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Strategic Distribution Network Design: Quantitative tuning of the distribution network selection matrixes

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INDEX

INDEX of Figures

INDEX of Graphs

INDEX of Tables

Abstract

The thesis is devoted to define the way of optimizing and tuning the existing distribution network model using quantitative mathematical methodologies.

In this work considered the mathematical approach to describe the process of tuning distribution network selection matrixes based on several quantitative methodologies that describe the relationship between distribution problem and distribution solution. The given approach can support the distribution network designers in strategic decision-making process about the future configuration of the distribution network, which is based on the match between distribution problem reflecting the products, service, demand and supply characteristics presented by firm, and distribution solution indicating the level of decentralization of the distribution network.

Key words: DISTRIBUTION NETWORK DESIGN, SELECTION MATRIXES, CORRELATION, CONFIRMATORY FACTOR ANALYSIS, DRIVERS' POOL, ARCS, NODES, ELECTRONICS INDUSTRY, FMCG.

In questo lavoro di tesi è stato definito il modo di ottimizzare e mettere a punto l'attuale modello di rete di distribuzione utillizando metodologie matematiche.

E' stato considerato il metodo matematico per descrivere il processo di messa a punto di matrici selettive della rete distributiva basata su diverse metodologie quantitative che descrivono la relazione tra problemi di distribuzione e la soluzione di distribuzione. L'approccio dato è in grado di supportare i progettisti nel prendere decisioni strategiche circa la futura configurazione della rete di distribuzione, che si basa sulla corrispondenza tra problemi di distribuzione, che riflettono i prodotti, i servizi, le caratteristiche della domanda e dell'offerta presentata dalla società, e tra la soluzione di distribuzione, indicante il livello di decentramento della rete di distribuzione.

Parole chiave: PROGETTAZIONE DI UNA RETE DI DISTRIBUZIONE, MATRICI SELETTIVE, CORRELAZIONE, ANALISI FATTORIALE CONFERMATIVA, DRIVERS' POOL, NODI, INDUSTRIA ELETTRONICA, FMCG.

Executive Summary

Reason to start the research

The distribution network design model consists of a wide range of issues involving the strategic decisions, tactical decisions and operational decisions in logistics management. The strategic planning attempts to design a rough structure of distribution network. Tactical level decisions refer to the exact position of the facility, the selection of the transportation, level of the inventory and so on. The operational planning aims at coping with the routine decisions of distribution process.

In this study, we need to optimize the existing distribution network selection matrix, which can solve the problems on strategic level of the distribution process. This network selection matrix is a kind of decision making tool used to determine the number of echelons, number of facilities in each echelon, and type of facility in the distribution network.

The existing distribution network selection matrix has been built based mainly on the qualitative way, despite a few of quantitative approaches were used to develop the matrix. The purpose of this study is trying to make the matrix more accurate by using mathematical models purely in order to avoid the subjectivity and bias of qualitative approach.

Objective

This thesis aims at optimizing the existing distribution network selection matrixes in Consumer Electronics industries and Fast Moving Consumer Goods industry (FMCG) in European level by taking mathematical method to find a more accurate relationship between distribution problem and distribution solution.

For the purpose of this main goal, we must achieve the following sub-objectives:

- Collecting drivers used to design distribution network for the sake of making the existing driver list to be completed;
- Identifying the mathematical models in order to obtain the more important drivers, which are more able to reflect the distribution problem based on the nature of industry;
- Filtering the drivers based on the application of mathematical tools;
- Figuring out the coefficient of each driver and evaluation function by using regression analysis after the driver selection;
- Finding out the accurate relationship between distribution problem and distribution solution based on the result of preceding sub-objective;
- Achieving the normative distribution network selection matrixes in Consumer Electronics industry and FMCG industry.

The distribution network selection matrix can support the users to make the strategic decisions on the configuration of distribution network, which is based on the match between distribution problem reflecting the products, service, demand and supply characteristics presented by firm, and distribution solution indicating the decentralization of the distribution network. Thereby, the correct distribution network could be obtained if the relationship between distribution problem and distribution solution can be described in an accurate way.

The existing model is able to describe the relationship between distribution problem and distribution solution. However, we assume that this relationship could be stronger because the mathematical tools should allow a more objective selection of the drives and a more accurate determination of the driver's coefficient in affecting the distribution network structure. Therefore, the core of this study is to refine the distribution network selection matrix by quantitative method in order to avoid the subjectivity and bias of qualitative approach and improve reliability.

Methodology

In order to achieve the objectives mentioned above, there are five main processes and seven micro steps we have to implement. The whole procedure is shown as the following figure:

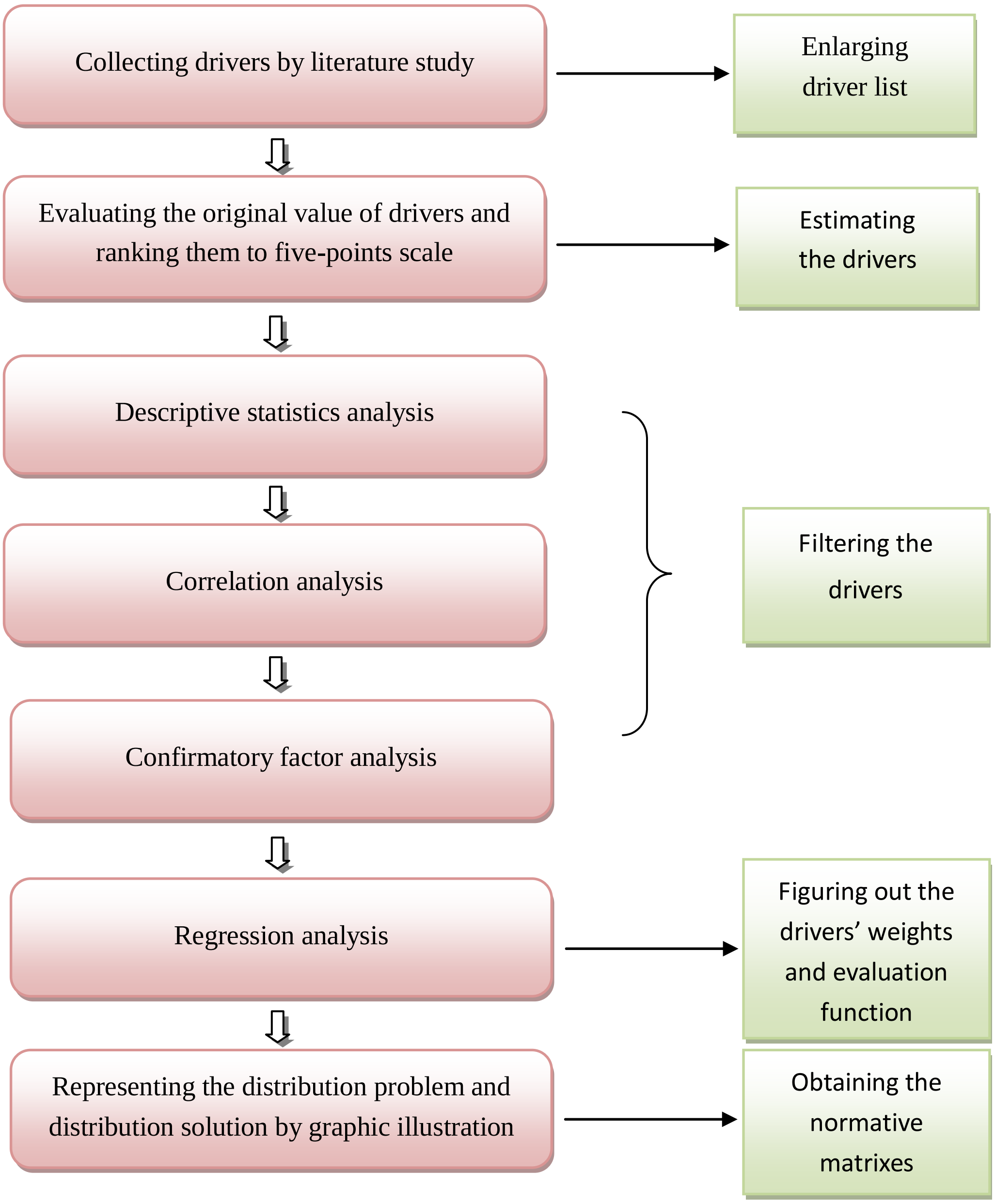


Figure 1 Research procedure

Firstly, we try to find more drivers in order to updating the current driver list. In the existing distribution network selection matrix, there are 22 drivers divided into four groups (product, service, demand, and supply). We have to collect more drivers, which are not included in the current driver list, in order to make the driver list to be more completed.

Secondly, we need to evaluate the punctual value of drivers, and rank them based on the five-point scale for the subsequently data analysis. In this study, we don't interview the firms directly because of the time constraint. With regard to the existing drivers, we can find their value from historic data collected by previous research. Taking advantage of the annual report and company's official website, the value of new drivers could be found.

After this, we have achieved a lot of drivers. We suppose that the distribution problems in one industry area can be described by part of these drivers we collected. Therefore, the following steps are to carry out the data analysis in order to filter the drivers. We intend to find out the more important drivers could depict the distribution problem based on the nature of an industry. We use descriptive statistics analysis and correlation analysis to see if some drivers could be removed or combined according to their standard deviation and correlation factor. The further analysis will be done by confirmatory factor analysis (CFA). The CFA model can reduce more drivers on the basis of the current theoretical model of distribution network selection matrix and the correlation matrix of the drivers.

According to the preceding process, we can obtain some more important drivers. The following step is to figure out the regression function for those important drivers and their regression coefficients. By taking into consideration the multicollinearity may exist among the drivers, we have to use principal component regression (PCR) model to solve this problem.

In the last step, we use the regression function and regression coefficients of the drivers to figure out the factors of Firm and Market characteristics for every distribution problem, and represent their value on the two-dimension graph to discover the relationship between distribution problem and distribution solution. The value of Firm characteristic is the sum of the driver's factor in product and supply characteristics, and the value of Market characteristics is the sum of the driver's factor in service and demand characteristics.

Results

Consumer Electronics Industry

Available drivers after quantitative analyses

After the descriptive statistics analysis, correlation analysis and confirmatory factor analysis, we get 20 available drivers for Consumer Electronics industry. Some drivers are deleted and/or combined due to the meaningless standard deviation factor, the high correlation factor and low factor loading.

Product	Variety
	Product value density
	Contribution margin
	Product complexity
	Stage of life cycle
	ABC product characteristic
	Level of competition
Service	Cycle time
	Completeness
	Accuracy & Punctuality
	Customer experience
Demand	Dimension of the orders
	Delivery frequency
	Predictability of demand
	Demand volatility
	Demand level

Supply	Number of plants
	Distance from plant to client
	Level of specialization
	Exclusivity of production in a plant

Table 1 Driver list in Consumer Electronics Industry

Regression function and coefficients

The regression function and relative drivers' coefficients are obtained by using the principal component regression analysis on SPSS. The value of adjusted R^2 and F estimator shows a well goodness-of-fit.

solution=-5.8029+(0.1748)variety+(-0.116)pvd+(-0.116)conmarg+(0.3773)procomp+(0.231)stalc+(0.6049)abcchar+(0.6049)levcomp+(-0.7206)cyctime+(2.5535)complet+(-0.2756)accupun+(-0.0163)cusexpe+(0.6176)dimorde+(0.0882)delfreq+(0.3024)preddem+(-0.6049)demdvol+(-0.1906)demdlev+(0.0776)numplat+(0.1388)distptc+(-0.3341)levlspe+(-0.0795)exclpro

R^2=0.952, adjusted R^2=0.856, F (10,5) =9.884, P=0.010

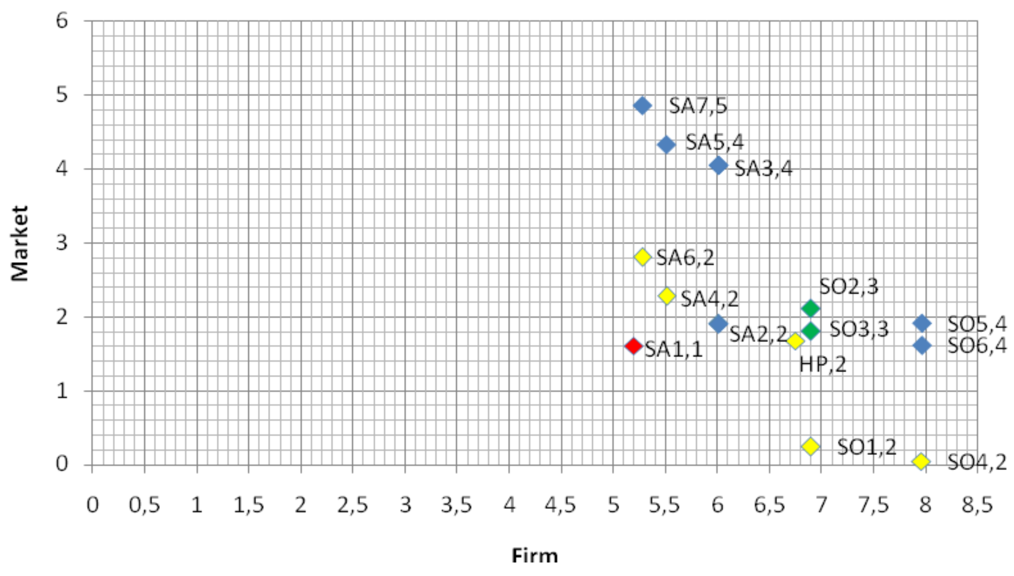
Consumer Electronics Industry	*Regression coefficient*
Constant	5.8029
Variety	0.1748
Physical Value Density	-0.1160
Contribution Margin	-0.1160
Product Complexity	0.3773
Stage of Life Cycle	0.2310
ABC product characteristic	0.6049
Level of Competition	0.6049
Cycle Time	-0.7206
Completeness	2.5535
Accuracy & Punctuality	-0.2756
Customer Experience	-0.0163
Dimension of the order	0.6176
Delivery Frequency	0.0882

Predictability of Demand	0.3024
Demand Volatility	-0.6049
Demand Level	-0.1906
Number of Plants	0.0776
Distance from plant to client	0.1388
Level of Specialization	-0.3341
Exclusivity of production in a plant	-0.0795

Table 2 Regression coefficient in Consumer Electronics industry

Relationship between distribution problem and distribution solution

We figure out the value of Firm and Market characteristics of every distribution problem and plot down the values we got on the chart (shown below). Each distribution problem is marked with its own spot on the chart, has the name and the value of distribution solution. For instance, SA1,1 means that we consider distribution problem Samsung1 (SA1) and distribution solution for this problem is 1 (direct shipment).

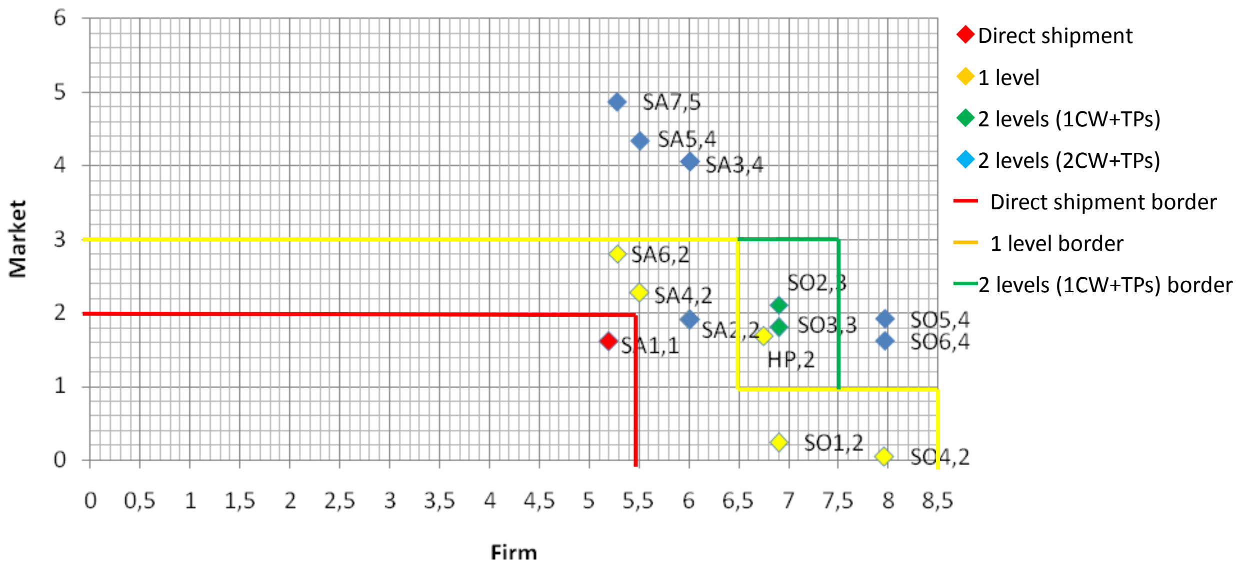


The value of the distribution solution is already scaled and the meaning of the scale is given below:

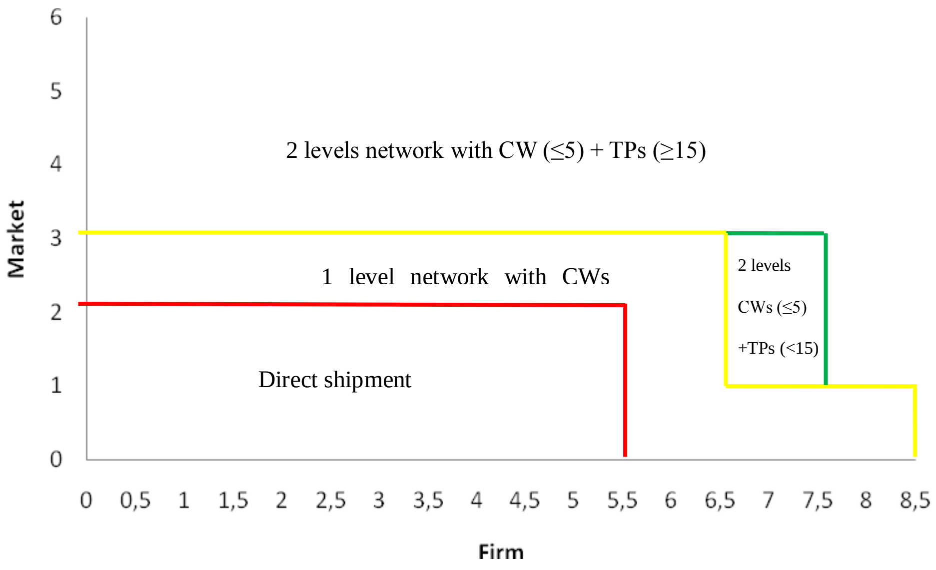
- 1: direct shipment;

- 2: 1 echelon with a few Warehouses/Transit Points (up to 3);
- 3: 2 echelons with a few Warehouses/Transit Points (up to 5) in the 1st echelon and a few Warehouses/Transit Points (less than 15) in the 2nd echelon;
- 4: 2 echelons with a few Warehouses/Transit points (up to 5) in the 1st echelon and several Warehouses/Transit Points (15 – 20) in the 2nd echelon;
- 5: 2 echelons with a few Warehouses/Transit points (up to 5) in the 1st echelon and many Warehouses/Transit Points (more than 20) in the 2nd echelon;

We use colored line to highlight the border of different distribution solution area on the chart thus we can achieve a clear illustration about the feature of distribution problem and the decentralization of distribution solution. The red, yellow and green line indicates the direct shipment, one level network and two levels network respectively.



Removing the plot of each distribution problem from the above diagram, we can achieve a clear normative distribution network selection matrix in Consumer Electronics industry. We can see that the distribution solution turns to be more decentralized in case the values of Firm and Market characteristics increase.



FMCG Industry

Available drivers after quantitative analyses

Based on the same research procedure and methodology, we obtain 17 available drivers for FMCG industry.

Product	Variety
	Product value density
	Risk of obsolescence
	Product complexity
	Level of competition
	Production strategy
Service	Completeness
	Accuracy
	Customer experience
	Punctuality
Demand	Dimension of the orders
	Number of customers
	Delivery frequency

	Predictability
Supply	Number of plants
	Distance from plant to client
	Exclusivity of production in a plant

Table 3 Driver list in FMCG Industry

Regression function and coefficients

The regression function and coefficients are shown below. The results of adjusted R2 and F estimator demonstrate the model's fit is good as well.

solutio=-14.0376+(-0.3636)variety+(-0.4481)pvd+(0.5065)riskobs+(0.218)complex+(-0.0971)compet+(1.0615)prodstr+(1.2107)complet+(0.3362)accur+(1.9791)cusexpe+(-0.2913)punct+(-0.3766)dimord+(0.1883)numcus+(0.0715)delfreq+(0.9039)predict+(-0.0919)numplan+(-0.0781)distptc+(-0.3961)exclu

R^2=1.000, adjusted R^2=0.990, F (11,1) =107.394, P=0.075

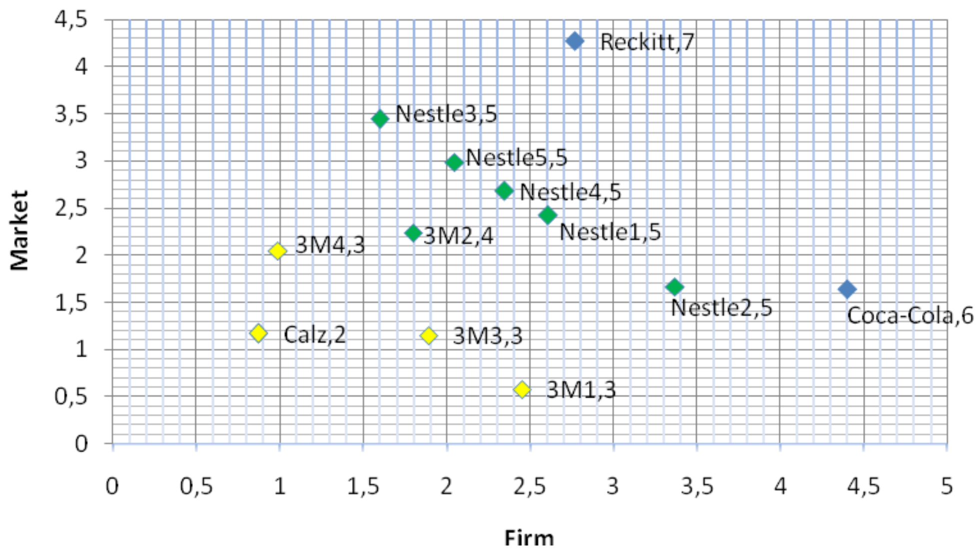
FMCG Industry	*Regression coefficient*
Constant	-14.0376
Variety	-0.3636
Physical Value Density	-0.4481
Risk of Obsolescence	0.5065
Product Complexity	0.2180
Level of Competition	-0.0971
Product Strategy	1.0615
Completeness	1.2107
Accuracy	0.3362
Customer Experience	1.9791
Punctuality	-0.2913
Dimension of the Order	-03766
Number of Customers	0.1883
Delivery Frequency	0.0715
Predictability of Demand	0.9039
Number of Plants	-0.0919

Distance from plant to client	-0.0781
Exclusivity of production in a plant	-0.3961

Table 4 Regression coefficient in FMCG industry

Relationship between distribution problem and distribution solution

Like the Consumer Electronics industry case, we plot down the values of Firm and Market characteristics on the chart (shown below). Each distribution problem is marked with its own spot on the chart, has the name and the value of distribution solution. For instance, Nestle3,5 means that we consider distribution problem Nestle3 and distribution solution for this problem is 5 (two echelons with several WH/TP in the first echelon and many WH/TP in the second one).

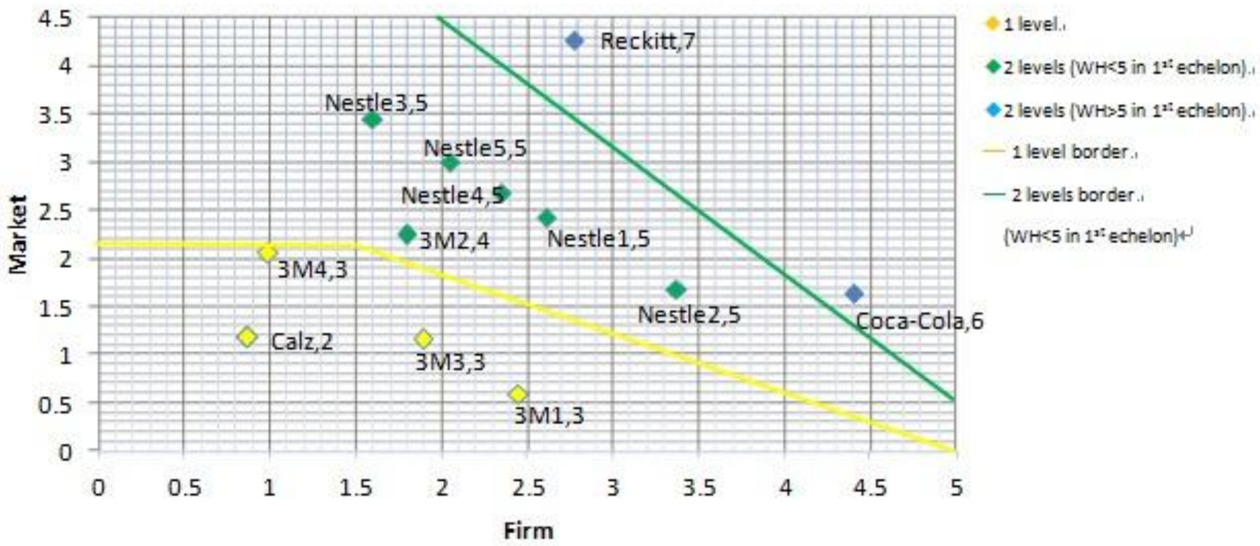


Each distribution solution is marked with color that illustrates their belonging to one of the four groups (the chart is given below):

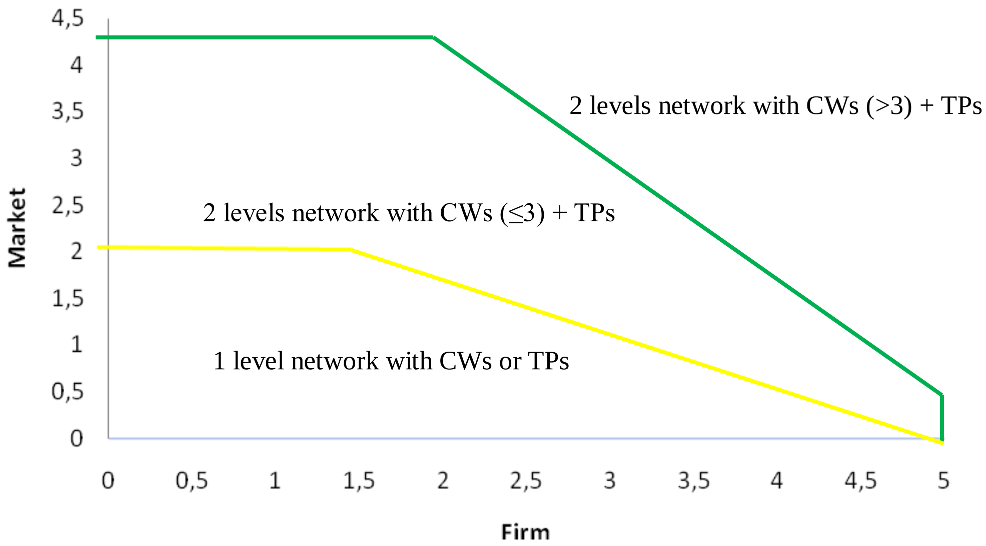
- In the group marked with yellow we have distribution solutions characterized by having just one level in the distribution network;
- In the group marked with green color we have distribution solutions characterized by having two levels in the distribution network with less than 5 Warehouses in the 1st echelons and number of Transit Points in the 2nd one

- In the group marked with blue color we have 2 levels distribution solutions with more than 5 Warehouses in the 1st echelon and number of Transit Points in the second one.

We can highlight the areas with the high concentration of the spots belonging to the particular group. The chart with the areas is presented below.



We take the same operation as the Consumer Electronics industry. The normative matrix of FMCG industry can be generated as shown below. The distribution solution becomes more decentralized if the values of Firm and Market increase.



Chapter 1. Literature Review: Methodologies to support designing-redesigning of the distribution network

1.1 Introduction

In this section we want to present some methodologies proposed by different authors related to the distribution network design problem. These methodologies provide a systematic approach to the problem of configuration (or reconfiguration) of the distribution network, splitting the decision-making process into steps, more manageable, which support is often provided using of operational research models and specific applications. In addition, for better understanding of the methodologies presented, we will provide some real examples.

