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Freight Transport and Logistics Assessment

A Model Proposed to Design Performance Indicators and Strategies to Improve Freight Transport Systems at Global and Urban Scale

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PhD in Civil Engineering and Architecture

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CYCLE XXIX

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To my family…

"If you can't measure it, you can't manage it"

Peter Drucker

Aknowledgements

Our decisions shape our lives. They represent the fundamental tool we use in facing the opportunities, the challenges and the uncertainties of life (Hammond, Keeney&Raiffa, 2015).
With my PhD thesis I tried to deepen the existing knowledge about methodologies and tools to evaluate transport and logistics performance, with the aim to support decision makers in making effective decisions. I hope my work can inspire readers to make questions and to further investigate on this field.
Personally, I can say this thesis represents the results of three years of hard work, sacrifice, but also exciting discovery and goals achievement. These years have been a good proof of my persistence and of my willingness to go ahead, despite everything. I have been hardheaded and determined, but sometimes problems seemed insuperable! So I would like to thank who supported me and patiently stood by me also when I was unbearable, helping me to overcome all the obstacles in this adventure. Let’s start!

I want to start with my first supporters, Mom and Dad. I want to thank you because you are always there, from the beginning to the end. Always able to support me, to tell me "Come on, you can do it!". I am very lucky because I have you! Every time and everywhere I am, I know I will never be alone because of you. You are my strength.. Thank you just for being you!

I want to thank my sister and my brother, Paola e Giovanni for supporting me every time I felt tired. Your smiles and sweet words encouraged me a lot! So, thank you!

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Sara F., my best mate and partner of studies and professional goals. We supported to each other during this pathway! Thank you for being always to my side!

Of course, I want to say thank you to Patti, Claudia and Michi! I cannot imagine these last years without you! You are not just my colleagues, you are my second family! We shared office, lunches, dinner, smiles and worries during these years. You are the best I could ever desire, a very preciuos gift in the path of my life. No distances could never split us up! Thank you for loving me as I am, your small 'Paddy"!

I want to thank Professor Gianfranco Fancello and Paolo Fadda, who supported my research work during these years, starting from my Master dissertation in 2012. Thank you for giving me the opportunity to do the best job ever!

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Finally, I would like to thank all those people who, in these last months, have remembered me that it is worth smiling, always! And who makes me smiling, again. Thank you!

I want to conclude citing a phrase of Conway Twitty, who said: "I did the best I could with what I had", which is very appropriate, I guess. I wish you a good reading.

Cagliari, 17th April 2017

Daniela Paddeu

Abstract

Transport and logistics have been widely recognized at national and international level as key factors to improve mobility and to provide benefits to individuals and businesses. However they are main responsible for negative impacts towards the environment, which are more significant in urban areas due to the presence of human beings. For this reason, the design of a freight transportation system should be based on a careful design of each component, which should be studied and assessed (ex-ante and ex-post) in terms of its effectiveness with respect to the stakeholders' needs and objectives. This can be achieved by considering quantitative indicators that enable the manager of the system firstly to understand if the activities are efficient and secondly to make decision aimed at improve the effectiveness of each activity and thus of the whole system. In fact, what can be measured, can be improved.

Based on the above considerations, this PhD thesis proposes a model to assess freight transport and logistics performance. In particular, the thesis analyses two important environments: (1) the supply chain environment, based on a firm-perspective; (2) the urban environment, based on a multi-stakeholder perspective. Due to the complexity of the considered systems, which involve different stakeholders with different needs and expectations, two models are proposed. They are designed by considering the same framework based on the same set of performance attributes, but on a different set of key performance indicators.

A case-study approach is used to test both models. In the first case, the supply chain of a manufacturer company based in Sardinia is considered. In the second case, the model is tested for both ex-ante and ex-post evaluation by analyzing two case studies: (1) the case of the Urban freight Consolidation Centre (UCC) serving the neighbouring cities of Bristol and Bath, UK (ex-post evaluation); (2) the potential implementation of a UCC serving the city of Cagliari, Italy (ex-ante evaluation).

The thesis does not aim to provide a comparison between the two models proposed, but wants to highlight how the effectiveness of a decision process is related to the analysis of the component to be assessed, which are very different depending on the system considered. The proposed models can be a useful tool for decision makers to evaluate their actions and to make decision at strategic, tactical and operational level. An in-depth analysis on city logistics schemes and on the barriers and drivers to their successful implementation is also provided. Considerations about limitations of the application of the proposed models and further research based on the results of this thesis are provided in the conclusions.

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Acronyms and abbreviations

SC Supply Chain
SCM Supply Chain Management
SCPM Supply Chain Performance Measurement
SCOR Supply Chain Operations Reference model
KPI(s) Key Performance Indicator(s)
UCC Urban Consolidation Centre
BBUCC Bristol and Bath Urban Consolidation Centre
Ho.Re.Ca. Hotel, Restaurant, Café
LGV(s) Light Goods Vehicle(s)
HGV Heavy Goods Vehicle(s)
MCA Multiple Correspondence analysis
PCA Principal Component Analysis

Introduction

People behave based on the weight they are measured.
World-class measures lead to world-class behaviours

What gets measured gets improved

If there is not a holistic set of logistics performance measures in place,
we may improve the wrong things

(Frazelle, 2002)

The three statements mentioned above are the pillars of the research leading to the writing of this doctoral thesis.

Background and motivations

In recent years, there has been growing interest in the definition of a tool to support companies in managing the logistics and transportation of goods, which represent the most significant cost item among costs related to logistics activities. A wrong management of these activities might prejudice the success of a company. For this reason, it was born the Supply Chain Management (SCM), a science that in recent years has gained great attention from academics, consultants, professionals and business managers. In fact, SCM aims to support managers in SC management to reach the common goal of customer satisfaction.

In the last ten years, there has been developed a constant research in the field of SCM, which has allowed defining tools to measure supply chain performance (SCPM) that are essential for a strategic and efficient management, which aims to reach the success of the firm.

Starting from an in-depth analysis of the literature published within SCMP, this PhD thesis wants to make a contribution to the research in this field. In particular, specific performance indicators for transport and logistics activities, suitable to be used as decision support systems, were defined. The indicators allow measuring and monitoring performance of activities and processes related to logistics, transportation and distribution of goods.

In addition, due to the fact that the transport sector is one of the most impactful in terms of air pollution and negative externalities, and European (as well as global) policies are increasingly addressed to environmental sustainability and to the reduction of polluting gas emissions, the PhD thesis pays particular attention to sustainable freight transport, by considering both the urban environment (where the effects of negative externalities are more significant: anthropic environment) and the more general supply chain environment. In fact, often stakeholders involved in the transport system, perceive practices and policies related to sustainable transport as a disadvantage in terms of costs and competitiveness. For this reason this PhD thesis wants also investigate the relationship between transport and logistics performance and 'green practices'.

In particular, the thesis is developed along two main strands:

(a) The study of the performance of goods distribution systems in urban areas (city logistics);

(b) The study of the performance of freight transport and logistics within the supply chain.

Research questions

The main research question of this study is:

How can the efficiency of a transport and logistics system be evaluated?

To address this question, further related questions are posed. They together allow answering the major research question raised above. In particular, five specific questions have been defined to develop the in-depth analysis:

1. ***What do transport and logistics performances depend on?***

   The evaluation of a system's performance provides a direct indication of the efficiency of the system: efficient systems show good performance. For this reason, the efficiency of a transport and logistics system can be studied by identifying the parameters that influence the performance of transport and logistics activities.

2. ***How 'green practices' influence SC performance?***

   Transport is one of the most impacting sectors in terms of pollution. For this reason, in the last years, national and international authorities have promoted sustainable measures and practices to reduce the negative externalities related to transport and logistics activities. Based on the main reaserch question of this PhD thesis, it is worth investigating the impact of green practices on transport and logistics performance (thus on the efficiency of the system).

3. ***What kind of drivers/barriers influence a successful implementation of a city logistics scheme?***

   This PhD thesis proposes a tool to evaluate the efficiency of transport and logistics systems at global (SC) and urban (city logistics) scale. A city logistics scheme can be defined 'successful' when it is efficiently implemented. However, due to the complexity of the relationships among the stakeholders involved, a successful implementation is not always achievable. Investigating drivers/barriers to a successful implementation is needed in order to understand which parameters influence the success/failure of these kind of schemes. This provides an indication on the evaluation of the efficiency of city logistics systems.

4. ***How do performance metrics and models vary on both cases (SC/City Logistics system)?***

   As already explained for the specific question 1, the efficiency of a system can be measured by evaluating its performance. It can be done through the definition of performance indicators and models. However, due to the difference between SC and city logistics schemes, related to the difference among the objectives and the perspective of the stakeholders involved, when one wants to evaluate the efficiency of the system, needs to define performance metrics and models that are different.

5. ***What type of relationship exists among the variables that affect the performance in each system?***
   In order to design the best framework to evaluate the efficiency of transport and logistics systems, the analysis of the inter-relationship among the performance variables is needed.

Methodological approach

The basic idea of the study is to design a model to assess transport and logistics systems, in order to both evaluate and monitor the performance of transportation and logistics activities over time. The study of the scientific literature showed that there is a reference model to evaluate supply chain performance (SCOR) in general, but there is not a model to assess city logistics performance. Also, usually performance indicators are not scientifically selected, but they are defined by considering experts' opinions. For this reason, the research aims to explore the phenomenon by considering the performance of supply chain and city logistics systems defined through the analysis of the needs and expectations of the decision makers involved in both systems. The idea is to design a set of indicators that can be used to have a quantitative measure of the efficiency of the activities performed in the systems. The indicators allow decision makers to measure the distance between the target reached by the activities assessed and the objective target with respect to each specific activity. To this aim, the collection of all the variables that potentially influence transportation and logistics performance is needed. Data collection considers interviews and questionnaire administration. Considering that the stakeholders involved in each system (SC and city logistics) have different needs and expectations, two different models with different indicators need to be defined. To test the validity of each model, statistical tools are required. Thus, the methodological approach relies on correspondence analysis for both qualitative and quantitative data and on multiple regression analysis. Based on the results of the statistical analysis of the indicators defined for each model, considerations about the interdependencies of the indicators and the efficacy of each model are provided for further application.

Thesis outline

This thesis includes three main parts that together with this introduction chapter and the last concluding chapter complete the PhD thesis (Figure A) entitled: "Freight Transport and Logistics Assessment: a Model Proposed to Design Performance Indicators and Strategies to Improve Freight Transport Systems at Global and Urban Scale".

PART I - Background and motivations

Part I introduces the supply chain environment (Chapters 1 and 2) and the urban context (Chapters 3 and 4). Both systems are introduced by considering: system's components, stakeholders involved, functional characteristics and barriers and limitations related to their implementation. A description of the content of each chapter is provided below.

Chapter 1

Logistics and Supply Chain Performance Measurement (SCPM): a review

Based on an in-depth literature review of the papers published in the field of Supply Chain Management (from 1990 onwards), the chapter provides a review of the most important methods and tools developed to measure supply chain performance. In particular, the chapter aims to:

- Understand the importance of SCPM for a successful management of the SC;
- Analyse the differences among the existing SCPM models;

- Gain insights into various SCPM systems and identify the most used variables to SC performance assessment in order to support the decision making process;
- Classify the literature to gain detailed insights into the SCPM models and metrics.

Chapter 2

Do green management practices influence supply chain performance?

This chapter wants to investigate the extent to which sustainable practices influence supply chain performance, in order to provide a useful tool to the decision makers who have not adopted sustainable practices yet, because they are not confident (and not aware) about their impact on the supply chain. Based on a survey carried out in earlier 2016, this chapter provides an insight on green practices applied to supply chain management. More than 50 supply chain managers and experts from all over the world were asked to express their point of view about the influence of green practices on supply chain performance; by considering an holistic perspective, SC performance have been expressed in terms of cost, time, efficiency, quality and customer satisfaction. A particular focus on the influence on environmental cost of the whole system is provided. Sustainable activities involving internal and external processes have been considered, in order to understand in which extent decision-makers are influenced by environmental quality when they make decisions to manage their supply chain.

Chapter 3

An overview on city logistics. Studies and experiences

This chapter aims to introduce the problem of urban freight distribution systems. It includes two main parts.

The first part of the chapter provides an analysis of the pillar concepts of urban freight transport and logistics. An in-depth description of the urban environment, of the stakeholders involved in the urban goods distribution process, of their requirement, together with the analysis of advantages and disadvantages of freight transport in urban areas are provided.

The second part of the chapter, offers a focus on some example of successful city logistics projects developed in Europe.

Chapter 4

City logistics schemes. Outlining drivers and barriers to the implementation

This chapter provides a focus on the stakeholders' perspective and the analysis of their needs and expectations. In fact, due to the importance of stakeholders' participation for the success of city logistics schemes, Chapter 4 aims to deal with this issue.

Having established the general conditions necessary for collaborative economy solutions to be successful in the freight sector, the first part of the chapter provides an analysis of the characteristics of the stakeholders involved in the urban system. A focus on stakeholders' behaviour and last mile of food products is also provided. Also, the barriers to the implementation of urban sharing mobility for goods are highlighted by considering the comparison of two case studies: Bristol (UK) and Cagliari (Italy). The analysis allows identifying and evaluating the perceptions and behaviour of an important target user group. Key success factors and potential barriers to the implementation of UCC schemes are identified by considering their perspective, on the basis that the success of sharing of urban goods transport strongly depends on the perceptions and inclinations of the stakeholders to participate.

Despite the significant benefit coming from the implementation of city logistics measures, local authorities are reluctant about the real advantage. They do not clearly have a quantifiable measure of the benefits related to this kind of schemes. In fact, there is a lack of research and constant monitoring of city logistics performance. For this reason, the chapter highlights the need of the identification and evaluation of the performance of city logistics schemes in order to understand if the system is efficient and, if it is not, identify the problems and find a feasible solution.

PART II - Evaluating the performance of the supply chain

Part II introduces the model proposed to evaluate the performance of the supply chain (Chapter 5) and the application to a specific case study (Chapter 6). A description of the content of each chapter is provided below.

Chapter 5

Methodological framework: Performance indicators and model definition for the supply chain

The chapter provides the definition of the model proposed to assess transport and logistics performance in a supply chain environment. Drawing on the most important model used to assess logistics and supply chain performance (SCOR), the model framework and its specific key performance indicators to assess freight transport and distribution activities are defined. The model considers four different and specific performance attributes, defined as:

- *Time;*
- *Cost;*
- *Quality;*
- *Productivity.*

Chapter 6

Application to the supply chain: a case study approach

This chapter provides the description of the application of the model proposed in Chapter 5 to the supply chain. The model is used to evaluate the performance of a manufacturing company based in Sardinia (Italy). A description of the case study, which includes the introduction and description of the company and the analysis of the scheme of its supply chain, is provided. Then, transportation and logistics performance of the company are evaluated by means of the model proposed in chapter 5.

Relationships and interdependencies among the KPIs of the model are analysed by means of correlation analysis and factorial analysis. Also, a multiple regression model is defined to understand how transport and logistics activities can influence the success of a company (in economic terms).

PART III - Evaluating the performance of city logistics systems

Part III introduces the model proposed to evaluate the performance of the city logistics schemes (Chapter 7) and the application to two case studies (Chapter 8). A description of the content of each chapter is provided below.

Chapter 7

Methodological framework: Performance indicators and model definition for urban goods distribution systems

The aim of this chapter is to provide a framework that includes a range of indicators to be used to evaluate and improve logistics and distribution performances of city logistics systems in order to improve the sustainability of logistics and the urban environment. Following the methodological approach used to define the model proposed to assess SC performance (Chapter 5), the model to evaluate city logistics performance considers the following performance attributes:

- *Time;*
- *Cost;*
- *Quality;*

- *Productivity;*
- *Environment.*

Likewise the model proposed to evaluate SC performance, each attribute includes different performance metrics. However, while in the case of the global scale performance metrics are defined by considering the objective of the firm, in the urban case, the whole system has to be considered. In fact, in this case, performance metrics should be defined by considering the different objectives of the stakeholders involved. Thus, performances are evaluated by considering different points of views: administrators, carriers, shippers, receivers and residents.

Chapter 8

Application to the urban context: a case study approach

Similarly to chapter 6, this chapter provides the description of the application of the model proposed in Chapter 7 to the urban context. In particular, two different examples of application are provided. The first one considers performance evaluation based on an ex-post analysis, whereas the second one ex-ante analysis. The application allows also evaluating differential performance by comparing two different scenarios (ex-ante and ex-post analysis). Two case studies are considered to the application: Bristol (UK) and Cagliari (Italy). Relationships among indicators are analysed by means of correspondence analysis and multiple regression analysis. The analysis aims to discover the interdependencies among variables and to highlight the variables that are the most important to describe the phenomenon.

Conclusion and final remarks

Finally, a summary of the results of the research work is provided. Further research directions are discussed in terms of improvements and follow-up research development. The thesis ends by providing recommendations for using this PhD research for academic and practical purposes.

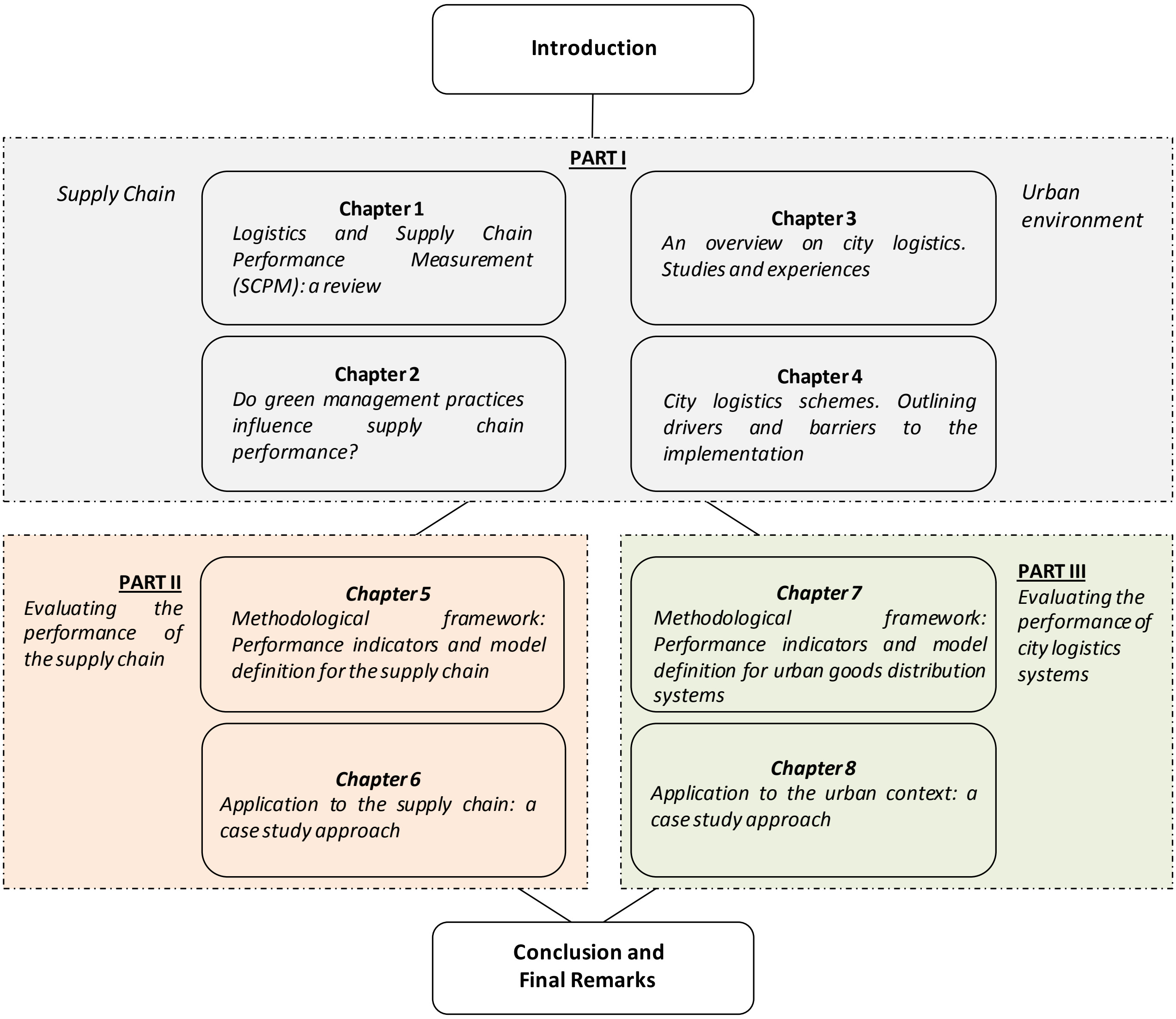

Figure A. The outline of the thesis

Part I - Background and motivations

Chapter 1

Logistics and Supply Chain performance measurement[1]

A review

The examination of the existing knowledge is the first step to discovering. Let's start!

Introduction

Logistics and transport of goods are more and more responsible for the success of a company, because their management has a significant impact on customer satisfaction and overall costs. In fact, an efficient and dynamic supply chain performance measurement system may give competitive advantages to a company. However, this research field has increased in recent years and no many studies have been carried out on supply chain performance assessment; also, the research in this area still lacks a focus on the methodology to be used. Starting from the difference between *logistics* and *supply chain* management, this chapter provides a review on qualitative and quantitative analysis and methodology used to evaluate supply chain performance. According to Chuang et al. (2014), “in modern business, competition is no longer between organizations, but among supply chains”. For this reason, in the last years, companies have been experiencing a growing need to be supported to manage their supply chain. Logistics and goods’ transport

[1] This chapter is mainly based on Paddeu, D. (2016). How do you evaluate logistics and supply chain performance? A review of the main methods and indicators. EUROPEAN TRANSPORT-TRASPORTI EUROPEI, (61).

represent the major components of supply chain management (SCM), because they strongly influence supply chain costs and times. In fact, a poor management of transport and logistics can undermine the success of a company. This is reason way Supply Chain Management (SCM) has been gaining high attention from academics, consultants, professionals and business leaders. The SCM, in fact, aims at assisting managers in the management of the supply chain (SC); it therefore helps companies to address the common goal of customer satisfaction. Over the past decade, there has been a continuous research in the field of SCM which leads, among others, to the definition of tools to measure supply chain performance (SCPM). In fact, SCPM is essential for an effective strategic management which aims at achieving the success of a company. A holistic approach should be considered to evaluate the performance of SC processes. In fact, activities, flows and systems should be integrated for a successful management of the SC (Vickery et al., 2003). Stevens (1989) and Tan et al. (1998) showed that integrated business processes create value for the firm's customers. For these reasons, performance measurement of SC should be made by considering the SC as the whole.

Based on an in-depth literature review of the papers published in the field of SCM (from 1990 onwards), the chapter provides a review of the main methods and tools developed to measure SC performance. The chapter aims to:

- Understand the importance of SCPM for a successful management of the SC;
- Analyse the differences among the existing SCPM models;
- Gain insights into various SCPM systems and identify the most used variables to SC performance assessment in order to support the decision making process;
- Classify the literature to gain detailed insights into the SCPM models and metrics.

1.1. Supply chain definition

According to Beamon (1998), Supply Chain (SC) can be defined as: "an integrated process wherein a number of various business entities (i.e., suppliers, manufacturers, distributors, and retailers) work together in an effort to: (1) acquire raw materials, (2) convert these raw materials into specified final products, and (3) deliver these final products to retailers".

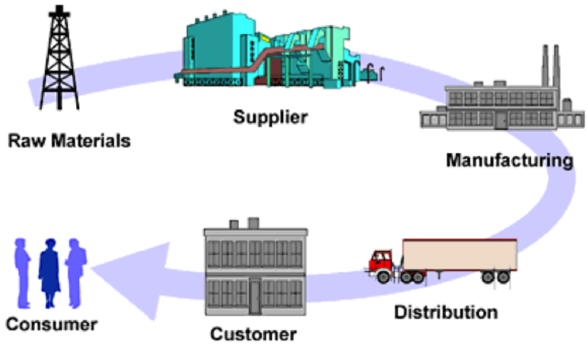

Figure 1.1. Example of Supply Chain (Vorhies, W., 2015)

Two types of flows are associated to the activities performed within the SC: (a) a forward flow of materials and (b) a backward flow of information. All the SC processes can be grouped into two main groups (Figure 1.2):

- *Production Planning and Inventory Control Process,* related to the design and management of the whole manufacturing process (including raw material scheduling and acquisition, manufacturing process design and scheduling, and material handling design and control).
- *Distribution and Logistics Process*, related to all the activities that aim to transport products from the warehouse to retailers; transport and delivery can be performed directly to retailers or by passing through distribution facilities, where deliveries are consolidated into a single load in order to be delivered to a common targeted area.

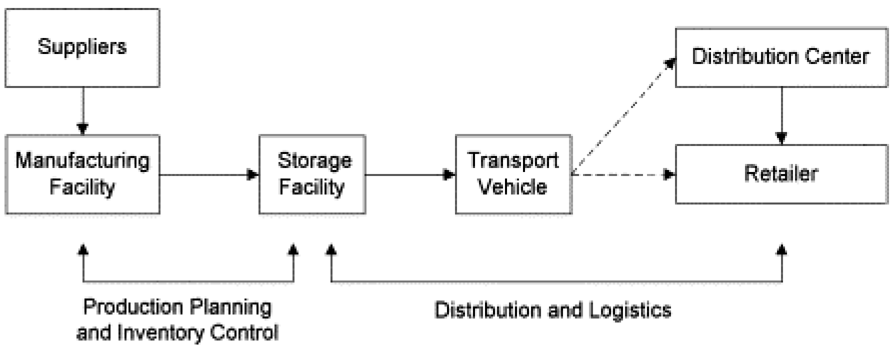

Figure 1.2. The supply chain process (Source: Beamon, 1998)

In the recent years, "Reverse Logistics" has been included into the traditional SC processes, such as the process about product recovery for the purposes of recycling, remanufacturing, and re-use. Even though in the past researchers and practitioners have primarily investigated the various processes of the supply chain individually, they started placing increasing attention on the performance, design, and analysis of the supply chain as a whole. In particular, the interaction among all the SC processes allows defining an integrated supply chain, which works to reach the necessary performance objectives. Furthermore, due to the high importance of the stakeholders involved in the SC processes, a focus on their needs is required. However, due to the complexity of the relationships among the stakeholders involved and their conflicting purposes and interests, process management effectiveness is hard to achieve (Fancello et al., 2014).

1.2. Logistics versus Supply Chain Management

Nowadays logistics can be considered a branch of engineering which creates "people systems" rather than "machine systems" (Islam et al., 2013). It is strictly related to the evaluation and optimization of times and costs related to processes and services of commercial activities. In fact, logistics can be considered the science that studies the management of the supply chain as the whole, which includes supply of raw materials, production process, warehousing and goods transport from one point to another one. In spite of this modern concept of logistics, it is worth noting that the term "logistics" finds its origins in the ancient Greece, exactly in the military discipline. There were a specific department of the army that was responsible for providing the necessary weapons, ammunition and rations when they were needed (Islam et al., 2013).

On the other hand, the concept of "Supply Chain Management" (SCM) was introduced at the beginning of the '80s (Cooper et al., 1997) and it started drawing the attention of the researchers at the beginning of the '90s. Actually, SCM interested not only marketing and business, but also scientific literature (Lambert et al., 2000). But, what is the difference between logistics and SCM? It is very thin. In fact, till few time ago, SCM was considered as the logistics related to the external stakeholders: suppliers and customers. For this reason, in 1998, the Council of Logistics Management (CLM) provided a new definition for logistics: ''that part of the supply chain process that plans, implements, and controls the efficient, effective flow and storage of goods, services, and related information from the point of origin to the point of consumption in order to meet customers' requirements '' (Cooper et al., 1997). On the other hand, the Global Supply Chain Forum (GSCF), a group made of non-competing firms and a team of academic researchers, provided a definition for SCM, which was defined as: "the integration of key business processes from end user through original suppliers that provides products, services, and information that add value for customers and other stakeholders".

With the latter definition, therefore, not only products' flows, but also information flows, stakeholders' integration and management are considered. The GDCF also defined the 8 key supply chain processes (Figure 1.3):

1. Customer relationship management;
2. Customer service management;
3. Demand management;
4. Order fulfilment;
5. Manufacturing flow management;
6. Procurement;
7. Product development and commercialization;
8. Returns.

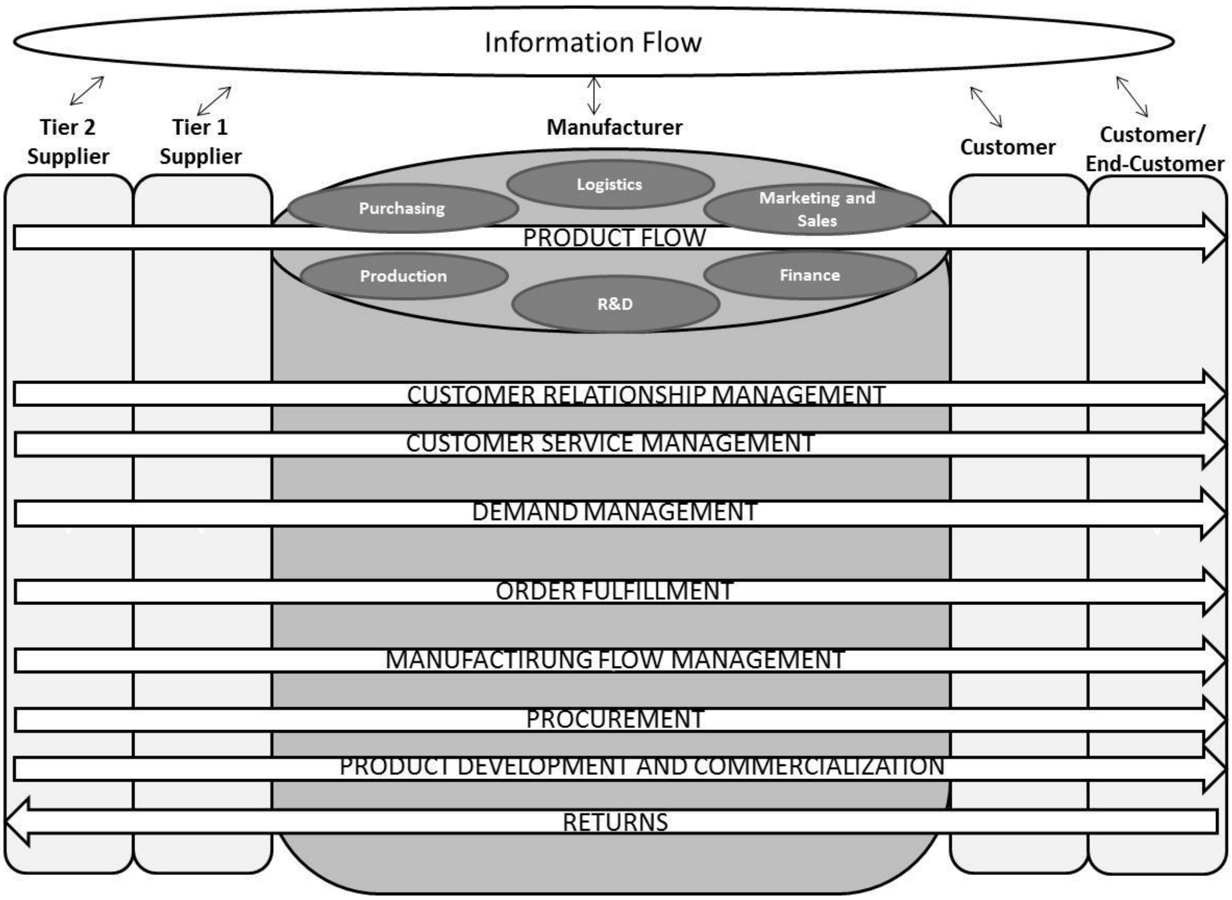

Figure 1.3. Supply chain management: integrating and managing business processes across the supply chain. [Cooper et al., 1997]

1.3. The concept of *measure* and the performance measurement in the Supply Chain

An effective system of performance measurement allows making decisions and undertaking actions in order to make the evaluator able to quantify the efficiency and effectiveness of past actions through the collection, selection, analysis, interpretation and dissemination of suitable data (Neely et al., 2001). The performance measurement is defined as the process that quantifies the efficiency and effectiveness of the action (Neely et al., 1995). Effectiveness is the measure to which customer needs are met, while the cost-efficiency measures, such as the company's resources, are used to achieve a predetermined level of customer satisfaction (Agami et al., 2012). In the last years, researchers have deeply studied supply chain performance measurement - SCPM (Agami et al., 2012). Performance assessment is an important and essential tool to successfully manage the supply chain (Gunasekaran et al., 2001) and the lack of a suitable assessment represents the main obstacle to an efficient supply chain management (Lai et al., 2002).

The design and development of a SCPM system imply various difficulties because SCPM represents a tool that generally leads to a company organizational change. According to Agami et al., 2012; Beamon, 1999; Keebler, 2001; Gunasekaran et al, 2004; Tangen, 2004; Ramaa et al, 2009; Akyuz and Erkan, 2010; Kurien and Qureshi, 2011 an effective SCPM should be characterized by:

1 “Wholeness”: it must cover all supply chain aspects and processes;
2 “Universality”: should allow comparison of performance over time and under different operating conditions;
3 “Measurability”: the output should be a quantitative measure;
4 “Consistency”: the measures must be compatible with the objectives of the supply chain.

The choice of the right measurement system represents an important problem. In fact, the most appropriate measure should not only provide an indication of the actual distance of the company from its objectives, but it should also provide a means to define its strategy and encourage its implementation (Agami et al., 2012). In the literature there are several works related to the definition of the most appropriate measurement system. According to Gunasekaran et al. (2004), a measurement system shall be used along the SC; it has to be "balanced", i.e. it must consider both financial and non-financial indicators that can be classified at strategic, tactical and operational levels. The SC performance measurement (SCPM) thus allows evaluating, in both qualitative and quantitative terms, if a supply chain is working well or not.

If we have a look to the past, the performances of a company have always been assessed through different measurement systems, which evolved over the centuries. Before the nineteenth century, performance measurements were expressed in terms of financial indicators related with the amount of product sold or purchased (i.e. cost per ton, cost per kilo, and so on). In the twentieth century, the company DuPont (1903) defined the "Rate of Return on Investment" (ROI - Return on Investment) to evaluate the performance of different units and so they developed the "DuPont System Scale", which has been widely adopted later. Since then, the financial indicators have become the most widely used method for measuring performance (Parker, 2000). After World War II, the climate of uncertainty has meant the birth of the need to balance marketing relationships, research and development, human resources and finance (Kurien and Qureshi, 2011). For these reasons, companies started using both financial and non-financial indicators. However, before the '80s, there was a tendency to still use traditional accounting systems with pure financial guidance. They relied only on quantitative generic financial parameters, ignoring any other important not financial indicator: such as the quality of service or customer loyalty. In the first following decade, these accounting systems have been strengthened and their application has been extended to the evaluation of specific processes and tasks within the supply chain. In the early 90's, Kaplan and Norton (1992) developed the Balanced Scorecard model (BSC), which represents the introduction of the concept of mixed systems for the first time.

As widely pointed out by the literature (Kurien and Qureshi, 2011; Lapide, 2000), despite financial measures are important to evaluate the financial health of a company, they are insufficient to measure the performance of the supply chain. Indeed, they tend to give short-term measures, which focus on the inner vision of the company and are focused on historical data. They also do not refer to important strategic non-financial performance indicators (such as customer satisfaction and the quality of the product) and are not directly related to the measure of operational effectiveness and efficiency.

1.4. A focus on supply chain performance measures

Based on the work proposed by Beamon (1998), this section provides a description of the most important performance measures highlighted by the literature. They can be classified into qualitative and quantitative measures.

1.4.1. Qualitative performance measures

Qualitative performance measures are not usually related to a numerical indicator, but, on the contrary, they express attributes that can be classified (e.g type of goods, delivery frequency, market segment, etc.).

However, sometimes qualitative measures can be associated to numbers in order to be quantifiable measures. The most used qualitative measures are:

- *Customer satisfaction*, which measures the level of customers' satisfaction with the product/service received. It can be related to: (i) satisfaction associated with service elements occurring prior to product purchase; (ii) satisfaction associated with service elements directly involved in the physical distribution of products; (iii) satisfaction associated with support provided for products while in use;
- *Flexibility*, which measures the degree of respondent to random fluctuations of the demand;
- *Information and material flow integration*, which measures the level of integration among all the SC activities in terms of communication;
- *Effective risk management*, which describes the degree to which the effects of SC risks is minimized;
- Supplier performance, which measures how suppliers deliver raw materials to production facilities in terms of timeliness and integrity of the product.

1.4.2. Quantitative performance measures

Quantitative measures, on the contrary, are expressed by numbers. They can be classified as follows:

i. Continuous variables, which can assume any type of value (including decimals) over a range, and can be measured in terms of kilograms, hours, dollars, euros, etc.
ii. Discrete variables, which can assume values from a finite or countable set (excluding integer values).

Beamon (1998) classifies quantitative measures into: (a) economic or financial measures, related to costs or profit; (b) measures based on customer responsiveness.

Some examples of measures being part of group (a) are:

- Cost minimization, which is the most widely used measure indicator;
- Sales maximization, used to maximize revenues or units sold;
- *Profit maximization*, used to maximizes revenues less costs;
- *Inventory investment minimization*, used to minimize the amount of inventory costs (including product costs and holding costs);
- *Return on investment maximization*, used to maximize the ratio of net profit to capital that was employed to produce that profit.

Measures being part of the group (b) are:

- *Fill rate maximization*, used to maximize the fraction of customer orders filled on time;
- *Product lateness minimization*, used to minimize the amount of time between the promised product delivery date and the actual product delivery date;
- Customer response time minimization, used to minimize the amount of time required from the time an order is placed until the time the order is received by the customer. Usually refers to external customers only;
- Lead time minimization, used to minimize the amount of time required from the time a product has begun its manufacture until the time it is completely processed.
- Function duplication minimization, used to minimize the number of business functions that are provided by more than one business entity.

1.5. A focus on Performance Measurement Models

Performance measurement is critical to improve the effectiveness and efficiency of a company (Beamon, 1999), and of its supply chain (Shepherd and Günter, 2006). A brief introduction of the most used models for the measurement of logistics performance in the following sub-sections is provided.

1.5.1. Key Performance Indicators (KPIs)

KPIs can be defined as a set of indicators used to measure the success of a company, through the measurement of the performance of a particular activity or process. They are not predetermined, but may change depending on the evaluation criteria or priorities that the company associates with each area. KPIs are used to understand the extent to which an area or process is working against the objectives that the company is responsible to achieve. In fact, based on the values of the indicators, the manager can decide which action has to be taken to improve the performance of a specific area. They can therefore be considered as a real decision support tool. The supply chain decision makers are focused on the development of indicators for assessing SC performance (Beamon, 1999; Gunasekaran et al., 2004) and, when these are properly developed and used, managers need to identify the critical measures related to the areas that need to be improved. Even though KPIs are useful to quickly identify critical areas, the determination of priorities of a given set of KPIs is a critical element in improving the management of the supply chain (SCM) for many companies (Cai et al., 2009).

Measure	Literature Support
On-Time Delivery Percentage	Bititci 2005; Ballou 2004; Murphy and Wood 2004; Rafele 2004; Coyle et al. 2003; Bowersox et al. 2002; Stock and Lambert 2001; Harding 1998; Johnson 1998; Boyd and Cox 1997; Davis 1993; Kaplan 1991; Kleinsorge et al. 1991; Wisner and Fawcett 1991
Logistics Costs as a Percentage of Sales	Bititci 2005; Ballou 2004; Bowersox et al. 2002; Stock and Lambert 2001; Gustin et al. 1995
Days Order Late	Chan et al. 2003; Bowersox et al. 2002; Johnson and Davis 1998; Davis 1993
Inventory Turnover Ratio	Bititci 2005; Wouters and Sportel 2005; Ballou 2004; Rafele 2004; Coyle et al. 2003; Bowersox et al. 2002; Keebler et al. 1999; Johnson 1998; Johnson and Davis 1998; Fisher 1997; Krupp 1994; Wisner and Fawcett 1991; Ellram et al. 1989
Complete Order Fill Rate	Ballou 2004; Rafele 2004; Chan et al. 2003; Coyle et al. 2003; Bowersox et al. 2002; Brewer and Speh 2000; Keebler et al. 1999; Harding 1998; Johnson 1998; Johnson and Davis 1998; Boyd and Cox 1997; Lee and Billington 1992; Ellram et al. 1989
Average Order Cycle Time	Ballou 2004; Murphy and Wood 2004; Rafele 2004; Chan et al. 2003; Coyle et al. 2003; Bowersox et al. 2002; Stock and Lambert 2001; Evers 1999; McMullen 1996
Order Cycle Time Variability	Ballou 2004; Bowersox et al. 2002; Stock and Lambert 2001; Ellram et al. 1989
Items Picked per Person per Hour	Wouters and Sportel 2005; Ballou 2004; Murphy and Wood 2004; Payne and Peters 2004; Coyle et al. 2003; Bowersox et al. 2002; Stock and Lambert 2001
Average Line Item Fill Rate	Ballou 2004; Murphy and Wood 2004; Coyle et al. 2003; Bowersox et al. 2002; Johnson 1998; Johnson and Davis 1998; Lee and Billington 1992; Harrington et al. 1991
Weeks of Supply	Bititci 2005; Bowersox et al. 2002; Johnson and Davis 1998; Krupp 1994
Average Backorder Fill Time	Bititci 2005; Rafele 2004; Bowersox et al. 2002; Johnson and Davis 1998
Sales Lost Due to Stockout	Stock and Lambert 2001; Fisher 1997; Emmelhainz et al. 1991
Percent Error Pick Rate	Murphy and Wood 2004; Rafele 2004; Bowersox et al. 2002; Stock and Lambert 2001; Brewer and Speh 2000
Logistics Costs per Unit	Wouters and Sportel 2005; Coyle et al. 2003; Bowersox et al. 2002; Brewer and Speh 2000

Figure1.4. Example of SC performance indicators [Griffis et al., 2007]

KPIs can be applied to different areas such as sales, marketing, finance, insurance, retail, health care, social media and, of course, supply chain and logistics. Garcia et al. (2012) proposed four performance attributes within which they defined specific KPIs related to each level of the whole logistics process. In particular, drawing out from the approach proposed by Frazelle (2002), who provided for the introduction of financial indicators, productivity, quality and cycle time processes, Garcia et al. (2009) proposed four new attributes related to logistics processes: "*quality*", "*timeliness*", "*logistics costs*", "*productivity and capacity*". The quality attribute is related to both the quality of the processes and that of the product along the supply chain; it is indispensable to measure the level of customer satisfaction. The timeliness attribute is related to the response time of the supply chain, which is required to meet the needs of customers. The logistics costs attribute is related to the financial logistics performance, whereas productivity and capacity attribute is related to the efficiency of the use of the resources.

KPIs can therefore be used to measure the performance of a specific process of the supply chain, to supervise the progress of its performance over time and, through the implementation of benchmarking techniques, to compare the performance of the supply chain of a company with those of the supply chain of the other competing companies (benchmarking). KPIs should be easy to understand, essential and updated over time. The indicators selected by Griffis et al. (2007) can be considered those most used by logistics managers to assess SC performance (Figure1.4).

1.5.2. Balanced Score-Card (BCS)

Another important model for SC performance measurement (SCPM) is the Balanced Scorecard model (BCS), introduced by Kaplan and Norton (Kaplan and Norton, 1992); it proposes a balanced approach between financial and non-financial measures.

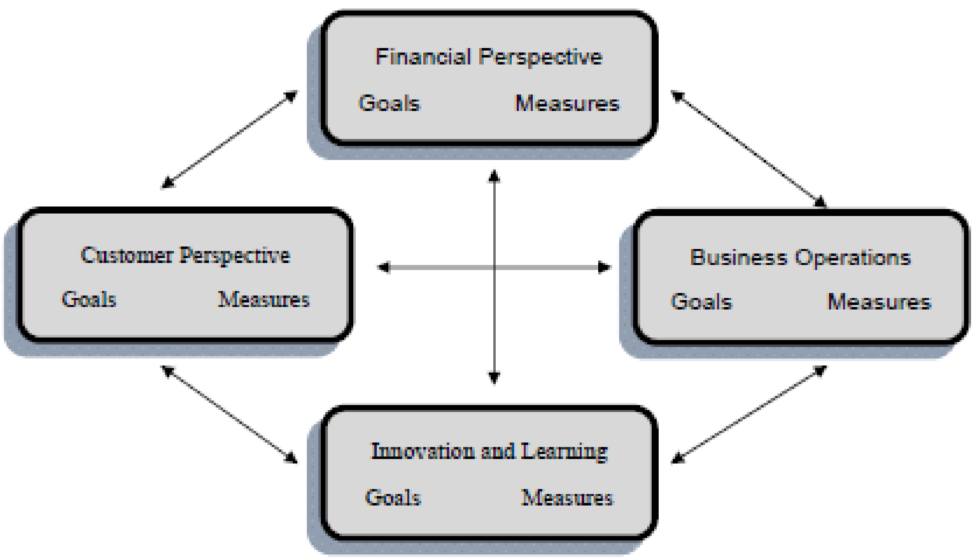

Figure 1.5. A Balanced Scorecard (United States, 2011).

Kaplan and Norton believed that the traditional financial measures (i.e. the indicator on return on investment - ROI) would offer an incomplete framework of the corporate performance and that did not provide a tool for continuous improvement and innovation. They argued instead the criteria for performance evaluation should also include non-financial indicators, which would consider customers, internal processes and learning and growth processes. These indicators are very important for the competitiveness of a company; in fact, they allow managers to consider all performance measures and thus take into consideration whether it is possible to achieve improvement in a specific area, without affecting the performance of other areas (Wu and Chang, 2012). The BSC has been widely applied to many services sectors, such as banking (Beechey and Garlick, 1999), commercial activities such as customer relationship management (Kim et al., 2006) and the supply chain management - SCM (Brewer and Speh, 2000). However, there are few studies that investigate the potential application of BSC to SC performance evaluation with respect to the external relations (Wu and Chang, 2012).

1.5.3. Business Excellence Model (EFQM)

The Business Excellence Model (EFQM) model was introduced in 1992 by the European Foundation for Quality Management to help companies to be more competitive (**Figure1.6**).

The model provides a non-prescriptive framework based on nine criteria:

- Five are called "*enablers*" and reflect the tasks carried out by the company;
- Four are called "*results*" and reflect on what the company achieves.

Results are strongly dependent on *enablers'* criteria. This model is usually used for quality control, so it has not to be limited to the evaluation of SC performance.

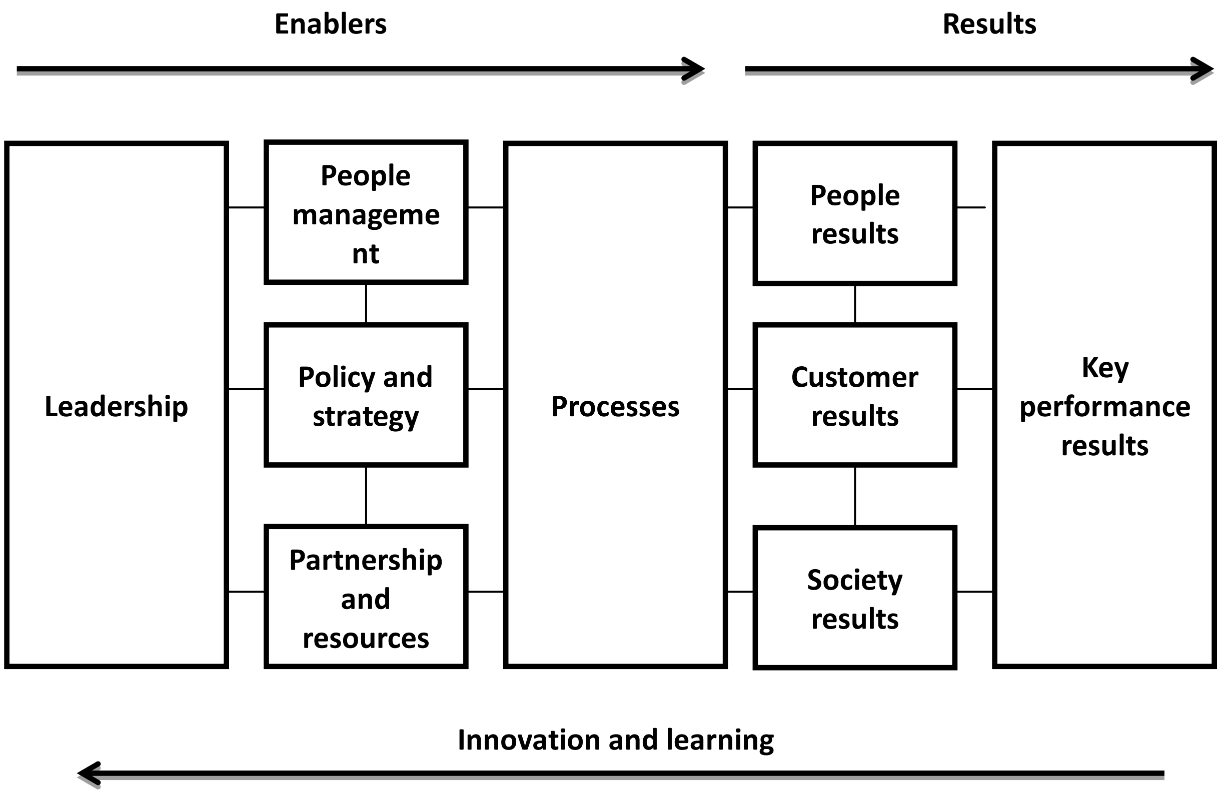

Figure1.6. Business Excellence Model (Source: McAdam, R. Business Excellence Model. Wiley Encyclopedia of Management)

1.5.4. Performance Prism

The Performance Prism is designed to meet the needs of a business in a dynamic environment, in which variables and processes often change over time. This model considers the relationships between the different actors involved in the SC and the processes and activities they carry out within the SC. The stakeholders are the core of the model, which considers five different (but related to each other) performance perspectives (Neely et al., 2012):

1. Stakeholders satisfaction;
2. Strategies;
3. Processes;
4. Ability;
5. Stakeholders' contribution.

However, despite being the model that more considers the contribution of stakeholders, it is limited in terms of effectiveness' measurement; it offers few, if any, indications to identify attributes and to select performance (Neely et al. 2012).

1.5.5. *Supply Chain Operations Reference (SCOR)*

The Supply Chain Operations Reference model (SCOR) is definitely the most used model in the field of SCPM; it was proposed by the Supply Chain Council (SCC) to manage and evaluate the performance of the supply chain. SCOR has been widely used by many companies all over the world and it has become the standard model for the management of the processes that characterize the SC (Hwang et al., 2008). It enables companies to analyse the performance of their SC in a systematic way by improving communication between the various members of the chain, while, at the same time, it allows optimising the network and the performance of each region and then of the supply chain as a whole. The model is designed by a 3-level hierarchical structure; processes and KPIs (grouped into the areas: reliability, responsiveness, flexibility, cost and resources) are associated to each level and they are defined with a specifying that increases from level 1 to level 3. The processes associated with each level are:

- *Source*, ordering and receiving raw materials and products;
- *Make*, manufacturing, producing, repairing, modifying or recycling materials and products;
- *Deliver*, receiving, programming, taking, packing and delivering products that are ordered by customers;
- *Return*, managing the logistics of returning products and goods not suitable for sale and packaging.

There is also another process, *Plan*, which involves all the previous processes. Three different decision levels are defined for each process: strategic, tactical and operational, corresponding respectively to the long (years), medium (months) and short (days) period (Souza, 2014).

1.5.6. *Statistics analysis for supply chain performance assessment*

Statistics analysis is widely used for supply chain management analysis (Vickery et al., 2003; Fugate et al., 2010; García et al., 2014; García-Alcaraz et al., 2015). In particular, descriptive statistics may be used to describe data behaviour in a study. By providing simple summaries about the sample and the measures achieved, data statistical analysis represents the foundation of a quantitative analysis. Statistics can also help to identify the existing relations among variables. In particular, in the field of SCPM, financial performance is usually chosen as dependent variable for regression analysis. Regression analysis, in fact, aims to identify the relationship between a dependent variable and one or more independent variables (Hwang et al., 2008; García-Alcaraz et al., 2015). When the relations analysis among variables is carried out, usually the reduction of the number of variables is advisable in order to consider only the most significant variables to explain the process. Factor analysis is widely used not only for this purpose, but also for detecting the structure of the relations among variables. This technique is commonly used for performance assessment (Vickery et al., 2003; García et al., 2014). Anyway, factor analysis is often used as confirmatory analysis before implementing structural equation modeling - SEM (Vickery et al., 2003). The latter represent a class of statistical models which can be considered confirmatory rather than exploratory technique. Factor analysis, path analysis and regression all represent special cases of SEM, even if it is younger than factor and regression analysis (1960s). SEM analysis is largely used within social and psychological science; in fact, it usually focuses on latent constructs (abstract psychological variables like "intelligence" or "attitude toward the brand") rather than on the manifest variables used to measure these constructs. For its characteristics, SEM it has been applied also to SCPM to explain direct and indirect relationships among performance variables (Vickery et al., 2003; Wisner, J. D., 2003; Fugate et al., 2010; García et al., 2014; García-Alcaraz et al., 2015).

