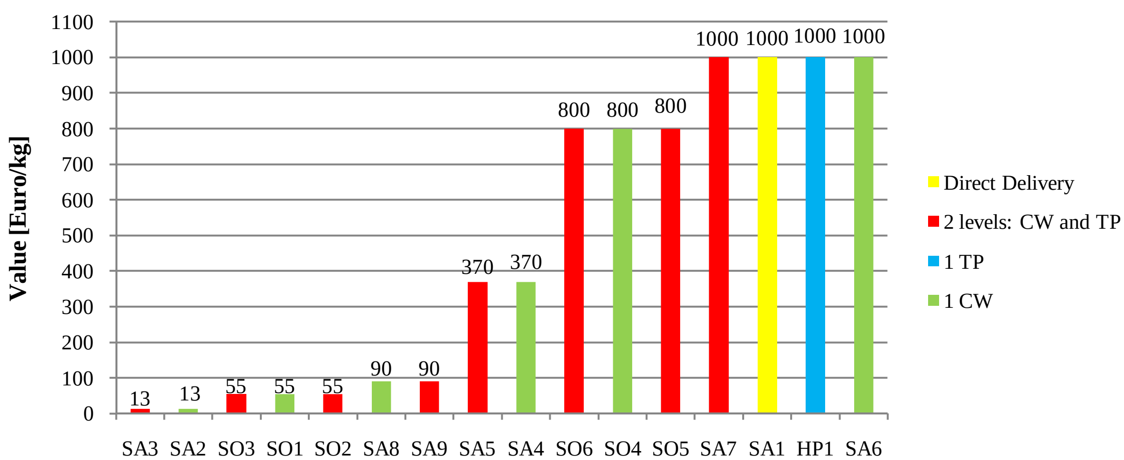
Cost of lost sale: as the value augments, the costs of stock out increase in a considerable way, in fact a lost sale of products with high value is translated into a huge revenue loss.

The unit of measure used for the analysis of the distribution problems was Euro/kg, and from the theoretical explanation above, products with high value should be considered as critic for the distribution network design. In this case, a centralized network might be implemented in order to reduce the levels of inventory and its handling costs, but having the appropriate cycle time to avoid stock outs.

From the analysis of the distribution problems, it was not possible to observe a clear pattern of relation between this driver and the distribution network implemented. For example, products with high value like mobile phones (SA1, SA6 and SA7) are distributed with three different networks going from centralized (direct delivery) to decentralized (2 level network of warehouses and transit points). The implementation of one network or another might be based on other drivers, and not on the value of the product.

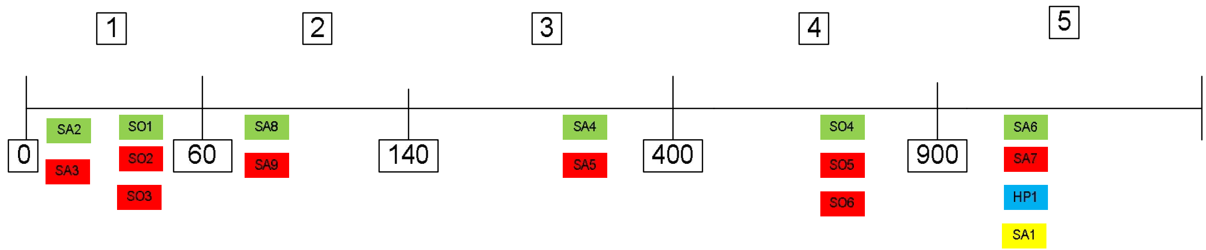
In the case of HP1, the value presented is an average from the complete variety of products and, as it was established by the company, all the products are delivered through a network with one transit point. With this policy, the company eliminates the inventory costs, and therefore reduce the total logistics costs.

In the case of products with lower values, a similar behavior as the high value ones was observed, were different network layouts are used for one particular relation Euro/Kg. As a conclusion of this analysis it can be said that the driver "Value" itself is not determinant for the distribution network design.



Graph 10 Relation between the value of the products, distribution problem and network applied

The scale of criticalities of the driver "Value" is presented below:



Graph 11 Scale of Criticality of the driver “Value”

Density

A decrease in the density, generate an increase in the total logistic costs.

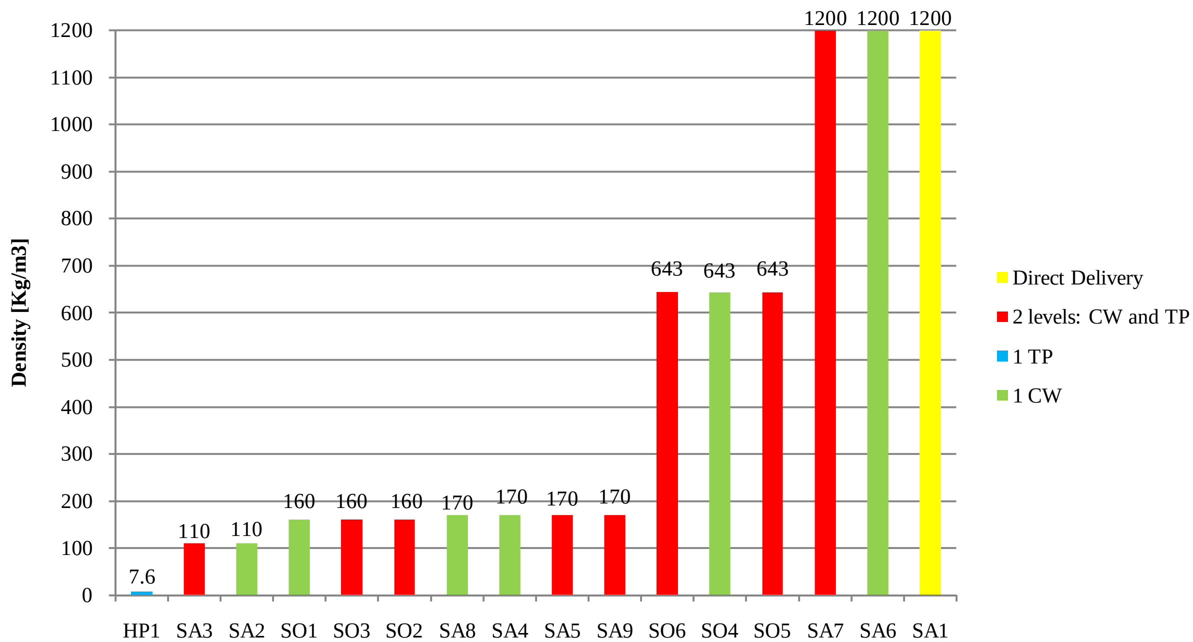
Transportation costs: a high density of the products favors the saturation of the transportation mean, allowing in this way the reduction of secondary transportation costs. Using a primary transportation delivery policy is cheaper than a combined one, and therefore with an increase in density, a reduction in cost of transport is achieved. In addition, high density products are less voluminous, so it takes less space in the transport mean and allows weight saturation instead of volume. In this way, the cost is distributed in a greater number of pieces.

Inventory costs: an augment in density can favor the reduction of storage costs. The saving is mainly due to the reduction of space needed to store the goods

Handling costs: with a decrease in the density of the products, the number of delivery trips required to meet demand increases, thus requiring more loading and unloading activities that increase the cost of handling.

Cost of lost sale: this cost does not vary with a variation in density.

For the analysis of the distribution problems, the density was measured in Kg/m^3, and different values were obtained, from 7,6 to 1200. The graph below presents the average values of density for each distribution problem, as well as the distribution network adopted.



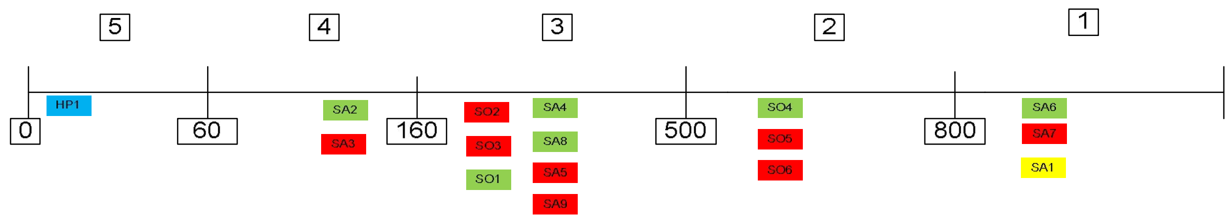
Graph 12 Relation between the density of the products, distribution problem and network applied

In theory, products having low value of density should be distributed with a centralized network in order to facilitate primary transport policies and reduce the amount of space required for inventories. From the analysis of the distribution problems this behavior was obtained just for the distribution problem HP1 which has a density value of 7,6 kg/m^3 and uses a distribution network of 1 level of transit points which eliminates the stocks and therefore just need space for in-transit goods.

For the rest of the distribution problems, a clear pattern was not observed because for the same value of density, different distribution networks were adopted. For example, products with relatively low density (170 kg/m^3) are distributed using two different types of networks: 1 level of central warehouses and 2 levels of central warehouses and transit points. The same performance was observed for medium and high density values.

With these results it may be assumed that the driver “Density” has not an important role during the design phase of the distribution network. It is possible that its impact will be higher for operational decisions such as warehouse management or transport routing.

The scale of criticality of the driver “Density” is presented below:



Graph 13 Scale of Criticality of the driver “Density”

Risk of obsolescence

A high risk of obsolescence of the products implies an increase in the total logistic cost.

Transportation costs: with a high risk of obsolescence there is an augment in both primary and secondary transportation costs. The products with this characteristic need presumably a high efficiency and reduced cycle time of transport, both involving an increase of costs.

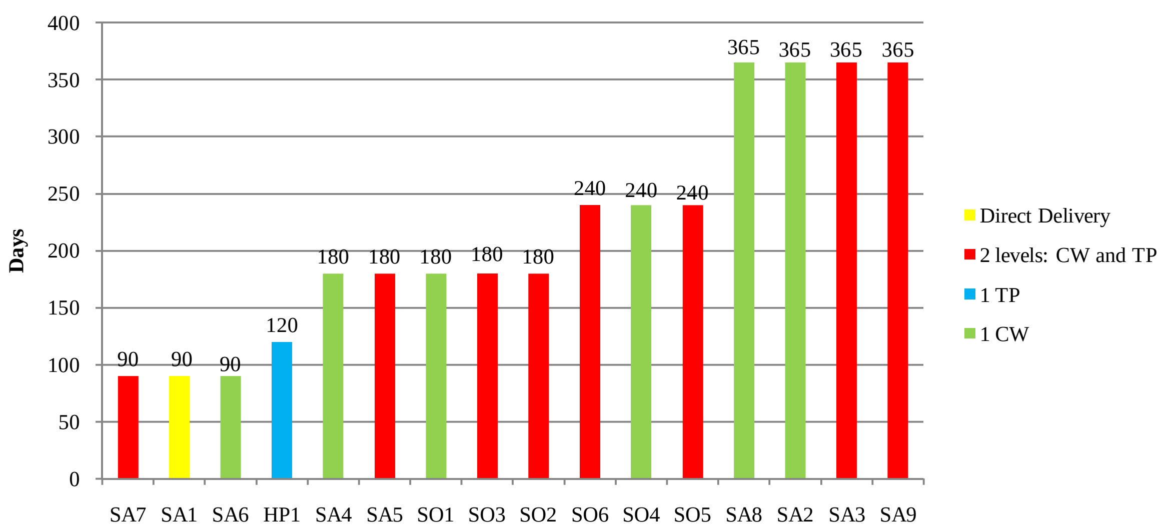
Inventory costs: with a presence of products highly risky there is a tendency to decrease the stocks, and with this all the associated costs. However a high risk of obsolescence causes in the products a constant depreciation that is translated in high costs of system management.

Handling costs: this cost is not affected by an increment in the risk of obsolescence.

Cost of lost sale: when the risk is high this cost tends to increase because once the product is expired it is not marketable anymore, but rather the disposal has to be managed.

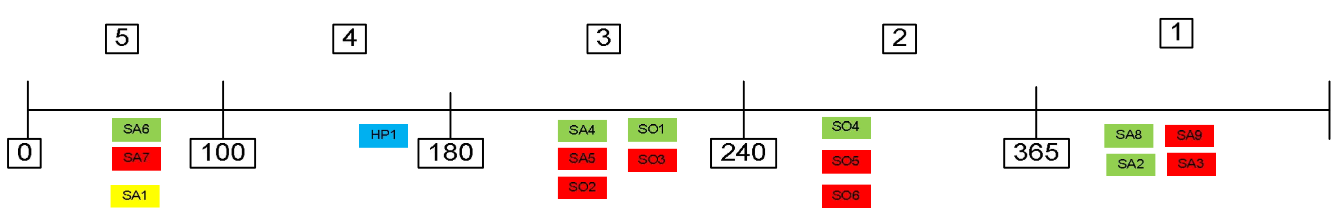
Theoretically, products with high risk of obsolescence (measured in Days) should be distributed with a centralized network in order to reduce the cycle times and the levels of stock. In the case of the consumer electronic industry, the gap of time between the expiration date and the delivery cycle time is big enough to allow longer distribution networks with warehouses and transit points. Aspect that does not happened in other industries, like for example fresh food, where the gap is small and fast distribution networks are mandatory.

Nevertheless, during the analysis of the company cases presented in the graph below, problems with relatively high risk of obsolescence (90 or 120 days) presented the implementation of Direct Delivery policies (SA1) or networks with 1 level of transit point (HP1). While for lower risk of obsolescence (180, 240 or 365 days) networks with 1 level of central warehouse or with 2 levels of central warehouses and transit points were adopted. Due to this reason, the driver "Risk of Obsolescence" is not considered as a determinant one for the distribution network design.



Graph 14 Relation between the Risk of Obsolescence, distribution problem and network applied

The following graph present the scale of criticalities adopted for the driver "Risk of Obsolescence".



Graph 15 Scale of Criticality of the driver "Risk of Obsolescence"

Contribution Margin

Transportation costs: the augment of the contribution margin of the product diminish the incidence of the transport cost over the product cost.

Inventory costs:

Maintenance of Stock: products with low contribution margin force to reduce the storage and maintenance costs.

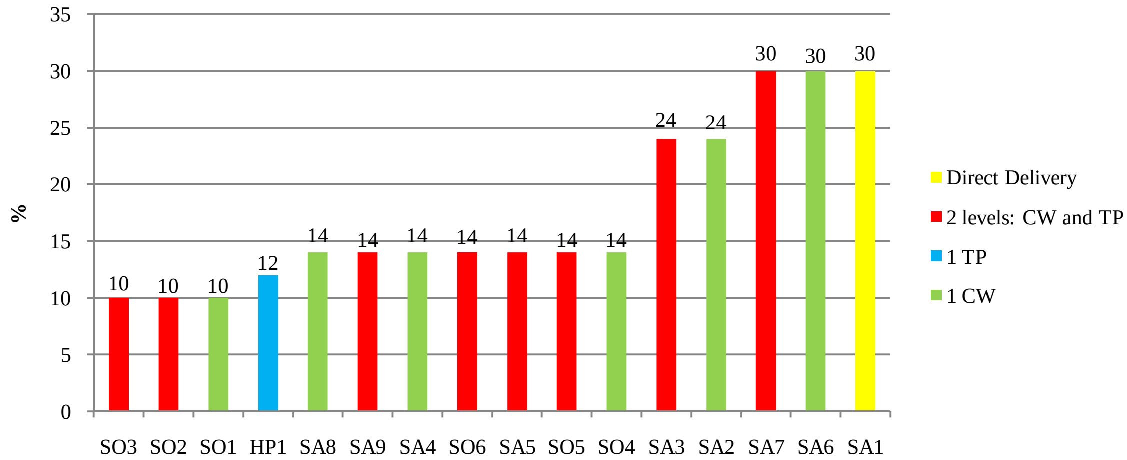
Order cost: there is no evident relation.

Handling costs: products with low contribution margin force to reduce the handling costs.

Cost of lost sale: the costs of lost sale increase considerably when the product has a high contribution margin since a sale that cannot be done represents an important lost in terms of profits. This is the cost that has the greater impact over the total logistic cost.

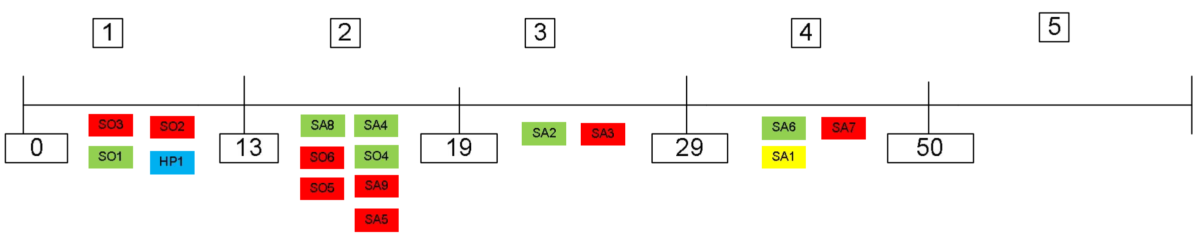
The contribution margin is a relation between the production costs and the price of the product sold and is expressed in percentage. Theoretically, products with high contribution margin allow to be distributed with networks using primary and secondary transport policies (1 or 2 levels), while ensuring the presence of the product on the shelf on time, in order to avoid considerable losses.

For the analysis of the company case studies, the contribution margin was calculated as the average of the contribution margins of the products pertaining to one distribution problem. It was not possible to associate a value of the contribution margin with a specific distribution network solution, as it is presented in the following graph. For example, the network of 2 levels with central warehouses and transit points was used by all the values except 12% (SO2, SO3, SO5, SO6, SA5, SA9, SA3 and SA7), and a similar behavior is present for networks of 1 level with central warehouses.



Graph 16 Relation between the Contribution Margin, distribution problem and network applied

Based on the previous analysis it is possible to say that the driver "Contribution Margin" is not determinant for the design phase of the distribution network. The scale of criticalities is presented below.



Graph 17 Scale of Criticality of the driver "Contribution Margin"

Service drivers:

Cycle time

The more the cycle lasts, the total logistic costs diminish. This performance has a significant impact over all the costs voices individually.

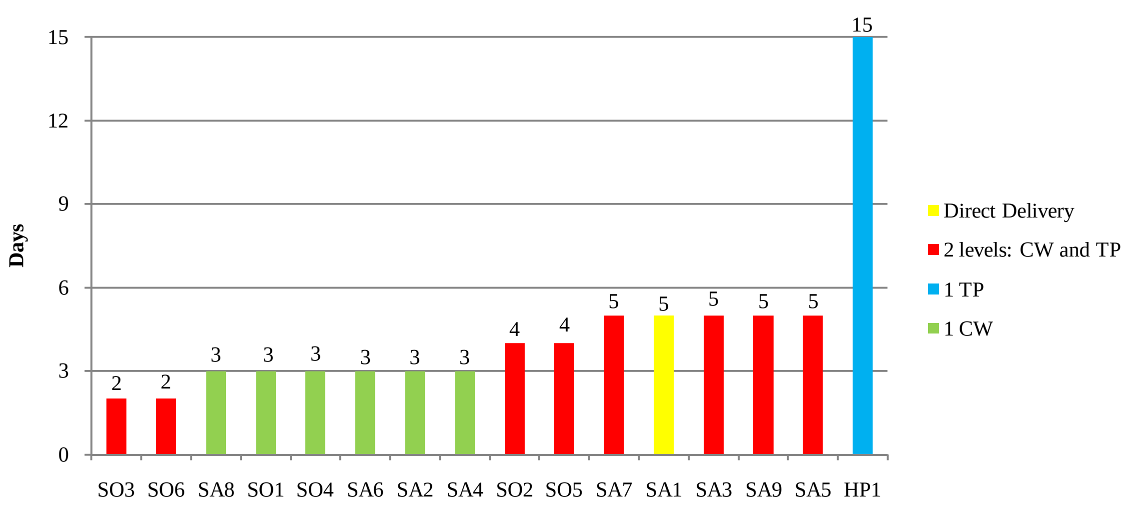
Transportation costs: when the cycle time increases it is obtained a reduction in both primary and secondary costs. The more the number of days for the delivery of orders, less would be the necessary resources either for the execution of transport or for what regards the distribution. If the cycle time is short, fast transportation modes should be required (air or road) which increases the costs.

Inventory costs: the more the value of the cycle time, the less is the level of stock required, so the storage costs are less significant.

Handling costs: in presence of a high cycle time, the efficiency in the activities of movement can be reduced and with this the associated costs.

Cost of lost sale: when the requested cycle time is high, the company sees a condition in the service less stringent, so in these conditions decrease the costs of lost sale.

The driver "Cycle Time" is considered as extremely important for the design phase of the distribution network. Based on the requirements and tolerances given by the clients, the company should decide whether to use one distribution network or another. The following graph present the values of Cycle Time (measured in Days) obtained for each distribution problem during the interviews.



Graph 18 Relation between the Cycle Time, distribution problem and network applied.

From the analysis of the company cases, a clear pattern was obtained due to the fact that each distribution network adopted provides a specific cycle time, except for the distribution problems SO3 and SO6 which are a particular case. This two problems corresponds to TVs and Peripherals, respectively, that are stored in one central warehouse located in the north of Italy and pass through the transit points of the logistics service provider, in this case DHL express, to be delivered to small clients which orders are also small (some boxes). Due to the size of the orders, and probably the low mix of them, the company is able to provide a cycle time of 2 days.

The distribution problems SO1, SO4, SA2, SA4, SA6 and SA8 corresponds to products that are stored in a central warehouse in the north of Italy and are delivered to big clients with order dimensions of more than half truck load, which accept 3 days of cycle time. The difference of one day between the previous 2 distribution problems and this 5, is mainly due to the dimension of the orders and the transport mean used.

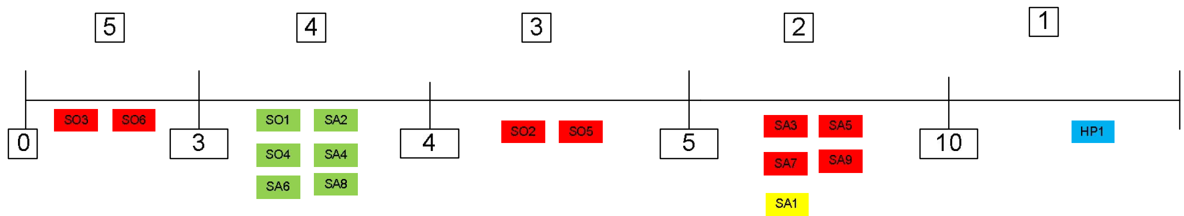
Next, the rest of distribution networks with 2 levels of central warehouses and transit points add 1 or 2 days to the cycle time with respect to the previous network, due to the activities of cross docking developed in the transit point. The distribution problems SO2 and SO5 correspond to similar products delivered in SO1 and SO4, but due to the dimension of the order (0,6 FTL) and probably because of the mix of products required, are delivered with one more day.