The literature analysis has shown that the methodologies helping to solve distribution network design problem can be grouped into two main categories/classes. The first class is represented by so-called "complete design" methods that address the entire design problem: strategic choices (network design, transport modes, etc.), operational choices (policies to manage the flow of materials, local delivery of programs, etc.). The second group includes the "partial" methods that are useful in solving some sub-problems related to the design of the distribution network. In particular, these methods focus mainly on the question of location - allocation of facilities, or on the issue concerning the location of nodes.

It was decided to describe only the main methods belonging to the first group, as providing procedures to support the entire design problem, due to the fact that these methods are more interesting for the purposes of this research work.

After the review of the main methodologies presented in the literature, the proposal to support the decision about the design of the distribution network will be highlighted.

1.2 The definition and main methods for the design of the distribution network presented in the literature

1.2.1 Distribution network design definition and key factors influence the designing process

Distribution network design problems involve strategic decisions which influence tactical and operational decisions. Thereby, they are core problems for each company (Ambrosino and Scutella, 2005) and are considered an important strategic weapon to achieve and maintain competitive strength (Mourtis and Evers, 1995).

Distribution refers to the steps taken to move and store a product from the supplier stage to a customer stage in the supply chain. Distribution is a key driver of the overall profitability of a firm because it directly impacts both the supply chain cost and the customer experience. Good distribution can be used to achieve a variety of supply chain objectives ranging from low cost to high responsiveness (Sunil Chopra, 2003).

As an essential part of the entire supply chain, distribution process comprises several decision issues. According to the previous contributions, the distribution system design revolves around three key decision areas of: inventory policy, facility location, and transport selection routing (Ronald H. Ballou, 1993). Hence, the relevant cost elements have to be distinguished. The distribution network design affects the following costs: inventories, transportation, facilities and handling, information (Sunil Chopra,2003). Additionally, the relations between these cost components are soberly logical: as the number of facilities in a supply chain increases, the inventory and resulting inventory costs also increase. As long as inbound transportation economies of scale are maintained, increasing the number of facilities decreases total transportation cost. If the number of facilities is increased to a point where there is a significant loss of economies of scale in inbound transportation, increasing the number of facilities increase total transportation cost. Facility costs decrease as the number of facilities is reduced, because a consolidation of facilities allows a firm to exploit economies of scale.

In order to design an appropriate distribution network, the trade-off between cost elements is a crucial task (Van de Ven, 1993). Based on the experiences, each cost element is related to several variables, that is to say, the selection of variables determine the appropriate distribution channels (Payne and Peters, 2004).

Ronald H. Ballou (1993) declares the product characteristics refer to the important logistical characteristics. Regarding the product characteristics, Marshall Fisher (1997) distinguished between functional and innovative products. He asserts that demand is predictable, the product life cycle long, and the contribution margin thin for products that are primarily functional; demand is unpredictable, the product life cycle short, and the contribution margin more generous for products that are primarily innovative. By taking into account the Fisher's theory, Christopher and Towill (2005) have extended this approach to a five generic parameter classification; duration of life cycle, time window, volume, variety and variability, known by the acronym DWV3. Besides, more drivers associated the product characteristics, such as substitutability, value/weight, weight/cubic volume ratio, competition, 80-20 principle, product complexity and so on, have been mentioned by the current researchers in some contributions (Lovell et al., 2005; Sharifi et al., 2006; Stavrulaki and Davis, 2010).

In addition to the product characteristics, there are some contributions emphasized the importance of demand factor and service factor in the distribution process. Sunil Chopra (2003) analyzes the effect of response time, order visibility and returanability on the distribution network. Martin Christopher (2006) states that the demand characteristics play a crucial role in selecting the logistics channel. Fari Collin (2009) demonstrates that the task of logistics network design can be approached from product drivers and customer (demand) drivers. Indeed, we can found many drivers on the demand and service characteristics, for example, the customer experience, number of customers, level of service, demand uncertainty, forecasting accuracy, demand level, etc (Lovell et al., 2005; Sharifi et al., 2006; Stavrulaki and Davis, 2010). What is more, from a border perspective, the drivers of supplier's characteristics can determine the configuration of distribution network even in the global scope (Archini and Banno, 2003; A. Creazza et al., 2010), for instance the number of suppliers and supplier's location.

1.2.2 Methodology for planning the logistics strategy

The approach proposed by the authors Alan Rushton and Saw Richard (2000) attracts particular interest, because this is a general criterion for the problem formulation and evaluation of logistics strategy, planning that identifies the distribution as integral part of the strategic planning process at corporate level. It therefore develops a model that considers both business issues and logistics issues, underlining the importance of identifying a distribution plan consistent with the entire business strategy. The criterion presented has four sequential stages:

1. Analysis of the business environment.
2. Generation of possible logistics configurations.
3. Quantitative evaluation of alternatives generated.
4. Comparison with the company's business strategy.

Now let's have a look on them more in details.

1) Analysis of the business environment: the first step is the analysis of the business environment within which the company operates in means the grouping of all the factors to be considered in the design. These can be divided into:

- External factors: hey are typically treated as exogenous and not depending on the company. They may vary depending on the sector, of the particular company and the market. Among the most important factors are:
    - available types of transport;

- infrastructural changes;
- legislative changes;
- technological changes;
- development of information technologies (for instance, EDI);
- environmental impact;
- new trends in the sector (for example, considering the continuous growth in the level of customer service, product life cycle shortening, developing relationships with 3PL operators, the continuing trend to reduce inventories in line with lean production policies);

- <u>Internal factors:</u> these factors can be divided into qualitative factors and quantitative factors. Both of these types of information are used to describe the business in an operational context.

Typical examples of qualitative data: groups of products made by the company, sources of supply, number and type of facilities, major transportation types used, used material handling systems, cargo units, organizational, relationship with providers of 3PL , major customers, customer service performance, information systems available.

Regarding to the quantitative data are considered of the main flows of products, depending on the division or the same type of transport, the demand by region and by product, market segmentation, and service performance, analysis of the couriers, profile of stocks, products and customers.

2) Generation of possible logistics configurations: the second phase of the methodology is to generate several alternative configurations. It's very important to give space to a large number of innovative solutions, because the planning horizon for a distribution network is very wide: the decision maker must try to predict possible future scenarios in order to create a system that can be sustainable. This could cause difficulties for many companies: to overcome these obstacles it could be positive to use external consultants and brainstorming techniques. These approaches allow you to develop a long list of options, some of which may initially seem very feasible. Then follows an analysis aimed at identifying what alternatives, including those proposed, could be effectively adopted considering the planning horizon. The output of this phase is then a short list of configurations to be analyzed in the next step, a quantitative assessment.

3) Quantitative evaluation of alternatives generated: at this point starts the third phase, which provides a quantitative assessment of the alternatives selected in the previous one, using mathematical models: the limitation of these techniques is that they do not allow to have an overall vision of the distribution network design problem , but instead focus only on parts of the supply chain (location of warehouses, vehicle routing, etc.), with the consequent risk of leading to suboptimal solutions. In other words, there are no quantitative global optimization techniques, which simultaneously consider all possible alternatives can be obtained by evaluating each time the realization of potential products in all plants, the transfer of goods by all modes of transportation available through all possible network configurations. Furthermore, even if there were such a technique, the resulting computational complexity makes it impractical to use.

This third phase of the problem considering the allocation of customers to sources of production: one of the worst mistakes you can commit is to consider that the minimum cost solution corresponds always to deliver the products required by each market from the nearest facility, subject to the constraints of capacity. In some cases this may be the optimal solution, however, when facilities have significant costs of conversion (high set-up time) and different products can be manufactured with different costs depending on the plant, maybe it could be more appropriate to supply the markets production units geographically most distant, thereby supporting higher transport costs, but lower production costs. Carefully considered all the main trade-off between costs and then determined the allocation of customers to production sources, it is necessary to evaluate in detail the modes to be adopted, the structure of the network and the articulation of the stock through the distribution system. The most common approach for this type of analysis involves the use of simulation techniques and software developed for this purpose.

The most usual method is to simulate the operating costs for each possible configuration. Several heuristic algorithms are also used as the criterion of the centre of gravity, which suggest the optimal location of the deposits in order to reduce transportation costs.

The method is based on the minimization of the transportation costs by finding the centre of gravity:

$$\min(Total\ Cost) = \min_{x,y} \sum_i [F_i \cdot R_i \cdot d_i(x,y)],$$

where:

(x, y) – coordinates of the centre of gravity;

(x_i, y_i) – coordinates of both the points of origin and destination;

F_i – inbound (for the point of destination) and outbound (for the point of origin) flows;

R_i – transportation rate per unit [Euro/(km*t)] (it depends on the weight and the distance);

It’s also assumed that the transportation costs linearly depend on the distance and the transported quantity.

In order to find the centre of gravity at least two steps have to be made:

1. A first approximation of the real position of the centre of gravity has to be found (the “centroid”). It’s an approximation because the real fares are not known at the beginning (as they depend on the distances to be traveled).

$$X^* = \frac{\sum_i F_i \cdot R_i \cdot X_i}{\sum_i F_i \cdot R_i} \qquad Y^* = \frac{\sum_i F_i \cdot R_i \cdot Y_i}{\sum_i F_i \cdot R_i}$$

The lower and the more concentrated are the flows the farthest approximated the centre of gravity is from the real one.

2. Starting from the position of the "centroid" (X^*, Y^*) we have to proceed with a further calculation of the position of the "centre of gravity" according to the following formulas

$$X^{**} = \frac{\sum_i \frac{F_i \cdot R_i \cdot X_i}{d_i}}{\sum_i \frac{F_i \cdot R_i}{d_i}} \qquad Y^{**} = \frac{\sum_i \frac{F_i \cdot R_i \cdot Y_i}{d_i}}{\sum_i \frac{F_i \cdot R_i}{d_i}}$$

d_i is the distance of the point (X_i, Y_i) from the centre of gravity.

Then, we have an iterative procedure: the more the number of iterations we perform the more precise the solution (quite often just the second step is enough).

However, this method provides good results when implemented by experienced users. There are two essential steps of the simulation chain. First, it is necessary to validate the model based on a known case (for example, the current situation of the company), reproduce the flows and the performance of customer service and verify that the costs approximated by the model that are predicted with sufficient accuracy. Once validated the model it is possible to test different alternatives in order to select the best.

4) Comparison with the company's business strategy: after you have modelled all possible configurations and selected the best one in terms of performance efficiency and effectiveness, it is necessary to assess the impact on the overall business strategy of the company. This analysis must take account of three essential elements:

- Cost of capital: if you expect increases in inventories, new stores, new equipment, new vehicles the capital becomes necessary, which, in some cases, may not be available, in some situations, therefore, the financial limits exclude various strategic alternatives, which might initially seem attractive;

- Operating costs: the minimum operating cost is often the main criterion for choosing between different alternatives. However, in some cases can be accepted an increase in those costs in exchange for future flexibility;

- Customer service: although the different configurations were initially developed with goals of increasing customer service level, they require careful consideration in the final phase with respect to performance effectiveness. The initial balance between efficiency and effectiveness may shift in favour of the first element in an effort to minimize costs. In such a situation could for example be a greater demand relocation of inventory close to customers to improve service reliability.

In our opinion, the limitation of this policy is the lack of a evaluation of strategic alternatives proposed. Only the final stage, when the configurations selected is compared with the strategy, emerging issues such as flexibility or customer service. It's clear that in this way it is difficult to assess comprehensive alternative configurations, in addition, the final evaluation is not to be exhaustive, because they are not set priorities, and scores of target levels for each element considered important, but there is merely a rough estimation. It is seems necessary an analysis that takes into account from the beginning, in a detailed and accurate way with both aspects of an economic nature, such as costs and the output of the company such as customer service level, flexibility, labour relations, etc.

1.2.3 Methodology "Integrated Planning Support Framework"

This methodology was developed to overcome the major defects that characterize most of the systems to support the design of the existing distribution network. The authors start from the observation that in fact all the techniques proposed in the literature have at least one of the following defects:

- Attention is focused on a particular part of supply chain activities;
- Focus on the part of the problem of the development of the distribution network;
- Difficult applicability to the real situations, due to the excessive amount of data required.

The objective of the proposed criterion is therefore to provide comprehensive support for all the logistics issues involved in developing the distribution network, bridging the gap between the mathematical abstraction of operations research tools and the practical problems faced by designers of the network.

The IPSF, which stands for Integrated Planning Support Framework, is based on a hierarchical approach to design problem in the sub-division, more easily manageable and highly correlated with each other. For each step there is a specific technique of analysis and application support.

This system was first developed with attention to the logistics problems to be solved, and only later, it was thought to the techniques and models to be used to support each decision. This is because the system must adapt the techniques available.

The proposed methodology is divided into 4 main phases:

- Definition of the network structure.
- Deployment of the resources across the network.
- Specification of the logic of the flow management.
- Specification of operations.

1) Definition of network structure: the first step is to design the layout of the distribution network. We want to determine the number, location, size of facilities and the allocation of customers and suppliers to the different nodes of the system. The main cost factors that influence the determination of the buoyancy of the network are fixed costs and transportation costs associated with specific arcs linking the nodes. The objective is to determine the most efficient location and allocation of facilities, so that all customers throughout the area covered by the company are served effectively. The optimization technique proposed in support of this phase is a linear programming model of mixed location / allocation;

2) Deployment of resources across the network: the goal of this phase is to find the optimal distribution along the system, inventory, and final assembly activities, based on the geographical configuration of the network established in the previous step. Each product is intended for one or more structures, where it is kept in stock and, where appropriate, assembled. The economies of scale both in transport and in stocks play an important role at this stage, as well as the coverage of stocks and lead times required by customers. You must address important strategic issues concerning the centralization (decentralization) of stocks and the choice between policies "assembly to order" (ATO) and "assembly to stock" (ATS). These decisions require the solution of complex trade-off: by centralizing inventory, for example, the increase in transport costs could exceed the resulting economies of scale, in addition the level of inventories in a regional warehouse could be lower if it would be supplied by a central repository rather than from a central transit point only, etc.

Also in support of this phase is a linear programming model proposed;

3) Specification of the logic of the flow management: at this point we want to determine, for each product, the size of the stocks in each node to ensure the replenishment lot size and frequency of reorganization. At this stage it is necessary to ask whether the structure of the network so far designed, is able to guarantee the service level target within the cost limits set. It is also important to ask whether the distribution system has sufficient flexibility so it has to be able to cope with unexpected demands of customers and sudden changes on the market. In support of the decision-making we should consider the various relationships between the existing logistics system accuracy required by the clients and the level of safety stock, or between the "economic order quantity" and' "economic transport quantity". The designer must consider all of these relationships simultaneously, since they are closely related. In addition, the basic characteristics of the network, in certain earlier stages, can now be checked through a sensitivity analysis.

The model in support of this phase has not yet been completed;

4) Specification of operations: with the support of the application developed specifically for this phase, the designer should be able to tackle questions such as:

- choice of procedure by which to ship customers' orders;
- the way of assembling and sending loads;
- rules for programming the final assembly operations;
- procedures for stock replenishment;
- routing algorithms for vehicles;
- policy of selection of the suppliers;
- procedures for communicating demand variations to the suppliers;

All the procedures established in this phase should be tested and controlled: in particular, such policies may be subject to a refinement to minimize costs while ensuring the fixed level of service. The additional objective of this phase is to evaluate the specific network configuration in terms of daily activities (operational): you want to understand the consequences of an operational nature related to the adoption of a specific spatial distribution, and then evaluate its performance.

Although all the steps are closely related, this does not exclude the possibility to address them individually. However, in order to avoid suboptimal solutions, you must, within the limits of time and cost, verify the results obtained with specific models. The designer should compare the results of each step with different techniques and evaluate if the overall solution is in line with expectations. For example, the first phase of the methodology uses a simple linear function for the evaluation of transportation costs: if the configuration of the network resulting in the next step generates significantly different transport costs, it is necessary to revise the parameters of the cost function adopted in the model in support of the previous phase.

In order to support the first three phases have been used several types of optimization models, while the last has been chosen by computer simulation. The proposed mix ensures the best compromise between the available techniques and is able to offer strategic insight of the influence of main parameters (marketing, financial, environmental and government) on the structure of the network. However, the precise definition of the distribution requires much more information than what optimization models are able to treat. In other words, to select the best alternative, the designer should create and evaluate various distribution plans corresponding to different strategic scenarios. When used in an interactive optimization facilitates the examination of a wide range of alternatives: different solutions can be examined under different parameters, such as costs, capacity constraints and customer demands. It is important to remember that the results of the optimization techniques should not be interpreted as the best choice of all: in fact, the models are based on a simplified representation of the real world. This implies that the results, along with other factors not modelled directly, as the business climate, trade union and political tensions that characterize the specific country under consideration, be used as information and support for the designer.

Unlike the policy described in the previous subsection, this methodology is much more complete and comprehensive as it addresses not only issues of strategic nature, but also the problems of a more strictly operational. However the policy does not give a precise indication of the necessary data for the design and even the mode of finding the same. In addition, there is no comparison of the logistics strategy with corporate business strategy, which could result in inconsistencies as a result of the implementation.

1.2.4 Ballou's methodology

Ronald H. Ballou is one of the most famous authors in the field of logistics, he is a professor of "Logistics Management" in "Weatherhead School of Management, Case Western Reserve University", and author of several books including "Business Logistics Management" and numerous articles for the journals "Journal of Business Logistics" and "International Journal of Physical Distribution and Logistics Management".

According to Baallou distribution network design is a conventional issue in logistics and has significant impact on the whole supply chain process. In the past two decades, many contributions involve the topic of distribution network in both theoretic and practical areas, which mainly focused on the analyses of logistics costs and case study for specific practitioners respectively (Ballou.1995, Jayaraman, 1998; Nozick *et al.*, 2001; Payne *et al*., 2004; Lalwani *et al*., 2006; Manzini and Gebennini, 2008). Ballou suggested, in support of the distribution network reconfiguration problem, a methodology divided into several stages, each described below in detail.

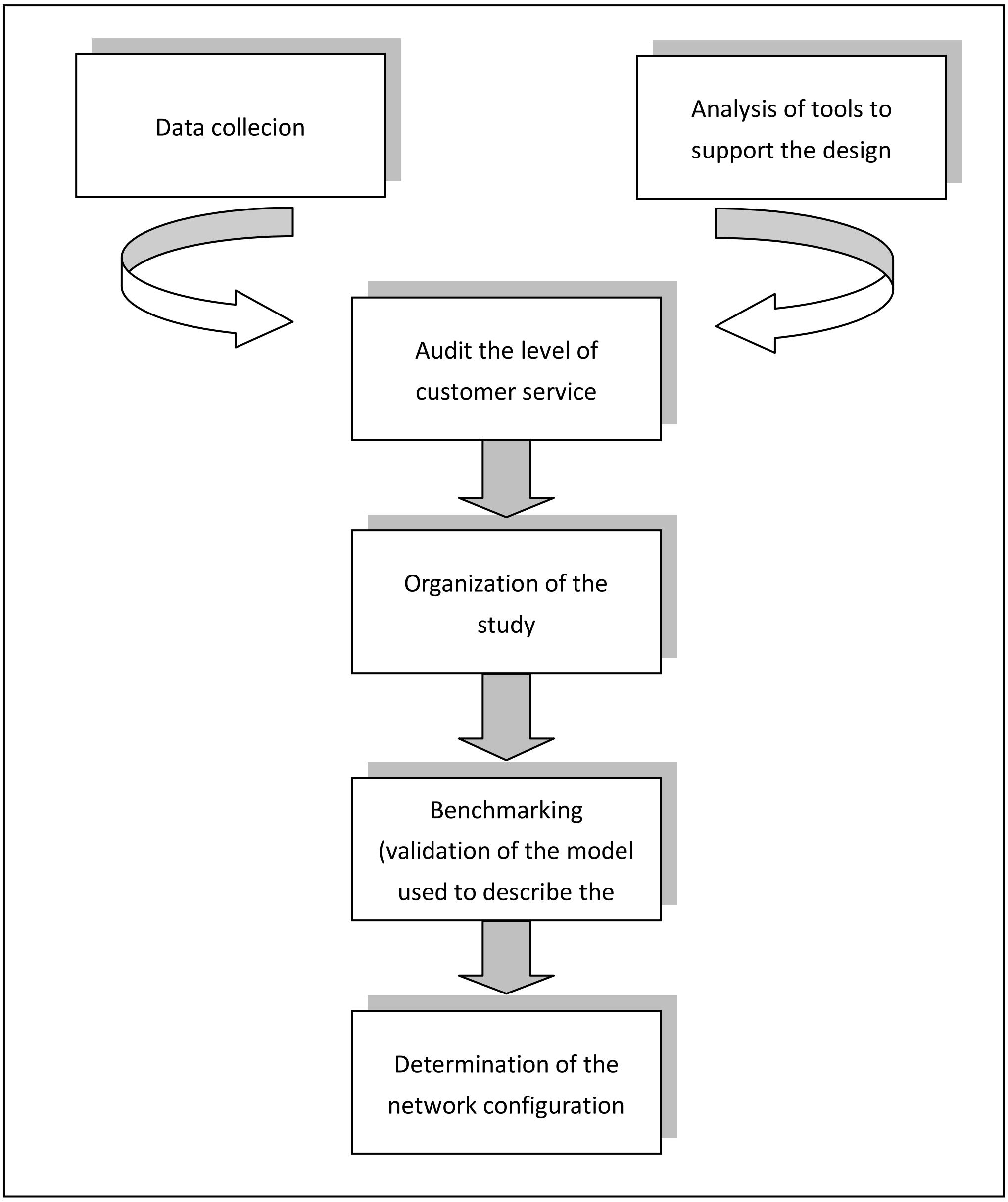


Figure 2 Flow chart of the Ballou's methodology

1) Data collection: network planning often requires a considerable amount of information from different sources. The most important data to be collected include:

- a list all company's products;
- location of customers, stores and factories;
- demand divided by product and by geographical area;
- freight rates;

- transit time, transmission time and rate of delivery of the order;
- storage costs;
- costs of production and purchasing (make-or-buy decision);
- size of shipment for each product;
- level of inventories by geographic location, product and techniques used to control inventory level;
- models of replenishment adopted (frequency, lot size, period of replenishment);
- cost of processing orders;
- cost of capital;
- customer service;
- equipment and facilities available with its capacity limits;
- current distribution models.

Many companies do not have logistics information systems capable to generating the data listed above. It is therefore necessary to find information from all possible sources, internal and external. The primary source includes all commercial documents such as sales orders, generally collected on the corporate information system and document production, purchasing, shipping, storage and handling, constantly checked and updated by the company. Other important sources of information are represented by the accounting records, especially with regard to cost, logistics research conducted internally but also externally, journals, reports of research sponsored by government, academic journals, judgments and opinions of people who work in the company.

Once you have collected all data deemed necessary, they must be organized, grouped and aggregated, so as to support the process of network planning. You must decide for example what is the unit of measurement to be used during the analysis (measures of weight, volume, currency, etc..) And then to relate all costs to that size, you have to group the products according to the similar characteristics for a more practical approach to the problem, it is appropriate to establish the profile of orders and shipments, group customers by geographical area, estimate the costs of internal and external transport, the costs of structures (fixed costs, storage and handling), the capacity limits, etc.. It is only then that the details become important information for the designer.

2) Analysis of tools to support the design: after getting adequate information for network planning, it is appropriate to analyze the available techniques used to support different decisions about the design problem. Although many models are developed, you can classify them into a few categories: techniques based on statistical maps, spreadsheet, comparison, simulation models, heuristic models, optimization models, expert systems.

The data collected in the previous step and the tools used to support the different project phases are combined, with the help of computers, the so-called "Decision Support System" (DSS). This system provides a valuable aid to decision making, allowing the user to interact directly with the database, to send data to the models, and describe the results in the most comfortable and effective. Some DSS provide an environment in which the designer can interact, allowing complete freedom for the final choice, in other cases the system may provide the best solution to implement. The first situation is typical when you have to make more strategic decisions, while the second characterizes mostly the operational design of the network;

3) Audit the level of customer service: now starts the planning process itself. A logical, but often optional, first step in designing the network is to analyze the level of customer service. This leads to the demand of customers who currently receive benefits of efficiency and level of service you would like to receive. For this purpose it is possible to conduct interviews via e-mail or send a questionnaire. The external audit would be followed by an audit conducted in-house. The objective is to establish the effectiveness of current performance that the company is able to provide and establish targets for service network design. However the reality is often more common for the service level goal is set by management or is set equal to the current one;

4) Organization of the study: the next step typically involves the definition of the purpose and objectives of the project, the organization of work teams, the assessment of availability of the required data collection instruments and procedures. It should be noted that the study team must be formed primarily by people whose work area may be affected by the results of the project and should also include all those able to provide valuable insights and opinions. It is particularly useful to include in the working group responsible for the production and marketing functions. The tasks in this phase are as follows:

- analysis of the present logistics situation in terms of cost, level of service and logistics, to provide a basis for assessing the potential alternative configurations. In other words, you must define a reference point for costs and the level of service, for which the improvements will be evaluated. Furthermore, due to changed circumstances (freight rates, handling costs and inventory, demand variations, etc..), this reference point may change over time: it is therefore necessary to review it periodically;
- interview the management and team members to ensure understanding by everyone of project goals and develop the knowledge necessary to define alternative logistics systems to be evaluated during the study;
- prepare a preliminary list of logistics, marketing policies and guidelines deemed critical in the evaluation of different alternatives;
- specify the criteria for evaluation and study of the output in terms of cost and service level;

- select the techniques and instruments deemed suitable for the analysis of different alternatives, prepare the input data, estimates of costs and time;
- to incorporate the specific information requested and provide input to the procedures;
- identify any manual corrections needed to supplement the results of the model, for a more accurate assessment of the impact of cost and service level;
- conduct a group to study the results, conclusions, the criterion for selecting models, and design the work plan;
- estimate the benefits in terms of cost reduction and/or improvement of the level of service expected from the study;
- suggest recommendations for immediate improvements in cost and service;
- the method of project management, estimating personnel, computer systems and other support tools needed for work in progress.

5) Benchmarking: this phase is the validation of the modelling or other analytical processes adopted during the planning. We want to create a landmark using the company's current policies and distribution models. The modelling is the most common approach to the problem of network design and benchmarking plays an important role in the analytic process. All the study design is to compare the network in its current configuration with a new and improved structure. Of course management would reflect that the comparison as much as possible the actual conditions, but the models are much easier to manipulate than the reality, so the modelling is adopted in order to make comparisons.

Benchmarking is the process by which it is checked if the modelling process faithfully reproduces the costs and the level of service corresponding to the current distribution structure. In this way you are sure that when the model represents a network configuration not yet experienced in reality, it measures the cost and with reasonable accuracy the level of service.

Benchmarking proceeds as follows: first we establish groupings of representative products. The optimal number is derived from a compromise between the distinctive characteristics of products, especially in terms of cost and service, and benefits related to the reduction of data to be processed, resulting from the aggregation of products. Then sales are aggregated geographically into a manageable number of demand centres. We define customer service policies for each group of goods, and collected data on the most relevant cost categories in the design of the network, such as transportation, inventory, handling and production/purchase. We define the current flow of goods and inventory maintenance policies. Finally, we evaluate, from the data collected, the relationship between costs, demand and service. The information is organized into categories of cost and service, in order to be compared with the output. The team analyzes the results to evaluate the correspondence or explain any deviations. Once the validation process is complete, you can proceed with the selection of the best configuration distribution;

6) Determination of the network configuration: the modern approach to planning the configuration of the distribution is to use the computer to manipulate the huge amount of data involved in the analysis. The models that address the problem of locating facilities in the network are particularly popular. They are used to answer questions such as number, size and location of factories and warehouses, to the allocation of demand nodes; assignment of products to stock in the various structures. However, there is an integrated model capable of tackling the entire design problem. It is therefore necessary to break the overall problem in more manageable parts. In practice, this means determining the location of structures, policies, inventory, transport planning, etc. separately, but following a recursive approach, so the results of analysis are used as input to another analysis. The objectives of the reconfiguration of the network are as follows:

- to minimize all relevant logistics costs, while maintaining the service level objective;

- to maximize the level of customer service, considering the limitation of fixed costs;
- to maximize profits by maximizing the difference between the revenue from an increase in the level of service and costs resulting from the performance of such guarantee of effectiveness.

The third goal is to better grasp the business point of view, however due to the difficulty connected with the evaluation of the relationship between the increase in the level of service and increased sales, most of the models are built around the first objective function.

Often there may be errors in the estimated costs and information as input for network planning. It is therefore appropriate to conduct a "what-if" analysis, which is to repeat the analysis to determine the best configuration, using the network scenario selected and modified cost parameters and capabilities. It's a more concrete way to use the analytic process, which allows a more robust network design and corresponding to reality. The "what-if" analysis is often considered more valuable than the models, as it allows the decision-maker to evaluate the optimal solution given a particular set of data. This is because often there are small differences in cost between alternative network configurations and because a more robust network design is often better than the optimal solution from the mathematical point of view.

