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Determining Delivery Frequencies in Distribution Management

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Abstract: Determining delivery frequencies in the distribution management is an issue faced, more and more often, by several companies. This thesis aims to describe the decision problem in general, outline the factors which play a role, and present an overview different quantitative operations management approaches that can provide decision support for this. Twenty-six papers have been analyzed in order to give a basis to this research, and to create several archetypes to consider for supporting decision-making on delivery frequency. Specific parameters, which have been considered important for this topic, have been used to analyze and classify these papers, finding the relationships between them.

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1 Introduction

The topic of Supply Chain Management is very wide and involves many factors. According with Wikipedia definition (Wikipedia. 2015. Supply chain management. Accessed 17.12.2015), it is possible to define Supply Chain management as the management of the flow of goods and services. It includes the movement and storage of raw materials, work-in-process inventory, and finished goods from point of origin to point of consumption. Interconnected or interlinked networks, channels and node businesses are involved in the provision of products and services required by end customers in a supply chain.
Supply chain management has been defined, by Cornell Engineering University (Cornell Engineering. 2015. Supply chain. Operations Research and Information Engineering. Accessed 17.12.2015), as the "design, planning, execution, control, and monitoring of supply chain activities with the objective of creating net value, building a competitive infrastructure, leveraging worldwide logistics, synchronizing supply with demand and measuring performance globally."

Warehouse management, routing problem, goods receipt or order creation are only some aspects which belong to this argument. Another important feature of Supply Chain Management is the determination of the delivery frequencies in the distribution management. In fact, they are often used and determining them is therefore an important decision in the design and operation of distribution networks.

Nowadays different modelling approaches exist to decide on delivery frequencies. The goal of this thesis is therefore to describe the decision problem in general, outline which factors play a role, and present an overview different quantitative operations management approaches that can provide decision support for this. A discussion of capabilities and limitations of modelling approaches also occurs.
This thesis is therefore a sort of overview of the delivery frequency problem, and includes the revision of twenty-six papers which deal with this topic. These papers have been then analyzed, and similarities, and differences as well, have been used to group the papers in several archetypes in order to choose a specific approach as a result of a given problem.

The thesis is structured in the following way. After this introduction in chapter 1, the generic distribution chain is described in chapter 2 and, afterwards, the focus shifts to the methodology of this research in chapter 3. Regarding this, 26 papers have been taken into consideration, and they are the basis on which the analysis is carried out. In chapter 4, a brief papers features overview occurs, including a table with all the characteristics, taken into consideration to classify the papers. In chapter 5, firstly, all the factors, which play a role in the determination of the delivery frequency in the distribution, are outlined. Then, the papers are grouped in accordance with their characteristics and relationships, and the different approaches, included in the papers, are described in order to establish their limitations and capabilities, the method used and when is appropriate to adopt it. The conclusions and comments are presented in chapter 6.

2 General Problem Description

In this section a generic supply chain is analyzed. This ideal chain consists of four main figures: suppliers, distribution centres, retailers and customers, and they are the most important parts which constitute a generic supply chain, and interact with each other. For this reason, in this section the focus is only on them.

Nevertheless, many other supply chain structures can be considered, such as single vendor-single buyer or particular cases like the ocean freight for example. In fact, every paper of this thesis is developed on its own supply chain model but this aspect is illustrated in the classification of each paper.

Here a table (Figure 2.1) of a generic supply chain follows.

D.C. = Distribution Centre.

→ = Flow of Goods.

↻ = Flow of Information (Orders and every type of information related to the products, such as feedbacks or delivery details).

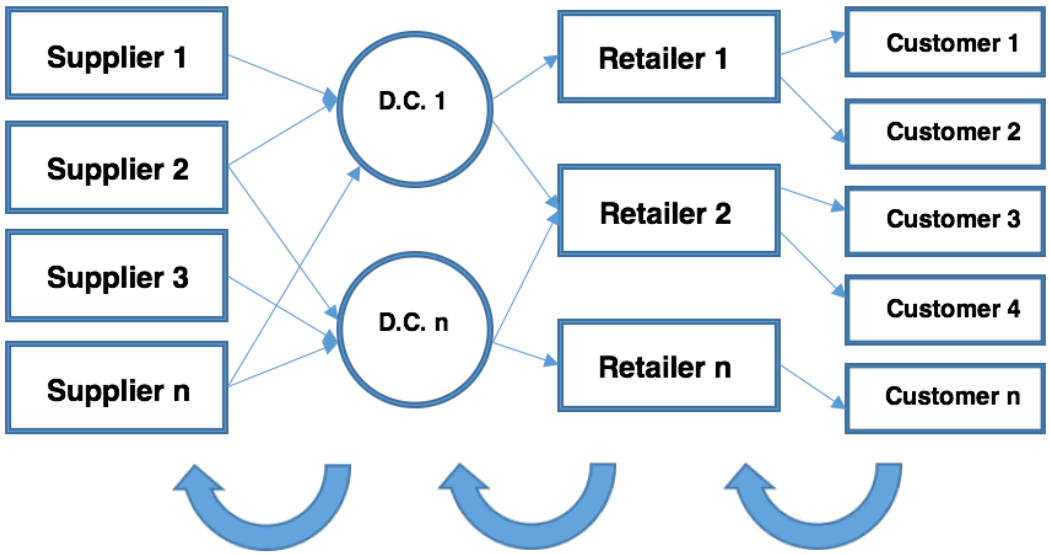

Figure 2.1 *The representation of the generic supply chain described in this chapter.*

2.1 Customers

As stated before, the customers are one of the four most important figures of a generic supply chain. Everything starts from the customer's demand, and all the activities of a general industry are based on it. In fact, the client's choice

determines which and how many products have to be ordered and, later, shipped. Usually, customer satisfaction is one of the most important goals of a supply chain's design. As a matter of fact, the evaluation by the clients affects a company's success or, sometimes, its failure therefore the attention paid to this point of the process must be high.

To know the method to manage the customer's orders, their preferences and their possible requirements have to be known in advance. With respect to this, several mathematical models, based on statistical forecasts, have been developed during the last decades. They help to know the required quantity of a particular product and, equally important, when the client needs it. For instance, pilling up orders for a typical Christmas cake, such as Pandoro, during the months of February and March would not be a great idea, because the goods have to be stored until their regular consumption period and this leads to greater costs, in particular, to storage costs.

2.2 Retailers

The second figure taken into consideration is the retail store, responsible for selling goods directly to the customers. The forecasts, mentioned before, are usually used by purchasing managers of an industry, a company, a restaurant or other. These persons are responsible for provisioning their retail store or plant, firstly, analyzing the information from the forecasts, secondly, creating an order directed to a distribution centre.

It has to be said that managing the flow of goods in a retail store is not an easy issue in fact several studies have been made in order to improve the utilization of the space, such as shelves placement and warehouse's replenishment.

Another important aspect is that, in addition to customer satisfaction, the aim of the majority of stores is also to maximize the profits and the best way to do this is to study all the possible costs involved, from an order generation to the good's delivery.

Several different models have been studied in order to determine the delivery frequency in the distribution management and, as stated before, this is the focus of this thesis. These models could be useful for suggesting to the responsible managers how many times a week an order has to be created. There are a lot of different authors who have developed approaches to achieve this aim and, as it will be presented during this thesis, this goal is followed, the majority of the time,

by minimizing the total costs. The delivery frequency determination is, in fact, only a component of a bigger problem: the minimization of total costs, that is, usually, the primary target of each paper.