The distribution problems SA3, SA5, SA7 and SA9 correspond to similar products of SA2, SA4, SA6 and SA8, respectively, but which order dimensions are smaller than a full truck load and require cross docking activities in the transit point, adding 2 more days to the cycle time.

In the case of the distribution problem SA1, although it is direct delivery and should have a small cycle time, the value obtained for this solution is equal to 5 days. The reason is because products distributed with this network are mobile phones and TV decoders that are produced in facilities located in the Far East and are delivered directly to few clients in Italy (mobile and television service providers) using a combined transportation mode (air and road) due to the high risk of obsolescence of this products.

The highest cycle time was obtained for the distribution problem HP1 which uses a network of 1 level of Transit Points. The reason is because this company adopted a policy of Zero stock and uses a particular dynamic of the flow of products; the order from a client in Italy (mainly big clients) is placed directly in the facilities located in the Far East, the production starts and takes 8 days approximately to be completed, then the product is delivered to a transit point located in the Netherlands with the objective of assemble the order and once it has been consolidated it is delivered using full truck loads, giving a total cycle time of 15 days.

The scale of criticalities of the driver “Cycle Time” is presented below, and it is possible to observe clearly the intervals of impact on the logistic costs.



Graph 19 Scale of Criticality of the driver “Cycle Time”

Completeness

While this performance increases, decreases the total logistic cost.

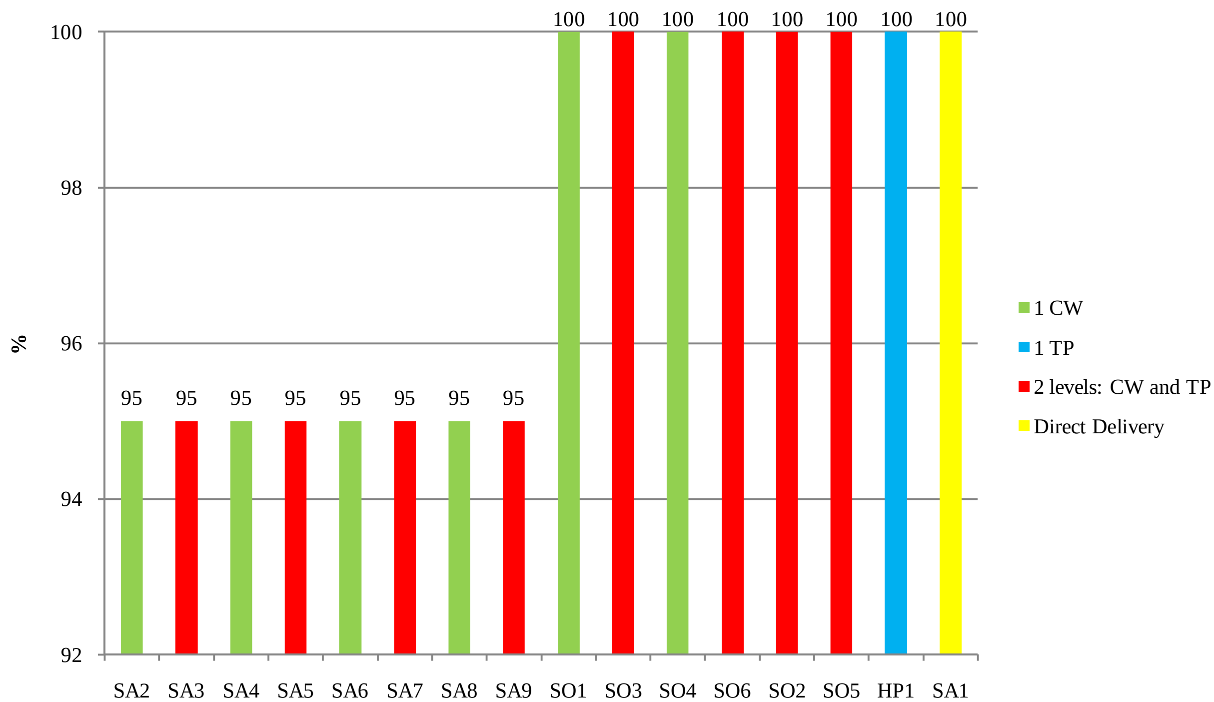
Transportation costs: if the completeness is reduced, the level of saturation of the transportation mean should not be the optimal one increasing the costs. Also, incurring in a situation of stock out, if the client accepts the late delivery of the rest of the order, the use of "ad hoc" means should be necessary, increasing also the transportation costs.

Inventory costs: the relation in this case is evident; in order to satisfy a complete order from a client, the average levels of stock should be increased and therefore, the costs will also augments.

Handling costs: if an incomplete order can be supplied in a later date, the handling costs are not affected by the level of completeness. If not, with a decrease in the level of completeness, the handling cost will also diminished, but having as an impact the reduction of the service level offered by the firm.

Cost of lost sale: the cost of lost sale decrease with an increase in the completeness.

From the analysis of the company cases, it was possible to observe that the level of completeness is not directly related with the type of distribution network adopted by the company. It is more an internal decision or goal of the firm rather than an effect of the distribution network as it can be observed in the following graph.



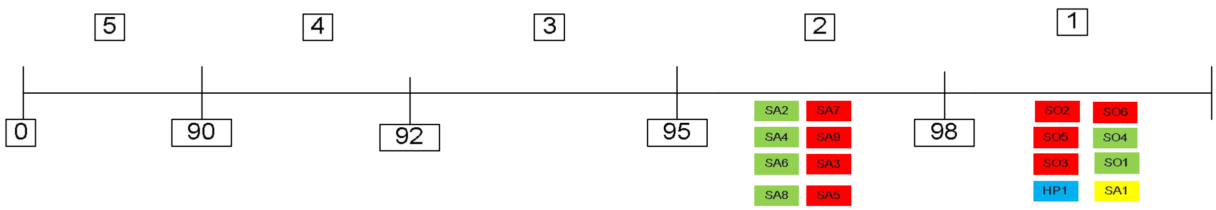
Graph 20 Relation between the Order Completeness, distribution problem and network applied

In the case of Samsung, the distribution problem SA1 reached 100% of completeness due to the fact that the orders are placed to the plants and are directly delivered to the clients once the order is complete; the completeness of the order depends on the production capacity of the facility. A similar behavior is observed in the distribution problem HP1.

For the rest of the distribution problems of Samsung, it is observed that no matter which distribution network is used (1 or 2 levels), the percentage of completeness of the order is 95%. This result might be caused by other factors like the forecast of demand and the level of stocks implemented by the firm.

In the case of Sony, the operational decisions of warehouse management and production capacity have given as a result the achievement of 100% of orders complete.

As a conclusion it can be said that the driver "Completeness" is not determinant for the design phase of the distribution network. The scale of criticalities is presented below.



Graph 21 Scale of Criticality of the driver "Order Completeness"

Returnability

The Returnability or Reverse logistics is the process of planning, implementing, and controlling the efficient, cost effective flow of finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal. Also includes processing returned merchandise due to damage, seasonal inventory, restock, salvage, recalls, excess inventory, recycling programs, hazardous material programs, obsolete equipment disposition, and asset recovery. (Rogers & Tibben-Lembke, 1998)

The impact on the total logistic costs, can be divided in:

Transportation Costs: managing returns implies an increase in the use of planes, trains or trucks to transport the goods from the customer to the return center or directly to the manufacturing plant, and therefore the costs rise significantly. When managing returned products, the trade-off between the saturation level of the used means in order to reduce costs and the customer service level is presented.

Handling Costs: products following a reverse flow may stop at different stages of the distribution network or the production process for example, central return centers, quality inspection, refurbishment and repackaging areas, or in the case the product cannot be reused, the disposal of it. All this steps consumes time and resources that increase the overall handling costs.

Inventory Costs: Reverse logistics can increase inventory costs in two ways. The first one is related to the stock of finished goods that the company should have in order to replace the product to the customer when it is returned by warranty, which should be considered as a part of the safety stock. The second corresponds to the stock of the returned products based on the route to follow: repair and sell it, sell it as is, recycle or disposal.

Cost of lost sale: companies adopt a reverse logistics process as a post-sale service to increase customer service level, but also it can be implemented to be seen by customers as an environmental responsible firm. The cost of lost sale associated to the reverse logistics can be defined as the difference in demand produced by the implementation or not of the reverse logistic service.

Distribution networks might be design to manage the flow of materials from the plant to the clients, but also in the opposite direction. The reverse logistics is mainly used by companies to cope with warranty claims or to receive obsolete devices from customers as a part of a marketing promotion and improve their market image in terms of environmental sustainability.

Although the reverse logistics is an area at which, from the perspective of the customers, most of the companies of the consumer electronic industry are paying attention, the reality obtained from the interviews is that distribution networks actually implemented do not manage in a considerable proportion this type of flow, in fact, a value of just 1% of the total flow of goods was obtained for all the distribution problems analyzed.

There are two possible reasons for this percentage of reverse logistics within the firms. The first one is that production facilities are improving their efficiency and quality, making warranty claims less frequent. The second one is that in many cases as the price of the goods are becoming every day smaller, for example for printers and consumables, it is cheaper for the company to discard the equipment with the failure and give the customer a new one, rather than send it back to the production facility or to an intermediate phase to repair it.

Theoretically, as the percentage of products returned increase, the criticality of this driver also rise because a more complex network is required. But due to the value obtained from the companies of the consumer electronic industry interviewed, the driver

“Returnability” is not considered as a determinant one for the design of the distribution network, and will not be included in the model proposed by this thesis.

Demand drivers:

Dimension of the order (typology)

With an augment in the dimension of the order, decreases the total logistic cost.

Transportation costs: this cost tends to suffer a strong decrease with increasing order size, because there is a greater probability of saturation of the transportation mean and of optimization of the secondary transport, consequently reducing the total transportation cost.

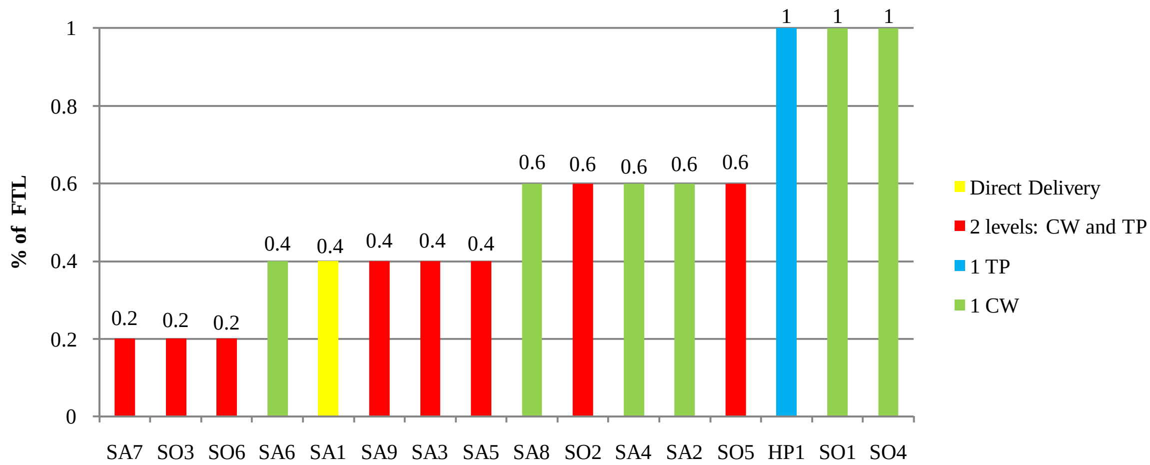
Inventory costs: tend to augment because, due to the increase in order size, should be more stocks in order to guarantee the deliveries.

Handling costs: with an increase in the dimension of the order, more handling activities should be done, therefore there is an increase in these costs.

Cost of lost sale: due to an augment of the dimension of the order, could be a greater probability of not being able to fully meet the demands of customers, so there is the possibility of increased costs of not selling.

For the analysis of the distribution problems, it was considered the order dimension as a percentage of Full truck Load. For example if the order dimension is of only some boxes then it corresponds to 20% of FTL, if it is of pallets then 60% of FTL. According to the costs relationship with this driver, a distribution problem is going to be more critical when the order dimension is low, so no saturation of the mean could be achieved.

The next graph shows that by having a bigger order dimension (0,6 and 1 FTL) the stocks tend to be more concentrated in one level of Warehouse or having stocks in transit. In contrast, if the order dimension of a distribution problem has a saturation of the mean of less than half (0,2 and 0,4 FTL), then it is more critical and the best option is to have a network structure of two levels, in order to saturate the transport mean with products from other companies managed by the same 3PL.



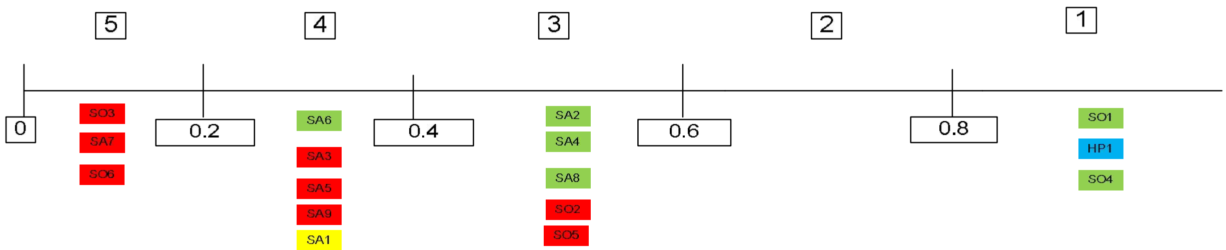
Graph 22 Relation between the Order Dimension, distribution problem and network applied

It can be confirmed by this graph the rule just explained. SO1 and SO4 are distribution problems which orders are of 1 FTL because customers attended are big enough to place them. Then, the distribution problems with 0,6FTL mainly implemented networks of 1 level of central warehouses, but also networks of 2 levels. The reason might be a corporate decision because Samsung adopted 1 level, while Sony 2 levels.

For the left side of the graph, because of the lower dimensions of the orders, the distribution network mainly adopted consists of 2 levels of central warehouses and transit points. Exceptions of the rule are also presented, for example SA1 which products are mobile phones that are delivered directly to mobile operators. SA1 has an order dimension of less than half full truck load because as the products are small it is difficult to saturate the mean.

From the analysis presented above, it can be concluded that the order dimension is an important driver to consider during the design of distribution networks, but some exceptions might be present due to the type of product.

Next it is shown the scale of criticalities of this driver.



Graph 23 Scale of Criticality of the driver "Order Dimension"

Number of customers

With an augment in the number of clients, there is an increase in total logistic cost.

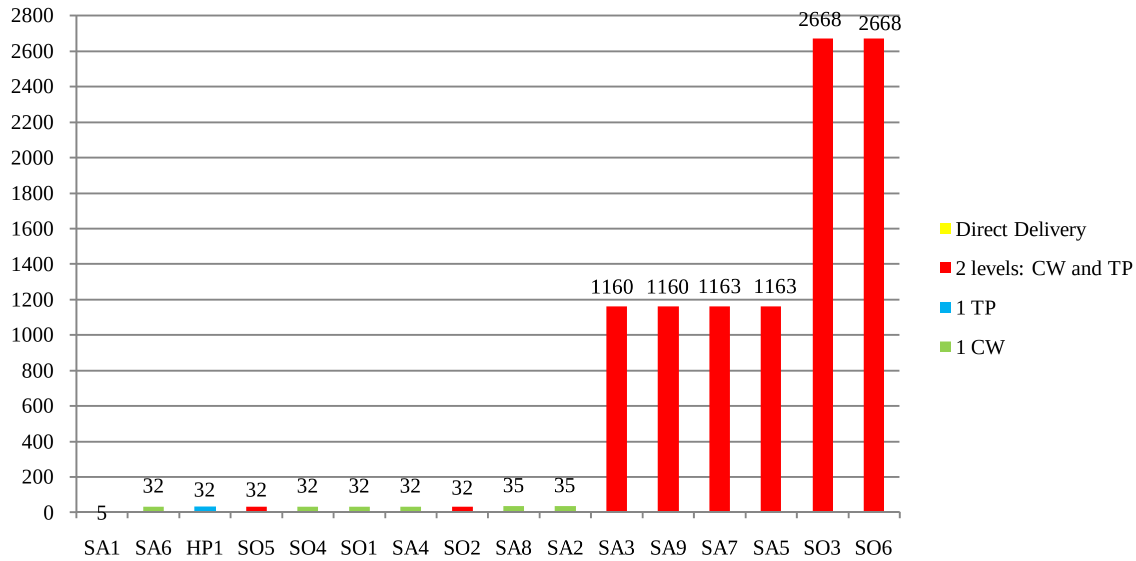
Transportation costs: at the same managed flow, a greater number of clients imply a high number of deliveries, which then leads to a significant increase in the cost of transport.

Inventory costs: by having a large number of customers more inventories are needed to satisfy the demand, and therefore this cost will increase.

Handling costs: as in the case of transport, the operations of moving are directly connected with the number of clients to serve, more these are numerous, more the handling costs are high.

Cost of lost sale: with a high number of customers, the probability of having stock out increase if the production capacity and the level of inventories are not enough to satisfy the demand, having as a consequence an increase in the cost of lost sale.

According to the costs relation with this driver a distribution problem is going to be more critical, if there are many customers being served. Theoretically a distribution problem with a number of customers high enough to be considered critical should belong to a decentralized network, which in the case of the companies analyzed should be a structure of two levels, where the second level is conformed of transit points to manage all the deliveries.

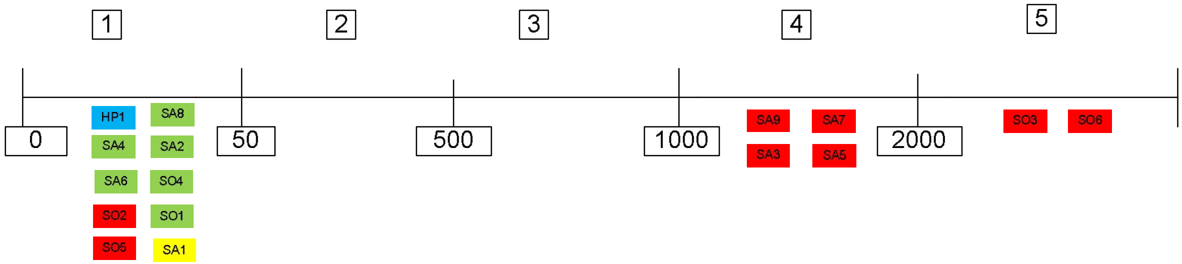


Graph 24 Relation between the Number of Clients, distribution problem and network applied

This behavior is confirmed by the group of distribution problems SA3, SA5, SA7, SA9, SO3 and SO6 which serve more than 1,160 small customers and whose network consists of two levels, being the second level conformed by transit points. Another perfect example is SA1 which only serves 5 customers using direct delivery. Similarly, distribution problems with 32 or 35 customers, with the exception of SO2 and SO5, while having a reduced number of customers serve with only one level network.

SO2 and SO5, although they serve a small number of customers they use a network of two levels, probably because of the mix of products and the order dimension required by the clients, which does not permit the use of one level networks.

Next it is shown the scale of criticalities of this driver.



Graph 25 Scale of Criticality of the driver “Number of Clients”

Frequency of delivery

An increase in the frequency of deliveries augments the total logistic cost.

Transportation costs: having to visit the same spot many times, the cost of transport augments, and in particular the cost of secondary transport that constitutes in this case the more relevant one.

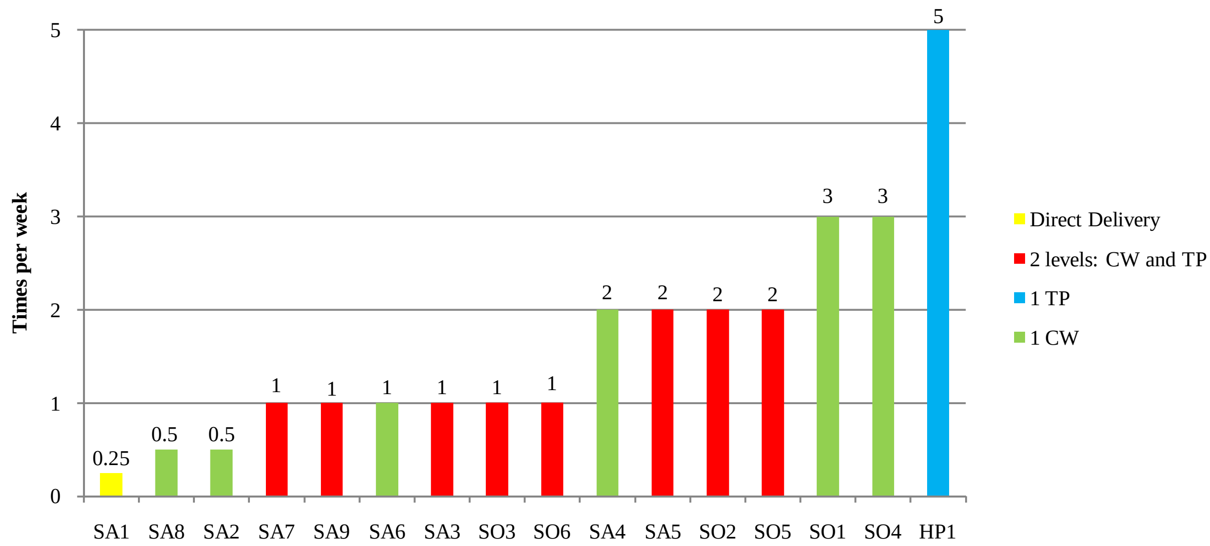
Inventory costs: for high values of frequency it is necessary to have higher stocks and therefore adequate safety stocks; in this way all the inventory costs are affected. In addition can be satisfy a high frequency of delivery, presumably only if stocks are close to the customer, this means that decentralization leads to an increase in the average stock and with it an increase in all the costs of reference.

Handling costs: more the frequency is high, more would be the costs to sustain the movements, because in the case of high values of this driver often correspond to low values for ordered volumes; so would be necessary to make many operations of loading, unloading and picking, for reduced volumes. In any case also at same volume of order, in presence of a high frequency, make more visits and therefore more operations of handling.

Cost of lost sale: there is no relation.

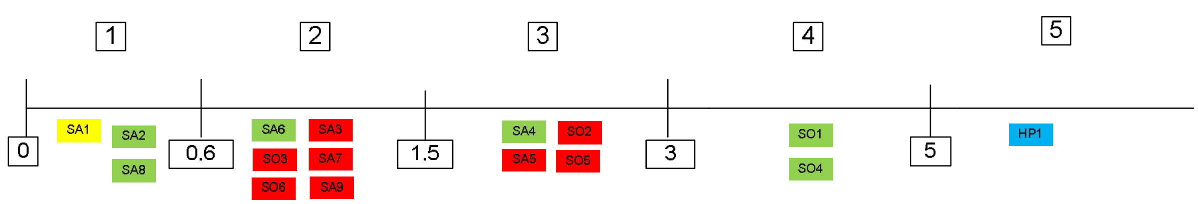
The frequency of delivery is measured in times per week, for example, if a distribution problem delivers once every two weeks then the frequency is 0.5 times per week.