1.6. A selection of the most relevant contributions from the scientific literature

The author carried out an analysis focused on scientific publications with empirical evidence in the field of SC Performance Measurement. The relevant period was set from 1990 onwards. A total of 17 international journals were selected as the most significant in terms of relevant papers published in the field of supply chain performance evaluation. All issues published from 1990 were examined for relevant papers; moreover, papers and works cited by the paper selected were also reviewed. A total of 80 papers were identified. Two review analyses were carried out. With the first analysis, papers selected were classified by considering the journal in which have been published, the number of citations they have at the moment of the review and the geographical origin of the authors; the second analysis, instead, concerns the methodologies applied and the variables used to performance assessment.

1.6.1. Descriptive analysis of the papers selected

The author decided to analyse the time period of the research in the field of SC Performance Measurement (figure 4) starting from 1990.

However, the first relevant paper was found in 1998. The year 2014 has the highest number of publications with 18 papers. It is worth noting that the journals considered do not show a regular growth in terms of number of publication in this field.

If we focus on the journals (Figure1.7), International Journal of Production Economics accounts for 35 papers, being at the first place for number of published papers in the field of SCPM. Second and third places are European Journal of Operational Research and Computers & Industrial Engineering and with respectively 8 and 7 papers published in this field.

USA is the first country for both number of papers and number of citations. Figure1.8 and Figure1.9 show respectively the number of papers and the number of citations per country. If on one hand China and UK follow USA per number of papers published in the field of SC performance measurement (Figure1.9), on the other hand USA is followed by India and Canada per number of citations (Figure1.10).

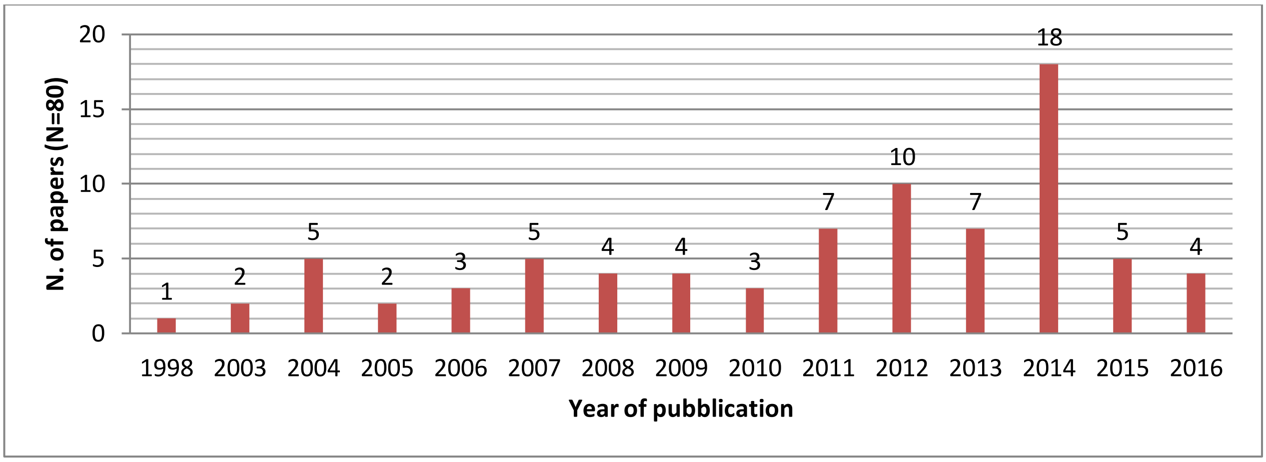

Figure1.7. Classification of the papers selected per year of publication

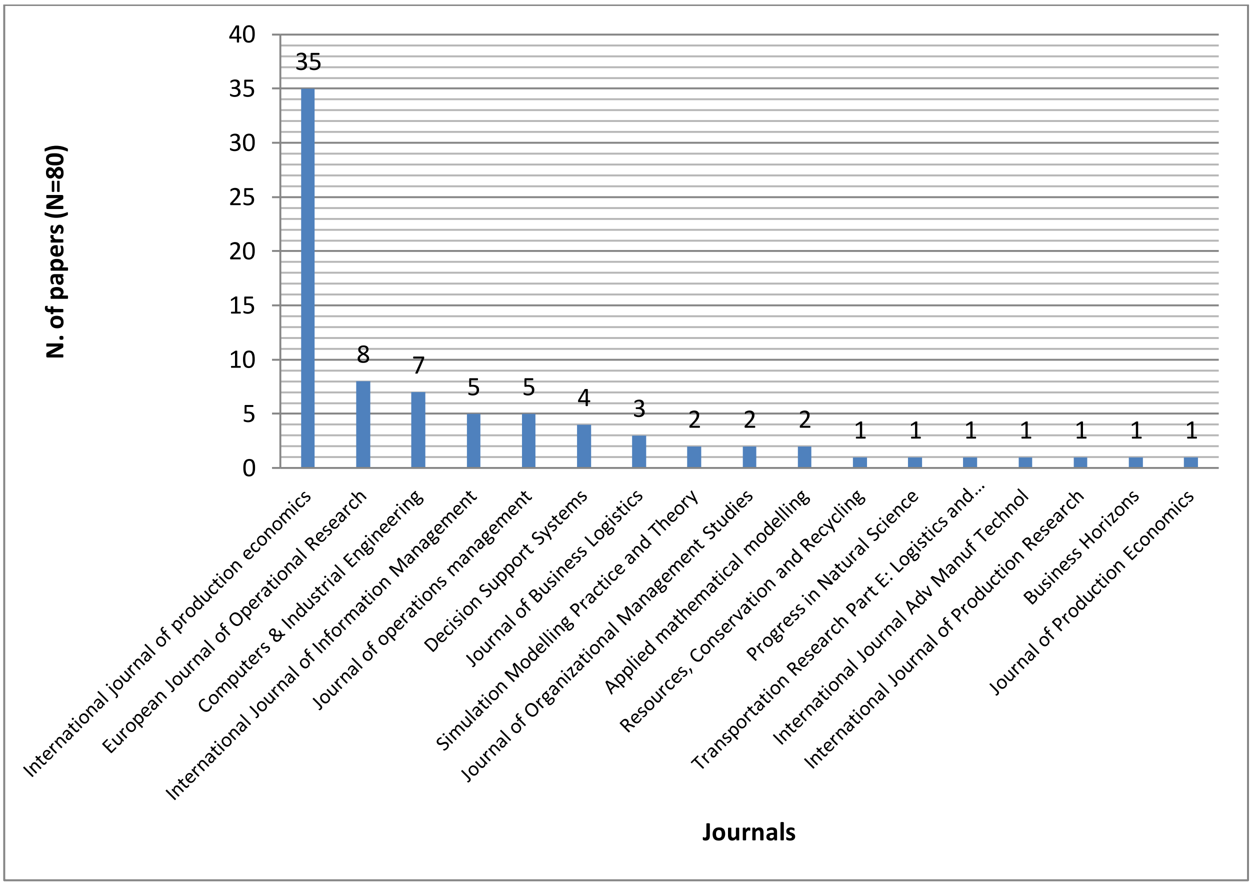

Figure1.8. Classification of the papers selected per journal

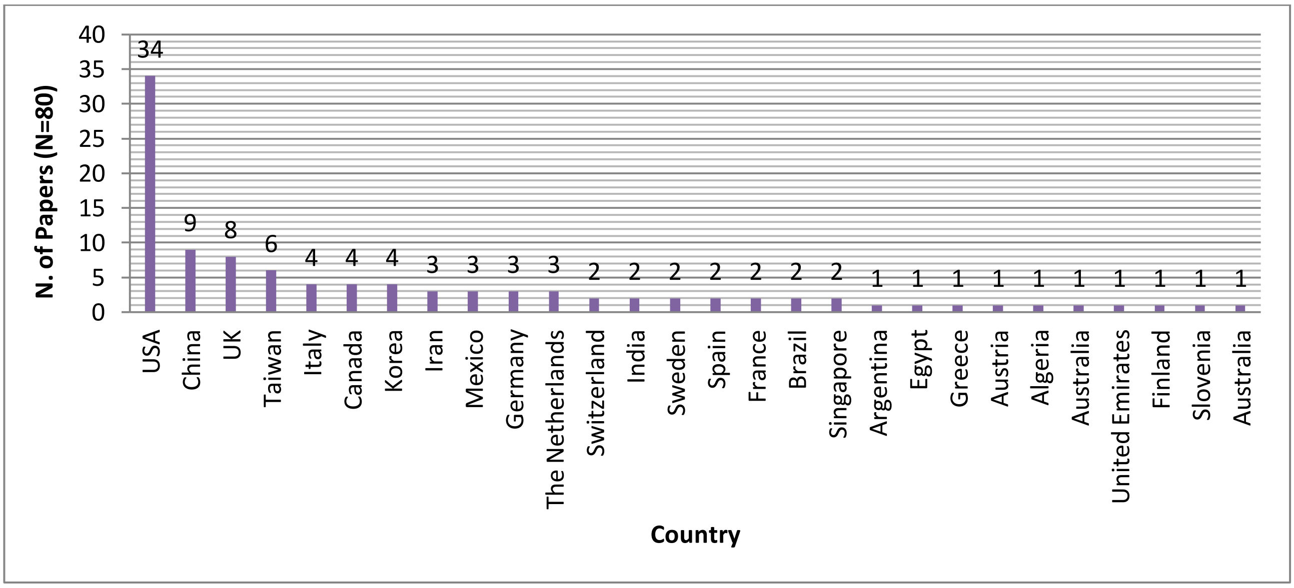

Figure1.9. Distribution of the papers by investigated countries

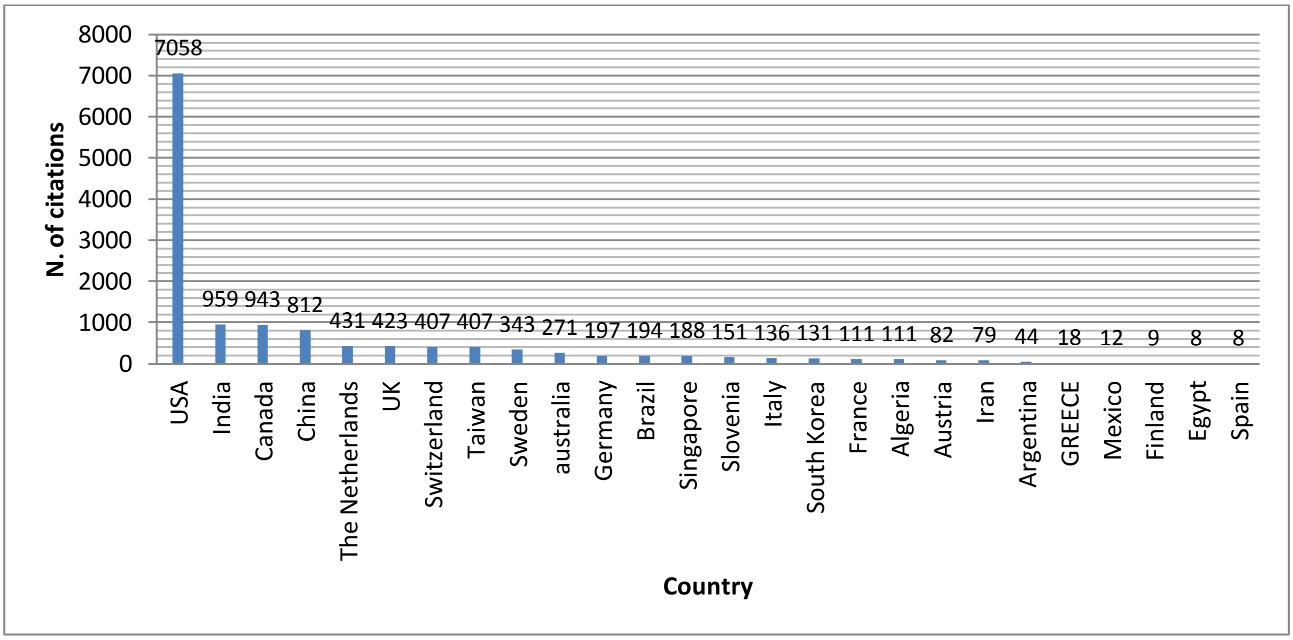

Figure1.10. Number of citations per country

1.6.2. Methodology and performance variables analysis

Case study analysis is used in 51 papers (more of the half of the sample) and it is carried out by collecting data by means of questionnaires and interviews. Moreover, in the most of the cases considered, data analysis and performance analysis are carried by means of statistical methods, such as SEM (27 papers), Correlation and Factorial Analysis (5 papers), Descriptive Statistics (12 papers), Regression Models (2 papers) and Hypothesis Test (3 papers). Specific methods developed for the SCPM, such as SCOR model (12 papers), Balanced Scorecard (5 papers) and KPIs (7 papers) are also widely used.

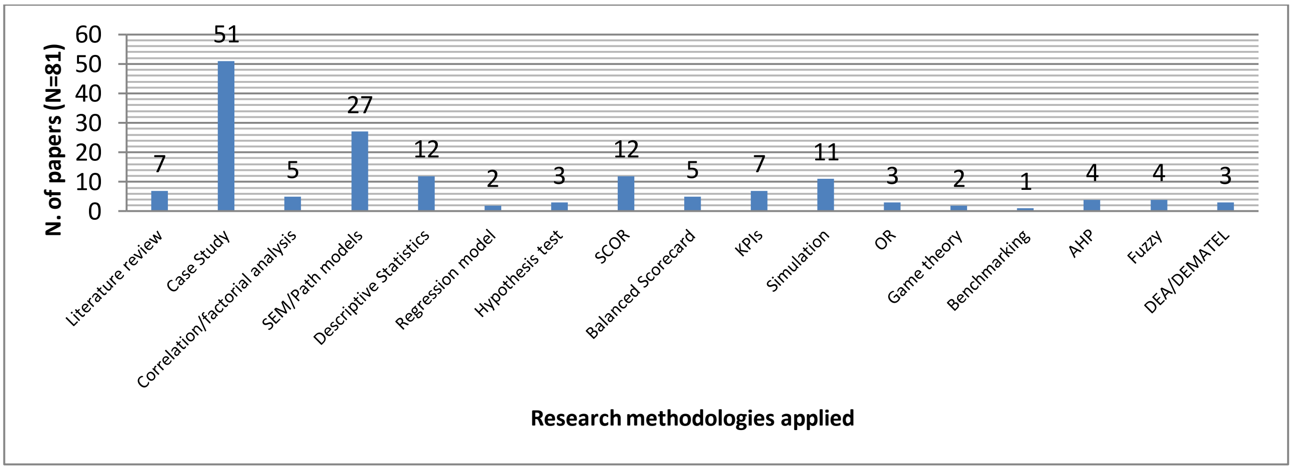

Figure 1.11. Research methodologies applied in the selected papers

Performance measures can be classified into (i) qualitative variables and (ii) quantitative variables. Of course, managers prefer quantifiable indicators in order to be able to perfectly understand the distance of the company from the company's goals. For instance, if a company want to manage its SC from an holistic point of view, then the organisation should include all the actors (e.g. suppliers, customers, distributors, etc.) in the SC decision process. In this case, supply chain integration can give an indication of the level of stakeholders' assimilation.

Among the papers selected, the most employed variables to performance assessment in the papers analysed are "*costs*", and "*information technologies*" (both at the first place with 17 papers); second are "*customers*" and "financial performance" variables, with 13 papers each and third is Supply Chain Integration with 11 papers (Figure 1.11).

It is worth noting that the majority of the papers are based on case study analysis, representing case examples and conceptual papers rather than theoretical framework development. Also, data are often collected by means of questionnaire addressed to SC experts/managers (Gunasekaran et

However, if we consider to group variables into categories, as shown in table 1.1, first category is "*cost/financial performance*" with 30 papers; second is "*Supply Chain communication*" with 28 papers and third is "*customers*" with 23 papers.

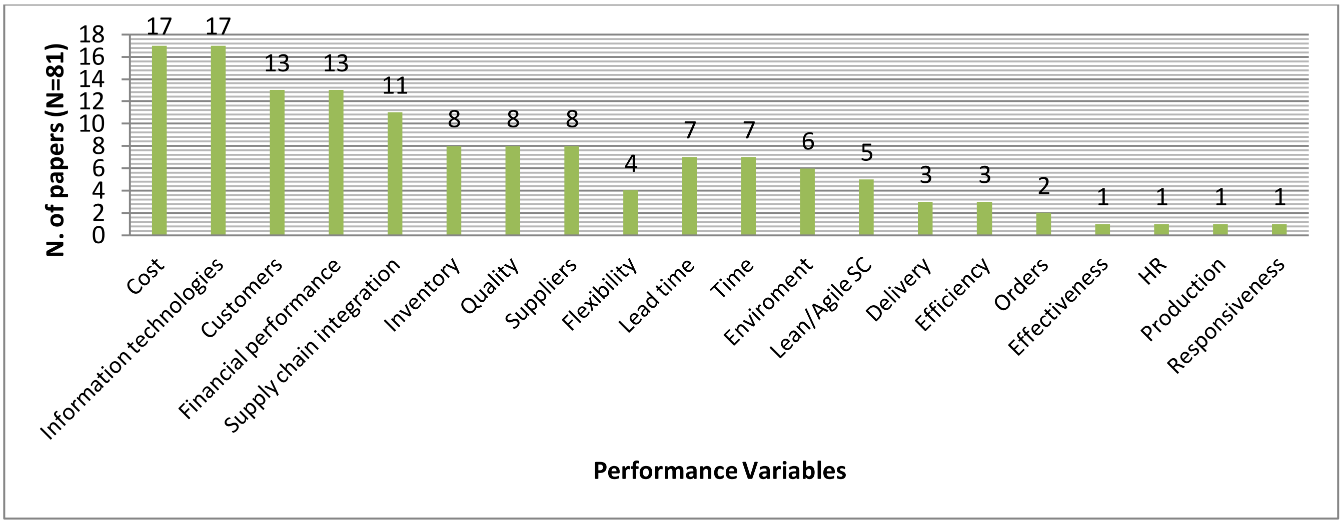

Figure 1.12. Variables used for performance assessment

<table>
<tr><th>N.</th><th>Performance Categories</th><th>N. of papers</th><th colspan="7">Performance Variables included in the category</th></tr>
<tr><td>1</td><td>COST/FINANCIAL PERFORMANCE</td><td>30</td><td colspan="3">Cost</td><td colspan="4">Financial performance</td></tr>
<tr><td>2</td><td>CUSTOMERS</td><td>23</td><td colspan="2">Customers</td><td colspan="3">Quality</td><td colspan="2">Orders</td></tr>
<tr><td>3</td><td>TIME</td><td>14</td><td colspan="3">Lead time</td><td colspan="4">Time</td></tr>
<tr><td>4</td><td>EFFECTIVE SC</td><td>17</td><td>Responsiveness</td><td colspan="2">Effectiveness</td><td>Efficiency</td><td colspan="2">Flexibility</td><td>Lean/Agile SC</td></tr>
<tr><td>5</td><td>COMPANY</td><td></td><td colspan="2">Production</td><td colspan="3">Inventory</td><td colspan="2">HR</td></tr>
<tr><td>6</td><td>SC COMMUNICATION</td><td>28</td><td colspan="3">Supply chain integration</td><td colspan="4">Information technologies</td></tr>
<tr><td>7</td><td>ENVIROMENT</td><td>6</td><td colspan="7">Environment</td></tr>
<tr><td>8</td><td>DELIVERY</td><td>3</td><td colspan="7">Delivery</td></tr>
<tr><td>9</td><td>SUPPLIERS</td><td>8</td><td colspan="7">Suppliers</td></tr>
</table>

Table1.1. Performance variables' categories

It is worth noting that the majority of the papers are based on case study analysis, representing case examples and conceptual papers rather than theoretical framework development. Also, data are often collected by means of questionnaire addressed to SC experts/managers (Gunasekaran et al., 2004; Vickery et al., 2003; Agarwal et al., 2006; Wisner, 2003; Cai et al., 2009; Fugate et al., 2010; Griffis et al., 2007; Hwang et al., 2008; Garcia et al., 2012; Garcia et al., 2014; Garcia-Alcaraz et al., 2015; Lii and Kuo, 2016; Lucas and Noordewier, 2016; Bourlakis et al., 2014; Qrunfleh and Tarafdar, 2014; Yusuf et al., 2014; Pettersson and Segerstedt, 2013; Gligor et al., 2015; Wu and Chang, 2012; Devaraj et al., 2007; Ranganathan et al., 2011); so, performance variables used to SCPM can be considered as a suggestion gathered from the expertise of SC managers rather than variables defined by empirical analysis. Environmental variables are not many (Vachon and Klassen, 2008; Merschmann and Thonemann, 2011; Gligor et al., 2015; Zhang et al., 2014; Ala-Harja and Helo, 2014; Lohman et al., 2004) because journals with specific topic in green logistics and sustainability have not been considered. Table1.2 (Appendix 1) shows a summary of the methodology used for SCPM and assessment by the authors of the selected papers.Table1.2. summarizes the methodology and performance variables used by the reviewed papers.

Conclusions

The chapter revealed that the effective management of the SC helps companies to acquire customers and to improve the level of service offered. However, improving the performance of a company is not a simple matter (Gunasekaran et al., 2004).

The review showed that performance measurement is essential for an efficient planning and monitoring of activities within the decision making process. Although most companies today use systems to measure performance of their internal and/or external processes, there are no many research studies that address the problem of balanced indicators under the SCM (Bhagwat and Sharma, 2007). Also, there are no recommendations about the number of indicators that should be used, nor there is a clear distinction among the indicators to be used for decisions to take at strategic, tactical and operational levels (Gunasekaran et al., 2001). Moreover, the existing methodologies do not clear how the most relevant processes for an efficient and effective SCM can be identified (Palma-Mendoza, 2014).

There is a gap between research and application in measuring and improving SC performance (Cai et al., 2009). Also, the performance indicators are often chosen depending on the opinions expressed by SC experts (by means of questionnaires in which they are asked to rate the usefulness of an indicator to another one) rather than on a rigorous scientific evaluation that proves their real effectiveness (Griffis et al., 2007; García-Alcaraz et al., 2015; Hwang et al., 2008; Wisner, 2003; Gunasekaran et al., 2004).

To conclude, there exists the need to define a universally valid framework that identifies the variables that mostly have influence on the overall performance of the SC.

Further studies could provide the definition of a tool that allows SC managers making decision to optimize SC processes through SCPM indicators.

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Chapter 2

Do green management practices influence supply chain performance?

An exploratory analysis to investigate the point of view of the supply chain experts

Introduction

Nowadays, global warming and climate change are strongly influencing people in the way of purchasing products. In fact, people prefer to purchase environmentally friendly products or products sold by environmentally friendly companies. With the aim to acquire a 'green reputation', companies are adopting green practices to manage their supply chain in order to make it more sustainable. However, often companies are not totally aware about the impacts of sustainable practices on supply chain performance and green operations are perceived as an extra-cost or a disadvantage. Especially in the last ten years, people have been increasingly concerned with climate change and sustainable development (Walker et al., 2008). Industry and transportation are the most polluting sectors, thus firms can be considered directly responsible for unsustainability; they have ethical responsibilities toward society, therefore they are required to make decisions that minimize impacts upon the environment (Hart, 1995; Henriques and Sadorsky, 1999; Walker et al., 2008). Due to pressures from various stakeholders (such as government regulators, community activists, etc.), many companies are experiencing the implementation of sustainable practices (Hassini et al., 2012). The adoption of environmental supply chain management practices includes the personal commitment of leaders, middle management, policy entrepreneurs, and investors (Walker et al., 2008). For this reason, green supply chain management is gaining increasing interest among researchers and practitioners in the field of supply chain (Srivastava, 2007). However, sustainable practices are so far to be broadly implemented, probably because, except for some regulations, their implementation is not mandatory by law. Also, often sustainable practices are perceived as a disadvantage for the business competitiveness. For example, within a study about green purchasing practices in US firms, it has been found out that cost concerns are the most serious obstacle for taking environmental factors into account in the purchasing process (Min and Galle, 2001). As pointed out by many researchers (Lehtinen and Ahola, 2010; Hassini et al., 2012; Searcy et al., 2009; Tweed, 2010), there is a lack of evidence of the relationships between the adoption of sustainable practices and supply chain performance.

For this reason, this chapter wants to investigate the extent to which sustainable practices influence supply chain performance, in order to provide a useful tool to the decision makers who have not adopted sustainable practices yet because they are not confident about their impact on the supply chain. Based on a survey carried out in 2016, this chapter provides an insight on green practices applied to supply chain management. In particular, the sample consisted of more than 50 supply chain managers and experts from all over the world. Interviewees were asked to express their point of view about the influence of green practices on supply chain performance; by considering an holistic perspective, SC performance have been expressed in terms of cost, time, efficiency, quality and customer satisfaction. A particular focus on the influence on environmental cost of the whole system is provided. Sustainable activities involving internal and external processes have been considered, in order to understand in which extent decision-makers are influenced by environmental quality when they make decisions to manage their supply chain.

2.1. Green practices and green supply chain management

According to Beamon (1998), Supply Chain (SC) can be defined as: "an integrated process wherein a number of various business entities (i.e., suppliers, manufacturers, distributors, and retailers) work together in an effort to: (1) acquire raw materials, (2) convert these raw materials into specified final products, and (3) deliver these final products to retailers".

The concept of “Supply Chain Management” (SCM) was introduced at the beginning of the ‘80s (Cooper et al., 1997) and it started drawing the attention of the researchers at the beginning of the ‘90s. Actually, SCM interested not only marketing and business, but also scientific literature (Lambert et al., 2000). Global Supply Chain Forum (GSCF), a group made of non-competing firms and a team of academic researchers, provided a definition for SCM, which has been defined as: “the integration of key business processes from end user through original suppliers that provides products, services, and information that add value for customers and other stakeholders”. With this definition, not only product flows, but also information flows, stakeholders’ integration and management are considered.

Despite of its strong importance, the concepts of ‘sustainability’ and ‘sustainable supply chain’ have emerged only in the last few years. Many and different definitions of ‘green supply chain’ have been elaborated by various researchers; all the definitions were joined by a common bottom line: the ‘environment’ (Olugu et al., 2011). According to Hassini et al. (2012) ‘*sustainable supply chain management*’ can be defined as “the management of supply chain operations, resources, information, and funds in order to maximize the supply chain profitability while at the same time minimizing the environmental impacts and maximizing the social well-being”. Sustainable supply chain management deals with different and various performance objectives, thereby taking into account the environmental and social dimension of sustainability (Seuring and Müller, 2008).

Sustainable practices are not easy to apply because supply chain environment is characterize by multiple stakeholders with different and possibly conflicting objectives. Also, environmental impact minimization and social well-being maximization are perceived as an extra-cost that negatively influences the achievement of common objectives, such as profit maximization and operation cost reduction (Hassini et al., 2012).

As pointed out by Hassini et al. (2012), the majority of the works published in this field are related to the manufacturing sector. This can be explained by the fact that companies that adopt lean manufacturing strategies are more likely to adopt sustainable practices (King and Lenox, 2001). Also, environmental regulations have always focused on manufacturing plants (e.g., pollution control). Walker et al. (2008) found regulation, customers, competitors, society and suppliers as external key drivers of environmental supply chain management practices. Also, green policies can be undertaken not with the aim to ‘save the world’, but because they can improve the financial performance of a firm and can provide competitive advantages (Gonzalez-Benito and Gonzalez-Benito, 2005; Porter and Van de Linde, 1995; Rao and Holt, 2005).

A great number of researchers have studied the effects of supply chain management within Small and Medium Enterprises (SMEs). The literature developed in this field show that results of green practice adoption depends on the industry sector. For example, performance of small firms in the metal finishing industry does not increase if the firm invests in environment risk management (Sarkis, 2006). Testa and Iraldo (2010) found that large firms benefit more than SMEs for adopting sustainable practices and that the rate of return on early adoption is not encouraging.

It is worth noting that usually environmentally friendly, green or sustainable, low carbon emission products tend to cost more to the firm and this extra cost is usually charged to consumers by higher prices (Hassini et al., 2012). In order to incentivize sales of sustainable products, businesses should quantify benefits related to this kind of products; while at the same time justify the value proposition to the customers.

Based on the results of the literature review, the author believes more research is required in this area.

2.2. Supply chain performance measurement and green practices

According to Chapter 1, the evaluation of the performance of the supply chain is essential to effectively and efficiently manage the supply chain, because it allows understanding whether a company should continue using its current strategy or, instead, if it should change. However, if we focus on 'green practices' and 'sustainable supply chain management metrics', the literature does not provide many contributions. Unfortunately, despite its importance, there is a lack of research on this subject (Hassini et al., 2012). It can be justified by the scarcity of research on supply chain metrics in general (Gunasekaran et al., 2004).

Zhu and Sarkis (2004) and Clemens (2006) found a positive relationship between financial and green performance, but this correlation is strengthened in the presence of government incentives. About environmental collaboration impacts on manufacturing performance, Vachon and Mao (2008) found that the influence is positive if collaboration with suppliers rather than with customers is considered. Upstream environmental collaboration with suppliers considers that the firm forces its upstream suppliers to adopt practices that aim to a more environmentally friendly supply scheme and material sources result in lower greenhouse gas (GHG) emissions as well as low impact on the environment. However, the adoption of this type of practices may make the supply of inputs more unreliable (Beamon, 1999). The use of environmentally friendly delivery vehicles can be considered a significant measure of sustainability. In fact, the mode of transportation strongly influences the production of GHG emissions. However, according to Dou and Sarkis (2010) and Triantafyllou and Cherrett (2010), customers want to receive products on time quickly and cheaply and this need often does not match the requirements for sustainability (polluting vehicles such as road trucks and airplanes are still the most used to deliver time sensitive and high value items). Lean supply chain includes waste minimization as a green practice (Khidir and Zailani, 2009). In fact, it provides for the reduction of environmental costs and also for the promotion of efficiency improvements in the SC process and cost reduction (Azevedo et al., 2011). Environmentally friendly packaging is a green practice that can be used like an information tool to indicate the 'green image' of the organization (Nair and Menon, 2008). In sum, it can represent a marketing strategy. The adoption of environmentally friendly packaging would reduce environmental costs and business waste (Huang and Matthews, 2008) and, at the same time, it works as a strategy to improve customer satisfaction (Nair and Menon, 2008).

Some practices such as ISO 14001 Certification can be adopted as green practices. In fact, ISO 14001 is an international standard used to environmental management. It is based on a voluntary subscription and it is applicable to every type of public or private organization that wants to reduce its environmental impact. It contributes to quality improvement and promotes the reduction of resource usage and waste (Nawrocka et al., 2009). The adoption of ISO 14001 requires that also suppliers adopt this standard in the global SC and, in general, ISO 14001 can act indirectly to influence all SC partners to adopt more environmentally friendly practices.

The certification is not free of charge, so usually companies perceive it as an environmental cost charged to the business (Azevedo et al., 2011). Another valuable green practice is reverse logistics, which makes the forward supply chain to close the loop. It is often associated to the '3R' concept: reuse, recycle and return. The idea is that the product will eventually be disassembled and components reused, re-manufactured or recycled into a source of raw materials (Olugu, 2011). The evaluation of the impacts of green practices to customer satisfaction is considered a very important indicator because customer satisfaction is the most valuable asset an organization can have (Olugu, 2011).

2.3. Methodology

2.3.1. Description of the conceptual framework of the model

The chapter aims to explore the influence of green practices on supply chain performance by exploring the perception of the decision makers, who are represented by the supply chain managers. To this purpose, based on evidence from the literature, seven different green practices have been identified. The effect of these practices on SC performance has been tested by considering six different SC areas.

In particular, the green practices that were proposed are the following:

- Environmental collaboration with suppliers;
- ISO 14001 certification;
- Minimizing waste;
- Environmentally friendly packaging/recycling;
- Maximizing load factor of delivery vehicles;
- Environmentally friendly delivery vehicles;
- Reverse logistics.

Figure 2.13. Conceptual framework of the model

While, the SC areas that were selected are:

- SC Cost;
- SC Time;
- SC efficiency;
- Quality;
- Customer satisfaction;

- Environmental Cost.

Figure 2.13 provides the conceptual framework of the model: the biggest circle, in the middle, represents the SC areas, whose performances are influenced by the green practices, represented by the smaller circles on the border.

2.3.2. Data collection

Based on the framework indicated in Figure 2.13, a web-based questionnaire was developed for investigating the influence of green practices upon supply chain performance. The questionnaire was composed by 2 main sections. The first one aimed to collect background information about the respondents (e.g. type of company, field, company size, market size, country, job title of the respondent). In the second section, respondents were asked to assign a score to each of the green practices to evaluate their importance and influence on the improvement of the performance of different SC areas. In order to express the extent to which a specific green practice 'helps to improve' SC performance, respondents could express a vote based on a Likert scale, which is typically used to measure attitudes or opinions by means of ordinal scales that measure levels of agreement/disagreement. Based on their own experience, respondents were asked to indicate on a scoring scale from 1 (meaning 'It is highly counterproductive/unhelpful') to 10 (meaning 'It is highly productive/helpful'), how a specific green practice can help to improve Supply Chain Performance on the selected areas. Scores lower than 5 mean the specific green practice negatively influences SC performance. On the contrary, scores higher than 5 mean the considered green practice support the manager to improve SC performance. The middle point of the scale (score 5) means "It makes no difference". Additionally, they were allowed to not to answer to the questions if they did not know or if they did not have enough information to answer or if they did not want to answer. In this way, they were not forced to provide an indication about the importance of the specific green practice on the improvement/worsening of SC performance.

The adoption of a green supply chain management is a decision made by supply chain managers. For this reason it was decided to address the survey to them. Infact, despite the significant role of green practices to mitigate freight transport and logistics impact, often SC managers are worried that reducing environmental risk and impacts could compromise corporate profit and market-share objective achievement. For this reason, data collection was designed in order to investigate SC managers' perspective on "green practices". In particular, SC managers being part of big important companies from all over the world were personally contacted and invited to participate to the online survey. Also, the survey was introduced and published on the most important Linkedin groups related to the SC, which include SC managers and professionals. All the responses were received between March and May 2016 (2 months). Of the 280 managers invited to participate, 56 decided to do it and to complete the questionnaire. A description of the sample is provided in section 2.4.1.

2.4. Results

2.4.1. Sample description

The majority of the managers involved in the survey come from Europe (57%); 18% come from the USA, 11% from South America, 5% from Asia; the rest of the sample comes from Australia, Africa and Canada (2% each) – Figure 2. Figure 3 shows the composition of the sample in terms of company size. Half of the sample is composed by companies that have between 1,000 and 5,000 employees (26%) and companies that have less than 100 employees (22%). The rest of the sample is composed as follows: 200-500 employees (8%), 500-1,000 (7%), 100-200 employees (14%), 30,000-100,000 employees (9%), 5,000-10,000 employees (5%) and only 2% has more than 100,000 employees.

If the SC field is considered, the sample is composed as follows (figure 4): Telecommunication (2%), Paper (4%), Pharmaceutical (5%), Electronic devices (9%), Automotive (14%), Food and Drinks (29%) and Other (37%).

Figure 2.5 shows that the majority of the companies involved in the survey is represented by manufacturers (59%), followed by suppliers (14%), distributors (11%), consulting (9%) and manufacturer&distributor companies (7%). Seventy percent of the interviewees declared their company applies some green practices (Table 2.3).

Sixty percent of the companies involved in the survey operates on the International market, 25% on the National and 9% on the Local market; 4% declared to operate on both Local and International markets, whereas 2% operates on both National and International markets. Seventy-one percent of the respondents are represented by SC managers, 15% is represented by warehouse managers, procurement managers and chief engineers (equally distributed), 8% is represented by compliances and consultants and the remaining 6% is represented by business unit managers, operation managers and HR officers.

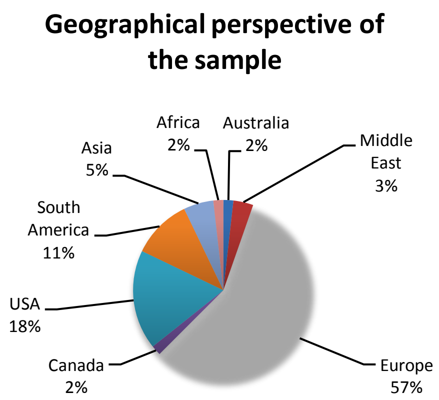

Figure 2.14. Geographical perspective of the sample

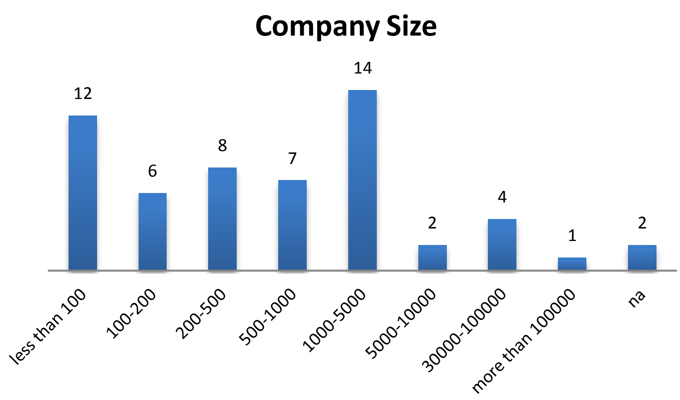

Figure 2.15. Company size

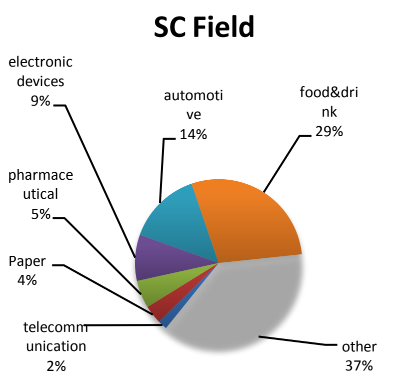

Figure 2.16. Supply chain field

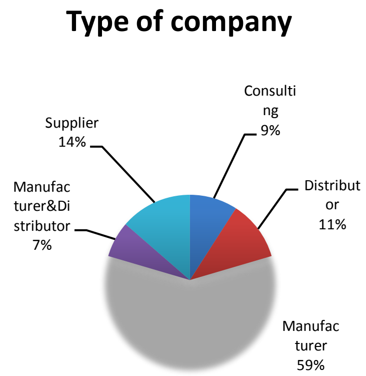

Figure 2.17. Type of company

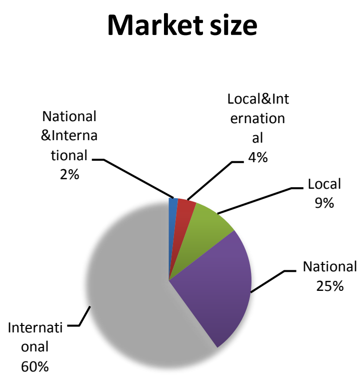

Figure 2.18. Market size

Type of company	Does your company apply some green practices?		
	No	Yes	Tot
Consulting	2	2	4
Distributor	2	3	5
Manufacturer	9	17	26
Manufacturer&Distributor	2	1	3
Supplier	0	6	6
transport&logistics	2	10	12
Tot	**17**	**39**	**56**

Table 2.3. "Does your company apply some green practices?" - Indication per type of company of the answers to the question

2.4.2. *Green practices vs supply chain performance*

Managers were asked to indicate how the proposed green practices influence the improvement of supply chain performance in terms of cost, efficiency, quality, customer satisfaction. They were also asked to indicate how green practices provide support to reduce environmental cost. Opinions were expressed in terms of scores. Ranking scale was 1 (it does not help at all) to 10 (it highly helps). This section provides the results of the opinion expressed by the managers who participated to the survey.

The first green practice proposed was "*Environmental collaboration with suppliers*" (Table 2.4). It considers all the sustainable measures that can be implemented in order to reduce pollution related to the supply activities, such as, for example, raw material transport made by means of low emission vehicles, or goods consolidation, etc.

Managers consider this green practice provides a quite important help to increase environmental cost performance (environmental cost reduction). About the other SC activities, managers consider this green practice has a neutral impact on their performance. For this reason, the overall influence of this practice on SC activities performance is not very significant.

I	Environmental collaboration with suppliers						Mean
	Supply Chain Cost	Supply Chain Time	Supply Chain Efficiency	Quality	Customer satisfaction	Environmental Cost	
Mean	5.73	5.20	5.64	6.61	6.66	**7.80**	6.27
min	1.00	1.00	2.00	2.00	2.00	2.00	1.67
max	10.00	10.00	10.00	10.00	10.00	10.00	10.00
St. Dev	2.45	2.30	2.36	2.19	2.03	2.00	2.22

Table 2.4. Ranking "Environmental collaboration with suppliers"

The second green practice proposed is "*ISO 14001 certification*" (Table 2.5). As explained in section 2.3, it is an environmental management system used by managers to control the impact that their activities have upon the environment. It can helps managers to prove to their customers that the company is aware of its environmental obligations and is looking to reduce the environmental impacts related to its SC activities.

II	ISO 14001 certification						Mean
	Supply Chain Cost	Supply Chain Time	Supply Chain Efficiency	Quality	Customer satisfaction	Environmental Cost	
Mean	5.43	5.25	5.70	6.36	6.24	**6.95**	5.99
min	1.00	1.00	1.00	1.00	1.00	1.00	1.00
max	10.00	10.00	10.00	10.00	10.00	10.00	10.00
St. Dev	2.37	2.52	2.46	2.23	2.26	2.12	2.33

Table 2.5. Ranking "ISO 14001 certification"

High influence on SC performance was expected by the implementation of this green practice. However, managers consider this green practice does not provide a significant support to increase SC performance. In fact, considering all the SC activities, the average vote expressed is lower than 6 (5.99). Probably only environmental cost performance benefits from ISO 14001 certification, even if not so much, because the vote is near to 7.

The third green practice proposed is “*minimizing waste*” (Table 2.6). Managers consider that this green practice supports managers to improve SC performance. In fact, in this case, the average score is 7.30. Three SC activities are positively influenced by this green practice (SC cost with 7.34; SC efficiency with 7.31 and SC Quality with 7.38). SC time performance and Customer Satisfaction are less influenced by green practices (6.66 and 6.86 respectively). On the contrary, environmental cost performance is strongly influenced by waste minimization (8.29).

III	Minimizing waste						Mean
	Supply Chain Cost	Supply Chain Time	Supply Chain Efficiency	Quality	Customer satisfaction	Environmental Cost	
Mean	7.34	6.66	7.31	7.38	6.86	**8.29**	7.30
min	2.00	2.00	2.00	2.00	2.00	3.00	2.17
max	10.00	10.00	10.00	10.00	10.00	10.00	10.00
St. Dev	2.25	2.13	2.03	2.07	2.14	1.80	2.07

Table 2.6. Ranking "Minimazing Waste"

The fourth green practice proposed is “*Environmentally friendly packaging/recycling*” (Table 2.7). Managers consider the influence that this green practice has on SC performance is not very significant (avg. score = 6.54). It has a positive influence on Customer Satisfaction (7.13) and on environmental cost (7.93); on the other hand experts do not think this practice has a very positive influence on SC Time and SC Efficiency (scores lower than six).

III	Environmentally friendly packaging/recycling						Mean
	Supply Chain Cost	Supply Chain Time	Supply Chain Efficiency	Quality	Customer satisfaction	Environmental Cost	
Mean	6.50	5.57	5.93	6.18	7.13	**7.93**	6.54
min	1.00	1.00	1.00	1.00	1.00	3.00	1.33
max	10.00	10.00	10.00	10.00	10.00	10.00	10.00
St. Dev	2.52	2.55	2.74	2.44	2.17	2.03	2.41

Table 2.7. Ranking "Environmentally friendly packaging/recycling"

The fifth green practice proposed is "*Maximize load factor of delivery vehicles*" (Table 2.8). Managers consider that both Environmental Cost (8.20) and SC Cost (8.18) are highly positively influenced by vehicles with high load factor. Also SC Efficiency is positively influenced (7.57). Less influence is related to SC Time (6.82), Customer Satisfaction (6.71) and SC Quality (6.41). If all the SC areas are considered, load factor maximization can be considered a good practice to increase SC performance (7.32).

V	Maximize load factor of delivery vehicles						Mean
	Supply Chain Cost	Supply Chain Time	Supply Chain Efficiency	Quality	Customer satisfaction	Environmental Cost	
Mean	8.18	6.82	7.57	6.41	6.71	**8.20**	7.32
min	3.00	1.00	3.00	1.00	1.00	1.00	1.67
max	10.00	10.00	10.00	10.00	10.00	10.00	10.00
St. Dev	1.83	2.44	2.19	2.33	2.32	2.08	2.20

Table 2.8. Ranking "Maximize load factor of delivery vehicles"

The sixth green practice proposed is "*Environmentally friendly delivery vehicles*" (Table 2.9Table 2.8). In the managers opinion, it strongly influences Environmental Cost (8.07). However, the performances of the other SC areas are not influenced by this green practice (see Table 2.9). Generally speaking, low emission vehicles have a neutral effect on the SC performance (6.03).

V	Environmentally friendly delivery vehicles						Mean
	Supply Chain Cost	Supply Chain Time	Supply Chain Efficiency	Quality	Customer satisfaction	Environmental Cost	
Mean	5.73	5.18	5.32	5.61	6.25	**8.07**	6.03
min	1.00	1.00	1.00	1.00	2.00	4.00	1.67
max	10.00	10.00	10.00	10.00	10.00	10.00	10.00
St. Dev	2.45	2.38	2.49	2.30	2.26	1.66	2.26

Table 2.9. Ranking "Environmentally friendly delivery vehicles"

The seventh green practice proposed is "*Reverse logistics*" (Table 2.10).

V	Maximize load factor of delivery vehicles						Mean
	Supply Chain Cost	Supply Chain Time	Supply Chain Efficiency	Quality	Customer satisfaction	Environmental Cost	
Mean	6.89	5.98	6.84	6.30	6.61	**7.50**	6.69
min	1.00	1.00	1.00	1.00	1.00	1.00	1.00
max	10.00	10.00	10.00	10.00	10.00	10.00	10.00
St. Dev	2.48	2.31	2.25	2.29	2.35	2.37	2.34

Table 2.10. Ranking "Reverse logistics"

Managers consider Reverse Logistics has a positive influence on Environmental Cost performance (7.50). Low influence is attributed to the other SC activities (see Table 2.10). In particular, the lowest score is related to SC time. Broadly speaking, Reverse Logistics has a positive (but not high) influence on SC performance (6.69).

2.4.3. Green practices by SC fields

After a general analysis proposed in the previous section, this section provides an in-depth analysis that considers the importance of green practices based on different SC fields. The analysis aims to highlight the different weight given to green practices in the improvement of SC performance by different field.

Automotive: The automotive sector provides on average the highest score to green practices in terms of SC performance improvement. The highest score is given to the maximization of vehicles' load factor, which allows improving SC cost and environmental cost.On the other hand, the lowest score is given to environmentally freiendly delivery vehicles, which do not helps to improve the efficiency of the SC.

Electronic devices: Similarly to automotive, the highest score is given to the maximization of vehicles' load factor, which allows improving SC cost and environmental cost; the lowest score in this case is given to ISO 14001 centrification, which is perceived as an obstacle to reduce SC costs.

Food&drink: Also this SC field considers the maximization of delivery vehicles' load factor as the most important practice able to improve SC efficiency. On the other hand, similarly to electronic devices, the lowest score is given to ISO 14001 which is considered a practice that worsens SC time.

Other: The most important green practice is waste minimization, which helps to reduce environmental costs. On the other hand, collaborating with suppliers by safeguarding the environment is perceived as negative with respect to SC time.

Paper: This SC field perceives vehicles' load factor maximization as very important to improve SC cost and efficiency. As in the previous case, sustainable collaboration with suppliers is perceived as a disadvantage to improve SC costand quality.

Pharmaceutical: This sector gives high score to load factor maximization for the improvement of SC and environmental costs and to waste minimization for the improvement of environmental costs. On the other hand, SC time is worse if practices as environmental collaboration with suppliers or waste minimization are adopted.

Telecommunication: This is the only field that considers ISO 14001 certification convenient to improve SC cost, time and efficiency. Another useful practice is load factor maximization to improve environmental costs. However, it is perceived not useful to improve SC time and customer satisfaction. Environmentally friendly delivery vehicles are perceived useful to improve environmental cost, but they make SC cost and time worse.

A summary of the results of the analysis carried out to investigate the point of view of the different SC fields is provided in Table 2.11.