The proposed methodology is very interesting: they are described in detail and relevant data for planning, finding sources of data and the means of aggregation, and tools to support the design of the network, with its advantages and disadvantages, both the sequential steps to follow when designing. As regards the latter, the most innovative, first mentioned in the proposed methodology and not present in the second, is the activity of benchmarking, which reasonably should precede the application of any analytical tool. Regarding the definition of the configuration distribution the proposed criterion is rather similar, the global design problem is divided into several parts, each addressed with the help of simulation models, or heuristic optimization. However, data are not an indication of the technique to use for each stage, but provides an overview of the tools available, leaving the designer free to choose.

1.2.5 Distribution network selection matrix

In this research, we focus on the strategic planning of the distribution network design. The main objective is to optimize the existing distribution network selection matrix, which aims at finding a rough distribution network structure that fits the specific distribution problem. The normative distribution network selection matrix is a tool in order to help the users to make the strategic decision in distribution process. Hence, making the correct strategic distribution decision depends upon the accuracy of normative distribution network selection matrix representing the relationship between distribution problem and distribution solution. The following diagram is the theoretic construct of existing distribution network selection matrix.

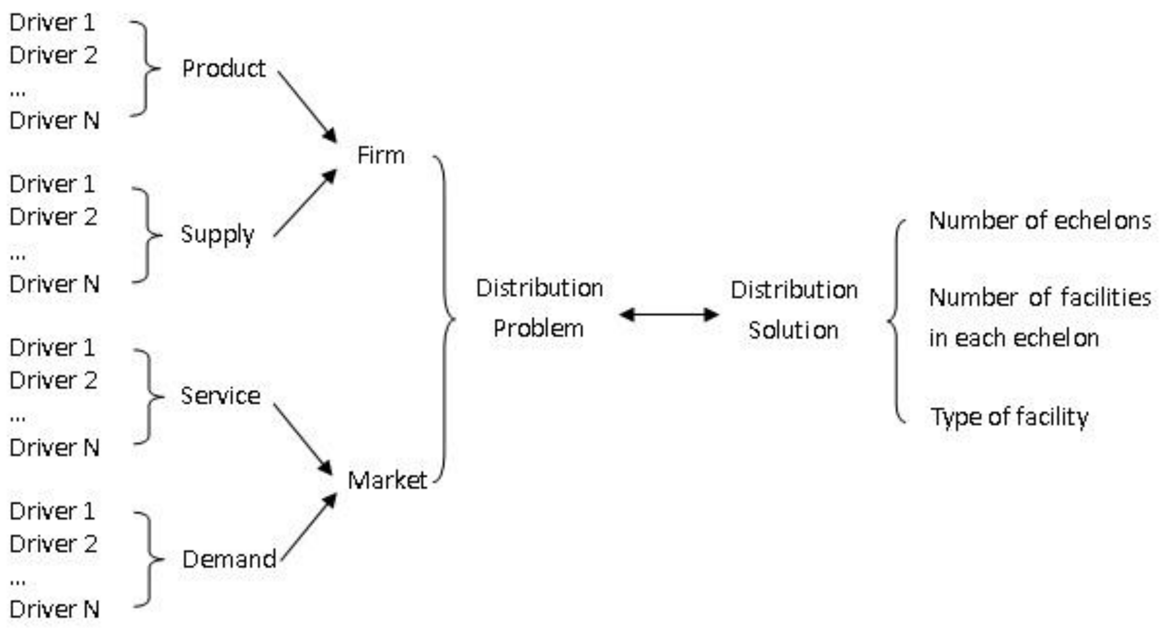


Figure 3 Theoretic model of distribution network selection matrix

Regarding the theory model, the distribution problem can be defined by a range of different drivers. These drivers are classified into four macrodrivers including product, demand, service and supply characteristics, each macrodriver can describe one feature of the distribution problem. Furthermore, the four characteristics can be integrated into two groups based on the different determinants. Hence, the characteristics of Firm and Market could be use to depict the distribution problem from macroscopic point of view.

The distribution network solution, or called distribution structure in literature, involves some issues like number of echelons, number of facilities for each echelon in the distribution network and type of the facility.

The existing normative distribution network selection matrix was developed by analyzing the distribution solutions of a number of leading companies, and evaluating the distribution problems of these companies in a qualitative way, eventually, the relationship of distribution problem and distribution solution can be represented in a two-dimension graph. There are two fundamental assumptions in this model. Firstly, every driver seems to be important to describe the distribution problem. Another hypothesis is that each driver is perceived has equally weight. In fact, these two hypotheses may bring the inaccuracy of relationship between distribution problem and distribution solution. Therefore, this research intends to adopt quantitative approach to examine and/or improve the accuracy of normative distribution network selection matrix.

1.3 Mathematical methodologies coupling the selection process

1.3.1 Mathematical methodologies coupling the selection process

To optimize the distribution network selection model, an extensive literature review on the relevant quantitative approaches was completed. By taking into consideration the objectives of this research, we need to measure the importance of the drivers in order to find the more important ones, and obtain a multiple regression result for these drivers for the sake of making the model to be more accurate.

Researchers have developed several methods to measure attribute importance (Fontenot et al., 2007). Yet, a literature review suggests that logistics researchers have traditionally used stated importance ratings and statistically inferred importance analysis.

Logistics researchers usually use stated importance ratings to measure attribute importance by rating the importance for each attribute from "not important" to "critically important", or by using a five-point Scale, where 1 means "no importance" and 5 means "critical importance". Many logistics research studies have taken this approach (Murphy and Poist, 2000; *Gibson et al.*, 2002; Min and Lambert, 2002). However, although common in practice, this method has major research limitations. The significant limitation is that stated importance ratings often discriminate poorly among attributes. Research often finds all attributes to be "critically important". If all attributes are found to be "very important", then the usefulness of research findings is extremely limited (Garver *et al.*, 2010).

Despite many logistics research studies show little variation in the importance of attributes when using stated importance, for example, the adoption of a seven-point scale rating (Crosby and LeMay, 1998), stated importance measures often discriminate poorly among logistics attributes.

In order to overcome the problem of stated importance ratings, the statistically inferred importance rating is an effective alternative. In this technique, researchers correlate or regress attribute performance against a dependent variable, or use factor analysis or apply an integrated approach to measure the importance of the attributes. In logistics research, all those methods have been used to infer attribute importance. For example, Patterson *et al.* (2003) used structural equation modelling to infer the importance of key drivers for evaluating the adoption of new technologies on supply chain management. Zhang *et al.* (2005) applied structural equation modelling to infer the importance of attributes on logistics flexibility. Skipper *et al.* (2009) used structural equation modelling and regression to examine the importance of risk drivers influencing the supply chain flexibility. Wanke and Zinn (2004) used correlation analysis and logistic regression analysis to infer the importance of influence on strategic decision making.

Considering the features of stated importance ratings and statistically inferred importance ratings, we use an integrated approach consisting of five-point Liker scale, correlation analysis and factor analysis to carry out the importance measurement of attributes. To achieve the accuracy of the distribution network selection matrix, regression modelling can be used in order to figure out the precise value of drivers after the importance measurement. The literature review suggests that the principal components regression (PCR) can be better work rather than the least square regression due to the drivers may highly correlated (Filzmoser, White Paper; Sutter *et al.*, 1992).

Chapter 2. The Selection of Drivers

We found 34 drivers involving four macrodrivers by literature study. In this section, we will discuss the definition and the measurement method of each driver. The first part argues the driver's implication and the effect on the distribution network. With regard to the second part, we will demonstrate the measurement method and the relationship between the driver's value and logistics costs.

2.1 Definition of the drivers

Product Characteristics

- **Variety (number of products)**

Variety indicates the 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. The main impact of products variety 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.

- **Product Value-Density (PVD)**

Product value density is widely recognized as an important factor but has not received much attention in the academic literature. Value density is highlighted in particular as a key determinant of the level of centralization, with high value density products being manufactured at a few large-scale plants. Voordijk (1998) identifies more centralized inventory holding associated with higher product value densities. As the value density of a product decreases the percentage of additional distribution costs increases.

Products that have low value density (coal, iron ore, bauxite, and sand) have low storage costs but high movement costs as a percentage of their sales price. Inventory carrying costs are computed as a fraction of the product's value. Low product value means low storage cost because inventory carrying cost is the dominant factor in storage cost. Transport costs, on the other hand, are pegged to weight. When the value of the product is low, transport costs represent a high proportion of the sales price.

High value density products (electronic equipment, jewelry, and musical instruments) show the opposite pattern with higher storage and lower transport costs. This results in a U-shaped total logistics cost curve. Hence, firms dealing with low value density products frequently try to negotiate more favorable transportation rates. If the product has a high value density, minimizing the amount of inventory maintained is a typical reaction.

- **Physical Density (kg/m^3, Weight-Bulk Ratio)**

The density of a product is defined as its mass per unit volume. Products of low physical density offer poor utilization of the storage and transportation system. Such products include boats, lampshades, and furniture.

The ratio of product weight to bulk is a particularly meaningful measure, as transportation and storage costs are directly related to them. Products that are dense, that is, have a high weight-bulk ratio (rolled steel, printed materials, and canned foods), show good utilization of transportation equipment and storage facilities, with the costs of both tending to be low. However, for products with low density (inflated beach balls, boats, potato chips, and lampshades), the bulk capacity of transportation equipments is fully utilized before the weight-carrying limit is reached. Also, the handling and space costs, which are weight-based, tend to be high relative to the product's sales prices.

As the product density increases, both storage and transportation costs decline as a percentage of the sales price. Although price may also be reduced by lower storage and transportation costs, they are just two cost factor s among many that make up price. Therefore, total logistics costs can decline faster than price.

- **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 fashion goods and consumer electronics goods.

- **Contribution Margin**

Contribution margin equals price minus variable cost divided by price and is expressed as a percentage. High profit margin products increase the cost of shortage, 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).

- **Substitutability**

In the case that the product is out of stock, the company could supply another product to satisfy the same customer need. If the company could not supply another product in case of out of stock, the customer may immediately go to a competitor to resource the product (Tim Payne, Melvyn J.Peters, 2004). Substitutability can be viewed in terms of lost sales to the supplier. Lower substitutability usually means a greater chance for a customer to select a competing product, thus resulting in a lost sale for the supplier.

- **Product Complexity**

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.

Demand is predictable, the product life cycle long, and the contribution margin thin for products that are primarily functional. Demand is unpredictable, the product life cycle short, and the contribution margin more generous for products that are primarily innovative. An innovative product needs a responsive supply chain, a functional product an efficient one.

- **Stage of Life Cycle**

The concept that products and groups of products advance through a sale cycle of introduction, rapid growth, maturity, and decline can be useful to strategic logistical planning. Each stage of the life cycle can mean a different network configuration would be most economical. Products that are in the introductory stages of the life cycle may receive limited distribution unless given a promotional push. When products are in their growth and maturity stages, more extensive distribution in the form of many stocking points and high stocking levels will likely be the best strategy when combining revenue and cost considerations. Products in their decline stage, where sales levels cannot support extensive distribution, are best consolidated into fewer locations (Ronald H. Ballou, 2007). Christopher and Peck (1999) highlight the increased importance of a supply chain that delivers reliability where products exhibit short life cycle.

- **Handling characteristic**

Differences in handling characteristic of products can also impact on distribution network costs and, therefore the most appropriate distribution network selection. For example, differences in the level of security or safety requirements of the vehicle can affect the type of mode or vehicle choice for a product, and can also lead to network constraints in the type of operation that can be used (Rushton et al.,2000).

- **Shelf Life (length of shelf life)**

Products with a short shelf life would lend themselves to networks that hold low levels of inventory and utilize faster transport modes (Lovell, Saw, and Stimson, 2005).

- **Value**

As supply chain costs are mainly activity driven, and the associated costs are based on this level of activity, then a higher value orderline (high value product) can stand a higher amount of activity as it passes along the supply chain, and still produce a reasonable return (Tim Payne, Melvyn J. Peters, 2004).

- **ABC product characteristic**

Based on the 80-20 concept, the products could be grouped or classified by their sales activity. The top 20 percent might be called A items, the next 30 percent B items, and the remainder C items. Each category of items could be distributed differently. A items might receive wide geographic distribution through many warehouses with high levels of stock availability, whereas C items might be distributed from a single, central stocking point with lower total stocking levels than for the A items. B item would have an intermediate distribution strategy where few regional warehouses are used.

- **Competition**

The effect of competition in the product line can be an important determinant of the final placement of warehouses, the stocking levels, and the method of delivery. Because physical distribution service can have a positive effect on sales, network configuration is often brought in line with that of competition as a way of avoiding lost sales. If competition maintains a high service level through close proximity of warehouses to customers, the network is also likely to conform to that of the competition (Ronald H. Ballou, 2007).

- **Production Strategy**

The foundation of production strategy is based on identifying four representative production modes (build-to-stock (BTS), assemble-to-order (ATO), make-to-order (MTO), and design-to-order (DTO)) that are appropriate for different products depending on the product's characteristics.

1) Build-to-stock

BTS is very common because they are appropriate for high volume, low profit margin, and commodity products. Such products tend to have a relatively stable demand, which can be forecasted with a low degree of error when accurate historical demand information is available.

Manufacturers in this production strategy tend to push product into retailers' points based on end-product forecasts. The product flow relies heavily on distribution centers and retailers that deliver products to consumers in the most cost-efficient manner. If the volume allows it, manufacturers may also make direct-to-store distribution agreements with large retailers.

This type of production strategy is the most prone to the bullwhip effect and must relentlessly focus on minimizing costs. For example, warehousing costs are reduced through the cross-docking concept, while transportation costs are minimized through the shipment in full truckload, purchasing in large volume can further increase the efficiency.

2) Assemble-to-order

This kind production strategy provides customers with a limited number of choices in the configuration of the final product. ATO is typically appropriate for higher priced consumer goods that are assembled to individual end customer specifications. These products are also frequently updated with the latest technologies, increasing their rate of obsolescence, have low profit margins and tend to operate within very competitive environment.

The ATO logistics process is typically controlled by the firms. These are often small number of intermediaries in distribution network, with end products either going to retailers for delivery to the end customer, or directly to the end customer.

The major management issue with the ATO logistics is the need to balance the pressures of achieving low cost, timely production and delivery while embrace both agile and lean elements in their capabilities.

3) Make-to-order

The MTO production strategy provides consumers with the opportunity to have at least some part of the product uniquely built to their individual specification. These products are low volume and high profit margin.

In the logistics process, the smaller number of supply chain intermediaries allows for a faster response to customer requests, as well as easier sharing of information among the supply chain partners. To ensure satisfied customers, the logistics processes of MTO must minimize the delay.

4) Design-to-order

The ability to completely customize a product is the key characteristic of DTO, resulting in the customer having the greatest amount of input into the finished product. DTO process allows customers to design the products to meet their unique individual tastes. Such products are by definition low volume (often one), with highly variable characteristics, and very high priced. Forecasting is hardly done at all. There is typically no finished goods inventory in DTO manufacturer point.

The DTO logistics process is usually controlled by the designer and builder, which typically deals directly with the end customer, and lead time tends to be long. DTO logistics must provide its diverse customers with the highest quality of product and service in a highly uncertain environment.

Service characteristics

- **Cycle Time**

Number of days it takes to deliver an order from the moment it was placed by the customer till customer receives the goods. The order cycle contains all the time-related events that make up the total time required for a customer to receive an order. The individual order cycle time elements are order transmittal time, order-processing time, order assemble time, stock availability, production time, and delivery time.

The stock availability has a dramatic effect on total order cycle time because it often forces product and information flows to move out of the established channel. A normal channel may be to supply customers through a warehouse. When stock is not available in warehouse inventories, a second, or backup, distribution channel may be used.

Another primary element in the order cycle over which the logistician has direct control is the delivery time – the time required to move the order from the stocking point to the customer location. It may also include the time for loading at the original point and unloading at the destination point (Chopra, 2003).

- **Completeness (item fill rate)**

It is the probability of having a product in stock when a customer's order arrives. An increase in the required completeness 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 customer in terms of completeness can, therefore, influence the most appropriate supply chain selection (Lovell, Saw, and Stimson, 2005).

- **Returnability**

Returnability represents ease with which a customer can return unsatisfactory merchandise and the ability of the network to handle such returns.

For some type of products, the possibility to return them become very important, for example, for electronic goods with parts that has 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 reuse them or to sell as raw material to other companies.

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 shipment, reverse supply chain will be expensive and difficult to implement (Chopra, 2003).

- **Accuracy**

It represents the capacity of the firm to fulfill orders in the exact way as it was placed by the customer.

- **Tracking (order visibility)**

It indicates the capacity of the firm to provide relative accurate information about the state of order in progress, or the ability of the customer to track their order from placement to delivery (Chopra, 2003).

- **Customer Experience**

Customer experience means ease with which the customer can place and receive the order (Chopra, 2003).

- **Punctuality**

It measures how accurate the supplier can deliver product to the points of customers within required cycle time.

- **Ability to Expedite Orders**

Expedited shipments are those that require special delivery in order to reduce the normal order cycle time. Although expending costs considerably more than standard delivery, the cost of a lost customer may be even higher (Ronald H. Ballou, 1999).

Demand characteristics

- **Dimension of the Order**

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. If the dimension of the order 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 product an increase of handling and inventory costs without a reduction in transport costs. With regard to smaller order size, 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 & Banno, 2003).

- **Number of Customers**

This attribute indicates the total number of customers the company has. 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 & Banno, 2003). On the other hand, this attribute is used to try to assess the risk of obsolescence. If a product has a few amounts of customers in a year, then it can be described as highly customized.

- **Frequency of delivery**

This driver corresponds to the amount of deliveries for unit of time (day, week, and month). 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 deliver the products more frequently to the customer, it is reasonable to think that the product should be closer to the client, which causes 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 in the handling and transportation costs (Archini & Banno, 2003).

- **Seasonality**

Seasonality indicates 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. 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 (Archini & Banno, 2003).

- **Predictability of demand**

Predictability of demand represents the average margin of error in the demand forecast at the time production is committed. The effect of demand predictability on supply chain design is widely discussed in the supply chain literature (Fisher, 1997; Lovell, Saw, and Stimson, 2005). The predictability of the demand has an impact on inventory holding policy 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, and Stimson, 2005).

- **Spatial Density**

The definition of spatial density is that 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.

- **Demand Volatility**

Demand volatility is a measure of overall demand variability. The volatility of a product is determined by dividing the standard deviation of demand over a 12-month period with the mean demand. It gives a representation of how variable the demand pattern is in relation to the average demand. A great volatility shows significant reductions in service, with associated larger levels of inventory to support that lower service level.

- **Demand Level**

This driver measures the total demand of a product in a specific time period. It influences factors such as modes of transport and warehouse size and location where the economies of scale of production or distribution influence supply chain costs.

Supply characteristics

- **Number of Plants**

Number of plants indicates the total number of plants a company has. 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 shipment.

- **Distance from plant to client**

The location of customers and the location of the plants have to be known in order to calculate the distance. The distance from plant to client affects total logistics costs since with the increase of distance there is a direct increase of transport cost. Also the cost of maintenance of inventories varies since with distance increments the stocks tend to grow due to decentralization.

- **Level of specialization**

The definition of level of specialization means the plants produce only one family of products. As the level of specialization of the plant in a supply chain decrease, the inventory and resulting inventory cost raise due to decentralization and loss of economies of scale. On the other hand, if the level of specialization increases, total transportation cost will also rise by increasing the distance from plant to clients or warehouses. Facility cost decreases as their number is reduced because consolidation allows the firm to exploit economies of scale (Chopra, 2003).

- **Exclusivity of production in a plant**

It is the exclusivity of realization of a product in one plant, or the level of production concentration in one plant. To some extent, this concept is adverse to level of specialization.

2.2 Measurement method of the drivers

Product characteristics

- **Variety (number of products)**

The variety of products could be measured directly in number of product codes. It can be said that with a great variety of products, the criticality of the driver raises and the distribution network should be centralized in order to avoid duplication and increase of the level of stock.

- **Product Value-Density (PVD)**

The unit of measurement used for the analysis is Euro/kg, and from the theoretical explanation above, the products with high value should be considered as critical for the distribution network design. In this case, a centralized network might be implemented in order to reduce the level of inventory and its handling cost, but having the appropriate cycle time to avoid stock out.

- **Physical Density (kg/m^3, Weight-Bulk Ratio)**

The density is measured in unit of Kg/ m^3. In theory, products having low value of density should be distributed with a centralized network in order to facilitate primary transport policy and reduce the amount of space required for inventory.

- **Risk of Obsolescence (days)**

The risk of obsolescence is measured in days. Theoretically, the products with high risk of obsolescence should be distributed with a centralized network in order to reduce the cycle time and the level of stock.

- **Contribution Margin**

The contribution margin is a relation between the production cost and the price of the product sold and is expressed in percentage. 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.

- **Substitutability**

This driver could be measured by the value of number of products codes per product family. This value represents the substitutability within one company. The lost of stock out is reduced, if the value is high.

- **Product Complexity**

This attribute is measured as the level of innovativeness of the product. The distribution network should be centralized if the product complexity is high, in another word, the product is more innovative. Furthermore, the total logistics cost is higher, since the firm has to adopt agile logistics strategy in order to distribute the innovative product to customer in a responsive way but not lean way. However, the level of innovativeness is a very qualitative driver, which has to be evaluated in a subjective way. The R&D investment, the number of R&D centers, the depth of research and development activities, the number of patent, and the number of new products launched could be considered in order to assess this driver.

- **Stage of Life Cycle**

The stage of life cycle could be measured and represented as the following table:

Scale	***Stage of life cycle***
Low	Introduction
Low-Medium	Introduction-Growth
Medium	Growth, Decline
Medium-High	Growth-Maturity
High	Maturity

Table 5 Measurement criterion on stage of life cycle

This driver should be measured in a subjective way. The risk of obsolescence, the level of innovativeness and the number of new products have deeply impact on this driver. If the products are highly innovative, which represents the risk of obsolescence is high, and the company has to launch more new products in order to maintain the market position only if the research and development ability of the company is high enough. The result is that many products are on the stage of introduction or decline.

- **Handling characteristic**

The driver could be measured according to how many handling requirements must be fulfilled. There are five main handling requirements: Temperature, shockproof, waterproof, fireproof, specific package (in order to prevent the surface of product from scratching). The fewer requirements needed by product, the low impact on the logistics cost.

Scale	***Handling characteristic***
Low	0-1 requirement
Low-Medium	2 requirement
Medium	3 requirement
Medium-High	4 requirement
High	5 requirement

Table 6 Measurement criterion on handling characteristic

- **Shelf Life (length of shelf life)**

This drive is measured in days. The products with short shelf life would bring the comparative high stock cost and related high handling costs in the logistics process.

- **Value**

The value of a product is measured by price on shelf in unit of Euro. Theoretically, the total logistics cost is higher if the product with high value.

- **ABC product characteristic**

It is hardly to investigate the exactly number of items sold by each business unit in a company. However, we are able to investigate how many product families account on top 80 percent sales volume. And then, we figure out the ratio of these product families to the whole number of product family the company has. The logistics cost is high if the ABC product characteristic ratio if large.

- **Competition**

The level of competition could be evaluated on the basis of the general competitiveness on the macro standpoint of industry sector and that of firm's point of view. The level of competition should be high if the competitiveness of industry sector is aggressive and the company is not at a prior market position. Hence, the company has to increase the level of inventory and delivery frequency in order to reduce the probability of stock out and increase the service level.

- **Production Strategy**

The production strategy could be investigated from firm's website and/or interview with production director. In general, the products produced with BTO strategy has comparative low total logistics costs, while the DTO strategy leads to comparative high total logistics costs.

Service characteristics

- **Cycle Time**

The cycle time is measured in days. 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 time 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.

- **Completeness (item fill rate)**

This driver is more an internal decision or goal of the firm rather than an effect of the distribution networks. The total logistics costs may high if the completeness is low, because this would bring high transportation cost and repeatable distribution activities.

- **Returnability**

The returnability is measured based on the level of importance of reverse logistics to the firm. Theoretically, as the percentage of products returned increase, the criticality of this driver also rise because a more complex network is required.

- **Accuracy**

It can be calculated by dividing the number of correct orders delivered by the total number of orders placed and expressed in percentage.

- **Tracking (order visibility)**

This driver is measured based on the level of importance of order visibility to the customer. This attribute has different level of impact on different industries. With regard to the commodity industry, the order visibility is meaningless, while as to express industry, this drive is critical to the customer service.

- **Customer Experience**

Customer experience could be measured based on the number of ways through which the customers can purchase the products. If the company provides more sales points, the logistics costs should be high due to both high facility cost and transportation cost, while the customer satisfaction is high.

- **Punctuality**

This driver could be measured based on the percentage of the products could be delivered to point of customer on time.

➢ **Ability to Expedite Orders**

This driver represents the flexibility of delivery, which indicates if the company is able to handle the customer's urgent and/or unusual delivery requirement. If the capacity of delivery flexibility is high, the firm could increase the logistics cost while the cost of lost sales would be decreased and maintain the customer's satisfaction. In fact, the flexibility of delivery is hard to evaluate. We have to measure this driver in a subjective way by evaluating the ability of company to deal with abnormal delivery requirement.

Demand characteristics

➢ **Dimension of the Order**

It is considered the order dimension as a percentage of Full Truck Load. For example, if the order dimension is only some boxes then it corresponds to 20% of FTL, if it is pallet then 60% of FTL. The transportation mean could not achieve saturation when the order dimension is low.

➢ **Number of Customers**

If the number of customer is high enough, it is considered critical to provide more facilities in order to reduce the transportation cost.

➢ **Frequency of delivery**

The frequency of delivery is measured in times per week, for example, if the delivery is once every two weeks then the frequency is 0.5 times per week. The logistics costs are high if the frequency of delivery is high. Theoretically, the distribution network with high frequency of delivery should be decentralized.

➢ **Seasonality**

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

a) Low: it may be seasonality but it is well known and controlled. For example, a product has a peak in sales from June to August; it only happens one time in a year and lasts a few months.

b) Low-Medium: seasonality is concentrated in the last third of the year.

c) Medium: peaks in sales occur two times per year.

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

e) High: peaks occur more than two times per year.

The logistics cost is higher, if the seasonality is high. The distribution network should be centralized in order to cope with the impact.

- **Predictability of demand (%)**

Predictability of demand is measured as percentage of accuracy of the prediction with the actual demand. If the predictability of demand is low, the total logistics cost is higher.

- **Spatial Density**

Spatial density is measured based on the number of customers per square kilometer (#of customer/km^2). If the spatial density is low, the local transportation cost is high compared with high spatial density, because the local delivery cost is related to the distance from DC to customer area, and the distance between points of customers. In order to achieve the local transportation economies of scale, the spatial density should be high since the distance from DC to customer area does not change whatever the number of customer in a specific area.

- **Demand Volatility**

This driver could be measured like the statement of definition, yet, it is hard to carry out. Here, we use the change rate of sales to indicate this driver due to the sales volume reflects the customers' demand directly. The average change rate of sales volume in recent 5 years is the measure of this driver and expressed in percentage. The demand volatility is high if the change is intensive.

- **Demand Level**

We can measure this driver according to the market share of the company in the specific industry. The larger market share a company has, the higher demand level would be generated.

Supply characteristics

- **Number of Plants**

The number of plants can be measured directly. When there are many plants, the total logistics cost increases.

- **Distance from plant to client**

This driver can be measured directly as well. The distance from plant to client is proportional to the total logistics costs.

- **Level of specialization**

If the level of specialization of the plants is high, the logistics cost is higher, mainly because of the higher distance between plants and clients and also due to the higher risk of stock out.

- **Exclusivity of production in a plant**

This driver could be represented by the ratio of total number of product family to total number of plants, which represents the number of product family produced in one plant. The exclusivity is high if the ratio is high.

Chapter 3. The Case Studies

We investigated 3 companies involving 16 distribution problems in Consumer Electronics industry, and 7 companies referring to 16 distribution problems in FMCG industry. Regarding to every distribution problem, we tried to find out the original value of each driver we explained in the preceding chapter and convert them into criticality value based on the related measurement method. The criticality value will be represented as five-point scale and shown in appendix.

3.1 Data collection of Consumer Electronics Industry

With regard to the Consumer Electronics industry, we investigated HP, Sony and Samsung by historic data and annual report. Hence, we achieve the original data for all of the drivers.

3.1.1 Hewlett Packard

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, including customers in the government, health and education sectors.

The operations are organized into seven business segments: Services, Enterprise Storage and Serves ("ESS"), HP Software, the Personal System Group ("PSG"), the Imaging and Printing Group ("IPG"), HP Financial Services ("HPFS"), and Corporate Investment.