According to the costs relation with this driver, a distribution problem is going to be more critical, meaning logistics costs are higher, if the frequency of delivery is high. Theoretically a distribution problem with high frequency of delivery should be decentralized, but unfortunately in the cases studied this is not confirmed; there is no clear relation between the driver and the distribution network implemented.



Graph 26 Relation between the Frequency of Delivery, distribution problem and network applied

Next it is shown the scale of criticalities of this driver.



Graph 27 Scale of Criticality of the driver “Frequency of Delivery”

Seasonality

When this driver grows, the total logistic cost augments.

Transportation costs: in the presence of seasonality, it is necessary to provide excess capacity to cover the peaks of request, this result in increased transport costs as more resources are used.

Inventory costs: to guard against increases in these phenomena of uneven demand, the company may decide to increase their stocks of products, with a consequent increase in costs related to them.

Handling costs: with the same explanation of the transportation, the handling costs increase when the driver is higher.

Cost of lost sale: it is possible that, in presence of high irregularities of the demand, the company can less easily satisfy the upcoming requests, thus involving an increase in cost of lost sale.

For the means of this study seasonality is measured by the times in a year the sales have a peak and the length of time, so being:

- Low: it may be seasonality but it is well known and controlled. For example products as home appliances which have a peak in sales from June to August, it only happens one time in a year and lasts a few months.

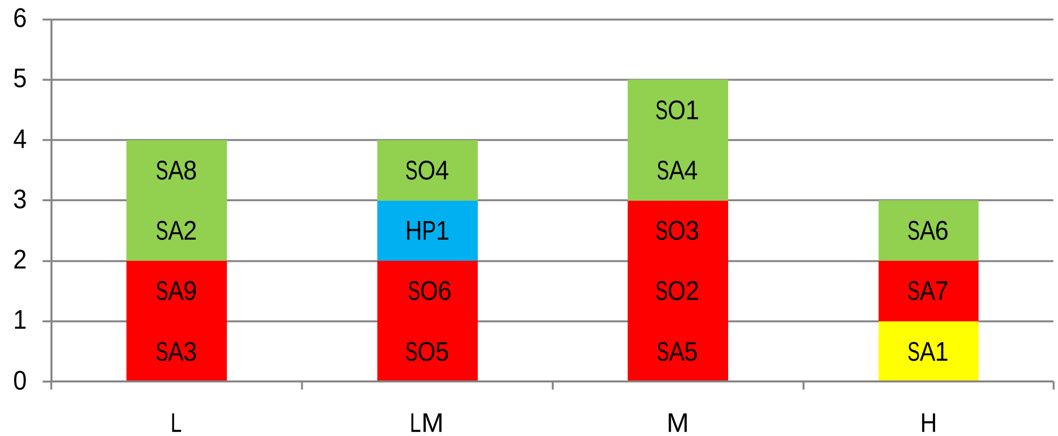
- Low- Medium: seasonality is concentrated in the last third of the year, for example audio-video and informatics products.

- Medium: peaks in sale occur two times per year. For example TVs which are sold mostly at the end of the year but also while big events and promotions.

- Medium-High: peaks occur two times per year but the duration is longer.

- High: peaks occur more than two times per year. For example mobile phones which are sold mostly at the end of the year, but also during important dates such as mother's day, father's day, etc.

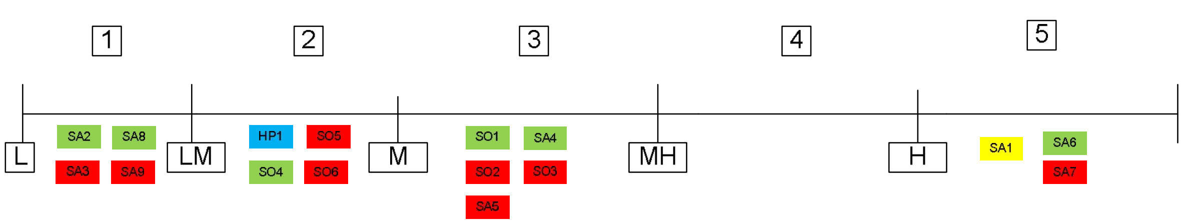
According to the costs relation with this driver a distribution problem is going to be more critical, meaning logistics costs are higher, if the seasonality is high. Theoretically a distribution problem with high seasonality should be centralized in order to cope with the impact, but unfortunately in the cases studied this is not confirmed; as shown in the graph below there is no clear relation between the driver of seasonality and the distribution network implemented.



Graph 28 Relation between the Seasonality, distribution problem and network applied

Next it is shown the scale of criticalities of this driver.

1. Low seasonality
2. Low medium seasonality
3. Medium seasonality
4. Medium high seasonality
5. High seasonality



Graph 29 Scale of Criticality of the driver "Seasonality"

Predictability of Demand

The predictability of the demand corresponds to the ability of the firm to forecast the demands of their products in an accurate way. This driver can have a significant impact on the logistics costs, which can be divided in:

Transportation Costs: If the demand cannot be predicted in a correct way, additional unexpected deliveries of products must be done in order to avoid stock out, and exist a great probability that the level of saturation of the means of transportation for these circumstances will not be the optimal one, increasing the transportation costs of the firm.

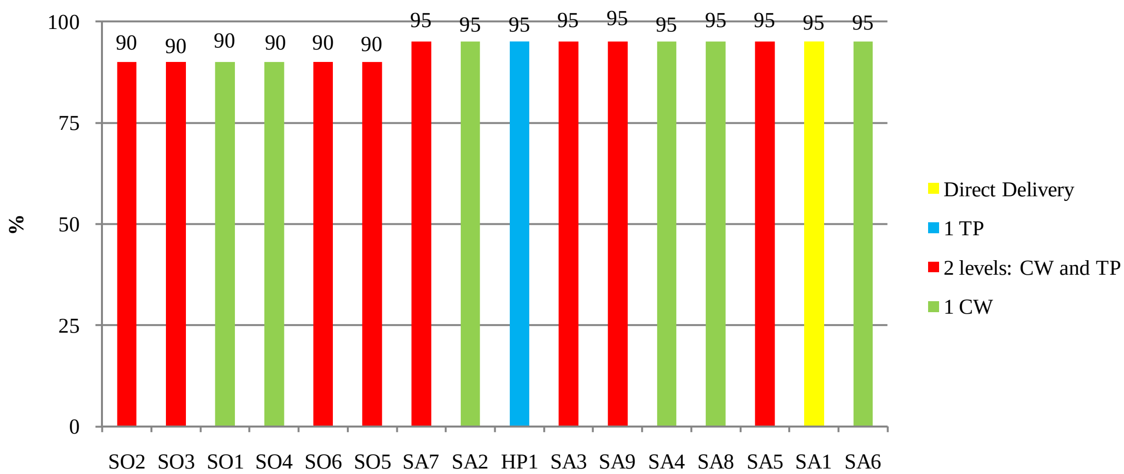
Inventory Costs: when a high level of uncertainty of the future demand is presented, inventory levels tend to increase in order to cope with unexpected increases in demand, inventories that are known as safety stocks, and as a consequence the inventory costs increase.

Handling Costs: low predictability of demand will force firms to deal with unexpected deliveries of products, increasing therefore the handling costs.

Cost of lost sale: when the forecast process cannot be done properly, the probability of stock out increases, having as a consequence a decrease in the service level and an increase in the cost of lost sale.

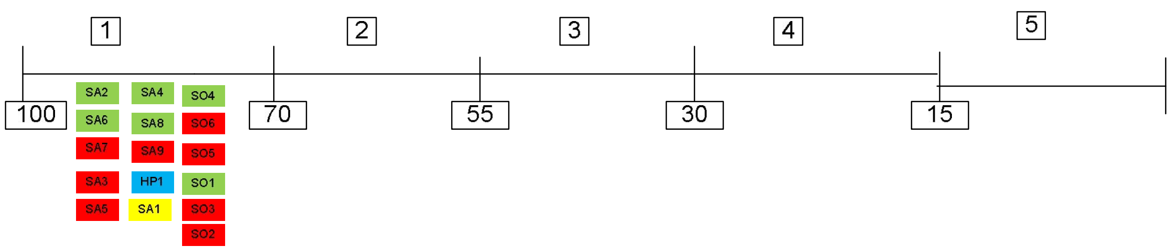
Predictability of demand is measured as percentage of accuracy of the prediction with the actual demand.

According to the costs relation with this driver a distribution problem is going to be more critical, meaning logistics costs are higher, if the predictability of demand is low. In the cases studied, as shown in the graph below, all the distribution problems have high predictability of demand; therefore there is no critical difference to understand the behavior of this driver with the network structure and will not be considered for the model proposed.



Graph 30 Relation between the Predictability of Demand, distribution problem and network applied

Next it is shown the scale of criticalities of this driver.



Graph 31 Scale of Criticality of the driver "Predictability of Demand"

Supply drivers:

Distance from plant to client:

When the distance is large, the total logistic cost is high.

Transportation costs: by having a large distance to travel, there is a direct increase in the transport costs.

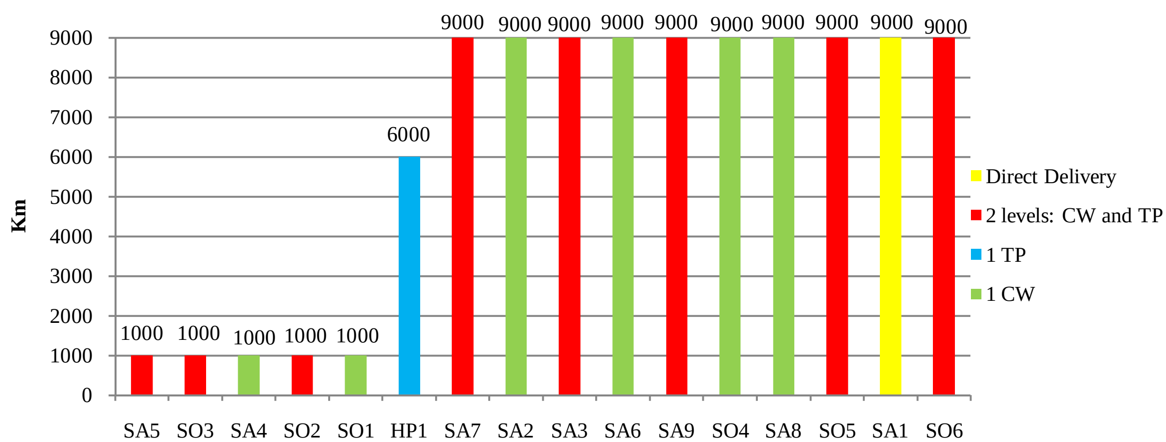
Inventory costs: these costs tend to increase, because due to the greater distance can be used the decentralization of stocks in intermediate levels. In addition the safety stocks are function of the lead time, which is as well function of the distance to reach the client.

Handling costs: the larger the distance, higher the handling costs, because may be required the presence of distributive structures, weather there is capacity to stock or not like regional warehouses or transit points.

Cost of lost sale: there is no direct relation.

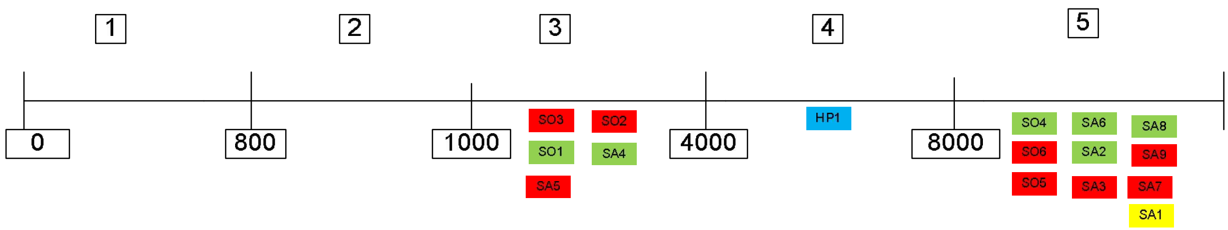
The distance is measured in kilometers. For the sake of this study, plants located in the Far East were given a distance of 9,000 km and plants located in Europe 1,000 km.

According to the costs relation with this driver a distribution problem is going to be more critical, meaning logistics costs are higher, if the distance traveled to reach the client is large. Theoretically by having a large distance to travel, the best option is decentralization in order to have stocks nearer the client. In the cases studied, as shown in the graph below most of the distribution problems have large distance from plant to client, due to the fact that the majority of plants are located in the Far East. There is no critical difference between centralized and decentralized distribution problems.



Graph 32 Relation between the Distance from plant to client, distribution problem and network applied

Next it is shown the scale of criticalities of this driver.



Graph 33 Scale of Criticality of the driver "Distance from plant to client"

Number of plants:

When there are many plants, the total logistic cost increase.

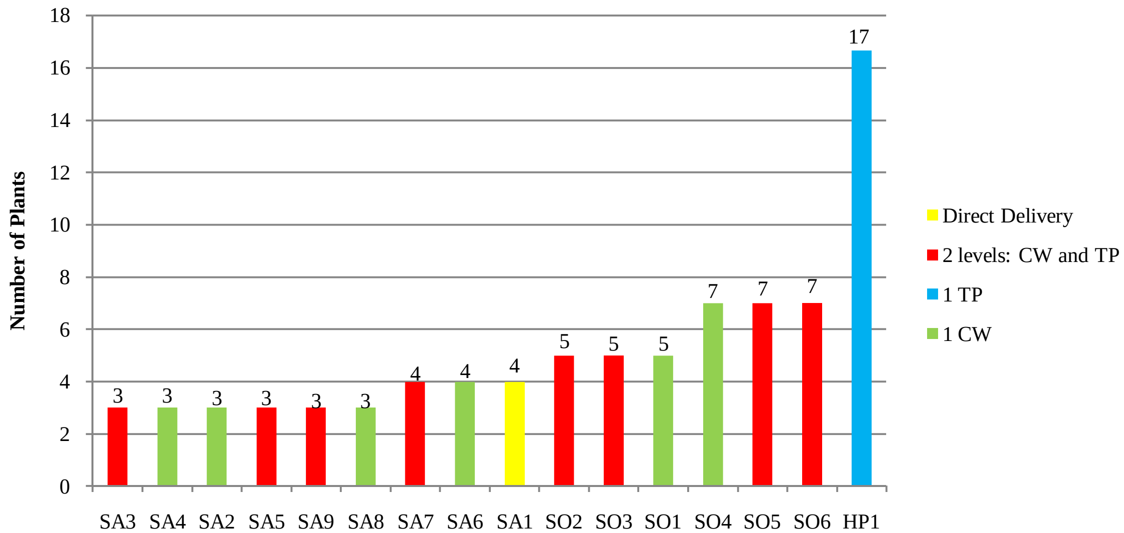
Transportation costs: the relation is with primary cost. It is evident that the transport costs are conditioned to the number of travels and from the distance to cover in each trip. If the plants, even if are high in number, are located close to each other, the average distance to get to the client does not change, while probably changes the number of travels if products from different plants cannot be picked by the same mean.

Inventory costs: there is no relation between this driver and the total costs.

Handling costs: by modifying the number of plants, the total flow of goods inside the warehouses or transit points does not vary; therefore the costs of handling do not vary. The only effect can be seen in the reduction of fixed times if it can benefit from economies of scale on aggregate flows obtained from a limited number of establishments.

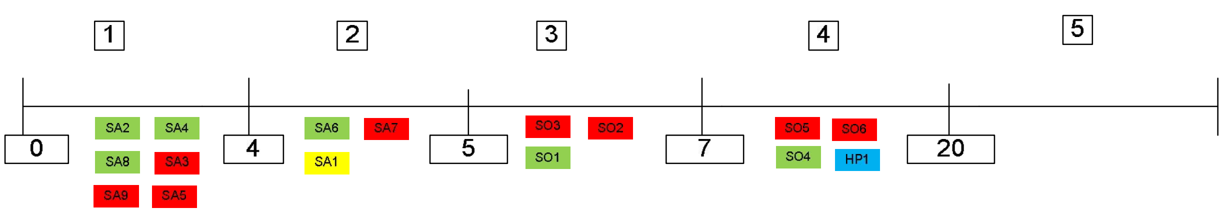
Cost of lost sale: there is no direct relation.

The plants considered are the plants that supply the Italian market for each distribution problem. In the cases studied, as shown in the graph below, there is no critical difference between the distribution problems and the network structures they follow.



Graph 34 Relation between the Number of Plants, distribution problem and network applied

Next it is shown the scale of criticalities of this driver.



Graph 35 Scale of Criticality of the driver "Number of Plants"

Level of specialization

The level of Specialization corresponds to the strategic decision of the firm of producing one product in more than one plant or just in one facility. Having a low level of specialization, the company can obtain an increase in the service level provided by bringing the production closer to its customers, but at the same time it could loss economies of scale. This driver directly affects the distribution network design process as it impacts the overall company costs, or more specifically the following costs:

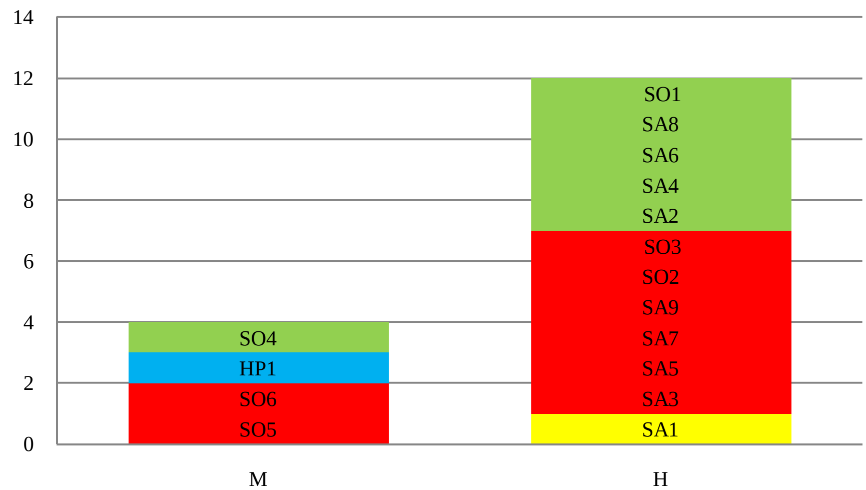
Transport Costs: As the level of specialization is low, or in other words the number of product sources increase, the distance between the plants and the warehouses or clients will be reduced, and therefore the costs of transportation will be also reduced.

Handling Costs: by increasing the number of product sources, more deliveries must be done from the plants to the warehouses or directly to the clients, increasing the handling cost of the firm.

Inventory Costs: having a low level of specialization, inventories of products are distributed among the plants incurring in duplication of them and losing economies of scale opportunities.

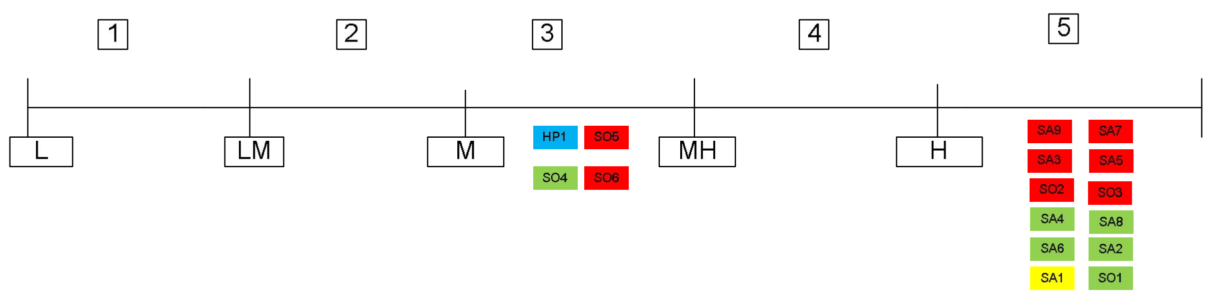
Costs of lost sale: if the level of specialization is low, the probability of stock out at the point of sale decreases because different plants can satisfy customers' orders. In the case of having specialized plants, if a failure or disruption of the production occurs, customer needs could not be satisfied by other plants and therefore the cost of lost sales will be elevated.

According to the costs relation with this driver a distribution problem is going to be more critical, meaning logistics costs are higher, if the level of specialization of the plants is high, mainly because of the higher distance between plants and clients and also due to the higher risk of stock out. In the cases studied, the level of specialization is mostly high, meaning that the driver is critical, but as different distribution networks are applied for the same level of specialization, this driver is not considered as a determinant driver for the distribution network design.



Graph 36 Relation between the Level of Specialization, distribution problem and network applied

Next it is shown the scale of criticalities of this driver.



Graph 37 Scale of Criticality of the driver "Level of Specialization"

Distribution Problems expressed with Criticalities

Using the scales presented above it was possible to characterize each distribution problem in terms of criticalities of the drivers. As mentioned previously, the drivers Returnability and Predictability of Demand were not considered for the calculus of the macrodriver´s criticality because the values obtained did not present considerable differences that could be associated with one distribution network adopted or another.

With the values presented in the following chart, it was possible to calculate the criticality of each macrodriver (Product, Service, Supply and Demand) and the groups of macrodrivers (Market and Firm) for all the distribution problems using the formula presented in 3.5.

MacroDriver	Driver	HP1	SO1	SO2	SO3	SO4	SO5	SO6	SA1	SA2	SA3	SA4	SA5	SA6	SA7	SA8	SA9
PRODUCT	Variety	5	2	2	2	4	4	4	1	1	1	3	3	1	1	1	1
	Value	5	1	1	1	4	4	4	5	1	1	3	3	5	5	2	2
	Density	5	3	3	3	2	2	2	1	4	4	3	3	1	1	3	3
	Risk of obsolescence	4	3	3	3	2	2	2	5	1	1	3	3	5	5	1	1
	Contribution Margin	1	1	1	1	2	2	2	4	3	3	2	2	4	4	2	2
SERVICE	Cycle Time	1	4	3	5	4	3	5	2	4	2	4	2	4	2	4	2
	Completeness	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2
DEMAND	Dimension of the order	1	1	3	5	1	3	5	4	3	4	3	4	4	5	3	4
	Number of customers	1	1	1	5	1	1	5	1	1	4	1	4	1	4	1	4
	Frequency of delivery	5	4	3	2	4	3	2	1	1	2	3	3	2	2	1	2
	Seasonality	2	3	3	3	2	2	2	5	1	1	3	3	5	5	1	1
SUPPLY	Distance from plant to client	4	3	3	3	5	5	5	5	5	5	3	3	5	5	5	5
	Number of plants	4	3	3	3	4	4	4	2	1	1	1	1	2	2	1	1
	Level of specialization	3	5	5	5	3	3	3	5	5	5	5	5	5	5	5	5

Table 19 Distribution Problems expressed with criticalities

Distribution Problems	Product	Service	Demand	Supply	MARKET	FIRM
HP1	4,0	1,0	2,3	3,7	1,6	3,8
SO1	2,0	2,0	2,0	3,7	2,0	2,8
SO2	2,0	1,7	2,2	3,7	1,9	2,9
SO3	2,0	2,3	3,2	3,7	2,8	2,8
SO4	2,8	2,0	1,8	4,0	1,9	3,4
SO5	2,8	1,7	2,0	4,0	1,8	3,4
SO6	2,8	2,3	3,0	4,0	2,7	3,4
SA1	3,2	1,3	2,4	4,0	1,9	3,6
SA2	2,0	2,3	1,4	3,7	1,9	2,9
SA3	2,0	1,7	2,4	3,7	2,0	2,8
SA4	2,8	2,3	2,2	3,0	2,3	2,9
SA5	2,8	1,7	3,0	3,0	2,3	2,9
SA6	3,2	2,3	2,6	4,0	2,5	3,6
SA7	3,2	1,7	3,4	4,0	2,5	3,6
SA8	1,8	2,3	1,4	3,7	1,9	2,7
SA9	1,8	1,7	2,4	3,7	2,0	2,7

Table 20 Macrodriver´s Criticality of the Distribution Problems

Chapter 8. Correlation Analysis

As it has been mentioned and demonstrated in the previous chapters, distribution networks are designed based on the characteristics of the distribution problem they try to solve, which are represented by a group of drivers related to the Product, Service, Demand and Supply.