Generally, through a deterministic or stochastic approach, a mixed integer linear problem (M.I.L.P.), a simulation or other different algorithms, which will be taken into consideration during this thesis, different scenarios are analyzed to find the best solution for a specific case study.

The costs involved in order to create these models are many. The transportation costs from the distribution centre to the retail store or from the suppliers to the distribution centre, the shelf filling costs, the storage costs, the order-making or penalty for early or tardy delivery are only some examples. In other case, as Green supply chain for instance which aims to protect and restore the environment, separating and recycling biodegradable waste costs can also be included. In most cases is the minimization of total costs that leads therefore to the perfect configuration of a delivery scheme.

2.3 Distribution centre

The orders from the retailer stores are collected and delivered to a distribution centre. A supply chain can include central or regional distribution centres, storage centres and also some internal consolidation points as well, but in this paragraph only the simplest configuration is taken into account, which is the presence of only a generic distribution centre, a place where the goods coming from the suppliers are stored before being shipped to the retailer stores.

A distribution centre is usually run by a wholesaler who, generally, signs a contract with each of the retailer markets. This contract fixes several points, such as the delivery frequency of the goods and the priority among the different customers. Normally, the same forecast models used by a retailer are the same which the distribution centre's managers use, in order to make the maximum profit and to satisfy the retail shops every time and, consequently, the final customer's demand.

In addition to this, it is necessary to plan a smart route which will be assigned to the trucks or ships. This means great costs reduction and better resource's utilization and is studied in many papers of this thesis, with the name of Vehicle Routing Problem.

Furthermore, not all the goods can be conserved in the same way. The foods, for

instance, are transported in different separate compartments: one for frozen foods, another one for chilled foods and last one for foods which must be conserved at room or ambient temperature. All these complications could be easily ignored in case of other types of products, for example furniture or petrol, which do not have deadlines as strict as the food industry but, in this last case, the quality and and the freshness of the products is of primary importance.
Finally, as in the case with the retailer shops, a periodic inventory must be performed by a specific attendant to help to know exactly the available amount of each product, necessary to make a new order.

2.4 Suppliers

The last step of a generic supply chain concerns with the suppliers. They are manufacturers, farmers, and any other producer who can serve a specific distribution centre. In fact, a distribution centre is often supplied by a lot of different channels, which can guarantee a constant restocking with different types of food. The logic behind the supply is similar to the other ones already mentioned: the distribution centre signs a contract with each supplier based on forecast models and the inventory level.

These four are the most important figures which play a role in a generic supply chain. As stated before, other types of supply chain can be present and they will be illustrated in the classification of each paper. The focus of this thesis will be then mainly on the different delivery approaches proposed by several authors and on the relationships between them. In every paper the type of supply chain considered is taken into consideration because it influences the selection of the model, furthermore the part of the supply chain, in which the different equations are applied, is pointed out.

3 Methodology of Research

In this chapter the research of the papers is presented, from their selection on different databases to the choice's criterions of the parameters useful to the paper's classification.

First of all, each database used for this search is, in this first section, presented. After that, the way in which the papers have been found, such as keywords or title in the research, is discussed, and, finally, every parameter for the selection of the papers is justified and described. The scheme of the methodology research is well approximated in Figure 3.1.

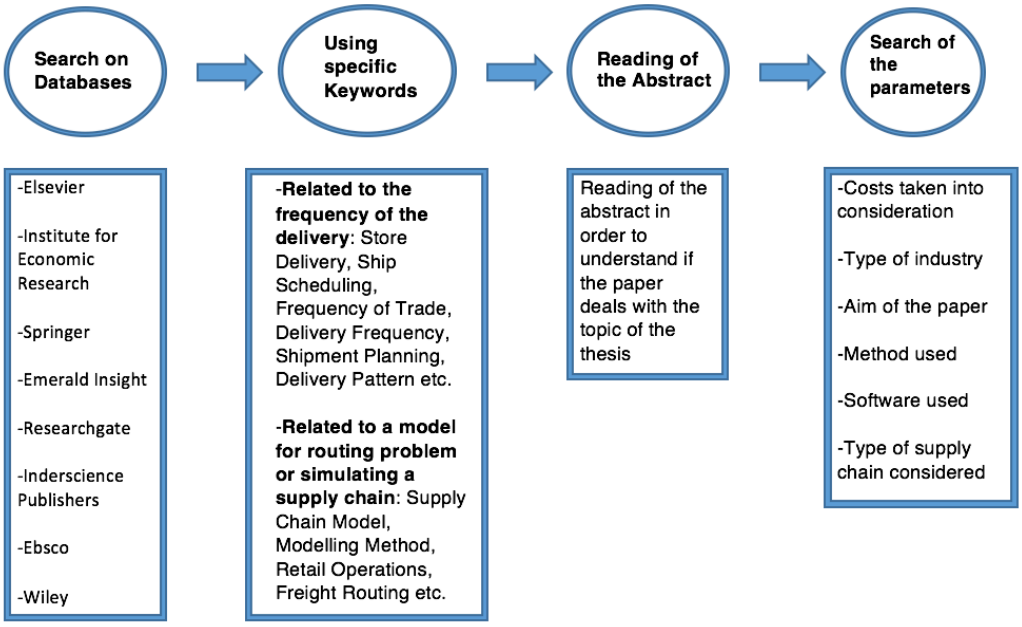

Figure 3.1 *Scheme of the research methodology used*.

3.1 Databases

This thesis has been developed only making consideration on an internet research because the amount of this topic available on the network is satisfactory and, especially, in this way finding articles related to the delivery frequency topic is definitely easier than looking at many catalogues in the libraries or elsewhere.

According with Wikipedia definition, these are the databases used for the search of the papers:

3.1.1 Elsevier: Elsevier B.V. is an academic publishing company that publishes medical and scientific literature. It is a part of the Relx Group (known until 2015 as Reed Elsevier). Based in Amsterdam, the company has operations in the UK, US, Mexico, Brazil, Spain, Germany, and elsewhere. Leading products include journals such as The Lancet and Cell, books such as Gray's Anatomy, the Science Direct collection of electronic journals that is the main searching engine used for this thesis, the Trends and Current Opinions series of journals, and the online citation database Scopus. Elsevier annually publishes approximately 350,000 articles a year in 2,000 journals. Its archives contain over 13 million documents. Total yearly downloads amount to 750 million (Wikipedia. 2016. Elsevier. Accessed 15.01.2016).

3.1.2 Institute for Economic Research: The IFO (Institute for Economic Research) is a Munich-based research institution. IFO is an acronym from Information and Forschung (research). As one of Germany's largest economic think-tanks, it analyses economic policy and is widely known for its monthly IFO Business Climate Index for Germany. Its research output is significant: about a quarter of the articles published by German research institutes in international journals in economics in 2006 were from IFO researchers (Wikipedia. 2016. Ifo Institute for Economic Research. Accessed 16.01.2016).

3.1.3 Springer: Springer Science + Business Media or simply Springer is a global publishing company that publishes books, e-books and peer-reviewed journals in science, technical and medical (STM) publishing. Springer also hosts a number of scientific databases, including SpringerLink that is one of the databases considered in this thesis research, Springer Protocols, and SpringerImages. Book publications include major reference works, textbooks, monographs and book series; more than 168,000 titles are available as e-books in 24 subject collections. Springer has major offices in Berlin, Heidelberg, Dordrecht, and New York City (Wikipedia. 2016. Springer Science + Business Media. Accessed 17.01.2016).