SC Field	Max Score	Green Practice	SC Area	Min Score	Green Practice	SC Area
Automotive	9.00	max LF	SC Cost	4.75	Environmentally friendly delivery vehicles	SC efficiency
Electronic devices	8.40	max LF	SC Cost; Environmental Cost	4.00	ISO 14001	SC Cost
Food&drink	8.69	max LF	SC Efficiency	4.38	ISO 14002	SC time
Other	8.81	min waste	Environmental cost	5.14	Environmental collaboration with suppliers	SC time
Paper	8.00	max LF	SC Cost; SC efficiency	4.50	Environmental collab with suppliers	SC cost; SC quality
Pharmaceutical	9.00	max LF	SC Cost; Environmental Cost	4.67	Environmental collaboration with suppliers	SC time
		min waste	Environmental Cost		min waste	SC time
Telecommunication	10.00	ISO 14002	SC Cost; SC time; SC efficiency	2.00	max LF	SC time; CS
		max LF	Environmental Cost		Environmentally friendly delivery vehicles	SC cost; SC time
		Environmentally friendly delivery vehicles	Environmental Cost			

Table 2.11. Green practices and SC performance by SC field

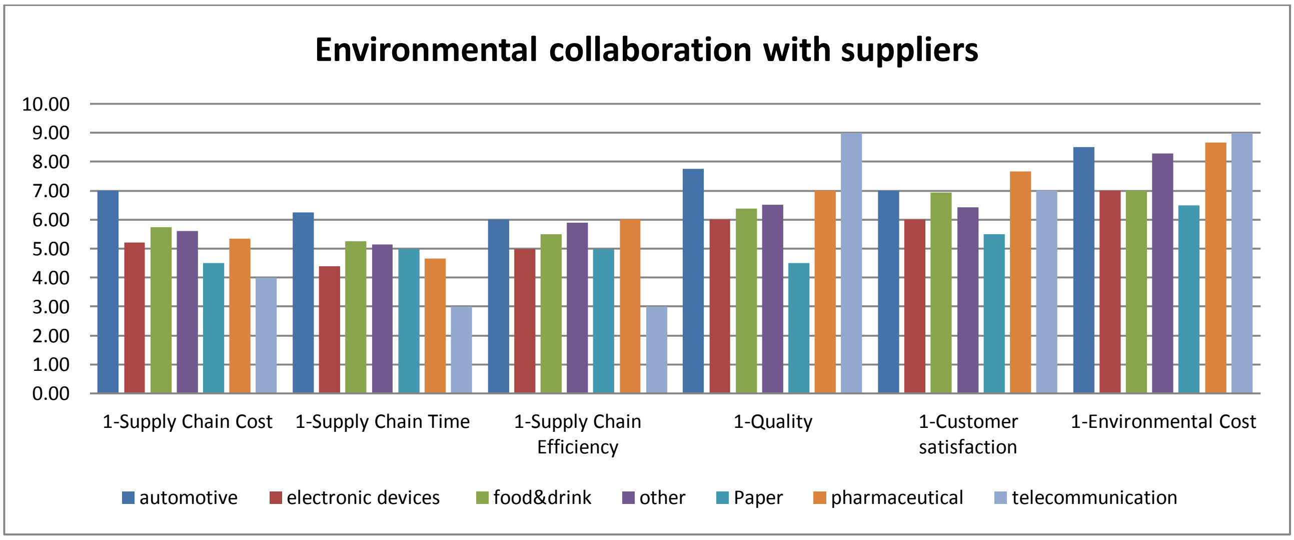

Figure 2.11. Ranking "Environmental collaboration with suppliers" by SC field

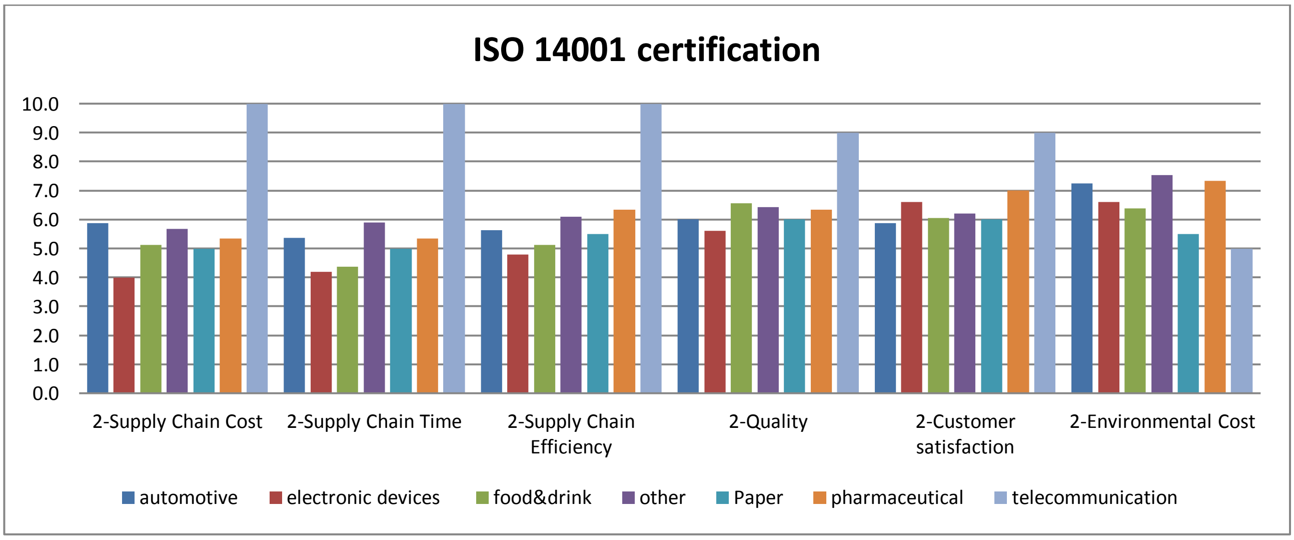

Figure 2.12. Ranking "ISO 14001 certification" by SC field

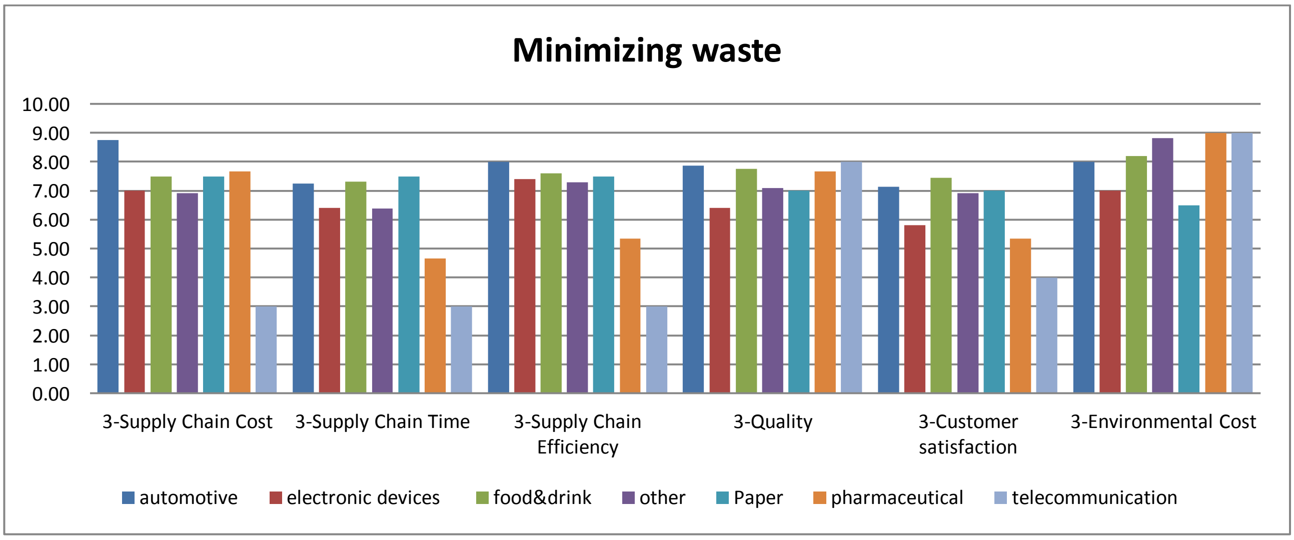

Figure 2.13. Ranking "Minimizing waste" by SC field

Figure 2.14. Ranking "Environmentally friendly packaging/recycling" by SC field

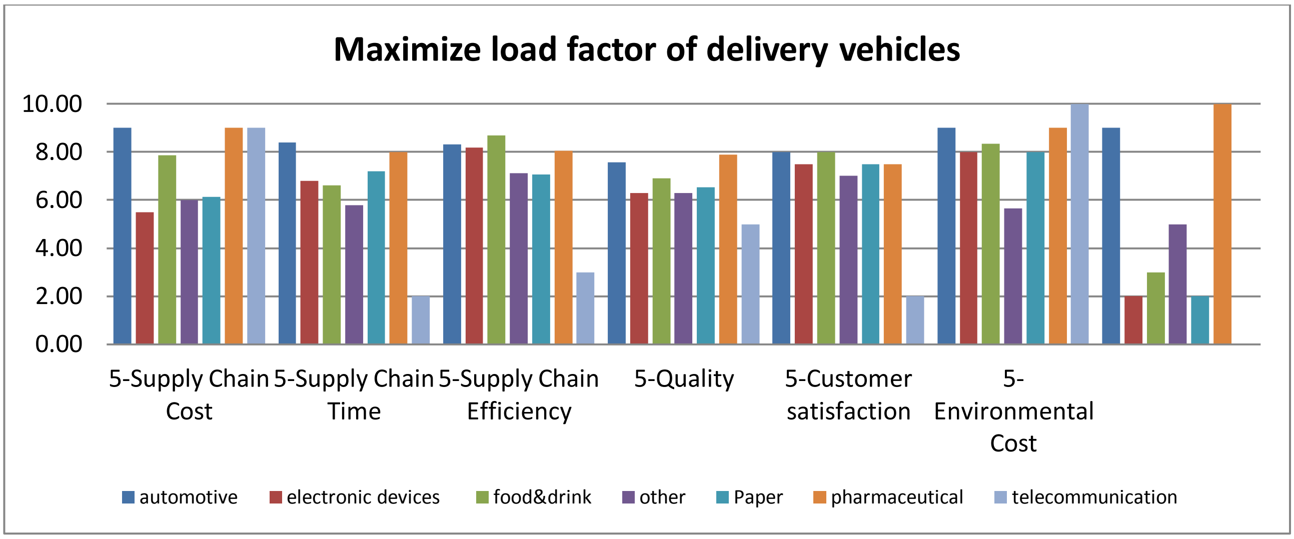

Figure2.15. Ranking " Maximize load factor of delivery vehicles " by SC field

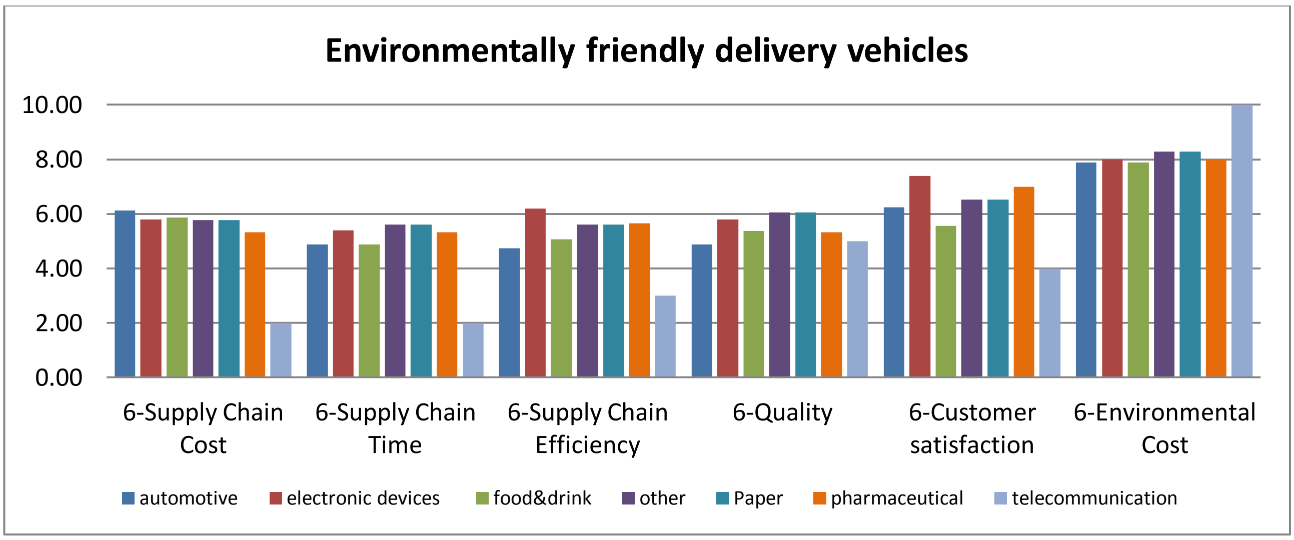

Figure 2.16. Ranking "Environmentally friendly delivery vehicles " by SC field

Conclusion

Even though sustainable transport and logistics are becoming increasingly important in making decision processes, SC decision makers are often not confident with these types of measures. Most times they are not aware about the actual benefit of green practices implementation.

The analysis pointed out that the green practice that are perceived as the one that most influences SC performance is load factor maximization (7.32), followed by waste minimization (7.30). The other practices are not very significant with respect to SC performance improvement (all values are lower than 7). Surprisingly, results showed managers participating the survey do not think "ISO 14001 certification" provides a positive effect on SC performance.

Moreover, if results are analysed from another perspective, by considering SC performance, the area that more benefits from the adoption of green practices is of course Environmental Cost. This result is rather trivial, because environmental costs decrease if green logistics and transport practices are applied. In addition, Customer Satisfaction positively benefits from green practices (6.64).

If the SC field is considered, the most load factor maximization is the most influencing practice in terms of SC improvement, except for Telecommunication, which consider it negative to improve SC time and customer satisfaction. This can be explained to high relation between SC time and customer satisfaction. In fact, customers prefer to receive their goods as soon as possible. In general, environmental collaboration with suppliers is perceived as negative for the improvement of SC performance. Pharmaceutical and Paper sectors guess it worsens the performance of SC cost, time and quality. Also, electronic devices and food&drink consider ISO 14001 certification can compromise the performance of SC time and cost.

Even though the analysis pointed out green practices do not strongly influence supply chain performance, it is worth considering that, on the other hand, the contrary cannot be said. In fact, average scores are always higher than five, which is considered the border line between positive and negative influence. Results suggest that green practices adoption is a useful tool for supply chain managers, especially in terms of strategic level plan. In fact, in the near future, access to capital markets could be avoided to businesses that do not have 'ethical or environmentally friendly' reputation. Moreover, market competition and demand flexibility may push companies to broaden their offer by including green, sustainable, or socially responsible products. However, in order to be successful, sustainable operations should be supported by the definition of an economic sustainable business framework.

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Chapter 3

An overview on city logistics Studies and experiences[2]

Introduction

The world's population is being increasingly concentrated in cities, and the urban population is expected to reach 6.3 billion by 2050 (Morganti and Gonzalez-Feliu (a), 2015). The economic vitality of a city strongly depends on the efficiency of urban goods distribution (Gonzalez-Feliu and Salanova, 2012). However, freight transportation is a major contributor to climate change and global warming and it contributes to about 5.5% of global greenhouse gas emissions (Zhang et al., 2015; McKinnon, 2010) and it is responsible for increasing gas emissions rates, congestion, noise and traffic safety issues (Nordtømme et al., 2015). According to the European Commission (EC, 2011), freight transport within the EU and associated international maritime freight activities will increase by 40% by 2030 and just over 80% by 2050. Roumboutsos et al. (2014)

[2] This chapter is based on:

- *Paddeu, D (2013). Customer Satisfaction Analysis. Users impact analysis of the Bristol Freight Consolidation Centre. Unpublished Master Dissertation*
- *Paddeu, D., Fadda, P., Fancello, G., Parkhurst, G. and Ricci, M. (2014). Reduced urban traffic and emissions within urban consolidation centre schemes: The case of Bristol. Transportation Research Procedia, 3, 508-517.*

recognized city logistics as an important tool able to decrease the problem overall as the economic crisis impacts consumption levels and overall mobility needs. However, usually studies of freight mobility focus only on restocking flows , without considering their relationship with shopping activities, fact that prevents the evaluation of the impact that freight flows have on location of freight facilities (e.g. warehouses, distribution centres) and shops, and on end-consumer's shopping choices (Nuzzolo and Papa, 2016).

The collaborative economy involves the pooling of economic assets so that they can be used by multiple agents, either synchronously, or asynchronously. The term is most often associated with the 'platform capitalist' businesses such as Airbnb and Uber, which obtain revenues from connecting peer owners with peer renters and peer sharers. In a generally critical review of the 'sharing economy' phenomenon, Martin (2016) identifies that although the transition has become 'co-opted' by specific business interests. For example, this might occur by intermediary companies extracting a short-term profit through 'rentier' behaviour in respect of monopoly access to market data. However, where collaborative strategies are long-term and for wider objectives, one of the potential benefits could be more sustainable resource utilization and consumption.

This chapter is organised in two main parts. Having established the general conditions necessary for collaborative economy solutions to be successful in the freight sector, the first part of the chapter provides an analysis of the pillar concepts of urban freight transport and logistics. The first case analyses the UCC established in Bristol (UK), an example notable for its longevity and therefore offering a rare example of resilience in this niche; the second analyses the behaviour of the potential users of a UCC proposed for Cagliari (Italy). The analysis allows identifying and evaluating the perceptions and behaviour of an important target user group. Key success factors and potential barriers to the implementation of UCC schemes are identified by considering their perspective, on the basis that the success of sharing of urban goods transport strongly depends on the perceptions and inclinations of the stakeholders to participate. The second part offers a focus on some example of success and failure of city logistics projects developed in Europe.

3.1. City logistics schemes: how it works

Whilst in the transport sector much of the high-profile attention is on shared mobility services for personal travel, collaborative city logistics solutions to reduce the negative externalities arising from increased freight motor vehicles in cities (Gonzalez-Feliu and Morana, 2010; Witkowski and Kiba-Janiak, 2014) are a measure being promoted by policy actors including the EC. In particular, city logistics schemes can be considered as schemes to manage the last leg of the supply chain. In this system, the corresponding logistics network consists of two transportation legs (Ehmke, J., 2012) an example of last-mile deliveries performed in a hub and spoke network is provided in Figure 3.19.

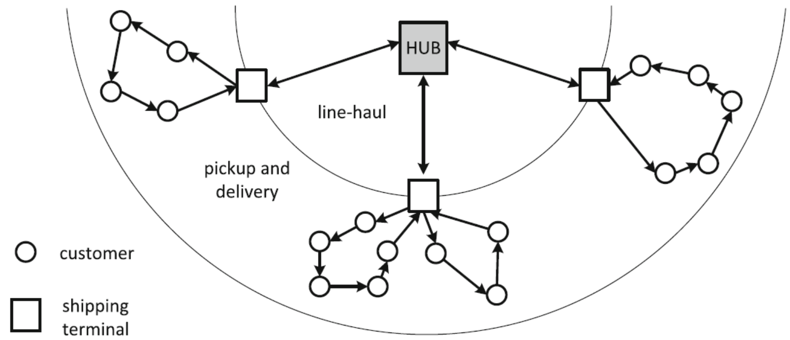

Figure 3.19. Last-mile delivery in a hub-and-spoke network (Ehmke, J., 2012)

- The first leg concerns the transportation of goods to shipping terminals by means of large trucks. Trans-shipment operations are performed at the terminals. Line-haul transports refer to long distance transportation between the sending depots and the hub and between the hub and the receiving depots, respectively.
- The second leg is related to city logistics services. Here, logistics providers pick up and deliver goods to customers, the so called "*last-mile delivery*". Last-mile delivery concerns short distance transportation by means of small trucks,

Urban Freight Consolidation Centres (UCCs) involve the delivery of multiple consignments destined for a city centre, to an interim location in the form of a consolidation centre operated by a third party on behalf of a collective of participating freight recipients. The warehouse infrastructure is hence shared, as too is the space in the vehicle operating the consolidated 'last mile' delivery rounds to the final destinations. It is managed by logistics providers who are in charge of the local distribution of goods, which have been prior consolidated in a shipping terminal. These systems are usually based on a private-public partnership that can be: (1) *Joint*

Venture, which considers a joint commitment by the public and private parties involved in a project (share the responsibility, risks financing, the losses and profits as shareholders, by forming a shareholding company); (2) *Concession*, which provides a better allocation of risk and between the public and private sectors. Usually a government agency provides a concession to a promoter (one or more private firms), who is responsible for the construction, financing, operation and maintenance of the facility over the granted concession period. In this case, all parties involved are equally concerned with achieving the objectives established for the project (Tsamboulas and Kapros, 2003).

The approach potential enhances urban transport and economic sustainability in a number of ways.

- As the consolidation facility is normally located on the periphery of an urban area, large freight vehicles can remain on the strategic road network, avoiding high vehicle-specific emissions of noxious pollutants in urban areas where the population is most exposed to poor air quality. At the same time, reducing the number of large vehicles in urban streets, which are often too narrow for their effective passage, increases the efficiency of operation.
- The benefits are enhanced if the last-mile deliveries are made using an ultra-low emissions vehicle, such as an electric lorry or van (Van Rooijen and Quak, 2010).
- System efficiency is improved, for example measured in terms of vehicle-km and energy consumption. Without the UCC, large vehicles make relatively long detours from the strategic road network to deliver what are often small individual consignments. Instead, provided there is sufficient participation in a UCC scheme by a range of end-receivers, the last-mile logistics can be organised in a highly efficient way, with relatively few rounds being made by vehicles that depart the depot with a high level of payload utilisation, all of which is destined for locations within a specific city centre.
- Additional services can be offered by the UCC to improve the overall quality of the supply chain (Verlinde et al., 2012), such as just-in-time stock holding for businesses with tight space constraints on their own premises.

The literature pointed out that city logistics measures are usually implemented in medium-sized cities. In fact, due to the complexity and the size of the commercial areas in big cities, city logistics schemes are more difficult to be implemented and managed. Also, this type of system is more successful when other policies (i.e. access regulation, limited traffic zone, etc.) are applied.

3.2. A review of the main studies carried out in the last decades

In last decades, logistics initiatives started in all of Europe in order to solve the issues related to freight transport in urban areas. However, policy measures implementation is very hard to achieve (Kelly et al., 2008; Nordtømme et al., 2015). Browne et al. (2005) carried out an analysis of the 67 Urban Freight Consolidation Centre (UCC) schemes developed in Europe and U.S., which actually are those the literature provides information about (Table 3.12). The analysed schemes date from the 1970s onwards (Browne et al., 2005).

Country	Total	Research/Feasibility[3]	Pilot or Trial	Operational[4]	1970-1975	1976-1990	1991-1995	1996-2000	2001+
Austria	1	1	-	-				1	
Belgium	1	1	-	-				1	
Canada	1	1	-	-		1			
France	8	5	2	1	1		5		2
Germany[5]	14	1	2	11			8	6	
Italy	5	-	2	3				1	4
Japan	3	-	2	1		1			1
Monaco	1	-	-	1		1			
Netherlands[6]	7	3	-	4		2	3	1	1
Portugal	1	-	1	-				1	
Spain	1	-	-	1					1
Sweden	4	1	1	2				2	2
Switzerland	2	-	2	-			2		
United Kingdom	17	12	1	4	4	4	1	4	4
U.S.A.	1	1	-	-	1				
Total	67	26	13	28	6	9	19	17	15

Table 3.12. Analysis of schemes by Country, category and date of investigation/start up (Source: Browne et al., 2005)

[3] 'Research/ Feasibility' refers to UCCs that did not progress beyond an initial research/feasibility project. Far more schemes have either been planned or trialled in Germany than shown in the table. The table contains schemes about which it has been possible to obtain literature.

[4] The 'operational' schemes include any that extended beyond the trial stage.

[5] In addition, German multi-modal freight centres that operate at a regional scale (referred to as Güterverkehrszentrum - GVZ) have been omitted from the table, as although some urban distribution does take place from some of these centres it is not their primary operational purpose.

[6] In the Netherlands Leiden had both a study and an operation and Maastricht had a study and a trial, in both cases in different years. For this Table only one event is recorded – Leiden / operation, Maastricht / study.

The countries that have been mostly involved in researching and piloting UCC schemes are France, Germany, Netherlands and the UK. The majority of the German UCC schemes were operational, whereas in the UK they have mostly been research and feasibility studies. In the three mainland European countries the main purpose of the schemes was to improve the environment (goods were delivered by means of alternatively powered vehicles to reduce air pollution); they were often civic-led with 'boards' of participating players. However, due to dissatisfaction with the service levels of those schemes, they are no longer operating (Browne et al., 2005).

The majority of the early research and feasibility studies started in UK in the 1970s were undertaken by local authorities. Since the mid-1990s, the schemes developed were mostly trails and operational schemes, which were led by commercial enterprises that recognised the benefit of controlling the logistics movements that affected their operations (Browne et al, 2005). The literature review highlights increasing interests in the UCC concept in the European countries during the 1990s and 2000s (Allen and Browne, 2008). Nevertheless many of these have been closed (Browne et al., 2005). The majority of the UCC schemes have been dependent on public funding from central, regional or local government such as, for example, Amsterdam and Monaco. Some UCC schemes have received funding from EU projects (such as La Rochelle, Nuremberg and Broadmead in Bristol), while others have been funded through financial support provided by commercial partners and contributions from receivers using the scheme (i.e. the Heathrow retail consolidation centre). However, funds do not cover the whole service provided by the UCC; this is the reason why the retailers involved are expected to pay some fee for the service received, in order cover at least part of the total operating costs.

To date, a lack of evidence-based information has been found concerning UCC to support policy-makers. Many UCCs trials that have been concluded do not appear to have been subject to published evaluation that quantifies scheme results. Moreover there is a risk that overly complicated solutions without a practical justification will produce counterproductive results. The literature suggests who mainly may take advantage of UCC are:

- Transport operator making small, multi-drop deliveries;
- Shared-distribution operation users;
- Business located in an environment with particular constraints with delivery operations;
- Independent and smaller retail companies.

Investigating about the total supply chain costs and benefits associated with the use of a UCC, including traffic and environmental benefits is needed. In fact, finding the best solution is less important than verifying which measure is the most feasible in each specific case. None of the countries that show sensibility about the topic pretends to have found the optimal solution to the urban freight transport problems, thus a further development of urban freight transport policy study is still needed. Further regulation of urban freight transport, as well as technological innovation will considerably influence policy-making in the future.

3.3. Urban freight Consolidation Centre (UCC)

This section provides an analysis of urban freight consolidation centre definition and classification.

3.3.1. Definition

In the last years, due to the ongoing globalisation of production, the demand for new logistics and distribution facilities (e.g. warehouses, distribution centres, transfer depots) has highly increased in many European regions (Cushmann and Wakefield, 2006; Jones Lang Lasalle, 2006; Wagner, 2010).

However, companies tend to streamline their supply chain by reducing warehousing space and consolidating the load (Wagner, 2010; McKinnon and Woodburn, 1994). These reasons and also the need of reducing emissions from last-mile freight transport (Nordtømme et al., 2015) make UCCs emerge during the last decades. Nordtømme et al. (2015) described a UCC as "*a location near a city centre where goods from outside the city centre are received, consolidated and subsequently delivered by smaller vehicles or by foot on designated routes in the city centre*" with the purpose to "*optimize deliveries and minimize transport*".

UCCs allow reducing congestion, parking and manoeuvring large trucks in narrow streets (Nordtømme et al., 2015). However, due to the complexity of the urban environment, a successful UCC implementation strongly depends on the involvement of all the stakeholders in the decision making process (Macharis et al., 2010). Also, the success or failure of a UCC is based on the ability of logistics companies to market and operate a freight transport service that meets the needs of its customers at a competitive price. Some range of potential logistics and pre-retail activities at UCC and possible benefits are provided in Figure 3.20.

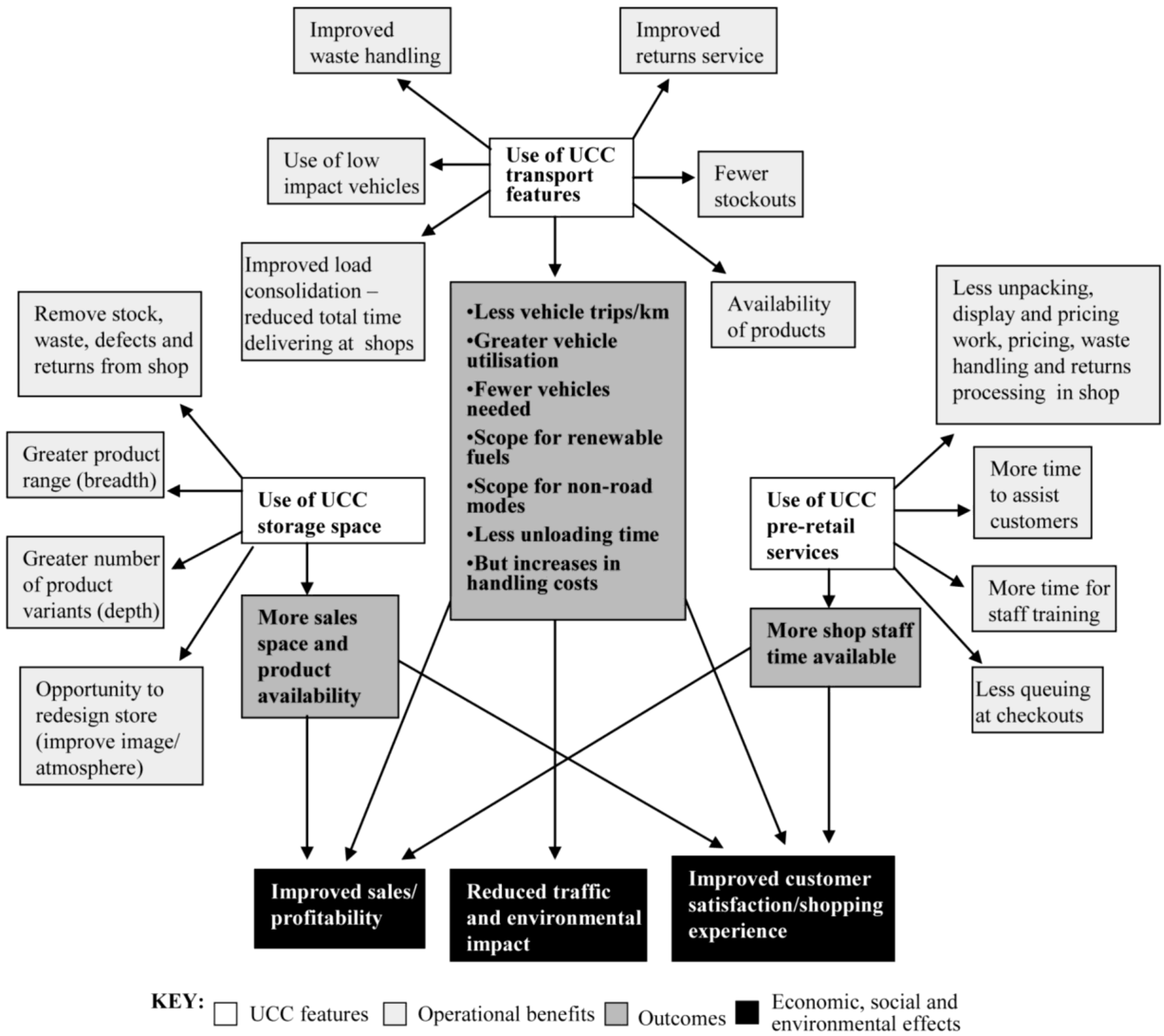

Figure 3.20. Range of potential logistics and pre-retail activities at UCC and possible benefits (Allen et al., 2014)

The review of 67 UCC schemes, allows Browne et al. (2005) to conclude that in general there is greatest potential for the success of a UCC scheme if one or more of the following five criteria are met:

- Strong public sector involvement in encouraging the use through a regulatory framework;
- Significant problems in the area;
- Bottom-up pressure from local interests;
- The logistics problems that are solved should be associated with a site that has single manager or landlord.
- The availability of funding.

Then, they recognised four requirements to be economically viable (Browne et al., 2005):

- Critical mass of users and volumes;
- Stakeholders should be willing to use the UCC;
- Additional services to gain extra revenues;
- No dependence upon subsidies.

3.3.2. Classification

Different categories of UCCs exist:

(a) UCCs serving all or part of an urban area usually associated with supply or retail products, office products, food supplies for restaurant and cafes. This scheme is used to serve historic urban areas with narrow streets. This type of UCC is usually suggested by local authority that hopes to benefit from the related traffic and environmental improvement. Examples of (a) are: La Rochelle (France) and Bristol (UK).

(b) UCCs serving large sites with a single landlord, which include airport, shopping centres and hospitals. Examples of (b) are London Heathrow airport retail, Meadowhall shopping centre in Sheffield and Hospital Logistics centre in London.

(c) Construction project UCCs, which are used to serve areas dedicated to major building project, to consolidate construction materials; the (c) types can exist only for the lifetime of the building project. An example of (c) is London Heathrow airport during major development work.

3.3.3. Business model

Initial funding of the central or local government is necessary for feasibility studies and trials during the first period time. UCCs must be financially viable during the medium-to long-term because public subsidies are not necessarily a desirable solution. Funds from other transport-related sources (e.g. congestion tax and road pricing) can be used to cover UCC costs, due to the traffic and environmental benefits coming from them. Less financial issues are related to (b) and (c) UCC types; in fact, the owner/manager of a shopping centre or an airport can define contractual conditions including the mandatory use of UCC. The (a) type, instead, especially in the first period of its lifetime, needs public funding from the local authority to keep down the prices charged by the UCC. Local authorities finance these trials for the positive effects that UCCs have in reducing environmental and social impacts of freight transport activities. However it has been subject to a substantial number of abandoned UCC trials. So, potential users may be persuaded about the convenience and efficiency of the centre so as to provide revenue and reduce public subsidy or remove the need of it when the UCC becomes financially self-supporting. The carriers delivering goods to a UCC receive major benefits in terms of time savings (e.g. the area to be delivered is usually congested, narrow streets, no nearby loading areas, etc). However, the most difficult thing is quantifying the potential savings from these centres on the total traffic, because no precise information on the proportion of traffic related to the different sectors of the economy is available. To date, public subsidies are still needed because "*there is no strong evidence that any self-financing scheme yet exists*" (Browne et al., 2005).

3.4. Examples of city logistics schemes in Europe

This section provides a focus on some examples of city logistics schemes developed in Europe in recent years. Four case studies are proposed in the following sub-sections: Bristol and Bath (UK), Nijmegen (The Netherlands), Parma (Italy) and La Rochelle (France).

CASE 1 - Bristol and Bath Urban Freight Consolidation Centre (United Kingdom)

The city of Bristol

Figure 3.22. The city of Bristol: geographic localization

Bristol is the largest centre of culture, employment and education in the South West of England. Bristol has a high level of productivity with per capita GDP of the city rising 23% above the national average, the second highest in England after London and 34th across Europe. In recent years major investment and re-development of the city centre, and harbour-side area has been undertaken, bringing new homes, offices and leisure sites into the city centre making it a more attractive place to work, live and visit. Bristol is affected by urban congestion, with around 500,000 car movements every day in and out of the city centre. This implies average speeds in Bristol lower of 25kph and this make it one of the most congested cities in the UK.7 Part of this congestion is due to the movements of freight vehicle. The transport strategy wishes to support the economy of the city and therefore the effective delivery of goods is seen as essential to achieving this aim; however it is necessary minimise the impact of freight distribution on the area it is serving. For this reason, the Central Area Cordon has been established surrounding the city centre and covering generally all the roads into the centre with regular monitoring of numbers of vehicles and types on the routes. This monitoring is only carried out annually surveying throughout the day from 7am to 7pm (covering morning and afternoon peak hours) where inbound and outbound movements on the roads into the centre total. 45% of NOx emissions (pollution) in Bristol are due to goods vehicles, 36% is due to cars and 19% to buses. A survey carried out in 2013 highlighted the total number of light and heavy goods vehicles recorded inbound to the centre were 13,888 (11,682 LGVs and 2,206 HGVs) working out as 13.3% of the total number of inbound vehicles (104,802).[8]

Figure 3.21. Air quality management areas in Bristol and Bath (Source: http://www.bristol.airqualitydata.com

The Bristol – Bath Freight Consolidation Centre (UK)

Bristol has been involved in three projects funded by EU that provided for the use of a Consolidation Centre. The first project was the CIVITAS VIVALDI (2002-2006). In 2007 the second project - START (Figure 3.10) - started (2007-2008). The third project was CIVITAS-RENAISSANCE, which indirectly involved Bristol, because it concerned the neighbouring city of Bath. However, due to the excellent results of the first and the second project, Bristol City Council decided to provide funds to finance the Bristol and Bath Freight Consolidation Centre (BBFCC) to cover also the retailers already involved in Bristol. Moreover, traffic and access restrictions are applied in Bristol, in order to incentivize new retailers to join the scheme. Nevertheless, not all the costs were covered by Bristol City Council, so the retailers have to pay a fee for the service; despite this, no one left the scheme after the EU projects ended, because the retailers realised they benefit of using the UCC.

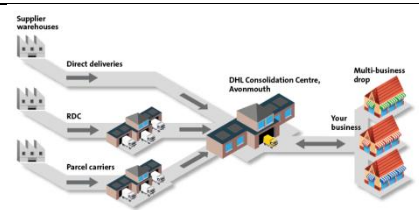

Figure3.24. BBFCC - how it works (Source: http://travelwest.info/freight-consolidation)

Figure 3.23. Broadmead and Cabot Circus – START – retailers involved

Benefits and limitations

Due to its long lifetime, BBFCC represents one of the most successful schemes. It is the only one in the UK that serves two cities. It is managed by DHL and deliveries are made by means of electric vans. BBFCC opened in Emersons Green in 2004 and moved to Avonmouth in 2007. It is joined with the major corridors coming from the North and the Midlands by motorways. It is connected to Bristol city centre by the low congested A4 - just 20 minutes of travel. It is primarily a cross dock centre and it is occasionally used for storage. It usually holds stock for a few days if retailers are experiencing some short of storage space problems. The goods primarily arrive from the Midland (Birmingham) by means of articulated

[7] In Bristol 23% of travelling time is spent stationary in traffic queues.

[8] Data provided by Bristol City Council during an interview made on the 25th of April, 2013.

vehicles, 18-tonne trucks, 7.5-tonne trucks and vans. Deliveries to the city centre are made by 9-ton electric vans with a load factor of 5-tonnes. The 3.5-tonne diesel vans are occasionally used for break-down problems or busy periods (Christmas).Deliveries are usually made between 7 a.m. and 2 p.m. Goods can be received also by night because it is open 24 hours. Except for perishable/fresh food, every type of products is delivered. In addition to deliveries, the BBFCC offers just-in-time deliveries, storage, pre-retailing, crisis stock management, drip feed of stock, recycling of packaging (cardboard and plastics). Additional services are charged at a reduced rate respect to normal commercial rates. The retailers who participate to the scheme are 81 in Bristol and 25 in Bath. They are part of big companies: 49 retailers which translate into 106 outlets in total. The BBFCC periodically runs marketing campaigns to involve more retailers in the scheme. However, in the opinion of the manager of BBFCC, the retailers that have not joined the project yet, do not do it because they perceive it as an additional cost or an extra link in the supply chain. They are happy as they are and do not see the need to change. Unfortunately there is a limited availability of information on costs, benefits and subsidies received because they are commercially sensitive. Retailers pay £9 per cage and £12 per pallet delivered. Both retailers and suppliers declare to benefit from BBFCC: retailers because of better quality of service and reliability; suppliers because they save time and money. Unfortunately no many (or strong) evaluations were carried out in the years and also there are limited BBFCC data. However, DHL carries out a monthly evaluation about the Kilometres saved and the related pollution reduction. Quantitative information about energy and emissions savings were provided by the analysis carried out within the European projects, which highlighted that a cleaner and more efficient goods distribution system has a significant impact on the environment. In all the projects, emission savings were higher than expected. To date, BBFCC allowed reduction of 375,000 Km driven, 146,000 Kg di CO_2, 4,700 Kg of NO_x (Travelwest, 2016).

Case 2 - Binnenstadservice.nl (The Netherlands)
The city of Nijmegen
Nijmegen is a municipality and a city in the east of the Netherlands, very closed to the German border. It is considered to be the oldest city in The Netherlands and celebrated its 2000th year of existence in 2005. The area is approximately 57.53 km^2 (22.21 sqm), with a population of 165,253. There are four train stations in the city; the central station is connected to the national Intercity network. The bus company Breng (a subsidiary of Connexxion) operates the city buses in the Arnhem-Nijmegen metropolitan area. The river is a busy freight transport route, with barges to the city as well as passing through on the way between the industrial regions of Germany and the docks at Amsterdam, Rotterdam and Hook of Holland. The Maas-Waal Canal also carries freight through the city.
The Nijmegen's Consolidation Centre: Binnenstadservice.nl

The UCC is Binnenstadservice.nl (BS) and it was established the 24th of April, 2008. According to Blom (2009), the difference with the others UCCs is that who initiated Binnenstadservice.nl is not the (local) government or a transport operator, but retailers. The UCC is located outside the city centre and it is open 18 hours a day. When the project started only twenty clients joined the scheme. This number grew to 98 after only one year, with a related growth of the delivered volume increased (Van Rooijen and Quak, 2010). BS provides not only transshipment, but also added services to the retailers, such as packaging, storage, delivering to the end-customer. At the beginning these types of services were free of charge to encourage the retailers to use the UCC and the local government provided subsides for the project. Retailers involved in BS are the store-owners of independent stores only. The goods are ordered by the store owner to the shippers and the shippers make the deliveries to BS. So BS, which receives goods from several suppliers, delivers in a single drop to the store-owner (Van Rooijen and Quak, 2010). In this way, stores pay less to the shippers for the transport service and the money saved could be used to pay BS for its services. By bundling the deliveries from multiple suppliers for the store-owner and delivering the goods at the time the retailer wishes, BS offers a service that saves the time of the retailers of small stores. BS only manages 'easy products' (i.e. no fresh food) and small deliveries. Environmentally friendly vehicles (such as electronic tricycles and natural gas trucks – Figure 3.25) are used to make the deliveries in the city centre in order to reduce pollution.

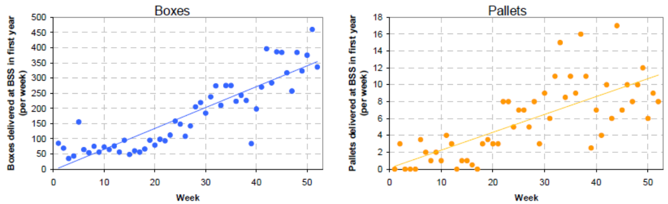

Figure 3.26. Increasing number of delivered pallets and boxes (Source: Van Rooijen and Quak, 2010)

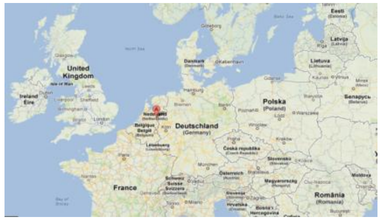

Figure 3.27. Nijmegen: the geographic localization

Figure 3.25. Electronic tricycle and natural gas truck used to make the deliveries

Benefits and limitations

By paying an extra fee, retailers can receive extra service such as: storage, home-deliveries, value - added logistics including reverse logistics. BS is innovative because it can perform deliveries also to other cities. It has been subject to a great deal of studies, which aimed at find a solution of self-financing; in fact, during the first year BS received a governmental subsidy. By the end of the trial period (first year), Van Rooijen and Quak (2010) highlighted positive impacts related to BS (e.g. reduction in terms of number of goods vehicles and kilometers travelled in the city centre), which increased in the period after. However, the improvement of local air quality and noise is limited due to the large number of cars and buses. The positive results of BSS in Nijmegen gave rise to BS franchise initiatives in other Dutch cities (e.g. BSS already started business in Den Bosch, without subsidy). By expanding the BS concept to other Dutch cities, BS becomes a more interesting partner for carriers, which could result in new revenues for BSS.

Table 3.13. BS - Estimated savings for Van Rooijen and Quak (2010)

Indicators	**Estimated saving**
Logistics results	
Truck-Kms and Truck travel time	Decrease of 5%
Truck stops	Decrease of 7%
Local effects	
NO2, PM10	Reduction in air pollution
Noise	No substantial reduction in noise
Shopping environment and traffic safety (respectively be related to the number of truck routes and the number of kilometres travelled in the city centre)	Both the shopping environment and the traffic safety improve when more stores join BSS.

Case 3 - Ecocity (Parma, Italy)

The city of Parma

Parma is a city and municipality in the Northern Italy. It is an important rail and road junction on the main routes from Milan to Bologna, which carry a third of Italy's freight. The economy of the city is mainly based on the agri-food sector. In fact, it can be considered the Italian capital of food, due to the traditional, high quality, food products (e.g. 'Parmigiano Reggiano' cheese, 'Prosciutto di Parma' ham, etc.). The urban environment is characterized by activities related to food. Independent food retailers are highly concentrated in the city centre, while supermarkets and hypermarkets are located in the suburb area. The corporate retail sector market is currently increasing, but there are 850 outlets of local independent suppliers. Also, in 2009, 806 Ho.Re.Ca. were listed in the Municipal register.

The Parma's Consolidation Centre: Ecocity

Ecocity started working on March 2008, being the first one in Italy and Europe to deliver perishable food. It is located 5 Km far from the city centre, exactly as other efficient Italian urban freight consolidation centres such as Padua, Modena and Vicenza. In Parma, 55% of pollution produced by road vehicles is related to freight transport. 40% of goods are delivered to the city centre. For this reason, local authorities decided to establish the consolidation centre. It is managed by a private company. However, to be successful, the scheme is supported by the implementation of access restriction policies established by public authority. Local authorities of Parma pursued three objectives (Morganti and Gonzalez-Feliu, 2015):

Figure 3.29. Parma: the geographic

- Reduction of air pollution, greenhouse gas emissions, waste and noise in order to avoid negative impacts on the health of citizens or nature;
- Improvement of the resource and energy efficiency and cost effectiveness of goods transport, by considering external costs;
- Improvement of the attractiveness and quality of the urban environment, by reducing the number of accidents, minimizing the road occupancy, without compromising the mobility of citizens.

Figure 3.28. Ecocity - geographic localization

The region of Emilia Romagna, the District of Parma, the Municipality of Parma and the publicly held company Infomobility invested 2M of Euros in the Ecocity project. This investment allowed paying the research work and pilot studies as well as the purchase of the vehicles and equipment.

Benefits and limitations

The case of Parma represents a successful example; it is probably one of the few cases of food consolidation centre. Food deliveries are exigent both for delivery frequency and time. Morganti and Gonzalez-Feliu (b) (2015) analised the consolidation centre of Parma. They pointed out that food deliveries are usually daily and the average frequency is extremely varied: it ranges from 1 to 3 deliveries a day for small retailers (e.g. grocery stores) to 7 to 10 deliveries a day for large food outlets, depending on the size and the diversity of the supplied goods. Hypermarkets are the bigger receiver points, with about 20–30 commercial vehicle trips a day. Also, food deliveries are usually made by own account transport carried out by food suppliers, producers or shop-owners themselves. The analysis pointed out that the majority of the customers involved in Ecocity are small retailers related to the Ho.Re.Ca. (Hotels-Catering-Cafes) sector, which is often seen as the most difficult segment to coordinate and change. 40 tons of food products per day are delivered by Ecocity within the city centre. Results show that after 3 years, there are 16 transport operators and carriers, 17 food manufacturers and suppliers (fresh and dry products), 7 corporate chain retailers and 10 produce wholesalers. The receivers are about 250 food businesses and food services, Ho.Re.Ca. establishments, grocery stores, corner shops, specialized stores, corporate retail points-of-sale (mostly superettes), which require daily deliveries of fresh and dry food products. Deliveries are performed by means of 3.5 tons vans powered by methane-fuel. Suppliers and transport operators have to deliver to the freight consolidation centre and then 14 vehicles deliver the goods to the receivers in the city centre. When needed, goods with temperature control constraints are managed by refrigerated warehouses and vehicles.

Deliveries of fresh food products represent a significant proportion of urban freight transport. However, probably because of the cold chain and of their quality preservation, costs related to the delivery of perishable goods are very high. This reason together with the shortage of available space for refrigerated platforms make such city logistics schemes extremely difficult to be implemented. Nevertheless, due to the low level of consolidation of fresh products with respect to the other types of goods delivery, the potential benefits of improved logistics can be high. According to Morganti and Gonzales-Feliu (b) (2015), the main obstacles to the success of the application of these schemes to fresh products deliveries are:

- The delivery size (small) and frequency (high);
- The organization of the network (a good deal of receivers which are spread around the city);
- The complexity of logistics activities (carried out by wholesalers, suppliers and shopkeepers).

Third-party logistics and transport operators turned out not to be appropriate for last mile deliveries of food products. Moreover, in the case of Parma, light good vehicles (LGVs) used for fresh food deliveries use approximately 25% of their loading capacity and deliveries are small size, due to the small storage space of the outlets (Morganti and Gonzalez-Feliu, 2015).

Case 4 – La Rochelle (France)

The city of La Rochelle

La Rochelle is a French city and municipality with 77,376 inhabitants and it is 480 kilometers far from Paris, on the Atlantic coast. It hosts various ports: the Old Port in the city centre, the marina at les Minimes, the Commercial port of La Pallice, and the fishing port of Chef de Baie. It is included in the national and international boating circuit. The city is one of the most dynamic and attractive point in France for the sailing and food industries. Due to the sustainable development in terms of urban ecology, low-pollution transport, the sorting of waste products, air and water quality, and noise La Rochelle is internationally known as a model of urban ecology (http://www.ville-larochelle.fr). In fact, the city privileges "clean" forms of transport (e.g. self-service bicycles, electric shuttles, sea bus, electric cars) and natural spaces (parks and gardens, the marsh of Tasdon, the "Pavillon bleu" listed beach).

The Consolidation Centre of La Rochelle

La Rochelle's distribution centre was developed in two key phases. The first started in 1998, within the European project ELCIDIS (ELectric City DIstribution System), with a UDC experiment in La Rochelle aimed to reduce the congestion due to the high number of deliveries in the historic town centre. The project was promoted by the Urban Community of La Rochelle, who involved different entities in the management and development of the UCC, such as: the Chamber of Commerce and Industry of La Rochelle, a group of transport carriers, and the Ministry of Land Transport (Trentini, 2012). The UCC was established on the surroundings of La Rochelle's town centre; 1,300 shops participated to the project. The trial started at the beginning of 2001 and was financed by ELCIDIS, the municipality of La Rochelle, the Urban Community of La Rochelle, the Regional Council, the Chamber of Commerce and Industry of La Rochelle, and the ADEME. Deliveries were performed by a fleet of electric vehicles (six Berlingo electric vans and an electric vehicle exceeding 3.5 tons). The platform was first operated by delegating the public service to a specific operator created and financed by the Urban Community. This first phase of the existence of La Rochelle UCC was characterised by high financial instability, which made the management of the scheme harder. Later, in December 2006, within the European project CIVITAS SUCCESS, the Urban Community of La Rochelle decided to assign the operational management to a Veolia Transport, a private-public transport company, in order to extend the scheme and allow new developments (Gonzalez-Feliu et al., 2013). Proxiway, a transport and logistics company that was nominated as subcontractor by Veolia Transport, was in charge of the management of the UCC. It offered two other services: Liselec (self-service electric vehicles hitherto managed by the Urban Community of La Rochelle) and an electric shuttle between the park-and-ride and the town centre (Gonzalez-Feliu et al. 2014). Proxiway is also encharged of the management of urban transport services for passengers in La Rochelle. Being responsible for the transport of both passengers and goods, allows Proxiway to reduce its service production costs by widening its range of services (joint service management) and by employing same facilities and personnel. In this way, it was able to spread the fixed costs (such as renting costs) over a larger number of products. Moreover, the possibility to have more services to provide, enabled Proxiway to compensate the typical initial loses of the UCC (due to the lack of minimum demand to make it economically viable). In fact, it could cover the costs of the UCC thanks to the income coming from the two other systems and in this way develop a strategy for reaching economic viability (Gonzalez-Feliu et al. 2014). Also, during the second phase, within CIVITAS SUCCESS, a new supervision system able to localise in real time the vehicles and to communicate with the driver in order to adapt the delivery round as demand changes was implemented. The La Rochelle UCC also offered to the retailers involved a place (room) to store their goods for a short period, together with some pre-retail activities (such as sorting products, labelling, tuning, etc.). The scheme also offered the opportunity of sharing part of the fleet with customers; since the same operator is in charge of the car sharing system, light utility vehicles may be offered to subscribers for their own goods transportation (CIVITAS Thematic Leadership. City of La Rochelle and Norwich. Goods distribution and city logistics. Available at: http://www.civitas.eu/sites/default/files/Results%20and%20Publications/CIV_TLS_brochure_temp_final.pdf).

Figure 3.31. La Rochelle: the geographic localization

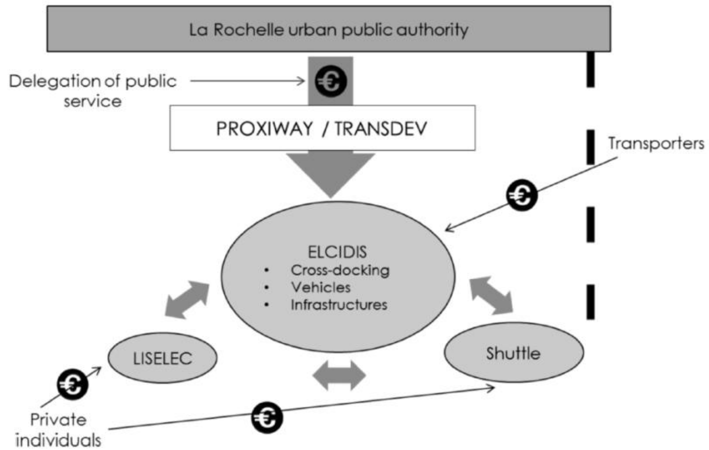

Figure 3.30.The model used to manage the La Rochelle UDC

Benefits and limitations [Source: McDonald, M., Hall, R., Hickford, A., Sammer, G., Roider, O., Klementschitz, R. (2010). Cluster Report 4: Logistics and Goods Distribution - Deliverable: D2.2 – CIVITAS Available at: http://civitas.eu/sites/default/files/civitas_guard_final_cluster_report_nr_4_logistics_and_goods_distribution.pdf
Significant problems were encountered in persuading local businesses to take part in such schemes. Some of the results of the CIVITAS SUCCESS project are summarised below: ▪ Redeployment of declining distribution activities of ELCIDIS logistics platform; ▪ Development of warehouse and delivery software tool; ▪ Slight increase in storage activities; ▪ Overall, 48% of operating costs are staff-related ▪ Journey distances per customer vary considerably on a monthly basis, due partly to low numbers of businesses using the service ▪ The new delivery service allowed the extension of delivery services, involving use of P+R as pick-up point for goods purchased in participating stores using electric vehicles as part of ELCIDIS distribution platform; it allowed achieving the following results: - B2C around €2000 to €2500 turnover per month; - B2B around €50 to €100 turnover per month (except Feb, Mar 08, turnover at €400, atypical activity from one customer); ▪ About the results related to Economy Energy Environment: - Around 40-50 deliveries per customer per month; - Delivery vehicles travelled around 2000km per month, around 6 km per delivery; ▪ About the results related to Transport: - Around 40-50 deliveries per customer per month; - Delivery vehicles travelled around 2000km per month, around 6 km per delivery; ▪ About the results related to the Society: - 30% increase in awareness of potential users of the service.

Conclusion

The chapter identifies the factors that influence the success of a UCC scheme. However, limited quantitative data can be found about UCC schemes and applications and usually no ex-post evaluation is carried out. For this reason, it is difficult determine to which extent the objectives are reached. In any case, the literature shows the best practices for the success of a UCC; also, all the surveys suggest the full participation of the shops of the target group can produce a reduction in terms of goods vehicle kilometers in the city centre. Scientific studies could provide more accurate advice, but evaluations of UCCs are often poorly documented.

City planning is mainly focused on passengers, rather than on freight transport and public authorities do not feel responsible for private firms; for those reasons scant data concerning urban goods management are available. Both, retailers and suppliers benefit from the UCC: retailers can receive a high quality and highly reliable delivery; suppliers can save time and money.

It is worth analysing under which conditions city logistics measures are successful and also identifying to what extent they are effective and in which environment they perform at best. Reducing subjectivity and arbitrariness and finding replicable, systematic and transparent methodology to approach the problem is needed. Despite the benefits coming from UCC schemes, they need subsides to be operative and when the economic support stops, the UCC may have financial issues to follow with providing the service. This is the reason why it is important to understand who benefits from it, because they can contribute paying (more) for the service. To deal with this issue, the study of the stakeholders' perspective and the analysis of their needs and expectations are needed. Due to the importance of stakeholders' participation for the success of city logistics schemes, Chapter 4 wants to deal with this issue.