For the development of the Distribution Network Design model, it is important to confirm that the list of drivers considered until this point are all necessary and contribute in an specific proportion to the definition of the distribution problem. For this purpose, a Correlation analysis was done taking as input data the tables of criticalities presented above (19 and 20), and obtaining as a result the diagonal and symmetric table that continues.

	Variety	Value	Density	Risk of obsolescence	Contribution Margin	Cycle Time	Completeness	Dimension of the order	Number of customers	Frequency of delivery	Seasonality	Distance from plant to client	Number of plants	Level of specialization	Product	Service	Demand	Supply	Market	Firm
Variety	1	0,4	0,2	0,0	-0,5	0,0	-0,6	-0,4	-0,1	0,7	-0,2	-0,2	0,7	-0,9	0,5	-0,2	0,0	-0,1	-0,1	0,4
Value	---	1	-0,5	0,6	0,5	-0,3	-0,1	0,0	-0,1	0,2	0,5	0,4	0,3	-0,5	0,9	-0,3	0,3	0,4	0,0	0,9
Density	---	--	1	-0,5	-0,6	-0,2	0,1	-0,4	0,0	0,3	-0,7	-0,3	-0,1	0,0	-0,2	-0,2	-0,4	-0,5	-0,4	-0,4
Risk of obsolescence	---	--	--	1	0,3	-0,2	-0,2	0,1	-0,1	0,2	0,9	-0,2	0,2	0,1	0,7	-0,3	0,5	0,2	0,3	0,7
Contribution Margin	---	---	---	---	1	-0,2	0,5	0,5	0,0	-0,6	0,5	0,6	-0,4	0,3	0,3	0,0	0,2	0,4	0,2	0,4
Cycle Time	---	---	---	---	---	1	-0,2	0,1	0,0	-0,2	-0,1	-0,1	0,2	0,0	-0,4	0,9	-0,1	0,1	0,5	-0,3
Completeness	---	---	---	---	---	---	1	0,3	0,2	-0,4	-0,1	0,2	-0,9	0,6	-0,2	0,3	0,0	-0,4	0,2	-0,3
Dimension of the order	---	---	---	---	---	---	---	1	0,7	-0,7	0,3	0,2	-0,3	0,4	-0,1	0,2	0,7	0,1	0,7	-0,1
Number of customers	---	---	---	---	---	---	---	---	1	-0,2	-0,1	0,0	-0,1	0,1	-0,2	0,1	0,8	-0,1	0,7	-0,2
Frequency of delivery	---	---	---	---	---	---	---	---	---	1	0,0	-0,5	0,6	-0,5	0,4	-0,4	0,0	-0,2	-0,3	0,3
Seasonality	---	---	---	---	---	---	---	---	---	---	1	-0,2	0,1	0,3	0,5	-0,1	0,5	0,2	0,4	0,5
Distance from plant to client	---	---	---	---	---	---	---	---	---	---	---	1	0,0	-0,3	0,1	0,0	-0,2	0,7	-0,2	0,4
Number of plants	---	---	---	---	---	---	---	---	---	---	---	---	1	-0,8	0,4	-0,2	0,1	0,5	0,0	0,5
Level of specialization	---	---	---	---	---	---	---	---	---	---	---	---	---	1	-0,5	0,2	0,1	-0,4	0,2	-0,6
Product	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	-0,5	0,3	0,2	0,0	0,9
Service	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	-0,1	-0,1	0,5	-0,4
Demand	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	0,0	0,8	0,3
Supply	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	0,0	0,6
Market	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	0,0
Firm	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1

Table 21 Correlation Analysis between drivers and macrodrivers

The correlation factors range from -1 to 1, meaning that for those variables that are inversely correlated (when one raises the other one decreases) negative values will be obtained, and for directly correlated variables (if one increase the other one will do it as well) the result will be a positive value. The 0 is obtained when no correlation is presented. For the purposes of this analysis, values of -0.7 or lower, and 0.7 or higher will be considered as relevant.

From this table it is possible to identify different areas or groups of correlation factors. First, the correlation factors between all the drivers located in the center of the table; then the importance of each driver within its macrodriver located in the black box on the right, and finally, the correlation between the macrodrivers and the groups of macrodrivers (Market and Firm) located at the bottom right side of the table.

8.1 Correlation between drivers

Within this area there are presented all the correlation factors between drivers without distinction of the macrodriver at which they pertain. Theoretically, the values observed should be near the No Correlation value (0) in order to demonstrate that the drivers considered are independent and necessary for the model to be proposed.

This behavior was observed in the majority of the cases, indicating that the total amount of drivers selected were the appropriate ones to define in a complete manner the distribution problems, without redundancy or duplication of data.

Some exceptions or pair of drivers with high correlation factor were obtained (highlighted in green), but complete correlations where not present. These cases are listed and explained below:

- **Variety – Number of Plants**: it was obtained a correlation factor of 0.7 which indicates that a high criticality on the variety (high number of product codes) is obtained mainly when the criticality of the number of plants is also high (many plants). This correlation also depends on the level of specialization of the plants as it will be see it in the next correlation.
- **Variety – Level of Specialization**: a correlation factor of -0.9 was obtained, meaning that a high criticality on the variety (high number of product codes) corresponds to a low criticality on the level of specialization (products are manufactured in more than one plant). Both correlations are reasonable, but does not justify the elimination of the driver Variety for two reasons: first, the data obtained for the level of specialization is allocated in just two values of criticalities (3 and 5) where different types of distribution networks are present, which means that this driver is not determinant for the design. And second,

because the driver variety pertains to a different macrodriver, meaning that it represents another aspect of the distribution problem.

- **Number of Plants – Level of Specialization**: as it might be expected after the explanation above, the correlation factor of these two drivers should be also considerable. In fact, a value of -0.8 was obtained, indicating that a high number of plants (high criticality) tend to a low level of specialization of them. Although the correlation factor is high, it is not considered to eliminate one of them, as some exceptions were present and it is a field which is continuously changing within firms and should be traced.
- **Dimension of the order – Number of Customers**: a correlation factor of 0.7 was obtained, indicating that a high criticality in the dimension of the order (small quantities) are distributed generally to high number of customers. From the interviews it was obtained that small clients, which orders are mainly of 0,2 or 0,4 FTL, are more than big clients, but as there are some cases were big clients order small quantities, none of the two drivers should be discard.
- **Dimension of the Order – Frequency of Delivery:** a negative correlation of -0,7 was obtained for this pair of drivers, meaning that when the criticality of the dimension of the order is high (small quantities), the frequency of delivery is reduced. As it was presented in the correlation before, small customers are the ones which orders generally are small, and because of lack of stock space or because of the amount of sales per week, the frequency of delivery is also reduced. In this case, some exceptions are also present, reason why none of the two drivers should be discard.

Other exceptions were the correlation factors of Risk of Obsolescence – Seasonality (0.9) and Completeness – Number of Plants (-0.9). In the first case, the relation between the two drivers is mainly due to the type of products, for example, mobile phones which have a high risk of obsolescence, also have high seasonality because of marketing promotions. Although the high correlation factor, none of the drivers is discard because they pertain to different macrodrivers and therefore analyze different aspects of the distribution problem. In the second case, the completeness of the order is considered to be a corporate decision rather than a result of the distribution network implemented and, as it will be presented, this driver does not have an important impact for the model, but it is not eliminated because it is one of the KPIs commonly used by firms.

8.2 Correlations between Drivers and Macrodrivers

The objective of this part of the analysis is to understand the impact or relation of each driver with respect to their correspondent macrodriver. Based on the correlation factor obtained and the interpretation of the importance of each driver with respect to the logistics costs done in chapter 7, each driver will be assigned with a specific weight for the calculus of the average of the macrodriver. Drivers with high correlation factor (positive or negative) will represent a greater proportion of the macrodriver, and the sum of the weights of the drivers pertaining to one macrodriver must be equal to 1.

From the total amount of drivers analyzed, six were highlighted in yellow as having an important correlation with their macrodriver. Starting from the Product, it can be observed that the driver Value presented a correlation factor of 0.9, indicating an almost perfect correlation, which is an expected result taking in consideration the industry object of the analysis. The second driver corresponds to the Risk of Obsolescence with 0.7, which although it was not considered as an important factor for the distribution network design presents a relatively high correlation. The driver Variety, occupies the third place probably due to the fact that the complete range of products might be delivered using different types of distribution networks.

For the macrodriver Service, the Cycle Time presented a correlation factor of 0.9 which is extremely high compared with the Completeness (0.3). This result was expected because as it was mentioned in the chapter 7, the Cycle Time is an intrinsic characteristic of the distribution network implemented and must be taken in consideration for its design.

In the case of the macrodriver Demand, the Dimension of the Order and the Number of Customers were the drivers that presented more correlation, 0.7 and 0.8 respectively. As well as the Cycle Time, these drivers were mentioned in the chapter 7 as important for the distribution network design.

Then, for the macrodriver Supply the driver that obtained a higher correlation factor was the Distance from Plant to Clients with 0.7, while the Number of Plants and the Level of Specialization presented 0.5 and -0.4, respectively. Taking into consideration that most of the consumer electronics production plants are located in Asia in order to take advantage of economies of scale, it is appropriate for this driver to be the most important within this cluster.

Finally, using the previous results it is possible to demonstrate that the formula for the calculation of the macrodrivers criticality presented in the chapter 3, that assumed equal weights for the drivers within each macrodriver, was not the optimal one. In the next table there are presented the corresponding weights of each driver that must be used.

Product	Variety	0.15
	Value	0.45
	Density	0.1
	Risk of obsolescence	0.25
	Contribution Margin	0.05
Service	Cycle Time	0.8
	Completeness	0.2
Demand	Dimensions of the order	0.4
	Number of customers	0.4
	Frequency of delivery	0.15
	Seasonality	0.05
Supply	Distance from plant to client	0.5
	Number of plants	0.25
	Level of specialization	0.25

Table 22 Driver´s weights

8.3 Correlation between Macrodrivers, Market and Firm

The last part of the correlation analysis table presents the correlation factors between the macrodrivers (Product, Service, Demand and Supply) with the two groups of macrodrivers (Market and Firm). The objective of this part is similar to the previous one, assign weights to the macrodivers based on their level of relation with the Market and the Firm, which will be used for the calculus of the average criticality.

The two macrodrivers that presented correlation with the Market were Service and Demand with 0.5 and 0.8, respectively. This result is coherent with what it was presented during the analysis of each macrodriver because for the Service just the Cycle Time presented an important correlation, while for the Demand two drivers, Dimension of the Order and Number of Clients, were highly correlated.

In the case of the Firm, the Product obtained 0.9 as correlation factor while the Supply 0.6. As it was mentioned before, two drivers pertaining to the Product macrodriver, Value and the Risk of Obsolescence, were highly correlated, while just the Distance from plant to client presented a high correlation with the macrodriver Supply, making the results for the Firm coherent.

The next table presents the weights for each macrodriver that must be used for the calculus of the Market and Firm criticalities.

FIRM	
Product weight	0.65
Supply weight	0.35

MARKET	
Service weight	0.35
Demand weight	0.65

Table 23 Macrodriver´s Weights

Then, using the data presented in the table 19, corresponding to the representation of the distribution problems in terms of driver´s criticalities, and the weights of the drivers and macrodrivers presented above, it was possible to calculate the correct values of each macrodriver, Market and Firm for all the distribution problems, using the following formulas:

$$C_i = \frac{\sum_{j}^{j_{max}} Wj * c_j}{j_{max}}$$

with: C_i = Macrodriver criticality i;

c_j = driver criticality j, with j = [1, …, j_{max}];

Wj = Weight of each driver

i = {product, service, demand, supply}

j = {variety, value, density, …., many products sources} = {all the drivers}

and: $$CF = \frac{Wp * Cp + Wl * Cl}{2}$$ $$CM = \frac{Ws * Cs + Wd * Cd}{2}$$

CF = firm criticality

CM = market criticality

Cp = product criticality

Cs = service criticality

Cl = supply criticality

Cd = demand criticality

W(p, l, s, d) = Weights (product, supply, service, demand)

Distribution Problems	Product	Service	Demand	Supply	MARKET	FIRM
HP1	4,6	1,0	1,7	3,8	1,4	4,3
SO1	1,9	3,4	1,6	3,5	2,2	2,4
SO2	1,9	2,6	2,2	3,5	2,3	2,4
SO3	1,9	4,2	4,5	3,5	4,4	2,4
SO4	3,2	3,4	1,5	4,3	2,2	3,6
SO5	3,2	2,6	2,2	4,3	2,3	3,6
SO6	3,2	4,2	4,4	4,3	4,3	3,6
SA1	4,0	1,8	2,2	4,3	2,1	4,1
SA2	1,4	3,6	1,8	4,0	2,4	2,3
SA3	1,4	2,0	3,6	4,0	3,0	2,3
SA4	3,0	3,6	2,1	3,0	2,6	3,0
SA5	3,0	2,0	3,7	3,0	3,1	3,0
SA6	4,0	3,6	2,4	4,3	2,8	4,1
SA7	4,0	2,0	4,0	4,3	3,3	4,1
SA8	1,7	3,6	1,8	4,0	2,4	2,5
SA9	1,7	2,0	3,6	4,0	3,0	2,5

Table 24 Weighted Macrodriver´s Criticality of the Distribution Problems

8.4 Synthetic representation of the firm cases

At this point, it is important to represent in a synthetic way each distribution problem to obtain a global perspective of all the characteristics. Thanks to the calculated average, four indicative values were obtained (product, service, demand, and supply). In order to point out the elements of higher criticality that characterize the problem, a graphical representation is necessary. The solution adopted is based on the graphics where each category of data (each macrodriver), has a specific axis that branches off the center point and where the criticalities values are placed for each distribution problem. The procedure for the design of the synthetic representations was detailed in section 3.7.

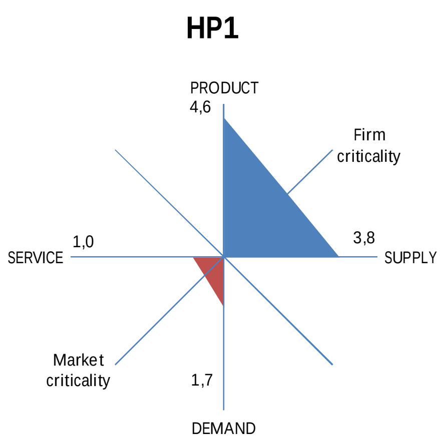
Hewlett Packard

Net revenues (2009): $114,552 million dollars
Market Share: worldwide leader in personal computers
N° Employees: approximately 304,000 worldwide
Business Unit to consider: The Personal Systems Group and The Imaging and Printing Group.

HP1

Personal computers, monitors, printers and professional products

Synthetic representation of data



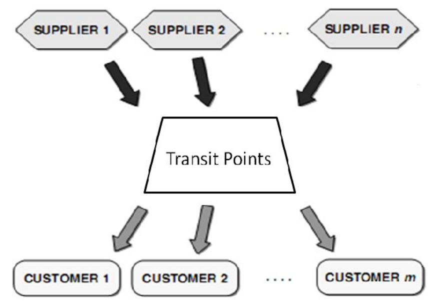
Punctual values and criticality

MACRODRIVER	DRIVER	VALUE	CRITICALITY
		HP1	HP1
PRODUCT	Variety [SKUs]	4000	5
	Value [€/Kg]	1000	5
	Density [Kg/m^3]	7,6	5
	Risk of obsolescence	120	4
	Contribution Margin:	12	1
SERVICE	Cycle Time [days]	15	1
	Completeness [IFR]	100	1
DEMAND	Dimension of the order	1	1
	Number of customers	32	1
	Frequency of delivery	5	5
	Seasonality	LM	2
SUPPLY	Distance from plant to	6000	4
	Number of plants	17	4
	Level of specialization	M	3

Criticalities

Product: 4.6	Demand: 1.7
Supply: 3.8	Service: 1
Firm: 4.3	**Market: 1.4**

Solution of the network



- One transit point in Luxemburg and the other in The Netherlands

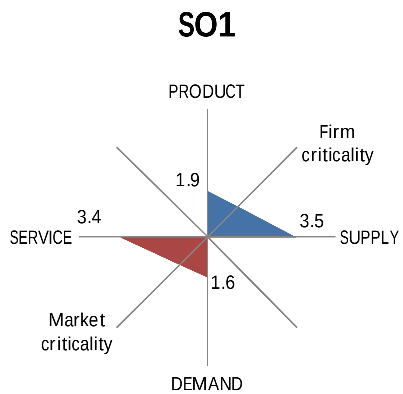
Sony

Net revenues (2009): ¥7,214.0 billion
N° Employees: approximately 167,000 worldwide
Business Unit to consider: Sony Electronics that include IT and consumer electronics

SO1

Televisions

Synthetic representation of data



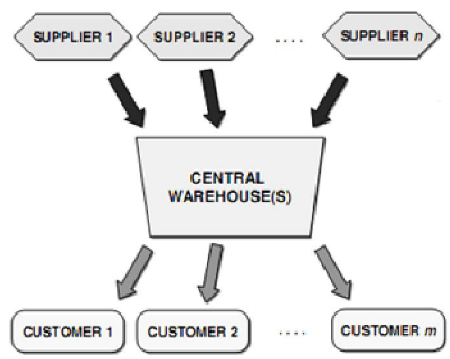
Punctual values and criticality

MACRODRIVER	DRIVER	VALUE SO1	CRITICITY SO1
PRODUCT	Variety	400	2
	Value [Euro/Kg]	55	1
	Density [kg/m^3]	160	3
	Risk of obsolescence	180	3
	Contribution Margin	10	1
SERVICE	Cycle time	3	4
	Completeness	100	1
DEMAND	Dimensions of the order (typology)	1	1
	Number of customers	32	1
	Ferequency of delivery	3	4
	Seasonality	M	3
SUPPLY	Distance from plant to client	1000	3
	Number of plants	5	3
	Level of Specialization	H	5

Criticalities

Product: 1.9	Demand: 1.6
Supply: 3.5	Service: 3.4
Firm: 2.4	**Market: 2.2**

Solution of the network



- 1 level Network of 1 Central Warehouse

- Located in Milano

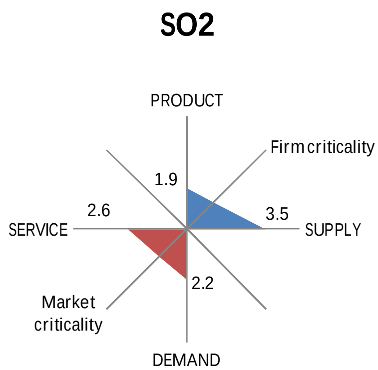
Sony

Net revenues (2009): ¥7,214.0 billion
N° Employees: approximately 167,000 worldwide
Business Unit to consider: Sony Electronics that include IT and consumer electronics

SO2

Televisions

Synthetic representation of data



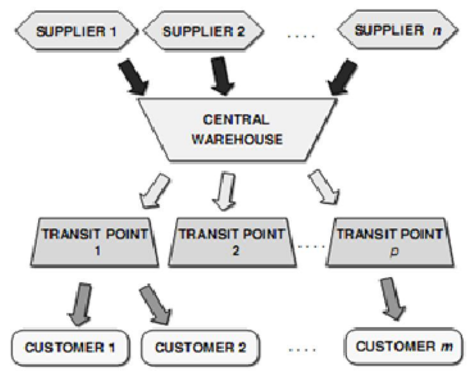
Punctual values and criticality

MACRODRIVER	DRIVER	VALUE SO2	CRITICITY SO2
PRODUCT	Variety	400	2
	Value [Euro/Kg]	55	1
	Density [kg/m^3]	160	3
	Risk of obsolescence	180	3
	Contribution Margin	10	1
SERVICE	Cycle time	4	3
	Completeness	100	1
DEMAND	Dimensions of the order (typology)	0.6	3
	Number of customers	32	1
	Ferequency of delivery	2	3
	Seasonality	M	3
SUPPLY	Distance from plant to client	1000	3
	Number of plants	5	3
	Level of Specialization	H	5

Criticalities

Product: 1.9	Demand: 2.6
Supply: 3.5	Service: 2.2
Firm: 2.9	**Market: 2.3**

Solution of the network



- 2 level Network of 1 Central Warehouse at the first level and 13 Transit Points

Central Warehouse located in Milano and Transit Points for each 1.5 Italian region.