3.1.4 Emerald Insight: Emerald Group Publishing Limited is a scholarly publisher of academic journals and books in the fields of management, business, education, library studies, health care, and engineering. It

was founded in the United Kingdom in 1967 and has its headquarters in Bingley. The company manages a portfolio of more than 290 journals and over 2650 books and book series volumes. It operates worldwide with offices and associates in Australia, Brazil, China, the Czech Republic, Dubai, India, Indonesia, Japan, Lithuania, Malaysia, Mexico, Singapore, South Africa, South Korea, Turkey, and the United States. The company is based in Howard House on the outskirts of Bingley, West Yorkshire. Emerald Insight is one of databases run by this company (Wikipedia. 2016. Emerald Group Publishing. Accessed 18.01.2016).

3.1.5 Researchgate: ResearchGate is a social networking site for scientists and researchers to share papers, ask and answer questions, and find collaborators. The website claims to have millions of users and to be influential. ResearchGate was founded in 2008 by virologist and computer scientist Ijad Madisch. It started in Boston, and moved to Berlin, Germany, shortly afterwards. In 2009, the company began a partnership with Seeding Labs in order to supply third-world countries with surplus lab equipment from the United States (Wikipedia. 2016. ResearchGate. Accessed 19.01.2016).

3.1.6 Inderscience Publishers: Inderscience Publishers is an academic publisher that publishes peer-reviewed journals in the fields of law, engineering and technology, management and business administration, and energy, environment, and sustainable development (Wikipedia. 2016. Inderscience Publishers. Accessed 19.01.2016).

3.1.7 Ebsco: EBSCO Information Services, headquartered in Ipswich, Massachusetts, is a division of EBSCO Industries Inc., the third largest private company in Birmingham, Alabama. EBSCO offers library resources to customers in academic, medical, K–12, public library, law, corporate, and government markets. Its products include EBSCONET, a complete e-resource management system, and EBSCOhost, which supplies a fee-based online research service with 375 full-text databases, a collection of 600,000-plus ebooks, subject indexes, point-of-care medical references, and an array of historical digital archives. (Wikipedia. 2016. EBSCO Information Service. Accessed 20.01.2016).

3.1.8 Wiley: John Wiley & Sons, Inc., also referred to as Wiley (NYSE: JW.A), is a global publishing company that specializes in academic publishing and markets its products to professionals and consumers, students and instructors in higher education, and researchers and practitioners in scientific, technical, medical, and scholarly fields. The company produces books, journals, and encyclopedias, in print and electronically, as well as online products and services, training materials, and educational materials for undergraduate, graduate, and continuing education students (Wikipedia. 2016. John Wiley & Sons. Accessed 22.01.2016).

It must be said that not all the papers present in the literature have been taken into consideration because some of them are very recent and protected by copyright. The papers which have been analyzed are free access paper or have been made accessible through the credentials of the Technische Universität München, that allowed the access to the majority of them.

The research has been carried out typing specific keywords and certain words in the title of the paper. Figure 3.2 and Figure 3.3 are typical interfaces used in this search of the papers.

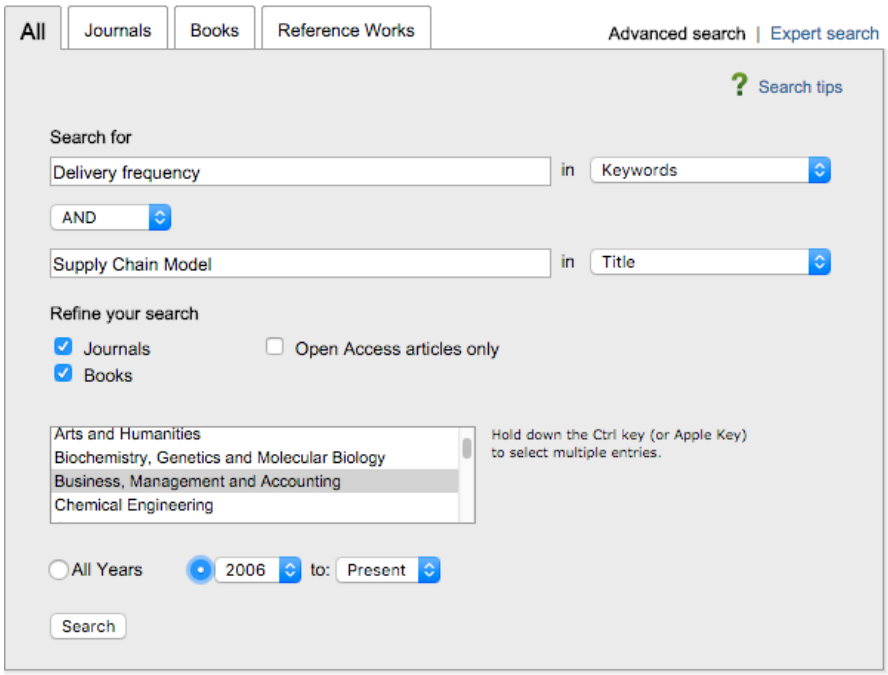

Figure 3.2 *Interface of the database Elsevier to search the papers. (Elsevier. 2015. Science Direct. Accessed 20.10.2015).*

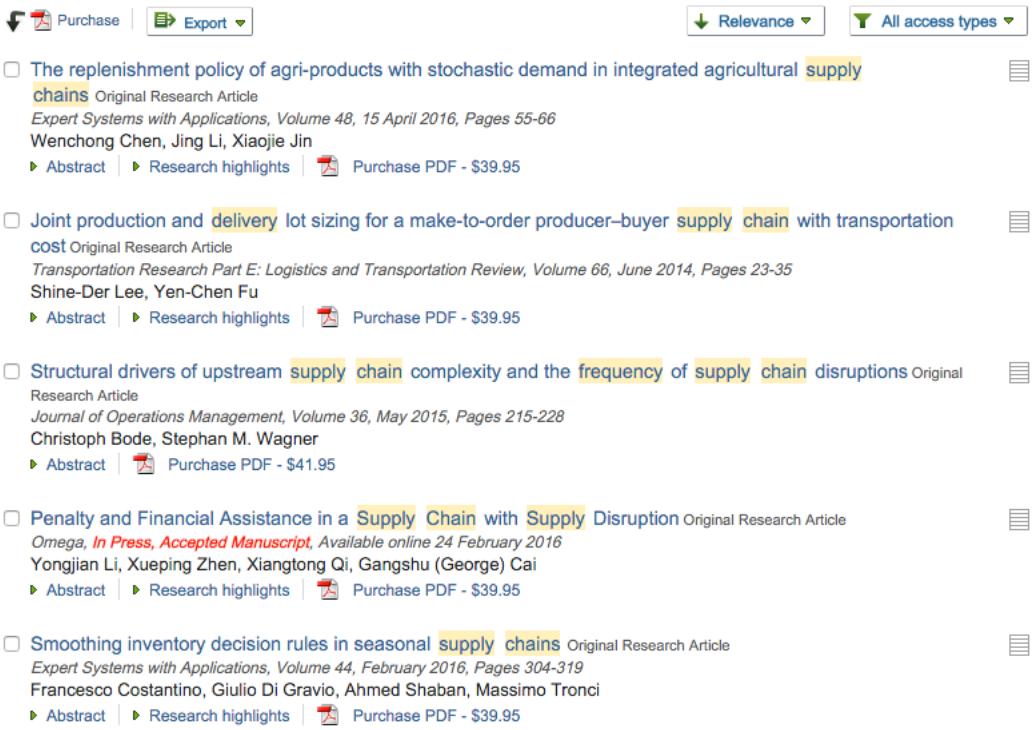

Figure 3.3 *Representation of the papers found after the preliminary search with the database Elsevier. The keywords are highlighted in the title and the abstract is easily reachable. (Elsevier. 2015. Science Direct. Accessed 20.10.2015).*