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Chapter 4

City logistics schemes

Outlining drivers and barriers to the implementation[9]

Introduction

Based on the considerations showed in Chapter 3, city logistics measures measure can only be delivered as a multi-stakeholder initiative and operated in a multi-stakeholder environment. All these stakeholders have different needs and expectations (Taniguchi and Tamagawa, 2005; Tseng et al., 2005; Kiba-Janiak and Cheba, 2011). Establishing the centre requires an actor in the role of policy-entrepreneur seeking system enhancements which are oriented towards the 'common good', for example to citizens' quality of life (Witkowski and Kiba-Janiak, 2014). Local Authorities consider freight villages a method for filling important gaps of national policies related to freight (Kapros, 2011). It would not usually be within the interests of a specific deliverer or recipient to invest resources (procuring a UCC facility and vehicle(s), and designing and promoting the service) in the context of a shared system.

[9] This chapter is based on:

- *Fancello, G., Paddeu, D., Fadda, P. (IN PRESS). Investigating last food mile deliveries: a case study approach to identify needs of food delivery demand. Research in Transportation Economics. Special Issue: Urban freight policy implementation: assessment methods and case studies.*
- *Paddeu, D., Fancello, G. and Fadda, P. (2016). An experimental customer satisfaction index to evaluate the performance of city logistics services. Transport, 1-10.*
- *Paddeu, D., Parkhurst, G., Fancello, G., Fadda, P. and Ricci, M. (IN PRESS). Multi-stakeholder collaboration in urban freight consolidation schemes: drivers and barriers to the implementation. Transport. Special Issue: Multi-Stakeholder Collaboration in Urban Transport (MSCUT).*

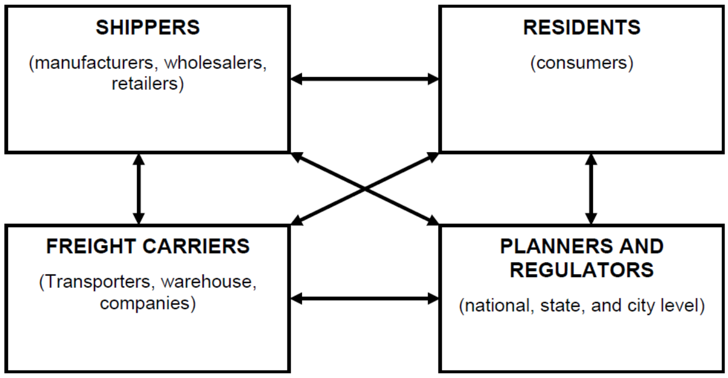

Figure 4.32. Key stakeholders in urban freight transport (Taylor, M., 2005)

This coordinating role has generally been taken by local authorities, although a commercial or not-for-profit interest can perform it (for example in the context of an airport). According to Kiba-Janiak et al. (2015), Lindholm and Browne (2013), Taniguchi (2014), within the multi-stakeholder environment that characterises the urban freight transport system, local authorities represent one of the most important groups of urban freight transport stakeholders. A key reason why local authorities are normally involved as policy-entrepreneur in the context of city logistics is that participation is voluntary, so charges must be attractive, and hence revenues are low, which means subsidy must be provided by, or be procured by, the local authority.

Despite the potential to make a contribution to urban sustainability and economic vitality, many local authorities in EU countries still do not treat urban freight transport as a priority (Kiba-Janiak et al., 2015). Also, the allocation of the costs (to the participants and local authorities) and the existence of producer surpluses, enjoyed by the logistics companies, create a problem for the viability of UCCs as an effective policy idea and sustainable mobility practice. Paddeu et al. (2014) identify significant efficiency savings from the operation of a UCC in Bristol, UK, likely to amount to net social benefits, suggesting that the lack of thriving UCC implementations is due to market failure. The majority of UCCs can only be subsided for a short period due to the limited availability of subsidies, and therefore most have a short lifespan (Browne et al., 2005; Van Duin, 2009). Therefore, identifying relevant stakeholders and their objectives, and evaluating the degree to which these objectives are met is essential to designing a business model for a shared system that can be more permanent (Zenerini et al., 2015).

Actors	Goals
Retailers, traders, manufacturers	• Fast deliveries and known schedules • Acceptable costs • High frequency of deliveries
Consumers	• Accessibility of shops • Affordable prices in urban centres
Transport operators (on own account)	• Freedom of self-provision • Freedom of hawking • Freedom of supply services in urban centers
Transport operators (3PL)	• Freedom of provision of efficient and effective distribution services, with minimum restrictions • Participation in the decision process for issuing restrictions for most polluting vehicles • Recognise the organisational effort to keep loading factors high.
Logistics, terminals, real estate operators	• Involvement in city logistics programming • Supply of areas for Urban Distribution Centres (inside and outside the city centre) • Supply of logistics services

Figure 4.33. City logistics actors and goals (CERTeT Bocconi)

Given that the most tangible benefits in terms of cost savings arise to the logistics companies, and that not all potential participants in an UCC have need of additional or different services, it is not a surprise that many potential delivery-recipient users do not perceive the added value of the UCC scheme to them, and are therefore reluctant to pay for the service (Zunder and Ibanez, 2004; Marcucci and Danielis, 2008). In order to incentivise suppliers and retailers to join the scheme, local authorities can apply restriction measures (Verlinde et al., 2012), such as, for example, access restrictions for freight vehicles in terms of time-windows or routes. However, despite such restrictions, many carriers prefer not to use the UCC and directly supply their customers because they perceive it as increasing their costs and reducing their profitability (Van Rooijen and Quak, 2010). In fact, according to Koehler (2004), Patier (2006), Van der Poel (2000) and Van Rooijen and Quak (2010), the justification for implementing measures such as UCC and freight traffic restrictions should be clearly communicated to the stakeholders involved in the urban context. For a successful UCC implementation, both suppliers and receivers should be convinced about the reason to change the current situation, because they usually are not fully aware of their responsibility for the environmental impacts associated with the deliveries they make/receive (Van Rooijen and Quak, 2010).

Improved awareness of the consequences of current choices can only be one factor in a complex model of supply-chain decision-making which is part based on individual judgement, part on corporate analysis. Some aspects, such as costs, may be shared, objective criteria; others, such as trust in the other actors may be personal-psychological, reflecting individual professional experience (AECOM/ITS, 2010).

In addition to the economic consequences of participation, other forms of barrier also exist, such as at the institutional level. For example Verlinde et al., (2012) identified that the likelihood of joining a UCC scheme strongly depends on the extent to which internal business practices would need to change. To some extent such barriers can be overcome by the engendering of cooperation and through effective consultation among the stakeholders involved (Verlinde et al., 2012). However, particularly relevant in the context of this chapter, is that there may be limits specifically on the willingness to share logistics and transport resources (e.g. warehouse, delivery vehicles, etc.) with the other competitors, or indeed to divulge confidential corporate information about competitive best practices (AECOM, 2010). According to Kiba-Janiak et al. (2015), cooperation among stakeholders can be effective when there exist 'common interests and benefits for stakeholders'; they also pointed out as 'regular communication and cooperation' in order to 'getting to know stakeholders before planning a project' represent a key success. Learning about mutual expectations and problems and realize effectively common projects for the future could be the focus of long-term cooperation established by local authorities with the other stakeholders (Kiba-Janiak et al., 2015). This can be achieved by interacting of community members, sharing of experiences and designing of shared representations. Such practices and processes can be expected to develop and strengthen the interpersonal trust relations necessary for collaborative freight solutions to be accepted.

4.1 A focus on stakeholders' behaviour and last mile of food products

A review of city logistics policies and measures applied in the urban area should be carried out starting from the identification of the key players (Lidasan, 2011). According to Papoutsis and Nathanail (2016), they are: shippers, service providers, local authorities and, of course, consumers. The influence of city logistics measures on the quality of service in terms of quality and reliability of the freight transport service is essential to convince the stakeholders of the benefits arising from these schemes (Papoutsis and Nathanail, 2016).

Probably, the most studied policies are those related to time-window regulations. A significant study was carried out by Holguín-Veras et al. (2008), who analysed the reaction of retailers to the prospect of night delivery. The results showed that receivers are the component of the system who decides on delivery times and their decision strongly depends on the type of goods to be delivered. It was pointed out also by Stathopoulos et al. (2012), who discovered that night-deliveries are preferred by carriers, while retailers prefer to receive the goods by day. The least popular access hours are between 9.00 and 10.00. Holguín-Veras et al. (2007) highlighted that appropriate policy instruments to effectively influence the behaviour of retailers are hard to find, probably because of the lack of knowledge of the most important factors that determine the relation between receivers and freight operators. Also, Holguín-Veras et al. (2005) pointed out that receivers are not willing to join a collaborative off-peak delivery system because the most of the costs are charged on the receivers, while carriers gather the benefits. Within another study, Holguín-Veras (2008) identified monetary incentives or tax-reductions rather than access restrictions as successful policies to make off-peak deliveries acceptable to retailers. However, the limited knowledge of relevant factors influencing the receivers' choice of delivery is still the main reason for find appropriate policy instruments to effectively influence their behaviour. The analysis carried out by Stathopoulos et al. (2012) in Rome, highlighted that stakeholders perceive as main problem areas: loading/unloading bays, time-window regulations and entrance fees. In particular, congestion and illegal parking at loading/unloading bays (that was denounced also by carrier representatives, which complained of the lack of control from the municipality) were indicated as the most severe problems. Also, the lack of urban distribution centres (UDCs) or pick-up points, was denounced and their placement and structure discussed. Also, stakeholders indicated the time-window regulation as an important problem, due to the unfair allocation of exemptions, based on type of goods distributed. It is worth noting that the urban food distribution scheme might vary depending on the type of supply chain it relates with (Morganti and Gonzalez-Feliu (b), 2015). An in-depth study of the characteristics of urban freight flows within the food chain is needed in order to define the needs of the delivery system.

During the 1970s, several urban freight studies have been carried out in the UK, by focusing on data about floor space and number of employees at the shops surveyed in order to investigate relationships between the number of freight flows (deliveries/collections) to these variables (Allen, et al., 2008). However results did not highlight significant outlook, probably because the urban delivery system depends also on other factors (e.g. product turnovers, product ranges, etc).

It is worth noting that the study carried out in 2004 in Ealing (London), which related 12-hour vehicle delivery rates per 100 square meters on typical weekday (7am-7pm), pointed out as the number of vehicles attracted by cafés and restaurants is higher than that related to the other type of commercial activities that were not related to food products (Browne et al., 2006). Not many studies have been carried out with the aim to collected data about the type of goods and there is not a classification for types of goods in urban freight research. On the contrary, urban transport and logistics behaviour is poorly known (Browne and Allen, 2006) and usually the estimation of the flows related to goods deliveries was measured only by counting the number of vehicles within cordon surveys, which give few information on the characteristics of the generators (shippers, forwarders, consignee) and of the receivers. For this reason, analysis and comparisons in this sense is difficult if not impossible (Allen, et al., 2008). Allen et al. (2000) reviewed a set of studies carried out in UK in the field of urban freight transport. They highlighted that the type of product delivered is one of the factors that influence on the average dwell time, which ranges from 8-34 minutes. They also pointed out that dwell time for loading/unloading is higher for restaurants and hotels than for other types of establishment that do not receive food products. Also, as a result of the study carried out by Kijewska and Iwan (2016), food deliveries are characterised by high frequency (daily deliveries, both using own transport and third party transport), often by means of old small diesel vehicles, which are able to transit on any streets in the city centre. However, they generate higher quantities of pollutant emissions than the gasoline vehicles of the same category. The type of product can influence on the efficiency and on the success of the implementation of city logistics measures (such as urban freight consolidation centre). In fact, usually urban freight consolidation centre is not used for food products. The case of Parma (Italy), which represents a successful example, is probably one of the few cases of food consolidation centre. Food deliveries are exigent both for delivery frequency and time. The results of a survey carried out by Morganti and Gonzalez-Feliu (a) (2015), showed that food deliveries are usually daily and the average frequency is extremely varied: it ranges from 1 to 3 deliveries a day for small retailers (e.g. grocery stores) to 7 to 10 deliveries a day for large food outlets, depending on the size and the diversity of the supplied goods. Hypermarkets are the bigger receiver points, with about 20–30 commercial vehicle trips a day. Also, food deliveries are usually made by own account transport carried out by the food suppliers, producers or shop-owners themselves. The analysis pointed out that the majority of the customers involved in the Ecocity project of Parma are small retailers related to the Ho.Re.Ca. sector, which is often seen as the most difficult segment to coordinate and change. Deliveries of fresh food products represent a significant proportion of urban freight transport. However, probably because of the cold chain and of their quality preservation, costs related to the delivery of perishable goods are very high. This reason together with the shortage of available space for refrigerated platforms make such city logistics schemes extremely difficult to be implemented. Nevertheless, due to the low level of consolidation of fresh products with respect to the other types of goods delivery, the potential benefit of improved logistics can be high.

According to Morganti and Gonzales-Feliu (b) (2015), the main obstacles to the success of the application of these schemes to fresh products deliveries are:

- The delivery size (small) and frequency (high);
- The organization of the network (a good deal of receivers which are spread around the city);
- The complexity of logistics activities (carried out by wholesalers, suppliers and shopkeepers).

Third-party logistics and transport operators turned out not to be appropriate for last mile deliveries of food products. Moreover, in the case of Parma, light good vehicles (LGVs) used for fresh food deliveries use approximately 25% of their loading capacity and deliveries are small size, due to the small storage space of the outlets (Morganti and Gonzalez-Feliu (a), 2015).

In sum, the literature review allows making considerations about the key factors for successfully implement an urban food distribution centre. They resulted being (i) the consensus of the stakeholders, (ii) the choice of a strategic location and suitable logistics facilities, (iii) the definition of an effective traffic and access regulation plan.

4.2. The potential of multi-stakeholder collaboration for sharing urban solutions

Collaborative solutions for transportation and logistics sound like new concepts in research, but are very popular in practice. They represent a good alternative to the more famous concept of UCC (Gonzales-Feliu, 2011). Before providing the definition of a model for sharing urban logistics systems, the authors want to make an analysis of the multi-stakeholder collaboration by considering different successful case studies related to urban freight multi-stakeholder collaborative schemes. As described in the introduction, urban environment involve a great deal of stakeholders, each one with different needs and expectations. According to Verlinde et al. (2012), in order to make urban freight distribution more sustainable and efficient, at least one of the stakeholders involved has to make changes to his internal procedures and processes; it can be said that they have to change their “behaviour”. Within the multi-stakeholder collaborative schemes, the most famous and widespread is the UCC. However, this section aims to provide an insight on collaborative schemes other than the more traditional UCC, which represents an additional transhipment point, often perceived as an added cost by its users. In general, even though a high participation of both receivers and carriers is essential for a successful implementation of a UCC scheme, the involvement of potential users is quite hard (Verlinde et al., 2012); in fact, receivers are reasonably pleased with the way they are delivered and, on the other hand, suppliers and carriers conform as much as possible to the needs of their receivers (Holguín-Veras et al., 2005). However, the addition of an additional transhipment point to the supply chain is not the only solution to consolidate urban freight flows more efficiently. In fact, it can be achieved by modifying the usual working methods of the stakeholders involved, in particular of carriers and receivers (Verlinde et al., 2012). The review of the most significant and successful examples of multi-stakeholder collaborative schemes provided by Verlinde et al. (2012), highlights as both receivers and carriers are only inclined to change their way of receive/deliver and want to participate in any kind of initiative if they think to personally benefit from it.

Receivers highly influence the setting of the operational constraints that must be satisfied by carriers and shippers, because they are the primary customers. For this reason, changing the behaviour of receivers means to have upstream impacts on supply chains (Holguín-Veras and Sánchez-Díaz, 2016). Receivers use to be more willing to participate due to the benefits provided by a UCC scheme to the quality of the city environment, i.e. shopping is more pleasant for customers if there are a low number of motorized vehicles in the area (Verlinde et al., 2012; Holguín-Veras and Sánchez-Díaz, 2016). Adapted behaviour by receivers and carriers is needed to successfully implement a collaborative scheme. However, there is a significant lack of knowledge about the roles played by the various economic agents involved in supply chains, and consequently, the most effective ways to make change (Holguín-Veras and Sánchez-Díaz, 2016). Also, according to Holguín-Veras et al. (2016), the effectiveness of a policy depends on which agent is the target. In particular, they pointed out that policies that target carriers wishing they might influence receivers to change behaviour are not likely to be effective; while, on the contrary, policies addressed to the receivers lead to behavior changes on the part of the carriers. This is because the receivers, being the most powerful agent, tend to impose their will on the carriers and, at the same time, carriers must be responsive to customers' demands if they want to stay in business (Holguín-Veras, 2008). As a result of the study carried out by Holguín-Veras and Sánchez-Díaz (2016), the use of regulation is less effective than voluntary programs. This is because the use of regulations to achieve a behaviour change is likely to force some participants to change operations and they perceive it as detrimental. On the contrary, voluntary programs allow increasing welfare because the participants that choose to adopt the measure are those that will benefit from it. The result is different if we talk about a shopping area belonging to a single landlord. In this case the imposing organisation (landlord) is able to control or strongly influence all the players and to make the solution successful, e.g. the UCC that serves Heathtorw Airport (Browne et al., 2007).

Some shippers showed of being reluctant to participate in UCCs. In fact, shippers lose control of their deliveries (by losing contact time with customers) and they cannot use their trucks, so they lose the opportunity to increase brand recognition. They could also lose their customers by leaving them to other competitors. Doig (2001) recognized opposition from shippers as one of the key factors responsible for the end of the UCCs created by the Port Authority of New York and New Jersey, in the 1940s.

In general, receivers' adaption resulted being successful in several cases. For example, within a Dutch project on demand driven consolidation, deliveries to the retailers were made by the same supplier or carrier agreeing on a mutual delivery day or time; it avoided carriers to consider retailer's preferences when planning their delivery tours (De Stad., S.L., 2005). Another successful example is that of the Swedish SMILE project, which involved 40-50 small food producers in the region with 5 purchasers in the city of Malmö (http://www.civitas-initiative.org/measure_sheet.phtml?id=255&language=en). Orders and deliveries were performed through a common food logistics system operated by both the producers and the purchasers. In this case, receivers and suppliers closely work together in order to reduce travel distance of fresh food supply. Also Binnenstadservice (BSS) represents a good example of UCC focused on receivers rather than carriers (Van Rooijen and Quak, 2010). In this case, retailers are who decide to use the UCC, so suppliers basically have to change the destination address of their deliveries from that of the retailer to the address of the UCC. BSS involves small and independent retailers, which usually do not optimise their deliveries. It offers a free-of-charge delivery service (performed by environmentally friendly delivery vehicles) that allows retailers to save their time. Retailers can also benefit from extra services with fee at BSS, such as storage, home-deliveries, value-added logistics including retour logistics, possibilities for e-tailing in the city of Nijmegen.

Contrary to the receivers, carriers directly benefit from UCC because every empty or half empty kilometre represents a cost to them (Verlinde et al., 2012). However, their willingness to join a UCC scheme might grow if they have clear evidence about the convenience of outsourcing last mile deliveries, e.g., fleet optimisation, pick-ups at more convenient times (Kin et al., 2016). An example of collaborative scheme that involves carriers is Teamtrans, a collaboration of 13 Dutch carriers who cover the whole Duch territory by dividing it in 13 service areas based on postal codes (teamtrans.nl.). With this project, each of the carriers serves one of these areas operating from his central depot. Carriers make deliveries to their own customers, but also to other carriers' customers that are in the area they serve. Another successful collaborative scheme is cargo pooling (trivizor.com; mobimix.be), which basically considers the possibility to rent available spaces of a freight vehicle to suppliers or carriers who want to deliver goods to a destination on (or close by to) the route of the vehicle. The system can be managed by means of a web-based platform able to combine free space with non-allocated cargo.

In general, according to Triantafyllou et al. (2014), cross-organizational collaboration allow improving service quality and cost reduction for businesses, but receivers have to set its operational scope in forming alliances with supply chain competitors to share assets, logistics, and expertise and exchange sensitive information. However, receivers might be dissuaded to participate because of losing control of the supply chain, additional costs, and poorer service standards (e.g. as happened in the case of the Norwich UCC in Norfolk). Different results are achieved if we talk, for example, about a new shopping area development. In this case, receivers would be more likely to join from the beginning a sharing scheme (Triantafyllou et al., 2014). On the other hand, logistics providers will have to develop common standards, content, and applications, which could be hard to achieve due to the fragmented and competitive nature of the logistics industry.

Even though the review pointed out collaboration among stakeholders is essential to make urban freight transport more sustainable, there is a lack of consultation between carriers and retailers, which represents the main cause for the inefficiencies of freight transport at the urban level.

4.3. Drivers and barriers to the implementation of sharing urban freight transport and logistics solutions[10]

This section is part of the research work carried out for this PhD thesis. The aim of this section is to investigate what drivers and limitations are related to the implementation of sharing logistics and urban freight transport policies, which involve multi-stakeholders, such as urban freight consolidation centres (UCCs). Due to the key role assumed by receivers in the success of the implementation of sharing logistics systems highlighted in the previous sections, the authors decided to investigate their point of view and their perception with respect sharing solution. Based on the analysis of the results of two surveys carried out in Bristol (2013) and in Cagliari (2015), the section presents an in-depth comparison of the differences in the perceptions of urban freight users and stakeholders towards UCC (Table 4.14). Factors which can positively influence stakeholders' behaviour in order to join this kind of schemes and the barriers to their implementation are analysed.

4.3.1. Methodology

With the aim to highlight the relationships among levers and limitations of collaborative urban transportation and logistics sharing schemes, a conceptual framework is defined. The theoretical model is based on that proposed by Gonzales-Feliu and Morana (2011), who considered socio-economic and legislative factors related to collaborative sharing schemes. The model proposed in this section allows analysing drivers and barriers by considering the perspective of the actual/potential users involved: the receivers (Figure 4.34).

The description of the different components of the model and of their respective relationships is provided below.

- Drivers to create Urban Logistics and Transportation sharing schemes; this part provides compelling reasons to partners to join the scheme. According to Gonzales-Feliu and Morana (2011), in the case of urban freight distribution, environmental safeguard (such as CO2 reduction), economic efficiency, legislative reasons (e.g. access restriction to the city centre, incentives to sharing approach, etc.) and common interests are the main

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[10] Data and results of the survey carried out in Bristol are extracted by "*Paddeu, 2013. Customer Satisfaction Analysis. Users impact analysis of the Bristol Freight Consolidation Centre. Unpublished Master Dissertation*"

This section is based on: *Paddeu, D., Parkhurst, G., Fancello, G., Fadda, P. and Ricci, M. (expected publication January 2017). Multi-stakeholder collaboration in urban freight consolidation schemes: drivers and barriers to the implementation. Transport. Special Issue: Multi-Stakeholder Collaboration in Urban Transport (MSCUT). (IN PRESS).*

motivators to join a sharing scheme. Drivers strongly influence strategic and tactical decision for all the stakeholders involved in the urban environment.

- Urban Logistics and Transportation Solution; UCC is considered as a sharing solution to make urban freight distribution more efficient.
- Logistics and Transportation sharing components; this part considers the components of an urban sharing scheme. They strongly depend on the type of sharing solution system considered. Components include: stakeholders, vehicles used to make the deliveries, logistics facilities.
- Results are influenced by the sharing system components and by the barriers to the implementation of sharing schemes. Also, outcomes expectations are set by drivers. Results provide the feedback about the efficacy of the specific sharing scheme considered.

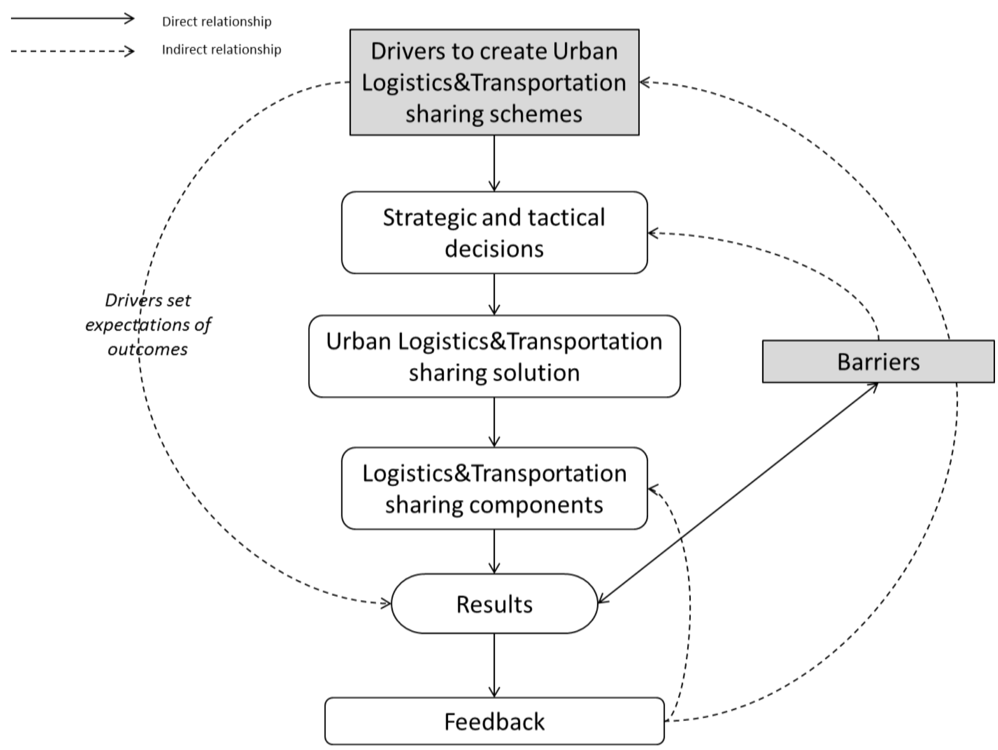


Figure 4.34. Conceptual model for sharing solutions applied to the urban freight distribution environment [Paddeu et al., 2017]

A case study approach in order to generate theory based on the analysis of the evidence of the case study was adopted (Eisenhardt, 1989). In particular, considering the UCC a good example of sharing solution, the most important levers and limitation to the implementation of UCC schemes is analysed by considering two case studies: the city of Bristol (UK) and he city of Cagliari (Italy). Due to the different scenarios characterising Bristol and Cagliari (in Bristol a UCC has been operating for 14 years, whereas in Cagliari it is yet to be implemented), the research questions driving the two surveys are different. However, results are combined to answer to the common research question: “which are the drivers and limitations of a collaborative UCC scheme”?

Moreover, the section analyses:

- How actual (Bristol) and potential (Cagliari) users perceive sharing collaboration systems (e.g. what kind of benefits does a sharing system provide to my business? Does it represent an advantage to my business?);
- If the inclination to join a sharing system depends on the type of products to be delivered, on the nature of the business to be involved, or on the culture of the users to be involved;
- What kind of issues can limit the implementation of sharing systems;
- How the organization of the sharing delivery system (e.g. delivery scheduling) can change depending on the type of product to be delivered and on the nature of the business;

The case studies mainly differ in terms of: existence of a UCC, type of products and nature of business (i.e. multiple retailers/SME).

The description of the case studies and of the data collection process is provided in Paddeu et al. (2017) – See annexes at the end of this thesis.

4.3.2. Description of the case studies

Table 4.14 provides a summary of the main differences between the case of Bristol and that of Cagliari. In order not to be too long and recurring, case studies are not described in this chapter (only the case of Bristol is described by the end of the chapter, except for the description of the survey, which is provided in Paddeu et al., 2016). A deeper description of the case of Cagliari and of the survey carried out is provided in Chapter 8 and in Fancello et al. (2016) – See annexes at the end of this thesis.

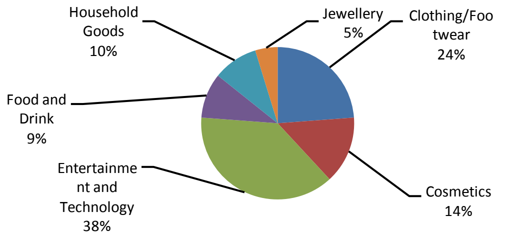
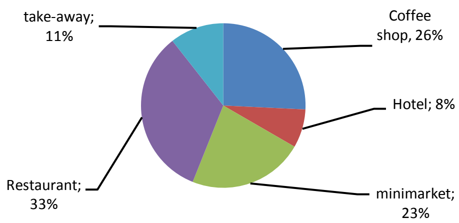
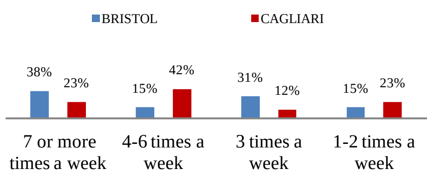
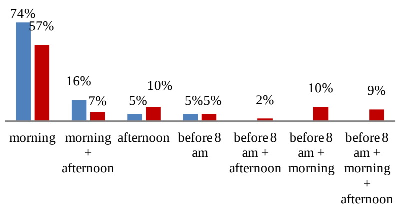
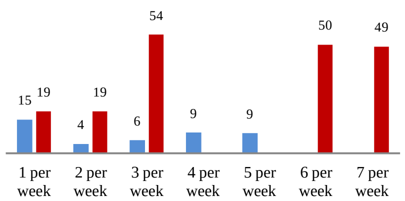
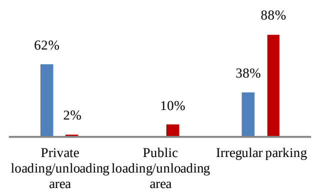
	Bristol	Cagliari
UCC?	European Projects: 1. CIVITAS VIVALDI (2002-2006); 2. START(2007-2008); 3. CIVITAS-RENAISSANCE (date) Bristol&Bath	It is yet to be implemented
Research questions	▪ What services, and with what frequency, do participating retailers receive from the Consolidation Centre? ▪ What are the advantages & disadvantages for the participating retailers? ▪ Are the retailers satisfied with the Consolidation Centre service?	▪ What are the characteristics of a typical food delivery (e.g. frequency, time, size, supply mode, etc.) and what kind of needs do last mile deliveries related to the food chain have? ▪ What kind of relationship exists among the variables that characterise food deliveries? ▪ Are city logistics measures suitable to satisfy logistics and deliveries needs related to this chain?
Sample		
Nature of business	Multiple Retailers	SME
Category of shop	Clothing/Footwear, Entertainment and Technology, Household Goods, Cosmetics, Jewellery, Food and drink (Chocolate)	Ho.Re.Ca. sector: Hotels, Restaurants, Coffee shops, Minimarkets, Take away
Category of product	Non-perishable; no food (except for chocolate).	Fresh and dry food
N. surveyed shops	21 (Bristol) + 16 (Bath) = 37	66
Delivery comparison	Overall weekly deliveries (delivery frequency) 	Delivery Time 
	Delivery Size 	Where do they park? Loading/unloading operations? 

Table 4.14. Summary of the main differences between Bristol and Cagliari

4.3.3. Drivers to the implementation

4.3.3.1. Drivers related to economic advantages

As highlighted by the literature review, some economic advantages are related to sharing logistics (e.g. time savings, space savings, additional services, etc.). When retailers interviewed in Bristol were asked to indicate the advantages for their business of participating to the scheme, they declared to perceive "delivery to stock room" as the most important benefit. In fact, BBUCC directly delivers goods to the stock room, allowing retailers to save their time and staff working time. Retailers perceive it as an economic advantage to their business. Also, they declared they do not need a big space to stock the goods into the stock room, so they can reduce the size of the stock room and they can use almost all the space available to sales. This represents a very important economic benefit, because retailers can benefit of the just-in-time service provided by the UCC and they can save money (the bigger is the shop, the higher are renting costs – which are usually high in the city centre). Also, due to the fact that city logistics measures are usually supplied by traffic restriction measures applied to the access of motorized vehicles to the city centre, being part of a logistics and transportation sharing scheme could be an advantage to easier receive goods. Moreover, during the first lifespan of BBUCC, European Commission and Local Authorities financed the trial and retailers did not have to pay to receive the deliveries. This incentivized the retailers to apply, because they could save money during that period. After that, they started paying, but they recognized the benefits and did not leave the scheme.

Another important advantage is related to additional services provided by the BBUCC, such as recycling. In fact, BBUCC collects cardboard and plastics (packaging) from the retailers. Interviewees declared they perceive it as an advantage because they do not care about the waste. At the same time, BBUCC sells the cardboard collected, so it represents a source of income.

4.3.3.2. Drivers related to practical advantages

According to Kin et al. (2016), stakeholders could be persuaded to join the scheme in order avoid inefficient last mile deliveries.

An important practical advantage is related to time saving. In fact, retailers interviewed in Cagliari declared they would like someone else collects goods to the supplier and make deliveries to the shop, because these activities represent a significant loss of time for them. However, they also declared not to know if they would be willing to let somebody performing these activities, because they want to be sure about the quality of the products they are buying, so they need to check it before collecting goods. They said they need “somebody to trust”. In this case, thinking about qualitative comments collected through the survey carried out in Bristol, retailers were very happy about the BBUCC delivery staff and they declared the staff is completely reliable, in terms of both timeliness and delivery safety. This could be an evidence to convince retailers to join a sharing logistics system in Cagliari. Also, Cagliari has an important port, which, according to Kin et al. (2016), the presence of a port in the case of Antwerp was recognized as beneficial for a UCC because it allows for intermodal transport (a great deal of goods is delivered to and picked-up in the port area).

Setting delivery times was recognized being a very important advantage for the retailers in Bristol. In fact, they declared they can receive goods at the time they prefer, so they avoid receiving goods during peak hours (i.e. when there are more customers at the shop). This can be an advantage also for the retailers in Cagliari, because they use to go buy and collect goods during off peak times. In the case they decide to be part of a sharing system and so to share logistics facilities and delivery vehicles, they could anyway decide to receive goods when they want.

4.3.3.3. Drivers related to the protection of the environment

Pollution and climate change are being of high interest among people of all over the world. These issues are increasingly influencing people in the way they buy products; in fact, even more people are encouraged to endorse environmentally friendly companies. For this reason, today sustainable practices and green logistics are strongly considered by companies that want to make their own supply chain more sustainable. This is the case of retailers belonging to big multiple-retailer chains in Bristol. In fact, they declared they participate to the BBUCC scheme because it provides a “green image” to their business, or because it is in line with the ethical principles of the company (qualitative data collected through the survey). The protection of the environment and a “green behavior” can be an important driver for a successful implementation of this type of scheme. In fact, as explained in the profile of the case study of Bristol provided by the end of this chapter, BBUCC allowed reducing polluting emissions and negative externalities related to urban freight transport. It can be used as a good example of collaborative multi-stakeholder solution able to improve the quality of life of a city centre. Also in Cagliari, when retailers were asked if they were willing to participate to a project that aims to make urban freight deliveries more sustainable, the majority of them replied yes. Some of them are already experiencing cycling deliveries performed by Bycicle Express 2.0, a delivery company that makes deliveries by bike in Cagliari. However, despite of the “green image” their business would acquire by participating to this kind of schemes, interviewees declared to be concerned about the costs related to this type of service. In fact, they declared to be willing to participate only if costs are not higher of those of the current situation (i.e. traditional deliveries, made by motorized vehicles).

4.3.4. Barriers to the implementation

4.3.4.1. Financial and practical barriers

Despite the UCC allows an overall cost reduction (e.g. reduction of delivery costs for the suppliers, of stock room space for the retailers, of social costs related to air pollution for the society, etc.), probably the main barrier related to the success of a UCC is exactly related to costs and in particular to its economic sustainability. In fact, in the most cases UCC requires initial funding from central or local authorities to start (e.g. for initial trials and research work) and when these subsidies are cut, often UCC is unlikely to proceed with its operational activities, due to the lack of financial resources (Browne et al., 2005; Allen et al., 2012). Also, according to Zunder and Marinov (2011), it is still difficult to understand if a UCC could operate without subsidy.

In the case of Bristol, the BBUCC was subject to a high amount of investments covered by EU and Bristol City Council. When EU projects finished, Bristol City Council did not stop to provide subsidies; however retailers started paying a fee for the services provided by the BBUCC. In this case, operational costs of the BBUCC are totally covered: they are partially covered by Bristol City Council and partially by retailers.

This suggests the intervention and participation of Cagliari local authorities (for both financial and marketing support) is essential for the success of a UCC in Cagliari.

Sharing resources allows making their utilisation and consumption more sustainable (e.g. air pollution and noise reduction, congestion reduction, accidents reduction, etc.) and it implies important social benefits. They should be quantified in economic terms in order to give to local authorities and to citizens a quantitative indication of the financial balance (i.e. money spent for the implementation versus costs suffered by the community due to negative externalities in urban areas). However, the stakeholders' willingness to participate to this type of scheme is influenced by their expectations of who should sustain the costs. This can be considered strictly related to social and cultural barriers, which are described in the following section.

4.3.4.2. Social and cultural barriers

Surely, during the launch and the first lifetime of a UCC, a big effort for recruiting retailers is required. In fact, despite of its success, BBUCC is not able to enlarge its market horizons, even though continuous marketing campaigns are organised. This can be attributed to scepticism to new delivery systems. Most of the retailers interviewed in Bath before the implementation of the BBUCC scheme declared to be satisfied with their delivery service and they did not want to change. So, even if they had to pay for their traditional delivery service and the new delivery service proposed by BBUCC was free of charge (during the EU project) and more additional services were provided, they were not willing to join the scheme. Innovation and change might worry people.

Probably the willingness to participate may be influenced by the nature of company involved. In fact, nowadays, big companies with multiple retailers are often conditioned by ethic values related to the "green image" concept; the idea to save the world and be part of a big community that fights for the common right to live in a cleaner and healthy world, is often an incentive to participate to these innovative and sustainable measures. So, a "green image reputation" reason can be considered to persuade retailers to participate to a UCC scheme. Anyway, based on the experience in Bristol, the involvement of a big company is difficult to achieve, due to the centralised system used to manage and schedule orders and deliveries; in fact, outlets are often remotely managed by the head office that does not have direct contact with the manager of the retail. On the other hand, a small business can be directly contacted, so easily involved; however, probably because of the business size, the manager of a small company is worried to change; in fact, a change in his/her business management can require a different investment that the manager is worried to not be able to support. So, if they are accustomed to a specific and traditional scheme, they unlikely leave it.

Another important dissuasive issue is related to competitiveness. Retailers may be not willing to share logistics facilities and delivery vehicles with their competitors. In this sense, sharing resources can be perceived a disadvantage for the business competitiveness, because resources, costs and benefits are shared, proportionally with the delivery size, with the competitors. This can be more significant in the case of Cagliari. In fact, when retailers were asked to indicate their willingness to join a shared delivery service, the majority of them seemed not to be totally convinced to want to use the same vehicles of the other commercial activities, their competitors. This may be related to the mistrust afflicting some commercial operators, above all in Sardinia. However, on the contrary of what some retailers can think, sharing economy can be a successful tool and a key of competitiveness for businesses due to cost savings. Also, due to the cooperative consumption sharing and the related pollution reduction, the whole community benefits from it.

Another category of stakeholders involved in the urban freight transport system is represented by carriers. Also in this case, they are often not willing to join this type of scheme because they cannot see the profitability; in fact, demand uncertainty is related to uncertain economy for them and this represents a deterrent for their participation. Also, carriers usually perceive UCC as an added node to the supply chain that avoids them to have a direct contact with the receivers. This can be perceived as a problem in terms of marketing strategy. In fact, as demonstrated in the case of Bristol, receivers recognise who makes the deliveries (in the specific case they even know the name of the delivery staff) and they trust in them. Direct contact is an important strategic key for a carrier company and they do not want to lose it. In this sense, maybe a big transport company, more than a carriers company, can perceive UCC as beneficial because of the significant cost saving.

4.3.4.3. Barriers related to the type of good to be delivered

There are no many cases of food UCC. In fact, logistics and transport of perishable goods could be more problematic to manage, due to the high quantity of goods to be delivered and on the needs related to this type of product (e.g. cold chain breaking up). Also, usually shop-keepers related the food sector are not confident with the delivery performed by logistics operators and prefer to be in charge of their own deliveries. This is the case of Cagliari, also the type of good delivered can represent a problem. In fact, retailers interviewed declared to want to choose perishable product by themselves, because they want to be sure products meet quality standards. It can represent a problem related to the culture of high quality cooking typical of Italian restaurants. When interviewees were asked if they were willing to order their product online or by phone and receive them by deliveries made by logistics operators, they declare it could be a big benefit for them in terms of time saved; however, the risk to receive low-quality products (in particular: fruit and vegetables, fish and meat) or deteriorated, make them not willing to receive deliveries by somebody other.

Based on the results and on the thoughts made in the previous sections, a summary of the Urban sharing logistics and transportation model is provided in Figure 4.35.

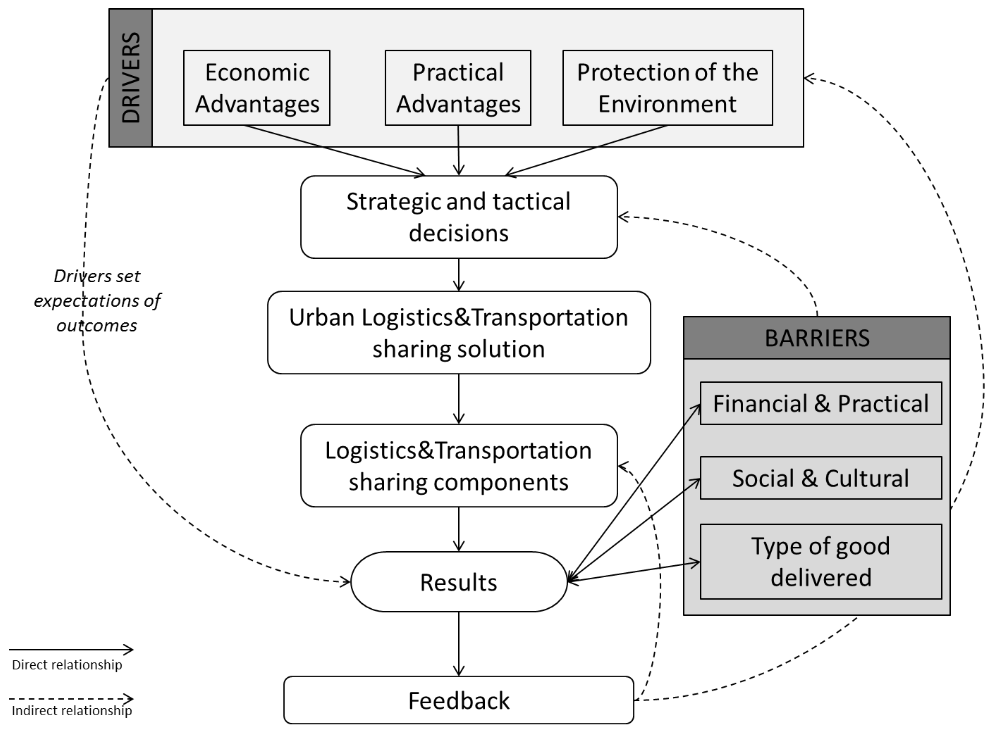


Figure 4.35. Urban sharing logistics and transportation model

Conclusion

Based on the concept of the sharing economy, multi-stakeholder collaboration in urban freight transport can represent a successful tool to improve the quality of life of cities. An example of this kind of approach is that of city logistics and in particular UCC. Stakeholders' participation is essential for the success of a shared delivery system. By sharing logistics facilities and delivery vehicles, stakeholders can benefit from the UCC in terms of cost and time savings and added value services. However, stakeholders involved in the urban system have different needs and objectives. This is the reason why most of the UCC schemes in Europe have been promoted and financed by policy makers in their initial phases and the ceased operation when the subsides ended (Van Rooijen and Quak, 2010). The sharing economy provides flexible opportunities for cost savings, pollution reduction and social value. However, as highlighted by the results of the survey carried out in Cagliari, despite the benefits it can potentially provide, it remains far from being universally accepted by potential users. The paper has provided an analysis of two multi-stakeholder schemes and a comparison of their inclination toward shared logistics facilities and freight transport vehicles. The analysis highlights that important benefits are provided by the UCC in Bristol, in particular in terms of reduced polluting emissions. Also, stakeholders involved in the scheme were very satisfied with the delivery service and the added services provided by the UCC. They recognised they achieve economic and practical benefits thanks to the BBUCC. However, despite the benefits coming from the UCC, there are significant problems related to its financial sustainability, which has been identified by the literature review (Gonzales -Feliu et al., 2014; Browne et al., 2005; Allen et al., 2012) and by the analysis of the results in Bristol as the most important barrier to UCC operation. It should be emphasised that most of the stakeholders interviewed for the BBUCC case-study were not in fact aware that they were part of the scheme. Communication and promotion campaigns should be organised to sensitise stakeholders to the benefits the sharing economy can provide to their businesses. Cost allocation is another issue related to the success of shared logistics systems. This is not easily resolved: a specific analysis related to the identification of who benefits from the UCC is needed. 'Who pays what' should be clear for all the stakeholders involved and costs should be allocated proportionally with each stakeholder's benefits. Another important barrier is related to the propensity to change and risk acceptance/aversion. However, based on the results of the survey in Bristol, it is worth noting that large companies may be willing to participate in shared logistics schemes due to the "green image" they provide to the firm.

Last but not least, the case of Cagliari highlighted the type of goods to be delivered as a major barrier to the feasibility of a shared logistics scheme, for example for food products, due to the needs and constraints related to the cold chain (i.e. higher management costs, short delivery times). Beyond the essential ingredient of political will, the decision to establish a UCC is related to a subset of decisions, such as the choice of the right location, an analysis of the current infrastructure level of the region involved, benefits and competitive conditions for business to be included and the relative economic effects in the region. Establishment of the scheme also requires the engagement of an experienced freight logistics operator (as in the case of Bristol) that identifies UCC as an opportunity, despite it being a small niche for an industrial sector increasingly dominated by national and international companies. For effective operations, there must be a sufficiently large pool of freight recipients that recognize the benefits of UCC participation (Kin et al., 2016). Generally, the value of these benefits is to some extent marketised through participants' willingness to pay additional delivery costs. The customers of UCCs have generally been city centre businesses and institutions such as retailers, hoteliers, and hospitals, although in principle could involve individual citizens, for example seeking control over when deliveries are made to their residences. The involvement of freight carriers – those charged with responsibility for completing the individual deliveries – is also required, but they can be expected to follow the instructions of the consignor/consignee and in any case is the only group of actors which is strongly incentivized to use the UCC: they benefit from time and fuel cost savings by not entering the city (Verlinde et al., 2012). In fact, even if the last mile represents the shortest part of the supply chain for a manufacturer or for a transport company, it represents 28% of the total delivery costs for carriers (Goodman, 2005). This potential for major efficiency savings suggests a combination of innovation, new technologies and professional commitment and it suggests the sector will continue to seek ways around barriers to 'smarter' city logistics.

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PART II - Evaluating the performance of the supply chain

Chapter 5
Methodological framework
Performance indicators and model definition for the supply chain

Introduction

Chapters 5 and 6 deal with the evaluation of transport and logistics performance for the supply chain. In particular, Chapter 5 propose a model for the performance assessment, whose validity proved by considering a case study approach (Chapters 6). Specific indicators are defined to assess performance. The model proposed is defined by considering the most important model used within logistics and supply chain performance: the SCOR model. A short introduction to SCOR is provided in Chapter 1 (Section 1.5.5). The following section proposes a deeper analysis of the structure of the model, which has been chosen as reference model for the development of the model proposed in this thesis.

5.1. A focus on the Supply Chain Operations Reference model (SCOR)

In 1996, the international Supply Chain Council (SCC) proposed the Supply Chain Operations Reference (SCOR) model, which became the most popular model in the world to be used to supply chain performance assessment (Xiao et al., 2009). The structure of the model allows supporting communication among partners through the link of business processes to metrics, best practices and technology features. It empowers the effectiveness of supply chain management as well as related supply chain improvement activities (Xiao et al., 2009). The model is based on a hierarchical structure with different levels of decomposition (Palma-Mendoza, 2014) that can be summarised as follows:

- Level 1: *Process Types*; Level 1 defines scope and content using five management processes (Figure 5.36): Plan, Source, Make, Delivery and Return (described in Section 1.5.5). These five management processes are represented in Figure 5.36. At this level the company defines its supply chain objectives.
- Level 2: *Process Categories*; by means of core process categories, level 2 defines configuration level. Organizations can configure their ideal or actual operations by using one or several of the core process categories.
- Level 3: *Process Activities;* Level 3 provides a decomposition of the processes in process elements, describing inputs and outputs, process performance metrics and recommended best practices. This level provides the information required for successfully planning and setting goals for supply chain improvements.

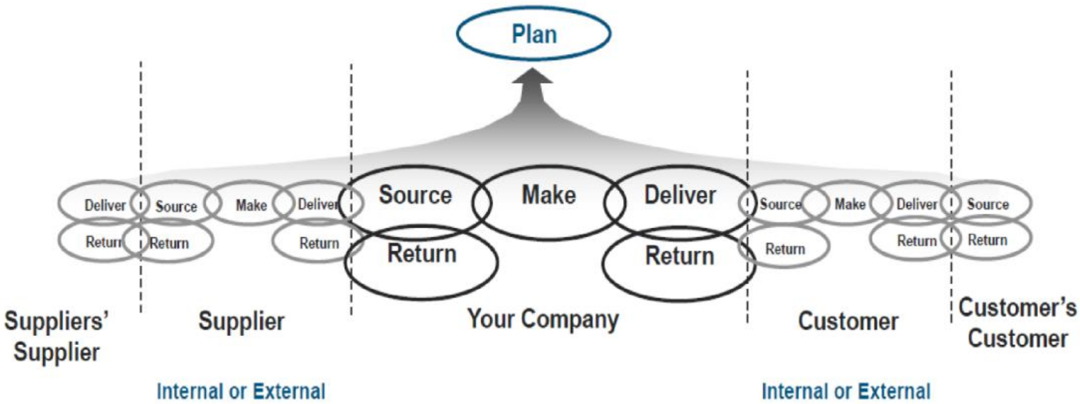

Figure 5.36. SCOR progess types (Ceroni and Alfaro, 2011)

According to Palma-Mendoza (2014), Levels 1 (process types) and 2 (process categories) can be used to identify and map the supply chain processes. SCOR provides performance attributes to describe generic supply chain characteristics. According to SCOR model version 11, performance *attributes* are (Figure 5.37):

- Reliability;
- Responsiveness;
- Agility;
- Supply Chain Cost;
- Asset management.

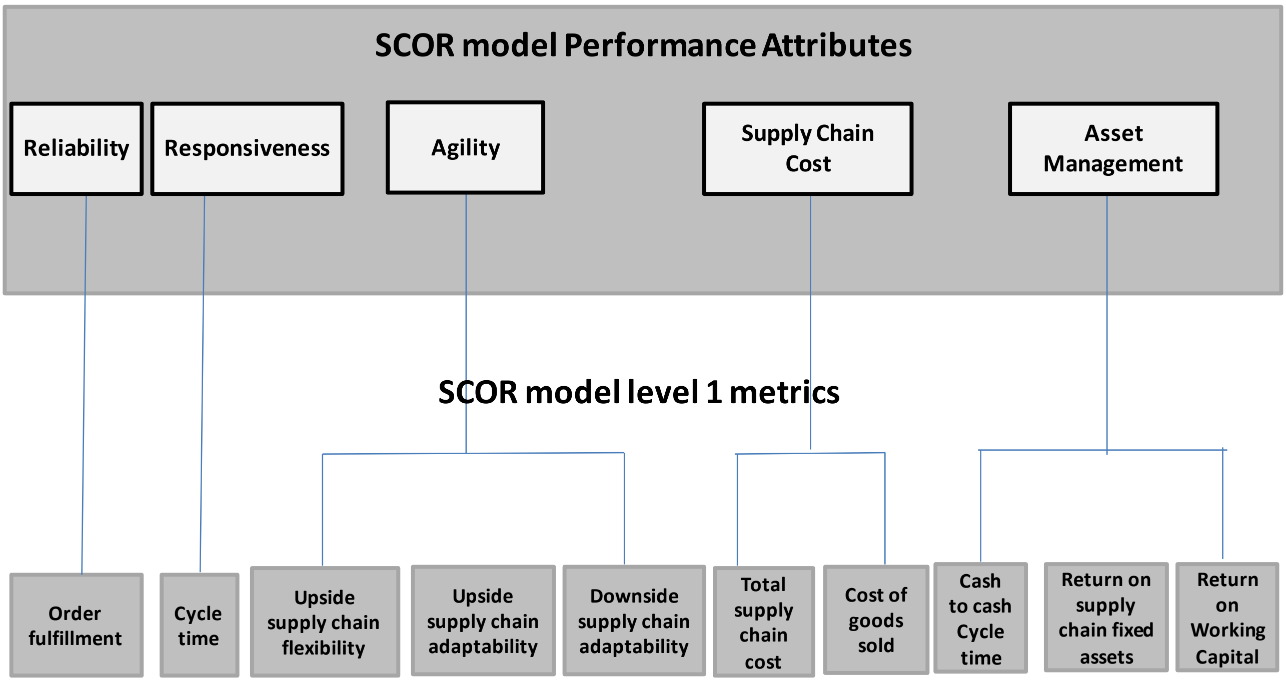

Figure 5.37. SCOR model performance attributes and 1st level metrics (Ceroni and Alfaro, 2011)

Each attribute includes specific metrics, which have different hierarchical levels, likewise to SCOR processes. For example, Figure 5.37 shows how metrics of Level 1 are related to performance attributes. They can be absolutely considered Key Performance Indicators (KPI) used to measure and express the overall performance of a particular performance attribute. On the other hand, the metrics included in the other levels can be considered such as "diagnostic measurements" associated with particular process activities (Level 3).