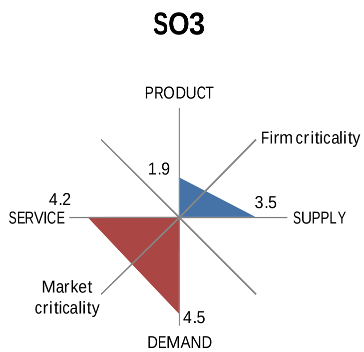
Sony

Net revenues (2009): ¥7,214.0 billion
N° Employees: approximately 167,000 worldwide
Business Unit to consider: Sony Electronics that include IT and consumer electronics

SO3

Televisions

Synthetic representation of data



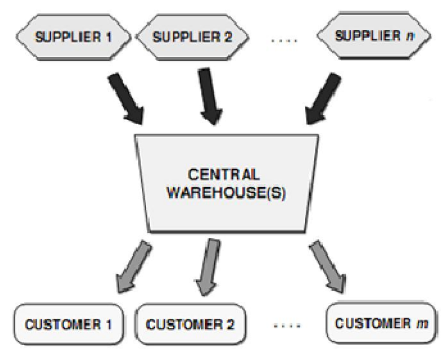
Punctual values and criticality

MACRODRIVER	DRIVER	VALUE SO3	CRITICITY SO3
PRODUCT	Variety	400	2
	Value [Euro/Kg]	55	1
	Density [kg/m^3]	160	3
	Risk of obsolescence	180	3
	Contribution Margin	10	1
SERVICE	Cycle time	2	5
	Completeness	100	1
DEMAND	Dimensions of the order (typology)	0.2	5
	Number of customers	2668	5
	Ferequency of delivery	1	2
	Seasonality	M	3
SUPPLY	Distance from plant to client	1000	3
	Number of plants	5	3
	Level of Specialization	H	5

Criticalities

Product: 1.9	Demand: 4.5
Supply: 3.5	Service: 4.2
Firm: 2.4	**Market: 4.4**

Solution of the network



- 1 level Network of 1 Central Warehouse

- Central Warehouse located in Milano

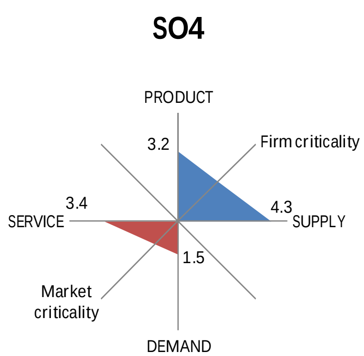
Sony

Net revenues (2009): ¥7,214.0 billion
N° Employees: approximately 167,000 worldwide
Business Unit to consider: Sony Electronics that include IT and consumer electronics

SO4

Notebooks, Peripherals, Audio, Digital Imaging

Synthetic representation of data



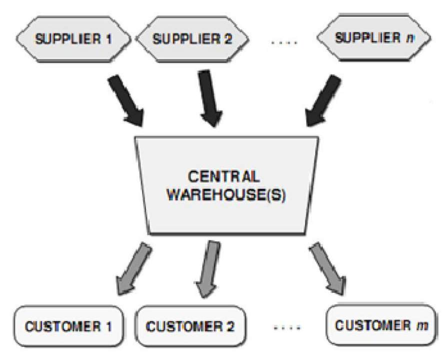
Punctual values and criticality

MACRODRIVER	DRIVER	VALUE SO4	CRITICITY SO4
PRODUCT	Variety	800	4
	Value [Euro/Kg]	800	4
	Density [kg/m^3]	643	2
	Risk of obsolescence	240	2
	Contribution Margin	14	2
SERVICE	Cycle time	3	4
	Completeness	100	1
DEMAND	Dimensions of the order (typology)	1	1
	Number of customers	32	1
	Ferequency of delivery	3	4
	Seasonality	LM	2
SUPPLY	Distance from plant to client	9000	5
	Number of plants	7	4
	Level of Specialization	M	3

Criticalities

Product: 3.2	Demand: 1.5
Supply: 4.3	Service: 3.4
Firm: 3.6	**Market: 2.2**

Solution of the network



- 1 level Network of 1 Central Warehouse

- Central Warehouse located in Milano

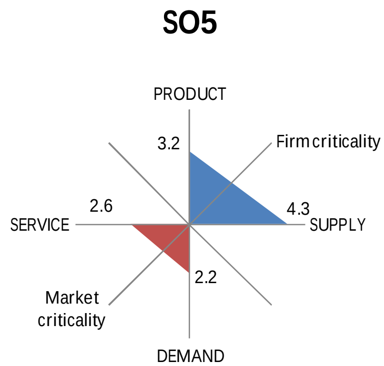
Sony

Net revenues (2009): ¥7,214.0 billion
N° Employees: approximately 167,000 worldwide
Business Unit to consider: Sony Electronics that include IT and consumer electronics

SO5

Notebooks, Peripherals, Audio, Digital Imaging

Synthetic representation of data



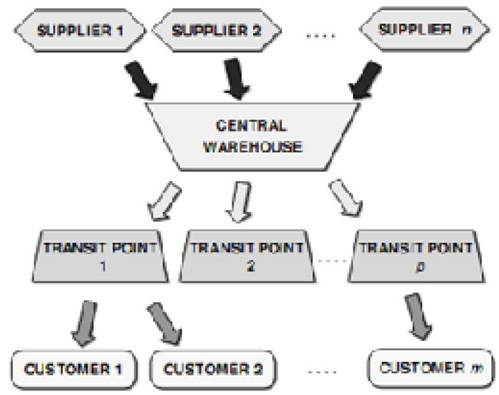
Punctual values and criticality

MACRODRIVER	DRIVER	VALUE SO5	CRITICITY SO5
PRODUCT	Variety	800	4
	Value [Euro/Kg]	800	4
	Density [kg/m^3]	643	2
	Risk of obsolescence	240	2
	Contribution Margin	14	2
SERVICE	Cycle time	4	3
	Completeness	100	1
DEMAND	Dimensions of the order (typology)	0.6	3
	Number of customers	32	1
	Ferequency of delivery	2	3
	Seasonality	LM	2
SUPPLY	Distance from plant to client	9000	5
	Number of plants	7	4
	Level of Specialization	M	3

Criticalities

Product: 3.2	Demand: 2.2
Supply: 4.3	Service: 2.6
Firm: 3.6	**Market: 2.3**

Solution of the network



- 2 level Network of 1 Central Warehouse at first level and 13 Transit Point at second level.

- Central Warehouse located in Milano and transit points every 1.5 italian regions

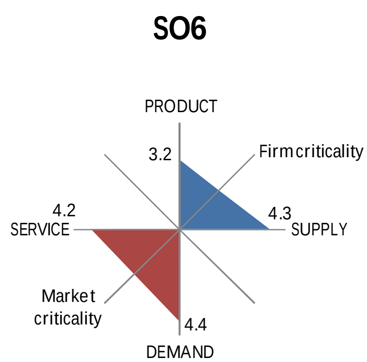
Sony

Net revenues (2009): ¥7,214.0 billion
N° Employees: approximately 167,000 worldwide
Business Unit to consider: Sony Electronics that include IT and consumer electronics

SO6

Notebooks, Peripherals, Audio, Digital Imaging

Synthetic representation of data



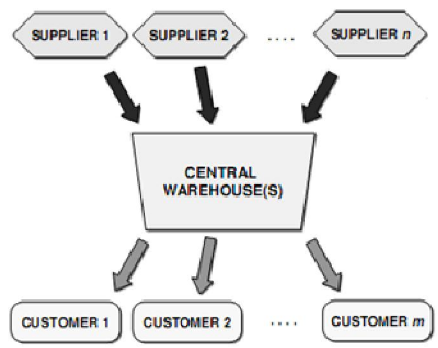
Punctual values and criticality

MACRODRIVER	DRIVER	VALUE	CRITICITY
		SO6	SO6
PRODUCT	Variety	800	4
	Value [Euro/Kg]	800	4
	Density [kg/m^3]	643	2
	Risk of obsolescence	240	2
	Contribution Margin	14	2
SERVICE	Cycle time	2	5
	Completeness	100	1
DEMAND	Dimensions of the order (typology)	0.2	5
	Number of customers	2668	5
	Ferequency of delivery	1	2
	Seasonality	LM	2
SUPPLY	Distance from plant to client	9000	5
	Number of plants	7	4
	Level of Specialization	M	3

Criticalities

Product: 3.2	Demand: 4.4
Supply: 4.3	Service: 4.2
Firm: 3.6	**Market: 4.3**

Solution of the network



- 1 level Network of 1 Central Warehouse

- Central Warehouse located in Milano

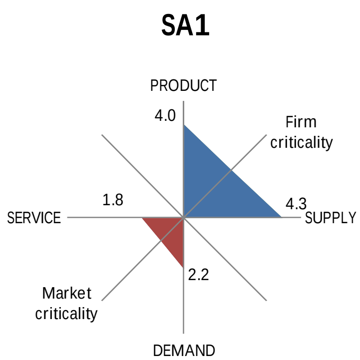
Samsung

- Net revenues (2009): 138,994 (billions of KRW)
- Market Share: LCD Monitor: 16.1%, Hard disk drive: 9.5%, Television set: 23%, Printers: 16.4%, Mobile phones: 23%, Digital camera: 9.1%
- N° Employees: approximately 164,000 worldwide
- Business Unit to consider: Audio and Video, Home Appliances, Informatics, Mobile, Networking

SA1

Mobile phones and television decoders

Synthetic representation of data



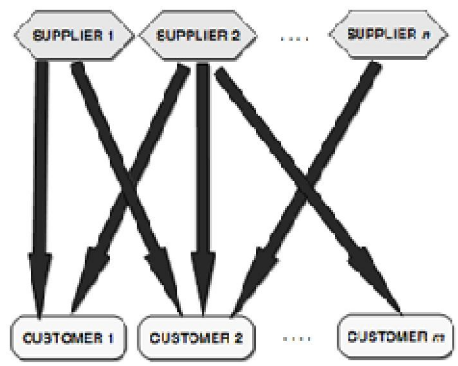
Punctual values and criticality

MACRODRIVER	DRIVER	VALUE SA1	CRITICITY SA1
PRODUCT	Variety	50	1
	Value [Euro/Kg]	1000	5
	Density [kg/m^3]	1200	1
	Risk of obsolescence	90	5
	Contribution Margin	30	4
SERVICE	Cycle time	5	2
	Completeness	100	1
	Returnability	1	1
DEMAND	Dimensions of the order (typology)	0.4	4
	Number of customers	5	1
	Ferequency of delivery	0.25	1
	Seasonality	H	5
	Predictability of demand	95	1
SUPPLY	Distance from plant to client	9000	5
	Number of plants	4	2
	Level of Specialization	H	5

Criticalities

Product: 4	Demand: 2.2
Supply: 4.3	Service: 1.8
Firm: 4.1	**Market: 2.1**

Solution of the network



- Direct delivery to mobile operators

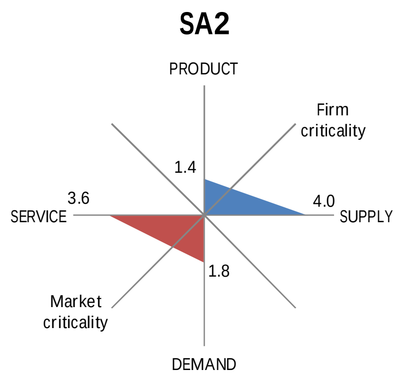
Samsung

- Net revenues (2009): 138,994 (billions of KRW)
- Market Share: LCD Monitor: 16.1%, Hard disk drive: 9.5%, Television set: 23%, Printers: 16.4%, Mobile phones: 23%, Digital camera: 9.1%
- N° Employees: approximately 164,000 worldwide
- Business Unit to consider: Audio and Video, Home Appliances, Informatics, Mobile, Networking

SA2

Home Appliances

Synthetic representation of data



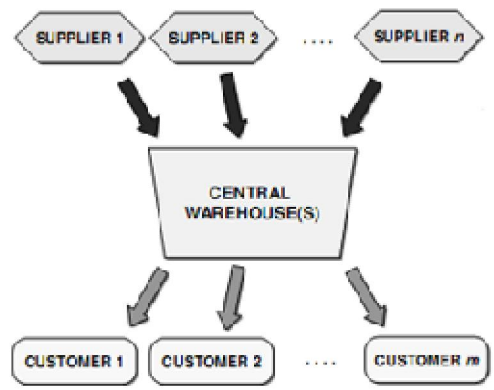
Punctual values and criticality

MACRODRIVER	DRIVER	VALUE SA2	CRITICITY SA2
PRODUCT	Variety	100	1
	Value [Euro/Kg]	13	1
	Density [kg/m^3]	110	4
	Risk of obsolescence	365	1
	Contribution Margin	24	3
SERVICE	Cycle time	3	4
	Completeness	95	2
	Returnability	1	1
DEMAND	Dimensions of the order (typology)	0.6	3
	Number of customers	35	1
	Ferequency of delivery	0.5	1
	Seasonality	L	1
	Predictability of demand	95	1
SUPPLY	Distance from plant to client	9000	5
	Number of plants	3	1
	Level of Specialization	H	5

Criticalities

Product: 1.4	Demand: 1.8
Supply: 4	Service: 3.6
Firm: 2.3	**Market: 2.4**

Solution of the network



- 1 level network composed of one Central Warehouse

- Located in Milano

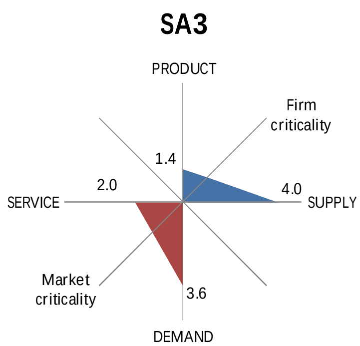
Samsung

- Net revenues (2009): 138,994 (billions of KRW)
- Market Share: LCD Monitor: 16.1%, Hard disk drive: 9.5%, Television set: 23%, Printers: 16.4%, Mobile phones: 23%, Digital camera: 9.1%
- N° Employees: approximately 164,000 worldwide
- Business Unit to consider: Audio and Video, Home Appliances, Informatics, Mobile, Networking

SA3

Home Appliances

Synthetic representation of data



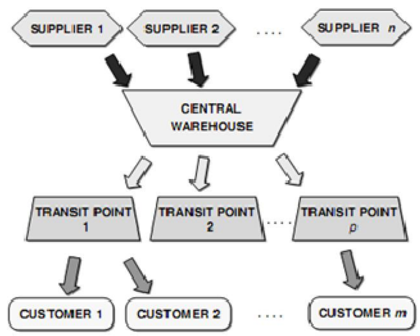
Punctual values and criticality

MACRODRIVER	DRIVER	VALUE	CRITICITY
		SA3	SA3
PRODUCT	Variety	100	1
	Value [Euro/Kg]	13	1
	Density [kg/m^3]	110	4
	Risk of obsolescence	365	1
	Contribution Margin	24	3
SERVICE	Cycle time	5	2
	Completeness	95	2
	Returnability	1	1
DEMAND	Dimensions of the order (typology)	0.4	4
	Number of customers	1160	4
	Ferequency of delivery	1	2
	Seasonality	L	1
	Predictability of demand	95	1
SUPPLY	Distance from plant to client	9000	5
	Number of plants	3	1
	Level of Specialization	H	5

Criticalities

Product: 1.4	Demand: 3.6
Supply: 4.0	Service: 2.0
Firm: 2.3	**Market: 3**

Solution of the network



- 2 level network composed of one Central Warehouse at first level and 20 transit points.

- Central Warehouse located in Milano and transit points every Italian region.

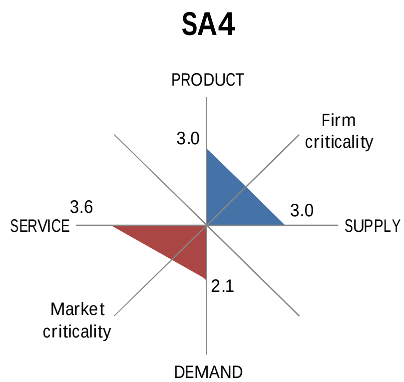
Samsung

- Net revenues (2009): 138,994 (billions of KRW)
- Market Share: LCD Monitor: 16.1%, Hard disk drive: 9.5%, Television set: 23%, Printers: 16.4%, Mobile phones: 23%, Digital camera: 9.1%
- N° Employees: approximately 164,000 worldwide
- Business Unit to consider: Audio and Video, Home Appliances, Informatics, Mobile, Networking

SA4

Audio, Video and Informatics products

Synthetic representation of data



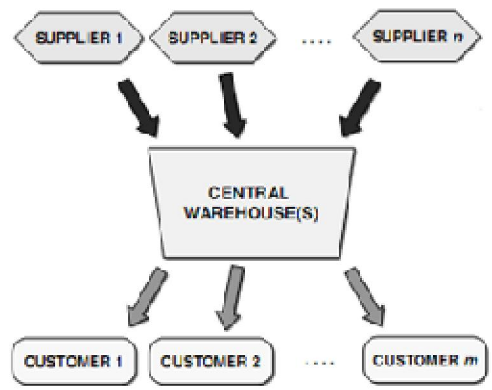
Punctual values and criticality

MACRODRIVER	DRIVER	VALUE	CRITICITY
		SA4	SA4
PRODUCT	Variety	700	3
	Value [Euro/Kg]	370	3
	Density [kg/m^3]	170	3
	Risk of obsolescence	180	3
	Contribution Margin	14	2
SERVICE	Cycle time	3	4
	Completeness	95	2
	Returnability	1	1
DEMAND	Dimensions of the order (typology)	0.6	3
	Number of customers	32	1
	Ferequency of delivery	2	3
	Seasonality	M	3
	Predictability of demand	95	1
SUPPLY	Distance from plant to client	1000	3
	Number of plants	3	1
	Level of Specialization	H	5

Criticalities

Product: 3.0	Demand: 2.1
Supply: 3.0	Service: 3.6
Firm: 3.0	**Market: 2.6**

Solution of the network



- 1 level network composed of one Central Warehouse

- Located in Milano

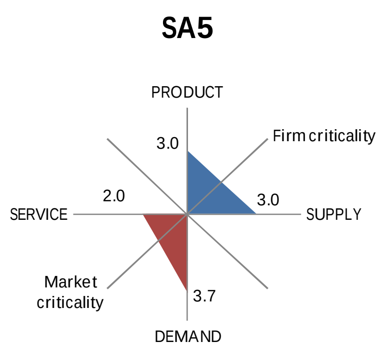
Samsung

- Net revenues (2009): 138,994 (billions of KRW)
- Market Share: LCD Monitor: 16.1%, Hard disk drive: 9.5%, Television set: 23%, Printers: 16.4%, Mobile phones: 23%, Digital camera: 9.1%
- N° Employees: approximately 164,000 worldwide
- Business Unit to consider: Audio and Video, Home Appliances, Informatics, Mobile, Networking

SA5

Audio, Video and Informatics products

Synthetic representation of data



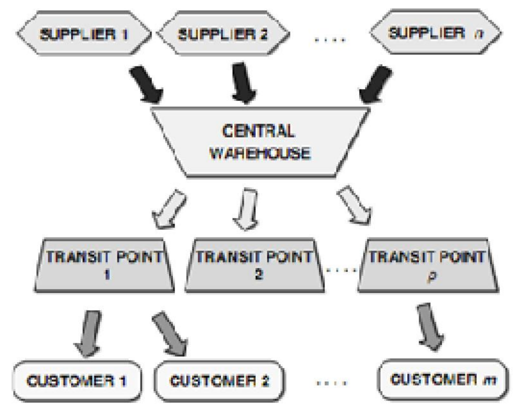
Punctual values and criticality

MACRODRIVER	DRIVER	VALUE SA5	CRITICITY SA5
PRODUCT	Variety	700	3
	Value [Euro/Kg]	370	3
	Density [kg/m^3]	170	3
	Risk of obsolescence	180	3
	Contribution Margin	14	2
SERVICE	Cycle time	5	2
	Completeness	95	2
	Returnability	1	1
DEMAND	Dimensions of the order (typology)	0.4	4
	Number of customers	1163	4
	Ferequency of delivery	2	3
	Seasonality	M	3
	Predictability of demand	95	1
SUPPLY	Distance from plant to client	1000	3
	Number of plants	3	1
	Level of Specialization	H	5

Criticalities

Product: 3.0	Demand: 3.7
Supply: 3.0	Service: 2.0
Firm: 3.0	**Market: 3.1**

Solution of the network



- 2 level network composed of one Central Warehouse at first level and 20 transit points.

- Central Warehouse located in Milano and transit points every Italian region.

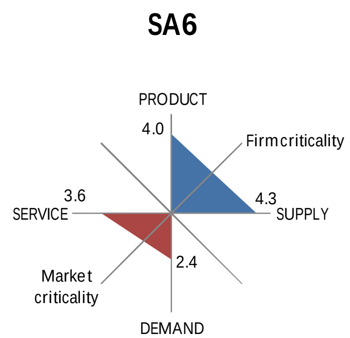
Samsung

- Net revenues (2009): 138,994 (billions of KRW)
- Market Share: LCD Monitor: 16.1%, Hard disk drive: 9.5%, Television set: 23%, Printers: 16.4%, Mobile phones: 23%, Digital camera: 9.1%
- N° Employees: approximately 164,000 worldwide
- Business Unit to consider: Audio and Video, Home Appliances, Informatics, Mobile, Networking

SA6

Mobile phones

Synthetic representation of data



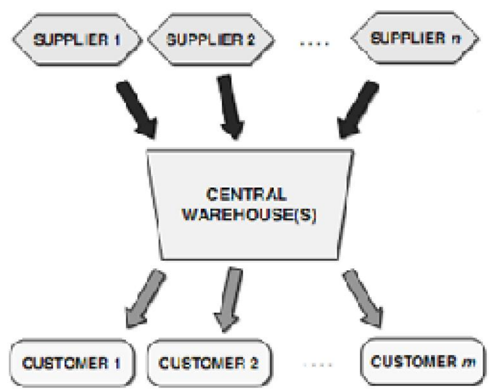
Punctual values and criticality

MACRODRIVER	DRIVER	VALUE SA6	CRITICITY SA6
PRODUCT	Variety	50	1
	Value [Euro/Kg]	1000	5
	Density [kg/m^3]	1200	1
	Risk of obsolescence	90	5
	Contribution Margin	30	4
SERVICE	Cycle time	3	4
	Completeness	95	2
	Returnability	1	1
DEMAND	Dimensions of the order (typology)	0.4	4
	Number of customers	32	1
	Ferequency of delivery	1	2
	Seasonality	H	5
	Predictability of demand	95	1
SUPPLY	Distance from plant to client	9000	5
	Number of plants	4	2
	Level of Specialization	H	5

Criticalities

Product: 4.0	Demand: 3.6
Supply: 4.3	Service: 2.4
Firm: 4.1	**Market: 2.8**

Solution of the network



- 1 level network composed of one Central Warehouse

- Located in Milano

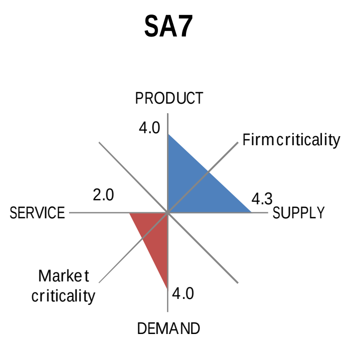
Samsung

- Net revenues (2009): 138,994 (billions of KRW)
- Market Share: LCD Monitor: 16.1%, Hard disk drive: 9.5%, Television set: 23%, Printers: 16.4%, Mobile phones: 23%, Digital camera: 9.1%
- N° Employees: approximately 164,000 worldwide
- Business Unit to consider: Audio and Video, Home Appliances, Informatics, Mobile, Networking

SA7

Mobile phones

Synthetic representation of data



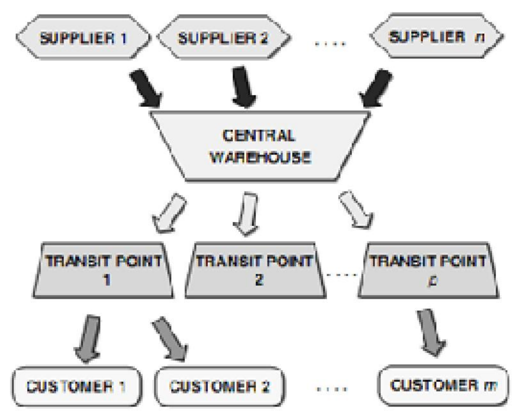
Punctual values and criticality

MACRODRIVER	DRIVER	VALUE SA7	CRITICITY SA7
PRODUCT	Variety	50	1
	Value [Euro/Kg]	1000	5
	Density [kg/m^3]	1200	1
	Risk of obsolescence	90	5
	Contribution Margin	30	4
SERVICE	Cycle time	5	2
	Completeness	95	2
	Returnability	1	1
DEMAND	Dimensions of the order (typology)	0.2	5
	Number of customers	1163	4
	Ferequency of delivery	1	2
	Seasonality	H	5
	Predictability of demand	95	1
SUPPLY	Distance from plant to client	9000	5
	Number of plants	4	2
	Level of Specialization	H	5

Criticalities

Product: 4.0	Demand: 4.0
Supply: 4.3	Service: 2.0
Firm: 4.1	**Market: 3.3**

Solution of the network



- 2 level network composed of one Central Warehouse at first level and 150 transit points at the second level

- Central Warehouse located in Milano and 7.5 transit points every region.