MACRODRIVER	DRIVER	VALUE
PRODUCT	Variety (SKUs)	4000
	PVD (euro/kg)	1000
	Physical Density (kg/m^3)	7.6
	Risk of obsolescence (days)	120
	Contribution Margin (%)	12
	Substitutability (SKUs/family)	118
	Product Complexity	H

	Stage of life cycle	G&M
	Handling characteristic (number of handling requirements)	2
	Shelf Life (days)	23
	Value (euro)	800-1000
	ABC product characteristic (ABC product characteristic ratio, %)	32.4
	Competition	MH
	Production Strategy	ATO,MTO
SERVICE	Cycle Time (days)	15
	Completeness (IFR)	100
	Returnability	L
	Accuracy (%)	100
	Tracking	L
	Customer Experience	MH
	Punctuality (%)	100
	Ability to Expedite Orders	L
DEMAND	Dimension of the order (%FTL)	1
	Number of customers	32
	Frequency of delivery (deliveries per week)	5
	Seasonality	LM
	Predictability of demand (%)	95
	Spatial Density (#customer/km^2)	1.1×10^{-4}
	Demand Volatility (%)	14.2
	Demand Level (%)	>25%
SUPPLY	Number of plants	17
	Distance from plant to client	6000
	Level of specialization	M
	Exclusivity of production in a plant (number of product family/plant)	2

Table 7 Original value of drivers in HP

3.1.2 Sony

Sony is a leading manufacturer of audio, video, communications, and information technology products for the consumers and professional markets. Its motion picture, television, computer entertainment, music and online business make Sony to be one of the most comprehensive entertainment and technology companies in the world.

Sony has eight business units, including Consumer Products & Devices, Networked Products & Services, B2B & Disc Manufacturing, Picture, Music, Financial Service, Corporate, All Other.

Sony has six different distribution problems in Italy, according to the locations of original points. We would like to name them as SO1, SO2, SO3, SO4, SO5 and SO6. 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 distribution 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 to big customers, which orders are big enough. The products are TVs, software and CDs produced in Europe plants.
- SO2: the same products produced in Europe plants, but the products are distributed through CW and Transit Points.
- SO3: the same products produced in Europe plants and delivered by 2 levels network like SO2. The difference between this and SO2 is that the deliveries are done to small clients.
- SO4: provides direct delivery from CW to big customers, which orders are big enough in order to satisfy the saturation of the mean. The products passed through this channel are supplied by Asia plants. Normally, the value density of products in this channel is higher than SO1-SO3, and more innovative.
- SO5: the same products produced in the Far East plants and delivered by 2 levels network.
- SO6: the same products produced in the Far Ease plants and distributed through CW for small customers.

MACRODRIVER	DRIVER	VALUE					
		SO1	SO2	SO3	SO4	SO5	SO6
PRODUCT	Variety (SKUs)	400	400	400	800	800	800
	PVD (euro/kg)	55	55	55	800	800	800
	Physical 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
	Substitutability (SKUs/family)	46	46	46	46	46	46
	Product Complexity	MH	MH	MH	H	H	H
	Stage of life cycle	G&M	G&M	G&M	G&M	G&M	G&M
	Handling characteristic (number of handling requirements)	2	2	2	2	2	2
	Shelf Life (days)	12	12	12	30	30	30
	Value (euro)	1000	1000	1000	800	800	800
	ABC product characteristic (ABC product characteristic ratio, %)	42.3	42.3	42.3	42.3	42.3	42.3
	Competition	H	H	H	H	H	H
	Production Strategy	MTO	MTO	MTO	MTO	MTO	MTO
SERVICE	Cycle Time (days)	3	4	2	3	4	2
	Completeness (IFR)	100	100	100	100	100	100
	Returnability	L	L	L	L	L	L
	Accuracy (%)	100	100	100	100	100	100
	Tracking	L	L	L	L	L	L
	Customer Experience	M	M	M	M	M	M
	Punctuality (%)	100	100	100	100	100	100
	Ability to Expedite Orders	L	LM	H	L	LM	H
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
	Spatial Density (#customer/km^2)	$1.1x10^{-4}$	$1.1x10^{-4}$	$8.9x10^{-3}$	$1.1x10^{-4}$	$1.1x10^{-4}$	$8.9x10^{-3}$
	Demand Volatility (%)	13.4	13.4	13.4	13.4	13.4	13.4
	Demand Level (%)	11.8	11.8	11.8	26	26	26
SUPPLY	Number of plants	5	5	5	7	7	7
	Distance from plant to client	1000	1000	1000	9000	9000	9000
	Level of specialization	H	H	H	M	M	M
	Exclusivity of production in a plant	0.6	0.6	0.6	3.3	3.3	3.3

Table 8 Original value of drivers in Sony

3.1.3 Samsung

Samsung is a digital leader and provides a wide range of home appliance and digital products. 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.

Samsung is comprised of eight independent businesses: Visual Display Business; IT Solution Business; Digital Appliances Business; Mobile Communication Business; Telecommunication System Business; Digital Imaging Business; Semiconductor Business; and LCD Business.

Samsung has 9 different distribution problems in Italy, due to the wide range of products the company provides. We denominate them SA1-SA9.

- 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 that stores products of the home appliances, produced in the Far East plants and are forwarded directly to big clients.
- SA3: consist of CW that stores home appliances products produced from Far East plants and 20 transit points that manage this type of products.
- SA4: consist of one level of CW that stores audio-video and informatics products produced in Europe plants and forwarded directly to big clients.
- SA5: consist of CW that stores audio-video and informatics products produced in Europe plants and 20 transit pints that manage these types of products.
- SA6: represented by mobile phones those are not delivered directly to mobile operators, but instead stop at one level of CW and then forwarded directly to big clients.
- SA7: represented by mobile phones, which are not delivered directly to mobile operators, but instead stop at one level of CW and then at a second level of 150

transit points that manage this type of products.

- SA8: characterized by air conditioners produced in the Far East plant, stop at one level of CW and then delivered directly to big clients.
- SA9: characterized by air conditioners produced in the Far East plants, stop at one level of CW and then at a second level of 20 transit points that manage this type of products and then forwarded to clients.

MACRODRIVER	DRIVER	VALUE				
		SA1	SA2	SA3	SA4	SA5
PRODUCT	Variety (SKUs)	50	100	100	700	700
	PVD (euro/kg)	1000	13	13	370	370
	Physical Density (kg/m^3)	1200	110	110	170	170
	Risk of obsolescence (days)	90	365	365	180	180
	Contribution Margin (%)	30	24	24	14	14
	Substitutability (SKUs/family)	16.7	16.7	16.7	41	41
	Product Complexity	H	H	H	H	H
	Stage of life cycle	G&M	Mat.	Mat.	G&M	G&M
	Handling characteristic (number of handling requirements)	2	2	2	2	2
	Shelf Life (days)	7	24	24	7	7
	Value (euro)	800	455	455	925	925
	ABC product characteristic (ABC product characteristic ratio, %)	35.5	35.5	35.5	35.5	35.5
	Competition	MH	MH	MH	MH	MH
	Production Strategy	MTO	MTO	MTO	MTO	MTO
SERVICE	Cycle Time (days)	5	3	5	3	5
	Completeness (IFR)	100	95	95	95	95
	Returnability	L	L	L	L	L
	Accuracy (%)	95	95	95	95	95
	Tracking	L	L	L	L	L
	Customer Experience	LM	LM	LM	LM	LM
	Punctuality (%)	95	95	95	95	95
	Ability to Expedite Orders	LM	LM	MH	LM	MH
DEMAND	Dimension of the order (%FTL)	0.4	0.6	0.4	0.6	0.4
	Number of customers	5	35	1160	32	1163
	Frequency of delivery (deliveries per week)	0.25	0.5	1	2	2
	Seasonality	H	L	L	M	M
	Predictability of demand (%)	95	95	95	95	95
	Spatial Density (#customer/km^2)	$1.7x10^{-5}$	$1.2x10^{-4}$	$3.9x10^{-3}$	$1.1x10^{-4}$	$3.9x10^{-3}$

	Demand Volatility (%)	15.9	15.9	15.9	15.9	15.9
	Demand Level (%)	24	39.5	39.5	26	26
SUPPLY	Number of plants	7	3	3	7	7
	Distance from plant to client	9000	9000	9000	1000	1000
	Level of specialization	H	H	H	H	H
	Exclusivity of production in a plant	1.4	0.7	0.7	3.3	3.3

MACRODRIVER	DRIVER	VALUE			
		SA6	SA7	SA8	SA9
PRODUCT	Variety (SKUs)	50	50	150	150
	PVD (euro/kg)	1000	1000	90	90
	Physical Density (kg/m^3)	1200	1200	170	170
	Risk of obsolescence (days)	90	90	365	365
	Contribution Margin (%)	30	30	14	14
	Substitutability (SKUs/family)	16.7	16.7	30	30
	Product Complexity	H	H	H	H
	Stage of life cycle	G&M	G&M	Mat.	Mat.
	Handling characteristic (number of handling requirements)	2	2	2	2
	Shelf Life (days)	7	7	24	24
	Value (euro)	200	200	1530	1530
	ABC product characteristic (ABC product characteristic ratio, %)	35.5	35.5	35.5	35.5
	Competition	MH	MH	MH	MH
	Production Strategy	MTO	MTO	MTO	MTO
SERVICE	Cycle Time (days)	3	5	3	5
	Completeness (IFR)	95	95	95	95
	Returnability (%)	L	L	L	L
	Accuracy (%)	95	95	95	95
	Tracking	L	L	L	L
	Customer Experience	LM	LM	LM	LM
	Punctuality (%)	95	95	95	95
	Ability to Expedite Orders	M	H	LM	MH
DEMAND	Dimension of the order (%FTL)	0.4	0.2	0.6	0.4
	Number of customers	32	1163	35	1160
	Frequency of delivery (deliveries per week)	1	1	0.5	1
	Seasonality	H	H	L	L
	Predictability of demand (%)	95	95	95	95
	Spatial Density (#customer/km^2)	$1.1x10^{-4}$	$3.9x10^{-3}$	$1.2x10^{-4}$	$3.9x10^{-3}$
	Demand Volatility (%)	15.9	15.9	15.9	15.9%
	Demand Level (%)	20.6	20.6	39.5	39.5%

SUPPLY	Number of plants	7	7	7	7
	Distance from plant to client	9000	9000	9000	9000
	Level of specialization	H	H	H	H
	Exclusivity of production in a plant	0.4	0.4	0.7	0.7

Table 9 Original value of drivers in Samsung

3.2 Data collection of FMCG Industry

As for the FMCG industry, 7 companies are investigated. We are not able to find the original data of every driver for all of the distribution problems since some data are hardly to evaluate or there is few relative information on the annual report and official website.

3.2.1 Nestle Italia

Nestle is the largest food and nutrition company in the world food and nutrition company in the world. Founded in1886 by Henri Nestle in Vevey, Switzerland. The company significantly during the First World War and again following the Second World War, eventually expanding its offerings beyond its early condensed milk and infant formula products. Today, the company operates in 86 countries around the world, and employs over 280000 people.

Nestle Italia is a company's branch in Italy established in December 2002. All the data regarding the company is provided in the table given below. Nestle Italia has 5 Business Units. Each of the units represents its own distribution problem. These Business Units are:

- Nestle1: Food & Nutrition Business Unit. The distribution network is presented by 2 echelons. In the first echelon there are 2 warehouses that distribute the goods among 26 warehouses/transit points that create the second echelon of the network.
- Nestle 2: Pasta & Slices Business Unit. The 2 level distribution network is presented by 3 warehouses in the first echelon and 24 warehouses/transit points in the second one.

- Nestle 3: Confectionery Business Unit. The distribution network in this case is also presented by 2 levels. 2 warehouses in the firsts level and 34 warehouses/transit points in the second one;
- Nestle 4: Bakery Business Unit. 2 levels network with 2 and 28 warehouses/transit points in the first and second levels respectively.
- Nestle 5: Foodservices Business Unit. The distribution network composed by 2 warehouses in the first level and 24 warehouses/transit points in the second one.

MACRODRIVER	DRIVER	VALUE				
		Nestle1	Nestle2	Nestle3	Nestle4	Nestle5
PRODUCT	Variety (# of products)	620	357	944	374	830
	PVD (euro/kg)	5.6 - 32.10	1.15 - 2.53	8.44 - 14.72	4.9	5.4
	Physical Density (kg/m^3)	323	253	212	178	196
	Risk of Obsolescence (days)	690	365 -1200	190 - 630	150	300
	Contribution Margin (%)	18.1	12.3	13.8	12.3	14
	Subsitutability (SKUs/product family)	>620	>357	>944	>374	>830
	Product Complexity (func vs innov)	L	L	L	L	L
	Stage of Life Cycle	Mat	Mat	Mat	Mat	Mat
	Handling characteristic	L	L	H	H	L
	Shelf Life (days)	210	180	150	30	200
	Level of Competition (qual)	H	H	H	H	H
	Production Strategy	BTS	BTS	BTS	BTS	BTS
SERVICE	Cycle Time (days)	6	5.9	5.5	1.5	4
	Completeness (Item fill rate, %)	98	98	98	98	98
	Accuracy (%)	97	97	97	97	97
	Tracking (qual)	H	H	H	H	H
	Customer Experience (qual)	H	H	H	H	H
	Punctuality (%)	90	90	90	90	90
DEMAND	Dimesion of the order	2.4 UL	15 UL	0.5 UL	1.5 UL	1 UL
	Number of Customer	11424	11424	26000	5700	22660
	Delivery Frequency (#of delivery/week)	0.23	0.07	0.25	0.28	0.16
	Seasonality (qual)	L	L	H	H	L
	Predictability of Demand (%)	H	H	H	H	H
	Spatial Density (#of customer/km^2)	$379x10^{-4}$	$379x10^{-4}$	$863x10^{-4}$	$189x10^{-4}$	$752x10^{-4}$
SUPPLY	Number of Plants	1	2	1	2	1
	Distance from plant to client(km)	600	600	600	600	600

Level of Specialization	Depends on the country/region, but tending to become MH					
Exclusivity of production in a plant	MH	MH	MH	MH	MH

Table 10 Original value of drivers in Nestle

3.2.2 Calzedonia

Calzedonia is a relatively young Italian company that was established in 1987 close to Verona. The company produces and sells underwear (brand intimissimi) and clothes (brand calzedonia). The detailed information about the company is given in the table below. Considering the fact that the company operates in a fashion, highly seasonal and hard predictable market and has 2 lines of brands we can distinguish two distribution problems the company has:

- Calz1: Brand line Calzedonia. The distribution network consists of 1 Central Warehouse.
- Calz2: Brand line Intimissimi. The network is composed by 1 level with 1 Central Warehouse.

MACRODRIVER	DRIVER	VALUE	
		Calz1	Calz2
PRODUCT	Variety (# of products)	3500	3500
	PVD (euro/kg)	50	50
	Physical Density (kg/m^3)	160	160
	Risk of Obsolescence (days)	180-several years	180-360
	Contribution Margin (%)	38.4	46.2
	Subsitutability (SKUs/product family)	>3500	>3500
	Product Complexity (func vs innov)	L	ML
	Stage of Life Cycle	Mat	Mat
	Handling characteristic	L	L
	Shelf Life (days)	90 - 360	30 - 180
	Level of Competition (qual)	H	MH
	Production Strategy	BTS	BTS
SERVICE	Cycle Time (days)	3	3
	Completeness (Item fill rate, %)	99.9	99.9
	Accuracy (%)	99.9	99.9
	Tracking (qual)	Not available	Not available

	Customer Experience (qual)	MH	MH
	Punctuality (%)	99.9	99.9
	Ability to Expedite Orders	No	No
DEMAND	Dimesion of the order	$0.27m^3$	$0.27m^3$
	Number of Customer	1400	1400
	Delivery Frequency (#of delivery/week)	3	3
	Seasonality (qual)	MH	H
	Predictability of Demand (%)	MH	MH
	Spatial Density (#of customer/km^2)	$6.3x10^{-4}$	$6.3x10^{-4}$
SUPPLY	Number of Plants	6	2
	Distance from plant to client(km)	>1000	>1000
	Level of Specialization	H	H
	Exclusivity of production in a plant	1	MH

Table 11 Original value of drivers in Calzedonia

3.2.3 Reckitt Benckiser

Reckitt Benckiser is a global consumer goods company located in Slough, UK. It is the world largest produser of the household products and the major producer of consumer healthcare and personal products. Its brands include Dettol (the world's largest-selling antiseptic), Strepsils (the world's largest selling sore throat medicine), Veet (the world's larges selling depilatory brand), Air Wick (the world's second largest-selling air freshener), Calgon, Cilit, Bang, Durex and Vanish. It has operations in over 60 countries and its products are sold in over 180 countries around the globe. More detailed information about the company is provided in the table below.

The distribution network of the company composed by 2 levels with more than 20 warehouses in the firsts echelon and more than 130 warehouses/transit points in the second one.

MACRODRIVER	DRIVER	VALUE
PRODUCT	Variety (# of products)	800
	PVD (euro/kg)	28.05
	Physical Density (kg/m^3)	375
	Risk of Obsolescence (days)	800
	Contribution Margin (%)	26.4
	Subsitutability (SKUs/product family)	>800

	Product Complexity (func vs innov)	L
	Stage of Life Cycle	Mat
	Handling characteristic	L
	Shelf Life (days)	360
	Level of Competition (qual)	MH
	Production Strategy	BTS
SERVICE	Cycle Time (days)	3
	Completeness (Item fill rate, %)	100
	Accuracy (%)	99
	Tracking (qual)	H
	Customer Experience (qual)	H
	Punctuality (%)	95
DEMAND	Dimesion of the order	0.5 Unit Load
	Number of Customer	1600
	Delivery Frequency (#of delivery/week)	2
	Seasonality (qual)	L
	Predictability of Demand (%)	H
	Spatial Density (#of customer/km^2)	$53x10^{-4}$
	Demand Variability (%)	21
SUPPLY	Number of Plants	6
	Distance from plant to client(km)	1000 - 1200
	Level of Specialization	ML
	Exclusivity of production in a plant	0.5

Table 12 Original value of drivers in Reckitt Benckiser

3.2.4 Coca-Cola Italia

The Coca-Cola Company is an American multinational beverage corporation and manufacturer, retailer and marketer of non-alcoholic beverage concentrates and syrups. The company is best known for its flagship product Coca-Cola, invented in 1886 by pharmacist John Stith Pemberton in Columbus, Georgia.[3] The Coca-Cola formula and brand was bought in 1889 by Asa Candler who incorporated The Coca-Cola Company in 1892. Besides its namesake Coca-Cola beverage, Coca-Cola currently offers more than 500 brands in over 200 countries or territories and serves over 1.7 billion servings each day. Detailed information related to the Italian branch is given below.

The distribution network of Coca-Cola Italia is presented by 10 warehouses in the 1st echelon and more than 100 transit points in the 2nd one.

MACRODRIVER	DRIVER	VALUE
PRODUCT	Variety (# of products)	130
	PVD (euro/kg)	0.8 - 2
	Physical Density (kg/m^3)	496
	Risk of Obsolescence (days)	365
	Contribution Margin (%)	24.1
	Subsitutability (SKUs/product family)	130
	Product Complexity (func vs innov)	L
	Stage of Life Cycle	Mat
	Handling Characteristics	L
	Shelf Life (days)	180 - 270
	Level of Competition (qual)	H
	Production Strategy	BTS
SERVICE	Cycle Time (days)	Not available
	Completeness (Item fill rate, %)	2.4 weeks of Stock Out
	Tracking (qual)	H
	Customer Experience (qual)	H
DEMAND	Dimesion of the order	15 UL
	Number of Customer	85000
	Delivery Frequency (#of delivery/week)	0.3
	Seasonality (qual)	H
	Predictability of Demand (%)	H
	Spatial Density (#of customer/km^2)	0.0995x10^{-4}
SUPPLY	Number of Plants	6
	Distance from plant to client(km)	500
	Level of Specialization	L
	Exclusivity of production in a plant	L

Table 13 Original value of drivers in Coca-Cola

3.2.5 3M

3M formerly known as the Minnesota Mining and Manufacturing Company. It is an American multinational conglomerate corporation based in Maplewood, Minnesota, United States.

With over 80,000 employees, they produce a wide range of products (more than 55,000 products), including: adhesives, abrasives, laminates, passive fire protection, dental products, electronic materials, medical products, car care products (such as sun films, polish, wax, car shampoo, treatment for the exterior, interior and the under chassis rust protection), electronic circuits and optical films. 3M has operations in more than 60 countries – 29 international companies with manufacturing operations, and 35 with laboratories. 3M products are available for purchase through distributors and retailers in more than 200 countries, and many 3M products are available online directly from the company. Detailed information about the company is given in the table below.

In 3M we can distinguish 4 distribution problems (one problem for one Business Unit):

- 3M1: Health & Care. The distribution network consists of 1 echelon with 5 warehouses in it.
- 3M2: Consumer & Office. The network is presented by 2 echelons with 5 warehouses in the 1st and 10-15 warehouses/transit points in the 2nd one.
- 3M3: Industrial Market. The network is composed by 1 echelon with 5 warehouses in it.
- 3M4: TGS. This Business Unit is engaged in producing metal signs. The distribution network is presented by 1 echelon with 5 warehouses in it.

MACRODRIVER	DRIVER	VALUE			
		3M1	3M2	3M3	3M4
PRODUCT	Variety (# of products)	50000			
	PVD (euro/kg)	MH	L	M	ML
	Physical Density (kg/m^3)	M	ML	MH	M
	Risk of Obsolescence (days)	L	L	L	L
	Contribution Margin (%)	31.44	21.55	17.41	23.63
	Subsitutability (SKUs/product family)	>MH	>L	>M	>ML
	Product Complexity (func vs innov)	H	L	MH	L
	Stage of Life Cycle	Mat	Mat	Mat	Mat
	Handling characteristic	M	L	L	L
	Shelf Life (days)				
	Level of Competition (qual)	MH	H	H	H
	Production Strategy	ATO/MTO	BTS	ATO	BTS
SERVICE	Cycle Time (days)	3	3	3	3
	Accuracy (%)	70	70	70	70

	Customer Experience (qual)				
	Punctuality (%)	90	90	90	90
DEMAND	Dimesion of the order	some packages - UL	some packages	some packages	some packages
	Number of Customer	2000	6500	6000	2500
	Delivery Frequency (#of delivery/week)	0.37	0.37	0.37	0.37
	Seasonality (qual)	H	H	H	H
	Spatial Density (#of customer/km^2)	*800x10^{-4}*			
SUPPLY	Number of Plants	50			
	Distance from plant to client(km)	1100	1100	1100	1100
	Exclusivity of production in a plant	H	H	H	H

Table 14 Original value of drivers in 3M

3.2.6 Unilever Bestfoods

Unilever Bestfoods is a part of Unilever Company that is focused on mayonnaise and other food products. The company has 2 main Business Units targeted on HORECA (Hotels, Restaurants and Cafes) and Retail chains respectively. Distribution network for HORECA Business Unit is presented by 2 echelons with 20 warehouses in the first echelon and 10 transit points in the second one. Retail Business Unit's network composed just 1 echelon with 20 warehouses in it. Detailed information about the company is provided in the table below.

MACRODRIVER	DRIVER	VALUE	
		Unil1	Unil2
PRODUCT	Variety (# of products)	200	300
	PVD (euro/kg)	7	7.5
	Physical Density (kg/m^3)	MH	MH
	Risk of Obsolescence (days)	365 - 1500	365 - 750
	Contribution Margin (%)	15	14.4
	Subsitutability (SKUs/product family)	>200	>300
	Product Complexity (func vs innov)	L	L
	Stage of Life Cycle	Mat	Mat
	Handling characteristic	H	H
	Shelf Life (days)	450	400
	Level of Competition (qual)	H	H
	Production Strategy	BTS	BTS

SERVICE	Cycle Time (days)	7.5	5
	Completeness (Item fill rate, %)	98	95
	Accuracy (%)	90	90
	Tracking (qual)	H	H
	Customer Experience (qual)	H	H
	Punctuality (%)	90	90
	Ability to Expedite Orders	Yes	No
DEMAND	Dimesion of the order	1 UL	1Transport Unit
	Number of Customer	7000	1000
	Delivery Frequency (#of delivery/week)	0.25	0.25
	Spatial Density (#of customer/km^2)	230x10^{-4}	33x10^{-4}
SUPPLY	Number of Plants	3	2
	Distance from plant to client(km)	1200	1200
	Level of Specialization	H	H
	Exclusivity of production in a plant	MH	H

Table 15 Original value of drivers in Unilever Bestfoods

3.2.7 Hackman

Hackman is a cutlery and cookware company founded in Finland in 1790. Nowadays the Hackman brand is owned by Iittala Group, which was acquired by Fiskars Corporation in 2007. Hackman is a prestigious brand name in Finland; according to a 2008 survey which included both Finnish and international brands, it was the fifth most respected brand among consumers. The distribution network is very different from the traditional one and composed by 2 echelons with 3 warehouses in the first echelon (central warehouses in Finland, Sweden and Norway) and just 1 transit point in the second echelon in Norway. The detailed information about the company is given in the table provided below.

MACRODRIVER	DRIVER	VALUE
PRODUCT	Variety (# of products)	Wide
	PVD (euro/kg)	39
	Physical Density (kg/m^3)	160
	Risk of Obsolescence (days)	L
	Contribution Margin (%)	23.9
	Subsitutability (SKUs/product family)	Wide
	Product Complexity (func vs innov)	M

	Stage of Life Cycle	Mat
	Handling characteristic	ML
	Shelf Life (days)	L
	Level of Competition (qual)	MH
	Production Strategy	BTS
SERVICE	Cycle Time (days)	Not available
	Completeness (Item fill rate, %)	98
	Accuracy (%)	95
	Tracking (qual)	MH
	Customer Experience (qual)	M
DEMAND	Dimesion of the order	1 UL up to Transport Unit
	Number of Customer	53
	Seasonality (qual)	H
	Predictability of Demand (%)	H
	Spatial Density (#of customer/km^2)	Not very high
	Demand Variability (%)	ML
SUPPLY	Number of Plants	5
	Distance from plant to client(km)	820 - 1500
	Level of Specialization	H
	Exclusivity of production in a plant	H

Table 16 Original value of drivers in Hackman

Chapter 4. The Description of Mathematical Methodology

We have presented the whole methodology in the executive summary. Driver list updating and data collection have been demonstrated in the above chapters. Hence, the accent of this chapter is on the description of the mathematical methodology.

We will describe the quantitative research procedure on the first part of this section and introduce the features of each main mathematical approach used in this study on the second part. The mathematical analysis is the prominent emphasis distinguishing from the previous relative research. Hence, the correctness of the mathematical methodology is crucial to the research as a whole.

4.1 The main procedure of mathematical analysis

With regard to the quantitative analysis, the objective is to make the relationship between distribution problem and distribution solution to be more accurate. Therefore, we have to adopt some mathematical tools. Through the literature study, we can found that some inferred statistics models can realize this purpose. The following diagram is the procedure of mathematical analysis in which three main processes include reducing the number of drivers, generating the regression function and obtaining the accurate relationship between distribution problem and distribution solution. The detailed application of this procedure will be shown in the next chapter.

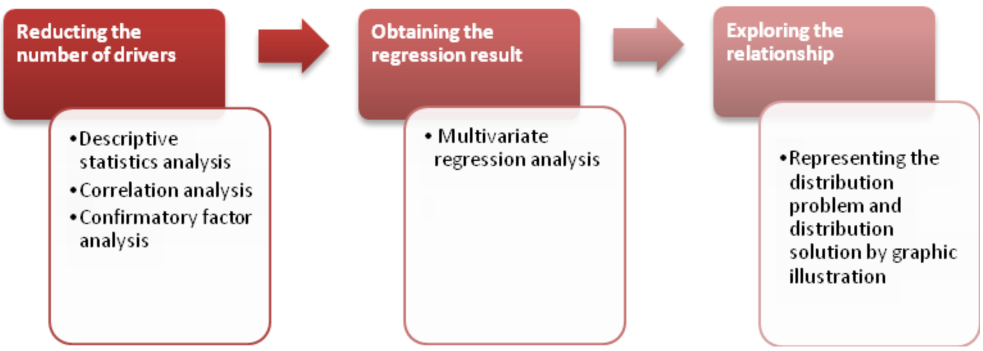


Figure 4 The procedure of mathematical analysis

According to the previous chapters, there are 34 drivers associated to the product, service, demand and supply characteristics have been found. By taking into consider the natures of Consumer Electronics industry and FMCG industry, we should find the drivers that are more able to describe those characteristics for two industries respectively. Hereby, we need to remove some drivers that are not significant to the Consumer Electronics industry and FMCG industry.

Firstly, we use descriptive statistics analysis and correlation analysis to see which drivers can be deleted and/or combined based on their standard deviation and correlation factor. The drivers have to be cut off in case the value of standard deviation is zero, since the value is meaningless to the inferred statistics model. The correlation factor can depict the relation between two variables. The driver can be neglected if it is highly related to another one whose concept is wilder.

The following step is to use the inferred statistics model to carry out the further statistical analysis. The confirmatory factor analysis (CFA) can reduce the number of drivers based on the group of drivers rather than the pair of drivers. Consequently, we can remove more drivers on this step.

Thanks to the preceding process, we can obtain some more important drivers for different industries. The second process is to figure out the regression function for those drivers and obtain their regression coefficients. By taking into consideration the multicollinearity may exist among the drivers, we have to use principal component regression (PCR) model to solve this problem.