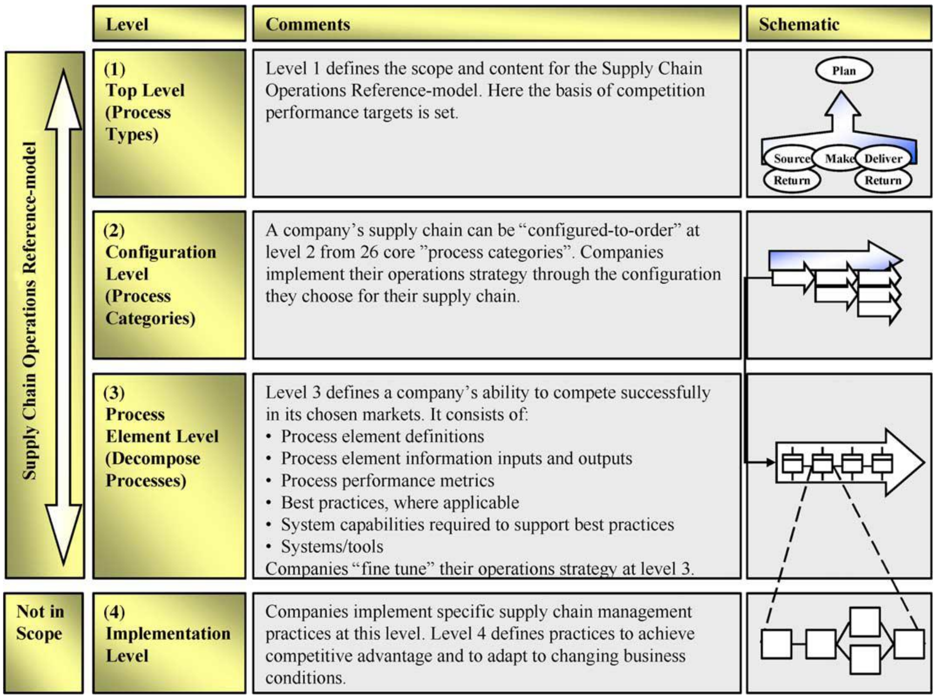

Figure 5.38. Overview of Supply Chain Operations Reference-model (Röder and Tibken, 2006)

5.2. Definition of the framework of the model: the Supply Chain Delivery and Transport Performance Model

Drawing on the framework proposed by Garcia et al. (2012) and on the KPIs identified by Frazelle (2002), the model proposed allows defining the Supply Chain Delivery and Transport Performance Model, which is composed by a set of key performance indicators for transport and logistics processes. In particular, the model framework is built by considering the *SCOR model* (Supply Chain Council, 2010), which allows defining 4 different and specific *performance attributes*, defined as:

- Time;
- Cost;
- Quality;
- Productivity.

The model is defined by considering a set of KPIs related to the Transportation and Distribution Activities. The logical framework of the model is shown in Figure 5.39. Each attribute includes different performance metrics (as reported in Figure 5.39).

Figure 5.39. Framework to assess supply chain performance: performance attributes and related metrics

5.3. Key performance indicators: the model components

The components of the model are described in the following sub-sections.

5.3.1. Delivery & Transportation Cost/Financial Performance Indicators (D&TCPIs)

Delivery and transportation cost and financial metrics include total transportation and delivery costs. If transportation and delivery are outsourced, the firm can avoid all the costs related to fleet and drivers management (e.g. fuel, fleet leasing, maintenance, insurance, driver payroll, etc.); it can be actually said that they are included into the transportation and delivery cost born by the logistics/transport operator per order delivered (costs depend on the amount of goods delivered, the distance to be travelled and the shipping company who makes the delivery).

D&TCPIs can be calculated as the sum of costs related to the transportation of goods from the production site to the firm warehouses added to costs related to the distribution of goods to the customers. In the last years, research in SCM has widely been dedicated to the definition and design of an efficient and cost effective distribution system (Gunasekaran et al., 2004). For this reason, to better evaluate the delivery system performance, the analysis of the total transportation cost is essential (Gunasekaran et al., 2004); in fact, it is worth noting that more than half of total logistics cost is represented by transportation cost (Griffin, 1996).

The model proposed in this chapter considers three cost-related measures:

- **C1**, which is the cost suffered by the firm to deliver the goods associated to a specific order from the warehouse of the firm to the depot of the customer; it is expressed in Euros per order;
- **C2**, which is the cost suffered by the firm to transport goods associated to a specific order from the production site to the warehouse of the firm; it is expressed in Euros per order;
- **C3**, which provides an indication of the influence that transportation and delivery costs (C1 and C2) have on the kilos delivered per order. In particular it responds to the question: "*How much T&D operations cost per each kilo delivered*"? It can be expressed in Euros per Kilo and can be calculated as follows:

$$\mathbf{C3} = \frac{(C1 + C2)}{Kg} \qquad \mathbf{[€/Kg]} \qquad (1)$$

Of course, the lower C1, C2 and C3 are, the better transportation&delivery performance is.

Also, the cost of return from customers C4 can be considered. It can be considered as follows:

- C4=0 if no goods are returned;
- C4>0 if goods are returned; it assumed the same value of C1/Kg delivered in the previous order/the kilos of goods returned.

However, C4 is not included in the model proposed.

5.3.2. Delivery & Transportation Time Performance Indicators

Time is very important in the management of the supply chain. In fact, within transportation and logistics activities, time literally represents money. Metrics related to the cycle time are widely used to evaluate transportation performance (Frazelle, 2002). Delivery and transportation time metrics consider the whole cycle time related to transportation and delivery operations. An example of the total logistics cycle time is provided in Figure 5.40.

In particular, the most important indicator related to time is the *"lead time"*, which is not strictly related to the transportation and delivery time, but, according to Heydari et al. (2016), it otherwise can be defined as: "*the duration between placing an order and receiving it*".

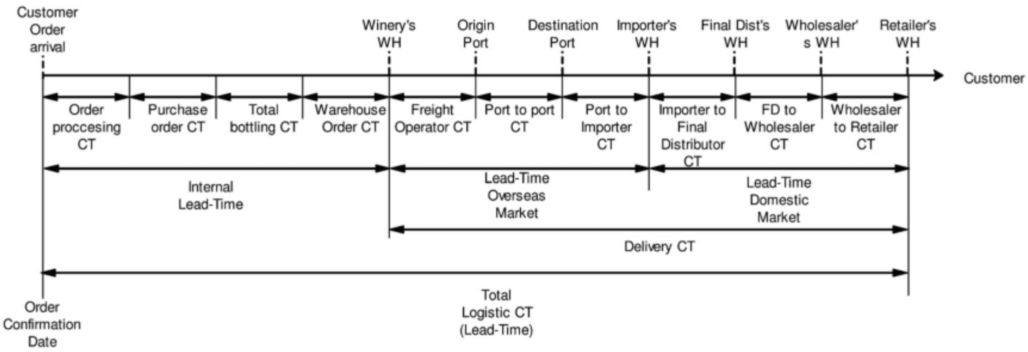

Figure 5.40. Example of the times that compose a wine-supply-chain lead time (Garcia et al., 2012)

This duration is due to the times related to all the SC activities associated to the specific order, such as order preparation time, queue time, processing time, move or transportation time, and receiving and inspection time. Thus, within the SC context, lead time can be considered as the time between the moment when an order is collected by the firm and the moment when goods ordered are received by the customer. According to Stewart (1995) and Gunasekaran et al. (2004) delivery performance benefits from the reduction of lead time.

The model proposed in this chapter considers three time-related indicators, all expressed in terms of hours per order:

- **T1**, which is the period of time from the moment the order is received by the firm and the moment the goods ordered arrive to the warehouse of the firm;
- **T2**, which is the time of storage in the warehouse of the firm;
- **T3**, which is the period of time from the moment the goods ordered by a customer leave the warehouse of the firm and the moment those goods arrive to the depot of the customer.

Of course, the lower T1, T2 and T3 values are, the better transportation and/or delivery performance is.

5.3.3. Delivery & Transportation Quality Performance Indicators (D&TQPIs)

Quality is related to all supply chain process, including: supply, production, warehousing, distribution and customer care. It is usually associated to the quality of the product delivered, but it can also relates to the quality of the processes and services provided. In fact, measuring the quality performance of logistics processes and products allows improving these processes and at the same time insure the customer's satisfaction level.

The model includes three quality-related measures; the first one (CSI) is related to customer satisfaction. It can be considered a first level indicator and it can consider satisfaction with different SC areas (e.g. timeliness, delivery time, delivery frequency, safety of delivery, etc.); the second one is related to the product delivered; in particular, it considers how logistics and transportation times influence the "remaining life" of the product (the longer are these times, the worse the system is performing); the third quality indicator is related to the logistics operations; in particular, it considers the number of breaking suffered by the load, because as higher is the number of breaking, the higher is the probability to enlarge the lead time and to damage the product delivered. The last indicator:

- **CSI**, which is the customer satisfaction index; it is a dimensionless measure, because it is based on a judgment expressed by customers about the quality of the service provided by the company. According to Paddeu et al. (2016), satisfied customers buy more often, generate a higher value of orders and can procure new customers. A businessman should understand the quality experience of his customers to be successful and he is able to do this by listening to his customers. Morfoulaki et al. (2010) terms customer satisfaction as '…the overall level of attainment of a customer's expectations…' adding that '…it is measured as the percentage of customer expectations which has actually been fulfilled'.

  Just because "happy and satisfied customers are of the utmost importance" (Gunasekaran et al., 2004), delivery needs to be well performed. In fact, customer satisfaction strongly depends on the delivery performance, because delivery represents the link between a company and its customers. This is the reason why supply chain performance assessment should consider metrics that measure customer satisfaction. Of course, high values of CSI correspond to good transportation/delivery performance. This thesis considers the formulation of the CSI provided by Paddeu et al. (2016), the CSI_{mod}, which is based on the CSI calculation proposed by Bhave (2002). CSI_{mod} is a quantitative indicator that places greater emphasis on the low scores of the responses' scale (scores that indicate users dissatisfaction). This formulation allows highlighting those areas in the service that leave rooms for improvement. It can be expressed as follows:

$$\boldsymbol{CSImod = A * \frac{1}{q} * \frac{1}{n} * \sum_{j=1}^{q} \sum_{i=1}^{n} xij * \frac{wj}{wj'} * \alpha mod} \qquad \text{[-]} \qquad (2)$$

Where:

A – 10 (scale 1–10);
n – Number of interviewees;
q – Number of parameters;
x_{ij} *– Score given by the interviewee i to the parameter j;*
w_j *– Weight assigned to the parameter j;*
$w_{j'}$ *– Average weight, being* $wj' = \sum_{j=1}^{q} \frac{wj}{q}$
α_{mod} *– Response weighting coefficient, being* $\alpha mod = \frac{xij}{5}$

The presence of α_{mod} allows highlighting the most problematic areas in terms of customer dissatisfaction. The extreme values of the scale are determinant in the increasing/decreasing process; in fact if the customer is very satisfied and gives a score of 10 to a specific service area, this score has double the value in the CSI determination process (score =10 means double the CSI value - α_{mod} = 2). At the same time, if the customer is totally dissatisfied and rates a specific service area as 1, this score converts the CSI value to one-fifth, thus drastically reducing the overall value; in this way CSI_{mod} makes it possible to highlight which areas are perceived as the worst, placing more emphasis thereon and thus making them immediately recognizable (α_{mod} = 1/5).

- **EL**, which is the "*Expired Life*" with respect to the shelf life of the products delivered; the shelf life depends on the freshness of the product and can be defined as: "*the period during which a good remains effective and free from deterioration, and thus saleable*" (www.businessdictionary.com). It can be expressed in terms of hours; the EL, instead, can be considered as the period of life of the product that is spent before the customer receives the product ordered (it is the exactly time-expired within the SC nodes and arcs that come before the customer). It represents the percentage of the product life that is already worn out when the product arrives to the customer. It is dimensionless and can be calculated as follows:

$$\mathbf{EL} = \frac{\mathbf{D\&TTPI}}{\boldsymbol{SL}} \qquad \textbf{[-]} \qquad (3)$$

The value of EL is expected to be bigger (so more relevant) for fresh products, due to their shorter shelf life.

- **LB**, which, considering a generic order indicates the number of breaking load, suffered from the delivery. The higher the number of load breaking is, the higher the probability to damage goods to be delivered is (especially for perishable goods). Also, breaking load imply longer lead times (and of course higher costs for the logistics operators who manage the delivery). For these reasons, if the value of LB is low, the delivery performance is good; in general the best scenario considers LB equal to zero.

$$\mathbf{LB} \qquad \textbf{[-]} \qquad (4)$$

- **RP**, which is the returned products percentage; it provides an indication of the amount of products returned (for example, because of packaging damages, quality of product deterioration, etc.) with respect to the total goods sold. Considering a generic order i, RP relates the amount of goods delivered to customer j (A_{ij}) to the amount of goods the customer decides to accept (not returned) (A_n);

$$\mathbf{RP} = \sum_{i=1}^{n} \sum_{j=1}^{m} A_{ij} - A_n \qquad \textbf{[\%]} \qquad (5)$$

5.3.4. Delivery & Transportation Productivity Performance Indicators (D&TPPI)

Usually, productivity-related measures include indicators related to the efficiency of the resources usage, such as resources utilization percentage. It can refers to vehicles, warehouse space, production machines utilization, requirements fill percentage and so on. It can refers to every activity and process performed along the SC. However, with this model it was decided to consider indicators related to the demand performance: is the system working well in order to satisfy the demand? For this reason, the model proposed considers three Delivery and Transportation Productivity Metrics expressed in terms of *demand* satisfaction. The first one considers the order performance, that is the variability of the demand with respect to the average delivery size. The second indicator relates costs and times related to a specific order; it allows understanding if delivery cost is befitting delivery time. The last indicator is similar to the first one, being an indicator related to demand variability. However, in this case it is measured by considering the variability of delivery size with respect to the previous order. D&TPPIs can be defined as follows:

- **P1**, which, considering a generic order i, relates the amount of goods delivered to customer j (A_{ij}) to the amount of goods delivered on average to the same customer (A_j); A_{ij} is calculated by considering the whole deliveries made to customer j. P1 is dimensionless because both numerator and denominator are expressed in terms of kilos. It can be calculated as follows:

$$\mathbf{P1} = \sum_{i=1}^{n} \sum_{j=1}^{m} \frac{Aij}{Aj} \qquad \textbf{[-]} \qquad (6)$$

Where:

i=[1,…,n] indicates the order numbers
j=[1,…,m] indicates the customers

It can provide an indication on the performance of the delivery with respect to the delivery size, by comparing the latter with the average size of the delivery made to a specific customer. It essentially represents demand variability related to the average order made by each customer. The higher this indicator is, the better the delivery performance is. In fact, delivery cost also depends on the weight of the goods to be delivered, thus, the higher P1 is, the lower cost per kilo delivered is.

- **P2**, which, considering a generic order, relates costs related to the transportation and delivery (C1 + C2, which have been defined before) to the lead time (SCD&TTPI) related to a specific delivery; it can be calculated as follows:

$$\boldsymbol{P2} = \frac{C1 + C2}{SCD\&TTPI} \qquad \textbf{[€/hours]} \qquad (7)$$

  Results can be interpreted as follows:

  (1) P2 assumes high values; this is the case of high costs and short lead time. In this case probably customers are happy because of the short lead time; however, company is not satisfied due to the high costs.

  (2) P2 assumes low values; this is the case of low costs and long lead time. In this case, customers are unsatisfied because of the long lead time; however, company is satisfied because delivery costs are lower than in the previous case.

  (3) P2 assumes values very closed to zero; in this case, costs and lead time assume very similar values, so delivery cost and lead time are equilibrated. In any case, on one hand, if they are very high, both customers and company are unsatisfied; on the other hand, it is quite the opposite.

  A good or bad result interpretation depends on the objective of the company: (1) is the best result if the company aims to reduce costs; (2) is the best result if the company aims to increase customer satisfaction; (3) is never a good result!

- **P3**, which, considering a generic order, indicates the *demand variability*. It is calculated as the increase or decrease amount of goods delivered to a customer with respect to the previous delivery made to the same customer. It can be:

  (1) P3>0, if demand is increasing with respect to the previous order;

  (2) P3<0, if demand is decreasing with respect to the previous order;

  (3) P3=0, if demand is stable with respect to the previous order;

  The company of course prefers high values of P3, because they mean that sales increased.

$$\boldsymbol{P3} = A_{2j} - A_{1j} \qquad \textbf{[Kg]} \qquad (8)$$

Where:

- *A2* is the amount of goods delivered to a specific customer j during the considered delivery;
- *A1* is the amount of goods delivered to a specific customer j during the delivery that comes before the considered delivery.

5.3.5. Summary of the model components and their interrelationship

Interrelationships between the values assumed by the indicators and customer satisfaction and delivery and transportation performance of the supply chain in general (SCD&T) are provided in Table 5.15. In fact, due to the high importance assumed by customer satisfaction for the success of a company, it was decided to strongly consider customers' perceptions for the performance evaluation.

Table 5.15 can be read as: "Is Customer Satisfaction (or SCD&T performance) increasing or decreasing when KPIs grow"? Symbols can be explained as: **↑**= "*it increases*"; **↓**= "*it decreases*"; **↔**= "*it is stationary*". Having a look at Table 5.15, it is worth making the following considerations:

- Customer satisfaction and supply chain performance decrease when times grow;
- If costs are born by the company, when they increase, supply chain performance decrease, but customer satisfaction does not vary;
- High values of CSI mean high values of customer satisfaction and it is due to a well performing supply chain;
- When the value of EL is high, it means the SC is not working well in terms of times, because a great part of the life of the products is expired during logistics and transportation activities. In this case, customer satisfaction decreases and also SC performance;
- If LB grows, both customer satisfaction and supply chain performance decrease, because to a high number of load breaking corresponds a higher probability to have the product damaged and to enlarge the lead time.
- Being RP the percentage of products returned, the higher is this value, the lower is customer satisfaction and supply chain performance.

- When P2 grows, it means costs are growing and lead times are shortening. It corresponds to an increasing customer satisfaction (due to the short lead times), but at the same time supply chain performance in decreasing.
- Finally, being P1 and P3 indicators related to the demand variability, when they grow, it means customers are ordering bigger size deliveries, so they are happy with the service (and the product) provided by the company. In this case, both customer satisfaction and SC performance increase.

If the KPIs show high values…	T1 ↑	T2 ↑	T3 ↑	C1 ↑	C2 ↑	C3 ↑	CSI ↑	EL ↑	LB ↑	RP ↑	P1 ↑	P2 ↑	P3 ↑
Customer Satisfaction	↓	↓	↓	↔	↔	↔	↑	↓	↓	↓	↑	↑	↑
SCD&T Performance	↓	↓	↓	↓	↓	↓	↑	↓	↓	↓	↓	↓	↑

Table 5.15. Interrelationships between SC performance indicators and Customers Satisfaction and SCD&T Performance (Legend: ↑= "it increases"; ↓= "it decreases"; ↔= "it is stationary").

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Chapter 6
Application to the supply chain
A case study approach

Introduction

This chapter provides the description of the application of the model proposed in Chapter 5 to the supply chain, whereas the application to the urban environment is presented in Chapter 8. A case study approach (Eisenhardt, 1989) is adopted in order to test the theoretical model for both cases.

In order to test the model applied to the supply chain environment, a case study involving a company belonging to the agrifood sector was involved in the study. Its market is domestic and international. The managers of the company supported and collaborated to the development of this study, by participating to several surveys and make data available for scientific purpose.

The chapter provides a description of the case study, which includes the introduction and description of the company and the analysis of the scheme of its supply chain. A description of the survey design and of data collection is provided. Then, the model proposed in chapter 4 is applied to the case study. Correlation analysis allows analysing the relationships internal to the model (among the indicators). A cluster analysis is performed in order to analyse the relationships among groups of variables (clusters). Principal Component Analysis (PCA) and linear multiple regression analysis are performed. The analysis aims to discover the interdependencies among the indicators and highlight the variables that are the most important to describe the phenomenon.

6.1. Description of the company

The company surveyed is Argiolas Formaggi and it belongs to the cheese industry. It is strong in the production of typical Sardinian cheese, made by local goat and sheep milk. The headquarter is based in Sardinia, where there is a production area of 10,000 square meters, able to process about 20 million litres of milk per year and to produce about 4 million kilograms of finished product. The production staff includes about 40 permanent and between 15 and 20 seasonal employees.

Figure 6.41. Representation of the domestic market per Italian region. The bigger is the circle, the higher is the volume of goods sold in the specific region

Figure 6.42. Representation of the path followed by the transport operator, who transports the load from the headquarter to the distribution centre (DC) in the Northern Italy

The company also has got an own distribution centre in the Northern Italy. Its market is mainly domestic, but about 15-20 percent of sales is made abroad. The Countries where the company exports are, in order of importance, the following: Japan, Germany, Croatia, Slovenia, Slovakia, England, Scandinavia, France, the United States, Canada, Australia, United Arab Emirates. Sixty-percent of customers belong to the large-scale retail trade (i.e. supermarkets), whereas forty-percent is represented by wholesalers.

Products sold are those of the ancient Sardinian dairy tradition made by the highest hygienic and technological standards. An advanced internal laboratory works to guarantee absolute certainty for product safety, by monitoring each phase of the production. The company is also equipped with a control system H.A.C.C.P. and was the first dairy company in Sardinia to obtain ISO 9001 certification in 1997. Traditional products are certified UNI EN ISO 22000: 2005 and BRC, while organic products are certified by ICEA.

6.2. Logistics and transport activities

Thanks to several questionnaires and interviews, it was possible to describe the logistics and transport activities performed and to define the supply chain of the company (Figure 6.43). Goods distribution is totally outsourced. Two or three times a week, a full load articulated vehicle leaves the production site of the company (in Sardinia) and deliver to the DC in the Northern Italy. Except for customers located in Sardinia, deliveries to the Italian and foreign customers are managed directly by the DC.

The company has three types of delivery policy (Figure 6.43):

1. Deliveries made to the multiple-retailer chain: the logistics operator collects goods at the DC of the company and transports them to its own depot (Figure 6.43); then, goods are delivered to the local depot of the multiple-retailer chain (7.1), which is in charge for the deliveries to each supermarket (8).
2. Deliveries made to wholesalers: the logistics operator collects goods at the DC of the company and transports them to its own depot (Figure 6.43); then, goods are delivered to the depot of the wholesaler (7.1), who is in charge for the deliveries to his own customers (8). For the last part of the chain, deliveries are usually made by smaller local logistics operators.
3. Deliveries made to foreign customers: the company pays for the transport made only into the national borders, thus foreign customers have to pay for the remaining part of the transport journey. Usually, for international deliveries, the logistics operator collects goods at the DC of the company and transports them to its own depot (Figure 6.436.3); then, goods are delivered to the depot of the foreign customer and delivered to its own customers (8). For the last part of the chain, deliveries are usually made by smaller local logistics operators. However, some foreign customers prefer to directly collect the products at the DC of the company.

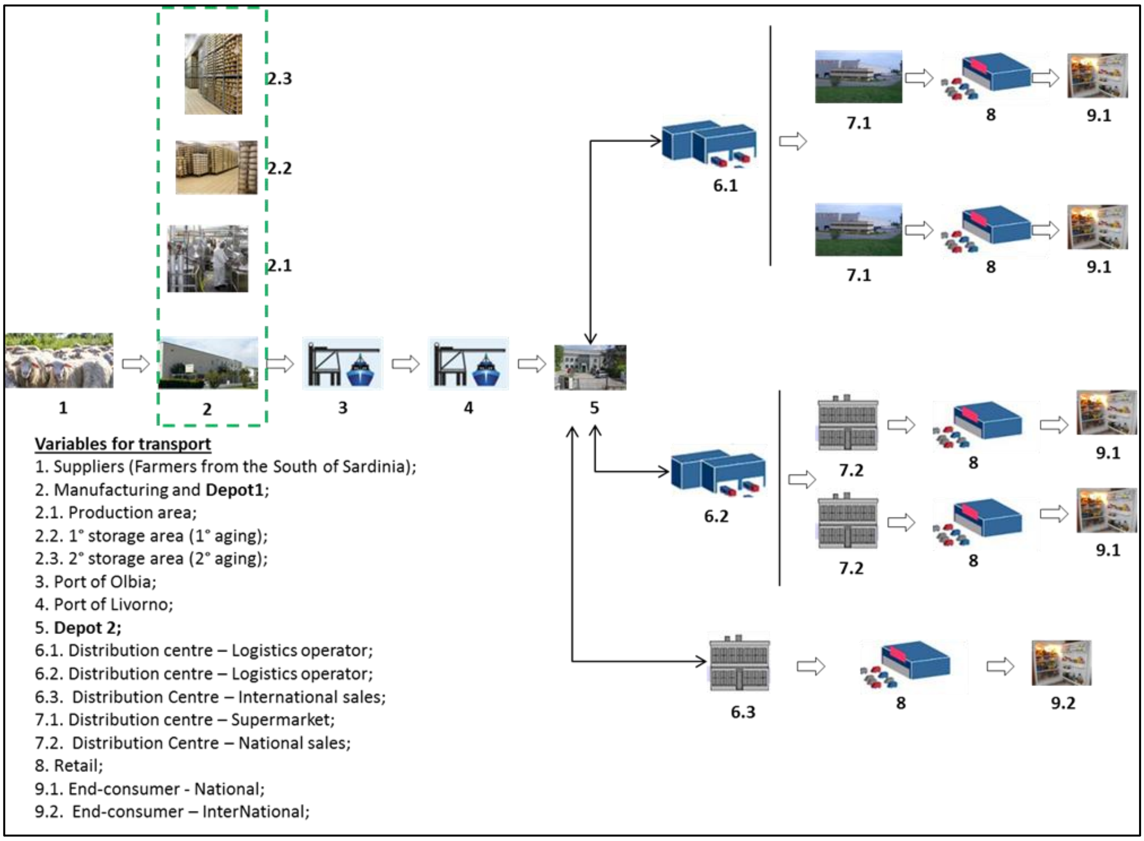


Figure 6.43. . Representation of the supply chain of the surveyed company

6.3. Methodological approach

This section introduces the methodology used to define and test the new model. Data are analysed by considering the following steps:

1. Construction of the dataset;
2. Analysis of the relationships among variables by means of Chi square analysis (categorical variables) and Pearson's coefficient (quantitative variables);
3. Cluster analysis;
4. Factorial analysis (PCA);
5. Estimation of the relations with linear regression.

6.4. Data selection and database construction

The dataset was built by considering:

- Orders received and fulfilled in period of one year, from January 2015 to December 2015;

- A sample of customers that: (i) is homogeneous in terms of geographical location (mixed from Italy and from abroad); (ii) includes all the most important customers in terms of revenue.

The dataset consists of a *n*X*p* matrix where:

- *n* is the number of independent observations (orders)
- *p* is the number of variables recorded for each observation

In particular, Y indicates the target variable (the continuous outcome measuring the income associated to each order) and X denotes the vector of quantitative and qualitative predictors: $X=(X_1, X_2,\dots,X_k)$.

6.4.1. The input variables

Based on the model defined in Chapter 5, the available variables that may potentially influence SC performance can be divided into five main groups:

- *time-related variables;*
- *cost-related* variables;
- *product-related variables;*
- productivity-related variables;
- quality-related variables;

6.4.2. The outcome variable

The outcome variable of the study is the performance of the SC, which is represented by the variable named "Tot_Revenue". The variable is expressed in Euros cashed per delivery.

6.4.3. Database structure

Two databases have been built. The first one contains all the information deduced by the company order management system. It consists of 656 rows (that represents the orders received by the selected customers from the 1st of January to the 31st of December 2015) and 14 columns (variables). Figure 6.44 shows the structure of the first database.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Input data															Outcome
2	Customer _name	From	Order_day _period	Order_ month	Order_day_ name	Day_customer	Batch	N_items	Sale	Final price	1_shipper	2_shipper	Kg_delivery	Shelf Life		Tot_Revenue
3	8	1	1	1	Monday	Friday	14365	152	0.183	11.77	1	0	292.632	600		2656.987
4	8	1	1	1	Thursday	Thursday	14365	152	0.183	11.77	1	0	271.442	600		2600.732
5	8	1	2	1	Monday	Friday	14365	130	0.183	11.77	1	0	307.236	600		3204.53
6	8	1	2	1	Wednesday	Thursday	14365	106	0.183	11.77	1	0	174.038	600		1746.813
7	8	1	2	1	Monday	Friday	14365	86	0.183	11.77	1	0	131.964	600		1364.235
8	8	1	3	1	Wednesday	Thursday	14367	104	0.183	11.77	1	0	178.334	600		1611.388
9	8	1	3	1	Monday	Friday	14367	44	0.183	11.77	1	0	91.116	3600		722.477
10	8	1	3	1	Wednesday	Thursday	14367	78	0.183	11.77	1	0	76.596	600		715.017

Figure 6.44. Structure of the first database

6.4.4. Data preparation

Before starting with data analysis, collected data should be prepared and transformed into the most suitable form for analysis. This is a key aspect to improve the quality of data and the quality and the reliability of the results. To this aim, data were cross checked in order to find possible error types or illogical correspondence. Moreover, outliers were removed. Missing values were not present because data were accurately entered into the database, by considering the orders provided by the company (pdf files). It is worth noting that, due to the modality by which data have been charged, a very rigorous check of data has been made during the first database construction.

6.4.4.1. Data cleaning

This step aims to correct data problems, such as missing values, extremely values, or values that are logically inconsistent in the dataset. Firstly, logical correspondence among variables was checked by cross-checking data. Secondly, outliers were removed. Missing values were not present because data were loaded by hand on the database, on the base of orders provided by the company by pdf files. It is worth noting that, due to the modality by which data have been charged, a very rigorous check of data has been made during the first database construction.

6.4.4.2. *Creation of new variables*

Based on the first database, on the literature review, on the information collected during the interviews to the company and on practical assistance of the experts, the first database has been completed by considering all the indicators defined in Chapter 5. The new database now assumes the following aspect (Figure 6.45):

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
1													Input data														Outcome
2	Customer_name	From	Order_day_period	Order_month	Order_day_name	Day_customer	Batch	N_items	Sale	Final price	1_shipper	2_shipper	Kg_delivery	Shelf Life	C1	C2	C3	EL	LB	P1	P2	P3	t1	t2	t3		Tot_Revenue
3	8	1	1	1	Monday	Friday	14365	152	0.18	11.770	1	0	292.6	600	11.705	41.642	0.020	0.170	1	1.451	0.523	0.000	72.000	6.000	24.000		2656.99
4	8	1	1	1	Thursday	Thursday	14365	152	0.18	11.770	1	0	271.4	600	10.858	38.626	0.019	0.290	1	1.346	0.284	-21.190	120.000	6.000	48.000		2600.73
5	8	1	2	1	Monday	Friday	14365	130	0.18	11.770	1	0	307.2	600	12.289	43.720	0.017	0.170	1	1.524	0.549	35.794	72.000	6.000	24.000		3204.53
6	8	1	2	1	Wednesday	Thursday	14365	106	0.18	11.770	1	0	174	600	6.962	26.280	0.019	0.330	1	0.863	0.168	-133.198	144.000	6.000	48.000		1746.81
7	8	1	2	1	Monday	Friday	14365	86	0.18	11.770	1	0	132	600	5.279	19.927	0.018	0.170	1	0.654	0.247	-42.074	72.000	6.000	24.000		1364.24
8	8	1	3	1	Wednesday	Thursday	14367	104	0.18	11.770	1	0	178.3	600	7.133	26.928	0.021	0.330	1	0.884	0.172	46.370	144.000	6.000	48.000		1611.39
9	8	1	3	1	Monday	Friday	14367	44	0.18	11.770	1	0	91.12	3600	3.645	15.101	0.026	0.028	1	0.452	0.184	-87.218	72.000	6.000	24.000		722.477
10	8	1	3	1	Wednesday	Thursday	14367	78	0.18	11.770	1	0	76.6	600	3.064	15.100	0.025	0.330	1	0.380	0.092	-14.520	144.000	6.000	48.000		715.017
11	8	1	1	2	Monday	Friday	15008	72	0.18	11.770	1	0	103.2	600	4.126	15.577	0.018	0.170	1	0.512	0.193	26.564	72.000	6.000	24.000		1109.62
12	8	1	1	2	Wednesday	Thursday	15007	70	0.18	5.166	1	0	161.9	3600	6.474	24.440	0.020	0.055	1	0.803	0.156	58.694	144.000	6.000	48.000		1548.62

Figure 6.45. Structure of the 'complete' database. Blue columns include the variables of the first database; Orange columns include performance indicators.

6.5. First-step analysis: descriptive statistics

First-step analysis concerns descriptive statistics, which was applied to describe and summarise data in a meaningful way. Depending on the characteristics of the variable, input variables can be grouped into two main groups:

- *Continuous* (or *Quantitative*) *variables*, which belong to the numerical variables group; they can theoretically take on any value within a defined range. They are generally obtained by means of an instrumental measure direct or indirect.
- *Categorical variables*, which are qualitative variables that refer to a specific class that allows the comparison only when two elements are identical (belong to the same class) or different (belong to different classes). No sort orders, or distance measurements are allowed. There is no intrinsic ordering to the categories. They can be further categorized as:
  - *Nominal variables*, which are variables that have two or more categories, but which do not have an intrinsic order.
  - *Dichotomous variables*, which are nominal variables which have only two categories or levels.
  - *Ordinal variables*, which are variables that have two or more categories just like nominal variables only the categories can also be ordered or ranked.

Based on this classification, Figure 6.41 (a) and (b) provide the description of the variables included into the 'complete' database.

Variable name	Type Of Variable Cont	Type Of Variable Cat	Description
Customer_name		x	n. of categories: 13 - 13 customers included
From		x	n. of categories: 2 - It indicates if a customer is located in Italy or abroad. It is = 1 if the customer is in Italy; it is = 0 if the customer is located abroad.
Order_day_period		x	n. of categories: 3 - It indicates the period of the month the order comes. Categories are: 1 (1^{st} to 10^{th}); 2 (11^{th} to 20^{th}); 3(20^{th} to the end of the month)
Order_month		x	n. of categories: 12 - It indicates the month the order comes. Categories are: 1 to 12 (indicating months from January to December)
Order_day_name		x	n. of categories: 7 - It indicates the day the order comes. Categories are: Monday to Sunday
Day_customer		x	n. of categories: 6 - It indicates the day goods are delivered to the customer. Categories are: Monday to Saturday
N_items	x		It indicates the number of items associated to each order. Some statistical results for this variable are: mean=209.75; max=2,160; min=0.02; st dev.=267.37
Sale	x		It indicates the sale applied to each order. Some statistical results for this variable are: mean=0.26; max=8.41; min=0.00; st dev.=0.37
Kg_delivery	x		It indicates the kilos of goods associated to each order. It is expressed in kilos. Some statistical results for this variable are: mean= 838.14; max=26,860; min=0.187; st dev.=3,048.75.
1_shipper		x	n. of categories: 4 - It indicates the shipping company who makes the delivery within the Italian borders. Categories are: 1 to 4
2_shipper		x	n. of categories: 5 - It indicates the shipping company who makes the delivery outside the Italian borders. Categories are: 1 to 5, being 5 meaning no deliveries are made by 2_shipper (this is the case of Italian customers).
SL		x	n. of categories: 7 - It indicates the shelf life of the products associated to each order. It is expressed in terms of days and it varies depending on the aging of the product. Categories are: 600 days, 720 days, 1080 days, 1800 days, 2400 days, 3600 days, 4320 days.
C1	x		It indicates the transportation cost associated to each order. It is expressed in Euros. Some statistical results for this variable are: mean= 33.52; max=1,074.4; min=0.007; st dev.=121.95.
C2	x		It indicates the delivery cost associated to each order. It is expressed in Euros. Some statistical results for this variable are: mean= 27.32; max=245.28; min=0.00; st dev.=29.71.
C3	x		It indicates the transportation cost associated to each kilo delivered. It is expressed in Euros per kilo. Some statistical results for this variable are: mean= 0.02; max=1.11; min=0.00; st dev.=0.04.
EL	x		It indicates the period of the product life-time expired during logistics and transportation activities. Some statistical results for this variable are: mean= 0.09; max=0.41; min=0.03; st dev.=0.07.
LB		x	n. of categories: 2 - It indicates the number of breaks suffered by the load. Categories are: 1 and 2 representing the number of breaks suffered by the load.
P1	x		It indicates the demand variability with respect to the average delivery size. Some statistical results for this variable are: mean= 1.00; max=7.54; min=0.001; st dev.=0.66.

Table 6.16. Description of the variables included into the 'complete' database (a)

Variable name	Type of Variable Cont	Cat	Description
P2	x		It relates the total delivery and transportation cost to the lead time. Some statistical results for this variable are: mean= 0.27; max=3.08; min=0.00; st dev.=0.26.
P3	x		It indicates the demand variability with respect to the previous delivery. Some statistical results for this variable are: mean= 1.16; max=5,141.79; min=-7,157.18; st dev.=696.27.
T1		x	n. of categories: 5 – It indicates the period of time from the moment the order is received by the firm and the moment the goods ordered arrive to the warehouse of the firm. Categories are: 72 hours, 96 hours, 120 hours, 144 hours, 168 hours.
T2		x	n. of categories: 5 – It indicates the time of storage in the warehouse of the firm. Categories are: 72 hours, 96 hours, 120 hours, 144 hours, 168 hours.
T3		x	n. of categories: 9 – It indicates the period of time from the moment the goods ordered by a customer leave the warehouse of the firm and the moment those goods arrive to the depot of the customer. Categories are: 24 hours, 48 hours, 49 hours, 72 hours, 73 hours, 96 hours, 144 hours, 744 hours, 792 hours.

Table 6.17. Description of the variables included into the 'complete' database (b)

6.6. Second-step analysis: relationships among variables

Second-step analysis concerns the study of the relationships among variables. To this aim, correlation analysis is carried out in order to highlight the relationships among variables and identify the variables that are strongly related to each others. A chi-square test is used to determine whether an association (or relationship) between 2 categorical variables in a sample is likely to reflect a real association between these 2 variables in the population.

6.6.1. Relationships among categorical variables: Tests of Independence (Chi-Square)

The chi-square test of independence is used to determine whether there is a relationship between two categorical variables. Two random variables x and y are called independent if the probability distribution of one variable is not affected by the presence of another.

Assume fij is the observed frequency count of events belonging to both i-th category of x and j-th category of y. Also assume eij to be the corresponding expected count if x and y are independent.

$$\chi^2 = \sum_{i,j} \frac{\left(f_{ij} - e_{ij}\right)^2}{e_{ij}} \tag{9}$$

In order to determine whether there is enough evidence to reject the hypothesis of independence, the significance value of the statistic is computed. The significance value is the probability that a random variate drawn from a chi-square distribution with a specific number of degrees of freedom is greater than the chi-square value. If this value is less than the alpha level specified on the Test Statistics tab (alpha=0.05), the hypothesis of independence can be rejected at the 0.05 level. In this case, *x* and *y* are related. Data have been analysed by means of SPSS IBM, software to perform statistics analysis. A larger chi-square statistic indicates a greater discrepancy between the observed and expected cell counts.

6.6.2. Analysis of the results of the tests of Independence - Chi-Square

The results of the tests of Independence (Chi-Square) are showed in Table 6.18 (see also APPENDIX 3). The analysis showed there is a relation among the variables highlighted with X. Results can be summarised as follows:

- Time-related variables: T3 is related to T2 and T1 and it makes sense, because it is the sum of T1 and T2. Also, t2 resulted being related to T1. It is also related to SL and LB.
- Quality-related variables: SL is related to T3, but also to Order_day_name, Day_customer and From; exactly as SL, also LB is related to t3, Order_day_name, Day_customer and From;
- Other orders' variables: Order_day_period and Order_day_month are totally independent to any other variable; Order_day_name and Day_customer are related to all the other variables except for Order_day_period and order_day_month; From is related to all the other variables except for T1, T2, Order_day_period and order_day_month;

Based on the results, it was decided to consider the following variables for the next step analysis:

- T3;
- Order_day_period;

- Order_day_month.

	Chi - Square									
	T1*	**T2***	**T3**	**SL***	**LB***	**Order_day_per**	**Order_day_mon**	**Order_day_n***	**From***	**Day_Customer***
T1*										
T2*	X									
T3	X	X								
SL*			X							
LB*			X							
Order_day_per										
Order_day_mon										
Order_day_n*	X	X	X	X	X					
From*			X	X	X			X		
Day_Customer*	X	X	X	X	X			X	X	

Table 6.18. Analysis of relationships between categorical variables - X corresponds to correlation between the correspondent couple of variables; variables with * are excluded by the next step analysis

6.6.3. Relationships among continuous variables: Pearson's correlation coefficient

The linear relationship among quantitative continuous variables has been analysed by means of the Pearson's correlation coefficient (r). It can ranges from -1 (which indicates a perfect negative linear relationship) to +1 (which indicates a perfect positive linear relationship between variables). There is no linear relationship between variables if the coefficient is equal to zero. It can be formulated as follows:

$$r = \frac{N \sum xy - \sum(x)(y)}{\sqrt{[N \sum x^2 - \sum(x^2)]\,[N \sum y^2 - \sum(y^2)]}} \tag{10}$$

Where:

r = Pearson r correlation coefficient
N = number of value in each data set
$\sum xy$ = sum of the products of paired scores
$\sum x$ = sum of x scores
$\sum y$ = sum of y scores
$\sum x^2$ = sum of squared x scores
$\sum y^2$ = sum of squared y scores

6.6.4. *Analysis of the results of the correlation analysis – Pearson's correlation coefficient*

The results of the correlation analysis (Pearson's correlation coefficient) are showed in Figure 6.44 (see also APPENDIX 3). The analysis showed there is a relation among the variables highlighted with X. Results can be summarised as follows:

- Cost-related variables: C1 is related to N_items and Kg_delivery; it makes sense, because it depends on the distance travelled by the logistics operator and on the kilos delivered. Also, C2 resulted being related to N_items. In fact, C2 also depends on the delivery size, which, in the case of cheese corresponds to the amount of kilos delivered. C3 is not related to any other variable. Also, there is a medium correspondence between C1 and P2 (0.514) and between C1 and N_items (0.504).
- Quality-related variables: EL is not related to any other variables;
- Productivity related variables: P2 and P1 are related to each other (0.707). P3 is not related to any other variables.
- Other variables: Kg_delivery is high related to C1 (1.000) and less related to P2 (0.514) and N_items (0.504). N_items is high related to C2 (1.000) and less related to C1 (0.504), P1 (0.526) and Kg_delivery (0.504). Sale is not related to any other variables.

	Correlations									
	C1	**C2**	**C3**	**EL**	**P1**	**P2***	**P3**	**kg_delivery***	**N_items***	**Sale**
C1										
C2										
C3										
EL										
P1										
P2*	X				X					
P3										
kg_delivery*	X					X				
N_items*	X	X			X	X		X		
Sale										

Table 6.19. Analysis of relationships between continuous variables - X corresponds to correlation between the correspondent couple of variables; variables with * are excluded by the next step analysis

Based on the results, it was decided to consider the following variables for the next step analysis:

- C1;
- C2;
- C3;
- EL;
- P1;

- P3;
- Sale.

6.7. Third-step analysis: Cluster analysis

6.7.1. Description of the methodology

Cluster Analysis is an exploratory tool designed to reveal natural groupings (or clusters) within data. It allows forming clusters of individuals who have similar characteristics or behaviour. I decided to use cluster analysis in order to split data in groups of orders that are similar to each other.

Different methodologies to develop a cluster analysis exist:

- Two-step cluster analysis; when data file is very big (even 1,000 cases is large for clustering) or it includes a mixture of continuous and categorical variables;
- Hierarchical clustering; when the data set is small and the analyst wants to examine solutions with increasing numbers of clusters.
- *K-means* clustering; when the data set is moderately sized and the analyst knows how many clusters he/she wants.

Based on the characteristics of the dataset, the Two-step cluster analysis procedure was selected as the most suitable. The algorithm employed by this procedure has several desirable features that differentiate it from traditional clustering techniques:

- The ability to create clusters based on both categorical and continuous variables;
- Automatic selection of the number of clusters;
- The ability to analyze large data files efficiently.

In order to handle categorical and continuous variables, the Two-Step Cluster Analysis procedure uses a likelihood distance measure which assumes that variables in the cluster model are independent. The procedure's algorithm can be summarized as follows:

- *Step 1*. The procedure begins with the construction of a Cluster Features (CF) Tree. The tree begins by placing the first case at the root of the tree in a leaf node that contains variable information about that case. Each successive case is then added to an existing node or forms a new node, based upon its similarity to existing nodes and using the distance measure as the similarity criterion. A node that contains multiple cases contains a summary of variable information about those cases. Thus, the CF tree provides a capsule summary of the data file.

- *Step 2*. The leaf nodes of the CF tree are then grouped using an agglomerative clustering algorithm. The agglomerative clustering can be used to produce a range of solutions. To determine which number of clusters is "best", each of these cluster solutions is compared using Schwarz's Bayesian Criterion (BIC) or the Akaike Information Criterion (AIC) as the clustering criterion.

6.7.2. Results of the two-step cluster analysis

Data have been analysed by means of SPSS IBM, software to perform statistics analysis. Based on the results of the chi-square test of independence and of the correlation analysis (Pearson), the cluster analysis was developed by considering the following variables:

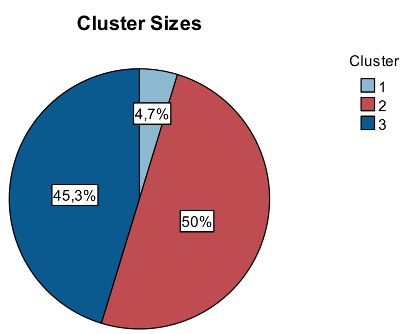
- T3;
- C1;
- C2;
- C3;
- EL;
- P1;
- P3;
- Sale.

The analysis identified 3 different clusters (Figure 6.45). The description of the characterization of each cluster is provided below and in APPENDIX 3:

1. *Cluster 1*, 4.7%. It is the smallest one; it is characterized by orders with the goods ordered delivered to the customer (from the warehouse of the firm) in 72 hours (t3 = 72) with an average related transportation cost of 9.59 and an average delivery cost C2 of 41.76 Euros per delivery. The majority of the orders belonging to this cluster are characterized by an expired life equal to 12% (average EL = 0.12), an average P1 of 1.000 and an average P3

equal to 3.04. The average C3 is 0.030; orders belonging to this cluster are subject to an average discount of price equal to 32% (Sale = 0.32).

2. *Cluster 2*, 50.0%. It is the biggest one; it is characterized by orders with the goods ordered delivered to the customer (from the warehouse of the firm) in 24 hours (t3 = 24) with an average related transportation cost of 21.49 and an average delivery cost C2 of 15.78 Euros per delivery. The majority of the orders belonging to this cluster are characterized by an expired life equal to 6% (average EL = 0.06), an average P1 of 0.900 and an average P3 equal to -20.34. The average C3 is 0.010;orders belonging to this cluster are subject to an average discount of price equal to 20% (Sale = 0.20).
3. *Cluster 3*, 45.3%. It is the medium one. It is characterized by orders with the goods ordered delivered to the customer (from the warehouse of the firm) in 24 hours (t3 = 24) with a high related transportation cost (average of 390.17 Euros per order) and an average delivery cost C2 of 11.08 Euros. The majority of the orders belonging to this cluster are characterized by an expired life equal to 10% (average EL = 0.10), an average P1 of 2.070 and an average P3 equal to 210.47. The average C3 is 0.040; orders belonging to this cluster are subject to an average discount of price equal to 31% (Sale = 0.31).



Size of Smallest Cluster	31 (4,7%)
Size of Largest Cluster	328 (50%)
Ratio of Sizes: Largest Cluster to Smallest Cluster	10,58

Figure 6.20. Cluster analysis: cluster dimensions

The most important predictor in the cluster analysis is T3, which is the time needed to deliver goods from the warehouse of the company to the customer’s depot. This is followed by the transportation cost to transport goods from the production site to the warehouse of the company (C1) and by the delivery cost born to transport goods from the warehouse of the firm to the customer’s depot. The fourth most important predictor is represented by a quality indicator that indicates the percentage of life expired during logistics and transportation activities. It is followed by a productivity indicator (P1), which is an expression of demand variability. Less important predictor for cluster analysis are C3, Sale and P3.

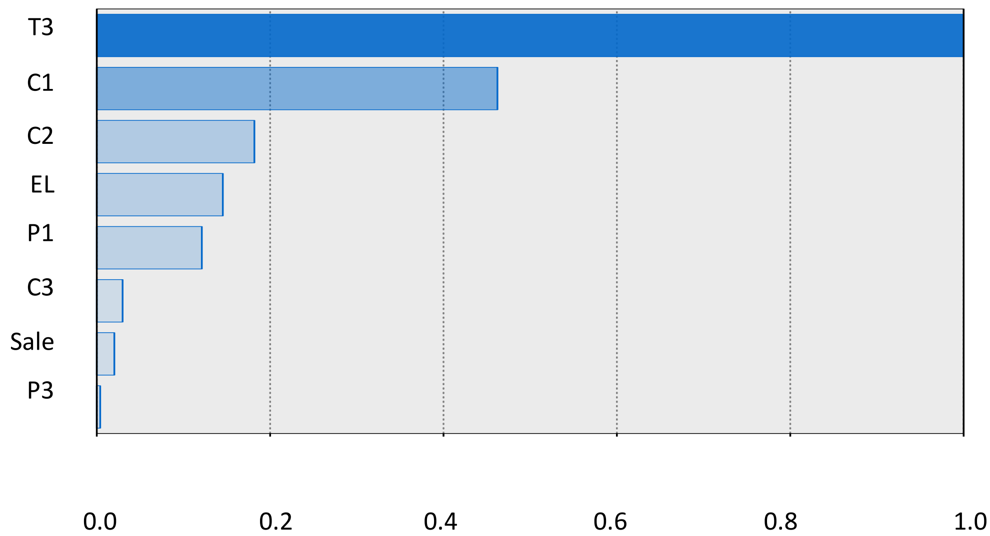


Figure 6.46. Cluster analysis: predictor importance

In sum, the cluster analysis highlighted three different clusters, characterised mainly by delivery size (and transport cost C1) and delivery time as follows:

- The smallest one (cluster 1) includes all orders characterised by high amount of goods (it can be deduced by the average value of C1) delivered to customers located close to the warehouse of the company (t3 = 24h) but also very far (t3 = more than 740h).
- The medium one (cluster 3) includes all orders characterised by not big size and delivered to the customers between 48 and 144 hours.
- The biggest one (cluster 2) includes all orders characterized by small size (average C1 = 0.01) and very short delivery time (24h).

6.8. Considering new variables

A cost related variable and a time related variable were included into the input variables in order to better explain the model. They can be described as follows:

- 1 time-related variable, lead time, which corresponds to the sum of all the times associated to the delivery (lead time = T1+ T2+ T3);

- 1-cost related variable, C_tot, which corresponds to the total cost born by the company for the delivery (C_tot=C1+C2).

6.9. Dimension reduction

Due to the high number of variables defined to carry out the analysis, a Principal Component Analysis (PCA) for quantitative variables was performed in order to reduce the dimension of the input database, without losing a large quantity of information.

6.9.1. Principal Component analysis (PCA)

6.9.1.1. Description of methodology

Principal component analysis (PCA) is a statistical technique used to emphasize variation and bring out strong patterns in a dataset. According to Smith (2002), PCA aims at identifying patterns in data, and at expressing the data in order to highlight their similarities and differences. Since patterns in data can be hard to find in data of high dimension, where the luxury of graphical representation is not available, PCA is a powerful tool for analysing data. The other main advantage of PCA is that once patterns are defined, data dimension is reduced, without much loss of information. PCA allows making a linear combination of the considered variables by ranking them depending on the importance of the information they provide. The first component of PCA is that providing the most of the information coming from the original input data. The following components complete the remaining information. PCA allows reducing the number of variables and providing a lower number of variables by a liner transformation of the observed variables.

6.9.1.2. Results of PCA

The variance explained by the initial solution, extracted components, and rotated components is displayed in Table 6.21. This first section of the table shows the Initial Eigenvalues. The Total column gives the eigenvalue, or amount of variance in the original variables accounted for by each component. The % of Variance column gives the ratio, expressed as a percentage, of the variance accounted for by each component to the total variance in all of the variables. The Cumulative % column gives the percentage of variance accounted for by the first n components. For example, the cumulative percentage for the second component (55.100) is the sum of the percentage of variance for the first and second components. For the initial solution eigenvalues greater than 1 were extracted, so the first three principal components form the extracted solution.