3.2 Keywords

The main keywords used are shown in Figure 3.4:

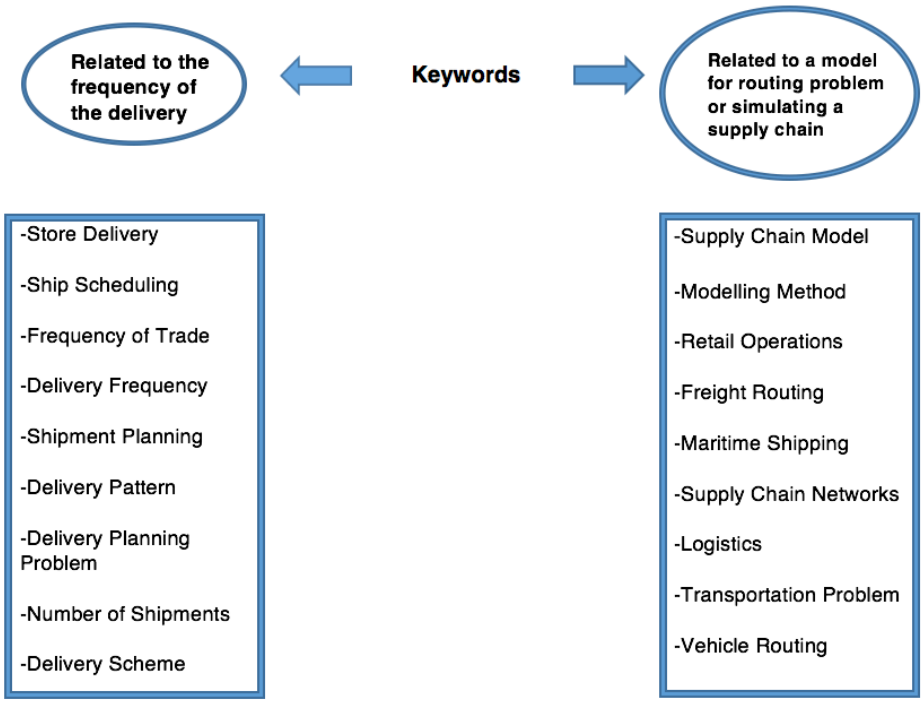

Figure 3.4 *List of the main keywords used for the research.*

These words have been used also in the title's research area in order to increase the chances to find more papers, which can be more appropriate to the topic of this thesis.
A lot of attention has been paid to the publication date of the papers. In fact, apart from a couple of cases, the papers are recent, and have been published in the last 4 years. In these way, the approaches and the solutions proposed are fully updated to the present day.

It is important to underline that the problem dealing with the determination of the delivery frequency in the distribution management is closely related to the general model proposed in the different papers. In other words, a paper, whose the aim is only to determine the delivery frequency in the distribution, does not exist, because extrapolating specific formulations from their original context is not possible. Determining delivery frequency is a way to reduce the total costs, store and transportation costs as usual, which is the main aim of almost every paper taken into consideration, by setting different scenarios or formulating specific equations. For this reason, it is not possible to talk about only the different delivery frequency models without considering the model as a whole.

3.3 Parameters of the Papers

The last aspect of the research methodology deals with the criteria through which the papers have been classified. The choice of these criteria, or parameters, has been determined by the fact that they have been considered as the best way to classify and, consequently, organize different models of papers, because these parameters reflect, analytically, the structure of every single paper.
After a reading of the abstract, in which the issue involved in the paper is presented, a research of these criteria in the text has been fundamental. In fact, as well as examining that the paper deals with the delivery frequency topic, particular attention has been paid to the detection of these criteria in the several articles.
The parameters considered and the reason why they have been selected follow here:

3.3.1 Costs Taken into Consideration: In each paper the costs, considered in the mathematical model, are highlighted. This is useful to understand on which costs

the authors wanted to put emphasis and which costs they find important. Some models, for instance, take into consideration only specific costs while they exclude others.

3.3.2 Type of Industry: Determining the type of industry, for which the paper is aimed, is as important as the costs considered. In fact, every type of industry has different needs which must be satisfied, and different constraints that have to be enforced. A fresh food industry, for example, can not have the same delivery pattern of a petrol or crude oil one because the attentions, and restrictions, paid to the freshness of the food are not comparable with the petrol one, in fact the lifetime of these products is completely different.
Usually, a case study of the method applied, on condition that it is present, follows in the final part of the generic paper. In this way it is possible verifying a real example of the method proposed by the author on a real company.

3.3.3 Aim of the Paper: Every single paper has a specific aim, which portrays the choice of the model, the type of supply chain considered and the related costs. As stated before, it is difficult to find a paper which aims only to determine the delivery frequency. The aim is, generally, to describe a new approach for a determined problem, give an overview on how to face a specific process in the supply chain and, eventually, support the manager's decisions about the business administration of the operations.
It is important to state that, despite the importance of the aim of the papers, this parameter has not been used in the general table which represents the list of the papers, but, however, it has been described in the Appendix, in the brief description of each article. This choice is justified by the fact that the main objective of this thesis is to analyze and compare different approaches dealing with the delivery frequency's determination, beyond the aim of every single paper, which, as just said, can focus also on other aspects, in addition to the delivery frequency.

3.3.4 Method Used: This is a very important parameter in order to classify the different papers, because it describes which kind of model has been used. In fact, every approach has been carried out with a specific mathematical model, that, as

the case may be, has both weaknesses and strong points. This suggests therefore when a particular method is required by a specific situation, or problem.

3.3.5 Software Used: In almost all the papers, the software, used to run the simulation or to solve the different equations, is named. It is interesting to understand why a specific software is preferred to another one as a result of different types of problems faced. As in the case of the method used, also the software presents several peculiarities; some of the software, in fact, are more appropriate to deal with a specific issue in the distribution management.

3.3.6 Type of Supply Chain Considered: As stated in the general problem description, many types of supply chains occur. This is reasonable, because different kinds of industry, different situations in which the model is applied, are described in the papers analyzed in this thesis. As a result of this, several types of supply chain are present, from the easiest one, single vendor - single buyer, to the most complicated one, such as suppliers, distribution centres, consolidation points, loading ports, retail stores and other figures involved for example.

These are the parameters used to classify the different papers. In the following chapter, a brief papers features overview is presented.

4 Papers Overview and Parameters Description

In this fourth section, an overview of all the papers is illustrated in Table 4.1. This overall table is very wide, and, for this reason, it is divided into two pages.
After that, each parameter is taken into analysis and described in order to spell out their meaning in this thesis.