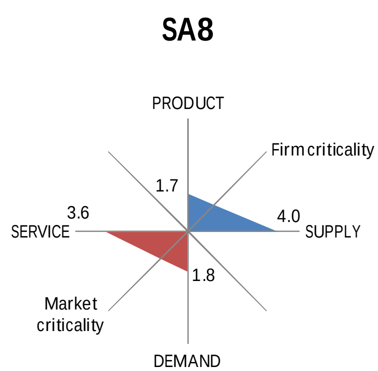
Samsung

- Net revenues (2009): 138,994 (billions of KRW)
- Market Share: LCD Monitor: 16.1%, Hard disk drive: 9.5%, Television set: 23%, Printers: 16.4%, Mobile phones: 23%, Digital camera: 9.1%
- N° Employees: approximately 164,000 worldwide
- Business Unit to consider: Audio and Video, Home Appliances, Informatics, Mobile, Networking

SA8

Air conditioning systems

Synthetic representation of data



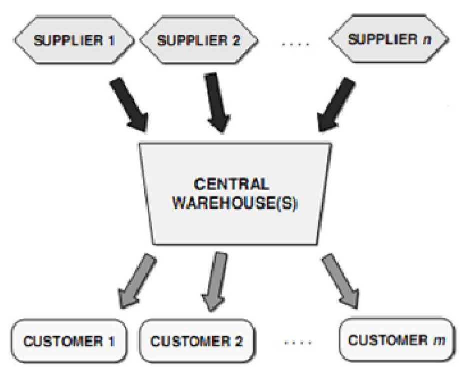
Punctual values and criticality

MACRODRIVER	DRIVER	VALUE SA8	CRITICITY SA8
PRODUCT	Variety	150	1
	Value [Euro/Kg]	90	2
	Density [kg/m^3]	170	3
	Risk of obsolescence	365	1
	Contribution Margin	14	2
SERVICE	Cycle time	3	4
	Completeness	95	2
	Returnability	1	1
DEMAND	Dimensions of the order (typology)	0.6	3
	Number of customers	35	1
	Ferequency of delivery	0.5	1
	Seasonality	L	1
	Predictability of demand	95	1
SUPPLY	Distance from plant to client	9000	5
	Number of plants	3	1
	Level of Specialization	H	5

Criticalities

Product: 1.7	Demand: 1.8
Supply: 4	Service: 3.6
Firm: 4.1	**Market: 2.4**

Solution of the network



- 1 level network composed of one Central Warehouse

- Located in Milano

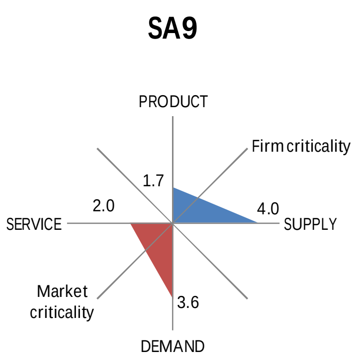
Samsung

- Net revenues (2009): 138,994 (billions of KRW)
- Market Share: LCD Monitor: 16.1%, Hard disk drive: 9.5%, Television set: 23%, Printers: 16.4%, Mobile phones: 23%, Digital camera: 9.1%
- N° Employees: approximately 164,000 worldwide
- Business Unit to consider: Audio and Video, Home Appliances, Informatics, Mobile, Networking

SA9

Air conditioning systems

Synthetic representation of data



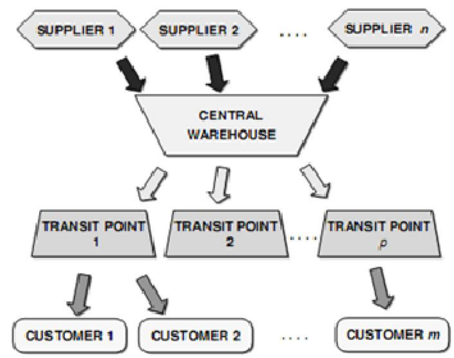
Punctual values and criticality

MACRODRIVER	DRIVER	VALUE	CRITICITY
		SA9	SA9
PRODUCT	Variety	150	1
	Value [Euro/Kg]	90	2
	Density [kg/m^3]	170	3
	Risk of obsolescence	365	1
	Contribution Margin	14	2
SERVICE	Cycle time	5	2
	Completeness	95	2
	Returnability	1	1
DEMAND	Dimensions of the order (typology)	0.4	4
	Number of customers	1160	4
	Ferequency of delivery	1	2
	Seasonality	L	1
	Predictability of demand	95	1
SUPPLY	Distance from plant to client	9000	5
	Number of plants	3	1
	Level of Specialization	H	5

Criticalities

Product: 1.7	Demand: 3.6
Supply: 4	Service: 2.0
Firm: 2.5	**Market: 3.0**

Solution of the network



- 2 level network composed of one Central Warehouse at first level and 20 transit points at the second level

- Central Warehouse located in Milano and 1 transit points every region.

Chapter 9. Analysis of the solutions

Once identified the solution clusters in which each distribution problem can lay, and once characterized the associated drivers, an empirical relation has to be found that shows the possible strategic network choices. The adopted model to obtain the relation is based on the theoretic considerations of the empirical analysis of the interviewed companies pertaining to the consumer electronic industry in Italy.

As will be shown later, the points in the graphs lead to the individuation of zones strongly characterized by drivers to which correspond specific network solutions; the exceptions are only a few and characterized by specific reasons outside the projection drivers. Each time a new distribution problem is introduced, its point lays always in the zone that is characterized by the adopted network solution. Thus there is a continuous confirmation of the validation of the method that in every moment is supported by theoretic justifications related to logistics costs.

Through this chapter will be analyzed the 4 choices related to the network structure, from the number and characterization of the levels to the choice of the number, location and allocation of the nodes for each level. As explained in chapter 8, each distribution problem is in fact characterized by different values of the four macrodrivers (product, service, demand and supply), each will influence over the multiple network choices. It is important to remark that the calculation of these drivers has to be done using the weights assigned in chapter 8, otherwise the results will not lead to the optimized network solution.

The instrument of analysis consists on a correlation matrix that confronts over the 2 axes every macrodriver considered. First it is studied the strategic choice of number and typology of levels; in the matrix, there are illustrated the main zones of membership of the solutions under consideration. After that, the adopted choice has to be characterized by number, location and allocation of the nodes for each level.

The summary of drivers used in the following analysis were presented in the table 24.

8.2 Analysis of the level and typology of network

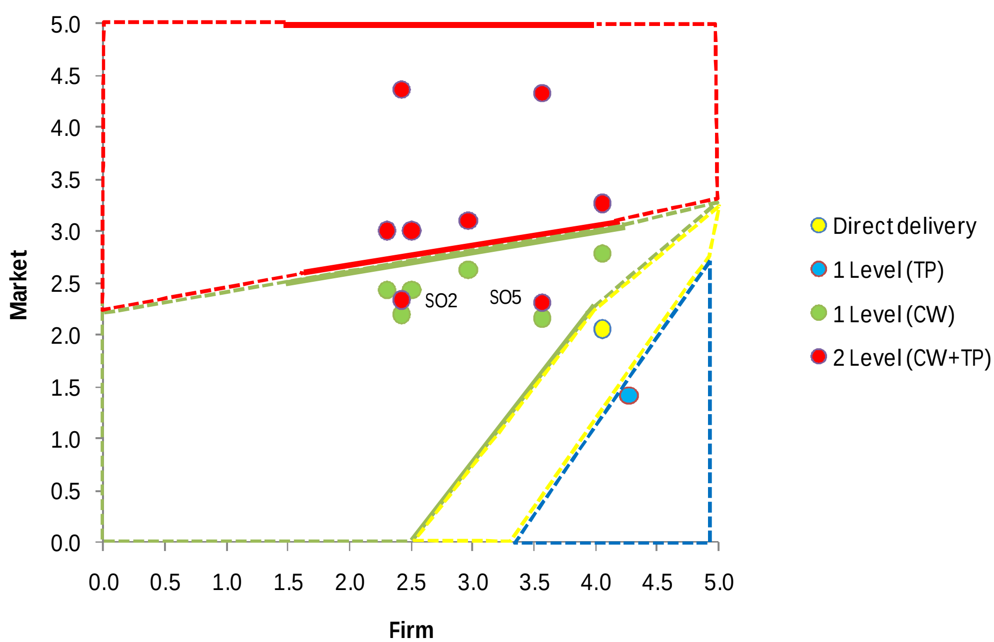
As explained before this is the first choice that has to be analyzed for the design of the distribution network. The clusters identified in this case are ordered according to the level of decentralization.

- Direct delivery
- 1 level network with Transit Points
- 1 level network with Central Warehouse
- 2 level network with Central Warehouse and Transit Points

In the graph Market-Firm (Graph 38) are easily identified the clusters just mentioned. The lines delimiting the clusters are continuous, while the dotted lines are projections; this means that through the companies interviewed all the distribution problems behave in a “similar” way and that is why are concentrated in one area and not spread through all the scale. Although, it is expected that similar cases belonging to the same type of industry will lay similarly as this examples, some projections were done in the case the distribution problem in question do not behaves the same.

It can be observed a slope line dividing the two big clusters. In the upper part of the line there are clustered all the distribution problems with 2 level network formed by central warehouse and transit points (red dots), below are the distribution problems with 1 level network formed by Central Warehouse (green dots).

In the bottom-right corner there are the direct delivery (yellow dot) and the 1 level network with transit point (blue dot). As for each case there is only one distribution problem it is difficult to assess the behavior of these types of solutions, however it was established a specific area for each of them.



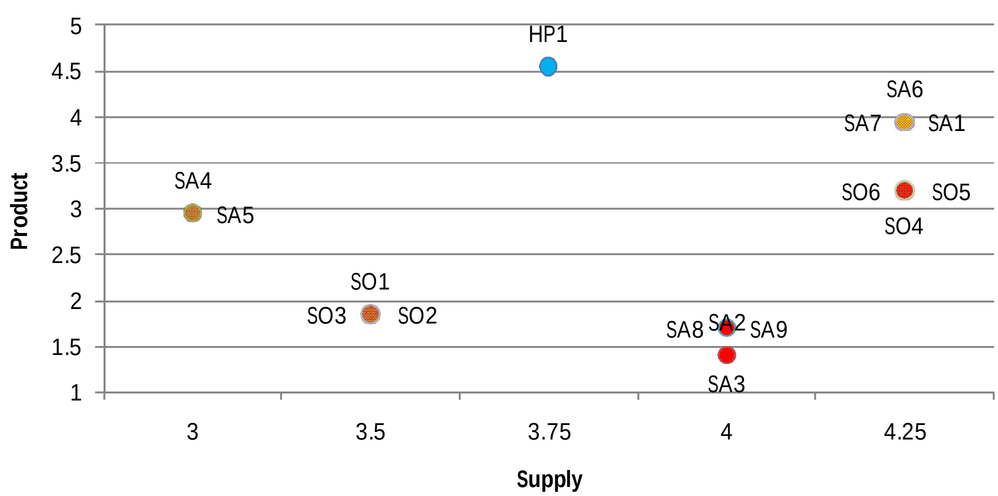
Graph 38 Market – Firm Matrix obtained

- The 2 level networks with central warehouse and transit points are characterized by market levels from 3 and up, while the firm levels are spread through all the scale. This behavior is true by understanding that these distribution problems are the most decentralized, thus they have critical demand and service characteristics, as will be shown later in this chapter.

- The 1 level networks with CW have market levels from 2.2 to 2.8, also in this case the firm levels are spread though the scale. Market levels are lower than the previous case because the demand and service drivers are not so critical. As for the exceptions, only two red dots were observed in the green area, which are SO2 and SO5. These two distribution problems have similar characteristics as the 1 level networks, but they have 2 level networks because of the fact that Sony shares 3PL with Samsung in order to saturate the transportation mean.

- The direct delivery network has market value of 2 and firm level of 4.05 and the 1 level networks with transit point is characterized by market level of 1.4 and firm level of 4.27. This behavior is logic while the two cases are the most centralized and have practically no stocks, thus market levels should be low and firm levels high.

Firm drivers

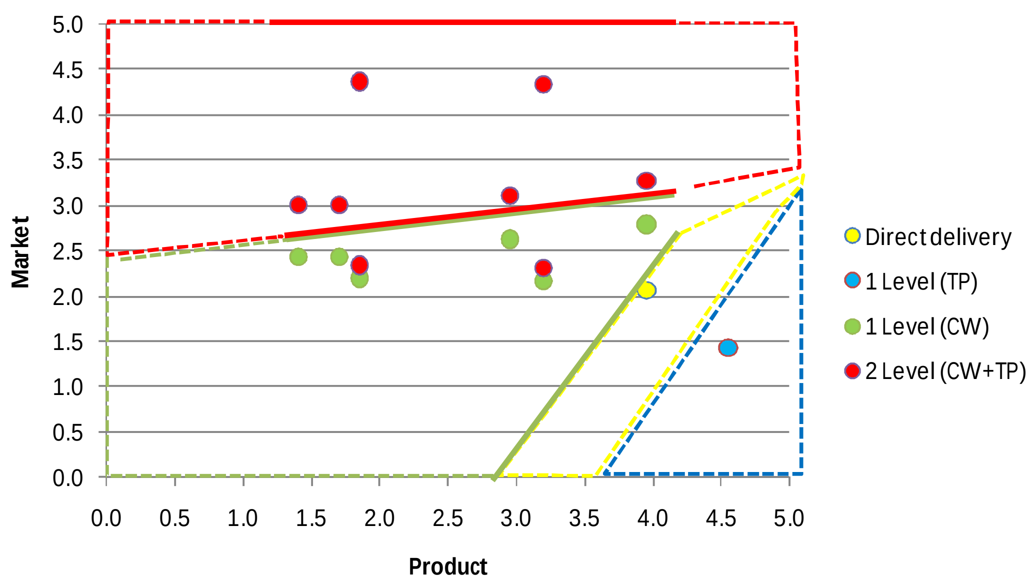


Graph 39 Product – Supply Matrix Obtained

From this graph, it can be understand that the Product component of the Firm macrodriver is more important than the Supply driver because it is more spread over the scale and also the points are overlapped due to the fact that the supply characteristics are the same for some of the distribution problems. The weighted average of these two drivers (0.65* Product criticality + 0.35* Supply criticality) gives as result the Firm macrodriver, which is a little constrained due to the Supply component.

Analysis Market-Product

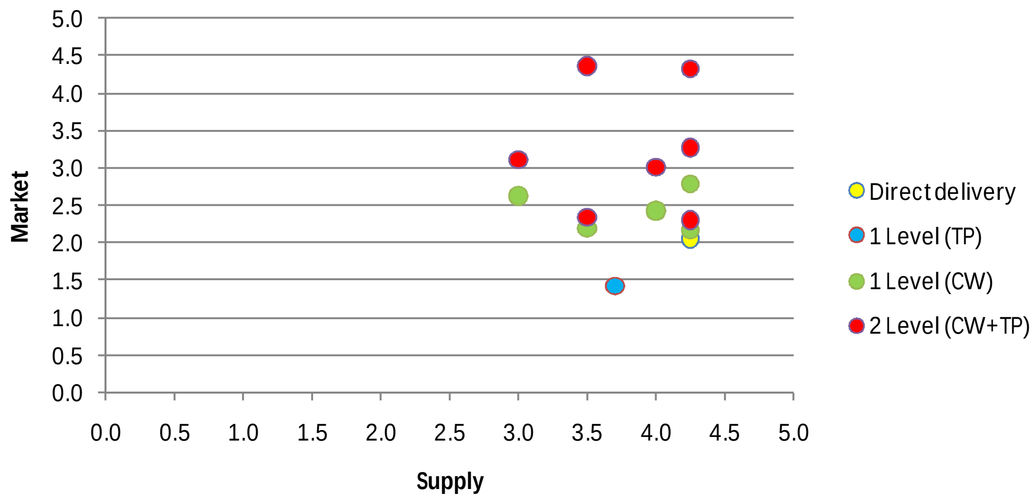
The graph 40 does not show a new report just that the product driver goes from 1.4 to 4.6. This is because, the characteristics of the products managed by each distribution problem are different, but not until the level that the criticality of the product driver is spread over the entire scale. It is observed that this scale is wider than the Firm scale of the previous Market-Firm graph.



Graph 40 Market – Product Matrix obtained

Analysis Market-Supply

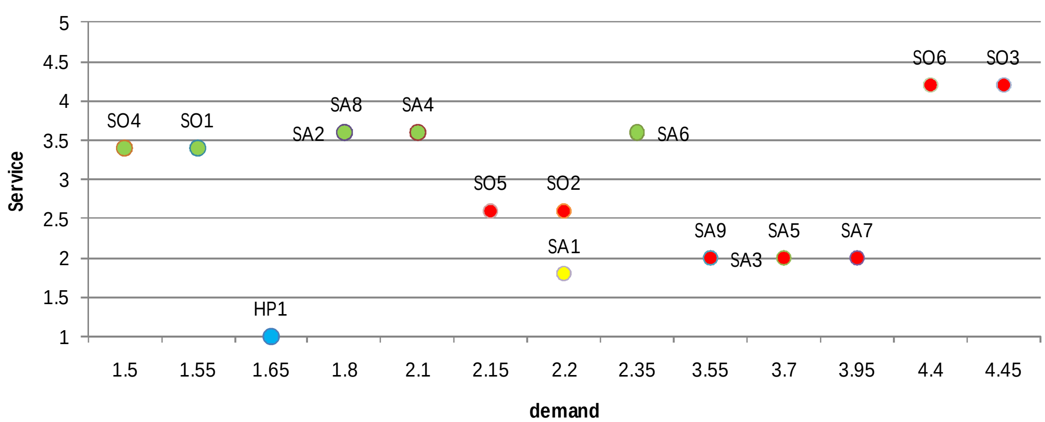
The matrix Market-Supply shows that the supply driver is concentrated on criticalities from 3 to 4.3; this means that the majority of the distribution problems have similar supply characteristics, for example the number of plants which most of them are located on the Far East.



Graph 41 Market – Supply Matrix Obtained

Market drivers

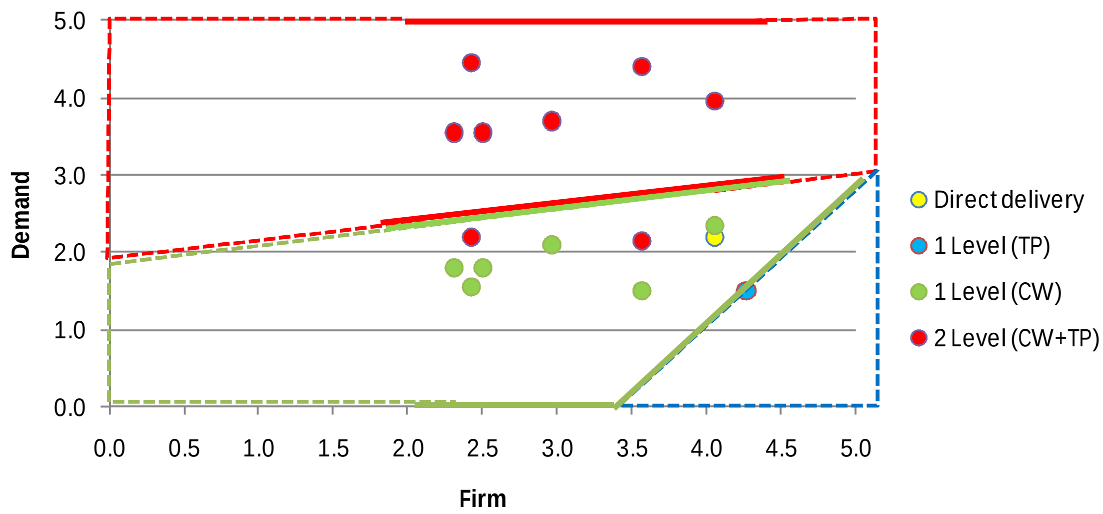
From the graph 42, it can be understand that both service and demand are important drivers for the Market macrodriver, since both have very noticeable differences for each cluster. The weighted average of these two drivers (0.65* Demand criticality + 0.35* Service criticality) gives as result the Market macrodriver, which is a little constrained due to the Supply component. It is also observed that the two exceptions of the Market - Firm graph, SO2 and SO5, are due to the demand criticality and not to the service criticality.



Graph 42 Service Demand Matrix Obtained

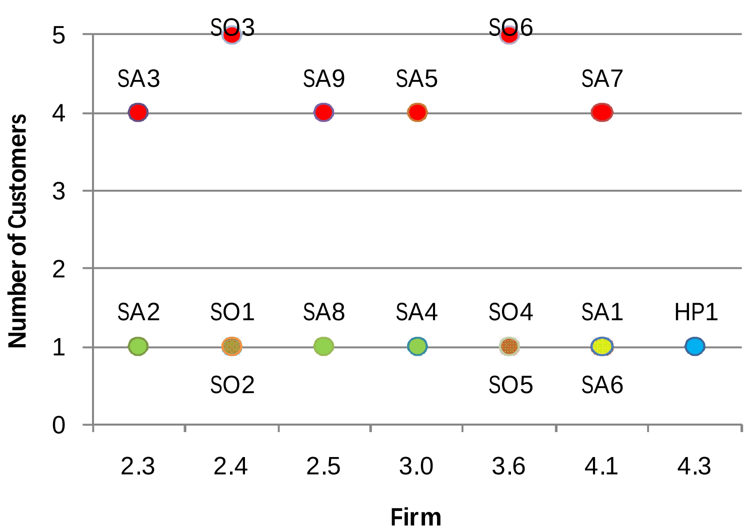
Analysis Demand-Firm

In the following graph it can be observed that the demand criticality for each cluster is different.