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.108	37.346	37.346	4.108	37.346	37.346	3.392	30.837	30.837
2	1.953	17.754	55.100	1.953	17.754	55.100	2.608	23.709	54.546
3	1.416	12.869	67.969	1.416	12.869	67.969	1.476	13.422	67.969
4	0.942	8.563	76.532						
5	0.896	8.147	84.679						
6	0.796	7.236	91.916						
7	0.438	3.986	95.901						
8	0.326	2.967	98.868						
9	0.124	1.132	100.000						
10	3.601E-12	3.273E-11	100.000						
11	1.480E-15	1.345E-14	100.000						

Extraction Method: Principal Component Analysis.

Table 6.21. Total Variance Explained

The first three components explain 67.97% of the variability in the original ten variables, which can be considered statistically significant and can considerably reduce the complexity of the data set by using these components, with only a 32% loss of information. In particular, the first component explains 37.35% of variance, the second component explains 17.75% of variance and the third component explains 12.86% of variance.

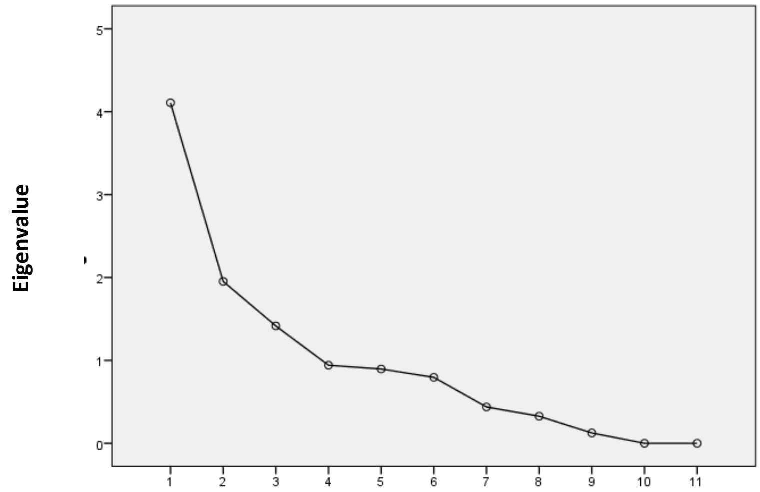
	Components		
	1	2	3
N_items	0.779	0.228	-0.292
Sale	-0.164	0.198	0.452
Kg_delivery	0.871	-0.461	0.082
EL	0.149	-0.115	0.608
P1	0.534	0.695	-0.119
P2	0.832	0.413	-0.010
P3	0.369	0.562	-0.238
C1	0.871	-0.461	0.082
C2	0.092	0.576	0.610
C3	-0.074	0.137	0.495
C_tot	0.899	-0.323	0.232

Table 6.22. Matrix of component

If the matrix of component is considered (Table 6.22), each component is characterized as follows:

1. Component 1 is characterized by cost (C_tot = 0.899);
2. Component 2 is characterized by productivity (P1 = 0.695);

3. Component 3 is characterized by quality (EL = 0.608).



Component Number

Figure 6.47. Scree-plot

The rotation maintains the cumulative percentage of variation explained by the extracted components, but that variation is spread more evenly over the components. However, there are no many differences between the results of rotated and un-rotated matrixes. If the scree-plot is considered to determine the optimal number of components, it is worth noting that the last big drop occurs between the third and fourth components, so using the first three components is a good choice.

For each case and each component, the component score is computed by multiplying the case's standardized variable values (computed using listwise deletion) by the component's score coefficients. The resulting three component score variables are representative of, and can be used in place of, the ten original variables with only a 32% loss of information.

Using the saved components is also preferable to using *C_tot, P1 and EL* because the components are representative of all ten original variables, and the components are not linearly correlated with each other. The linear correlation between the components is guaranteed to be 0.

The relationship between factors and variables can be expressed as follows:

$$F1 = 0.779\ N_{items} - 0.164\ Sale + 0.871\ Kg_{delivery} + 0.149\ EL + 0.534\ P1 + 0.832\ P2 + 0.369\ P3 + 0.871\ C1 + 0.092\ C2 - 0.074\ C3 + 0.899\ C\_tot$$

$$F2 = 0.228\ N_{items} + 0.198\ Sale - 0.461\ Kg_{delivery} - 0.115\ EL + 0.695\ P1 + 0.413\ P2 + 0.562\ P3 - 0.461\ C1 + 0.576\ C2 + 0.137\ C3 - 0.323\ C_{tot}$$

$$F3 = -0.292\ N_{items} + 0.452\ Sale + 0.082\ Kg_{delivery} + 0.608\ EL - 0.119\ P1 - 0.010\ P2 - 0.238\ P3 + 0.082\ C1 + 0.610\ C2 + 0.495\ C3 + 0.232\ C\_tot$$

6.10. Linear regression

6.10.1. Description of methodology

According to Gujarati (2012), "*regression analysis is concerned with the study of the dependence of one variable, the dependent variable, on one or more other variables, the explanatory variables, with a view to estimating and/or predicting the (population) mean or average value of the former in terms of the known or fixed (in repeated sampling) values of the latter*". As the independent variables are more then 1, a multiple regression analysis was considered, because it is "*regression analysis conditional upon the fixed values of the regressors, and what we obtain is the average or mean value of Y or the mean response of Y for the given values of the regressors*" (Gujarati, 2012).

6.10.2. Why multiple regression analysis?

The choice of using the linear regression model is due both to its ease in representing the correlation between variables involved in the process and the clarity with which its results can be read (Paddeu et al., 2014). The aim of this section is to estimate (if any) the correlation between variables related to the orders (including KPIs) and the income associated to each order delivered. The proposed model is based on a multiple linear regression model with k=10 independent variables, by means of which the correspondences between dependent and independent variables are analysed. To this aim, the total revenue (Tot_Revenue) associated to each order was chosen as dependent variable and the variables selected in the previous sections as independent variables.

Constant was excluded from the model, because income is achieved only if a delivery is performed. The model is linear because it is linear in the parameters Xj.

The model proposed in this section is developed by the following linear equation:

$$Y = b1X1 + b2X2 + b3X3 + \cdots + bnXn \qquad (11)$$

Where:

Y= total revenue associated to each order delivered;

X1, … Xn = independent variables

b1, … bn = variable coefficients (they indicate how Y changes on average when Xj increases by one unit considering that the other explanatory variables have constant values). The coefficients are estimated on the basis of n data.

6.10.3. Interpretation of results

In order to understand if the regression model fits the data, R^2 can be considered. This statistic represents how much of the variance in the response is explained by the weighted combination of predictors. The value of R^2 tends to increase with an increasing number of independent variables. For this reason, it is better to consider the value of R^2-adjusted for the interpretation of the results:

$$adjR^2 = 1 - (1 - R^2)^2 \frac{N-1}{N-K-1} \qquad (12)$$

Where:

N= sample size;

K = number of independent variables.

In sum, R^2 and R^2-adjusted indicate if explicative variables are suitable to forecast (or explain) the values of the dependent variable. They provide an indication about the combined effect of all the independent variables of the equation, but they do not provide information about the contribution of each variable. For this reason a test of significance is needed.

The standardized coefficients are shown in Table 6.25. The sign of the coefficient indicates whether the predicted response increases or decreases when the predictor increases, all other predictors being constant. For categorical data, the category coding determines the meaning of an increase in a predictor. The value of the coefficient reflects the amount of change in the predicted preference ranking. Using standardized coefficients, interpretations are based on the standard deviations of the variables. Each coefficient indicates the number of standard deviations that the predicted response changes for a one standard deviation change in a predictor, all other predictors remaining constant.

6.10.4. Test of significance

6.10.4.1. Test for Significance of Regression

In order to be able to understand the statistics significance of each parameter within the model, a test for significance of regression in the case of multiple linear regression analysis is carried out using the analysis of variance. The test is used to check if a linear statistical relationship exists between the response variable and at least one of the predictor variables. The statements for the hypotheses are:

$$H_0 : \ b1 = b2 = \cdots = bn = 0$$

$$H_1 : bj \ \neq 0 \, for \ at \ least \ one \ j$$

The test for H_0 is carried out using the following statistic:

$$F_0 = \frac{MS_R}{MS_E} \tag{13}$$

Where:

MS_R = regression mean square;

MS_E = error mean square.

If the null hypothesis (H_0) is true then the statistic F_0 follows the F distribution with k degrees of freedom in the numerator and n – (k+1) degrees of freedom in the denominator. The null hypothesis (H_0) is rejected if the calculated statistic F_0 is such that:

$$F_0 > f_{\alpha,k,n-(k+1)}$$

6.10.4.2. Test on Individual Regression Coefficients (t Test)

The t-test is used to check the significance of individual regression coefficients in multiple linear regression model. Adding a significant variable to a regression model makes the model more effective, while adding an unimportant variable may make the model worse. The hypothesis statements to test the significance of a particular regression coefficient b_j are:

$$H_0 : b_j = 0$$

$$H_1 : b_j \neq 0$$

To support the results the test t-student with n-2 degrees of freedom is used. If p-value observed is less of theoretical p-value (set at 0.05), the parameter significantly explains the variance of Y and so it must be included into the model. Based on the results showed in Table 6.24, it can be concluded that the following parameters, not only show low value, but they are also not significant for the explanation of the variance. For these reasons, they can be excluded by the model.

However, the collinearity statistics results show a tolerance lower than 0.20 for T3 (tol=0.101) and C1 (tol=0.116). In fact it means that at least the 20% of the variance explained by the mentioned independent variables is shared with some other independent variables. It is also confirmed by the Variance Inflation Factor (VIF), which is usually considered indication of multicollinearity when its value is greater than 5.

Considering the results of the significant test analysis, it was decided to consider new variables into the model and to exclude those variables that are not significant (T3 and C1). The descriptions of the new variables and of the results of the new model analysis are introduced in the following section.

6.11. Summary of the results

6.11.1. Regression model considering factors (PCA)

In order to avoid the problem of the indeterminate matrix, the estimation was done with SPSS software through the stepwise technique (criterion for entry or removal of variables are the probabilities of F, respectively, 0.05 and 0.10) after some iterations the less significant variables and the variable with a coefficient with incorrect sign were excluded.

The multiple regression analysis was performed by considering the three factors defined with the PCA described in section 6.9.1.

6.11.2. Results of the regression analysis

Three factors were considered to perform the regression analysis (likelihood of F <=0.050).

Model	R	R Square	Adjusted R Square
1	0.245[a]	0.060	0.059

a. Predictors: REGR factor score 3 for analysis 1

Table6.23. Model summary

This model does not show good results due to the low values of R^2 and $R^2_{adjusted}$. For this reason a traditional multiple regression analysis was performed, by considering all the parameters identified after the correlation analysis. They are: t3, C1, C2, C3, C_tot, P1, P3, EL, Sale and Lead Time. The analysis of the results is discussed in the following section.

6.11.3. Traditional multiple regression analysis

Twenty-five different combinations of variables have been considered (Table 6.24) in order to find the best suitable combination that maximizes the values of R^2 and R^2_{adj} and, at the same time, to make it statistically significant (i.e. ANOVA, t-test and VIF respected). Thirteen models are statistically significant. A representation of the values of R^2_{adj} is provided in Figure 6.48.

Based on the analysis of the results, the best suitable multiple regression model is represented by Model 23, which considers the following variables: C1, C2, Sale, lead time. This model explains 80.4% of the variance (R^2_{adj}=0.804), so it is a good model to represent the relationship among dependent and independent variables.

					Summary of results									ANOVA		Sig. tests	
Model	T3	C1	C2	C3	C_tot	P1	P3	EL	Sale	lead_time	R	R-square	R-square adj	F	Sig.	t-student	VIF
1				x							0.003	0.000	-0.001				
2			x								0.006	0.000	-0.001				
3							x				0.044	0.002	0.000				
4						x					0.049	0.002	0.001				
1								x			0.050	0.003	0.001				
2	x										0.075	0.006	0.004				
3										x	0.078	0.006	0.005				
4					x						0.084	0.007	0.005				
5		X									0.088	0.008	0.006				
6									x		0.725	0.525	0.524				
7		X							x		0.726	0.527	0.526	364.909	0.000	NR	OK
8		X						x	x		0.809	0.654	0.652	411.15	0.000	OK	OK
13				x		x	x	x	x	x	0.831	0.691	0.688	241.879	0.000	OK	OK
14				x	x	x		x	x		0.837	0.701	0.699	305.814	0.000	OK	OK
15				x	x	x		x	x		0.837	0.701	0.699	305.814	0.000	OK	OK
25			x						x		0.837[c]	0.701	0.700	756.900	0.000	OK	OK
9		X				x		x	x		0.840	0.706	0.704	391.600	0.000	OK	OK
16				x	x	x	x	x	x		0.842	0.709	0.706	263.707	0.000	OK	OK
17				x	x	x	x	x	x		0.842	0.709	0.706	263.707	0.000	OK	OK
18		X		x		x	x	x	x		0.850	0.723	0.720	282.600	0.000	OK	OK
24			x						x	x	0.852	0.727	0.725	578.400	0.000	OK	OK
19		X	x	x		x	x	x	x		0.867	0.752	0.749	280.486	0.000	OK	OK
20				x	x	x	x	x	x	x	0.871	0.759	0.757	292.396	0.000	NR	NR
10		X							x	x	0.886	0.784	0.783	791.386	0.000	OK	OK
11	x	X						x	x	x	0.886	0.785	0.784	476.770	0.000	NR	NR
21	x	X	x	x		x			x		0.887	0.786	0.784	398.133	0.000	OK	NR
22	x	X							x	x	0.886	0.785	0.784	596.760	0.000	NR	NR
12		X				x			x	x	0.888	0.788	0.787	606.200	0.000	OK	OK
23		X	x						x	x	0.897	0.805	0.804	673.280	0.000	OK	OK

Table 6.24. Summary of results (NR = Not Respected - not statistically significant)

Also Model 12 showed good results. In fact, by considering C1, P1, Sale and lead time, it explains 78.7% of variance. Almost the same can be said for Model 10, which consider C1, Sale and lead time and explains the 78.3% of variance. This result is very close to that achieved with the best model (Model 23), but in this case the model is easier because it only considers 3 variables.

Models 16, 17, 18, 19 and 24 also show good results because of the high values of R^2_{adj} (respectively: 0.706, 0.706, 0.720, 0.749 and 0.725). However, they are more complicated, because they consider 6 to 7 variables. Also Model 25 and Model 9 show good values of R^2_{adj} (0.700 and 0.704 respectively).

Models 8, 13, 14 and 15 show statistically significant results, but the values of R^2_{adj} even though higher than 0.650, are lower than those of the previous models. The other models are not statistically significant.

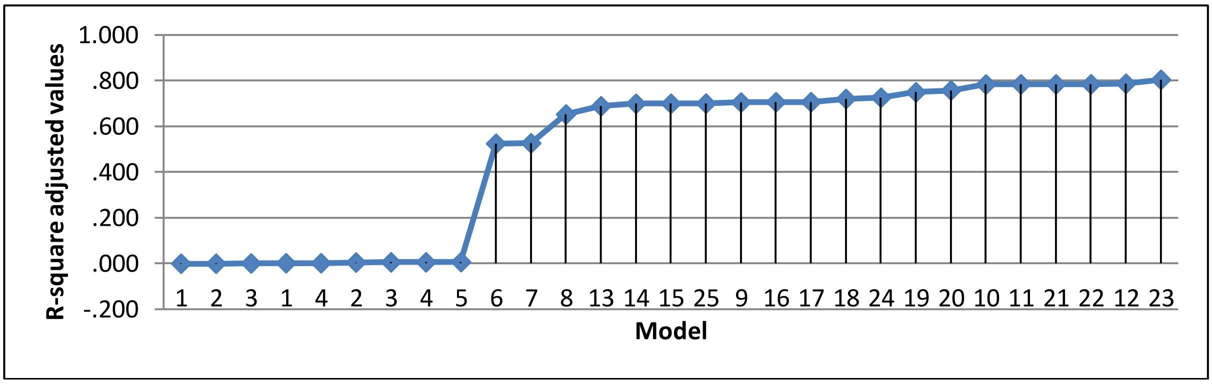


Figure 6.48. Trend of the values of R-square adjusted

6.12. Definition of the model and meaning of the parameters

Due to the results of the regression models, Model 23 was identified as the best one.

Model	Unstandardized Coefficients	Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Beta			Tolerance	VIF
Sale	985,045.049	1.130	51.573	0.000	0.623	1.606
C2	-2,072.989	-0.211	-8.342	0.000	0.466	2.146
lead_time	-1,063.659	-0.618	-18.183	0.000	0.258	3.870
C1	1,290.131	0.412	16.206	0.000	0.463	2.161

Table 6.25. Coefficients of linear regression through the origin with Tot_Revenue as dependent variable

Parameters were standardized as follows:

$$b'_{yxi} = b_{yxi}\,\frac{s_{xi}}{s_y} \tag{14}$$

Where:

x_i is every time a different independent variable (X1, ..., X10).

Standardized parameters are used to understand which parameter is the most important to explain the dependent variable. In this case, the sign of the parameter is not important: the highest standardized parameter (absolute value) is the most important within the equation to explain the y.

Considering the values of the regression coefficients showed in Table 6.25, Sale can be identified as the most important parameter to explain the total revenue associated to an order (c = 1.130). It is followed by the lead time (d = -0.618) and C1 (a = 0.412). The parameter C2 is the one that shows the lowest relationship with the dependent value (b = -0.211). An explanation of the meaning of the contribution of each parameter is provided below.

a = 0.412, it is related to C1, which represents the price that the company pays to transport goods from the production site to its own warehouse. It is positive, meaning that the income associated to an order grows when the transportation cost (C1) grows. It can be explain by considering the formulation of this indicator, which depends on the distance travelled and on the amount of goods transported. Considering that the distance is the same for every order considered in the analysis of this specific case study, C1 can be considered depending on the amount of goods transported. So, the sign of this coefficient is logical because the bigger is the size of the delivery the higher is the income associated to it.

b = - 0.211; it is related to C2, which represents the delivery cost to transport goods to the warehouse of the company to the depot of the customer. It is negative, meaning that if this cost increases, the income decrease. As in the case of C1, also C2 is calculated by considering distance travelled and amount of goods delivered. It can be interpreted as follows: if a customer is far from the warehouse of the company, C2 is bigger so the income is lower. This can mean that customers located closer to the warehouse generate a higher income. This interpretation corresponds to the reality, because the company declared their "best customers" are located in the same region where the warehouse is (and this is also the reason why they decided to locate the warehouse in that region).

c = 1.130; it is related to Sale (discount on the basic price). It is positive, meaning that if sale increase, also revenue increase. It can be considered as a parameter related to marketing. In fact, based on the results, the higher is the sale applied to an order the more the customer is willing to spend.

d = -0.618; it is related to lead time. It is negative, meaning that the shorter is the lead time associated to an order the higher is the income that order provides.

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PART III - Evaluating the performance of city logistics systems

Chapter 7
Methodological framework
Performance indicators and model definition for urban goods distribution systems

Introduction

As highlighted in Chapter 3, local authorities are reluctant about the actual advantages coming from city logistics practices. They do not clearly have a quantifiable measure of the benefits related to this kind of schemes. There is a lack of research and constant monitoring of city logistics performance (Tadić and Zečević, 2005). A study of the current situation together with the identification and evaluation of the city logistics performance is needed in order to understand if the system is efficient and, if it is not, identify the problems and find a feasible solution (Thompson, 2014). It can be possible by using performance metrics that can provide a quantifiable indication about the efficiency of the different transport and logistics activities. Many European city logistics projects and experiments have been carried out in the last years. However, it remains impossible to understand and fully quantify benefits related to them and to compare their results, because there is a lack of evaluation (Patier and Browne, 2010). It was confirmed by Balm et al. (2014), who stated that best practices are hard to be defined because of the lack of systematic evaluation and assessment of the effects of city logistics schemes in the short and long term.

In order to define a reference framework to assess city logistics performance, it is worth focusing on the urban system. In this case, performance attributes and indicators are different than in the case of the application to the global scale. In fact, while in the case of the global scale performance metrics are defined by considering the objective of the firm, in the urban case, all the objectives of the stakeholders involved in the system have to be considered. Thus, performances should be evaluated by considering different points of view: the logistics operator of the UCC, receivers, suppliers, local authorities and inhabitants (society).

No many contributions exist in the literature dealing with city logistics performance assessment. Probably the most significant contribution is provided by SUGAR, which defines key performance indicators for characterizing good practices in an objective manner. However, the indicators were not homogeneous and flexible to be applied to all the case studies as the same. Published researches focus on evaluate the performance of some specific aspects of the scheme. A holistic approach is needed.

The aim of this chapter is to provide a framework that includes a range of indicators to be used to evaluate and improve logistics and distribution performances of city logistics systems in order to improve the sustainability of logistics and the urban environment.

7.1. Definition of the performance assessment framework

Urban goods delivery represents the extension of the supply chain to the urban environment. For this reason, it was decided to define the performance framework based on the concepts on which the previous model was defined (that of the supply chain).

Key Stakeholder Group	Common Goals and Objectives
Shipper	Maximize levels of service, including cost, time for picking up or delivering, and reliability of transport (delivery without any delay with respect to designated time at customers)
Carriers	Minimize the costs associated with collecting and delivering goods to customers to maximize their profits
Residents	Minimize traffic congestion, noise, air pollution, and traffic accidents near their residential and retail areas
Administrators	To enhance the economic development of the city and increase employment opportunities To alleviate traffic congestion To improve the environment and increase road safety within the city

Figure 7.49. Stakeholder goals and objectives (Thompson, R.G., 2014)

However, conversely to the model proposed to evaluate the performance of the SC, which was 'firm-oriented', the model proposed in this chapter aims to integrate performance metrics related to activities addressed to different stakeholders. The identification and analysis of the stakeholders' objectives is very important, because they provide an indication on what should be measure to evaluate the performance of the scheme. Some examples of stakeholder goals and objectives are provided in Table 7.26.

Following the scheme of the performance framework proposed to assess SC performance (Chapter 5), city logistics performance can be evaluated by considering the following performance attributes:

- Cost;
- Time;
- Quality;
- Productivity;
- Environment.

Each attribute includes different performance metrics (as reported in Figure 7.50).

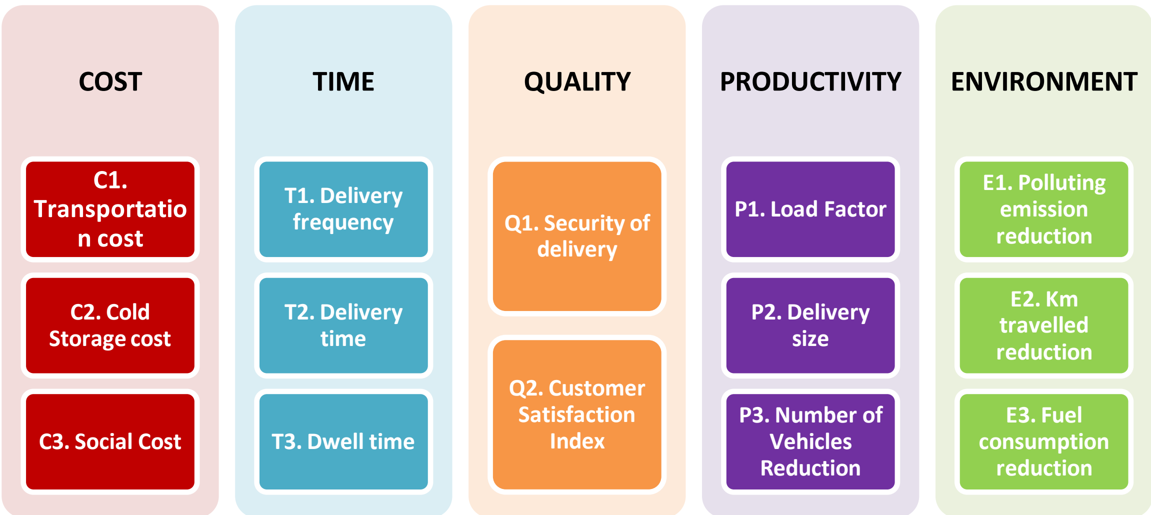


Figure 7.50. Framework to assess city logistics performance: Performance attributes and related metrics

Performance Metrics	Performance Attribute	Stakeholders involved				
		Local Authorities	Receivers	Suppliers	Logistics Operator (UCC)	Society (Citizens, end-consumers)
Transportation Cost	Cost				X	
Cold Storage Cost	Cost				X	
Social Cost	Cost	X				X
Delivery Frequency	Time		X	X	X	
Delivery Time	Time		X	X	X	
Dwell Time	Time		X		X	
Security of Delivery	Quality		X		X	
Customer Satisfaction	Quality		X		X	
Load Factor	Productivity				X	
Delivery Size	Productivity					
Number of Vehicles Reduction	Productivity					
Polluting Emission Reduction	Environment	X				X
Kilometres Reduction	Environment	X				X
Fuel Consumption Reduction	Environment			X	X	

Table 7.26. Performance metrics related to each stakeholder

7.2. Key performance indicators: the model components

The performance attributes consider different performance metrics, which are defined and described in the following sections.

7.2.1. City Logistics - Delivery & Transportation Cost/Financial Performance Indicators (D&TCPIs)

The model considers only variable costs. Three cost-related measures can be defined:

- **C1. Transportation Cost**, which is the cost of transportation born by the logistics operator to make the deliveries to the city centre. It depends on the size of the delivery and on the distance travelled. It can be calculated as follows:

$$\mathbf{C1} = \boldsymbol{c_{tr}} * \boldsymbol{d_{ij}} * \boldsymbol{q_{ij}} \qquad [€/\mathrm{Kg} * \mathrm{Km}] * [\mathrm{Km}] * [\mathrm{Kg}] \qquad (16)$$

*C_{tr}= cost for transport 1 Kilo of product per 1 km [€/Kg*Km];*

d_{ij}= distance travelled to transport item k from DC i and customer j [Km];

q_{ij}= quantity of goods delivered from from DC i and customer j [Kg].

This thesis considers only road transport for urban distribution. In this case, the cost of transportation to deliver goods to the city centre is directly proportional to the distance travelled (Figure 7.51) because it depends on the amount of fuel consumed.

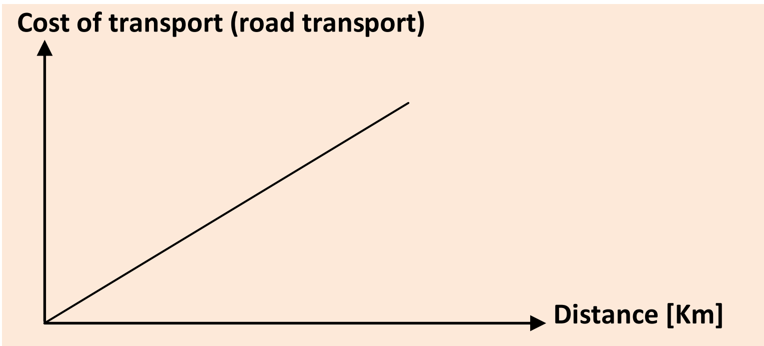


Figure 7.51. Relationship between cost of road transport and distance travelled

- **C2. Cold Storage Cost**, which is the cost of storage for fresh products. It is of course related to the management and transportation of fresh products that need temperature control (cold chain). It depends on the demand related to the cold chain; this type of cost is considered only for perishable-fresh food; thus, in the case of non-perishable (or dry) goods that do not need cold storage, this cost is equal to zero (Table 7.27).

Type of product	Cold Storage Cost (C2)
Perishable goods, or goods that need cold storage	It varies depending on the amount of goods stored (storage volume) and on the type of goods to be stored (storage temperature).
	= 0
Non-perishable goods, or goods that do not need cold storage	It does not depend on the amount of goods stored in this case. In fact, for non-perishable products a fixed storage cost can be considered (i.e. the rent of the warehouse usually does not vary depending on the volume of goods to be stored.

Table 7.27. Storage cost for goods

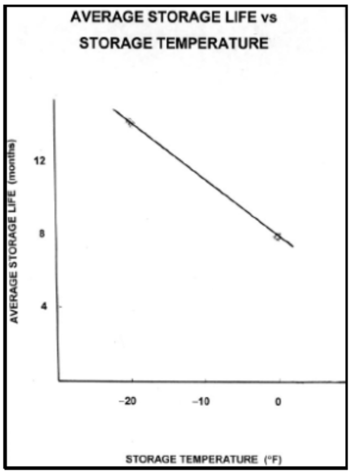


Figure 7.52. Average storage life of approximately a dozen common Pacific Northwest seafood species (Ronald and Cole, 2015)

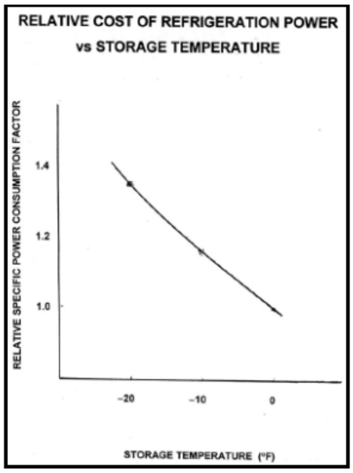


Figure 7.53. Relative cost of power for cold storage operation versus storage temperature species (Ronald and Cole, 2015)

The selection of a low operating temperature, while extremely beneficial from a product durability and quality standpoint, is not without cost. Drawing on these considerations, C2 can be calculated as follows:

$$\mathbf{C2} = \sum_{i=1}^{n} \boldsymbol{P} * \boldsymbol{V} * \boldsymbol{t} * \boldsymbol{c_p} \qquad \text{[KW/m3] [m3] [h] [€/KWh]} \tag{17}$$

[i,n]= active refrigerating rooms;
P= power of refrigerating rooms [KW/m3];
V= volume of the refrigerating rooms [m3];
t= time the refrigerating room is working [h];
cp= cost of electricity [€/KWh].

Based on Miari (2010), some practical values indicating the relationships between characteristics of refrigerating room (volume and power), temperature and type of goods are provided in Table 7.28.

Table 7.28. Refrigerating rooms and their characteristics for (i) fruits and vegetables, (ii) meat and fish, (iii) frozen goods. (i) and (ii) consider the daily introduction of goods, whose volume is equal to a 10% of refrigerating room capacity to cool in 24h; (iii) considers the introduction of chilled products.

Temperature of refrigerating room	Type of goods	V [m^3]	P [W/m^3]
0°C	Fruits and vegetables	<100*	60
		>100	35
0°C	Meat and fish	<100*	55
		>100	30
-25°C	Frozen goods		17

- **C3. Social Cost**, which are the costs due to air polluting emissions produced by transport and suffered by society. It can be calculated as follows:

$$\mathbf{C3} = \sum_{k=1}^{K} c_e * E \qquad [€/\text{tonne}]\ [\text{tonne}] \tag{18}$$

k = polluting elements (CO_2, NO_x, PM_{10} and CO);
c_e = monetary value for computing polluting emissions related to each delivery [€/tonne of emissions]; it vary depending on the type of polluting factor considered. It can be estimated according to Air quality: economic analysis published by Department for Environment, Food & Rural Affairs.
E= amount of emissions produced to perform a delivery [tonne]; it can be calculated as follows (Paddeu et al., 2014):

$$E = e_{ki} * dist * v_i \qquad [tonne] \tag{19}$$

i = type of polluting vehicles (articulated vehicles, 18-tonne vehicles, 7.5 - tonne vehicles, vans);
e_{ki}=polluting emission indicator [tonne/Km]; it depends on the type of polluting factor considered (k) and on the vehicle used (i);
dist=distance travelled to perform the delivery [Km]
vi=number of vehicles of type (i)

This indicator can be included within either ‘cost performance attribute’ or ‘environment performance attribute’.

7.2.2. City Logistics - Delivery & Transportation Time Performance Indicators

The model considers three time-related measures:

- **T1. Delivery Frequency**, which indicates the number of deliveries received per week or per month by the receiver. It differs from city to city and depends on the type of activity and of product sold, together with the users' behaviour, time of the year, policies and regulations applied to the specific urban area, etc. Usually low delivery frequency is related to big size deliveries and to longer dwell times. The higher is the delivery frequency, the more complex is to manage the system.

- **T2. Delivery Time**, which indicates the time when the delivery is fulfilled to the receiver. It represents an important indicator to plan activities of all the stakeholders involved in the delivery process (e.g. shippers, receivers and the logistics providers). It is usually influenced by time regulations that define access restrictions for the delivery vehicles (e.g. if a low traffic zone is established in the city centre). It also depends on the type of product. In fact, there are time-sensitive goods, which lose their value over time (e.g. daily newspapers, fresh dairy and bakery products, etc.). According to Cherrett et al. (2012), receivers usually are not able to decide the delivery time, which instead is decided by suppliers and carriers. The larger is the ‘delivery time range’ accepted by the logistics operator, the more flexible is the service provided by the scheme. However, deliveries have to be scheduled in order to optimize the system and often delivery times depend on the combination of a great deal of deliveries to be performed to different receiving points.
- **T3. Dwell Time,** which indicates the duration of the stop due to loading/unloading operations. It affects the deliveries coordination, vehicle routing, planning and better use of loading/unloading zones or street parking places. Different studies established that the average time spent for unloading the vehicle depends on the type of vehicle used. Also, it is recognised that there is not a strong correlation between the average dwell time of the delivery vehicle and the size of the facility, i.e. the supply system (Cherrett et al., 2012). Allen et al. (2000) pointed out that the most important variables influencing dwell times are:
  - The distance from the goods vehicle to the premises being served;
  - The location where the vehicle parks (off-street vs. on-street);
  - The size of the delivery and the weight of the goods;
  - The type of product and whether or not the goods are unitised;
  - The means of getting goods off the vehicle and conveying them to the premises;
  - Whether the driver has to close and lock the vehicle;
  - The number of people performing the delivery;

- Whether staff at the receiving establishment assist with loading/unloading;
- Whether or not the goods have been pre-ordered by the establishment;
- Whether or not goods have been sorted for delivery prior to the vehicle's dispatch from the warehouse;
- The extent to which the receiver checks the goods;
- Whether or not staff at the receiving establishment need to be present at the time of delivery;
- Whether or not the driver requires a signature for delivery;
- Whether or not other deliveries/collections are taking place at the receiving establishment at the same time (resulting in queuing).

Study	Year	Type[b]	Artic HGV	Rigid HGV	Van	Car
Bar End[a]	2001	Est	50	20	8	7
Winnall[a]	2001	Est	21	13	7	7
City[a]	2001	Est	31	21	9	9
High St.[a]	2001	Est	41	20	12	7
Reading	2002	Est	11	11	9	6
Bexleyheath	2003	Obs	22	22	7	6
Ealing	2004	Obs	16	14	19	8
Chichester	2005	Est	42	33	11	–
Crawley	2005	Est	48	14	7	–
Horsham	2005	Est	33	18	7	–
Worthing	2005	Est	38	33	7	–
Wallington	2005	Obs	21	7	7	–
All studies			31	19	10	8

Table 7.29. Mean dwell times for loading/unloading in recent UK studies by vehicle type [Source: Allen et al., 2008]. [a]Surveys undertaken in Winchester by Cherrett and Smyth (2003). [b]Type of survey undertaken (Est – Establishment survey; Obs – Observation survey).

7.2.3. City Logistics - Delivery & Transportation Quality Performance Indicators

The model considers two quality-related measures:

- **Q1. Security of Delivery,** which can be evaluated by considering the number of damaged products delivered to the receivers. This is an indicator of the reliability of the delivery and measures the quality of the service provided in terms of attention to the safety of the product delivered. Damages can be considered in terms of packaging, product entirety, product property quality (i.e. cold chain interruption for fresh food products), etc.

- **Q2. Customer Satisfaction Index (CSI),** which indicates the level of satisfaction of customers with the service provided by the scheme. Exactly as for supply chain performance evaluation, it can be evaluated in terms of satisfaction with delivery frequency, delivery time, security of delivery and so on. This model considers the same indicators used to assess customer satisfaction for the supply chain (Chapter 5); it is the CSI_{mod} proposed by Paddeu et al. (2016) and it is widely described in Chapter 5.

7.2.4. City Logistics - Delivery & Transportation Productivity Performance Indicators

The model considers three productivity-related measures:

- **P1. Load Factor,** which indicates the % of delivery vehicles occupied by goods when the vehicle accesses the urban area. Two types of load factor can be defined:
  - *Load Factor depot-to-customers* (D-C), which considers the load factor of the vehicles used to make the deliveries from the depot to the customers, calculated at the moment the vehicle leave the depot (before delivering to the first customer);
  - *Load Factor customers-to-depot* (C-D), which is the load factor of the vehicles that return to the depot, calculated after performing the last delivery of the trip. It is associated to reverse logistics. The higher this value is the better reverse logistics is performing.
- **P2. Delivery Size,** which indicates the number of boxes (or the whole weight in Kg) received per week or per month by the receiver. It depends on the type of activity and of product sold, together with the users' behaviour, time of the year, policies and regulations applied to the specific urban area, etc.
- **P3. Number of Vehicles Reduction**, which is the number of heavy and light good vehicles (HGVs/LGVs) reduced due to the use of the freight consolidation centre. In fact, by delivering to the UCC the goods addressed to the urban area, HGVs and LGVs do not have to pass through the city centre. This allows reducing the negative externalities related to freight transport.

7.2.5. *City Logistics - Delivery & Transportation Environment Performance Indicators*

The model considers three environment-related measures:

- **E1. Polluting emission reduction,** which are the emissions avoided thanks to the use of the scheme. They can be calculated by the following formula (Paddeu et al., 2014):

$$Ek_{poll} = \sum V_i * I_i - \sum V_j * I_j \quad (20)$$

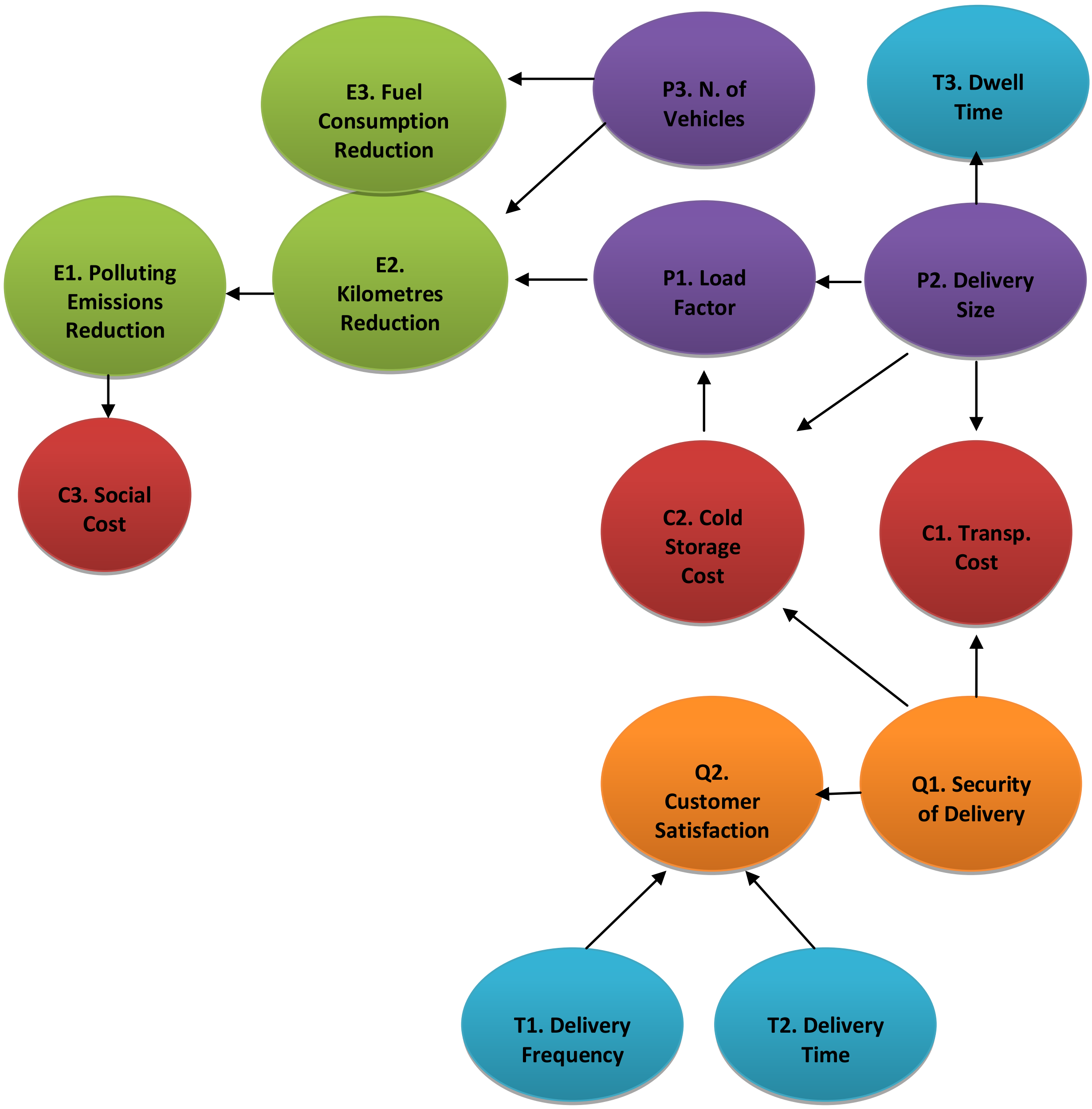
Ek_{poll} = total emission reduction related to each polluting element;
k = polluting elements (CO_2, NO_x, PM_{10} and CO);
i = polluting vehicles (articulated vehicles, 18-tonne vehicles, 7.5 - tonne vehicles, vans);
j = delivery vehicles used by the UCC;
V = number of vehicles;
I = Emission factor.

Reductions are calculated by considering potential polluting emissions produced if the polluting HGVs or LGVs access to the city centre to make the deliveries $(Vi * Ii)$ minus the polluting emissions produced by the delivery vehicles used by the UCC vehicles to make the same deliveries to the city centre $(V_j * I_j)$. Emission factors are calculated by considering the UK National Atmospheric Environmental Inventory (NAEI), which provides figures related to emissions per kilometre travelled by vehicle type. Polluting emission rates are calculated by considering the specific context of driving and average speed. In particular they are calculated for hot exhaust and cold start emission factors by vehicle type.

- **E2. Kilometres travelled reduction,** which indicates the Km travelled avoided because of the UCC. It is based on the number of delivery vehicles that deliver to the UCC instead of to the city centre and on the distance to be travelled to arrive at the destination point from the UCC.
- **E3. Fuel consumption reduction,** which indicates the reduction in terms of fuel consumption due to the Km travelled avoided because of the UCC. Fuel consumption rates are calculated by considering the UK National Atmospheric Environmental

Inventory (NAEI), which provides fuel consumption per kilometre travelled by vehicle type.

7.3. Interdependencies by performance metrics



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Chapter 8

Application to the urban environment

A case study approach

Introduction

This chapter presents the findings of the application of the performance model designed in Chapter 7 to the urban context; it is developed by considering two case studies: Bristol (UK), where city logistics measures have been successfully implemented for years (as widely described in chapters 3 and 4) and Cagliari, where city logistics has not been adopted yet. As highlighted in Chapter 4, the characteristics of the two cities and of the two schemes (the real one in Bristol and the likely one in Cagliari) are very different. In the next sections, a description of the two case studies and of the surveys carried out in both cases is provided. Also the application of the model proposed in chapter 7 is provided.

In particular, the chapter provides two different examples of application:

- Performance evaluation based on an ex-post analysis;
- Performance evaluation based on an ex-ante analysis;
- Comparison of performance based on ex-ante and ex-post analysis.

Relationships among variables are analysed by means of correspondence analysis and multiple regression analysis. The analysis aims to discover the interdependencies among variables and to highlight the variables that are the most important to describe the phenomenon.

8.1. The case of Bristol[11]

A wide description of the case study of Bristol is provided by Chapters 3 and 4. Data used to the application to Bristol have been collected in 2013, within the development of a Master Dissertation (Paddeu, 2013), which aimed to evaluate the quality of service offered by the urban consolidation centre by considering the perspective of its users: the participating retailers. The most significant findings of the survey are presented in Paddeu et al. (2014), Paddeu et al. (2016) and in Paddeu et al. (2017).

8.1.1. Application to Bristol

The application to the case of Bristol considers the evaluation of the performance of the UCC serving the city of Bristol and Bath. Drawing on the model proposed to evaluate the performance of city logistics schemes proposed in chapter 7, this section provides the evaluation of the scheme based on an ex-post analysis. Deliveries are supposed entirely performed by 9-tonne Smith Newton electric vehicles. They are quiet, clean and cost-effective vehicles. A typical 9-tonne diesel truck achieves urban fuel economy of approximately 10 miles per gallon, meaning it burns 60p per mile in fuel. The Smith Newton costs less than 10p per mile in electricity. Some data about the emissions produced by a traditional 9-tonne diesel vehicle and a Smith Newton electric vehicle are provided in Table 8.30.

Vehicle	CO_2 per km (kg)	Saving per km (kg)	% Saving
Average 9t diesel truck	0.689		
Smith Newton 9t	0.340	0.349	51%

Table 8.30. Comparison between CO2 emissions produced by electric vehicles and traditional HGVs

[11] Data collected for the survey carried out in Bristol are showed in: "*Paddeu, D., 2013. Customer Satisfaction Analysis. Users impact analysis of the Bristol Freight Consolidation Centre. Unpublished Master Dissertation*"

According to the description of data provided by Paddeu et al. (2014), the impacts of introducing a city logistics scheme to reduce traffic, energy consumption and polluting emissions related to freight transport in urban areas is analysed. The model implementation was carried out using data collected by the consolidation centre manager during the study period, for 17 months (from January 2011 to May 2012). The European Union financed this scheme to propel the mobility and environmental sustainability. As previously mentioned in Chapter 3, the BBUCC has been involved in the following projects: CIVITAS VIVALDI (2002-2006), START (2006-2008), CIVITAS RENAISSANCE (2009-2013). BBUCC serves the Broadmead and Cabot Circus shopping areas in central Bristol and the central shopping area of Bath. The goods delivered are non-perishable and exclude potentially hazardous items requiring specialised handling (gas canisters, cooking oil, pressurised kegs) and very high value products. Following the ending of the 'pump priming' phases when the Centre was supported with European grants as well as local authority subsidy, the retailers which take part in the scheme pay a fee for the service. The deliveries are received at the BBUCC Monday to Friday, with onward deliveries into central Bath and Bristol made daily.

The matrix of data takes into account the number of deliveries made to the BBUCC by HGVs and the number of retailers which have been visited by the BBUCC vehicles for the 'last mile' deliveries. Non-working days (Saturday, Sunday and Holidays) are excluded to the analysis. HGVs that make the deliveries to the BBUCC are classified in articulated vehicles, 18- tonne vehicles, 7.5-tonne vehicles and vans. In some cases a vehicle might have made a delivery direct to a retailer in the city centre not taking part in the consolidation scheme as well as visiting the BBUCC. Therefore, in order to understand the extent to which freight vehicle trips were being completely removed from the city centre, when a vehicle delivered to the BBUCC the Consolidation Centre staff noted the vehicle type and established through discussion with the driver whether or not the vehicle had made, or would make, other deliveries to Bristol city centre that day. Hence the HGVs which delivered to the BBUCC could be summarised in two categories: (1) HGVs that made deliveries to BBUCC but passed through Bristol city centre anyway (to make deliveries to other store(s). not part of the consolidation scheme); (2) HGVs that make the deliveries to BBUCC and do not pass through Bristol city centre to make deliveries. Category (1) HGVs were excluded from the analysis as they in any case produce polluting emissions in Bristol as result of making other deliveries.

All variables related to the number and type of deliveries (i.e. social costs, load factor, n. of vehicles' reduction, polluting emissions' reduction, km travelled reduction, fuel consumption reduction) were estimated by considering these input data. All the other indicators were calculated and deduced by considering data collected during the survey addressed to the retailers involved in the scheme and carried out in 2013 (Paddeu, 2013).

8.1.2. Database structure

Input data consider the KPIs included in the model defined in chapter 7, but some other indicators are included. All input data are summarized in Table 8.31.

Indicator	Is it in the model?	Definition
Distance	NO	It indicates the kilometers travelled to perform a delivery, from the depot to the receiver (round trip is considered).
Transportation Cost per delivery	YES	It is calculated according to formula (16), indicated in Chapter 7, Section 7.2.1. D&TCPIs - Cost/Financial Performance Indicators.
Transportation Cost per week	YES	It is calculated by considering the transportation cost per delivery - formula (16), indicated in Chapter 7, Section 7.2.1. D&TCPIs - Cost/Financial Performance Indicators) multiplied by the number of deliveries performed weekly (delivery frequency).
PM [g]	NO	It indicates the grammes of PM produces during a typical delivery. It was calculated by considering the formula (19) to calculate the quantity of emissions used to calculate social costs. It is indicated in Chapter 7, Section 7.2.1. D&TCPIs - Cost/Financial Performance Indicators.
NOx [g]	NO	It indicates the grammes of NO_x produces during a typical delivery. It was calculated by considering the formula (19) to calculate the quantity of emissions used to calculate social costs. It is indicated in Chapter 7, Section 7.2.1. D&TCPIs - Cost/Financial Performance Indicators.
CO2 [g]	NO	It indicates the grammes of CO_2 produces during a typical delivery. It was calculated by considering the formula (19) to calculate the quantity of emissions used to calculate social costs. It is indicated in Chapter 7, Section 7.2.1. D&TCPIs - Cost/Financial Performance Indicators.
Social Cost PM	YES	It is calculated according to formula (18), indicated in Chapter 7, Section 7.2.1. D&TCPIs - Cost/Financial Performance Indicators. PM monetary value for computing unit social costs is based on the 2015 updated estimates for damage costs, produced by the UK Department for the Environment Food and Rural Affairs (DEFRA). Values related to "transport urban medium" were considered in Table 1: "Damage costs by pollutant, location and source (2015 prices)s". PM monetary value is indicated equal to 66,264£/tonne. Pounds are converted in euros by the following conversion: 1£ = 1.19€
Social Cost NOx	YES	It is calculated according to formula (18), indicated in Chapter 7, Section 7.2.1. D&TCPIs - Cost/Financial Performance Indicators. NOx monetary value for computing unit social costs is based on the 2015 updated estimates for damage costs, produced by the UK Department for the Environment Food

		and Rural Affairs (DEFRA). Values related to “transport urban medium” were considered in Table 1: “Damage costs by pollutant, location and source (2015 prices)s”[12]. PM monetary value is indicated equal to 28,788£/tonne. Pounds are converted in euros by the following conversion: 1£ = 1.19€
Social Cost CO2	YES	It is calculated according to formula (18), indicated in Chapter 7, Section 7.2.1. D&TCPIs - Cost/Financial Performance Indicators. DECC’s short-term traded carbon values for use in policy appraisal and modelling were updated in 2015 accounting for the latest market data and revised assumptions that included the EU-wide 2030 energy efficiency, renewables and GHG targets. Overall, the same methodological approach as in 2014 has been used for the 2015 update. The value used for the analysis refers to Table 1: “DECC’s updated traded carbon values for modelling purposes, £/tCO2e in real 2015 terms”. CO2 monetary value for 2016 is indicated equal to 5.91£/tonne. Pounds are converted in euros by the following conversion: 1£ = 1.19€.
T1 - Weekly delivery frequency	YES	It indicates the number of deliveries received per week by a receiver. It is described in Chapter 7, Section 7.2.2. D&TTPIs - Delivery & Transportation Time Performance Indicators.
Type of vehicle	NO	Vehicles are classified into 4 categories: (1) petrol car; (2) diesel car; (3) Light Goods Vehicle – LGV; (4) Heavy Goods Vehicle – HGV.
Type of fuel	NO	Fuel can vary between petrol, diesel and electric.
Delivery Time	YES	It is described in Chapter 7, Section 7.2.2. D&TTPIs - Delivery & Transportation Time Performance Indicators. It can be include into one of the following categories: (1) morning; (2) before 8 am; (3) afternoon; (4) before 8 am&morning&afternoon (all day long); (5) before 8 am&afternoon; (6) before 8 am&morning; (7) morning&afternoon. Also, if a receiver is not able to define a fixed delivery time, because it varies depending on suppliers’ and/or logistics operator’s needs, in this case the receiver belongs to category (8) na.
Dwell Time	YES	It is described in Chapter 7, Section 7.2.2. D&TTPIs - Delivery & Transportation Time Performance Indicators. It is the time needed for loading/unloading operations.
Security of Delivery	YES	It is described in Chapter 7, Section 7.2.3. D&TQPIs - Delivery & Transportation Quality Performance Indicators. This indicator is a expressed in terms of 1-to-5 rate, being 1 not safe and 5 very safe delivery (in terms of damages).
Customer Satisfaction	YES	It is described in Chapter 7, Section 7.2.3. D&TQPIs - Delivery & Transportation Quality Performance Indicators. This indicator is widely described in Paddeu et al. (2016).
Load Factor	YES	It is described in Chapter 7, Section 7.2.4. D&TPPIs - Delivery & Transportation Productivity Performance Indicators. It indicated the percentage of the delivery vehicle occupied by goods.
Delivery Size	YES	It is described in Chapter 7, Section 7.2.4. D&TPPIs - Delivery & Transportation Productivity Performance Indicators. In order to level out the data, delivery size is expressed in terms of number of boxes delivered; the size of a typical fruit box (500 mm length x 300 mm width x 190 mm height) as reference load unit is considered.
Number of Vehicles Reduction	YES	It is described in Chapter 7, Section 7.2.4. D&TPPIs - Delivery & Transportation Productivity Performance Indicators. It indicates the reduction in terms of number of vehicles reduced due to the use of the freight consolidation centre.
Polluting Emission Reduction	YES	It is described in Chapter 7, Section 7.2.5. D&TPPIs - Delivery & Transportation Environment Performance Indicators. Emissions’ reduction is calculated by considering the formula proposed by Paddeu et al. (2014). CO_2, PM and NO_x emissions are considered.
Kilometres Reduction	YES	It is described in Chapter 7, Section 7.2.5. D&TPPIs - Delivery & Transportation Environment Performance Indicators. It indicates the reduction in terms Km travelled,

[12] Monetary values are indicated in: "*Air quality economic analysis. Damage costs by location and source*" edited by Department for Environment, Food and Rural Affairs. The damage cost for NOX was updated on 12 September 2015 to reflect the latest evidence. Available from: <https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/460398/air-quality-econanalysis-damagecost.pdf> [Access date: 15th of June 2016]

		which are avoided because of the UCC.
Fuel Consumption Reduction	YES	It is described in Chapter 7, Section 7.2.5. D&TPPIs - Delivery & Transportation Environment Performance Indicators. It indicates the reduction in terms of fuel consumption due to the Km travelled avoided because of the UCC
Load/Unload_where?	NO	It indicates the place where delivery vehicles are left during loading/unloading operations. It can be include into one of the following categories: (1) roadside; (2) double parked; (3) pavement; (4) Public loading/unloading area; (5) Private loading/unloading area.