4.1 Papers Overview

Table 4.1 *Overall table representing the list of the papers taken into consideration in this thesis. Part 1.*

PAPER (YEAR)	INDUSTRY (CASE STUDY)	SUPPLY CHAIN CONSIDERED	METHOD USED	SOFTWARE USED	TRANSPORTATION	HOLDING/ INVENTORY	LOADING/ UNLOADING	GOOD RECEIPT	ORDER GENERATION	PENALTY (EARLY,TARDY, UNDER OR OVER SUPPLY)	PRODUCTION (SET-UP, MATERIAL..)
Van Der Vorst et al. (1999)	Multi-Echelon Food Systems (Salads Supply Chain in Netherlands)	Producers→Manifacturers→ D.C.→Outlets→Customers	Simulation (Discrete events)	Petri Net	✓	✓	✓	✓		✓	
Jansen et al. (2000)	Contract Catering (Fresh,Chilled,Dry and Frozen Foods in a Dutch Company)	Suppliers→Wholesalers→Cat erers→Customers	Simulation (Discrete events)	Arena	✓	✓	✓	✓	✓		
Sternbeck and Kuhn (2014)	Grocery Retailing (Major European Retail Company)	Central D.C.→Regional D.C.→Internal Consolidation Point →Store	Binary integer selection model	CPLEX	✓	✓		✓	✓		
Zanoni and Zavanella (2006)	Perishable Goods (Numerical Example)	Single Origin (Production node) → Single Destination (Distribution node)	MILP + Heuristic	CPLEX	✓	✓					✓
Memaria et al. (2015)	Automotive (Malasyan Automaker)	Manifacturers → Distributors → Dealers	MILP + MOGA (Multiple objective genetic algorithm)	Matlab	✓	✓				✓	✓
Amin and Zhang (2014)	Battery Industry (Company in North India)	Disassembly Center → Recycling Center → New Battery Manifacturing → Distributer, Retailer, Factory, Outlet	Simulation	Arena	✓						
Schuh et al. (2015)	Generic Manifacturing Company (Numerical Example)	Supplier → Manifacturing → Customers	Simulation	Anylogic		✓			✓		
Tang et al. (2013)	Aerospace Manifacturing (Aerospace System Design Laboratory in Georgia)	Suppliers → Fabrication/Assembly → Customers	MILP	GNU Linear Programming Kit	✓						✓
Jauhari (2014)	Generic Manifacturing Company (Numerical Example)	Single Vendor → Single Buyer	Iterative Procedure	Not Stated	✓	✓			✓	✓	✓
Bruzzone and Longo (2012)	Fresh Foods (Italian Fresh Fish Foods Company)	Supplier → D.C. → Store → Customer	Simulation	Marlin	✓	✓		✓		✓	
Lin and Tsai (2014)	Maritime Liner Shipping (Shanghai, Hong Kong and Singapore ports)	Not Stated	Local search + Heuristic (Lagrangian relaxation technique)	CPLEX	✓		✓			✓	
Chen et al. (2014)	Fashion Retailer Chain and Multi Plant Manifacturing Network (Numerical Example)	Many Retailers , 1 Depot	Local search + Heuristic	CPLEX	✓		✓				

Table 4.1 *Overall table representing the list of the papers taken into consideration in this thesis. Part 2.*

PAPER (YEAR)	INDUSTRY (CASE STUDY)	SUPPLY CHAIN CONSIDERED	METHOD USED	SOFTWARE USED	TRANSPORTATION	HOLDING/ INVENTORY	LOADING/ UNLOADING	GOOD RECEIPT	ORDER GENERATION	PENALTY (EARLY,TARDY, UNDER OR OVER SUPPLY)	PRODUCTION (SET-UP, MATERIAL..)
Meng et al. (2015)	Automobile Industry (Shanghai Automobile Industry Corporation)	Manifacture → D.C., Storage Center	Simulation + Stochastic programming model (Lagrangian relaxation technique)	CPLEX	✓	✓					
Amin and Zhang (2014)	Generic Manifacturing Company (Copier Remanifacturing Company)	Plants → Retailers → Collection Center → Disposal Center → Plants	MILP	CLPEX	✓						✓
Dabbene et al. (2008)	Fresh Foods (Salads Supply Chain)	Single Vendor → Many Retailers	Local search (Stochastic hybrid discrete event model)	Not Stated	✓					✓	
Bahri and Tarokh (2013)	Generic Supply Chain (Numerical Example)	Single Vendor → Single Buyer	Simulation + Stochastic integrated model	Matlab		✓			✓	✓	✓
Hariga et al. (2013)	Generic Supply Chain (Numerical Example)	Single Vendor → Many Retailers	MINP + Heuristic	Not Stated	✓	✓		✓	✓	✓	✓
Mutlua et al. (2015)	Liquefied Natural Gas (Numerical Example)	Loading Ports → Artificial Ports → Customer Ports	Heuristic	CPLEX	✓		✓			✓	
Dong and Turnquist (2015)	Inbound Material Industry (Dayton Company in Ohio)	Suppliers → Consolidation Center → Manifacture Plants	MILP + Heuristic	Lingo	✓	✓					
Siddiqui et al. (2013)	Crude Oil (Vela International Marine Limited)	Single Supplier → Many Customers	MILP + Heuristic	CPLEX	✓		✓				
Kurz and Zapfel (2013)	Generic Manifacturing Company (Numerical Example in a Company in Linz, Austria)	Single Supplier → Many Customers	MILP (2 objectives mathematical model) + Heuristic	CPLEX	✓	✓				✓	
Ho et al. (2013)	Generic Industry (Numerical Example)	Single Supplier → Many Retailers	Local Search (Replenishment cycle division method)	Not Stated	✓	✓			✓		✓
Anne and Jan Kramer (2010)	Logistics Service Providers (Numerical Example)	Single Supplier → Many Retailers	Simulation	Not Stated	✓	✓					
Pujawan and Arief (2015)	Bulk Cement Industry (Indonesian Company)	Distribution Port → Customers and Fabrics	Simulation	Arena	✓	✓					
Békés et al. (2014)	Generic Industry (French Firms)	Firm → Warehouse → Many Customers	Deterministic + Stochastic inventory model (Empirical methodology)	Not Stated	✓	✓		✓		✓	
Masson et al. (2015)	Diary Industry (PLQ, Les Producteurs de lait di Quebec)	Producers→ Collection Plant	Simulation + Local search	CPLEX	✓					✓	

The width of this table is due to the large number of papers considered and, obviously, to the several parameters used to describe the main characteristics of the papers. As stated before, the parameter "Aim of the paper" has been studied for every single paper but it has not been illustrated in this table because, despite of its relevance, it is not strictly related to the main goal of this thesis, or at least not so important for the papers classification which is carried out in this section.

4.2 Publication Date

An important aspect, as stated in the chapter dealing with the methodology research, is the publication date of the papers. Every year, new models and mathematical formulas are discovered and presented by different authors. Some of these models remain unchanged through the years, because they represent a specific problem in a very detailed and accurate way, or because not many breakthroughs in that field have been made.

It is usually that, in the supply chain management, many papers are based on a previous model, already presented, which is appropriately edited by the authors, adding or removing some parameters or constraints for instance. The authors try

therefore to modify an old model in order to adapt it to another particular situation.

Regarding the articles considered in this thesis, it is interesting to classify them based on three different classes: aged papers, recent papers, very recent papers. Figure 4.2 shows this classification.