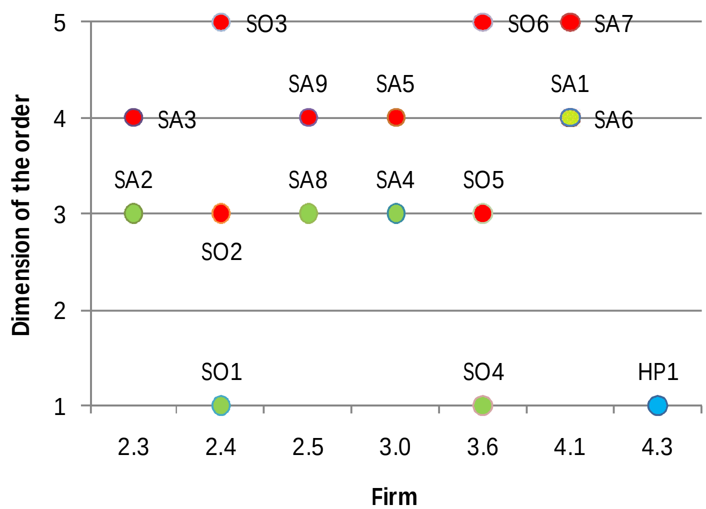


Graph 43 Demand – Firm Matrix Obtained

Through the next zoomed graphs we can understand better the behavior of each cluster.



Graph 44 Number of Customers – Firm Matrix Obtained



Graph 45 Dimension of the Order – Firm Matrix Obtained

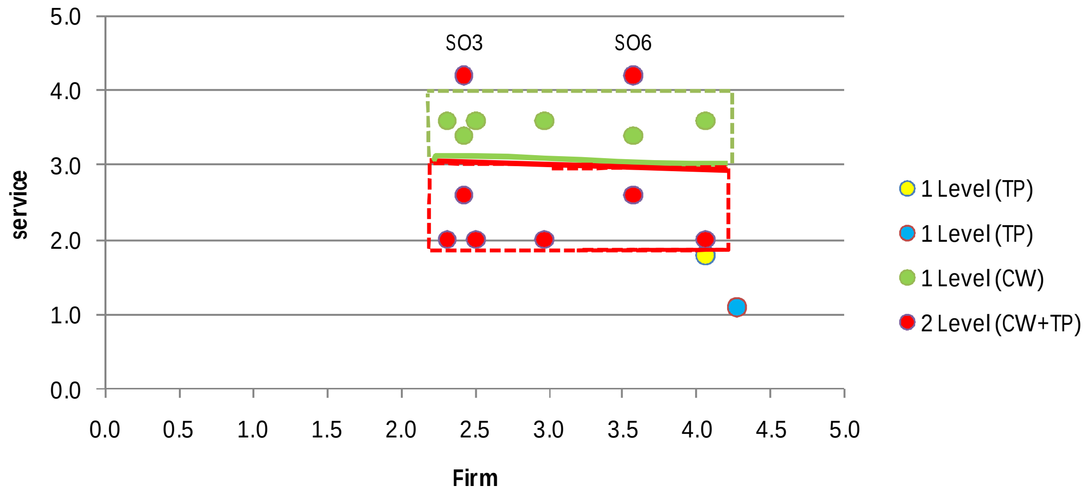
- The 2 level networks are characterized by high demand criticality, for example they have high number of customers (graph 44) and small order dimension (graph 45). Remembering that small order dimension means high driver criticality.

- The 1 level networks are characterized by small demand criticality, because they have smaller number of customers and higher order dimension than the previous group. The 2 exceptions as explained before are SO2 and SO5.

- The direct delivery network has demand criticality of 2.2 while the 1 level networks with transit points has demand criticality of 1.65.

Analysis Service-Firm

From the next graph it can be observed the clusters according to the service criticality.

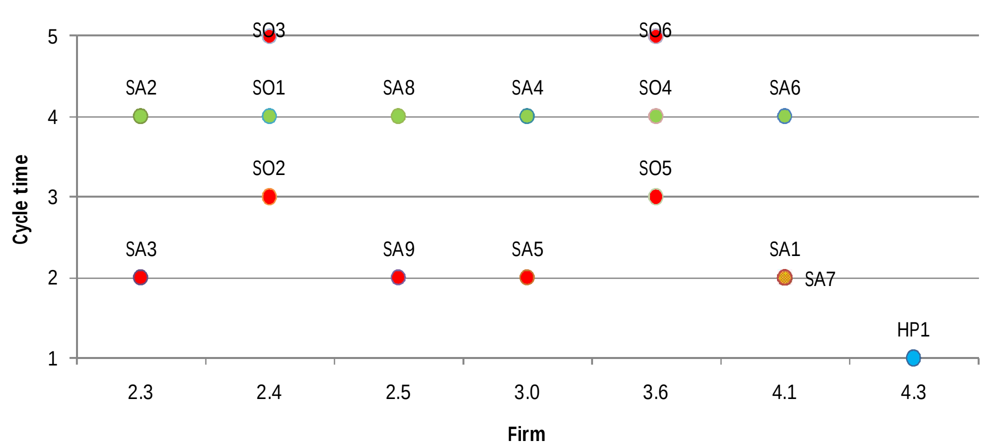


Graph 46 Service – Firm Matrix Obtained

- The 2 level networks are characterized by low service criticality, for example they have higher cycle time (graph 47). Remembering that high cycle time means lower driver criticality. This is theoretically true because by having 1 level of TP adds one or two days more.

- The 1 level networks are characterized by high service criticality, because they have shorter cycle time. The 2 exceptions in this case are SO3 and SO6 which are distribution problems with the shortest cycle time because they use DHL express, but as they use the DHL transit points they are considered in the red cluster instead of the green cluster.

- The direct delivery network has service criticality of 1.8 while the 1 level networks with transit points has service criticality of 1.

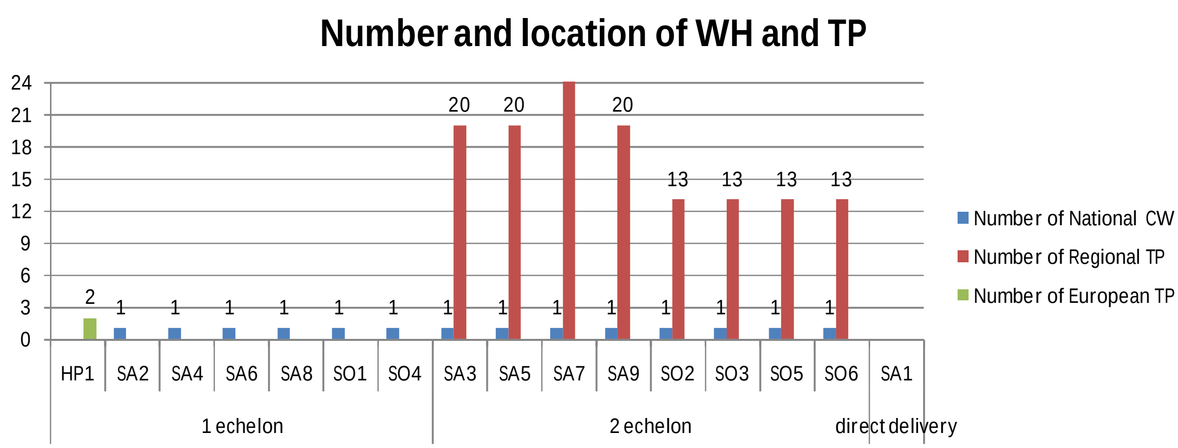


Graph 47 Cycle Time – Firm Matrix Obtained

8.3 Analysis of the other strategic decisions

The other strategic decisions considered for this model cannot be analyzed since the data gathered only contains few solutions. However it can be concluded for this type of industry, as shown in the graph 48, the following:

- When having one level network of CW the number and location should be 1 CW for national territory
- When having two level network with CW and TP the number and location of the CW should be 1 for national territory and the number of transit points should be at least one for each main region.
- When having one level network of TP the number and location should be from the information obtained 2 for European territory, but it cannot be considered as a precise rule.



Graph 48 Number and location of Warehouses and Transit Points

Chapter 10. Normative model

In this section it is described in detail the methodology to apply for designing the distribution network, which was previously developed by Archini and Bannò, (2003), but re-arranged in this Thesis project in order to meet requirements for the consumer electronics industry.

The procedure is simple and the necessary data is easy to be found. In particular it has 5 steps:

6. Company analysis and collection of data
7. Identification of the distribution problems and allocation of data for each distribution problem
8. Driver criticality analysis of the distribution problem
9. Individualization of the adequate network typology
10. Characterization of the network

The first 3 steps analyze the company reality, identifying the most important distribution problems and giving a synthetic representation in order to express the principal characteristics of each distribution problem.

The step 4 has the objective of determining the network typology, meaning the number and types of levels that minimize the relevant logistics costs, defined in paragraph 2.5, and respecting the service level defined by the company. The solution could be:

- Direct delivery
- 1 level network with transit point
- 1 level network with central warehouse
- 2 level network with central warehouse and transit points

10.1 Description of the steps

Company analysis and data collection

The first step has the objective of obtain a complete and detailed vision of the logistic requirements and processes of each company. The tool used for this is the questionnaire (Appendix 1), specifically until the section 3.1 for the case of designing a new distribution network, and the complete set of questions for the re-design of an existing one, in order to compare the actual with the proposed by the model.

Identification of the distribution problems and allocation of data for each distribution problem

This step is very important because it is where the different distribution problems of each company are identified. By distribution problem is meant, a group of products and clients characterized by similar driver values that justify a specific flow management. It is very important to single out and describe these distribution problems in order to understand the factors that mostly affect the strategic decisions and the network planning.

From the detailed analysis of the drivers and macrodrivers (product, supply, service and demand), it is possible to construct the distribution problems, while in the case of redesign, the analysis of the flow diagrams permits to see the distribution problems already existent and then validate or modify them. The values collected in the previous phases have to be grouped according to the identified distribution problems (DP1, DP2,…, DPN)

Macrodriver	Driver	Value		
		DP1	DP2	DP3
Product	Variety (SKUs)			
	Value (euro/kg)			
	Density (kg/m3)			
	Risk of obsolescence (days)			
	Contribution Margin (%)			
Service	Cycle Time (days)			
	Completeness (%)			
Demand	Dimension of the order (%FTL)			
	Number of customers			
	Frequency of delivery (deliveries per week)			
	Seasonality (L - LM - M - MH - H)			
Supply	Distance from plant to client (km)			
	Number of plants			
	Level of Specialization (Low, Medium or High)			

Table 19 Drivers table: Punctual values

Driver criticality analysis of the distribution problem

In order to detect immediately the relevance of each driver, once known the punctual values, it is proposed a scale of projection composed of 5 reference intervals that identify the criticality of each driver. The objective of the scale is to obtain an absolute reference system that allows the comparison of drivers with different unit of measurement and to make visible the impact that different drivers' values have over the costs.

The five intervals are:

1: low criticality

2: medium low criticality

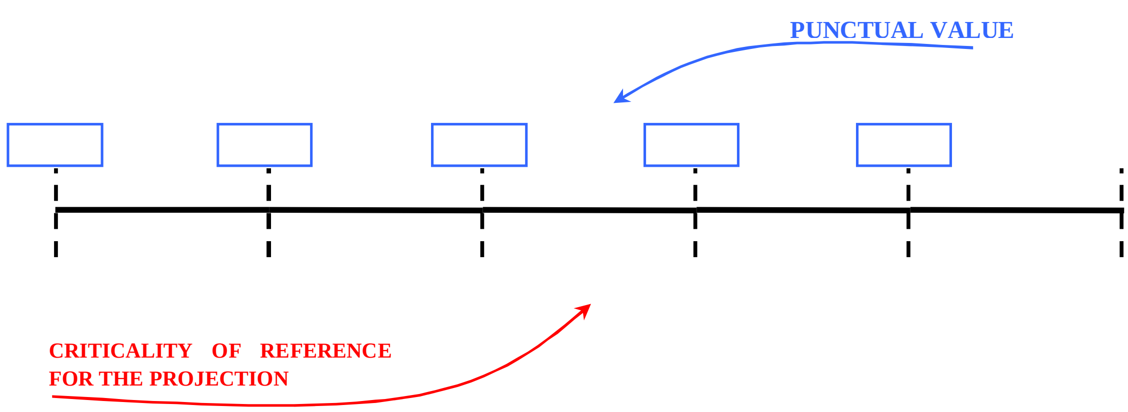
3: medium criticality

4: medium high criticality

5: high criticality

The identification of these criticalities is through the use of axes divided into discrete intervals as was mentioned before. On the axes are placed the exact values identified in the previous step (step 2) and according to the interval where the value is placed, a critical evaluation between 1 to 5 is given to each driver.

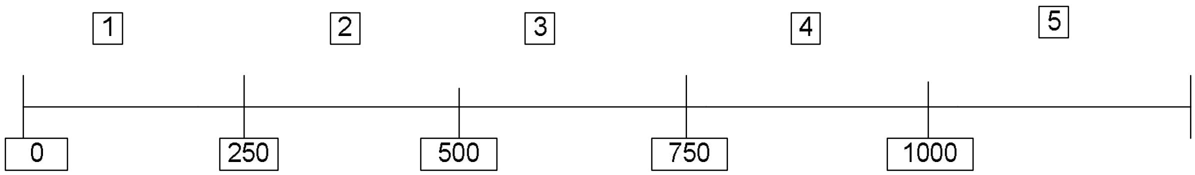
Here is an explanation of the axes to identify the critical value of each driver.



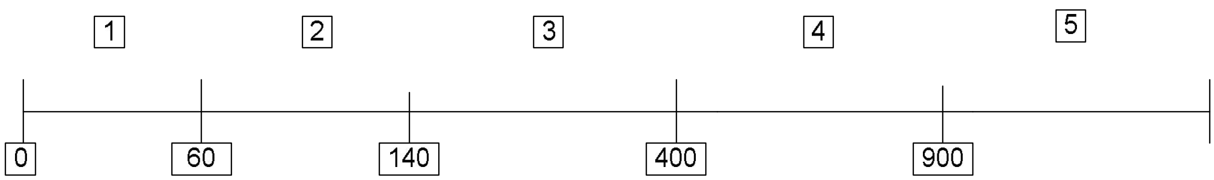
Now, each driver with its axes of criticality:

PRODUCT:

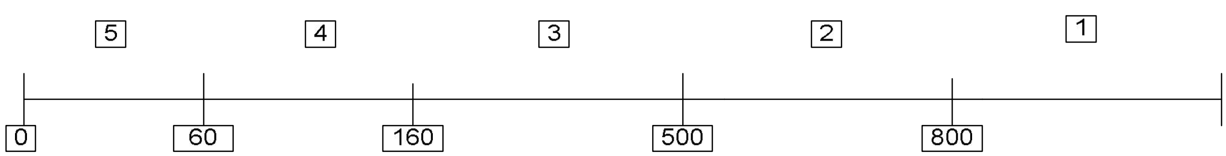
Variety (number of products):



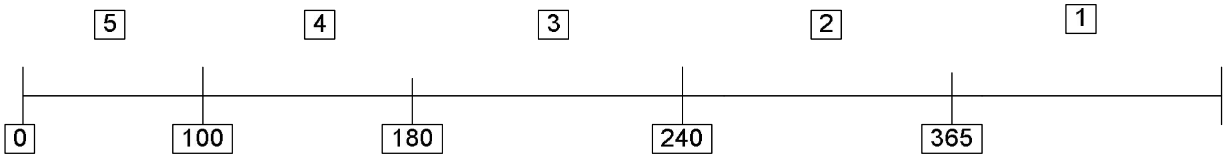
Value (Euro/Kg):



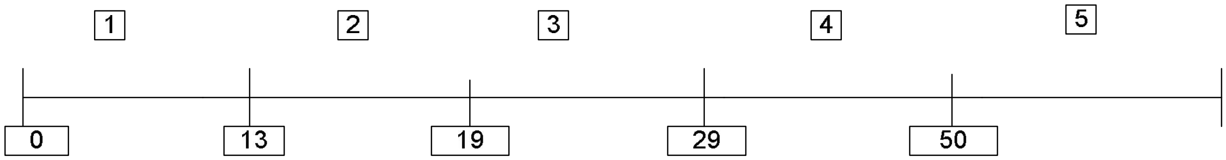
Density (Kg/m^3):



Risk of obsolescence(days):

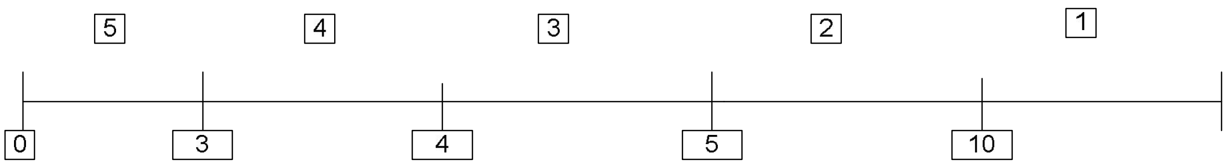


Contribution Margin:

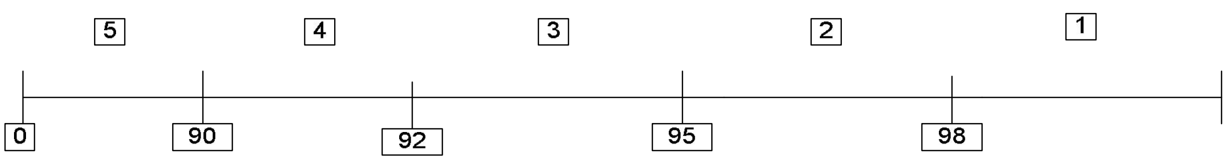


SERVICE:

Cycle time (days):

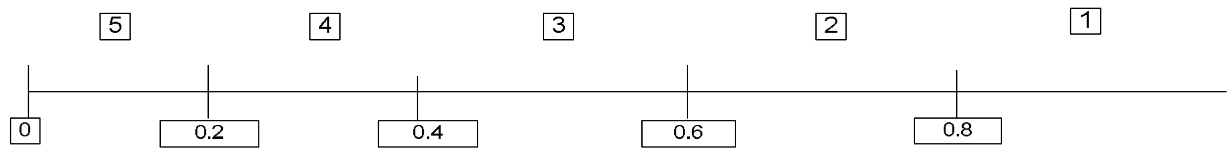


Completeness (item fill rate):

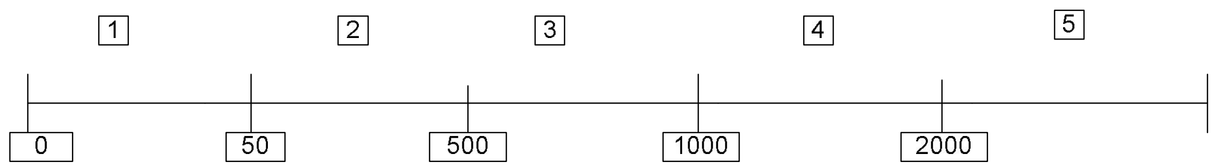


DEMAND:

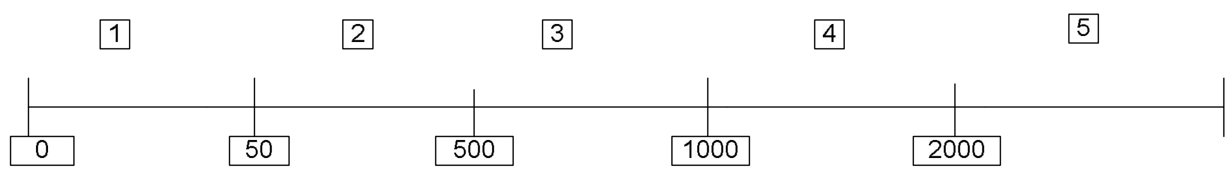
Dimension of the order:



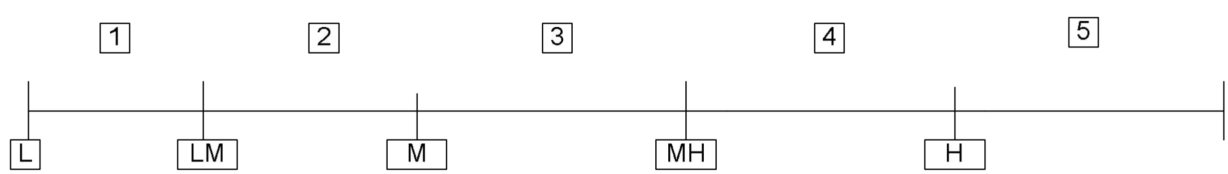
Number of customers:



Frequency of delivery (deliveries/week client):

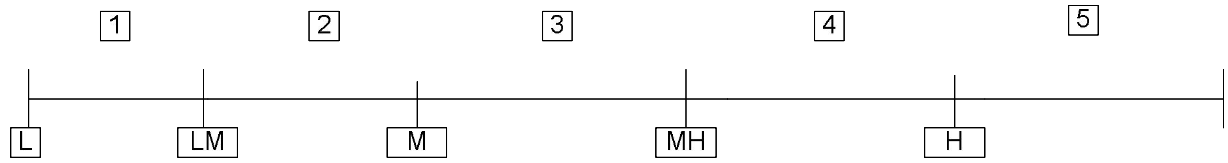


Seasonality (qualitativo):

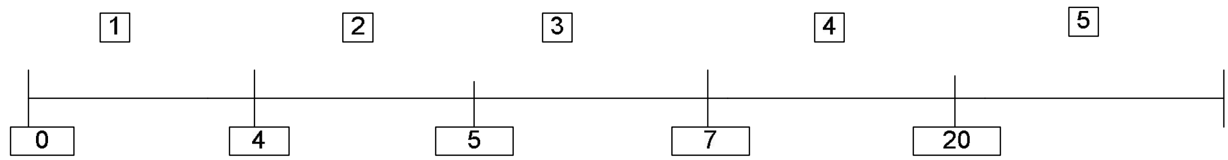


SUPPLY:

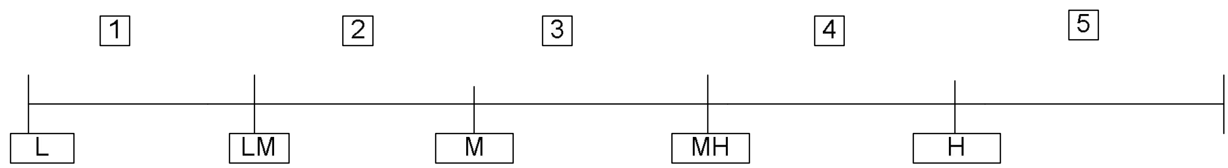
Distance from plant to client (Km):



Number of plants:



Level of Specialization:



The values, between 1 and 5, indicating the criticality of the specific drivers for each distribution problem, should be reported in the next table.

Macrodriver	Driver	Criticality		
		DP1	DP2	DP3
Product	Variety			
	Value			
	Density			
	Risk of obsolescence			
	Contribution Margin			
Service	Cycle Time			
	Completeness			
Demand	Dimension of the order			
	Number of customers			
	Frequency of delivery			
	Seasonality			
Supply	Distance from plant to client			
	Number of plants			
	Level of Specialization			

Table 20 Drivers table: Criticalities

At this point, for each distribution problem it is necessary to express synthetically the criticalities of each macrodriver. This can be done by calculating the weighted average of the drivers that compose each macrodriver by utilizing the following weights in the next formulas.