Table 8.31. Variables and KPIs considered for the analysis of the application to the urban freight distribution

8.1.3. Data preparation

As in the case of Chapter 6, also in this case data collected have been cleaned (i.e. missing data, possible errors, etc.) and transformed into the most suitable form for analysis.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Receiver	Distance	Transportation Cost per delivery	Transportation Cost per week	Social Cost PM [euro] (reduction) per	Social Cost NOx [euro] Reducti	Social Cost CO2 [euro] Reducti	Social Cost PM [euro] Reduct	Social Cost NOx [euro] Reducti	Social Cost CO2 [euro] Reducti	Delivery Frequency	Delivery Time	Delivery safety	CSI
2	RET0001	25.74	0.340	0.681	0.064	1.544	0.00007	0.128	3.089	0.00014	2	1	4	185.60
3	RET0002	25.74	0.374	1.121	0.064	1.544	0.00007	0.192	4.633	0.00021	3	2	5	185.60
4	RET0003	25.74	0.754	1.509	0.064	1.544	0.00007	0.128	3.089	0.00014	2	na	3	120.00
5	RET0004	25.74	0.314	0.314	0.064	1.544	0.00007	0.064	1.544	0.00007	1	3	4	105.60
6	RET0005	25.74	0.374	1.121	0.064	1.544	0.00007	0.192	4.633	0.00021	3	5	4	171.20
7	RET0006	25.74	0.526	2.630	0.064	1.544	0.00007	0.320	7.721	0.00035	5	2	4	185.60
8	RET0007	25.74	0.374	1.121	0.064	1.544	0.00007	0.192	4.633	0.00021	3	2	4	105.60
9	RET0008	25.74	0.608	1.823	0.064	1.544	0.00007	0.192	4.633	0.00021	3	5	4	145.60
10	RET0009	25.74	0.374	1.121	0.064	1.544	0.00007	0.192	4.633	0.00021	3	6	4	131.20
11	RET0010	25.74	0.374	1.121	0.064	1.544	0.00007	0.192	4.633	0.00021	3	3	4	145.60
12	RET0011	25.74	0.374	1.121	0.064	1.544	0.00007	0.192	4.633	0.00021	3	7	4	145.60
13	RET0012	25.74	0.440	0.440	0.064	1.544	0.00007	0.064	1.544	0.00007	1	5	4	185.60
14	RET0013	25.74	0.340	0.681	0.064	1.544	0.00007	0.128	3.089	0.00014	2	4	5	134.80
15	RET0014	25.74	0.314	0.314	0.064	1.544	0.00007	0.064	1.544	0.00007	1	2	4	156.80
16	RET0015	25.74	0.365	2.190	0.064	1.544	0.00007	0.384	9.266	0.00042	6	3	3	134.40
17	RET0016	25.74	0.403	0.807	0.064	1.544	0.00007	0.128	3.089	0.00014	2	5	4	142.40
18	RET0017	25.74	0.520	1.561	0.064	1.544	0.00007	0.192	4.633	0.00021	3	5	4	128.00
19	RET0018	25.74	0.440	0.440	0.064	1.544	0.00007	0.064	1.544	0.00007	1	na	5	200.00
20	RET 0019	25.74	0.629	0.629	0.064	1.544	0.00007	0.064	1.544	0.00007	1	5	5	171.20
21	RET 0020	25.74	0.629	0.629	0.064	1.544	0.00007	0.064	1.544	0.00007	1	2	4	171.20
22	RET 0021	25.74	0.629	0.629	0.064	1.544	0.00007	0.064	1.544	0.00007	1	5	4	171.20

	A	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB
1	Receiver	Load factor	N. of boxes per week	Delivery Size	N. veh reduction per week	PM [g] reduction per week	NOx [g] reduction per week	CO2 [g] reduction per week	Fuel consumption reduction per week	Kilometres Reduction" [per week]	PM [g] reduction per delivery	NOx [g] reduction per deliver	CO2 [g] reduction per deliver	Fuel consumption reduction per	Kilometres Reduction" [per delivery
2	RET0001	0.505	10	5	1.845	0.162	9.016	1.977	465.410	47.496	0.081	4.508	0.988	232.705	23.748
3	RET0002	0.437	261	87	2.745	0.243	13.523	2.965	698.115	70.662	0.081	4.508	0.988	232.705	23.554
4	RET0003	0.700	348	174	1.657	0.162	9.016	1.977	465.410	42.655	0.081	4.508	0.988	232.705	21.327
5	RET0004	0.700	87	87	0.929	0.081	4.508	0.988	232.705	23.901	0.081	4.508	0.988	232.705	23.901
6	RET0005	0.437	15	5	2.745	0.243	13.523	2.965	698.115	70.662	0.081	4.508	0.988	232.705	23.554
7	RET0006	0.542	435	87	4.402	0.405	22.539	4.942	1163.526	113.317	0.081	4.508	0.988	232.705	22.663
8	RET0007	0.437	6	2	2.745	0.243	13.523	2.965	698.115	70.662	0.081	4.508	0.988	232.705	23.554
9	RET0008	0.700	6	2	2.586	0.243	13.523	2.965	698.115	66.556	0.081	4.508	0.988	232.705	22.185
10	RET0009	0.437	12	4	2.745	0.243	13.523	2.965	698.115	70.662	0.081	4.508	0.988	232.705	23.554
11	RET0010	0.437	9	3	2.745	0.243	13.523	2.965	698.115	70.662	0.081	4.508	0.988	232.705	23.554
12	RET0011	0.437	15	5	2.745	0.243	13.523	2.965	698.115	70.662	0.081	4.508	0.988	232.705	23.554
13	RET0012	0.300	2	2	0.900	0.081	4.508	0.988	232.705	23.166	0.081	4.508	0.988	232.705	23.166
14	RET0013	0.505	10	5	1.845	0.162	9.016	1.977	465.410	47.496	0.081	4.508	0.988	232.705	23.748
15	RET0014	0.700	174	174	0.929	0.081	4.508	0.988	232.705	23.901	0.081	4.508	0.988	232.705	23.901
16	RET0015	0.470	20	5	3.502	0.487	27.047	5.931	1396.231	90.151	0.081	4.508	0.988	232.705	15.025
17	RET0016	0.305	8	4	1.817	0.162	9.016	1.977	465.410	46.761	0.081	4.508	0.988	232.705	23.381
18	RET0017	0.470	18	6	2.645	0.243	13.523	2.965	698.115	68.088	0.081	4.508	0.988	232.705	22.696
19	RET0018	0.300	3	3	0.900	0.081	4.508	0.988	232.705	23.166	0.081	4.508	0.988	232.705	23.166
20	RET 0019	1.000	87	87	0.857	0.081	4.508	0.988	232.705	22.063	0.081	4.508	0.988	232.705	22.063
21	RET 0020	1.000	174	174	0.857	0.081	4.508	0.988	232.705	22.063	0.081	4.508	0.988	232.705	22.063
22	RET 0021	1.000	174	174	0.857	0.081	4.508	0.988	232.705	22.063	0.081	4.508	0.988	232.705	22.063

Figure 8.54. Database structure

8.2. Evaluating the performance of the system in Bristol

8.2.1. Data analysis

8.2.1.1. Data description and descriptive statistics

Data analysis of the case of Bristol allowed highlighting the following aspects:

- Social costs are considered in terms of "*reduction*", so in terms of costs (Euros) avoided. The highest social costs are related to the emissions of NO_x, with a mean value of 3.677 Euros per week; Social costs related to the emissions of PM and CO2 are quite lower (0.152 and 0.00016 Euros per week respectively);
- Transportation cost is on average 0.452 Euros per delivery and 104.762 Euros per week. It suggests a high number of deliveries performed.
- Delivery frequency ranges from less than once a month and 7 or more times a week. The majority of the retailers receive deliveries from the consolidation centre between 1 and 3 times a week (38%) or 7 or more times a week (33%).
- Almost all the retailers receive deliveries in the morning.

- The surveyed area receives 1,874.000 boxes per week, with about 89 boxes received per retailer. In particular, the average delivery size is 52 boxes per receiver.
- Delivery safety ranges between rates 3 and 5.
- CSI ranges between 105.6 and 200, with a mean value of 153.467, which is a very high value, meaning retailers are very satisfied with the service provided by BBUCC (Paddeu et al., 2016[13]).
- Also Load Factor (LF) showed a very good result, been in average equal to 0.56.
- About the indicators related to the "environment performance" (see the model to assess performance of city logistics systems - CHAPTER 7, section 7.2.5. City Logistics - Delivery & Transportation Environment Performance Indicators), 43 vehicles are avoided every week, with a related reduction of 52 kilometers travelled and of 554 grams of fuel.

Likewise the case of the supply chain (Chapter 6), the second-step analysis concerns the study of the relationships among variables, which is described in the next sections.

8.2.1.2. Relationships among categorical variables: Tests of Independence (chi-square test)

The methodology of the chi-square test of independence is widely described in Chapter 6. It is used to determine whether there is a relationship between two categorical variables. Results are shown in Table 8.32.

Table 8.32. The analysis showed there is no relation among variables.

		Pearson Chi-Square Tests				
		Delivery_frequency_week	**Vehicle**	**Delivery_Time**	**load_unload_operations**	**Fuel**
Delivery_frequency_week	χ2	1				
Vehicle	χ2	38.765	1			
	Sig.	0.003				
Delivery_Time	χ2	32.429	12.096	1		
	Sig.	0.958	0.438			
load_unload_operations	χ2	70.210	7.870	25.893	1	
	Sig.	0.096	0.896	0.893		
Fuel	χ2	3.000	1.750	2.932	2.236	1
	Sig.	0.809	0.417	0.569	0.692	

[13] To know more about the application and the results of the customer satisfaction analysis and the CSI elaborated and calculated for the case of Bristol, please refer to: *Paddeu, D., Fancello, G. and Fadda, P. (2016). An experimental customer satisfaction index to evaluate the performance of city logistics services, in Transport, 1-10.*

Table 8.33. Results of the test of independence (Chi-Square)

		Pearson Chi-Square Tests		
		Delivery_frequency	**Delivery_time**	**Delivery_safety**
Delivery_frequency	χ^2	1		
Delivery_time	χ^2	22.860	1	
	Sig.	0.528		
Delivery_safety	χ^2	13.469	11.895	1
	Sig.	0.097	0.454	

8.2.1.3. Relationships among continuous variables: Pearson's correlation coefficient

The methodology used to evaluate correlation among continuous variables (Pearson's correlation coefficient) is described in Chapter 6. Results are shown in **Errore. L'origine riferimento non è stata trovata.**Appendix 4. The analysis highlighted the following relations:

- Cost-related indicators: Transportation cost per week is related to the social cost of polluting emissions (0.895) and with all the indicators related to the environment (n. of vehicle weekly reduction: 0.872; polluting emissions reduction: 0.895; weekly fuel reduction: 0.895; weekly kilometres reduction: 0.872). Delivery cost is quite related to the load factor (0.615). Weekly social cost related to polluting emissions are related to each other (1.000) and to the indicators related to the environment (n. of vehicle weekly reduction: 0.947; polluting emissions reduction: 1.000; weekly fuel reduction: 1.000; weekly kilometres reduction: 0.947).
- Productivity related indicators: Delivery size is related to the load factor of the vehicles (0.713).
- Quality relater indicators: CSI is not related to the other indicators.
- Environment-related indicators: they are all related to each others.

8.2.1.4. Linear regression

Due to the low number of rows that compose the input matrix data, it was decided not to consider a next step analysis, such as linear regression analysis, because it cannot provide significant results.

8.3. The case of Cagliari (Italy)[14]

8.3.1. Description of the demanding area

Cagliari is the capital of the island of Sardinia, an autonomous Region of Italy (Figure 8.55). It has nearly 150,000 inhabitants, while its metropolitan city, which has been established in 2016 by a Sardinia Regional Law and includes Cagliari and 16 other nearby municipalities, has more than 431,000 inhabitants. Cagliari is the 26th largest city in Italy and the largest city on the island of Sardinia. The Cagliari - Sarroch port system was the third in Italy for goods movements in 2014. The first department store, opened in 1931 in the city centre, and it is still open today. Nowadays there are many commercial centres in the metropolitan area, hosting many European chain stores. Tourism is one of the major industries of the city. Cruise ships touring the Mediterranean often stop for passengers at Cagliari, and the city is a traffic hub to the nearby beaches. Especially in Summer many clubs and pubs are goals for young locals and tourists. They are all concentrated in the city centre, characterised by narrow streets. The city centre includes the following districts: Stampace, Marina, Villanova and Castello. In Cagliari there are 180 Bed and Breakfast and 22 hotels that totals 3,300 beds.

8.3.2. The survey

A wide description of the survey carried out in Cagliari is presented in Fancello et al. (2016) and in Paddeu et al. (2017). Some results and evidences are also presented in Chapter 4.

The survey was addressed to the commercial activities located in Marina district, which is characterised by high density of activities related to the food chain (Figure 8.56). The study and analysis of food last mile deliveries received by the surveyed area allowed determining the needs of the receivers in order to define the characteristics and the limits of last food mile deliveries. The area includes a significant number of activities related to the Ho.Re.Ca. sector (i.e. Hotels, Restaurants, Cafés), mini-markets and take-away companies. In addition, it is a low traffic zone area, characterised by narrow streets, some of which are accessible only to pedestrian.

[14] The results of this survey are described in Fancello et al. (2016) and in Paddeu et al. (2017).

Figure 8.55. The city of Cagliari

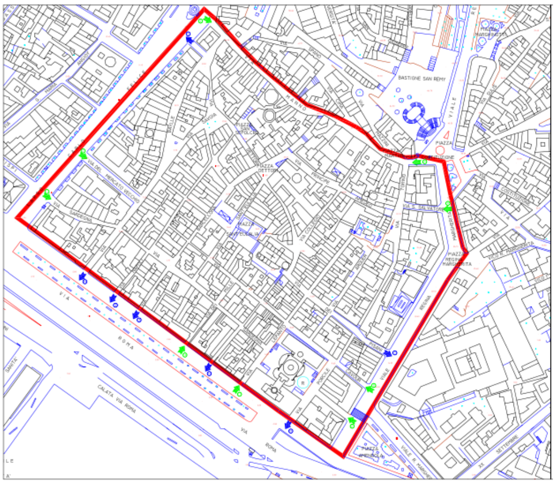

Figure 8.56. The surveyed area (Green points represent the incoming points to the area, whereas the blue ones represent the outgoing points)

8.3.3. Data Collection

Data collection was organised by means of questionnaires administration and face-to-face interviews with the shopkeepers between February and March 2015. Food delivery information was collected for five categories of commercial activities: restaurants; hotels; coffee shops; minimarkets; take-away.

Two questionnaires were designed and administered to these operators by means of Paper-and-Pencil Interviewing (PAPI): a longer one, consisting of 37 questions and an 8-item abbreviated version. The questionnaire administration strategy depended on the willingness of the interviewees to respond. The aim was to collect data on the food delivery habits considering the different types of goods delivered, mode of delivery (self-supply or outsourcing or delivered by the suppliers), delivery frequency, time, size, etc. Information was collected considering fresh and non-fresh products that can be grouped into 9 different goods categories: fruit and vegetables, cured meats and cheese, meat, fresh bakery, fish, other dry goods, other fresh goods, beverages and other. Qualitative data about goods delivery problems and needs, accessibility to the area, loading/unloading operations and parking were investigated in the last part of the longer questionnaire. All the commercial activities located in the surveyed area in the city centre of Cagliari were entered into a database. The population consisted of 127 different businesses, 54% of which participated in the survey. Some operators were interviewed by means of face-to-face interviews (PAPI), others preferred to complete the questionnaire by themselves and have it collected later.

8.3.4. Results

Sixty-six businesses participated in the survey; 33% of the sample consists of restaurants, 26% of coffee shops, 23% of minimarkets, 10% of take-away and 8% of hotels. 67% of the interviewees decided to participate in the full survey, completing the longer questionnaire. All the businesses involved are small and medium-sized independent enterprises (none were chain stores) and are open 6 days a week (7 days a week in summer).

To analyse supply modes, operators were classified by the transport option they used. 14% of interviewees declared to exclusively use their own vehicles to transport goods, while 20% receive all the deliveries by logistics operators (the most of them are minimarket – 62%). In general terms, 29% of the sample declared to provide for 75-95% of their deliveries by themselves (especially restaurants), while 22% of the sample declared to receive 60-80% of the deliveries by logistics operators (especially cafes).

37% of the operators stated they received deliveries 6 days a week, 23% 7 days a week, 23% 1-2 days a week, 12% 3 days a week, 5% 4-5 days a week. With regard to delivery size, the authors decided to level out the data by considering boxes with the size of a typical fruit box (500 mm length x 300 mm width x 190 mm height) as reference load unit. 54% of the operators surveyed stated they received between 20 and 50 boxes of goods per week, 18% less than 20 boxes per week, 15% more than 100 boxes per week and 13% between 51 and 100 boxes per week.

Concerning the delivery frequency of fresh food products, if on the one hand products like fruit and vegetables (45%) and fish (56%) can be defined high frequency goods (6-7 times per week), on the other, products such as cured meats and cheese (88%) and meat (57%) can be defined low frequency goods (1-2 times per week). Referring to the non-fresh food categories, they can all be defined low delivery frequency products (70% or more deliveries are made 1-2 times a week), except fresh bakery (69% of deliveries are made 6-7 times a week). The results are summarised in Figure 8.58.

To have a broader description of the results, please see Fancello et al. (2016) in the Annex part at the end of this thesis.

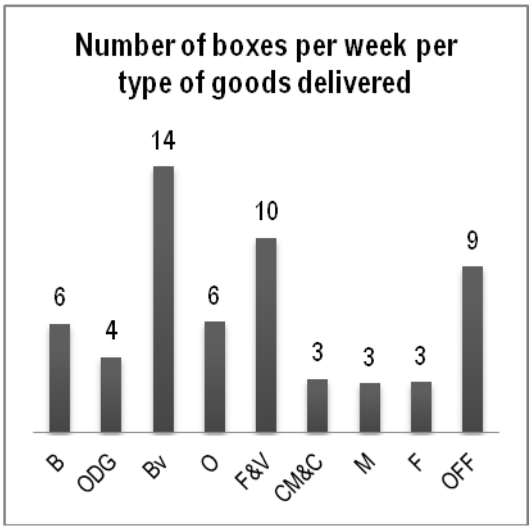

Figure 8.57. Fresh food products and non-fresh food products: N. of boxes received on average per week and per type of good[15]

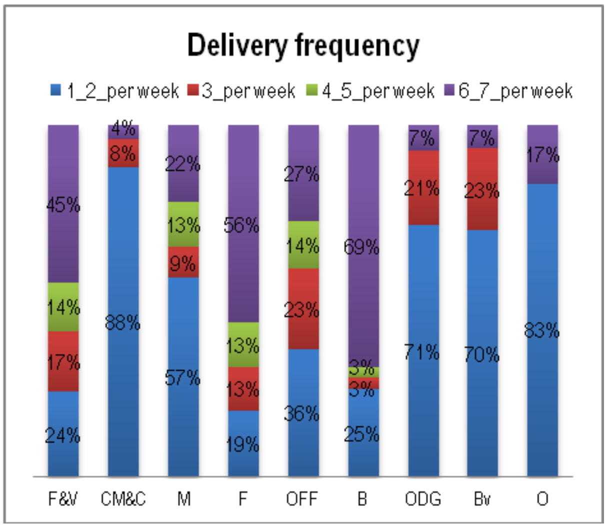

Figure 8.58. Delivery frequency analysis per type of product delivered

8.4. Evaluating the performance of the system in Cagliari

The analysis considers two scenarios:

- *Scenario 1*, based on the real situation; it analyses the performance of the system as it is in the current situation.
- *Scenario 2*, based on the hypothetical situation of establish a UCC, which serves the surveyed area in the city centre of Cagliari. Deliveries are performed with the same vehicle used by Bristol and Bath UCC to make the deliveries. It is a 9-tonne Smith Newton Electric Truck (a description of the characteristics of the vehicle are provided in Section 8.1.1.).

The majority of the interviewees involved in the survey, declared to buy their products in a specific area that is distant 7.9 Km from Marina district (Figure 8.59). For the application, it was supposed the establishment of a UCC in the proximity of that area.

[15] *B = Fresh Bakery; ODG = Other Dry Goods; Bv = Beverages; O = Other. F&V = Fruit and Vegetables; CM&C = Cured meats and Cheese; M = Meat; F = Fish; OFF = Other Fresh Food.*

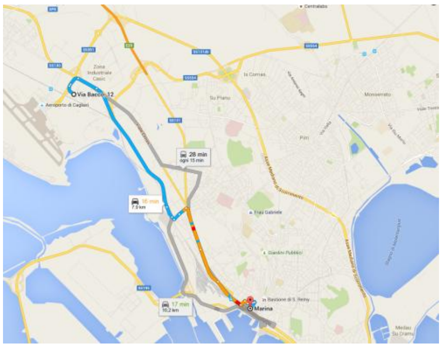

Figure 8.59. Travel distance from the hypothetical UCC to Marina district

8.4.1. Database structure

Based on the KPIs defined in Chapter 7 to assess the performance of city logistics schemes, Figure 8.59 shows the structure of the database used for the application to the case of Cagliari. In addition to the KPIs defined in the model, the database also includes some specific variables characterizing each scenario. Based on the input variables already introduced in Table 8.31 for the case of Bristol, due to the nature of the products delivered (i.e. fresh food), the case of Cagliari also considers costs related to cold storage for scenario 2 (Table 8.34).

Table 8.34. Variables and KPIs considered for the analysis of the application to urban freight distribution

Indicator	Is it in the model?	Definition	Scenario 1	Scenario 2
Cold Storage Cost	YES	It is calculated according to formula (17), indicated in Chapter 7, Section 7.2.1. D&TCPIs - Cost/Financial Performance Indicators.	-	X

8.4.2. Data preparation and cleaning

As in the case of Bristol, data were prepared and cleaned in order to be analysed.

8.4.3. Output variable

In order to understand the relationship among the performance of the whole system and the KPIs defined to evaluate city logistics performance, a regression model was defined. The indicator used to represent the performance of the whole system is the number of deliveries performed. In particular, the number of deliveries performed to each commercial activity every day is considered.

8.4.4. Evaluating city logistics performance based on ex-ante analysis - Scenario 1

8.4.4.1. Data analysis

8.4.4.1.1. Data description and descriptive statistics

Data analysis of scenario 1 allowed highlighting the following aspects (

Table 8.35):

- The highest social costs are related to the emissions of NO_x, with a mean value of 1.627 Euros per week; it is about 4.7 times higher than the cost due to PM emissions and about 7 times higher than that related to CO_2 emissions. In fact, even though the amount of CO2 produced (about 6,508 kg per delivery) is higher than that of the other pollutant emission factors; NO_x emissions (about 9.8 Kg per delivery) are more dangerous for public health, so the related costs are higher.
- The average distance travelled to make the delivery is 16.3 km.
- Every receiver spends about 7.30 Euros per delivery; delivery costs are about 16.3 Euros per week.
- Delivery frequency ranges from 1 to 12 times a week, with an average value of 5 times a week.
- Broadly speaking, load factor is very low (mean=1.5%) and ranges between 0 and 9%.
- The surveyed area receives more than 4,000 boxes per week, with about 77 boxes received per retailer. In particular, the average delivery size is 12 boxes per receiver, which corresponds to 0.105 m^3.

The summary statistics of the results is shown in Appendix 4. Second-step analysis concerns the study of the relationships among variables. To this aim, correlation analysis is carried out.

8.4.4.1.2. Relationships among categorical variables: Tests of Independence (chi-square test)

The methodology of the chi-square test of independence is widely described in Chapter 6. It is used to determine whether there is a relationship between two categorical variables. Results are shown in Table 8.35. The analysis showed there is no relation among variables.

Table 8.35. Results of the test of independence (Chi-Square)

		Pearson Chi-Square Tests				
		Delivery_frequency_week	Vehicle	Delivery_Time	load_unload_operations	Fuel
Delivery_frequency_week	χ^2	1				
Vehicle	χ^2	38.765	1			
	Sig.	0.003				
Delivery_Time	χ^2	32.429	12.096	1		
	Sig.	0.958	0.438			
load_unload_operations	χ^2	70.210	7.870	25.893	1	
	Sig.	0.096	0.896	0.893		
Fuel	χ^2	3.000	1.750	2.932	2.236	1
	Sig.	0.809	0.417	0.569	0.692	

8.5. Relationships among continuous variables: Pearson's correlation coefficient

The methodology used to evaluate correlation among continuous variables (Pearson's correlation coefficient) is described in Chapter 6. Results are shown in Appendix 4. The analysis highlighted the following relations:

- Cost-related variables: Transportation cost per week is quite related to the social cost related to CO_2 emissions (0.610) and to the distance travelled (1.000). Social cost related to the emissions of PM is related to the emissions of NO_x produced (1.000). Social cost related to the emissions of NO_x is related to the emissions of CO_2 produced (1.000) and to the emissions of PM produced (0.616). Social cost related to the emissions of CO_2 is related to the emissions of PM produced (0.613).
- Productivity related variables: Delivery size is related to the load factor of the vehicles (0.713).
- Environment-related variables: emissions of CO_2 produced per delivery are related to the emissions of PM (0.616).

Based on the results, the following variables were considered for the next step analysis:

- Load factor;
- N. of boxes delivered per week;
- Transportation cost per delivery;
- Social cost related to the emissions of PM per delivery;
- Social cost related to the emissions of NO_x per delivery;
- Social cost related to the emissions of CO_2 per delivery.

Due to the size of the database, which is bigger than that one of Bristol, it was decided to proceed with a deeper analysis of the variables considered. In particular, a Principal Component Analysis (PCA) for quantitative variables were performed in order to analyse the structure of the variables involved in the model.

8.5.1. Principal Component analysis

The description of the methodology is provided in chapter 6. The variance explained by the initial solution (4 components) is displayed in Table 8.36. The first section of the table shows the Initial Eigenvalues. The Total column gives the eigenvalue, or amount of variance in the original variables accounted for by each component. The % of Variance column gives the ratio, expressed as a percentage, of the variance accounted for by each component to the total variance in all of the variables. The Cumulative % column gives the percentage of variance accounted for by the first n components. For example, the cumulative percentage for the second component (55.890) is the sum of the percentage of variance for the first and second components. 88.73% of total variance is explained by 1 to 4 components.

In particular, if the matrix of components is considered (

Table8.37), each component is characterized as follows:

- Component 1 is characterized by social cost of CO_2 emissions (C_tot = 0.834);
- Component 2 is characterized by productivity (load factor = 0.896);
- Component 3 is characterized by delivery cost and distance travelled (0.857);
- Component 4 is characterized by the quantity of NOx emissions produced per delivery (0.554).

The rotation maintains the cumulative percentage of variation explained by the extracted components, but that variation is spread more evenly over the components. However, there are no many differences between the results of rotated and unrotated matrixes. The scree plot (Figure 8.60) shows the eigenvalue of each component in the solution.

Table 8.36. Total variance explained (un-rotated and rotated solutions)

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.527	29.391	29.391	3.527	29.391	29.391	3.121	26.009	26.009
2	3.180	26.499	55.890	3.180	26.499	55.890	2.960	24.664	50.674
3	2.371	19.759	75.649	2.371	19.759	75.649	2.306	19.213	69.887
4	1.570	13.085	88.734	1.570	13.085	88.730	2.262	18.847	**88.734**
5	0.918	7.651	96.385						
6	0.4	3.329	99.714						
7	0.03	0.247	99.961						
8	0.004	0.035	99.996						
9	0.001	0.004	100.000						
10	1.20E-02	9.98E-02	100.000						
11	1.55E-04	1.29E-03	100.000						
12	1.00E-10	1.04E-10	100.000						

Extraction Method: Principal Component Analysis.

Table8.37. Component matrix [yellow cells indicate the highest values; orange cells indicate likewise high values]

	Component			
	1	2	3	4
Distance	-0.019	0.284	0.857	-0.367
Load_factor	0.317	0.896	0.092	0.198
N_boxes_week	0.722	0.528	-0.221	0.221
Del_size_boxes	0.725	0.500	-0.258	0.182
Transp_Cost_del	-0.019	0.284	0.857	-0.367
Transp_Cost_week	0.473	0.459	0.379	0.212
PM_del	0.455	-0.746	-0.197	-0.110
NOx_del	0.179	-0.573	0.544	0.554
CO2_del	0.771	-0.323	0.011	-0.491
Soc_cost_PM_del	0.178	-0.574	0.544	0.554
Soc_cost_NOx_del	0.771	-0.325	0.007	-0.489
Soc_cost_CO2_del	0.834	-0.228	0.063	0.166

Extraction Method: Principal Component Analysis.

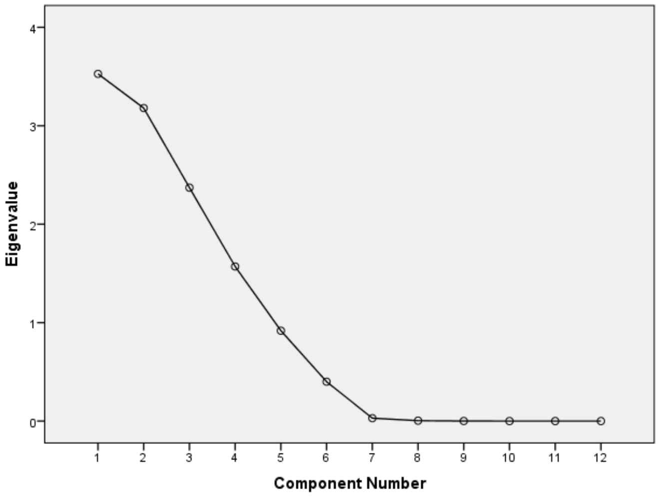

Figure 8.60. Scree plot

The relationship between factors and variables can be expressed as follows:

$F1 = -0.019\ Distance + 0.317\ Load\ Factor + 0.722\ N.boxes\_week + 0.725\ delivery\_size - 0.019\ delivery\ cost + 0.473\ weekly\ delivery\ cost + 0.455\ PM\_del + 0.179\ NOx\_del + 0.771\ CO2\ del + 0.178\ PM\_social\_del\ cost + 0.771\ NOx\_social\_del\ cost + 0.834\ CO2\_social_{del}cost$

$F2 = 0.284\ Distance + 0.896\ Load\ Factor + 0.528\ N.boxes\_week + 0.500\ delivery\_size + 0.284\ delivery\ cost - 0.459\ weekly\ delivery\ cost - 0.746\ PM\_del - 0.573\ NOx\_del - 0.323\ CO2\ del - 0.574\ PM\_(social\_del\ cost) - 0.325\ NOx\_(social\_del\ cost) - 0.228\ CO2\_social\_del\ cost$

$F3 = 0.857\ Distance + 0.092\ Load\ Factor - 0.221\ N.boxes_{week} - 0.258\ delivery_{size} + 0.857\ delivery\ cost + 0.379\ weekly\ delivery\ cost - 0.197\ PM_{del} + 0.544\ NOx_{del} + 0.011\ CO2\ del + 0.544\ PM_{social_{del}cost} + 0.007\ NOx_{social_{del}cost} + 0.063\ CO2\_social_{del}cost$

$F4 = -0.367\ Distance + 0.198\ Load\ Factor + 0.221\ N.boxes_{week} + 0.182\ delivery_{size} - 0.367\ delivery\ cost + 0.212\ weekly\ delivery\ cost - 0.110\ PM_{del} + 0.554\ NOx_{del} - 0.491\ CO2\ del + 0.554\ PM_{social_{del}cost} - 0.489\ NOx_{social_{del}cost} + 0.166\ CO2\_social_{del}cost$

8.6. Linear regression

The description of the methodology is provided in chapter 6. Also in this case, in order to avoid the problem of the indeterminate matrix, the estimation was done with SPSS software through the stepwise technique (criterion for entry or removal of variables are the probabilities of F, respectively, 0.05 and 0.10). The *dependent variable* considered in this case is represented by the number of deliveries received by each retailer per week. After some iterations the less significant variables and the variable with a coefficient with incorrect sign were excluded. The multiple regression analysis was performed by considering the four factors defined with the PCA described in Section 8.5.1.

8.7. Results of the regression analysis

Factors were considered to perform the regression analysis. However, even though different combination of factors were considered, they were not suitable to the model, because of the values of R^2 and $R^2_{adjusted}$ and for the significant tests (Table 8.38).

Model	Fact 1	Fact 2	Fact 3	Fact 4	Vehicle	Delivery_Time	R	R^2	R^2_{adj}	F	Sig.	t-student	VIF
1	x	x	x	x			0.374	0.140	-0.041	0.773	0.556	NR	OK
2	x	x	x				0.356	0.126	-0.005	0.965	0.429	NR	OK
3	x	x	x		x	x	0.934	0.872	0.823	17,738.000	0.000	NR	NR

Table 8.38. Summary of regression analysis performed with factors (Cells with NR are not significant – NR = Not Respected criterion)

For this reason a traditional multiple regression analysis was performed, by considering all the parameters identified after the correlation analysis. They are: Load factor, N. of boxes delivered per week, Transportation cost per delivery, Social cost of PM per delivery, Social cost of NO_x per delivery, Social cost of CO_2 per delivery. The analysis of the results is discussed in the following section.

8.7.1. Traditional multiple regression analysis

Sixteen different combinations of variables have been considered (Table 8.39) in order to find the best suitable combination that maximizes the values of R^2 and R^2_{adj} and, at the same time, is statistically significant (i.e. ANOVA, t-test and VIF respected). Thirteen models are statistically significant. A representation of the values of R^2_{adj} is provided in Table 8.39 and Figure 8.61.

Based on the analysis of the results, the best suitable multiple regression model is represented by Model 18, which considers delivery frequency as independent variable. This model explains 100% of the variance (R^2_{adj}=1.000); however, this result is trivial because the number of deliveries received by each receiver per day depends on the delivery frequency, so it is an obvious result.

	Summary of results														ANOVA		Sig. tests	
Model	Load factor	n. boxes_week	Transp. Cost_del	S_cost_PM_del	S_cost_NOx_del	S_cost_CO2_del	Delivery_frequency_week	Vehicle	Delivery_Time	lod/unload operations	Fuel	R	R^2	R^2_{adj}	F	Sig.	t-student	VIF
4		x										0.358	0.128	0.112	7.958	0.007	OK	OK
5	x											0.609	0.370	0.361	37.652	0	OK	OK
6										x		0.704	0.496	0.486	49.188	0	OK	OK
7				x								0.717	0.514	0.507	67.787	0	OK	OK
8					x							0.764	0.584	0.577	89.769	0	OK	OK
9											x	0.874	0.764	0.752	64.763	0	OK	OK
10									x			0.88	0.774	0.770	191.641	0	OK	OK
11								x				0.889	0.79	0.787	236.840	0	OK	OK
12						x						0.893	0.797	0.794	250.834	0	OK	OK
13			x									0.905	0.819	0.816	289.461	0	OK	OK
14								x	x	x	x	0.955	0.912	0.877	25.843	0	NR	NR
15			x			x		x	x			0.974	0.950	0.946	244.675	0	NR	NR
16	x	x	x	x	x	x			x	x		0.982	0.964	0.954	93.345	0	NR	NR
17	x	x	x	x	x	x						0.981	0.962	0.958	208.898	0	NR	NR
18							x					1.000	1.000	1.000	689,203,318,589.000	0	OK	OK
19			x				x					1	1	1	545,845,105.00	0	OK	NR

Table 8.39. Summary of the results of regression models (Cells with NR are not significant – NR = Not Respected criterion)

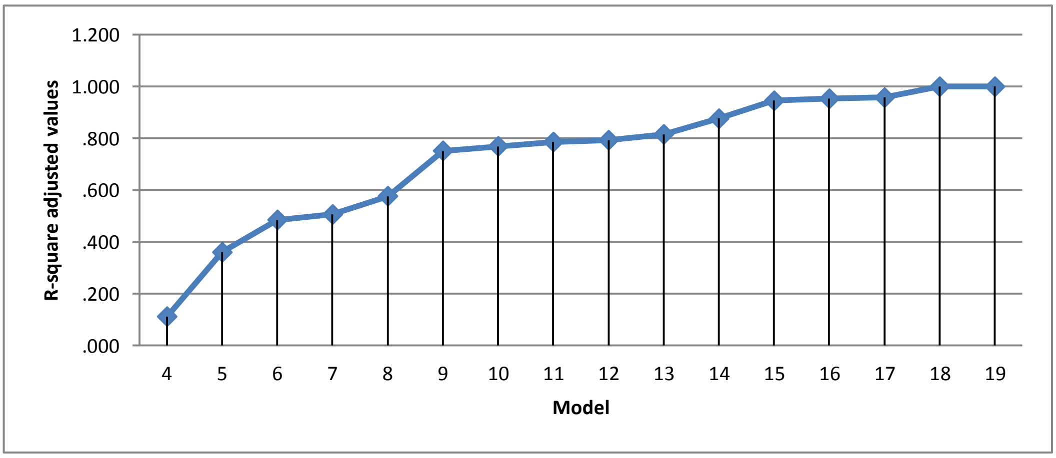

Figure 8.61. Trend of the values of R-square adjusted

Other good results was achieved with the following models:

- Model 13, which considers delivery cost and shows a value of R^2_{adj} equal to 0.816;
- Model 12, which considers social cost of CO_2 emissions and shows a value of R^2_{adj} equal to 0.794;
- Model 11, which considers the type of vehicle and shows a value of R^2_{adj} equal to 0.787;

- Model 10, which considers delivery time and shows a value of R^2_{adj} equal to 0.770;
- Model 9, which considers the type of fuel and shows a value of R^2_{adj} equal to 0.752.

The coefficient of the suitable regression models are indicated in Table 8.40.

Table 8.40. Regression coefficients (Cagliari - Scenario 1)

Coefficients						
		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
9	Fuel	3.940	0.490	0.874	8.048	0.000
10	Delivery_Time	0.927	0.067	0.880	13.840	0.000
11	Vehicle	2.167	0.141	0.889	15.385	0.000
12	S_Cost_CO2_d	15.601	1.251	0.842	12.474	0.000
13	Transp_Cost_d	0.682	0.040	0.905	17.005	0.000

8.8. Evaluating city logistics performance based on ex-ante analysis - Scenario 2

Scenario 2 considers the hypothetical implementation of a UCC to serve the surveyed area. Input demand data are the same used for scenario 1. Delivery frequency is lower or equal to 7. In fact, due to the use of the UCC, receivers can receive goods consolidated in one single deliveries. In this way, the number of delivery journeys is reduced. The average distance travelled to perform the deliveries is 16.30 Km

With this scenario, goods are consolidated onto one truck, a "Smith Newton" all-electric vehicle, which makes a full delivery round into the city. The battery-powered truck also collects recyclable cardboard and plastic from the participating stores. The Smith Newton is quiet, clean and cost-effective. It provides lower total ownership costs through reduced maintenance regimes and substantially lower "fuel" bills. A typical 10 tonne diesel truck achieves urban fuel economy of approximately 10 miles per gallon, meaning it burns 60p£ per mile in fuel. The Smith Newton costs less than 10p£ per mile in electricity.

8.8.1. Data analysis

8.8.1.1. Data description and descriptive statistics

Data analysis of scenario 2 allowed highlighting the following aspects:

- The highest social costs are related to the emissions of NO_x, with a mean value of 1.130 Euros per week; it is about 3 times higher of the cost due to PM emissions and about 5 times higher of that related to CO_2 emissions.
- An average delivery reduction of 6,610 kilos of CO_2 was estimated with Scenario 2. Also, NO_x and PM delivery reductions were respectively 7.13 and 0.92 kilos.
- The average distance travelled to make the delivery is 16.30 km.
- The delivery cost is on average 0.26 Euros and the average weekly delivery cost is 1.19 Euros.
- Cold storage cost is considered with Scenario 2. In this case, an average cost of 1.84 Euros per week was estimated.
- Delivery frequency ranges from 1 to 7 times a week, with an average value of 5 times a week.
- Scenario 2 considers a load factor maximization, with a mean value of 90%.
- The number of boxes received every week by the surveyed area does not change with scenario 2 (more than 4,000 boxes p/week).
- The area receives 187 vehicles less than with scenario 1. The reduction in number of vehicles ranges between 2 and 7.
- More than 60 thousand kilometers travelled were reduced every week with scenario 2 (mean value of 1,112.44 Km).

The summary statistics of the results is shown in Appendix 4. As for Scenario 1, relationships among variables were analysed by means of correlation analysis for continuous variables and chi-square test of independence for categorical variables.

8.8.1.2. Relationships among categorical variables: Tests of Independence (Chi-Square)

The methodology of the chi-square test of independence is widely described in Chapter 6. used to determine whether there is a relationship between two categorical variables. The results of the tests of Independence (Chi-Square) are showed in Table 8.41. The analysis showed there is no relation between variables.

Table 8.41. Results of the test of independence (Chi-Square)

		Delivery_frequency_week
Delivery_time	Chi-square	29.545
	Sig.	0.768

8.8.1.3. Relationships among continuous variables: Pearson's correlation coefficient

The methodology used to evaluate correlation among continuous variables (Pearson's correlation coefficient) is described in Chapter 6. The results of the correlation analysis are showed in Appendix 4. The analysis showed that there is a relation among variables. Results can be summarised as follows:

- Cost-related variables: Transportation cost per week is trivially related to transportation cost per delivery (0.906) and to the number of boxes delivered per week (0.986). The latter is also related to the delivery cost (0.955). Cold storage cost is based on the volume of goods to be stored, so it is related to the number of boxes delivered per week (1.000). The social cost related to CO_2 emissions are related to the reduction of NO_x emissions (0.817) and to social costs of NO_x emissions (0.816). Social costs of PM emissions are related to the delivery size (0.634) and to the reduction of PM emissions (1.000). Social cost related to the emissions of NO_x is related to the reduction of NO_x emissions (1.000), to the social costs of CO_2 emissions (0.816) and to the reduction of CO_2 emissions (0.816).
- Productivity related variables: Delivery size is related to the reduction of the emissions of PM (0.636) and to the social cost of PM (0.634).
- Environment-related variables: reduction of CO_2 per delivery is related to social cost of NO_x emissions per delivery (0.816); reduction of emissions of NO_x is related to the reduction of CO_2 (0.817), to the social costs of NO_x (1.000) and to the social cost of CO_2 (0.817); reduction of PM is related to the social costs of PM emissions per delivery (1.000).
- Also, the reduction of kilometres travelled is related to the number of vehicles reduced per week (0.734) and to the load factor (0.618).

Based on the results, the following variables were considered for the next step analysis:

- Distance;

- Transportation cost per delivery;
- Cold storage cost;
- Reduction of CO_2 emissions per delivery;
- Social cost related to the emissions of CO_2 per delivery;
- Load factor;
- Delivery size (n. of boxes per delivery);
- Reduction of number of vehicles.

8.8.1.4. Dimension reduction

Due to the high number of variables defined to carry out the analysis, a Principal Component Analysis (PCA) for quantitative variables was performed in order to reduce the dimension of the input database, without losing a large quantity of information and to understand the interralationships among variables.

8.8.1.5. Results of Principal Component analysis

The description of the methodology is provided in chapter 6. The variance explained by the initial solution (3 components) is displayed in Table 8.42. This first section of the table shows the Initial Eigenvalues. The Total column gives the eigenvalue, or amount of variance in the original variables accounted for by each component. The % of Variance column gives the ratio, expressed as a percentage, of the variance accounted for by each component to the total variance in all of the variables. The Cumulative % column gives the percentage of variance accounted for by the first n components. 75.81% of total variance is explained by 1 to 3 components.

Table 8.42. Total variance explained (un-rotated and rotated solutions)

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.805	35.065	35.065	2.805	35.065	35.065	2.218	27.730	27.730
2	1.760	21.998	57.063	1.760	21.998	57.063	2.216	27.700	55.430
3	1.500	18.751	75.814	1.500	18.751	75.814	1.631	20.384	75.814
4	0.945	11.808	87.622						
5	0.578	7.221	94.843						
6	0.381	4.758	99.601						

7	0.032	0.399	100.000
8	1.57E-02	0	100.000

In particular, if the matrix of component is considered (

Table8.37), each component is characterized as follows:

- Component 1 is characterized by social cost of CO_2 emissions (0.782) and reduction of CO_2 emissions per delivery (0.782);
- Component 2 is characterized by delivery size (0.630);
- Component 3 is characterized by productivity (load factor = 0.642).

Table 8.43. Component matrix

	Component		
	1	**2**	**3**
Distance	0.173	0.179	-0.325
Transp_Cost_del	0.728	-0.501	0.423
Cold_Stor_Cost	0.724	-0.401	0.516
CO2_del_red	0.782	0.517	-0.271
Soc_cost_CO2_del	0.782	0.516	-0.271
Load_factor	-0.322	0.434	0.642
Del_size_boxes	0.314	0.630	0.545
N_Veh_red_week	-0.543	0.444	0.304

The rotation maintains the cumulative percentage of variation explained by the extracted components, but that variation is spread more evenly over the components. However, there are no many differences between the results of rotated and unrotated matrixes. The scree plot (Figure 8.62) shows the eigenvalue of each component in the solution.

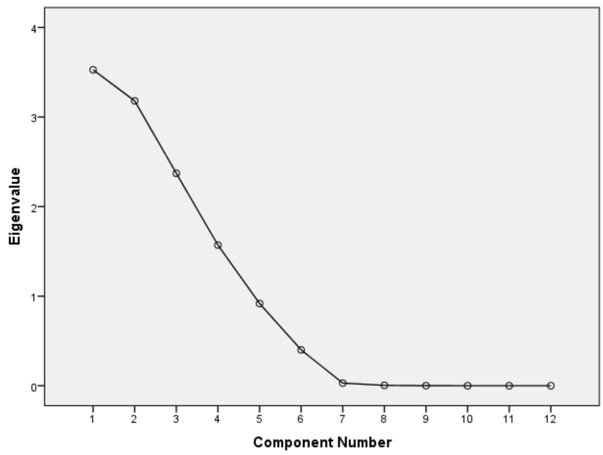

Figure 8.62. Scree plot

The relationship between factors and variables can be expressed as follows:

$$F1 = 0.173\, Distance + 0.728\, delivery\ cost + 0.724\, cold\ storage\ cost + 0.782\, CO2_{del_{reduction}} + 0.782\, CO2_{social_{del}cost} - 0.322\, Load\ Factor + 0.314\, delivery\ size - 0.543\, n.veh\ reduction$$

$$F2 = 0.179\, Distance - 0.501\, delivery\ cost - 0.401\, cold\ storage\ cost + 0.517\, CO2_{del_{reduction}} + 0.516\, CO2_{social_{del}cost} + 0.434\, Load\ Factor + 0.630\, delivery\ size + 0.444\, n.veh\ reduction$$

$$F3 = -0.325\, Distance + 0.423\, delivery\ cost + 0.516\, cold\ storage\ cost - 0.271\, CO2_{del_{reduction}} - 0.271\, CO2_{social_{del}cost} + 0.642\, Load\ Factor + 0.545\, delivery\ size + 0.304\, n.veh\ reduction$$

8.8.1.6. Linear regression

The description of the methodology is provided in chapter 6. Also in this case, in order to avoid the problem of the indeterminate matrix, the estimation was done with SPSS software through the stepwise technique (criterion for entry or removal of variables are the probabilities of F, respectively, 0.05 and 0.10) after some iterations the less significant variables and the variable with a coefficient with incorrect sign were excluded. Exactly as in the previous scenario, the *dependent variable* considered in this case is represented by the number of deliveries received by each retailer per week.

The multiple regression analysis was performed by considering the four factors defined with the PCA described in section 8.8.1.5.

8.8.1.6.1. Results of the regression analysis

Factors were considered to perform the regression analysis. However, as in the previous case they were not suitable to the model, because of the values of R^2 and $R^2_{adjusted}$ and for the significant tests (Table 8.44).

Table 8.44. Summary of regression analysis performed with factors

Model	INPUT - Independent Variables				Summary of results			ANOVA		Sig. Tests	
	Fact 1	Fact 2	Fact 3	Delivery_Time	R	R^2	R^2_{adj}	F	Sig.	t-student	VIF
1	x	X	x		0.305	0.093	0.031	1.509	0.225	NR	OK
2	x	X	x	x	0.940	0.884	0.872	70.535	0.000	NR	OK

For this reason a traditional multiple regression analysis was performed, by considering all the parameters identified after the correlation analysis. They are: transportation cost per delivery, Cold storage cost, CO_2 emissions reduction per delivery, Social cost of CO_2 emissions, Load factor, delivery size (n. of boxes), n. of vehicles reduction per week, delivery frequency and delivery time. The analysis of the results is discussed in the following section.

8.8.1.6.2. Traditional multiple regression analysis

Eighteen different combinations of variables have been considered (Table 8.45) in order to find the best suitable combination that maximizes the values of R^2 and R^2_{adj} and, at the same time, is statistically significant (i.e. ANOVA, t-test and VIF respected). Ten models are statistically significant. A representation of the values of R^2_{adj} is provided in Table 8.45 and Figure 8.63.

Table 8.45. Summary of the results of regression models (Cells with NR are not significant – NR = Not Respected criterion)

	INPUT - Independent Variables										Summary of results			ANOVA		Sig. Tests	
Model	Distance	Transp_Cost_del	Cold_Stor_Cost	CO2_del_red	S_cost_CO2 del	Load_factor	Del_size_boxes	N_Veh_red_week	Delivery_frequency	Delivery_Time	**R**	**R^2**	**R^2_{adj}**	**F**	**Sig.**	**t-student**	**VIF**
3			x								0.339	0.115	0.101	8.300	0.005	OK	OK
4		x									0.460	0.212	0.200	17.204	0.000	OK	OK
5		x	x								0.479	0.230	0.205	9.403	0.000	NR	OK
6				x							0.781	0.610	0.604	98.720	0.000	OK	OK
7					x						0.781	0.610	0.604	98.719	0.000	OK	OK
8		x	x	x							0.789	0.623	0.604	33.587	0.000	NR	OK
9									x		0.999	0.998	0.997	25,755.493	0.000	OK	OK
10										x	0.878	0.771	0.767	188.819	0.000	OK	OK
11								x			0.893	0.798	0.794	212.938	0.000	OK	OK
12		x	x							x	0.898	0.807	0.796	75.097	0.000	NR	OK
13							x				0.898	0.806	0.803	261.059	0.000	OK	OK
14	x										0.913	0.833	0.831	320.042	0.000	OK	OK
15						x					0.958	0.918	0.916	516.499	0.000	OK	OK
16						x				x	0.960	0.922	0.918	229.982	0.000	NR	NR
17						x					0.960	0.922	0.918	265.023	0.000	NR	NR
18						x				x	0.962	0.925	0.919	156.690	0.000	NR	NR
19						x	x				0.965	0.932	0.929	309.020	0.000	OK	OK
20						x	x	x			0.973	0.947	0.943	262.438	0.000	OK	NR

Based on the analysis of the results, the best suitable multiple regression model is represented by Model 19, which considers load factor and delivery size as independent variables. This model explains 100% of the variance (R^2_{adj}=0.929). Other good results was achieved with the following models:

- Model 15, which considers load factor and shows a value of R^2_{adj} equal to 0.916;
- Model 14, which considers distance and shows a value of R^2_{adj} equal to 0.831;
- Model 13, which considers delivery size and shows a value of R^2_{adj} equal to 0.803;
- Model 11, which considers the number of delivery vehicles reduced every week and shows a value of R^2_{adj} equal to 0.794;
- Model 10, which considers delivery time and shows a value of R^2_{adj} equal to 0.767.