Finally, the relationship between distribution problem and distribution solution can be achieved if we put the original critical value of the necessary drivers into the regression function to figure out the value of Market and Firm characteristics for each distribution problem, and represent their value on the two-dimension diagram.

4.2 The description of mathematical tools

4.2.1 Descriptive statistics

Descriptive statistics quantitatively describes the main features of a collection of data (Introductory Statistics, 1995). In a research study we may have lots of measures. Or we may measure a large number of people on any measure. Descriptive statistics help us to simply large amounts of data in a sensible way. Each descriptive statistic reduces lots of data into a simpler summary.

Descriptive statistics are distinguished from inferential statistics (or inductive statistics), in that descriptive statistics provide simple summaries about the sample and the measures, rather than use the data to learn about the population that the data are thought to represent. With descriptive statistics we are simply describing what is or what the data shows. With inferential statistics, we are trying to reach conclusions that extend beyond the immediate data alone. Thus, we use inferential statistics to make inferences from our data to more general conditions; we use descriptive statistics simply to describe what's going on in our data. This generally means that descriptive statistics, unlike inferential statistics, are not developed on the basis of probability theory.

Descriptive statistics include the numbers, tables, charts, and graphs used to describe, organize, summarize, and present raw data. Descriptive statistics are more often used to examine:

- Central tendency - location of data, i.e. where data tend to fall, as measured by mean, median, and mode.
- Dispersion – variability of data, i.e. how spread out data are, as measured by the variance and its square root, the standard deviation.
- Skew – symmetry of data, i.e. how concentrated data are at the low or high end of the scale, as measured by the skew index.

- Kurtosis – peak of data, i.e. how concentrated data are around a single value, as measured by the kurtosis index.

Descriptive statistics are recommended when the objective is to describe and discuss a data set more generally and conveniently than would be possible using raw data along. They are routinely used in reports which contain a significant amount of qualitative or quantitative data. Descriptive statistics help summarize and support assertions of fact (Data Analysis, 1995).

A thorough understanding of descriptive statistics is essential for the appropriate and effective use of all normative and cause-and-effect statistical techniques, including hypothesis testing, correlation, and regression analysis. Unless descriptive statistics are fully grasped, data can be easily misunderstood and, thereby, misrepresented.

In this study, the primary purpose of the application of descriptive statistics is to summarize the drivers in order to reduce the number of them. Hence, we examine the central tendency and disperse of the data. Even if the four descriptions of data set mentioned above are suggested to be examined in literature, the characteristics of skew and kurtosis do not make any sense in our research. Since statistical analysis software and most spreadsheets generate all required descriptive statistics, computer applications offer the best means of preparing such information. We use Excel application of Microsoft Office, to implement the descriptive statistics.

4.2.2 Correlation analysis

Correlation is a statistical technique that can show whether and how strongly pairs of variables are related. Like all statistical techniques, correlation is only appropriate for certain kinds of data. Correlation works for quantifiable data in which numbers are meaningful, usually quantities of some sort. It cannot be used for purely categorical data, such as gender, brands purchased, or favorite color.

A correlation coefficient (r) is a statistic used for measuring the strength of a supposed linear association between two variables; that is, how well changes in one variable can be predicted by changes in another variable. It ranges from -1.0 to +1.0. The closer r is to +1 or -1, the more closely the two variables are related:

- +1 representing absolute positive linear relationship (X increases, Y increases).
- -1 representing absolute inverse relationship (X increases, Y decreases).
- 0 representing no linear relationship (X and Y have no pattern).

Before making any decisions based upon correlation analysis, one must recognize that correlation does not imply one variable is responsible for the movement of another. Correlation simply measures the relationship of movement between two variables (Correlation Analysis, 2007).

In this thesis, one driver can be removed if the correlation coefficient is high enough, or two drivers are combined into one new attribute. Microsoft's Excel spreadsheet program can analyze the level of correlation between two variables through its data analysis function.

4.2.3 Confirmatory factor analysis

Factor analysis is a collection of methods used to examine how underlying constructs influence the responses on a number of measured variables. The main applications of factor analytic techniques are: (1) to reduce the number of variables and (2) to detect structure in the relationships between variables. Therefore, factor analysis is applied as a data reduction or structure detection method

There are basically two types of factor analysis: exploratory and confirmatory.

- Exploratory factor analysis (EFA) attempts to discover the nature of the contracts influencing a set of responses.
- Confirmatory factor analysis (CFA) tests whether a specified set of constructs is influencing response in a predicted way.

The primary objectives of an EFA are to determine (1) the number of common factors influencing a set of measures in order to identify the nature of the constructs underlying responses in a specific content area and (2) the strength of the relationship between each factor and each observed measure.

However, confirmatory factor analysis (CFA) is able to determine if the number of factors and the loading of measured (indicator) variables on them conform to what is expected on the basis of pre-established theory. Measured variables are selected on the basis of prior theory and factor analysis is used to see if they load as predicted on the expected number of factors. The research's priori assumption is that each factor is associated with a specific subset of measured variables. A minimum requirement of confirmatory factor analysis is that one hypothesis beforehand the number of factors in the model, but usually also the research will posit expectations about which variables will load on which factors.

As for our study, the predefined factor model in which there are four factors is shown in chapter 1. Our purpose is to examine the strength between the variables and related factor in order to delete those variables which are less significant to the factors.

There are two approaches for confirmatory factor analysis:

a) The traditional method. Confirmatory factor analysis can be accomplished through any general-purpose statistical package which supports factor analysis. Note that for SEM CFA one uses principle axis factoring (PAF) rather than principle component analysis (PCA) as the type of factoring. This method allows the researcher to examine factor loadings of measured variables to determine if they load on latent variables as predicted by the researcher's model.

b) The SEM approach. Confirmatory factor analysis can mean the analysis of alternative measurement models using a structural equation modeling package such as AMOS or LISREL. While SEM is typically used to model causal relationship among latent variables, it is equally possible to use SEM to explore

CFA measurement models. This is done by removing from the model all straight arrows connecting latent variables, adding curved arrows representing covariance between every pair of latent variables, and leaving in the straight arrows from each latent variable to its measured variables as well as leaving in the straight arrows from error and disturbance terms to their respective variables. Such a measurement model is run like any other model and is evaluated like other models, using goodness-of-fit measures generated by SEM package.

For data analysis in this research, LISREL was used to perform confirmatory factor analysis. Using LISREL for confirmatory factor analysis provides a more rigorous assessment of the fit between the collected data and the theoretical factor structure.

4.2.4 Principal component regression

Regression analysis includes any techniques for modeling and analyzing several variables, when the focus is on the relationship between a dependent variable and one or more independent variables. Regression analysis helps one understand how the typical value of the dependent variable changes when any one of the independent variables is varied, while the other independent variables are fixed.

In statistics, principal component regression (PCR) is a regression analysis that combines principal component analysis (PCA) and linear regression when estimating regression coefficients. Linear regression is a type of regression analysis to be studied rigorously, and to be used extensively in practical applications. This is because models which depend linearly on their unknown parameters are easier to fit than models which are non-linearly related to their parameters and because the statistical properties of the resulting estimators are easier to determine. Principal component analysis is a mathematical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of uncorrelated to make a kind of regularized estimation. Therefore, PCR is a procedure used to overcome problems which arise when the variables are close to being colinear.

PCR (principal components regression) is a regression method that can be divided into three steps:

1. The first step is to run a principal components analysis on the table of the explanatory variables,
2. The second step is to run an ordinary least squares regression (linear regression) on the selected components: the factors that are most correlated with the dependent variable will be selected
3. Finally the parameters of the model are computed for the selected explanatory variables.

We can achieve the drivers' regression function and regression coefficients by using PCR model in order to get rid of the problem of multicollinearity. Regarding the application of this model, the most of statistics software can support the implementation of PCR. We use SPSS to carry out the PCR analysis due to the simplicity on usage.

Chapter 5. Application of the Mathematical Models

In this chapter, we present the application of the mathematical models based on the procedure we showed in the previous section. At the end of this chapter, we will obtain a series of the drivers that are more important and carry out the further analysis in order to get the relationship between distribution problem and distribution solution.

5.1 Application in Consumer Electronics Industry

5.1.1 Descriptive statistics analysis

Description of drivers associated product macrodriver

As for the electronic industry, the products are comparative highly innovative and the level of competition is high as well. On the other hand, the most of products we investigated are on the growth and mature stage of the whole life cycle. Therefore, these three related drivers' mean value is higher than 4, which is the highest in product marcodriver group.

With regard to the standard deviation, we can see the value of handling characteristic is zero, indicating the criticality value of the every sample is totally same. We have to remove this attribute from the driver list, because correlation analysis does not work on this driver if the standard deviation is zero.

Driver	*Mean*	*Std.Dev*
Variety	2.25	1.39
Physical Value Density	2.94	1.65
Physical Density	2.69	1.14
Risk of Obsolescence	2.75	1.44
Contribution Margin	2.31	1.01
Substitutability	3.25	1.44
Product Complexity	4.81	0.40
Stage of Life Cycle	4.25	0.45

Handling characteristic	2.00	0.00
Shelf Life	3.13	1.63
Value	3.19	1.22
ABC product characteristic	3.38	0.50
Level of Competition	4.38	0.50
Production Strategy	3.94	0.25

Table 17 Descriptive statistics result 1 in Consumer Electronics industry

Description of drivers associated service macrodriver

As the following table shows, the mean value and standard deviation of returnability and tracking is 1 and 0 respectively. From the previous chapter, we have known that the returnability and tracking are not important to electronic industry's companies; hence the value of these two drivers is low and same. Like what we did on handling characteristic, we also delete both returnability and tracking from the driver list because they do not make sense for the correlation analysis.

Driver	*Mean*	*Std.Dev*
Cycle Time	3.19	1.22
Completeness	1.50	0.52
Returnability	1.00	0.00
Accuracy	1.56	0.51
Tracking	1.00	0.00
Customer Experience	2.50	0.63
Punctuality	1.56	0.51
Ability to Expedite Orders	2.81	1.47

Table 18 Descriptive statistics result 2 in Consumer Electronics industry

Description of drivers associated demand macrodriver

With regard to the drivers in demand group, we do not have any special case for all the attributes' mean value and standard deviation. Therefore, all these eight drivers could be implemented on the correlation analysis.

Driver	*Mean*	*Std.Dev*
Dimension of the order	3.31	1.35
Number of Customer	2.94	1.24
Delivery Frequency	2.50	1.15
Seasonality	2.63	1.41
Predictability of Demand	3.75	1.00
Spatial Density	3.25	1.24
Demand Volatility	2.56	0.51
Demand Level	3.06	0.68

Table 19 Descriptive statistics result 3 in Consumer Electronics industry

Description of drivers associated supply macrodriver

From the following figure, we can see that the mean value of distance from plant to client and level of specialization is high, while the standard deviation of all the drivers is normal. In our samples, the minimum distance from plant to client is 1000km, but mostly are 9000km, which leads to the high criticality value on this driver and the high mean value. With regard to the level of specialization, by taking into account the high level of competition, the providers have to produce one product family in one plant as more as possible for the sake of economies of scale and the reduce of total operation costs.

Driver	*Mean*	*Std.Dev*
Number of Plants	2.31	1.25
Distance from plant to client	4.31	0.95
Level of Specialization	4.50	0.89
Exclusivity of production in a plant	2.13	1.41

Table 20 Descriptive statistics result 4 in Consumer Electronics industry

Based on the result of descriptive statistics, three drivers, Handling characteristic, Returnability, and Tracking could be eliminated by considering two reasons. The first is that the standard deviation of these drivers is zero, which indicates the value of each sample is the same. Thus, we cannot identify the difference among the samples on these drivers. The second reason is that the criticalities of these drivers are very low, representing these drivers have very slight impact on the logistics costs. Consequently, we could neglect these three drivers on electronics industry. Therefore, there are 31 drivers are left in the driver list. We will conduct the correlation analysis for these 31 attribute on the next step.

5.1.2 Correlation analysis

The correlation analysis is done by considering the criticality of every driver. We intend to eliminate and/or combine drivers, which have high correlation with others. For this purpose, the value of -0.7 or lower, and 0.7 or higher will be considered as exception in the correlation matrix.

According to the existing distribution network design model, we figure out four correlation matrixes based on four macrodrivers. In this section, we will discuss those exceptions highlighted with yellow. On the other hand, the drivers allocated in different macrodrivers may also have high correlation. However, the drivers in different marcodriver group reflect different aspects of the distribution problem. Such kind high correlation will not be argued.

Product macrodriver:

	Variety	*Product value density*	*Physical density*	*Risk of obsolescence*	*Contribution margin*	*Substitutability*	*Product complexity*	*Stage of life cycle*	*Shelf life*	*Value*	*ABC product characteristic*	*Level of competition*	*Production strategy*
Variety	1.00	-	-	-	-	-	-	-	-	-	-	-	-
Product value density	0.36	1.00	-	-	-	-	-	-	-	-	-	-	-

Physical density	0.22	-0.54	1.00	-	-	-	-	-	-	-	-	-	-
Risk of obsolescence	0.00	0.64	-0.50	1.00	-	-	-	-	-	-	-	-	-
Contribution margin	-0.44	0.57	-0.49	0.42	1.00	-	-	-	-	-	-	-	-
Substitutability	-0.83	0.04	-0.32	0.06	0.81	1.00	-	-	-	-	-	-	-
Product complexity	0.09	0.58	-0.14	-0.09	0.64	0.43	1.00	-	-	-	-	-	-
Stage of life cycle	-0.54	-0.52	0.43	-0.73	0.11	0.52	0.28	1.00	-	-	-	-	-
Shelf life	-0.40	0.10	-0.34	0.73	0.26	0.30	-0.27	-0.41	1.00	-	-	-	-
Value	0.13	-0.46	0.33	-0.43	-0.75	-0.45	-0.33	0.15	-0.11	1.00	-	-	-
ABC product characteristic	0.43	-0.21	-0.13	-0.14	-0.64	-0.70	-0.62	-0.45	-0.31	0.20	1.00	-	-
Level of competition	0.43	-0.21	-0.13	-0.14	-0.64	-0.70	-0.62	-0.45	-0.31	0.20	1.00	1.00	-
Production strategy	-0.53	-0.33	-0.54	-0.23	0.08	0.42	-0.12	0.15	0.18	0.04	0.20	0.20	1.00

Table 21 Correlation analysis result 1 in Consumer Electronics industry

- **Variety – Substitutability** -0.83

It was obtained a correlation factor of -0.83 which indicates that a high criticality on the variety (high number of product codes) is obtained when the criticality on substitutability is low. However, the lower criticality of substitutability represents the higher number of product codes per product family and the lower lost of stock out. In other words, the number of substitute products is high as long as the high number of product codes is obtained. Obviously, the variety and substitutability has a strong logical relation. The substitutability could be seen once the number of product codes is known. Hence, we eliminate substitutability.

- **Risk of obsolescence – Stage of life cycle** -0.73

The stage of life cycle of product is very difficult to define and measure. In this work, we evaluate the stage of life cycle based on some other drivers including risk obsolescence. This is the reason of why these two drivers have strong correlation with

-0.73. However, the two drivers indicate very different concept. Thus, we consider this correlation factor is reasonable.

- **Risk of obsolescence – Shelf Life** 0.73

We can obtain a positive correlation factor of 0.73 between risk obsolescence and shelf life, indicating the entire product life cycle is proportional to the length of life cycle on the shelf. The products with low criticality on risk obsolescence means the long product life cycle, and the life cycle on shelf is long as well. In additional, both of two drivers affect the inventory level and the transportation modes. Therefore, we intend to delete one driver. By taking into account that the risk of obsolescence is used as a performance indicator by companies generally, while the shelf life is not a common driver, hence, we remove shelf life from the driver list.

- **Contribution margin – Substitutability** 0.81

The substitutability was removed. Hence, we don't discuss this exception.

- **Contribution margin – Value** -0.75

From the result of correlation factor -0.75 between contribution margin and value, we can see that the profit margin is inverse proportional to the price of the product. From the previous discuss about driver's concept, we have known that product value is one important factor when we figure out the contribution margin. What is more, contribution margin is a frequently used indicator for almost every firm in order to measure the company's performance. Hence, the value is eliminated because these two drivers are overlapped.

- **Substitutability – ABC product characteristic, Level of competition** -0.70

We don't discuss this because substitutability was deleted.

- **ABC product characteristic – Level of competition** 1.00

These two drivers are fully correlated in our matrix. However, they are very different no matter on the concept and the measurement method. We think this exception results from the measurement error because the sample size is not large. Therefore, no driver would be eliminated.

Service macrodriver:

	Cycle time	*Completeness*	*Accuracy*	*Customer experience*	*Punctuality*	*ability to expedite orders*
Cycle time	1.00	-	-	-	-	-
Completeness	-0.16	1.00	-	-	-	-
Accuracy	-0.29	0.88	1.00	-	-	-
Customer experience	0.04	-0.82	-0.93	1.00	-	-
Punctuality	-0.29	0.88	1.00	-0.93	1.00	-
ability to expedite orders	0.06	0.31	0.24	-0.32	0.24	1.00

Table 22 Correlation analysis result 2 in Consumer Electronics industry

- **Accuracy – Punctuality** 1.00

The delivery accuracy and punctuality are fully correlated since both of them reflect different one aspect of service level respectively. The accuracy indicates the right order could be delivered to right customer. The punctuality represents the delivery is on time. We consider that these two drivers could be combined as delivery accuracy & punctuality, and we use this new integrated driver for the following analyses.

- **Completeness – Customer experience** -0.82

The correlation factor -0.82 was obtained between completeness and customer experience. However, there is no obvious logical relation between these two drivers.

Therefore, we consider this high correlation results from the measurement error. We don't eliminate any driver.

- **Completeness – Accuracy & Punctuality** 0.88

The completeness and accuracy & punctuality are highly correlated. Completeness indicates the probability of having a product in stock when a customer's order arrives. This driver can be seen the prerequisite to product delivery, while the accuracy & punctuality reflects the quality of delivery. They have different function in logistics system. Therefore, we think this high correlation is caused by measurement error and don't delete any attribute

- **Customer experience – Accuracy & Punctuality** -0.93

The customer experience is highly correlated with accuracy & punctuality. However, we don't think there is a logical relation between them. Hence, both drivers are left.

Demand macrodriver:

	Dimension of the orders	***Number of customers***	***Delivery frequency***	***Seasonality***	***Predictability of demand***	***Spatial density***	***Demand volatility***	***Demand level***
Dimension of the orders	1.00	-	-	-	-	-	-	-
Number of customers	0.65	1.00	-	-	-	-	-	-
Delivery frequency	-0.70	-0.30	1.00	-	-	-	-	-
Seasonality	0.28	-0.28	-0.04	1.00	-	-	-	-
Predictability of demand	-0.18	0.04	0.35	-0.07	1.00	-	-	-
Spatial density	-0.59	-0.92	0.13	0.16	-0.32	1.00	-	-
Demand	0.18	-0.04	-0.35	0.07	-1.00	0.32	1.00	-

volatility								
Demand level	0.03	0.15	-0.41	-0.67	-0.57	0.13	0.57	1.00

Table 23 Correlation analysis result 3 in Consumer Electronics industry

- **Dimension of the orders – Delivery frequency** -0.70

A negative correlation factor of -0.70 was obtained for this pair of drivers, meaning that the frequency of delivery is reduced when the criticality of order dimension is high while the value of that is low. We consider that small customers are the ones which orders generally are small, and because of lack of stock space or because of the small amount of sales per week, the frequency of delivery is small as well. Thus, the correlation is reasonable and none of drivers should be removed.

- **Number of customers – Spatial density** -0.92

By taking into consider that spatial density is highly correlated with number of customers, we may eliminate this driver. We have two reasons to delete spatial density. First of all, the spatial density is measured based on the number of customers per square kilometer (#of customer/km^2). However, the exact market area is not easy to measure, and this attribute is not usually used in companies. Secondly, number of customers can affect transportation cost, handling cost and order management cost, while the spatial density only has impact on local transportation cost. Hence, we remove spatial density from the driver list.

- **Predictability of demand – Demand volatility** -1.00

The predictability of demand is negative correlated with demand volatility, and the factor is -0.88. The level of predictability is determined by several factors, such as the use of information system, the effective of management control system in company, the extraneous factor and so on. Despite the demand volatility may increase the difficulty to predict the demand; we don't remove any driver, because the logical relation between these two attributes is not obvious.

Supply macrodriver:

	Number of plants	*Distance from plant to client*	*Level of specialization*	*Exclusivity of production in a plant*
Number of plants	1.00	-	-	-
Distance from plant to client	-0.03	1.00	-	-
Level of specialization	-0.80	-0.28	1.00	-
Exclusivity of production in a plant	0.39	-0.08	-0.69	1.00

Table 24 Correlation analysis result 4 in Consumer Electronics industry

- **Number of Plants – Level of Specialization** -0.80

The correlation factor -0.80 indicates the large number of plants is obtained when the criticality of production specialization level is low (value of specialization level is high or medium). It is very possible to consider that if the number of plants is very large, one product family may be allocated to more than one plant to produce. Hence, the negative correlation between this pair of drivers is reasonable.

According to the preceding correlation analysis, substitutability is eliminated because the implication of variety covers that of substitutability. Shelf life is removed from driver list since this driver could be replaced by risk of obsolescence. Value and spatial density are deleted because contribution margin and number of customers are more frequently used in practice.

Delivery accuracy and delivery punctuality could be combined by taking into consideration both of them reflect service level but on different aspects. Furthermore, these two drivers are perfectly correlated. Hence, they can be integrated to one driver as Accuracy & Punctuality.

The result of available drivers in Consumer Electronics industry

Product	Variety
	Physical Value Density
	Physical Density
	Risk of Obsolescence
	Contribution Margin
	Product Complexity
	Stage of Life Cycle
	ABC Product Characteristic
	Level of Competition
	Production Strategy
Service	Cycle Time
	Completeness
	Accuracy & Punctuality
	Customer Experience
	Punctuality
Demand	Dimension of the Order
	Number of Customers
	Delivery Frequency
	Seasonality
	Predictability of Demand
	Demand Volatility
	Demand Level
Supply	Number of Plants
	Distance from plant to client
	Level of specialization
	Exclusivity of production in a plant

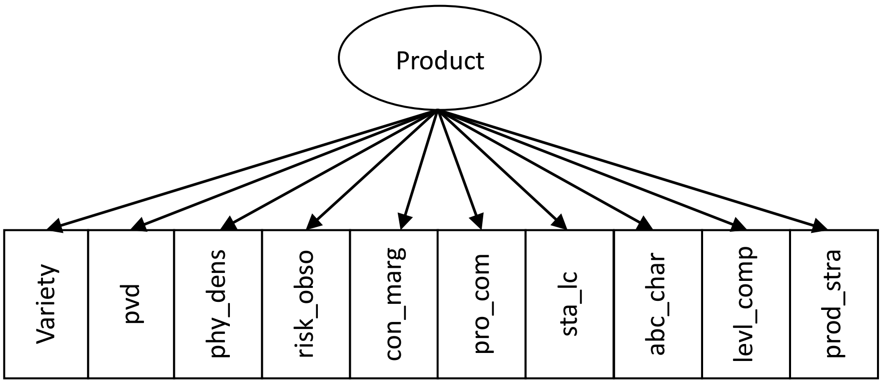
Total: 26

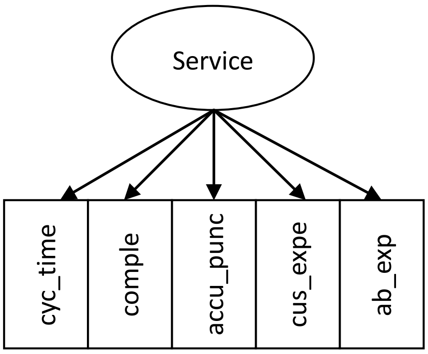
Table 25 Driver list after correlation analysis in Consumer Electronics industry

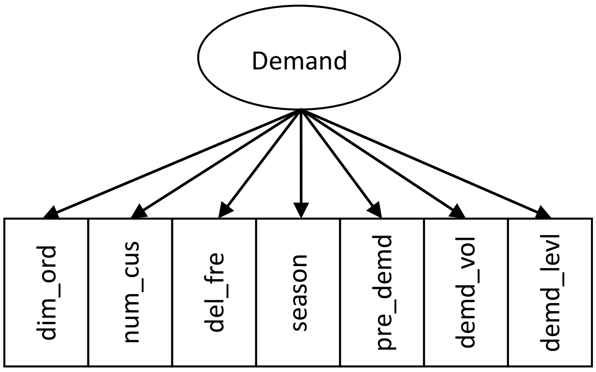
5.1.3 Confirmatory factor analysis

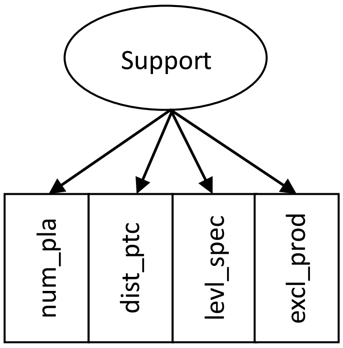
Theoretical Model

In the existing distribution network model, there are four factors comprising several variables respectively. We assume that these factors are mutual independent. The following diagrams represent the construct of each factor.









Graph 1 Theoretical model of CFA in Consumer Electronics industry

Methods for data analysis

In general, the overall model fit can be tested using the comparative fit index (CFI), non-normed fit index (NNFI), root mean square error of approximation (RMSEA), and normed chi-square (i.e. x^2 per degree of freedom). Values of CFI and NNFI between 0.80 and 0.89 represent a reasonable fit and scores of 0.90 or higher are evidence of good fit. Values of RMSEA less than 0.08 are acceptable. The normed chi-square (x^2 divided by degrees of freedom) estimates the relative efficiency of competing models. For the statistic, a value less than 3.0 indicates a reasonable fit and a value less than 2 shows a good fit.

The recommended value of goodness of fit:

CFI	*NNFI*	*RMSEA*	x^2/*df*
>0.8	>0.8	<0.08	<3

Table 26 Recommended value of goodness-of-fit for CFA

Hypotheses

In the previous introduction, we have known the implication of the attributes and the relation of these variables with different factors as the theoretical model we showed. In the following discussion, we need to make hypotheses for every variable in order to test if they really are important to the factor.

Product Factor:

Variety. The variety of products has direct impact on the stock cost and maintenance cost for the total logistics costs. Therefore, H1P based on this influence.

H1P. Variety is positively related to product factor.

Physical value density. High value density products bring higher storage and lower transport costs. On the other hand, the low value density products have opposite impact on the storage and transport costs.

H2P. Physical value density is positively related to product factor.

Physical density. The physical density could influence both storage and transportation costs.

H3P. Physical density is positively related to product factor.

Risk of obsolescence. The length of life cycle tends to impact the inventory and transportation costs in the logistics management.

H4P. Risk of obsolescence is positively related to product factor.

Contribution margin. The contribution margin is corresponding to transport policy in logistics management, and hence impacts on the transportation costs.

H5P. Contribution margin is positively related to product factor.

Product complexity. Product complexity is related to the centralization of distribution channel, and hence influences the total logistics costs.

H6P. Product complexity is positively related to product factor.

Stage of life cycle. Stage of life cycle is related to the strategy of logistical planning, and requires the distribution network configuration is implemented in economical way. Therefore, the stage of life cycle could impact the whole logistics costs.

H7P. Stage of life cycle is positively related to product factor.

ABC product characteristic. On the basis of 80-20 concept, ABC product characteristic influences the total logistics costs due to the distribution network configuration of different items may different.

H8P. ABC product characteristic is positively related to product factor.

Level of competition. Level of competition may bring the high inventory cost in order to reduce the probability of stock out.

H9P. Level of competition is positively related to product factor.

Production strategy. Production strategy has impact on the inventory cost and transport cost.

H10P. Production strategy is positively related to product factor.

Service Factor:

Cycle time. Cycle time could influence the number of facility and transportation costs.

H1S. Cycle time is positively related to service factor.

Completeness. An increase in the required completeness will bring additional inventory cost, but increase the service level.

H2S. Completeness is positively related to service factor.

Accuracy & Punctuality. Accuracy and punctuality influence the transportation cost and inventory cost.

H3S. Accuracy & punctuality is positively related to service factor.

Customer experience. Customer experience is influenced by the way of customers purchase the product and the number of sales points. Hence, this variable has impact on the facility cost and the lost of stock out.

H4S. Customer experience is positively related to service factor.

Ability of expedite orders. Ability of expedite orders could increase the logistics costs while the cost of lost sales would be decrease and enhance the service level.

H5S. Ability of expedite orders is positively related to service factor.

Demand Factor:

Dimension of the order. Dimension of the order which is determined by customer's demand requirement has impact on transport cost.

H1D. Dimension of the order is positively related to demand factor.