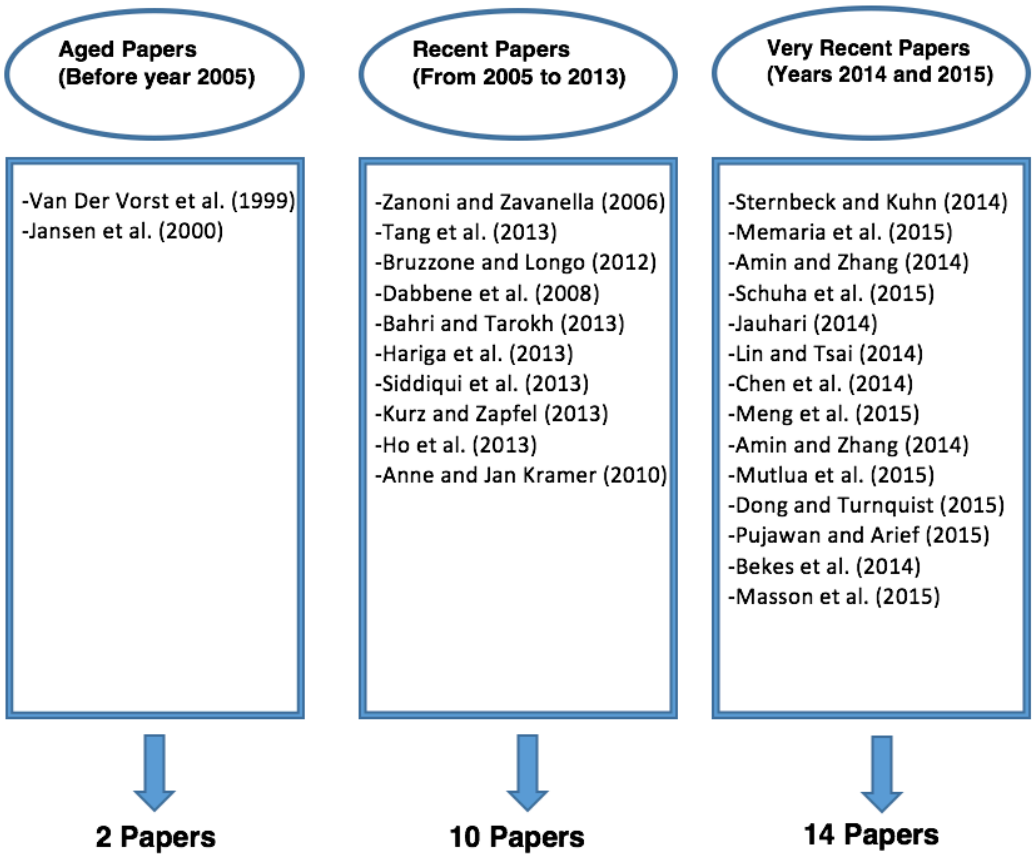

Figure 4.2 *Date publication classification*.

As illustrated in Figure 4.2, more than half of the total papers number has been published in the last two years. This fact helps make this thesis completely updated with respect to the methods used, without omitting important publications of older years.

4.3 Type of Industry

The type of industry observed are mainly: food industry (fresh foods in particular), vehicle industry, maritime shipping industry (such as natural gas or crude oil for example), generic manufacturing industry. In addition to these, other particular kinds of industries occur, including batteries, bulk cement, fashion retailer and others. The description of the main characteristics of these types of

industries, helpful for the aim of the thesis, are described in the chapter 5, when the papers are grouped according to their attributes.

4.4 Aim of the Paper

The aim of the paper depends, obviously, on each article, but, generally, it deals with the minimization of the total costs. It is presented, however, in the description of each paper, grouped in the Appendix.

4.5 Supply Chain Considered

With regard to the supply chain considered, a generic one has already been described in the second chapter. Some of the supply chains analyzed in the papers are easier than the generic one; in fact, they consist, for instance, in only one supplier, that must provide goods to many customers without a consolidation point or a distribution centre. Obviously, a supply chain such this does not need a more accurate description, because it is like considering a generic supply chain, excluding some figures. Furthermore, there are other types of supply chain, such as the maritime shipping case for instance, which are composed of different features, that exercise the same function of the generic supply chain already described. For example, in the maritime freight, loading and storage ports can be found, which can reasonable be compared with the distribution centre in the generic supply chain, because, beyond the appearance, their function is the same.

After a careful analysis of every single paper, the equations, aimed to find the best delivery scheme in the supply chain model, can be collocated mainly in two steps of the chain:

4.5.1 From the Suppliers to the Distribution Centre: for example, Masson et al. (2015) consider a number of milk producers scattered throughout the territory of Quebec. The main objective is developing a model to determine the route problem in the milk collection from the farms to the processing plant, which has the same function of a distribution centre, before that it will be delivered to several retail groceries or markets. Generally, the focus is on the determination of a delivery pattern from many suppliers to one distribution centre, or to another collecting point which has the same function.

4.5.2 From the Distribution Centre to the Retailers: this case includes most papers, and consists in finding the best delivery scheme and frequency from, usually, one distribution centre to many retailers. In the case of maritime shipping, such as crude oil or natural gas for example, the equations have been developed from a loading port, also called loading point, to the ports of the customers. The food industry is another example, in fact, taking Sternbeck and Kuhn (2014) into consideration, the equations are developed between the Distribution Centre (in this case both Central Distribution Centre and Regional Distribution Centre are present) and the retailers.

4.5.3 From the Suppliers to the Distribution Centre & from the Distribution Centre to the Retailers: this little category includes both the equations, developed between the suppliers or producers and the distribution centre, and other equations, focused between the distribution centre and the retailers. Van Der Vost et al. (1999)" is one of the few papers which have developed the equations, aimed to determine the delivery frequency, in both steps of a typical supply chain. It is not easy to find an article which describes delivery scheme in both steps because, usually, is preferable to focus only on a specific part of a determined supply chain considered.

4.6 Method Used

During the analysis of the articles included in this thesis, several methods, in order to solve a specific problem, have been used. After a careful analysis, the most frequent techniques have been recognized and they can be mainly divided into: Simulation, M.I.L.P., Heuristic, Local Search (Metaheuristic) and other particular methods which have been used in only one paper, such as Stochastic integrated model or Iterative procedure for instance. As the case of the type of industry, the analysis of the different techniques used is presented in the chapter 5, when the papers are grouped according to their characteristics.

4.7 Software Used

4.7.1 Main Software Presentation

All the methods, presented in this thesis have been performed with specific software, which are, in most cases, defined. According with Wikipedia definition, the most common are:

4.7.1.1 Cplex: IBM ILOG CPLEX Optimization Studio (often informally referred to simply as CPLEX) is an optimization software package. CPLEX Optimizer solves integer programming problems, very large linear programming problems using either primal or dual variants of the simplex method or the barrier interior point method, convex and non-convex quadratic programming problems, and convex quadratically constrained problems. It is very suitable for the models proposed in this thesis, in fact it is the most used software in the different papers (Wikipedia. 2016. CPLEX. Accessed 26.01.2016).

4.7.1.2 Arena: Arena is a discrete event simulation and automation software developed by Systems Modelling and acquired by Rockwell Automation in 2000. In this software, the user builds an experiment model by placing modules (boxes of different shapes) that represent processes or logic. Connector lines are used to join these modules together and to specify the flow of entities. While modules have specific actions relative to entities, flow, and timing, the precise representation of each module and entity relative to real-life objects is subject to the modeller. Statistical data, such as cycle time and WIP (work in process) levels, can be recorded and outputted as reports (Wikipedia. 2016. Arena (software). Accessed 26.01.2016).

4.7.1.3 Matlab: Matlab (matrix laboratory) is a multi-paradigm numerical computing environment and fourth-generation programming language. A proprietary programming language developed by Math Works, Matlab allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, Java, Fortran and Python (Wikipedia. 2016. Matlab. Accessed 27.01.2016).

4.7.1.4 Anylogic: AnyLogic is a multimethod simulation modelling tool developed by The AnyLogic Company (former XJ Technologies). It supports agent-based, discrete event, and system dynamics simulation methodologies (Wikipedia. 2016. AnyLogic. Accessed 27.01.2016).