Product	Variety	0.15
	Value	0.45
	Density	0.1
	Risk of obsolescence	0.25
	Contribution Margin	0.05
Service	Cycle Time	0.8
	Completeness	0.2
Demand	Dimensions of the order	0.4
	Number of customers	0.4
	Frequency of delivery	0.15
	Seasonality	0.05
Supply	Distance from plant to client	0.5
	Number of plants	0.25
	Level of specialization	0.25

Table 21 Weights proposed for the drivers

$$C_i = \frac{\sum_{j}^{j_{max}} Wj * c_j}{j_{max}}$$

with: C_i = Macrodriver criticality i;

c_j = driver criticality j, with j = [1, …, j_{max}];

Wj = Weight of each driver

i = {product, service, demand, supply}

j = {variety, value, density, …., many products sources} = {all the drivers}

Product weight	0.65
Service weight	0.35
Demand weight	0.65
Supply weight	0.35

Table 22 Weights proposed for the Macrodrivers

$$CF = \frac{Wp * Cp + Wl * Cl}{2}$$

$$CM = \frac{Ws * Cs + Wd * Cd}{2}$$

CF = firm criticality

CM = market criticality

$Cp =$ product criticality

$Cs =$ service criticality

$Cl =$ supply criticality

$Cd =$ demand criticality

W(p, l, s, d) = Weights (product, supply, service, demand)

In order understand better the previous results; a synthetic graph can be represented for each distribution problem. For example in the next figure, aggregation was carried out using two broken lines to connect the values of product and supply and service and demand.

The two areas generated, colored different, provide immediately the idea of which ones are the more critical drivers for each distribution problem considered.

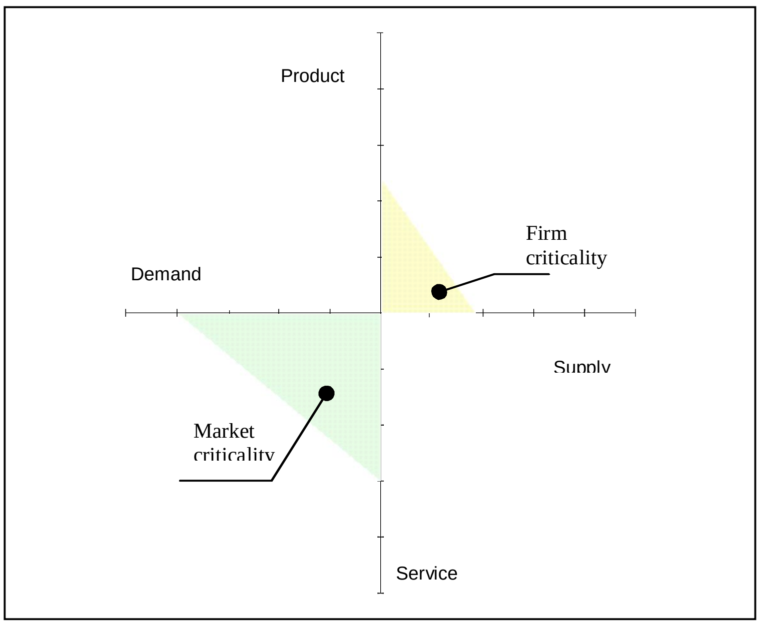


Figure 25 Graphical representation of the distribution problem

The bigger the colored area is, the higher the criticality of the macrodriver for that distribution problem: green area indicates market and yellow area indicates firm.

Individualization of the adequate network typology

This step consists in position the distribution problem, synthesized as in step 3, in the aggregated matrix market-firm of Figure 26. According to the area to which the distribution problem belongs it is possible to obtain information about the most appropriate level of centralization/decentralization of the distribution network. Different zones are identified:

- Yellow zone: direct delivery;
- Green zone: 1 level network of central warehouse
- Blue zone: 1 level network of transit points
- Red zone: 2 level network with central warehouse at first level and transit points at second level

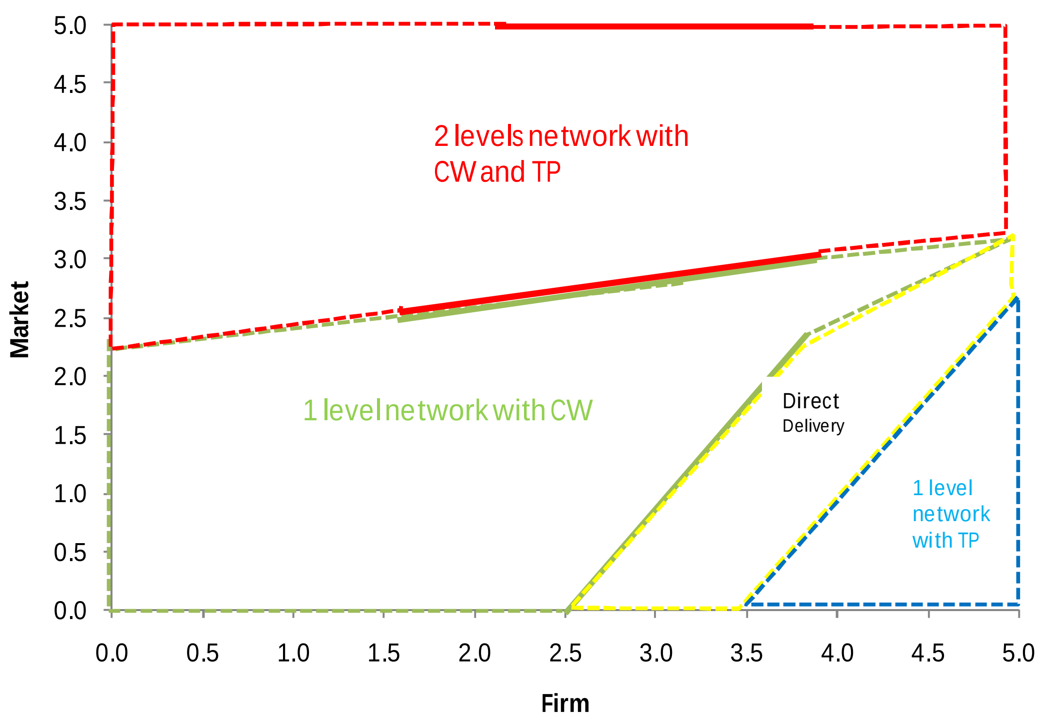


Figure 26 Proposed aggregated matrix Market-Firm and network levels.

Characterization of the network

- Networks with 1 level of CW should have one CW at National level.
- Networks with 1 level of TP should have at least 2 TP at European level.
- Networks with 2 levels should have one CW at National level and at least 1TP every 1.5 Italian region.

Conclusions

- From the literature analysis and the interviews realized, it can be said that nowadays firms are paying more attention to the design of their Distribution Networks as it has been proved its important impact over the financial performance.
- Not all the drivers mentioned on the papers analyzed resulted to be useful for the design of distribution networks in the consumer electronics industry.
- The list of drivers that were considered as important for the distribution network design were:
    - Product Macrodriver: Variety, Value, Density, Risk of Obsolescence and Contribution Margin.
    - Service Macrodriver: Cycle Time and Completeness
    - Demand Macrodriver: Dimension of the order, Number of customers, Frequency of delivery and Seasonality.
    - Supply Macrodriver: Distance from plant to client, Number of plants and Level of specialization.
- The allocation of specific weights for each driver applied on the model proposed by this work, correspond to an improvement on the procedure with respect to the base model used.
- The Distribution Network Design model presented as the result of this thesis is applicable to the consumer electronics industry in Italy, easy to follow by distribution network designers, understandable to decision makers, and easy to adapt to changing requirements.
- The proposed aggregated matrix Market – Firm presents well defined areas for networks with 1 level of CW (green) and 2 levels of CW and TPs (red), while for the network with 1 level of TPs (Blue) and the Direct Delivery decision (yellow), the information obtained was not enough to present this cases as a rule.

Bibliography

Ambrosino, D., & Scutell, M. (2005). Distribution Network Design: Modelling and Info considerations. *European Journal of Operational Research* .

Archini, G., & Bannó, M. (2003). *Modelli di evoluzione dell'assetto dei sistemi logistico produttivi di aziende multinazionali operanti du base europea.*

Ashayeri, J., & Rongen, J. (1997). Central Distribution in Europe. *International Journal of Logistics Management* .

Ballou, R. (2004). *Business Logistics/ Supply Chain Management.*

Ballou, R. (1995). Logistics Network Design: Modeling and Info considerations. *International Journal of Logistics Management* .

Ballou, R. (1993). Reformulating a Logistics Strategy: A concern for the Past, Present and Future. *International Journal of Physical Distribution* .

Borchert, E. (2008). Consumer Electronics and Household appliances- comparative price levels in 37 European countries for 2997.

Business Glossary. (2010). Obtenido de http://www.allbusiness.com/glossaries/correlation-analysis/4964988-1.html.

Chopra, S. (2003). Designing a Distribution Network in a Supply Chain. *Transportation Research Part E* .

Christopher, M. (2006). A taxonomy for selecting global supply chain strategies. *International Journal of Logistics Management* .

Chung-Plaw, T. (2002). Column generation: Application in distribution network design.

Creazza, A., Dallari, F., & Melacini, M. (2007). Evaluating logistics network configurations for a global supply chain. *Supply Chain Management: an International Journal* .

den Ven, V., & Ribbers. (1993). International Logistics: A diagnostic method for the allocation of production and distribution facilities. *International Journal of Logistics Management* .

Dornier, Fender, & Kouvelis. (s.f.). Global operations and logistics text and cases.

Eero, E., & Holmström, J. (2009). How to design the right supply chain for your customers. *Supply Chain Management: an international journal* .

Eleonatra, E., & Holmström, J. (2009). How to design the right supply chain for your customers. *Supply chain Management an International Journal* .

Ferretti, I., Zanoni, S., & Zavanella, L. (2009). Distribution network design under uncertain demand. *Universitá degli studi di Brescia* .

Fisher, M. (1997). What is the right supply chain for your products? *Harvard Business Review* .

Hammel, T., Keuttner, D., & Phelps, T. (2002). The re-engineering of Hewlett Packard's CD-RW supply chain . *Supply Chain Management: An International Journal* .

Jay, J.-K., Ozment, J., & Sink, H. (2007). Logistics capability, logistics outsourcing and firm performance in an e-commerce market. *International Journal of Physical Distribution and Logistics Management* .

Jayaraman, V. (1998). Transportation, facility location and inventory issues in distribution network design. *International journal of operations & production management* .

Lalwani, C., & Naim, M. (2006). On assessing the sensitivity to uncertainty in distribution network design. *International Journal of Physical Distribution and Logistics* .

Lashine, S., Fattouh, M., & Issa, A. (2008). Location/allocation and routing decisions in in supply chain network design. *Journal of Modelling in Management* .

Lin, J.-R., & Lei, H.-C. (2009). *Distribution system Design with two level routing considerations.* Department of Transportation and Navigation Science, National Taiwan Ocean University.

Lovell, A., Saw, R., & Stimson, J. (2005). Product value-density: managing diversity through supply chain segmentation. *The Internationl Journal of Logistics Management* .

Manzani, R., & Gebennini, E. (2006). Optimization models for the dynamic facility location and allocation problem. *International journal of production research* .

Manzini, R., & Bindi, F. (2008). Strategic design and operational management optimization of a multistage physical distribution system. *Transportation Research part E* .

McQuitty, S., & Peterson, R. T. (2000). Selling home entertainment on the Internet: an overview of a dynamic marketplace.

Mourtis, & Evers. (1995). Distribution Network Design an Integrated Planning Support Framework. *International Journal of Physical Distribution & Logistics* .

Nansi, P. (s.f.). What is logistics? What does it mean to projects? *Project Monitor* .

Nozick, L., & Turnquist, M. (2000). Inventory, transportation, service quality and location of distribution centers. *European Jorunal of Operations research* .

Pasin, F., & Cordeau, J.-F. (2006). *An integrated model for logistics network design.* HEC Montreal.

Payne, T., & J. Peters, M. (2004). What is the right supply chain for your products? . *Journal of Logistics Management* .

Ratliff, D. (1993). Distribution/Logistics Network Planning. *Georgia Tech* .

Rogers, D. S., & Tibben-Lembke, R. S. (1998). Going Backwards: Reverse logistics trends and practices. *Univeristy of Nevada* .

Rushton, A., Croucher, P., & Baker, P. (2006). *The Handbook of Logistics and Distribution Mangement.* Kogan Page.

Selldin, E., & Olhager, J. (2007). Linking products with supply chains: testing fisher's model. *Supply Chain Management: an international journal* .

Sharifi, H., Ismail, H., & Reld, I. (2006). Achieving agility in Supply chains through simultaneous design of and design for supply chains. *Journal of Manufacturing Technology Management* .

Sharma, M., Moon, I., & Bae, H. (2008). Analytic hierarchy process to assess and optimiza distribution netowrk. *Applied mathematics and computation* .

Thomas, R. (2002). De Novo Programming Model for optimal DND. *A Proposal for the Faculty of research Grant* .

van den Berg, E., & Vos, B. (1996). Assessing International Allocation Strategies. *International Journal of Logistics Management* .

van der Vorst, J., van Dijk, S., & Beulens, A. (2001). Supply chain design in the food industry. *International journal of Logistics Management* .

W.L, N., & Neuman, W. (1997). Social Research Methods: Qualitative and Quantitative Approaches. *Allyn and Bacon* .

Appendix 1: Questionnaire

<u>Research of Distribution Network of the Consumer Electronic Industry in Italy</u>

1. Data Context

1.1 General data of the interview

Date:____

Name of the company:____

Address:____

Web Site :____

Interviewee:

I. Name:____

Function: ____

II. Name:____

Function:____

1.2 Company general data

Member of a Group:____

Sector:____

Multinational: (Yes/No) Type:____

Dimensions: Total Sales: ___________Market Share: ________N° Employees:_______

Business Unit to consider: ____

2. Commercial Organization

2.1 Organization of the commercial function

____

____

____

____

2.2 Types of clients:

2.2.1 Distributors:____

2.2.2. Retailers:____

2.2.3 Final consumer:____

2.2.4 Wholesalers:____

Direct clients: (Clients with direct shipment)

____

3. Characterization of the actual Distribution Network

3.1 Drivers for the design of the Distribution Network

Product Drivers:

Variety (SKUs):____

Value (€/Kg): ____

Density (Kg/m^3): ____

Risk of obsolescence (Days):__________________________________

Contribution Margin (%):______________________________________

Service Drivers:

Cycle Time (days order-delivery):_____________________________

Completeness (item fill rate):________________________________

Returnability:____

Demand Drivers:

Dimension of the order (%FTL): _______________________________

Number of customers: ____

Frequency of delivery (per week):_____________________________

Seasonality :____

Predictability of demand:_____________________________________

Supply drivers

Distance from plant to client (Km):______________________________

Number of plants: ______________________________

Level of Specialization:______________________________

Other Drivers: ______________________________

3.2 Characterization of the Supply Chain

Number, Localization and characteristics of each node.

# Plants	Location	Own establishment?	Products	Exclusivity of products	Average distance from plant to client
1					
2					
3					
4					
…..					

Own Establishments

____

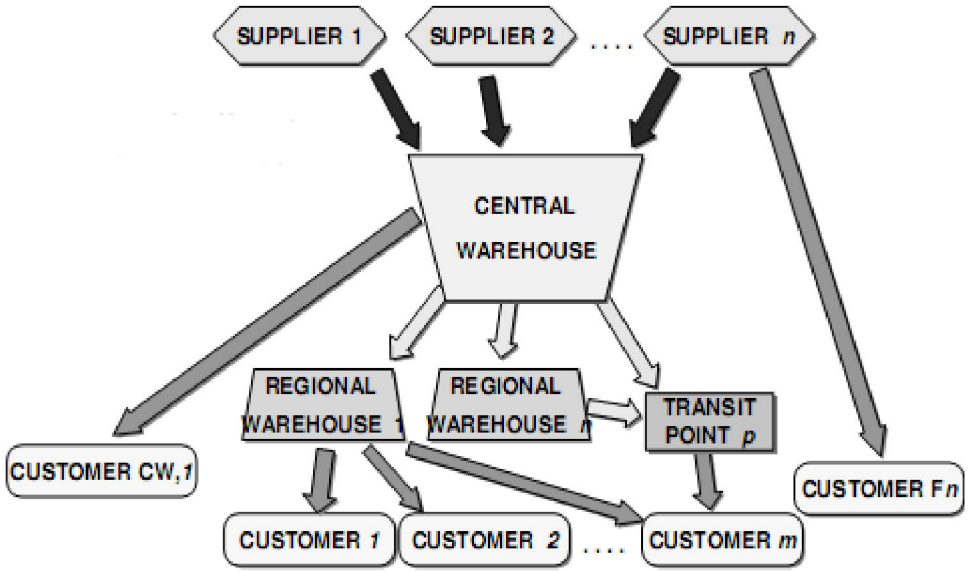
____

Supplier Establishments

____

____

3.3 Actual Distribution Network



According to the model above, please specify how is the actual distribution network of the firm, clarifying the number of echelons, plants, warehouses, transit points and the flows. Also specify what is outsourced.

Network classification

Direct delivery:____

1- Echelon: ____

2- Echelon: ____

3- Echelon: ____

4- mixed network : ____

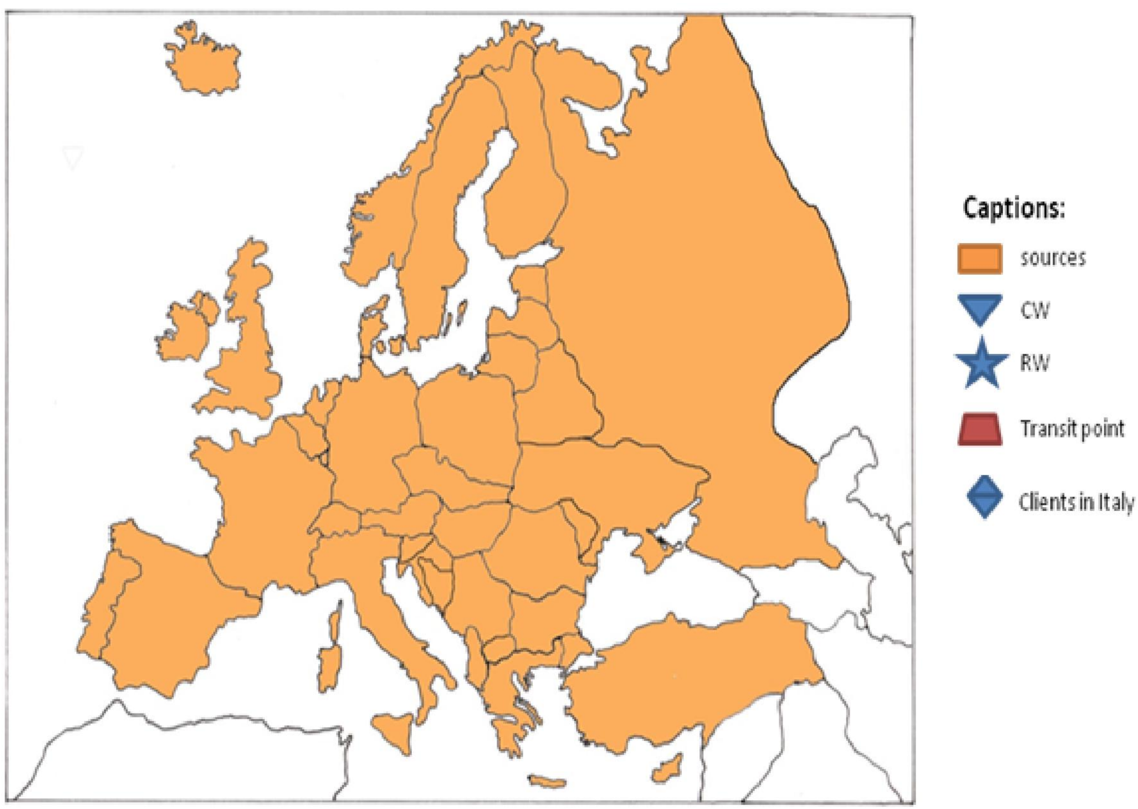
Node characterization: (location and allocation)

- Types of nodes

Central WH: ____

Regional WH: ____

Transit Point:____



- Activities, resources and capacity of each typology

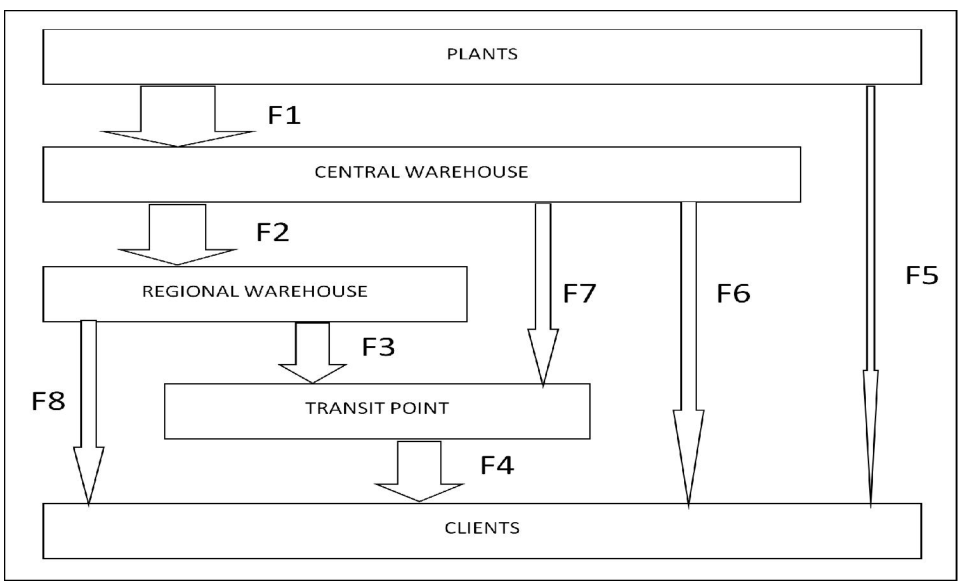
Central WH

Regional WH

Transit Point

---

4. Flows Characterization



From the scheme above, identify the type/s of flow/s used, the percentage and type of products that follows that route, the location of the points of origin and destination and the typical quantity per delivery for each type of flow used (FTL, LFTL, Pallets, etc) (Primary or Secondary Transportation). Indicate the nodes and/or arcs that are outsourced.

5. Managerial logic

5.1 Stocks

Safety Stocks

Service Level: (K utilized) and decisions about centralization/decentralization

Logic of the material flow planning: Indicate the anticipation period used to forecast the demand and how the safety stocks are estimated.

5.2 Transport

Organization of primary transport

Organization of secondary transport

5.3 Outsourcing

Activities in outsourcing

Companies that handle the outsourced activities (with which terms and conditions)

Why to outsource? Which drivers to consider?

5.4 Reverse Logistics

5.4.1 Indicate if Reverse Logistics is used. Amount of returned products as a percentage of products sold. Which distribution network is used.