Number of customers. The number of customers has significant impact on the transportation cost due to the number of deliveries is caused by this attribute.

H2D. Number of customers is positively related to demand factor.

Delivery frequency. Delivery frequency influences the stock and maintenance costs, which affects the different total logistics costs.

H3D. Delivery frequency is positively related to demand factor.

Seasonality. Seasonality affects stocking cost 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.

H4D. Seasonality is positively related to demand factor.

Predictability of demand. Predictability of demand has direct impact on the inventory cost in order to cover the error in the demand forecast.

H5D. Predictability of demand is positively related to demand factor.

Demand volatility. Demand volatility is associated the inventory cost. The inventory cost is high if the average demand change rate is large.

H6D. Demand volatility is positively related to demand factor.

Demand level. Demand level influences transport polity and warehouse size and location, hence affects the transportation and facility costs.

H7D. Demand level is positively related to demand factor.

Supply Factor:

Number of plants. Number of plants has significant impact on the facility cost, and influences the transportation cost as well.

H1Su. Number of plants is positively related to supply factor.

Distance from plant to client. The distance from plant to client affects total logistics costs since with the increase of distance there is a direct increase of transport cost.

H2Su. Distance from plant to client is positively related to supply factor.

Level of specialization. Level of specialization of the plant influences the inventory cost and transportation cost.

H3Su. Level of specialization is positively related to supply factor.

Exclusivity of production in a plant. Exclusivity of production in a plant is adverse to level of specialization, while also has impact on the inventory cost and transportation cost.

H4Su. Exclusivity of production in a plant is positively related to supply factor.

Hypotheses	
Product Factor	
1	Variety is positively related to product factor.
2	PVD is positively related to product factor.
3	Physical density is positively related to product factor.
4	Risk of obsolescence is positively related to product factor.
5	Contribution margin is positively related to product factor.
6	Product complexity is positively related to product factor.

7	Stage of life cycle is positively related to product factor.
8	ABC product characteristic is positively related to product factor.
9	Level of competition is positively related to product factor.
10	Production strategy is positively related to product factor.
Service Factor	
1	Cycle time is positively related to service factor.
2	Completeness is positively related to service factor.
3	Accuracy & punctuality is positively related to service factor.
4	Customer experience is positively related to service factor.
5	Ability of expedite orders is positively related to service factor.
Demand Factor	
1	Dimension of the order is positively related to demand factor.
2	Number of customers is positively related to demand factor.
3	Delivery frequency is positively related to demand factor.
4	Seasonality is positively related to demand factor.
5	Predictability of demand is positively related to demand factor.
6	Demand volatility is positively related to demand factor.
7	Demand level is positively related to demand factor.
Supply Factor	
1	Number of plants is positively related to supply factor.
2	Distance from plant to client is positively related to supply factor.
3	Level of specialization is positively related to supply factor.
4	Exclusivity of production in a plant is positively related to supply factor.

Table 27 Hypotheses for CFA in Consumer Electronics industry

Measurement model results

The measurement model examines how much the independent variable could explain the latent factor, and the result is represented by factor loading. This assessment is conducted separately for product, service, demand, and supply factor. In some cases where refinement is indicated, part of variables is deleted if such action was theoretically sound (Anderson, 1987).

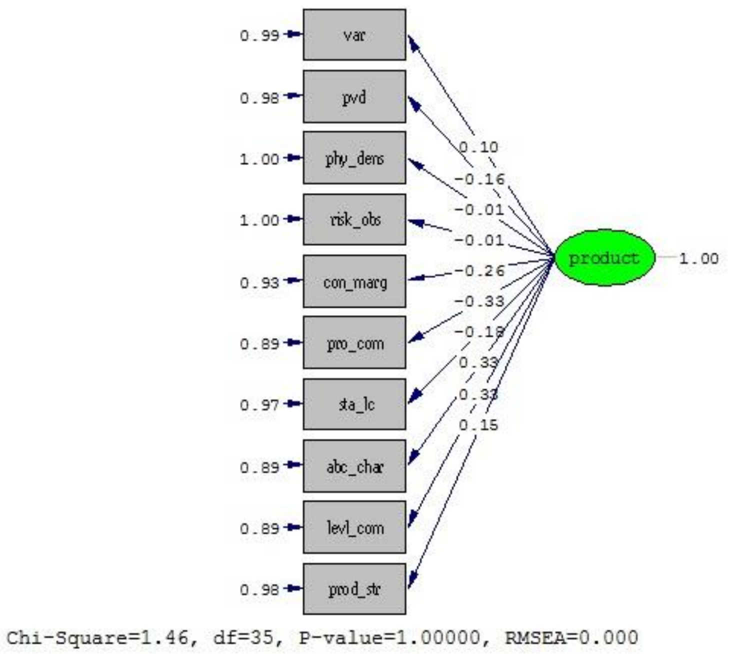
What is more, the factor loading can be larger than one, which does not necessarily imply that something is wrong, although, it might suggest that there is a high degree of multicollinearity in the data (Karl G Joreskog, 1999).

Product Factor:

The initial fit indices for product factor (e.g. NNFI=-0.02) suggest that improvement could be made in the measures. Examination of the factor loadings suggests that physical density, risk of obsolescence, and production strategy should be dropped from the product factor because of low loadings.

After the refinement, the re-specified measurement model for product factor indicates an acceptable fit CFI=0.92, NNFI=0.87, RMSEA=0.144(acceptable), x^2/df=1.056, *P*-value<0.1.

The first run:

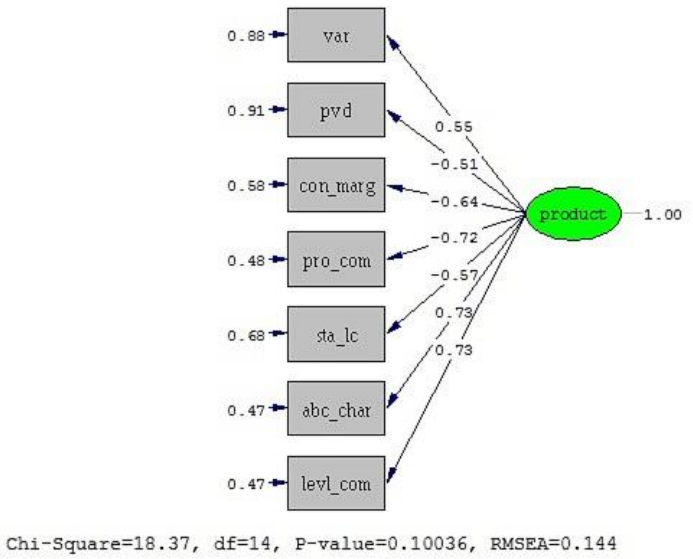


CFI	*NNFI*	*RMSEA*	x^2 */df*
N/A	-0.02	0.000	0.042

Table 28 Initial result of CFA for product factor in Consumer Electronics industry

After improvement:

Item	***Indication***	***Action***
Physical density	low loading(0.01)	Drop
Risk of obsolescence	low loading(0.01)	Drop
Production strategy	low loading(0.15)	Drop



CFI	***NNFI***	***RMSEA***	χ^2***/df***
0.92	0.87	0.144	1.312

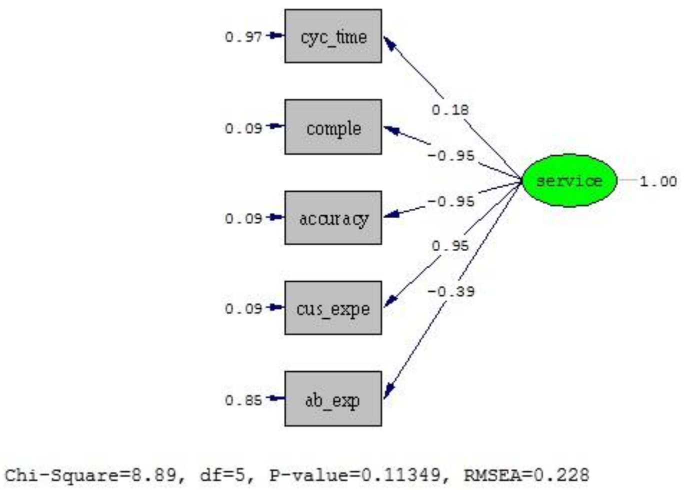
Table 29 Final result of CFA for product factor in Consumer Electronics industry

Service Factor:

The initial fit indices for service factor (e.g. NNFI=0.69, RMSEA=0.228) suggest that improvement could be made in the measures. Therefore, we drop the ability of expedite orders from the driver list. We consider the cycle time should be a important variable based on the previous literature study even if the factor loading of this driver is low.

After the improvement operation, the re-specified measurement model for product factor indicates an acceptable fit CFI=0.81, NNFI=0.84, RMSEA=0.079, χ^2/df=3.155, *P*-value=0.043.

The first run:

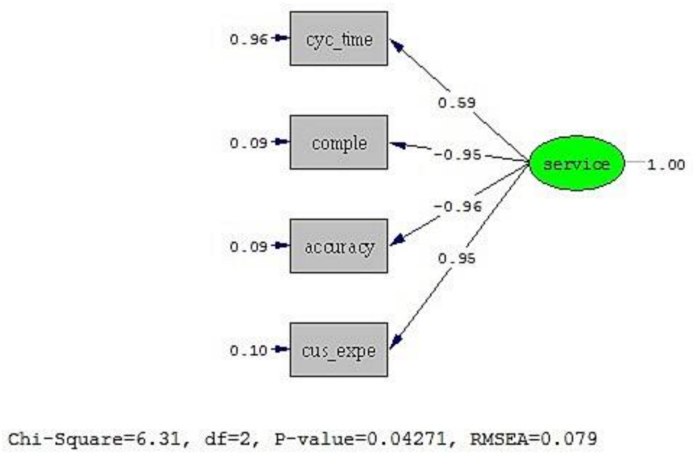


CFI	*NNFI*	*RMSEA*	χ^2/df
0.85	0.69	0.228	1.778

Table 30 Initial result of CFA for service factor in Consumer Electronics industry

After improvement:

Item	*Indication*	*Action*
Ability to expedite orders	low loading(0.39)	Drop



CFI	*NNFI*	*RMSEA*	χ^2/df
0.81	0.84	0.079	3.155

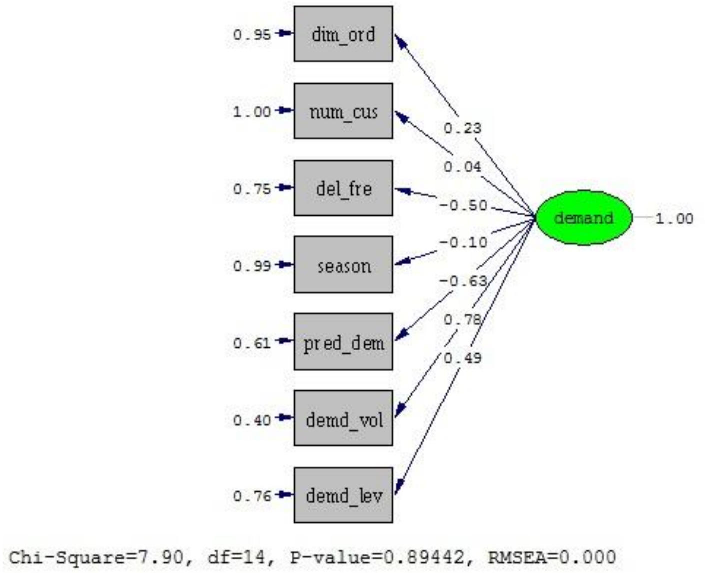
Table 31 Final result of CFA for service factor in Consumer Electronics industry

Demand Factor

From the following diagram, we can see that the first fit indices for demand factor (e.g. CFI=N/A, NNFI=-4.42) propose that refinement should be done in order to obtain a better goodness of fit. Two drivers, number of customers and seasonality have to be removed due to the lowest factor loading.

After the refinement, a good model's fit is generated: CFI=0.80, NNFI=0.81, RMSEA=0.088, x^2/df=1.532, *P*-value=0.076.

The first run:

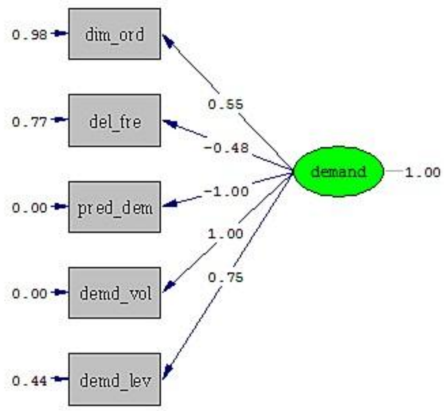


CFI	*NNFI*	*RMSEA*	x^2 */df*
N/A	-4.42	0.000	0.564

Table 32 Initial result of CFA for demand factor in Consumer Electronics industry

After improvement:

Item	*Indication*	*Action*
Number of customers	low loading(0.04)	Drop
Seasonality	low loading(0.10)	Drop



Chi-Square=7.66, df=5, P-value=0.07614, RMSEA=0.088

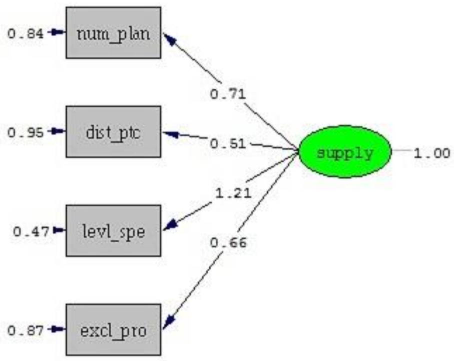
CFI	*NNFI*	*RMSEA*	*x^2 /df*
0.80	0.81	0.088	1.532

Table 33 Final result of CFA for demand factor in Consumer Electronics industry

Supply Factor:

The initial fit indices for supply factor shows a good model's fit: CFI=1.00, NNFI=0.82, RMSEA=0.047, x^2 /df=0.29, *P*-value=0.047. This result indicates none of the drivers would be deleted.

The first run:



Chi-Square=0.58, df=2, P-value=0.04683, RMSEA=0.000

CFI	*NNFI*	*RMSEA*	*x^2 /df*
1.00	0.82	0.047	0.29

Table 34 Final result of CFA for supply factor in Consumer Electronics industry

Finally, the results of measurement model show us a set of variables associated four different factors in Consumer Electronics industry. These variables are selected by the factor loading on the basis of covariance between the drivers and specific latent factor, and the corresponding hypotheses are tested according to the statistics indicator.

Product	Variety
	Product value density
	Contribution margin
	Product complexity
	Stage of life cycle
	ABC product characteristic
	Level of competition
Service	Cycle time
	Completeness
	Accuracy & Punctuality
	Customer experience
Demand	Dimension of the orders
	Delivery frequency
	Predictability of demand
	Demand volatility
	Demand level
Supply	Number of plants
	Distance from plant to client
	Level of specialization
	Exclusivity of production in a plant

Total: 20

Table 35 Driver list after CFA in Consumer Electronics industry

Hypotheses		
Product Factor		
1	Variety is positively related to product factor.	True
2	PVD is positively related to product factor.	True
3	Physical density is positively related to product factor.	False
4	Risk of obsolescence is positively related to product factor.	False
5	Contribution margin is positively related to product factor.	True
6	Product complexity is positively related to product factor.	True
7	Stage of life cycle is positively related to product factor.	True
8	ABC product characteristic is positively related to product factor.	True
9	Level of competition is positively related to product factor.	True
10	Production strategy is positively related to product factor.	False
Service Factor		
1	Cycle time is positively related to service factor.	True
2	Completeness is positively related to service factor.	True
3	Accuracy & punctuality is positively related to service factor.	True
4	Customer experience is positively related to service factor.	True
5	Ability of expedite orders is positively related to service factor.	False
Demand Factor		
1	Dimension of the order is positively related to demand factor.	True
2	Number of customers is positively related to demand factor.	False
3	Delivery frequency is positively related to demand factor.	True
4	Seasonality is positively related to demand factor.	False
5	Predictability of demand is positively related to demand factor.	True
6	Demand volatility is positively related to demand factor.	True
7	Demand level is positively related to demand factor.	True
Supply Factor		
1	Number of plants is positively related to supply factor.	True
2	Distance from plant to client is positively related to supply factor.	True

3	Level of specialization is positively related to supply factor.	True
4	Exclusivity of production in a plant is positively related to supply factor.	True

Table 36 Hypotheses result of CFA in Consumer Electronics industry

5.1.4 Principal component regression

Before the operation of principal component regression model, we need to evaluate the value of distribution solution and standardize them for each distribution problem, since the distribution solution should be used as dependent variable in the regression model.

Value and criticality of distribution solution

Company	*Distribution Solution*	*Value*	*Criticality*
HP	1 echelon: 2 transit points	2	2
SO1	1 echelon: 1 national CW	1	2
SO2	2 echelons: 1 national CW+ 13 transit points for big clients	7	3
SO3	2 echelons: 1 national CW+ 13 transit points for small clients	7	3
SO4	1 echelon: 2 CWs (international + national)	2	2
SO5	2 echelons: 2 CWs (international+national) + 13 transit points for big clients	7.5	4
SO6	2 echelons: 2 CWs (international+national) + 13 transit points for small clients	7.5	4
SA1	Direct shipment	N/A	1
SA2	1 echelon: 1 regional CW for big clients	1	2
SA3	2 echelons: 1 regional CW + 20 transit points	10.5	4
SA4	1 echelon: 1 regional CW for big clients	1	2
SA5	2 echelons: 1 regional CW + 20 transit points	10.5	4
SA6	1 echelon: 1 regional CW for big clients	1	2
SA7	2 echelons: 1 regional CW+150 transit points	150.5	5
SA8	1 echelon: 1 regional CW for big clients	1	2
SA9	2 echelons: 1 regional CW+20 transit points	10.5	4

Table 37 Distribution solution in Consumer Electronics industry

We use level of decentralization to evaluate the distribution solution of each distribution problem. The formula of decentralization level is: number of facilities/number of echelon. If the value is high, it is could be said the distribution network has more facility points in the distribution channel, meanwhile the complexity and robustness of distribution network is high. The value of decentralization level is shown on the above table.

The regression analysis could be implemented as long as the value of both dependent and independent variables are obtained.

Regression Function

solution=-5.8029+(0.1748)variety+(-0.116)pvd+(-0.116)conmarg+(0.3773)procomp+(0.231)stalc+(0.6049)abcchar+(0.6049)levcomp+(-0.7206)cyctime+(2.5535)complet+(-0.2756)accupun+(-0.0163)cusexpe+(0.6176)dimorde+(0.0882)delfreq+(0.3024)preddem+(-0.6049)demdvol+(-0.1906)demdlev+(0.0776)numplat+(0.1388)distptc+(-0.3341)levlspe+(-0.0795)exclpro

R^2=0.952, adjusted R^2=0.856, F (10,5) =9.884, P=0.010

Driver	*Regression coefficient*
Variety	0.1748
Physical Value Density	-0.1160
Contribution Margin	-0.1160
Product Complexity	0.3773
Stage of Life Cycle	0.2310
ABC product characteristic	0.6049
Level of Competition	0.6049
Cycle Time	-0.7206
Completeness	2.5535
Accuracy & Punctuality	-0.2756
Customer Experience	-0.0163
Dimension of the order	0.6176
Delivery Frequency	0.0882
Predictability of Demand	0.3024

Demand Volatility	-0.6049
Demand Level	-0.1906
Number of Plants	0.0776
Distance from plant to client	0.1388
Level of Specialization	-0.3341
Exclusivity of production in a plant	-0.0795

Table 38 Regression coefficient of drivers in Consumer Electronics industry

5.2 Application in FMCG Industry

5.2.1 Descriptive statistics

Description of drivers associated product macrodriver

With regard to FMCG industry, the level of competition is very aggressive. Hence, the mean value of this driver is higher. From the following table, we can see an exception on the stage of life cycle. The standard deviation of this attribute is zero, which makes no sense for the further analysis. We have to remove this driver as what we did in the electronic industry.

Driver	*Mean*	*Std.Dev*
Variety	2.56	1.03
Physical Value Density	2.50	1.15
Physical Density	3.06	0.99
Risk of Obsolescence	2.19	1.17
Contribution Margin	3.44	1.20
Substitutability	2.56	1.03
Product Complexity	1.63	1.26
Stage of Life Cycle	3.00	0.00
Handling characteristic	2.44	1.86
Shelf Life	2.19	1.17
Level of Competition	4.50	1.03

Production Strategy	2.19	0.54

Table 39 Descriptive statistics result 1 in FMCG industry

Description of drivers associated service macrodriver

Driver	*Mean*	*Std.Dev*
Cycle Time	2.25	1.13
Completeness	3.19	0.54
Accuracy	2.25	1.13
Tracking	3.56	0.51
Customer Experience	3.44	0.73
Punctuality	3.44	0.73

Table 40 Descriptive statistics result 2 in FMCG industry

Description of drivers associated demand macrodriver

Driver	*Mean*	*Std.Dev*
Dimension of the order	2.25	1.53
Number of Customer	3.19	1.28
Delivery Frequency	2.38	1.26
Seasonality	3.63	1.86
Predictability of Demand	3.75	0.45
Spatial Density	3.25	1.39

Table 41 Descriptive statistics result 3 in FMCG industry

Description of drivers associated supply macrodriver

In general, the products profit in FMCG industry is not high. Therefore, the supplier has to reduce the production cost by the economies of scale. This is the reason of why the mean factor on level of specialization is a little bit higher than that of other drivers in this group.

Driver	*Mean*	*Std.Dev*
Number of Plants	2.50	1.67

Distance from plant to client	3.31	1.25
Level of Specialization	4.00	1.10
Exclusivity of production in a plant	3.19	1.05

Table 42 Descriptive statistics result 4 in FMCG industry

5.2.2 Correlation analysis

As what we did for Consumer Electronics industry, we also highlighted the value of -0.7 or lower, and 0.7 or higher that will be considered as exception in the correlation matrix.

Product macrodriver:

	Variety	*Product value density*	*Physical density*	*Risk of obsolescence*	*Contribution margin*	*Substitutability*	*Product complexity*	*Handling characteristic*	*Shelf life*	*Level of competition*	*Production strategy*
Variety	1.00	-	-	-	-	-	-	-	-	-	-
Product value density	0.87	1.00	-	-	-	-	-	-	-	-	-
Physical density	-0.36	-0.20	1.00	-	-	-	-	-	-	-	-
Risk of obsolescence	-0.04	0.02	0.45	1.00	-	-	-	-	-	-	-
Contribution margin	0.38	0.55	-0.08	-0.06	1.00	-	-	-	-	-	-
Substitutability	1.00	0.87	-0.36	-0.04	0.38	1.00	-	-	-	-	-
Product complexity	0.48	0.55	-0.03	-0.49	0.33	0.48	1.00	-	-	-	-
Handling charactristic	-0.14	-0.05	0.20	0.27	-0.27	-0.14	-0.12	1.00	-	-	-
Shelf life	-0.04	0.02	0.45	1.00	-0.06	-0.04	-0.49	0.27	1.00	-	-
Level of competition	-0.59	-0.61	0.36	-0.14	-0.61	-0.59	-0.10	0.16	-0.14	1.00	-
Production strategy	0.39	0.37	0.10	-0.37	0.27	0.39	0.89	-0.02	-0.37	-0.06	1.00

Table 43 Correlation analysis result 1 in FMCG industry

- **Variety – Product value density** 0.87

Even despite the fact that the correlation analysis shows high level of relation between these factors, there is no logical explanation that can proof this relation. Thus we decided to leave both factors for successive analysis.

- **Variety – Substitutability** 1.00

It was obtained a correlation factor of 1.00 which indicates that a high criticality on the variety (high number of product codes) is obtained when the criticality on substitutability is low. We met the same situation in electronic industry. Therefore, we delete substitutability.

- **Product value density – Substitutability** 0.87

Here we have the same situation as we had with "variety" and "substuitability" before. High level of correlation in this case can be explained by the fact that "variety" and "product value density" are strongly correlated between each other and behave in the same way regards other drivers. As the previous case, there is no logical explanation that can proof the relation we observe between "product value density" and "substitutability". That's why we do not eliminate any driver on this stage of the analysis.

- **Risk of obsolescence – Shelf life** 1.00

The risk of obsolescence and shelf life are fully correlated. We intend to delete one driver. By taking into account that the risk of obsolescence is used as a performance indicator by companies generally, while the shelf life is not a common driver, hence, we remove shelf life from the driver list.

- **Product complexity – Production strategy** 0.89

As in some other cases, we have encountered before, here we can also observe an absence of logical facts that can help to explain the relationship between "product complexity" and "production strategy". The result is that we leave both of the drivers.

Service macrodriver:

	Cycle time	*Completeness*	*Accuracy*	*Tracking*	*Customer experience*	*Punctuality*
Cycle time	1.00	-	-	-	-	-
Completeness	-0.11	1.00	-	-	-	-
Accuracy	-0.33	0.56	1.00	-	-	-
Tracking	-0.14	-0.22	0.45	1.00	-	-
Customer experience	0.31	-0.36	-0.37	0.51	1.00	-
Punctuality	-0.14	0.84	0.60	-0.35	-0.67	1.00

Table 44 Correlation analysis result 2 in FMCG industry

➢ **Completeness – Punctuality** 0.84

The correlation analysis shows us that there can be some relation between two drivers: "completeness" and "punctuality". It can be not so obvious, but if we think a little bit deeper, we can understand that really these two drivers can be connected. The driver "completeness" described as item fill rate. If the value of the driver is low, it means that the company is not able to complete the order in terms of number and ranged of SKUs asked by the client. It can lead to some delays in verifying the availability of the particular SKU in other warehouses and waiting for their delivery. In the end it affects the overall response time of the network and in this way affects the "punctuality" driver as the ability to deliver requested quantity on time.

Demand macrodriver:

	Dimension of the orders	*Number of customers*	*Delivery frequency*	*Seasonality*	*Predictability of demand*	*Spatial density*
Dimension of the orders	1.00	-	-	-	-	-
Number of customers	0.15	1.00	-	-	-	-
Delivery frequency	-0.43	-0.63	1.00	-	-	-
Seasonality	-0.41	-0.11	0.26	1.00	-	-
Predictability of demand	0.39	0.44	-0.53	-0.36	1.00	-
Spatial density	-0.50	0.27	-0.44	0.27	-0.11	1.00

Table 45 Correlation analysis result 3 in FMCG industry

Supply macrodriver:

	Number of plants	*Distance from plant to client*	*Level of specialization*	*Exclusivity of production in a plant*
Number of plants	1.00	-	-	-
Distance from plant to client	0.49	1.00	-	-
Level of specialization	-0.07	0.54	1.00	-
Exclusivity of production in a plant	0.40	0.61	0.81	1.00

Table 46 Correlation analysis result 4 in FMCG industry

- **Level of specialization – Exclusivity of production in a plant** 0.81

As these two drivers can be seen as somehow similar one to another, we decide to leave just one of them to reduce the complexity of the further analysis.