4.7.2 Frequency of Software Utilization

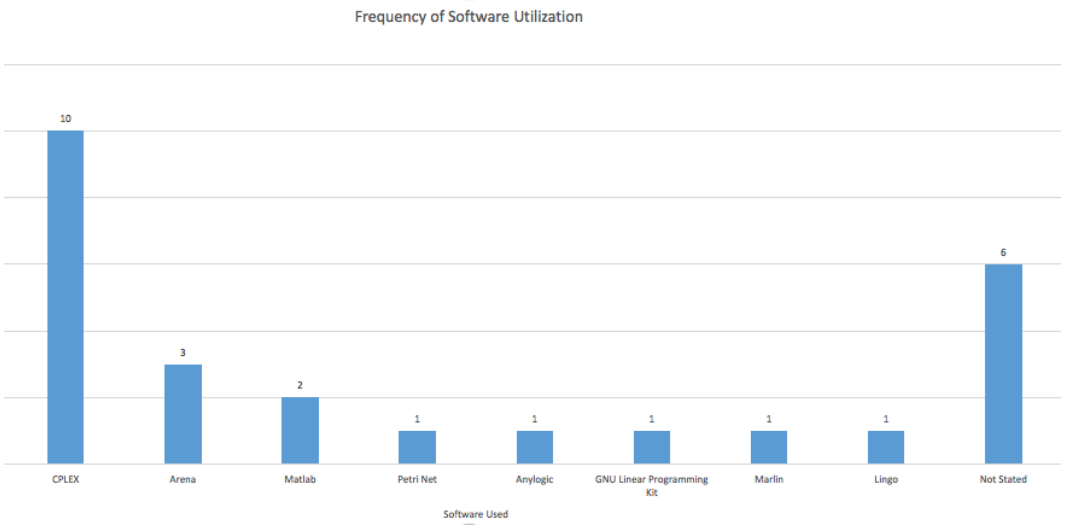

Figure 4.3 *Utilization of the different software used in the papers of this thesis*.

4.7.2.1 Cplex Utilization

As Figure 4.3 shows and already stated before, CPLEX has been the most used software. This is due to the fact that this software is very versatile in the supply chain modelling, and designed to handle very well both Heuristic and M.I.L.P, but also Simulation and other particular methods. This is immediately visible in Table 4.4.

Table 4.4 *Utilization of the software CPLEX.*

PAPER (YEAR)	METHOD USED	SOFTWARE USED
Amin and Zhang (2014)	MILP	CPLEX
Lin and Tsai (2014)	Local search + Heuristic (Lagrangian relaxation technique)	CPLEX
Massona et al. (2015)	Simulation + Local search	CPLEX
Sternbeck and Kuhn (2014)	Binary integer selection model	CPLEX
Zanoni and Zavanella (2006)	MILP + Heuristic	CPLEX
Chen et al. (2014)	Local search + Heuristic	CPLEX
Meng et al. (2015)	Simulation + Stochastic programming model (Lagrangian relaxation technique)	CPLEX
Mutlua et al. (2015)	Heuristic	CPLEX
Siddiqui et al. (2013)	MILP + Heursitc	CPLEX
Kurz and Zapfel (2013)	MILP (2 objectives mathematical model) + Heuristic	CPLEX

Table 4.4 illustrates all the ten papers in which the software CPLEX has been used. After a brief look at the table, it is notable that seven out of ten articles use CPLEX in the case of a M.I.L.P. or Heuristic model. This software can also handle other models, such as Simulation, Binary Integer Selection Model, Local Search, and Stochastic Programming Model for example.

4.7.2.1 Arena Utilization

As stated before, Arena is a simulation software, and it is therefore interesting to note its relationship with the papers. To confirm this, it is possible to see that this software has been used exclusively for the simulation approach.

Table 4.5 *Utilization of the software Arena*.

PAPER (YEAR)	METHOD USED	SOFTWARE USED
Jansen et al. (2000)	Simulation (Discrete events)	Arena
Pujawan and Arief (2015)	Simulation	Arena
Amin and Zhang (2014)	Simulation	Arena

Table 4.5 shows that, obviously, all the papers, which have used the software Arena, have developed a Simulation model. This means that, in the supply chain management, this software represents the best solution in the event that a simulation model is preferred or, sometimes, required.

4.8 Costs Considered

4.8.1 Costs description

The last criterion to classify the different papers deals with the costs involved in the model to optimize the supply chain configuration, the delivery pattern in particular. It must be said that, during the analysis of the papers, a lot of different costs have been found, but, as in the final section of this paragraph is illustrated, most of them are present in only one or two papers; this is why they can not be considered as a parameter to classify the different articles, and therefore they have not been included. Here a brief description of every cost considered in the thesis table follows:

4.8.1.1 Transportation Costs and Vehicle Routing Problem: According to the definition given by Business Dictionary, transportation costs mean the expenses involved in moving products or assets to a different place, which are often passed on to consumers. For example, a business would generally incur a transportation cost if it needs to bring its products to retailers in order to have them offered for sale to consumers (Business Dictionary. 2016. Transportation Costs. Accessed 02.02.2016).

These costs are, as well as the storage costs, present in almost all articles, because of their importance in the delivery frequency determination, and they usually involve fuel costs, drivers costs and vehicle routing planning costs.

A particular attention must be paid to the Vehicle Routing Problem (VRP), that is a combinatorial optimization and integer programming problem which asks "What is the optimal set of routes for a fleet of vehicles to traverse in order to deliver to a given set of customers?" (Wikipedia. 2016. Vehicle Routing Problem. Accessed 02.02.2016). This issue is faced by the following eight papers:

-Siddiqui et al. (2013)

-Meng et al. (2015)

-Dong and Turnquist (2015)

-Masson et al. (2015)

-Chen et al. (2014)

-Kurz and Zapfel (2013)

-Lin and Tsai (2014)

-Sternbeck and Kuhn (2014)

As suggested by the publication date, the Vehicle Routing Problem has been studied in the recent years, because of the necessity to increase the efficiency of a delivery company in order to face the competition of the world market.

According to Wikipedia definition, the VRP, basically, concerns the service of a delivery company, within a supply chain. How things are delivered from one or more depots, such as different supplier plants or distribution centres for example, which has a given set of vehicles and operated by a set of drivers who can move on a given road network to a set of retailers or directly to customers, depending on the type of supply chain considered. It asks for a determination of a set of routes, S, (usually, one route for each vehicle that must start and finish at its own depot) such that all customers' requirements and operational constraints are satisfied and the global transportation cost is minimised. This cost may be monetary, distance or otherwise; in all the papers analyzed it is usually monetary.

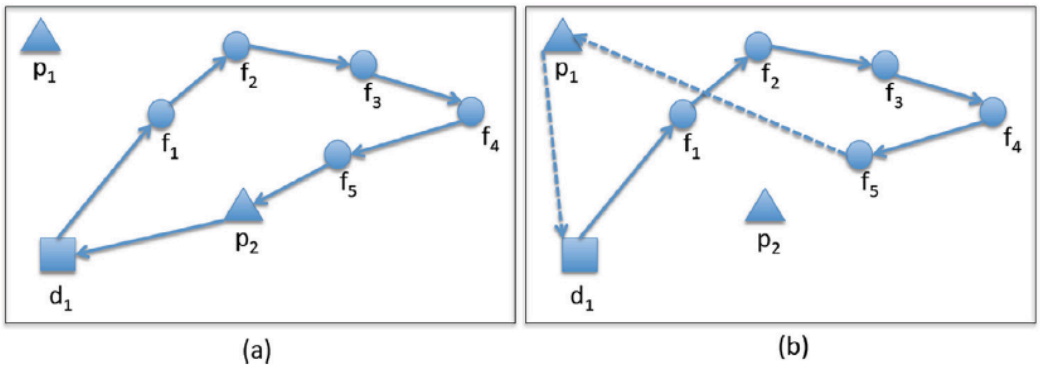

Figure 4.6 *Typical scheme of a Vehicle Routing Problem, in which two possible situations, developed in different scenarios, are considered. (Masson et al. 2015).*

The road network, shown in Figure 4.6, can be described using a graph where the lines are roads and vertices are junctions between them. The lines may be directed or undirected due to the possible presence of one way streets or different

costs in each direction. Each line has an associated cost which is generally its length or travel time which may be dependent on vehicle type.