Results of Model 9 are not considered, because it considers delivery frequency, so this results is trivial and not significant. Except for Model 19, the other suitable models are all simple regression models. The coefficient of the suitable regression models are indicated in Table8.46.

Table8.46. Regression coefficients (Cagliari - Scenario 2)

Coefficients

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
3	Cold_Stor_Cost	0.284	0.099	0.338	2.877	0.005
4	Transp_Cost_d	5.320	1.222	0.478	4.352	0.000
6	DeliverySizenboxesperdelivery	11.840	0.765	0.888	15.468	0.000
10	DeliveryTime	0.904	0.063	0.886	14.324	0.000
11	NumberofVehiclesReductionperweek	2.472	0.369	0.851	6.694	0.000
13	DeliverySizenboxesperdelivery	11.840	0.765	0.888	15.468	0.000
14	Distance	0.297	0.016	0.920	18.766	0.000
15	AVGLoadFactor	6.000	0.000	1.000		
19	AVGLoadFactor	6.000	0.000	1.000		
	DeliverySizenboxesperdelivery	-8.280E-15	0.000	.000		

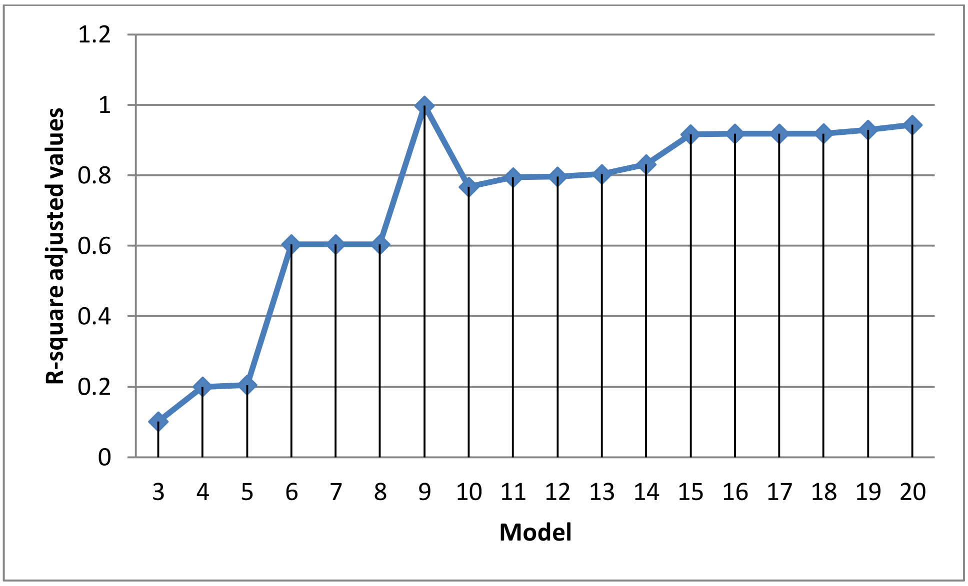

Figure 8.63. Trend of the values of R-square adjusted

8.9. Ex-ante and ex-post scenarios: how do performances change?

The comparison between "*Ex-ante*" (Scenario 1) and "*Ex-post*" (Scenario 2) scenarios allowed the assessment of the improvement/worsening of the performance after the implementation of a hypothetical UCC in Cagliari. No investment costs were considered, because no investment for infrastructure was needed (only costs related to the establishment of the UCC could be considered, but they are not included in the model – they might be considered in the case of a cost-benefit analysis). Neither differential between operational costs *ex-ante* and *ex-pos*t were assumed. The only difference in terms of cost indicators is the cost for *cold storage* born by the UCC for the storage of goods subject to the constraints of the cold chain. The other cost indicators considered are *social costs* due to polluting emissions and *transportation cost* per delivery and per week. Both scenarios consider the same delivery time and frequency and the same number of boxes delivered per week. In terms of *productivity* indexes, *load factor* and *delivery size* are considered. Also, scenario 2 considers the *reduction of number of delivery vehicles*. *Environment indicators* considered include *polluting emission reductions* and *reduction* in terms of *kilometers travelled*. The calculation of *fuel reduction* was excluded because it requires more precise input data about the characteristics of the delivery vehicles, which were not available for scenario 1. For this reason, results related to fuel reduction might have been not significant because based on approximate input data.

	Scenario 1 (ex-ante)		Scenario 2 (ex-post)		Difference of performance	
	Mean	*Std. Deviation*	*Mean*	*Std. Deviation*	*Mean*	*Std. Deviation*
Soc_cost_PM_week	0.343	0.236	0.338	0.215	-0.006	-0.021
Soc_cost_NOx_week	1.602	1.325	1.129	0.968	-0.473	-0.356
Soc_cost_CO2_week	0.228	0.196	0.224	0.181	-0.004	-0.015
Transp_Cost_del	7.337	0.515	0.260	0.400	-7.077	-0.114
Transp_Cost_week	36.893	17.800	1.191	2.283	-35.703	-15.517
Cold_Stor_Cost	0.000	0.000	1.839	6.072	1.839	6.072
PM_del	0.906	0.410	0.000	0.000	-0.906	-0.410
CO2_del	6,507.990	4,038.806	0.000	0.000	-6,507.990	-4,038.806
NOx_del	9.793	6.570	0.000	0.000	-9.793	-6.570
Load_factor	0.170	0.298	0.899	0.178	0.728	-0.120

Table 8.47. Comparison of performance between ex-ante and ex-post scenarios in Cagliari

Based on the results of the comparison shown in Table 8.47, the following considerations can be made:

- In general, social costs related to polluting emissions decrease with the implementation of a UCC. This is a trivial result, because scenario 2 considers electric vehicles to make the deliveries in the city centre. So, the amount of polluting emissions produced per delivery is less with scenario 2.
- Transportation cost per delivery and per week is less with scenario 2. This is due to the more effective delivery scheme. In fact, sharing the same vehicle for multiple-deliveries allows reducing the costs related to the distribution of goods to the urban area. On average 36 Euros per week less per point to be delivered, which correspond to more than 1,800 Euros per year each.
- Last food mile deliveries are considered in the case of Cagliari. This implies considering costs related to cold storage at UCC. This represents the only increased value in the column 'difference of performance'. However, it is worth noting that, even though this is considered equal to zero in scenario 1, it is not actually zero. In fact, this cost is born by the warehouse where shopkeepers buy their products or by themselves (goods stored in their own fridges).
- Being the system more efficient, load factor increases in scenario 2, which can be considered a positive result of the implementation of a UCC. In fact, the higher the load factor, the lower the number of vehicles.

- The reduction of 187 vehicles, which corresponds to a reduction of about 1,112 kilometers travelled per week was estimated with scenario 2 (Table 8.39).

Table 8.47 presents the findings of the comparison between Scenario 1 and Scenario 2. Negative values (third column) correspond to a decrease of the corresponding indicator passing from Scenario 1 to Scenario 2. The only positive values are 'Cold storage cost' and 'Load factor', which increase passing to Scenario 2.

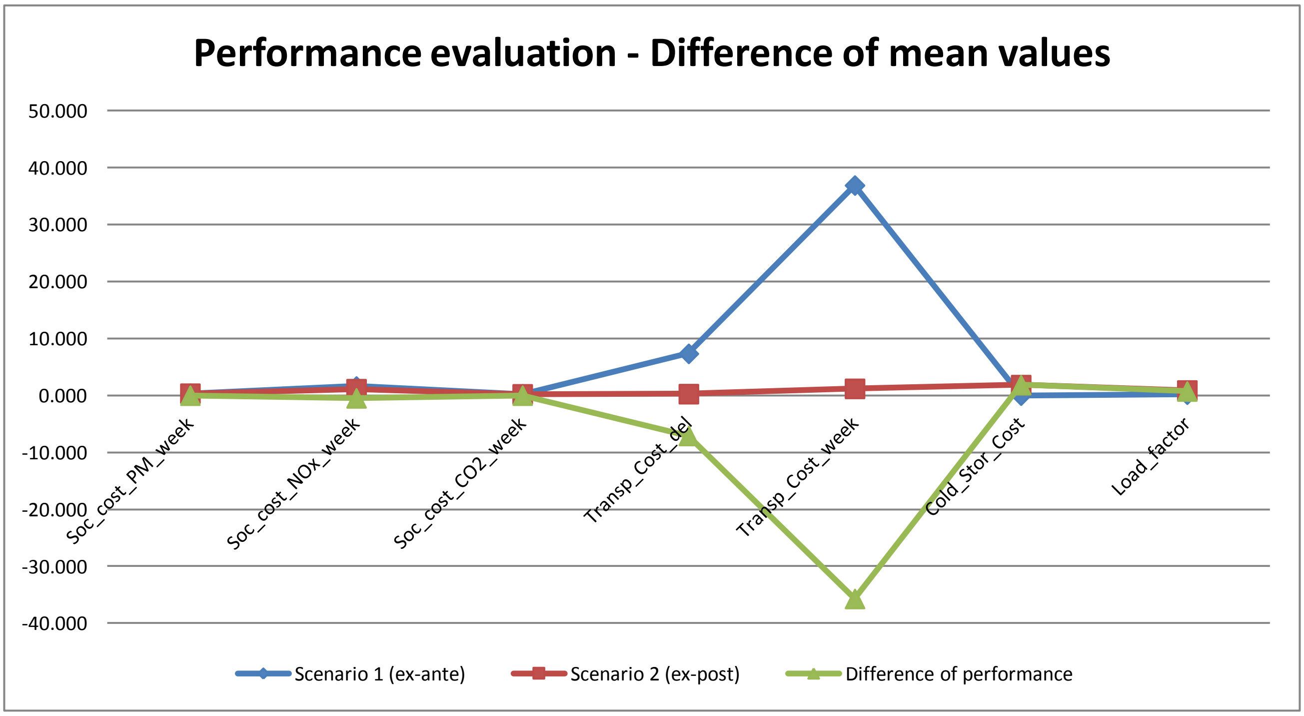

Figure 8.64. Performance evaluation - Difference of mean values

8.10. Concluding remarks

This chapter considers the application of the model proposed in Chapter 7 to assess the performance of city logistics systems. The model has been applied to two case studies in order to evaluate the performance of an existing scheme (Bristol) and of a likely scheme (Cagliari).

In the case of Bristol, the model was applied to an ex-post analysis, because the scheme actually exists. The analysis allowed identifying the benefits coming from the UCC of Bristol. The most important benefits coming from the implementation of the scheme are due to the environmental benefits, related to the reduction of polluting emissions (such as social costs reduction, n. of vehicles reduction, kilomerers travelled reduction and fuel consumption reduction). Based on the survey addressed to the retailers' perception (Paddeu et al., 2016), both delivery safety index and customer satisfaction index showed very positive results, meaning high quality service performed by BBUCC. In particular, as highlighted by Paddeu et al. (2016), very high values of CSI were calculated for the retailers in Bristol, who showed being very satisfied of the service.

In the case of Cagliari, the KPIs belonging to the model were used to a multiple-scenario analysis. It allowed considering how the performance of the urban system change if a UCC is established. The analysis highlighted positive effects coming from the UCC, with all the cost indicators showing a cost reduction. Cold storage costs increase with the UCC, but this is because they are not considered by Scenario 1 because they are assumed to be born by the retailers or by the wholesaler (i.e. goods stored into their own fridges). Being the system more efficient with the UCC (scenario 2), load factor increases, with a corresponding reduction of the number of vehicles and of the kilometers travelled in the urban area. Considering the factorial analysis performed for scenario 1, the majority of the variance is explained by factor 1 (characterized by costs - social costs due to CO_2) and factor 2 (characterized by productivity - load factor). If the performance of the system is expressed in terms of number of deliveries performed, the regression analysis pointed out it is highly related to the delivery cost and to social costs due to polluting emissions. Scenario 2 considers the hypothetical establishment of a UCC to serve the surveyed area. The model pointed out improvement in the system in terms of reduction of number of delivery journeys, and a correspondent reduction of the number of vehicles (187 vehicles less than scenario 1). Similarly to scenario 1, also in this case factorial analysis highlights the majority of the variance is explained by factor 1, characterized by social costs due to CO2, by factor 2, characterized by delivery size and factor 3, characterized by load factor. Regression analysis for scenario 2 outlined that the number of deliveries performed is related to load factor and delivery size.

In general, the model appears suitable to both ex-ante and ex-post analysis of city logistics schemes. The model and its components (KPIs) allows evaluating city logistics performance in terms of cost, time, quality, productivity and environmental performance. Quantitative expressions of the performance allow having a quantitative indication of the efficiency of the system.

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Conclusion

Contribution of the research

This thesis presents the importance of measuring transport and logistics performance to plan, evaluate and monitor the performance of freight transport systems within the decision theory. In the last years the definition of a tool to support managers in the management of transportation systems was needed. In fact, despite the majority of the firms use performance measurement systems to evaluate their activities/processes, the literature does not provide many studies dealing with the problem of the choice of a balanced set of performance indicators. Also, there is any indication about the number and type of indicators to be used at strategic, tactical and operative level. Freight transport and logistics activities represent significant components that strongly affect costs and times of transportation systems and their bad management can compromise the success of the whole system. However, the literature review highlighted a gap between application and research in the field of performance measurement and improvement. Also, many performance indicators have been defined to evaluate freight transport and logistics performance, but no general methods which consider the whole system without separating it in a number of independent smaller sub-sections have been presented. For this reason, the thesis proposes a model that can be used to measure and monitor the performance of transport and logistics by including different components of the whole system. Due to the strong impact freight transport has on the environment and consequentely on the lifeability of our cities, the thesis considers also the evaluation of sustainable systems for urban freight transport distribution: city logistics systems. In fact, decision makers are often reluctant about the actual advantages coming from city logistics practices. They do not clearly have a quantifiable measure of the benefits related to this kind of schemes. The literature review highlighted a lack of research and constant monitoring of city logistics performance. For all these reasons, the identification and evaluation of the city logistics performance is needed in order to understand if the system is efficient and, if it is not, identify the problems and find a feasible solution.

Considering the different context characterizing supply chain and city logistics systems, the different nature of the stakeholders involved and the different objectives and needs, the thesis proposes two different models:

1. The first one deals with the measurement of transportation and logistics performance for the supply chain environment;
2. The second one considers city logistics schemes, thus provides a set of indicators to assess the performance of urban freight distribution.

A measurement model is effective if it measures the 'right things', that is the activities that are targeted by the decision makers. It is worth noting that the study of the stakeholders represented a key driver for the definition of both models. In fatc, both models have been designed by considering the point of view of the decision makers, their needs and objectives. Exactly for this reason, because the stakeholders of the two considered cases are very different, also the two models measure different things (different KPIs), even though they are based on the same model framework (performance attributes).

Both models consider several performance attributes, such as time, cost, quality and productivity. Also, in the case of city logistics schemes, the "environment" attribute is considered.

The main difference between the models proposed lies in their components, the key performance indicators defined for each attribute. In fact, key performance indicators should allow measuring the distance between the objectives of the system and the actual situation (how the system is far from its target, which are different in the two cases). A good measurement model should be a tool to define the management strategy and to support its implementation.

In particular, KPIs allow us to understand in what extent a specific area/activity is working with respect to the target that the system wants to reach. Based on the values of the indicators, decision makers can decide what kind of action/measure need to be undertaken to improve the performance of a specific area. For this reason, the models proposed can be considered a decision support system for decision makers in the field of the management of freight transport systems, because they are useful and easy to use.

Key findings The outcomes of the research provide the answers to the research questions posed in the Introduction:

- *What do transport and logistics performances depend on?*

  Based on the study of the literature, the question is answered in Chapter 1 by the analysis of the main methods and indicators used to assess transport and logistics performance. A measurement system should be 'balanced', that is it should consider both financial and non financial indicators. Chapter 5 and 7 provide a model that can be used to evaluate transport and logistics performance for the supply chain and for the urban environment (see Figure 5.39 and Figure 7.50). A holistic approach has been adopted to define both models. In fact, the models consider the evaluation of cost, time, quality and productivity performance at the same time. The analysis pointed out that freight transport and logistics performance depend on the attributes identified during the literature review and the building of both models. In fact, performances depend on transportation costs, times and productivity. Also, the attribute 'quality' is significant, because it considers customers' satisfaction (CSI), which is essential to make the system successful. The indicators related to the environmental performance of the system are also important, because they indicate the impact the system has on the environment. A 'well-performing' system should also limit its impact on the environment.

- *How 'green practices' influence SC performance?*

The answer is explained in Chapter 2, which provides the results of a survey that involved SC managers and investigated their perspective about the influence of green practices on SC performance. Often companies are not totally aware about the impacts of sustainable practices on supply chain performance and green operations are perceived as an extra-cost or a disadvantage. Conversely, the analysis pointed out that green practices do not significantly influence SC performance. However, results suggest the adoption of green practices can improve the competitiveness of a firm because it can broaden its offer in terms of green, sustainable, or socially responsible products.

- *What kind of drivers/barriers influence a successful implementation of a city logistics scheme?*

The answer to this question is provided in Chapter 4, which examines drivers and barriers to the implementation of a collaborative multi-stakeholder scheme for urban freight distribution. After an introduction to urban freight distribution systems and city logistics (Chapter 3), the analysis is carried out by considering the point of view of actual and potential users, through the analysis of the case of Bristol and the case of Cagliari. Three main barriers have been identified: (1) Financial and Practical barriers, due to the not financial sustainability of these schemes, which, in the most of the cases, need public funds to be operative; (2) Social and Cultural barriers, due to the difficult propensity to change and risk acceptance/aversion. However, based on the results of the survey in Bristol, it is worth noting that large companies may be willing to participate in shared logistics schemes due to the “green image” they provide to the firm. (3) Barriers related to the type of products delivered; in fact, the case of Cagliari pointed out perishable goods (i.e. food products) would be more problematic to manage due to the needs and constraints related to the cold chain (i.e. higher management costs, short delivery times). On the other hand, three main drivers to a successful implementation were identified: (1) Economic advantages, such as money savings, time savings, added value services, etc.; (2) Practical advantages, because this type of schemes allow avoiding inefficient last mile deliveries (e.g. timeliness, delivery safety, time saving, etc.); (3) The protection of the environment, because reduction of polluting emissions due to urban freight transport is achieved; also, being part of the scheme can provide a ‘green image’ to the participating users, so it can be considered as a good marketing strategy.

- *How do performance metrics and models vary on both cases (SC/City Logistics system)?*

The answer to this question is provided in Chapters 5 (supply chain) and chapter 7 (city logistics schemes). The models were designed by considering the objectives of the decision makers. In the first case, the decision maker is the supply chain manager, who makes decisions depending on the objectives that the firm wants to achieve. In this case, in fact, all the indicators were defined by considering a firm-perspective. In this case, both cost and time need to be low, because the firm is supposed to born all the costs of the service offered and the shorter the lead time, the higher the probability to have customers satisfied, which is needed to have an effective system. In the case of the city logistics system, different stakeholders are involved. Their different needs and expectations imply the definition of performance indicators that aim to measure transportation and logistics activities by considering different points of view. In this case, the efficiency of the system is evaluated by considering the efficiency in terms of costs (born by the logistics operator, but also by the society), times (addressed to the users involved, but also to the logistics operator who manages the service), quality of the service provided (that considers the security of the products delivered, but also the satisfaction of customers, which is expressed by considering different aspects of the service provided, such as timeliness, delivery time, overall service, etc.), productivity (related to the optimization of the resources used, such as the delivery vehicles) and finally, the environement (reduction of negative externalities due to urban freight transport, such as reduction of polluting emissions and kilometers travelled, fuel consumption reduction). Also, the model designed to evaluate city logistics performance revealed being suitable for both ex-ante and ex-post analysis.

In sum, both models can be used to evaluate the performance of the system, but they are based on key performance indicators that are very different. This is due to the characteristics of the system components and of the decision makers. In fact, the models represent a decision support system for the decision makers of both systems, so the choice of the type of elements to be evaluated depends on the objectives of the decision maker considered.

- *What type of relationship exists between the variables that affect the performance in each system?*

The answer to this question is presented in chapter 6 for the supply chain and in chapter 8 for city logistics scemes. The methodological approach has been validated by means of three case studies: a manufacturer firm in Sardina (SC), the UCC of Bristol and a potential UCC of Cagliari.

In the first case it was highlighted a strong relationship between time-related indicators and quality-related indicators, such as lead time and shelf life. In fact lead time need to be short for fresh products (with a short shelf life). Cost-related indicators are related to the delivery size (number of items and Kg delivered), because delivery costs depend on the distance travelled and on the delivery size (outsourced deliveries). The cluster analysis allowed grouping indicators in three main clusters: (1) the smallest one, characterized by big size deliveries; (2) the medium one, characterized by not big size deliveries performed in 48-144 hours; (3) the biggest one, characterized by small size deliveries performed in a very short time (by 24 hours). Also, the regression analysis identified sale, lead time and transportation cost as the most important indicators to explain the economic performance of the SC (i.e. income associated to each order). In the case of city logistics schemes a correlation between transportation cost and all the indicatorse related to the environment (i.e. polluting emissions reduction, n. of vehicles reduction, fuel reduction, etc) was identified. Transportation cost is also related to social costs due to pollution.

Limitation and Reccomandation for further research

In this thesis new methods and models to evaluate transport and logistics performance for the supply chain and for urban freight distribution systems are proposed. However, some limitations occurred in the application of both models due to the unavailability of all the data needed to build the database, which limited the completeness of the results. The most complicated case is that of city logistics, whose complexity is due to the articulated structure of the stakeholders involved. In this case, the evaluation model is based on an integrated approach that considers data and information on many other aspects of the design and functioning of the system, such as land planning, urban infrastructures, business and economic development.

Future developments of this research can be made by considering the elaboration of an exact method to evaluate the performance, based on the test of the models with more precise data. Also, the model can be applied to different type of systems, which include not only UCC, but also other types of measures adopted to make urban freight transport more sustainable. Indicators could be used also for benchmarking a set of different measures in order to understand ex-ante which one is the best performing.

Furthermore, due to the complexity associated to its type of chain, it is worth examine in depth the urban food transport and the associated economic and social impacts. For example, based on the model proposed in Chapter 7, it would worth considering a specific set of indicators to evaluate the performance of the cold chain for last food mile deliveries.

APPENDIX 1

This section shows the analysis of the literature carried out in the field of SCPM (Chapter 1)

Summary of the methodology and performance variables used by the reviewed paper (a)

		Methodology																	Performance Variables																				
N.	Reference	Case study	Literature review	SCOR	Correlation/factorial analysis	SEM/Path models	Statistics	Regressio mocel	AHP	Balanced Scorecard	Simulation	KPIs	Hypothesis test	Game theory	Benchmarking	Fuzzy	DEA/DEMATEL	OR	Cost	Customers	Responsiveness	Time	Flexibility	Financial performance	Information technologies	Supply chain integration	Lead time	Quality	Lean/Agile SC	Suppliers	Inventory	Efficiency	Effectiveness	Orders	Production	HR	Delivery	Enviroment	Fle1ibility
1	Agami et al. (2012)		x																																				
2	Agarwal, et al. (2006)	x			x				x										x								x	x	x										
3	Ala-Harja and Helo (2014)	x		x								x							x			x					x											x	
4	Beamon, B. M. (1999)		x																x	x	x	x	x																
5	Bhagwat and Sharma (2007)	x								x									x	x														x			x		
6	Bourlakis et al. (2014)	x					x																x					x											
7	Cai et al. (2009)	x		x	x							x							x	x			x	x															
8	Cheng (2011)	x				x																		x															
9	Cho and Lee (2013)										x														x		x												
10	Cho et al. (2012)	x														x				x					x					x									
11	Cigolini et al. (2014)						x				x																												
12	Costantino et al. (2014)										x																												
13	DeGroote and Marx (2013)	x				x																			x	x		x	x										
14	Devaraj et al. (2007)	x				x														x										x									
15	Elgazzar et al. (2012)			x					x																														
16	Estampe et al. (2013)		x																																				
17	Fleisch and Tellkamp (2005)	x					x				x								x					x							x								
18	Fu and Piplani (2004)										x																			x	x								
19	Fugate et al. (2010)	x				x	x						x																			x	x						
20	Gallear et al. (2012)					x																				x													
21	Ganga et al. (2011)			x			x									x																							
22	Garcia et al. (2012)	x		x								x			x				x			x						x											
23	García et al. (2014)	x			x	x	x																			x				x	x	x							
24	García-Alcaraz et al. (2015)	x				x	x	x					x											x							x				x	x			
25	Germain et al. (2008)																							x		x													

Summary of the methodology and performance variables used by the reviewed paper (b)

N.	Reference	Methodology																	Performance Variables																				
		Case study	Literature review	SCOR	Correlation/factorial analysis	SEM/Path models	Statistics	Regressio mocel	AHP	Balanced Scorecard	Simulation	KPIs	Hypothesis test	Game theory	Benchmarking	Fuzzy	DEA/DEMATEL	OR	Cost	Customers	Responsiveness	Time	Flexibility	Financial performance	Information technologies	Supply chain integration	Lead time	Quality	Lean/Agile SC	Suppliers	Inventory	Efficiency	Effectiveness	Orders	Production	HR	Delivery	Enviroment	Fle'libility
26	Geunes et al. (2016).													x					x			x																	
27	Gligor et al. (2015)	x				x													x	x				x					x									x	
28	Griffis et al. (2007)	x										x	x						x			x									x			x					
29	Guiffrida and Jaber (2008)																	x	x			x																	
30	Guiffrida and Nagi (2006)																																				x		
31	Gunasekaran and Kobu (2007)		x																																				
32	Gunasekaran et al. (2004)	x		x																																			
33	Hassini et al. (2012)	x	x									x											x																
34	Hwang et al. (2008)	x		x				x																															
35	Jammernegg and Reiner (2007)	x									x																				x								
36	Jin et al. (2014)	x				x																	x		x														
37	Kumar and Nigmatullin (2011)										x																x												
38	Kwak and Gavirneni (2011)																	x							x						x								
39	Lai et al. (2004)	x																	x									x											
40	Lee et al. (2014)	x				x																			x														
41	Liao and Kuo (2014)	x				x																		x		x													
42	Liao et al.(2009)			x												x			x																				
43	Lii and Kuo (2016)	x				x																				x													
44	Lin et al. (2005)	x				x														x								x		x									
45	Liu et al. (2013)	x				x																			x				x										
46	Lohman et al. (2004)	x								x										x				x														x	
47	Lucas and Noordewier (2016)	x							x															x															
48	Merschmann and Thonemann (2011)	x				x																	x															x	
49	Naini et al. (2011)	x								x				x																									
50	Nakandala et al. (2013)															x											x										x		
51	Narasimhan and Nair (2005)					x																			x	x		x											
52	Palma-Mendoza (2014)			x					x																														
53	Pero et al. (2010)						x				x																												
54	Persson and Araldi (2009)	x		x							x																												
55	Pettersson and Segerstedt (2013)	x										x							x																				
56	Prajogo and Olhager (2012)	x				x																				x													
57	Qin et al. (2016)						x																																
58	Qrunfleh and Tarafdar (2014)	x			x	x																			x														
59	Rached et al. (2015)										x														x														

Summary of the methodology and performance variables used by the reviewed paper (c)

N.	Reference	Methodology																	Performance Variables																				
		Case study	Literature review	SCOR	Correlation/factorial analysis	SEM/Path models	Statistics	Regressio mocel	AHP	Balanced Scorecard	Simulation	KPIs	Hypothesis test	Game theory	Benchmarking	Fuzzy	DEA/DEMATEL	OR	Cost	Customers	Responsiveness	Time	Flexibility	Financial performance	Information technologies	Supply chain integration	Lead time	Quality	Lean/Agile SC	Suppliers	Inventory	Efficiency	Effectiveness	Orders	Production	HR	Delivery	Enviroment	Fle1ibility
60	Ranganathan et al. (2011)	x				x																		x	x					x									
61	Rexhausen et al. (2012)	x				x																																	
62	Schmitz and Platts (2004)	x										x																		x									
63	Shafiee et al. (2014)	x								x							x			x			x	x				x				x							
64	Souza (2014)		x	x																																			
65	Subramanian and Gunasekaran (2015)		x																																				
66	Tavana at al. (2013)	x															x																						
67	Trkman et al. (2010)	x		x		x																			x														
68	Vachon and Klassen (2008)	x																																				x	
69	Vickery, et al. (2003)	x			x	x	x													x				x	x	x													
70	Wagner et al. (2012)	x					x																	x															
71	Whicker et al. (2009)																		x			x																	
72	Wisner (2003)	x				x														x										x									
73	Wong et al. (2015)	x				x														x					x														
74	Wu and Chang (2012)	x								x																x													
75	Wu et al. (2014)					x														x					x	x													
76	Xu et al. (2009)	x															x																						
77	Yang (2014)					x													x						x				x										
78	Youn et al. (2014).	x				x																			x														
79	Yusuf et al. (2014)	x					x																				x												
80	Zhang et al. (2014)	x																x	x								x											x	

APPENDIX 2

Summary statistics and frequency distribution for the survey dealing with green practices and SC performance

This section shows the summary statistics and the correlation matrix of continuous and categorical variables used as input data for the model proposed to assess the performance of the supply chain (Chapter 6).

Type of company

	Frequency	Percent	Valid Percent	Cumulative Percent
Consulting	4	7.100	7.100	7.100
distributor	1	1.800	1.800	8.900
Distributor	4	7.100	7.100	16.100
Manufacturer	26	46.400	46.400	62.500
Manufacturer&Distributor	3	5.400	5.400	67.900
Supplier	6	10.700	10.700	78.600
transport&logistics	12	21.400	21.400	100.000
Total	56	100.000	100.000	

Field

	Frequency	Percent	Valid Percent	Cumulative Percent
Automotive	8	14.300	14.300	14.300
Electronic Devices	5	8.900	8.900	23.200
Food&Drink	16	28.600	28.600	51.800
Other	21	37.500	37.500	89.300
Paper	2	3.600	3.600	92.900
Pharmaceutical	3	5.400	5.400	98.200
Telecommunication	1	1.800	1.800	100.000
Total	56	100.000	100.000	

Market size (Local, National, International)

	Frequency	Percent	Valid Percent	Cumulative Percent
International	33	58.900	58.900	58.900
local	1	1.800	1.800	60.700
Local	4	7.100	7.100	67.900
Local&International	2	3.600	3.600	71.400
na	1	1.800	1.800	73.200
National	14	25.000	25.000	98.200
National&International	1	1.800	1.800	100.000
Total	56	100.000	100.000	

Does your company apply some green practices?				
	Frequency	Percent	Valid Percent	Cumulative Percent
No	17	30.400	28.600	28.600
Yes	39	69.600	69.600	100.000
Total	56	100.000	100.000	

Company size (n. of employees)				
	Frequency	Percent	Valid Percent	Cumulative Percent
100-200	6	10.700	10.700	10.700
1000-5000	14	25.000	25.000	35.700
200-500	8	14.300	14.300	50.000
30000-100000	4	7.100	7.100	57.100
500-1000	7	12.500	12.500	69.600
5000-10000	2	3.600	3.600	73.200
less than 100	12	21.400	21.400	94.600
more than 100000	1	1.800	1.800	96.400
na	2	3.600	3.600	100.000
Total	56	100.000	100.000	

Country				
	Frequency	Percent	Valid Percent	Cumulative Percent
Australia	1	1.800	1.800	1.800
Bahrain	1	1.800	1.800	3.600
Belgium	5	8.900	8.900	12.500
Benelux	1	1.800	1.800	14.300
Brazil	3	5.400	5.400	19.600
Canada	1	1.800	1.800	21.400
France	2	3.600	3.600	25.000
Guatemala	2	3.600	3.600	28.600
Hong Kong	1	1.800	1.800	30.400
Hungary	1	1.800	1.800	32.100
Iran&Germany	1	1.800	1.800	33.900
Italy	15	26.800	26.800	60.700
Malaysia	1	1.800	1.800	62.500
Mexico	1	1.800	1.800	64.300
Myanmar	1	1.800	1.800	66.100
Serbia	2	3.600	3.600	69.600
Spain	2	3.600	3.600	73.200
Sudan	1	1.800	1.800	75.000
Sweden	1	1.800	1.800	76.800
Swiss	1	1.800	1.800	78.600
UK	2	3.600	3.600	82.100
USA	9	16.100	16.100	98.200
USA&Germany	1	1.800	1.800	100.000
Total	56	100.000	100.000	

Job title of respondent				
	Frequency	Percent	Valid Percent	Cumulative Percent
Business Unit Manager	1	1.800	1.800	1.800
Chief Engineer	3	5.400	5.400	7.100
Compliance	2	3.600	3.600	10.700
Consultant	2	3.600	3.600	14.300
HR officer	1	1.800	1.800	16.100
Operations Manager	1	1.800	1.800	17.900
Procurement Manager	3	5.400	5.400	23.200
SC manager	40	71.400	71.400	94.600
Warehouse manager	3	5.400	5.400	100.000
Total	56	100.000	100.000	

APPENDIX 3

Supply chain - Summary statistics and correlation analysis of input data

Results of the test of independence – Categorical variables (Chi-Square) - The Chi-square statistic is significant at the 0.05 level.

		Chi-Square Tests								
		T1	T2	T3	SL	LB	Order_day_period	Order_day_month	Order_day_name	From
T1	Chi-sq									
	df									
	Sig.									
T2	Chi-sq	106.634								
	df	16								
	Sig.	0.000								
T3	Chi-sq	290.808	593.502							
	df	32	32							
	Sig.	0.000	0.000							
SL	Chi-sq	59.049	86.762	964.050						
	df	24	24	48						
	Sig.	0.000	0.000	0.000						
LB	Chi-sq	66.621	30.996	466.013						
	df	4	4	8						
	Sig.	0.000	0.000	0.000						
Order_day_period	Chi-sq	5.747	4.945	16.832	18.851	0.012				
	df	8	8	16	12	2				
	Sig.	0.675	0.763	0.397	0.092	0.994				
Order_day_month	Chi-sq	28.827	29.475	48.750	65.591	0.827	19.018			
	df	44	44	88	66	11	22			
	Sig.	0.962	0.954	1.000	0.491	1.000	0.644			
Order_day_name	Chi-sq	2624.000	175.804	577.382	117.253	88.644	8.210	45.870		
	df	24	24	48	36	6	12	66		
	Sig.	0.000	0.000	0.000	0.000	0.000	0.768	0.972		
From	Chi-sq	69.326	11.578	432.594	189.082	531.856	0.108	1.247	102.765	
	df	4	4	8	6	1	2	11	6	
	Sig.	0.000	0.021	0.000	0.000	0.000	0.947	1.000	0.000	
Day_Customer	Chi-sq	414.372	624.248	1267.410	194.937	141.675	2.614	22.853	636.500	111.481
	df	20	20	40	30	5	10	55	30	5
	Sig.	0.000	0.000	0.000	0.000	0.000	0.989	1.000	0.000	0.000

Results of the test of correlation - Continuous variables (Pearson)

		Correlations									
		C1	**C2**	**C3**	**EL**	**P1**	**P2**	**P3**	**kg_delivery**	**N_items**	**Sale**
C1	P. Corr	1									
	Sig. (2-tailed)										
C2	P. Corr	-0.147	1								
	Sig. (2-tailed)	0.000									
C3	P. Corr	-0.071	0.197	1							
	Sig. (2-tailed)	0.070	0.000	0.000							
EL	P. Corr	0.162	0.202	0.063	1						
	Sig. (2-tailed)	0.000	0.000	0.107	0.000						
P1	P. Corr	0.143	0.325	-0.050	-0.028	1					
	Sig. (2-tailed)	0.000	0.000	0.201	0.481						
P2	P. Corr	0.514	0.346	-0.005	0.003	0.707	1				
	Sig. (2-tailed)	0.000	0.000	0.907	0.948	0.000	0.000				
P3	P. Corr	0.083	0.069	-0.008	-0.009	0.488	0.393	1			
	Sig. (2-tailed)	0.034	0.079	0.846	0.815	0.000	0.000	0.000			
kg_delivery	P. Corr	1.000	-0.147	-0.071	0.162	0.143	0.514	0.083	1		
	Sig. (2-tailed)	0.000	0.000	0.070	0.000	0.000	0.000	0.034	0.000		
N_items	P. Corr	0.504	1.000	-0.089	-0.002	0.526	0.745	0.419	0.504	1	
	Sig. (2-tailed)	0.000	0.000	0.022	0.963	0.000	0.000	0.000	0.000	0.000	
Sale	P. Corr	-0.128	0.194	0.068	0.036	-0.010	-0.095	0.036	-0.128	-0.205	1
	Sig. (2-tailed)	0.001	0.000	0.082	0.357	0.790	0.015	0.354	0.001	0.000	

APPENDIX 4

City Logistics - Summary statistics and correlation analysis of input data

This section shows the summary statistics and the correlation matrix of continuous and categorical variables used as input data for the model proposed to assess the performance of city logistics systems

The case of Bristol - Descriptive statistics of data

	Minimum	Maximum	Sum	Mean	Std. Deviation
Tr_cost_ day	0.314	0.754	9.494	0.452	0.128
Tr_cost_ week	0.314	2.630	22.000	104.762	0.616
Social_cost_PM_ day	0.064	0.064	1.343	0.064	0.000
Social_cost_NOx_ day	1.544	1.544	32.430	154.427	0.000
Social_cost_CO2_ day	0.00007	0.00007	0	0.0000695	0.00000001
Social_cost_PM_week	0.064	0.384	3.197	0.152	0.087
Social_cost_NOx_ week	1.544	9.266	77.213	3.677	2.099
Social_cost_CO2_ week	0.00007	0.00042	0.000	0.00016	0.00009
Delivery_safety	3.000	5.000	86.000	4.095	0.539
CSI	105.600	200.000	3222.800	153.467	27.777
LF	0.300	1.000	11.817	0.563	0.220
N_boxes_week	2.000	435.000	1,874.000	89.238	126.279
Delivery_size	2.000	174.000	1,095.000	52.143	68.741
Veh_red_week	0.857	4.402	43.000	2.048	1.022
PM_red_ week	0.081	0.487	4.055	0.193	0.110
NOx_red_ week	4.508	27.047	225.389	10.733	6.127
CO2_red_ week	0.988	5.931	49.421	2.353	1.343
Fuel_red_ week	232.705	1,396.231	11,635.256	554.059	316.309
Km_red_ week	22.063	113.317	1,106.820	52.706	26.316
PM_red_day	0.081	0.081	1.703	0.081	0.000
NOx_red_ day	4.508	4.508	94.664	4.508	0.000
CO2_red_ day	0.988	0.988	20.757	0.988	0.000
Fuel_red_ day	232.705	232.705	4,886.808	232.705	0.000
Km_red_ day	15.025	23.901	476.423	22.687	1.905

The case of Cagliari – Scenario 1 - Descriptive statistics of data

	Minimum	Maximum	Sum	Mean	Std. Deviation
Soc_cost_PM_week [Euros]	0.006	1.125	22.306	0.348	0.234
Soc_cost_NOx_week [Euros]	0.131	7.255	104.144	1.627	1.319
Soc_cost_CO2_week [Euros]	0.031	0.911	14.798	0.231	0.195
Distance [Km]	14.200	19.000	1,059.800	16.305	1.143
Transp_Cost_del [Euros]	6.390	8.550	476.910	7.337	0.514
Transp_Cost_week [Euros]	7.110	91.800	2,398.050	36.893	17.800
PM_del [grammes]	0.000	1.541	58.917	0.906	0.409
NOx_del [grammes]	0.000	35.296	636.547	9.793	6.570
CO2_del [grammes]	0.000	13,990.780	423,019.360	6,507.990	4,038.805
Delivery_frequency_week	1.000	12.000	-	5.020	2.380
Load_factor	0.000	0.089	-	0.015	0.020
N_boxes_week	7.000	1,750.000	4,247.000	77.000	232.872
Del_size_boxes	0.000	250.000	-	11.783	30.860
Del_size_m3	0.006	1.071	5.788	0.105	0.161

The case of Cagliari – Scenario 1 - Descriptive statistics of data

	N	Minimum	Maximum	Sum	Mean	Std. Deviation
Transp_Cost_del [Euros]	65	0.000	2.000	17.000	0.260	0.400
Transp_Cost_week [Euros]	65	0.000	12.000	77.000	1.190	2,283.000
Cold_Stor_Cost_week [Euros]	65	0.000	49.000	120.000	1.840	6,072.000
PM_del_red [Kg]	64	0.000	2.000	59.000	0.920	0.397
NOx_del_red [Kg]	64	0.000	15.000	456.000	7.130	5,301.000
CO2_del_red [Kg]	64	2,885.000	13,991.000	423,019.000	6,609.680	3,985,986.000
Soc_cost_PM_del [Euros]	64	0.000	0.000	5.000	0.070	0.031
Soc_cost_NOx_del [Euros]	64	0.000	1.000	16.000	0.240	0.182
Soc_cost_CO2_del [Euros]	64	0.000	0.000	3.000	0.050	0.028
Soc_cost_PM_week [Euros]	64	0.000	1.000	22.000	0.340	0.215
Soc_cost_NOx_week [Euros]	64	0.000	4.000	72.000	1.130	0.968
Soc_cost_CO2_week [Euros]	64	0.000	1.000	14.000	0.220	0.181
Delivery_frequency_week	65	1.000	7.000	316.000	4.860	2,089.000
N_boxes_week	55	7.000	1,750.000	4,247.000	77.220	232,872.000
Del_time	57	1.000	7.000	282.000	4.950	1,747.000
Load_factor [%]	47	0.000	1.000	42.000	0.900	0.178
Del_size_boxes	64	0.000	1.000	22.000	0.340	0.215
Del_size_m3	64	0.000	4.000	72.000	1.130	0.968
N_Veh_red_week	55	-2.000	7.000	187.000	3.400	2,282.000
Km_red_week	55	-112.000	1,904.000	61,184.000	1,112.440	732,681.000

The case of Bristol - Results of the test of correlation - Continuous variables (Pearson)

		Correlations																		
		Tr_cost_d	Tr_cost_w	S_cost_PM_d	S_cost_NOx_d	S_cost_CO2_d	S_cost_PM_w	S_cost_NOx_w	S_cost_CO2_w	CSI	LF	N_boxes_w	Del_size	Veh_red_w	PM_red_w	NOx_red_w	CO2_red_w	Fuel_red_w	Km_red_w	PM_red_d
Tr_cost_d	P. corr	1																		
	Sig. (2-tailed)																			
Tr_cost_w	P. corr	0.232	1																	
	Sig. (2-tailed)	0.312																		
S_cost_PM_d	P. corr	.[a]	.[a]	1																
	Sig. (2-tailed)																			
S_cost_NOx_d	P. corr	.[a]	.[a]	.[a]	1															
	Sig. (2-tailed)																			
S_cost_CO2_d	P. corr	0.199	0.136	.[a]	.[a]	1														
	Sig. (2-tailed)	0.386	0.555																	
S_cost_PM_w	P. corr	-0.173	0.895	.[a]	.[a]	0.064	1													
	Sig. (2-tailed)	0.453	0.000			0.782														
S_cost_NOx_w	P. corr	-0.173	0.895	.[a]	.[a]	0.064	1.000	1												
	Sig. (2-tailed)	0.453	0.000			0.782	0.000													
S_cost_CO2_w	P. corr	-0.173	0.895	.[a]	.[a]	0.064	1.000	1.000	1											
	Sig. (2-tailed)	0.453	0.000			0.781	0.000	0.000												
CSI	P. corr	0.104	-0.140	.[a]	.[a]	-0.265	-0.181	-0.181	-0.181	1										
	Sig. (2-tailed)	0.654	0.545			0.246	0.433	0.433	0.433											
LF	P. corr	0.615	- 0.0147	.[a]	.[a]	0.060	-0.368	-0.368	-0.368	0.007	1									
	Sig. (2-tailed)	0.003	0.525			0.796	0.101	0.101	0.101	0.975										
N_boxes_w	P. corr	0.466	0.336	.[a]	.[a]	0.144	0.091	0.091	0.091	0.196	0.390	1								
	Sig. (2-tailed)	0.033	0.136			0.534	0.695	0.695	0.695	0.395	0.080									
Del_size	P. corr	0.513	-0.172	.[a]	.[a]	0.157	-0.387	-0.387	-0.387	0.097	0.762	0.749	1							
	Sig. (2-tailed)	0.017	0.457			0.496	0.083	0.083	0.083	0.676	0.000	0.000								
Veh_red_w	P. corr	-0.195	0.872	.[a]	.[a]	0.045	0.947	0.947	0.947	-0.154	-0.428	0.128	-0.424	1						
	Sig. (2-tailed)	0.396	0.000			0.845	0.000	0.000	0.000	0.505	0.053	0.579	0.056							
PM_red_w	P. corr	-0.173	0.895	.[a]	.[a]	0.064	1.000	1.000	1.000	-0.181	0-.368	0.091	-0.387	0.947	1					
	Sig. (2-tailed)	0.453	0.000			0.782	0.000	0.000	0.000	0.433	0.101	0.695	0.083	0.000						
NOx_red_w	P. corr	-0.173	0.895	.[a]	.[a]	0.064	1.000	1.000	1.000	-0.181	-0.368	0.091	-0.387	0.947	1.000	1				
	Sig. (2-tailed)	0.453	0.000			0.782	0.000	0.000	0.000	0.433	0.101	0.695	0.083	0.000	0.000					
CO2_red_w	P. corr	-0.173	0.895	.[a]	.[a]	0.064	1.000	1.000	1.000	-0.181	-0.368	0.091	-0.387	0.947	1.000	1.000	1			
	Sig. (2-tailed)	0.453	0.000			0.782	0.000	0.000	0.000	0.433	0.101	0.695	0.083	0.000	0.000	0.000				
Fuel_red_w	P. corr	-0.173	0.895	.[a]	.[a]	0.064	1.000	1.000	1.000	-0.181	-0.368	0.091	-0.387	0.947	1.000	1.000	1.000	1		
	Sig. (2-tailed)	0.453	0.000			0.782	0.000	0.000	0.000	0.433	0.101	0.695	0.083	0.000	0.000	0.000	0.000			
Km_red_w	P. corr	-0.195	0.872	.[a]	.[a]	0.045	0.947	0.947	0.947	-0.154	-0.428	0.128	-0.424	1.000	0.947	0.947	0.947	0.947	1	
	Sig. (2-tailed)	0.396	0.000			0.845	0.000	0.000	0.000	0.505	0.053	0.579	0.056	0.000	0.000	0.000	0.000	0.000		

The case of Cagliari – Scenario 1 - Results of the test of correlation (Pearson)

		Correlations											
		Distance	Load_factor	N_boxes_week	Del_size_boxes	Transp_Cost_del	Transp_Cost_week	PM_del	NOx_del	CO2_del	S_cost_PM_del	S_cost_NOx_del	S_cost_CO2_del
Distance	P. corr	1											
	Sig. (2-tailed)												
Load_factor	P. corr	0.051	1										
	Sig. (2-tailed)	0.688											
N_boxes_week	P. corr	-0.015	0.485	1									
	Sig. (2-tailed)	0.911	0.000										
Del_size_boxes	P. corr	-0.092	0.713	0.995	1								
	Sig. (2-tailed)	0.678	0.000	0.000									
Transp_Cost_del	P. corr	1.000	0.051	-0.015	-0.092	1							
	Sig. (2-tailed)	0.000	0.688	0.911	0.678								
Transp_Cost_week	P. corr	0.227	0.425	0.172	0.307	0.227	1						
	Sig. (2-tailed)	0.069	0.000	0.208	0.154	0.069							
PM_del	P. corr	0.113	-0.445	0.068	0.097	0.113	-0.184	1					
	Sig. (2-tailed)	0.371	0.000	0.622	0.658	0.371	0.142						
NOx_del	P. corr	0.066	-0.194	-0.107	-0.155	0.066	-0.138	0.356	1				
	Sig. (2-tailed)	0.604	0.121	0.437	0.479	0.604	0.273	0.004					
CO2_del	P. corr	0.250	-0.207	0.224	0.277	0.250	0.010	0.616	0.000	1			
	Sig. (2-tailed)	0.044	0.098	0.100	0.201	0.044	0.936	0.000	0.997				
S_cost_PM_del	P. corr	0.065	-0.194	-0.107	-0.156	0.065	-0.138	0.357	1.000	-0.001	1		
	Sig. (2-tailed)	0.606	0.121	0.436	0.478	0.606	0.272	0.004	0.000	0.996			
S_cost_NOx_del	P. corr	0.247	-0.208	0.224	0.277	0.247	0.008	0.616	0.000	1.000	-0.001	1	
	Sig. (2-tailed)	0.048	0.096	0.100	0.200	0.048	0.949	0.000	0.997	0.000	0.996		
S_cost_CO2_del	P. corr	0.127	-0.100	0.214	0.389	0.127	0.610	0.613	0.138	0.472	0.138	0.471	1
	Sig. (2-tailed)	0.315	0.43	0.116	0.066	0.315	0.000	0.000	0.272	0.000	0.272	0.000	

The case of Cagliari – Scenario 2 - Results of the test of correlation (Pearson)

		Distance	Transp_Cost _del	Transp_Cost_ week	Cold_Stor_ Cost	PM_del_ red	NOx_del_ red	CO2_del_ red	S_cost_ PM del	Soc_cost_ NOx del	Soc_cost_ CO2 del	N_boxes_ week	Load_fac tor	Del_size_b oxes	N_Veh_ red week	Km_red_ week
Distance	Pearson Corr	1														
	Sig. (2-tailed)															
Transp_Cost_ del	Pearson Corr	0.026	1													
	Sig. (2-tailed)	0.835														
Transp_Cost_ week	Pearson Corr	0.119	0.906	1												
	Sig. (2-tailed)	0.344	0.000													
Cold_Stor_Co st	Pearson Corr	-0.011	0.400	0.561	1											
	Sig. (2-tailed)	0.930	0.001	0.000												
PM_del_red	Pearson Corr	0.108	-0.180	-0.107	0.095	1										
	Sig. (2-tailed)	0.397	0.154	0.402	0.457											
NOx_del_red	Pearson Corr	-0.091	-0.048	-0.123	-0.200	-0.068	1									
	Sig. (2-tailed)	0.476	0.706	0.333	0.112	0.595										
CO2_del_red	Pearson Corr	0.249	-0.049	0.060	0.231	0.595	-0.817	1								
	Sig. (2-tailed)	0.048	0.698	0.639	0.066	0.000	0.000									
Soc_cost_PM _del	Pearson Corr	0.106	-0.179	-0.106	0.096	1.000	-0.066	0.593	1							
	Sig. (2-tailed)	0.405	0.156	0.404	0.452	0.000	0.605	0.000								
Soc_cost_NO x_del	Pearson Corr	-0.091	-0.048	-0.123	-0.200	-0.067	1.000	-0.816	-0.066	1						
	Sig. (2-tailed)	0.475	0.706	0.333	0.112	0.596	0.000	0.000	0.607							
Soc_cost_CO2 _del	Pearson Corr	0.245	-0.050	0.059	0.232	0.595	-0.817	1.000	0.594	-0.816	1					
	Sig. (2-tailed)	0.051	0.694	0.643	0.065											
N_boxes_wee k	Pearson Corr	-0.015	0.955	0.986	1.000	0.068	-0.202	0.224	0.069	-0.202	0.224	1				
	Sig. (2-tailed)	0.911	0.000	0.000	0.000	0.622	0.138	0.100	0.616	0.138	0.100					
Load_factor	Pearson	-0.037	-0.181	-0.091	-0.095	-0.190	0.089	-0.197	-0.193	0.090	-0.197	-0.095	1			

	Corr															
	Sig. (2-tailed)	0.805	0.225	0.544	0.525	0.200	0.550	0.185	0.194	0.550	0.184	0.525				
Del_size_boxes	Pearson Corr	0.134	-0.114	0.093	0.229	0.635	-0.178	0.470	0.634	-0.177	0.469	0.224	0.402	1		
	Sig. (2-tailed)	0.292	0.371	0.464	0.069	0.000	0.160	0.000	0.000	0.161	0.000	0.100	0.005			
N_Veh_red_week	Pearson Corr	-0.154	-0.399	-0.303	-0.292	-0.314	-0.003	-0.216	-0.314	-0.003	-0.217	-0.292	0.356	0.197	1	
	Sig. (2-tailed)	0.262	0.003	0.024	0.031	0.020	0.985	0.113	0.020	0.984	0.112	0.031	0.014	0.150		
Km_red_week	Pearson Corr	-0.046	-0.373	-0.204	-0.178	-0.383	-0.062	-0.187	-0.386	-0.063	-0.188	-0.178	0.618	0.444	0.734	1
	Sig. (2-tailed)	0.741	0.005	0.135	0.194	0.004	0.651	0.172	0.004	0.650	0.168	0.194	0.000	0.001	0.000	

ANNEXES

This part provides a summary of the papers and chapters of book already published (or in press) that have been produced thanks to the research work carried out with this PhD thesis.

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