The result of available drivers in FMCG industry

Product	Variety
	Physical Value Density
	Physical Density
	Risk of Obsolescence
	Contribution Margin
	Product Complexity
	Handling characteristic
	Level of Competition
	Production Strategy
Service	Cycle Time
	Completeness
	Accuracy
	Tracking
	Customer Experience
	Punctuality
Demand	Dimension of the order
	Number of Customer
	Delivery Frequency
	Seasonality
	Predictability of Demand
	Spatial Density
Supply	Number of Plants
	Distance from plant to client
	Exclusivity of production in a plant

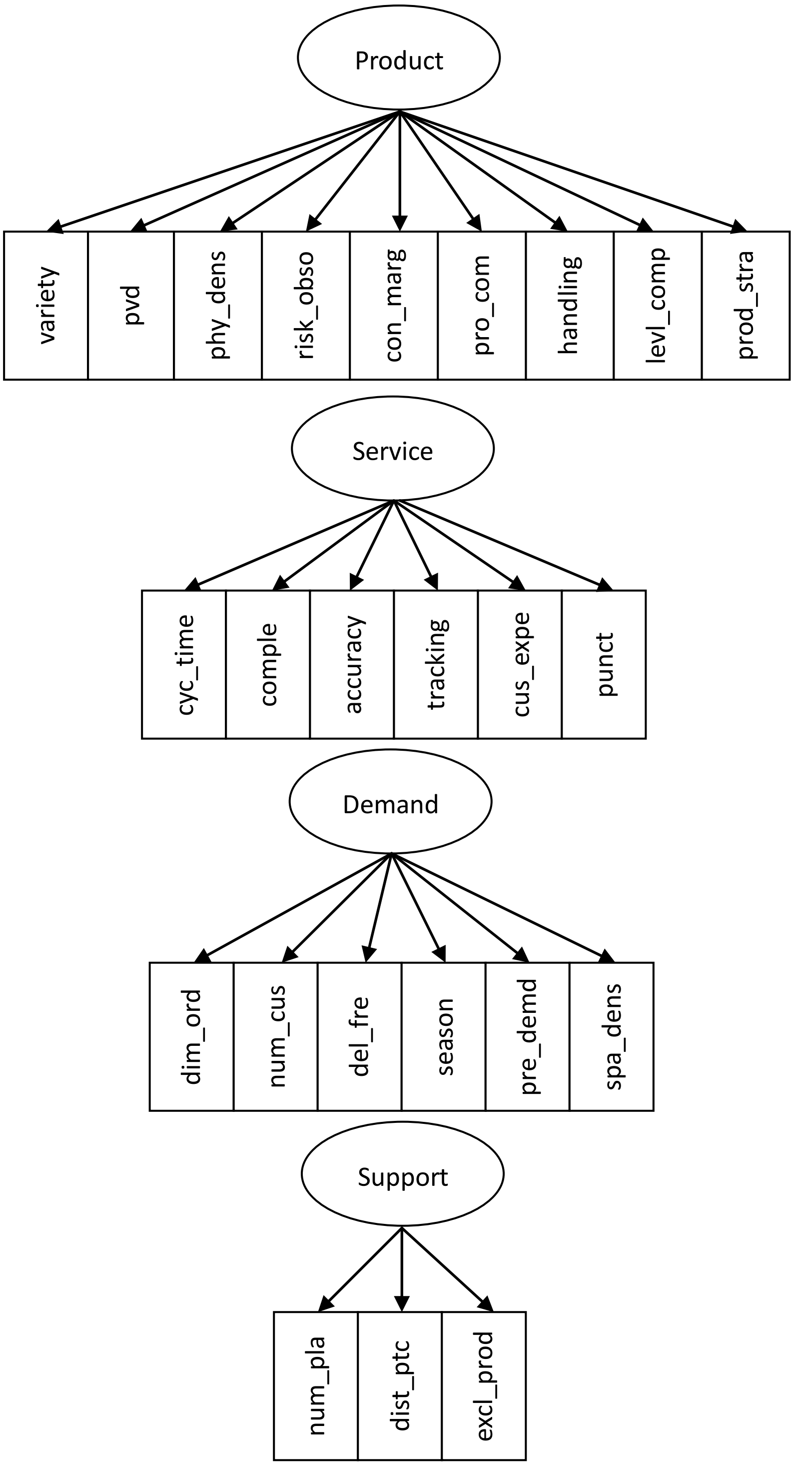
Total: 24

Table 47 Driver list after correlation analysis in FMCG industry

5.2.3 Confirmatory factor analysis

Theoretical Model

We assume that four factors are mutual independent. The following diagrams represent the construct of each factor.



Graph 2 Theoretical model of CFA in FMCG industry

Hypotheses

In the previous introduction, we have known the implication of the attributes and the relation of these variables with different factors as the theoretical model we showed. In the following discussion, we need to make hypotheses for every variable in order to test if they really are important to the factor.

Product Factor:

Variety. The variety of products has direct impact on the stock cost and maintenance cost for the total logistics costs. Therefore, H1P based on this influence.

H1P. Variety is positively related to product factor.

Physical value density. High value density products bring higher storage and lower transport costs. On the other hand, the low value density products have opposite impact on the storage and transport costs.

H2P. Physical value density is positively related to product factor.

Physical density. The physical density could influence both storage and transportation costs.

H3P. Physical density is positively related to product factor.

Risk of obsolescence. The length of life cycle tends to impact the inventory and transportation costs in the logistics management.

H4P. Risk of obsolescence is positively related to product factor.

Contribution margin. The contribution margin is corresponding to transport policy in logistics management, and hence impacts on the transportation costs.

H5P. Contribution margin is positively related to product factor.

Product complexity. Product complexity is related to the centralization of distribution channel, and hence influences the total logistics costs.

H6P. Product complexity is positively related to product factor.

Handling characteristic. Differences in handling characteristic of products can impact on distribution network costs and, therefore the most appropriate distribution network selection should be done.

H7P. Handling characteristic is positively related to product factor.

Level of competition. Level of competition may bring the high inventory cost in order to reduce the probability of stock out.

H8P. Level of competition is positively related to product factor.

Production strategy. Production strategy has impact on the inventory cost and transport cost.

H9P. Production strategy is positively related to product factor.

Service Factor:

Cycle time. Cycle time could influence the number of facility and transportation costs.

H1S. Cycle time is positively related to service factor.

Completeness. An increase in the required completeness will bring additional inventory cost, but increase the service level.

H2S. Completeness is positively related to service factor.

Accuracy. Accuracy influences the transportation cost and inventory cost.

H3S. Accuracy is positively related to service factor.

Tracking. This attribute has different level of impact on different industries. The direct influence on the logistics costs is the information cost.

H4S. Tracking is positively related to service factor.

Customer experience. Customer experience is influenced by the way of customers purchase the product and the number of sales points. Hence, this variable has impact on the facility cost and the lost of stock out.

H5S. Customer experience is positively related to service factor.

Punctuality. Punctuality influences the transportation cost and inventory cost.

H6S. Punctuality is positively related to service factor.

Demand Factor:

Dimension of the order. Dimension of the order which is determined by customer's demand requirement has impact on transport cost.

H1D. Dimension of the order is positively related to demand factor.

Number of customers. The number of customers has significant impact on the transportation cost due to the number of deliveries is caused by this attribute.

H2D. Number of customers is positively related to demand factor.

Delivery frequency. Delivery frequency influences the stock and maintenance costs, which affects the different total logistics costs.

H3D. Delivery frequency is positively related to demand factor.

Seasonality. Seasonality affects stocking cost 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.

H4D. Seasonality is positively related to demand factor.

Predictability of demand. Predictability of demand has direct impact on the inventory cost in order to cover the error in the demand forecast.

H5D. Predictability of demand is positively related to demand factor.

Spatial density. Spatial density mainly has impact on local transportation cost.

H6D. Spatial density is positively related to demand factor.

Supply Factor:

Number of plants. Number of plants has significant impact on the facility cost, and influences the transportation cost as well.

H1Su. Number of plants is positively related to supply factor.

Distance from plant to client. The distance from plant to client affects total logistics costs since with the increase of distance there is a direct increase of transport cost.

H2Su. Distance from plant to client is positively related to supply factor.

Exclusivity of production in a plant. Exclusivity of production in a plant is adverse to level of specialization, while also has impact on the inventory cost and transportation cost.

H3Su. Exclusivity of production in a plant is positively related to supply factor.

Hypotheses	
Product Factor	
1	Variety is positively related to product factor.
2	PVD is positively related to product factor.
3	Physical density is positively related to product factor.
4	Risk of obsolescence is positively related to product factor.
5	Contribution margin is positively related to product factor.
6	Product complexity is positively related to product factor.
7	Handling characteristic is positively related to product factor.
8	Level of competition is positively related to product factor.
9	Production strategy is positively related to product factor.
Service Factor	
1	Cycle time is positively related to service factor.
2	Completeness is positively related to service factor.
3	Accuracy is positively related to service factor.

4	Tracking is positively related to service factor.
5	Customer experience is positively related to service factor.
6	Punctuality is positively related to service factor.
Demand Factor	
1	Dimension of the order is positively related to demand factor.
2	Number of customers is positively related to demand factor.
3	Delivery frequency is positively related to demand factor.
4	Seasonality is positively related to demand factor.
5	Predictability of demand is positively related to demand factor.
6	Spatial density is positively related to demand factor.
Supply Factor	
1	Number of plants is positively related to supply factor.
2	Distance from plant to client is positively related to supply factor.
3	Exclusivity of production in a plant is positively related to supply factor.

Table 48 Hypotheses for CFA in FMCG industry

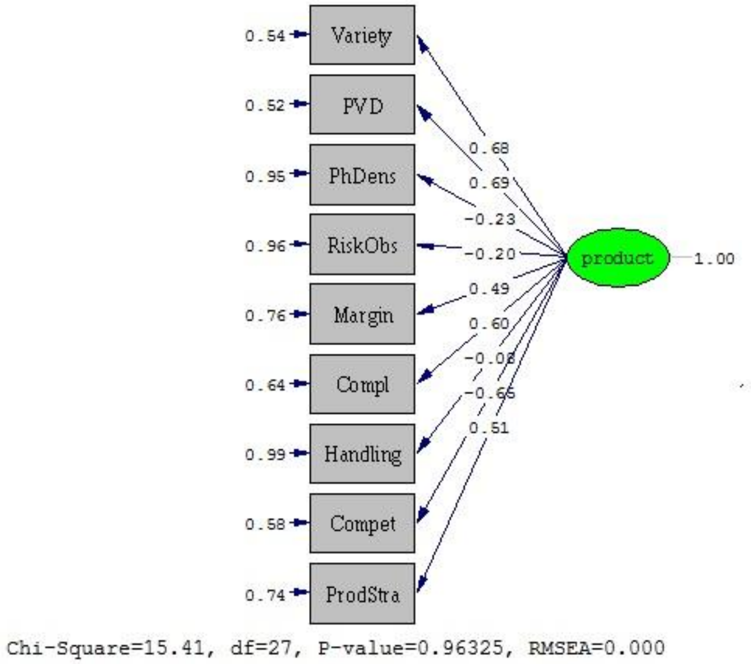
Measurement model results

Product Factor:

The initial fit indices for product factor (e.g. P-value=0.963) suggests that improvement could be made in the measures.

After the refinement, the re-specified measurement model for product factor indicates an acceptable fit CFI=0.98, NNFI=0.97, RMSEA=0.008, x^2 /df=1.175, *P*-value<0.1.

The first run:

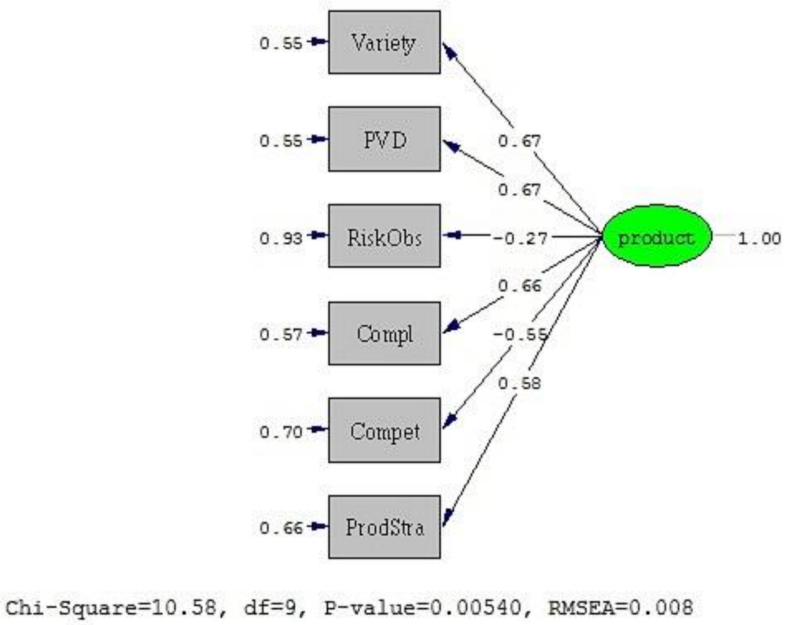


CFI	*NNFI*	*RMSEA*	χ^2 */df*
N/A	N/A	0.000	0.57

Table 49 Initial result of CFA for product factor in FMCG industry

After improvement:

Item	*Indication*	*Action*
Physical density	low loading(0.23)	drop
Contribution margin	low loading(0.49)	drop
Handling characteristic	low loading(0.08)	drop



CFI	*NNFI*	*RMSEA*	x^2 */df*
0.98	0.97	0.008	1.175

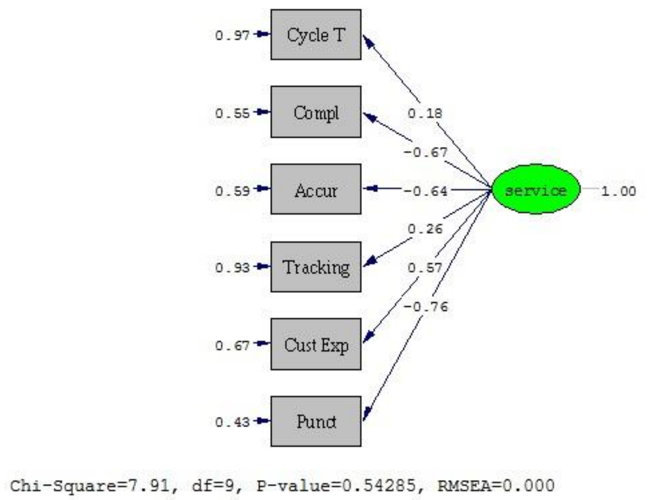
Table 50 Final result of CFA for product factor in FMCG industry

Service Factor:

The initial fit indices for service factor (e.g. RMSEA=0.878, P-value=0.543) suggest that improvement could be made in the measures.

After the improvement operation, the re-specified measurement model for product factor indicates an acceptable fit CFI=0.91, NNFI=0.72, RMSEA=0.002, x^2 /df=3.42, *P*-value=0.003

The first run:

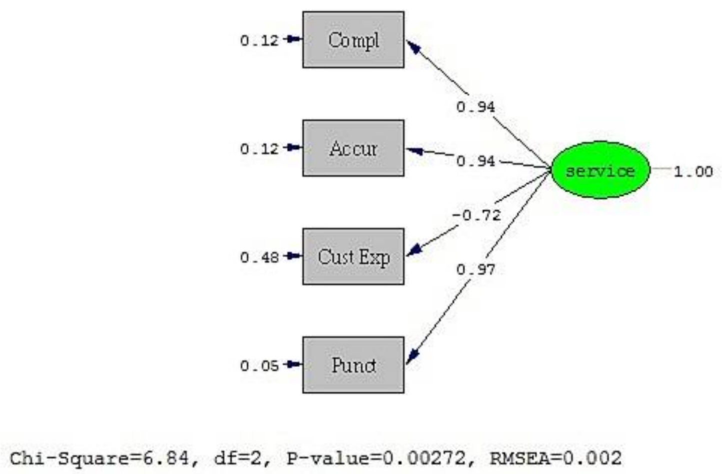


CFI	*NNFI*	*RMSEA*	χ^2/df
0.82	0.70	0.878	1.778

Table 51 Initial result of CFA for service factor in FMCG industry

After improvement:

Item	*Indication*	*Action*
Cycle time	low loading(0.18)	drop
Tracking	low loading(0.26)	drop



CFI	*NNFI*	*RMSEA*	χ^2/df
0.91	0.72	0.002	3.42

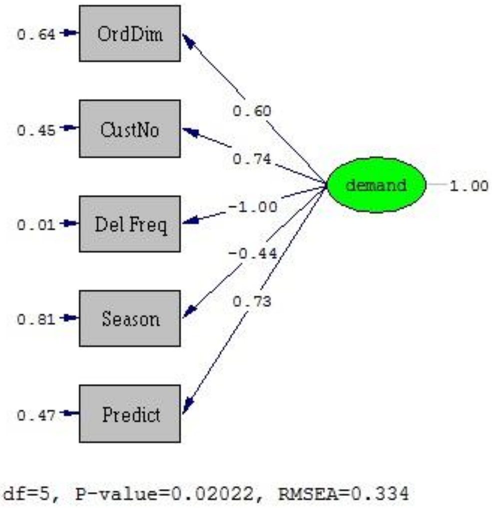
Table 52 Final result of CFA for service factor in FMCG industry

Demand Factor

From the following diagram, we can see that the first fit indices for demand factor (e.g. CFI=0.59, NNFI=0.19) propose that refinement should be done in order to obtain a better goodness of fit.

After the refinement, a good model's fit is generated: CFI=0.86, NNFI=0.88, RMSEA=0.051, x^2/df=1.05, *P*-value=0.017

The first run:

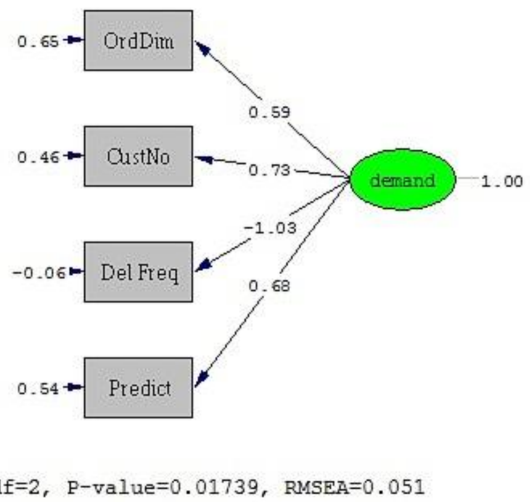


CFI	NNFI	RMSEA	x^2/df
0.59	0.19	0.334	2.672

Table 53 Initial result of CFA for demand factor in FMCG industry

After improvement:

Item	Indication	Action
Seasonality	low loading(0.44)	drop



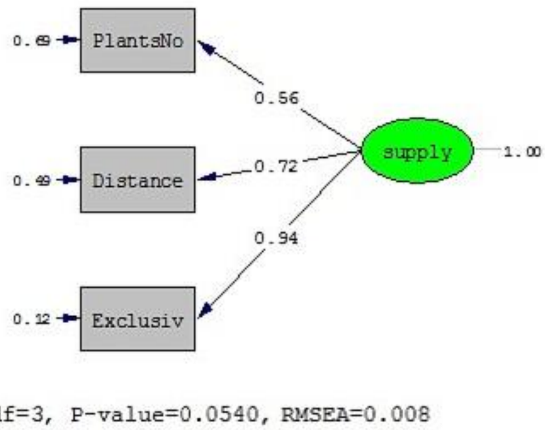
CFI	*NNFI*	*RMSEA*	x^2/df
0.86	0.88	0.051	1.05

Table 54 Final result of CFA for demand factor in FMCG industry

Supply Factor:

The initial fit indices for supply factor shows a good model's fit: CFI=0.87, NNFI=0.75, RMSEA=0.008, x^2/df=0.61, *P*-value=0.054. This result indicates none of the drivers would be deleted.

The first run:



CFI	*NNFI*	*RMSEA*	x^2/df
0.87	0.75	0.008	0.61

Table 55 Final result of CFA for supply factor in FMCG industry

Finally, the results of measurement model show us a set of variables associated four different factors in FMCG industry. These variables are selected by the factor loading on the basis of covariance between the drivers and specific latent factor, and the corresponding hypotheses are tested according to the statistics indicator.

Product	Variety
	Product value density
	Risk of obsolescence
	Product complexity
	Level of competition
	Production strategy
Service	Completeness
	Accuracy
	Customer experience
	Punctuality
Demand	Dimension of the orders
	Number of customers
	Delivery frequency
	Predictability
Supply	Number of plants
	Distance from plant to client
	Exclusivity of production in a plant

Total: 17

Table 56 Driver list after CFA in FMCG industry

Hypotheses		
Product Factor		
1	Variety is positively related to product factor.	True
2	PVD is positively related to product factor.	True
3	Physical density is positively related to product factor.	False

4	Risk of obsolescence is positively related to product factor.	True
5	Contribution margin is positively related to product factor.	False
6	Product complexity is positively related to product factor.	True
7	Handling characteristic is positively related to product factor.	False
8	Level of competition is positively related to product factor.	True
9	Production strategy is positively related to product factor.	True
Service Factor		
1	Cycle time is positively related to service factor.	False
2	Completeness is positively related to service factor.	True
3	Accuracy is positively related to service factor.	True
4	Tracking is positively related to service factor.	False
5	Customer experience is positively related to service factor.	True
6	Punctuality is positively related to service factor.	True
Demand Factor		
1	Dimension of the order is positively related to demand factor.	True
2	Number of customers is positively related to demand factor.	True
3	Delivery frequency is positively related to demand factor.	True
4	Seasonality is positively related to demand factor.	False
5	Predictability of demand is positively related to demand factor.	True
6	Spatial density is positively related to demand factor.	False
Supply Factor		
1	Number of plants is positively related to supply factor.	True
2	Distance from plant to client is positively related to supply factor.	True
3	Exclusivity of production in a plant is positively related to supply factor.	True

Table 57 Hypotheses result of CFA in FMCG industry

5.2.4 Principal component regression

We evaluate the value of distribution solution and standardize them for each distribution problem, since the distribution solution should be used as dependent variable in the regression model.

Value and criticality of distribution solution

Company	*Distribution Solution*	*Value*	*Criticality*
Cazledonia (calzedonia)	1 echelon: 1 WH	1	2
Calzedonia (intimissimi)	1 echelon: 1 WH	1	2
Nestle (food)	2 echelons: 2 WH + 26 WH/TP	13	5
Nestle (Pasta)	2 echelons: 3 WH + 24 WH/TP	13.5	5
Nestle (Confectionery)	2 echelons: 2 WH + 34 WH/TP	18	5
Nestle (Bakery)	2 echelons: 2 WH + 28 WH/TP	15	5
Nestle (Foodservices)	2 echelons: 2 WH + 24 WH/TP	13	5
Reckitt Benckiser	2 echelons: >20 WH + >130 WH/TP	75	7
Unil. Bestfoods (HORECA)	2 echelons: 20 WH + 10 WH/TP	15	N/A
Unil. Bestfoods (Retail)	1 echelon: 20 WH	20	N/A
Coca Cola	2 echelons: 10 WH + >100 WH/TP	55	6
Hackman	2 echelons: 3 WH + 1 WH/TP	2	N/A
3M (Health & Care)	1 echelon: 5 WH	5	3
3M (Consumer & Office)	2 echelons: 5 WH + 10-15 WH/TP	10	4
3M (Industrial market)	1 echelon: 5 WH	5	3
3M (TSG metal signs)	1 echelon: 5 WH	5	3

Table 58 Distribution solution in FMCG industry

Here, three distribution problems, Unil.Bestfoods HORECA, Unil.Bestfoods Retail and Hackman are not considered, due to their distribution solutions are not the ordinary tree-shape network. We are not able to evaluate the value of these solutions in the usual method.

Regression Function

solutio=-14.0376+(-0.3636)variety+(-0.4481)pvd+(0.5065)riskobs+(0.218)complex+(-0.0971)compet+(1.0615)prodstr+(1.2107)complet+(0.3362)accur+(1.9791)cusexpe+(-0.2913)punct+(-0.3766)dimord+(0.1883)numcus+(0.0715)delfreq+(0.9039)predict+(-0.0919)numplan+(-0.0781)distptc+(-0.3961)exclu

R^2=1.000, adjusted R^2=0.990, F (11,1) =107.394, P=0.075

Driver	*Regression coefficient*
Variety	-0.3636
Physical Value Density	-0.4481
Risk of Obsolescence	0.5065
Product Complexity	0.2180
Level of Competition	-0.0971
Product Strategy	1.0615
Completeness	1.2107
Accuracy	0.3362
Customer Experience	1.9791
Punctuality	-0.2913
Dimension of the Order	-03766
Number of Customers	0.1883
Delivery Frequency	0.0715
Predictability of Demand	0.9039
Number of Plants	-0.0919
Distance from plant to client	-0.0781
Exclusivity of production in a plant	-0.3961

Table 59 Regression coefficient of drivers in FMCG industry

Chapter 6. Results

In this section, we will demonstrate the relationship between distribution problem and distribution solution of the cases we investigated both in Consumer Electronics industry and FMCG industry. As we introduced in the first chapter, the theoretic model of distribution network selection matrix consists of four factors, which could be divided into Firm and Market characteristics. In order to obtain the final results, we figure out the value of these two characteristics and represent them in a graphic illustration way.

6.1 Result of Consumer Electronics Industry

6.1.1 Analysis of four basic characteristics of distribution problem

First of all, as it is shown in the table provided below, we would like to analyze the results we got for the Consumer Electronics Industry. For each of the distribution problems that were described in details in the previous chapters, there are four characteristics of product, service, demand and supply. Thereby, we should figure out the values of these four characteristics of each distribution problem.

Distribution problem	*Product*	*Service*	*Demand*	*Supply*
HP	7.11	1.49	0.18	-0.38
SO1	7.99	-0.65	0.89	-1.10
SO2	7.99	0.07	2.04	-1.10
SO3	7.99	-1.37	3.19	-1.10
SO4	8.26	-0.65	0.70	-0.32
SO5	8.26	0.07	1.85	-0.32
SO6	8.26	-1.37	2.99	-0.32
SA1	6.18	0.53	1.08	-0.98
SA2	6.99	1.64	0.27	-0.98
SA3	6.99	3.08	0.98	-0.98
SA4	6.99	1.64	0.64	-1.49
SA5	6.99	3.08	1.26	-1.49

SA6	6.18	1.64	1.17	-0.90
SA7	6.18	3.08	1.79	-0.90
SA8	6.99	1.64	0.27	-0.98
SA9	6.99	3.08	0.98	-0.98

Table 60 Values of four basic characteristics in Consumer Electronics industry

6.1.2 Analysis of Firm and Market characteristics

As what we demonstrated in literature review, the theoretical model of existing distribution network selection matrix could be described by the values of firm, market and distribution solution. The values of firm and market of distribution problem are the sum of product and supply factors, and the sum of service and demand factors as the table shown above respectively. The value of the distribution solution is already scaled and the meaning of the scale is given below:

- 1: direct shipment;
- 2: 1 echelon with a few Warehouses/Transit Points (up to 3);
- 3: 2 echelons with a few Warehouses/Transit Points (up to 5) in the 1st echelon and a few Warehouses/Transit Points (less than 15) in the 2nd echelon;
- 4: 2 echelons with a few Warehouses/Transit points (up to 5) in the 1st echelon and several Warehouses/Transit Points (15 – 20) in the 2nd echelon;
- 5: 2 echelons with a few Warehouses/Transit points (up to 5) in the 1st echelon and many Warehouses/Transit Points (more than 20) in the 2nd echelon;

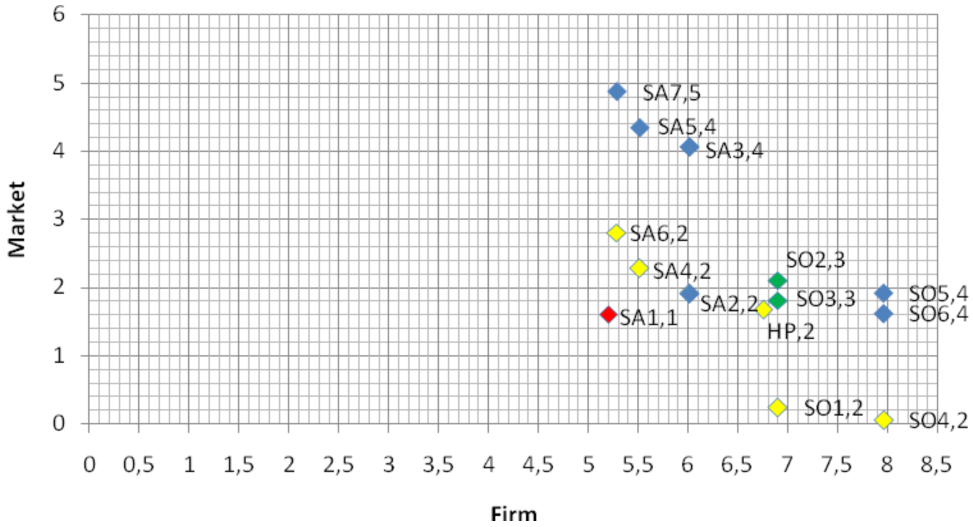
Distribution problem	***Firm***	***Market***	***Distribution solution***
HP	6.75	1.68	2
SO1	6.90	0.24	2

SO2	6.90	2.11	3
SO3	6.90	1.81	3
SO4	7.96	0.05	2
SO5	7.96	1.92	4
SO6	7.96	1.62	4
SA1	5.20	1.61	1
SA2	6.01	1.91	2
SA3	6.01	4.06	4
SA4	5.51	2.28	2
SA5	5.51	4.34	4
SA6	5.28	2.81	2
SA7	5.28	4.87	5
SA8	6.01	1.91	2
SA9	6.01	4.06	4

Table 61 Result of Firm and Market characteristics in Consumer Electronics industry

6.1.3 Relationship between distribution problem and distribution solution

Now let's plot down the values we got on the chart (shown below). Each distribution problem is marked with its own spot on the chart, has the name and the value of distribution solution. For instance, SA1,1 means that we consider distribution problem Samsung1 (SA1) and distribution solution for this problem is 1 (direct shipment).

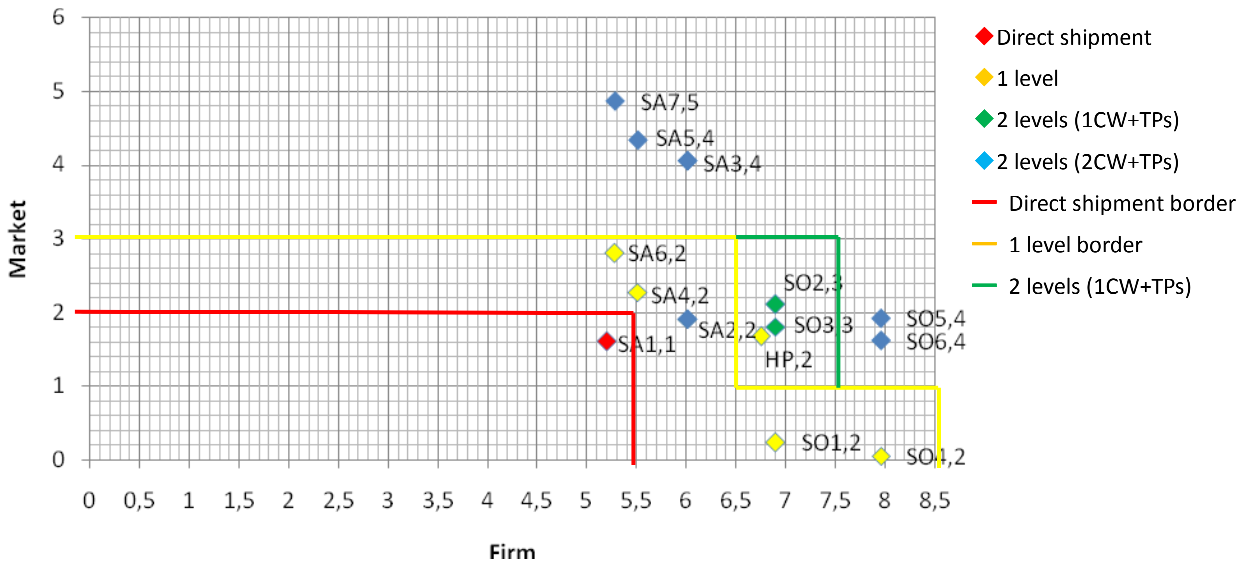


Graph 3 Scatter diagram of distribution problems in Consumer Electronics industry

Each distribution solution is marked with color that illustrates their belonging to one of the four groups (the chart is given below):

- In the group marked with red we have distribution solutions characterized by direct shipping;
- In the group marked with yellow we have distribution solutions characterized by having just one level in the distribution network;
- In the group marked with green color we have distribution solutions characterized by having two levels in the distribution network with 1 Central Warehouse in the 1st echelons and number of Transit Points in the 2nd one;
- In the group marked with blue color we have 2 levels distribution solutions with 2 Central Warehouses in the 1st echelon and number of Transit Points in the second one.

After having all the spots on the chart we can highlight the areas with the high concentration of the spots belonging to the particular group. The chart with the areas is presented below.



Graph 4 Relationship diagram in Consumer Electronics industry

6.2 Result of FMCG Industry

6.2.1 Analysis of four basic characteristics of distribution problem

For the industry of Fast Moving Consumer Goods we will perform the same approach of analyzing the data. In the table given below, again, for each of the distribution problems that were described in details in the previous chapters, there are values of product, service, demand and supply.

Distribution problem	*Product*	*Service*	*Demand*	*Supply*
Calz1	0.52	14.19	3.83	-2.65
Calz2	-0.06	14.19	3.83	-2.07
Nestle1	1.45	15.21	3.93	-1.83
Nestle2	2.21	15.21	3.18	-1.83
Nestle3	0.44	15.21	4.88	-1.83
Nestle4	1.19	15.21	4.26	-1.83
Nestle5	0.89	15.21	4.43	-1.83
Reckitt	1.55	16.46	4.67	-1.78
Coca Cola	2.06	14.92	3.37	-0.66

3M1	2.22	14.20	3.24	-2.75
3M2	1.56	14.20	4.76	-2.75
3M3	1.65	14.20	3.74	-2.75
3M4	0.75	14.20	4.64	-2.75

Table 62 Values of basic characteristics in FMCG industry

6.2.2 Analysis of Firm and Market characteristics

According to the procedure we have done for Consumer Electronics industry above, we can obtain the values of firm, market and distribution solution after the analysis of four basic characteristics of distribution problem. The value of the distribution solution is already scaled and the meaning of the scale is given below:

- 1: direct shipment;
- 2: 1 echelon with a few Warehouses/Transit Points (up to 3);
- 3: 1 echelon with many Warehouses/Transit Points (more than 3);
- 4: 2 echelons with a few Warehouses/Transit Points (up to 3) in the 1st echelon and a few Warehouses/Transit Points (up to 3) in the 2nd one;
- 5: 2 echelons with a few Warehouses/Transit Points (up to 3) in the 1st echelon and many Warehouses/Transit Points (more than 3) in the 2nd one;
- 6: 2 echelons with many Warehouses/Transit Points (more than 3) in the 1st echelon and a few Warehouses/Transit Points (up to 3) in the 2nd one;
- 7: 2 echelons with many Warehouses/Transit Points (more than 3) in the 1st echelon and many Warehouses/Transit Points (more than 3) in the 2nd one.

Distribution problem	***Firm***	***Market***	***Distribution solution***
Calz1	-2.13	18.17	2

Calz2	-2.13	18.17	2
Nestle1	-0.39	19.42	5
Nestle2	0.37	18.67	5
Nestle3	-1.40	20.44	5
Nestle4	-0.65	19.68	5
Nestle5	-0.95	19.99	5
Reckitt	-0.23	21.27	7
Coca Cola	1.40	18.64	6
3M1	-0.55	17.58	3
3M2	-1.20	19.24	4
3M3	-1.11	18.15	3
3M4	-2.01	19.05	3

Table 63 Result of Firm and Market characteristics in FNCG industry

On the above table, the value of Firm and Market is figured out by the drivers' coefficients. In order to compare the value of Firm and Market characteristics, a coordinate transformation has to be carried out. A positive factor 3 and negative factor 17 are assigned to the value of Firm and Market respectively.

After the transformation:

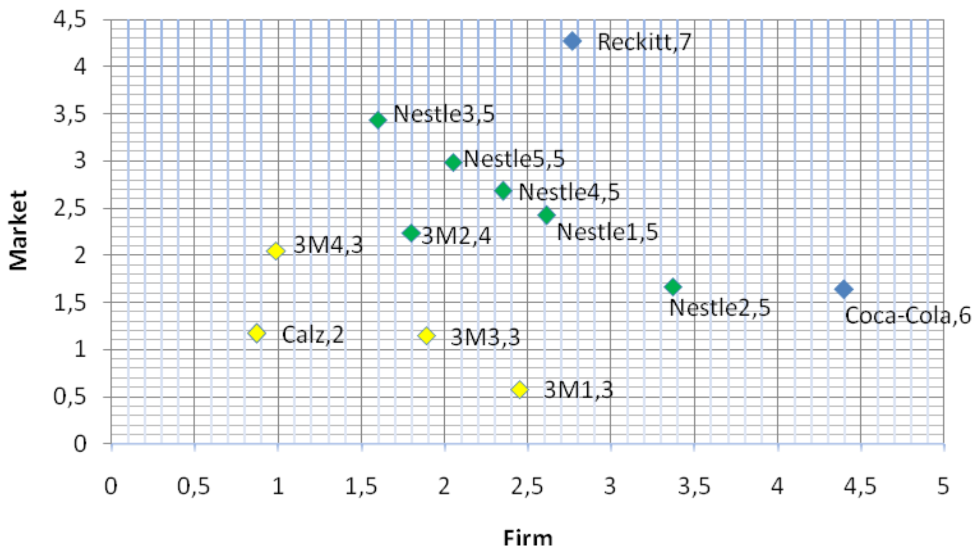
Distribution problem	***Firm***	***Market***	***Distribution solution***
Calz1	0.87	1.17	2
Calz2	0.87	1.17	2
Nestle1	2.61	2.42	5
Nestle2	3.37	1.67	5
Nestle3	1.60	3.44	5
Nestle4	2.35	2.68	5

Nestle5	2.05	2.99	5
Reckitt	2.77	4.27	7
Coca Cola	4.40	1.64	6
3M1	2.45	0.58	3
3M2	1.80	2.24	4
3M3	1.89	1.15	3
3M4	0.99	2.05	3

Table 64 Result transformation in FMCG industry

6.2.3 Relationship between distribution problem and distribution solution

Again, like in the previous case, let's plot down the values we got on the chart (shown below). Each distribution problem is marked with its own spot on the chart, has the name and the value of distribution solution. For instance, Nestle3,5 means that we consider distribution problem Nestle5 and distribution solution for this problem is 5 (two echelons with several WH/TP in the first echelon and many WH/TP in the second one).

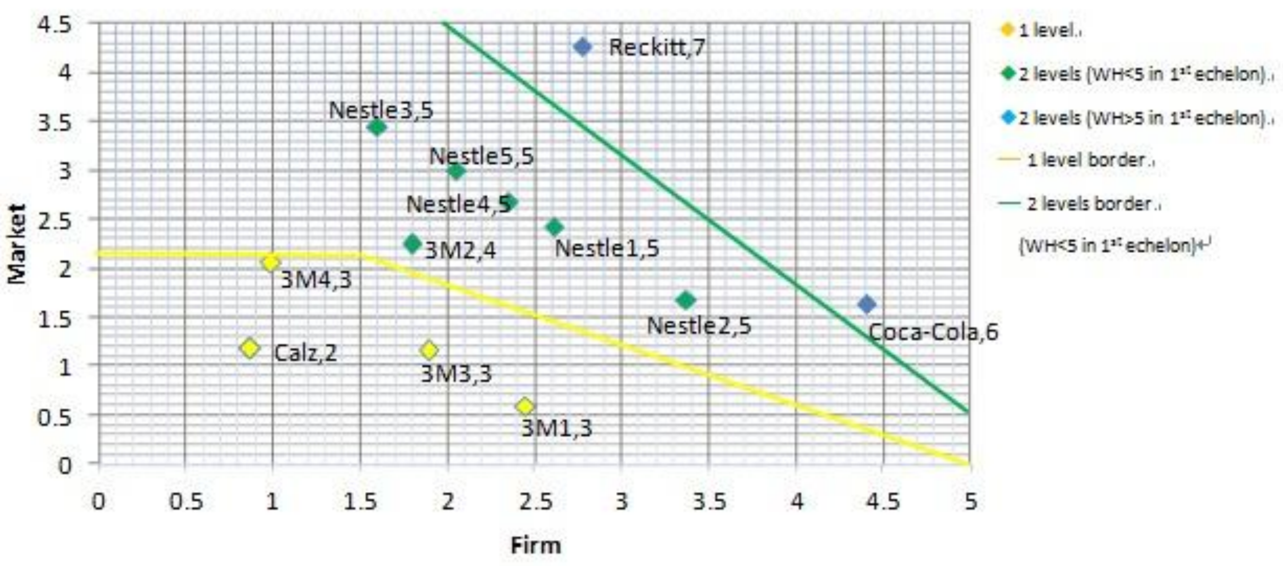


Graph 5 Scatter diagram of distribution problems in FMCG industry

Each distribution solution is marked with color that illustrates their belonging to one of the four groups (the chart is given below):

- In the group marked with yellow we have distribution solutions characterized by having just one level in the distribution network;
- In the group marked with green color we have distribution solutions characterized by having two levels in the distribution network with less than 5 Warehouses in the 1st echelons and number of Transit Points in the 2nd one;
- In the group marked with green color we have distribution solutions characterized by having two levels in the distribution network with less than 5 Warehouses in the 1st echelons and number of Transit Points in the 2nd one;
- In the group marked with blue color we have 2 levels distribution solutions with more than 5 Warehouses in the 1st echelon and number of Transit Points in the second one.

After having all the spots on the chart we can highlight the areas with the high concentration of the spots belonging to the particular group. The chart with the areas is presented below.



Graph 6 Relationship diagram in FMCG industry

Chapter 7. Conclusion

7.1 Comparison of drivers in different industries

In chapter 5, we have achieved 20 and 17 more important drivers for Consumer Electronics industry and FMCG industry respectively after the application of mathematical models. All of these drivers are able to reflect the product, service, demand and supply features of a distribution problem. Some drivers could be used for the two industries commonly, and several drivers have to be allocated to a kind of industry especially due to the particular nature of an industry. Regarding the practical application, we can use these drivers to evaluate the distribution problem in both Consumer Electronics industry and FMCG industry.

	Consumer Electronics Industry	**FMCG Industry**
Product	Variety	Variety
	Product value density	Product value density
	Contribution margin	Risk of obsolescence
	Product complexity	Product complexity
	Level of competition	Level of competition
	ABC product characteristic	Production strategy
	Stage of life cycle	
Service	Completeness	Completeness
	Accuracy & Punctuality	Accuracy
	Customer experience	Customer experience
	Cycle time	Punctuality
Demand	Dimension of the orders	Dimension of the orders
	Delivery frequency	Delivery frequency
	Predictability of demand	Predictability of demand
	Demand volatility	Number of customers
	Demand level	

Supply	Number of plants Distance from plant to client Exclusivity of production in a plant Level of specialization	Number of plants Distance from plant to client Exclusivity of production in a plant

Table 65 Comparison of drivers

From the above table, we can see there are five common drivers associated to the product characteristic, and we obtain two special drivers, ABC product characteristic and stage of life cycle, in Consumer Electronics industry, but production strategy is only used for FMCG industry.

With regard to service characteristic of distribution problem, completeness and customer experience can be used for two industries. The cycle time is an especial attribute for Consumer Electronics industry. In this group, delivery accuracy and punctuality are two drivers affecting the service level from different way in distribution process. From the cases we investigated in Consumer Electronics industry the values of accuracy and punctuality are definitely same, hence, we can combine them into one driver reflecting the service level. However, these two drivers have different value in FMCG drivers, indicating us they should be used separately.

Associated to the demand characteristic, we have three common drivers, and number of customers is more important for FMCG industry obviously. Demand volatility and demand level are two critical attributes in Consumer Electronics industry, since the change in demand can affect the unitary production cost, which is much higher than that in FMCG industry.

In the driver list, we have four attributes associated tosupply characteristics, and all of these can be used in Consumer Electronics industry. However, the level of specialization was removed for FMCG industry due to the high correlation factor with exclusivity of production in a plant.

7.2 Comparison of drivers' coefficients and regression functions

By using the principal component regression model, we obtained the drivers' coefficients and regression function related to different industries. The driver's coefficient is a kind of weight, and the regression function can be seen the evaluation function. Both of them can be used to evaluate the values of Firm and Market characteristics of a distribution problem in order to match a relevant distribution solution. We list the drivers' coefficient and the value of constant part on the following table.

Consumer Electronics Industry		FMCG Industry	
Constant	5.8029	Constant	-14.0376
Variety	0.1748	Variety	-0.3636
Product value density	-0.1160	Product value density	-0.4481
Contribution margin	-0.1160	Risk of obsolescence	0.5065
Product complexity	0.3773	Product complexity	0.2180
Level of competition	0.2310	Level of competition	-0.0971
ABC product characteristic	0.6049	Production strategy	1.0615
Stage of life cycle	0.6049		
Completeness	-0.7206	Completeness	1.2107
Accuracy & Punctuality	2.5535	Accuracy	0.3362
Customer experience	-0.2756	Customer experience	1.9791
Cycle time	-0.0163	Punctuality	-0.2913
Dimension of the orders	0.6176	Dimension of the orders	-03766
Delivery frequency	0.0882	Delivery frequency	0.1883
Predictability of demand	0.3024	Predictability of demand	0.0715
Demand volatility	-0.6049	Number of customers	0.9039
Demand level	-0.1906		
Number of plants	0.0776	Number of plants	-0.0919
Distance from plant to client	0.1388	Distance from plant to client	-0.0781

Exclusivity of production in a plant	-0.3341	Exclusivity of production in a plant	-0.3961
Level of specialization	-0.0795		

Table 66 Comparison of drivers' coefficients

The coefficients listed on the above table are not same in two industries even if for the same driver since the different criticality value of this driver. However, the results of goodness-of-fit are very good, the factor of each estimator indicate the results of coefficients and the functions are believable and acceptable. We can see them on the below table.

Consumer Electronics Industry		FMCG Industry	
Adjusted R^2	0.856	Adjusted R^2	0.990
F (10,5)	9.884	F (11,1)	107.394
P-value	0.010	*P*-value	0.075

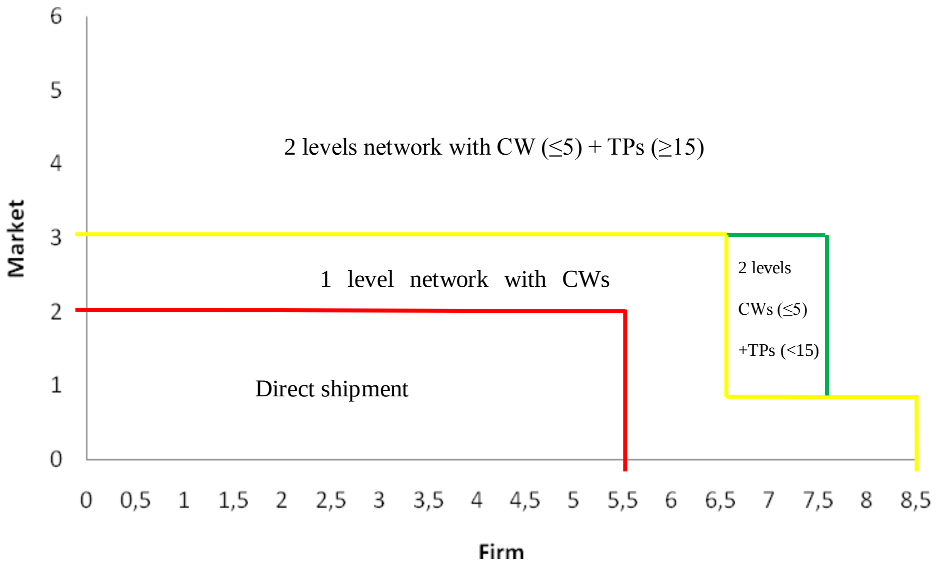
Table 67 Result of goodness-of-fit for PCR

7.3 Comparison of normative selection matrixes

We have shown the distribution selection matrixes for both Consumer Electronics industry and FMCG industry in the preceding chapter. The relationship between distribution problem and distribution solution was represented in a graphic illustration. We have known that the distribution network is more decentralized along with the increase of the values of Firm and Market characteristics.

The following figures are the normative distribution network selection matrixes in different industries.

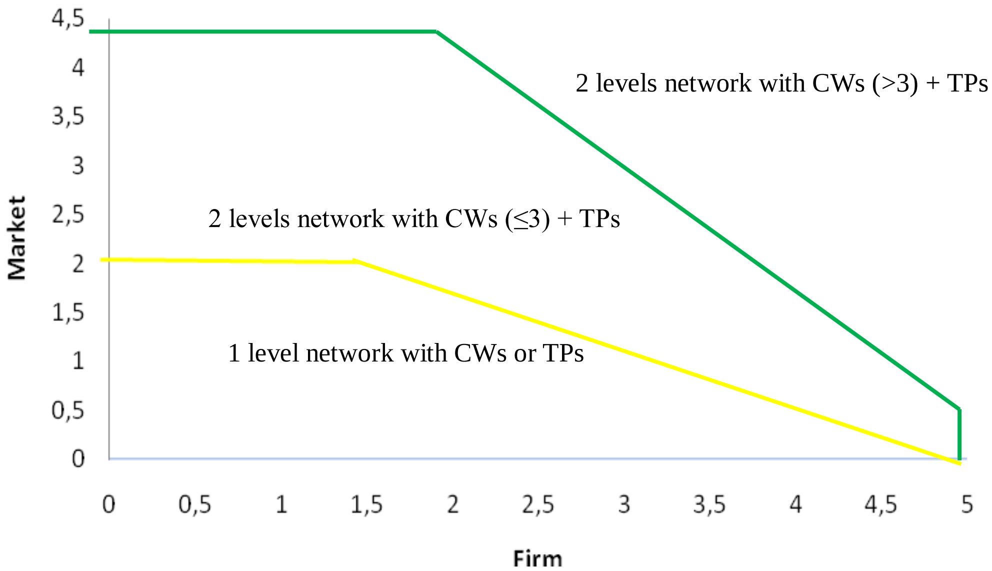
Consumer Electronics Industry



Graph 7 Normative matrix in Consumer Electronics industry

The above figure is able to depict the relationship between distribution problem and distribution solution obviously. We can allocate a distribution problem on a correct position to match a distribution solution based on the factors of Firm and Market characteristics, which can be figured out by using the drivers' coefficients and evaluation function we achieved already.

FMCG Industry



Graph 8 Normative matrix in FMCG industry

With regard to FMCG industry, we do not find any company adopts direct shipment as distribution solution in the case study. This normative matrix is obtained after the coordinate transformation we introduced in the previous chapter, hence, we have to transform the factors of Firm and Market characteristics when we are figuring out them by the drivers' coefficients and evaluation function.

7.4 Further development

We have used mathematical models to optimize the existing distribution network selection matrixes for Consumer Electronics industry and FMCG industry. The necessary important drivers' lists and related coefficients, evaluation functions have been obtained. Finally, we achieved two normative distribution network selection matrixes for the two industries. Therefore, based on the current results, we can continue further development, for instance:

- The sample size of both two industries in this study is 16, which is not large enough. Hence, we may investigate more cases in order to enlarge the sample size in order to make the quantitative analyses more accurate since the number of samples can affect the accuracy of the statistical model.
- This study is done based on Consumer Electronics industry and FMCG industry. In fact, we can carry out the similar research for other more industries.

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Appendix

Criticality value for Consumer Electronic industry

Product macrodriver

	Variety	*PVD*	*Physical Density*	*Risk of Obsolescence*	*Contribution Margin*	*Substitutability*	*Product Complexity*	*Stage of Life Cycle*	*Handling Characteristic*	*Shelf Life*	*Value*	*ABC Product Characteristic*	*Level of Competition*	*Production Strategy*
HP	5	5	5	4	2	1	5	4	2	2	3	3	4	3
SO1	2	1	3	3	1	2	4	4	2	4	4	4	5	4
SO2	2	1	3	3	1	2	4	4	2	4	4	4	5	4
SO3	2	1	3	3	1	2	4	4	2	4	4	4	5	4
SO4	4	4	2	2	2	2	5	4	2	1	3	4	5	4
SO5	4	4	2	2	2	2	5	4	2	1	3	4	5	4
SO6	4	4	2	2	2	2	5	4	2	1	3	4	5	4
SA1	1	5	1	5	4	5	5	4	2	5	3	3	4	4
SA2	1	1	4	1	3	5	5	5	2	2	2	3	4	4
SA3	1	1	4	1	3	5	5	5	2	2	2	3	4	4
SA4	3	3	3	3	2	3	5	4	2	5	4	3	4	4
SA5	3	3	3	3	2	3	5	4	2	5	4	3	4	4
SA6	1	5	1	5	4	5	5	4	2	5	1	3	4	4
SA7	1	5	1	5	4	5	5	4	2	5	1	3	4	4
SA8	1	2	3	1	2	4	5	5	2	2	5	3	4	4
SA9	1	2	3	1	2	4	5	5	2	2	5	3	4	4

Service macrodriver

	Cycle Time	*Completeness*	*Returnability*	*Accuracy*	*Tracking*	*Customer Experience*	*Punctuality*	*Ability to Expedite Orders*
HP	1	1	1	1	1	4	1	1
SO1	4	1	1	1	1	3	1	1
SO2	3	1	1	1	1	3	1	2
SO3	5	1	1	1	1	3	1	5
SO4	4	1	1	1	1	3	1	1
SO5	3	1	1	1	1	3	1	2
SO6	5	1	1	1	1	3	1	5
SA1	2	1	1	2	1	2	2	2
SA2	4	2	1	2	1	2	2	2
SA3	2	2	1	2	1	2	2	4
SA4	4	2	1	2	1	2	2	2
SA5	2	2	1	2	1	2	2	4
SA6	4	2	1	2	1	2	2	3
SA7	2	2	1	2	1	2	2	5
SA8	4	2	1	2	1	2	2	2
SA9	2	2	1	2	1	2	2	4

Demand macrodriver

	Dimesion of the order	*Number of Customer*	*Delivery Frequency*	*Seasonality*	*Predictability of Demand*	*Spatial Density*	*Demand Volatility*	*Demand Leve*
HP	1	2	5	2	3	3	3	3
SO1	1	2	4	3	5	4	2	1
SO2	3	2	3	3	5	4	2	1
SO3	5	5	2	3	5	1	2	1
SO4	1	2	4	2	5	4	2	3
SO5	3	2	3	2	5	4	2	3
SO6	5	5	2	2	5	1	2	3
SA1	4	1	1	5	3	5	3	3
SA2	3	3	1	1	3	4	3	5
SA3	4	4	2	1	3	3	3	5
SA4	3	2	3	3	3	4	3	3
SA5	4	4	3	3	3	3	3	3
SA6	4	2	2	5	3	4	3	2
SA7	5	4	2	5	3	3	3	2
SA8	3	3	1	1	3	4	3	5
SA9	4	4	2	1	3	3	3	5

Supply macrodriver

	Number of Plants	*Distance from plant to client*	*Level of Specialization*	*Exclusivity of production in a plant*
HP	4	4	3	3
SO1	3	2	5	1
SO2	3	2	5	1
SO3	3	2	5	1
SO4	4	5	3	4
SO5	4	5	3	4
SO6	4	5	3	4
SA1	2	5	5	2
SA2	1	5	5	1
SA3	1	5	5	1
SA4	1	2	5	4
SA5	1	2	5	4
SA6	2	5	5	1
SA7	2	5	5	1
SA8	1	5	5	1
SA9	1	5	5	1

Criticality value for FMCG industry

Product macrodriver

	Variety	PVD	Physical Density	Risk of Obsolescence	Contribution Margin	Substitutability	Product Complexity	Stage of Life Cycle	Handling Characteristic	Shelf Life	Level of Competition	Production Strategy
Calz1	4	4	2	3	5	4	1	3	1	3	1	2
Calz2	4	4	2	2	5	4	2	3	1	2	4	2
Nestle1	3	3	4	4	3	3	1	3	1	4	5	2
Nestle2	2	1	3	3	2	2	1	3	1	3	5	2
Nestle3	3	3	3	2	2	3	1	3	5	2	5	2
Nestle4	2	1	2	1	2	2	1	3	5	1	5	2
Nestle5	3	2	2	2	2	3	1	3	1	2	5	2
Reckitt	3	3	4	4	5	3	1	3	5	4	4	2
Unilever1	1	2	4	4	3	1	1	3	5	4	5	2
Unilever2	2	2	4	3	2	2	1	3	5	3	5	2
Coca Cola	1	1	5	2	4	1	1	3	1	2	5	2
Hackman	3	4	2	1	4	3	3	3	2	1	4	2
3M1	4	4	3	1	5	4	5	3	3	1	4	4
3M2	1	1	2	1	4	1	1	3	1	1	5	2
3M3	3	3	4	1	3	3	4	3	1	1	5	3
3M4	2	2	3	1	4	2	1	3	1	1	5	2

Service macrodriver

	Cycle Time	*Completeness*	*Accuracy*	*Tracking*	*Customer Experience*	*Punctuality*
Calz1	2	5	5	4	4	5
Calz2	2	5	5	4	4	5
Nestle1	1	4	4	5	5	3
Nestle2	1	4	4	5	5	3
Nestle3	1	4	4	5	5	3
Nestle4	5	4	4	5	5	3
Nestle5	3	4	4	5	5	3
Reckitt	2	5	5	5	5	4
Unilever1	1	4	3	5	5	3
Unilever2	2	4	3	5	5	3
Coca Cola	3	4	4	5	5	4
Hackman	1	4	4	4	3	4
3M1	3	4	1	4	5	3
3M2	3	4	1	4	5	3
3M3	3	4	1	4	5	3
3M4	3	4	1	4	5	3

Demand macrodriver

	Dimesion of the order	*Number of Customer*	*Delivery Frequency*	*Seasonality*	*Predictability of Demand*	*Spatial Density*
Calz1	1	2	5	4	4	2
Calz2	1	2	5	5	4	2
Nestle1	3	4	1	1	5	3
Nestle2	5	4	1	1	5	3
Nestle3	1	5	2	5	5	5
Nestle4	2	3	2	5	5	3
Nestle5	2	5	1	1	5	4
Reckitt	1	2	4	1	5	2
Unilever1	2	4	2	4	5	3
Unilever2	5	2	2	1	5	2
Coca Cola	5	5	2	5	5	1
Hackman	3	1	3	5	5	2
3M1	2	2	2	5	4	5
3M2	1	4	2	5	5	5
3M3	1	3	2	5	4	5
3M4	1	3	2	5	5	5

Supply macrodriver

	Number of Plants	*Distance from plant to client*	*Level of Specialization*	*Exclusivity of production in a plant*
Calz1	3	5	5	5
Calz2	1	5	5	4
Nestle1	1	2	4	4
Nestle2	1	2	4	4
Nestle3	1	2	4	4
Nestle4	1	2	4	4
Nestle5	1	2	4	4
Reckitt	3	4	2	3
Unilever1	2	4	5	4
Unilever2	1	4	5	5
Coca Cola	2	1	1	1
Hackman	3	4	5	5
3M1	5	4	4	5
3M2	5	4	4	5
3M3	5	4	4	5
3M4	5	4	4	5