In the different eight papers the basic idea to set up this problem is quite similar, with the exception of the nomenclature and the scheme considered, and it states that, to know the global cost of each route, the travel cost and the travel time between each customer and the depot must be known. The cost on each line is the lowest cost between the two points on the original road network. This is easy to do as shortest path problems are relatively easy to solve. This transforms the sparse original graph into a complete graph. For each pair of vertices i and j, there exists an line (i,j) of the complete graph whose cost is written as C_{ij} and is defined to be the cost of shortest path from i to j. The travel time t_{ij} is the sum of the travel times of the lines on the shortest path from i to j on the original road graph (Wikipedia. 2016. Vehicle Routing Problem. Accessed 02.02.2016).

4.8.1.2 Holding / Inventory Costs: According to Wikipedia definition, in business management, holding cost is money spent to keep and maintain a stock of goods in storage. The most obvious holding costs include rent for the required space, equipment, materials, and labor to operate the space, insurance, security, interest on money invested in the inventory and space, and other direct expenses. Some stored goods become obsolete before they are sold, reducing their contribution to revenue while having no effect on their holding cost. Some goods are damaged by handling, weather, or other mechanisms. Some goods are lost through mishandling, poor record keeping, or theft (Wikipedia. 2016. Holding Costs. Accessed 03.02.2016).

Inventory or stock refers to the goods and materials that a business holds for the ultimate purpose of resale (or repair). Inventory management is a science primarily about specifying the shape and percentage of stocked goods. It is required at different locations within a facility or within many locations of a supply network to precede the regular and planned course of production and stock of materials (Wikipedia. 2016. Inventory. Accessed 03.02.2016).

4.8.1.3 Loading / Unloading Costs: Loading and unloading means the services of loading or unloading cargo between any place or point of rest on a wharf or terminal, and railcars, trucks, or any other means of land transportation and

barges. These costs include therefore all the operations that deal with the flow of goods from the loading point to the store or vice versa, which are not incorporated in the transportation costs (The Jackson Kearney Group. 2016. Loading/Unloading Rules, Regulations & Charges. Accessed 04.02.2016).

4.8.1.4 Goods Receipt Costs: These are the costs involving the management of an official document issued by a port, shed, warehouse or shipping terminal operator to acknowledge receipt of items listed in it, under customary or specified terms and conditions (Business Dictionary. 2016. Good Receipt Costs. Accessed 04.02.2016).

4.8.1.5 Order Generation Costs: These are the total costs to be incurred by the company on advertising, sales promotions and sales force activities to generate an order from the customer (Mbaskool. 2016. Order Generation Costs. Accessed 05.02.2016).

4.8.1.6 Penalty Costs: The penalty costs can be defined in more ways. Firstly, they can deal with the penalty due to a shortage, when the supplier runs out of the particular product in demand, occurring within a definite lead time, a stock-out of the product occurs and the supplier has to incur penalty cost of lost sales (Mbaskool. 2016. Penalty Costs. Accessed 05.02.2016). In some papers, also the case of over-supply, and not only under-supply, occurs.
Secondly, the penalty costs can also deal with the penalty for an early or tardy delivery. This case is very frequent in the maritime shipping, such as for natural gas or crude oil for example, because the deliveries, sometimes, need a lot of time, and in this way they can be more controlled.

4.8.1.7 Production Costs: They are the costs incurred by a production centre or a supplier when manufacturing a good or producing a service. Production costs combine raw material and labor (Investopedia. 2016. Production Costs. Accessed 06.02.2016). Also the Set-up are included in these costs.

A brief examination of the costs considered shows that they are all strictly related to the frequency with which an order, therefore a delivery, is performed. In fact, the costs of store, transport, order generation and the others, directly affect a

delivery planning decision. For example, Sternbeck and Kuhn (2014) state that, if the delivery frequency is low, the holding costs will be higher while the transportation costs or the goods receipt, for instance, will be lower than a high-frequency delivery case.

The production costs affect the delivery frequency, in particular with the determination of the number of set-up. In fact, as in the case of a multi-product Just in Time industry, every time a set-up is required, additional costs occur. If the time between two set-ups is short, the delivery frequency must be higher. Regarding this point, a couple of papers explain the determination of an economic production batch in order to manage the delivery frequency between the production centre and the distribution centre.

4.8.2 Costs Relevance

To conclude this section, dedicated to the costs considered, it is interesting to note that, as briefly mentioned, not all the costs have the same relevance when a delivery pattern must be designed. The Transportation and Holding/Inventory costs, as well as the Penalty costs especially in the case of maritime shipping, are the most influential costs that must be considered. This is inferred from the fact that determining delivery frequency in the distribution management consists mainly of finding the best compromise between the costs faced in transport and costs faced in the storage of goods. In addition to this, some authors preferred to include Loading/Unloading costs and Good Receipt costs in the Transportation costs only in order to make the model easier, or because the distinction of these costs was not so important to the aim of their paper.

Here Figure 4.7 shows the relevance and the frequency of each cost in the papers studied in this thesis. A more accurate analysis of the relationships between the papers and the costs taken into consideration is presented in chapter 5.

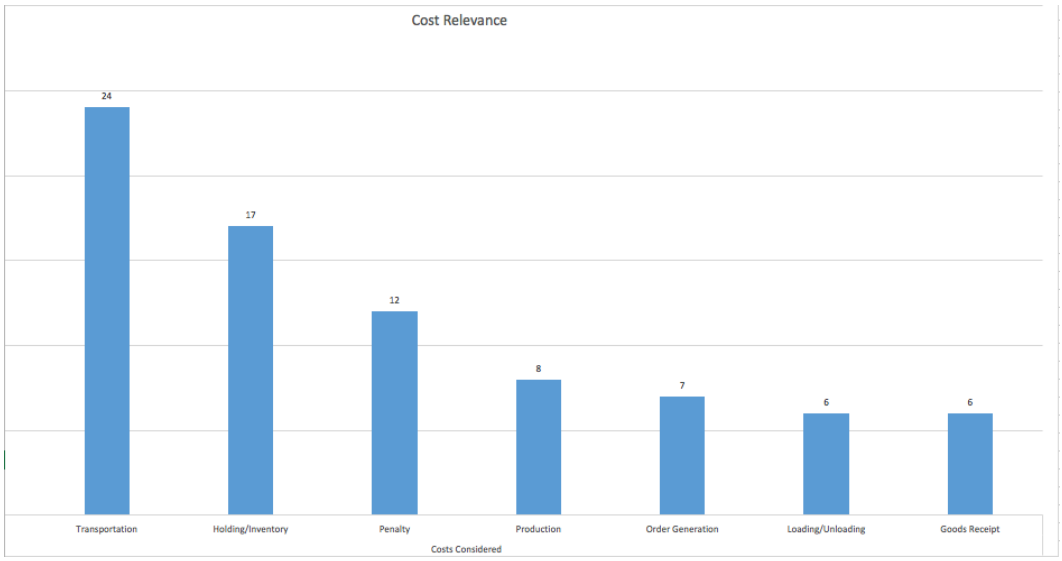

Figure 4.7 *The relevance of all the costs taken into consideration*.

As stated at the beginning of this section, many other costs are considered in the papers of this thesis, but they are present in few of them therefore they have not been taken into consideration in order to create some archetypes. Here, in figure 4.8, a list of all the other costs found, but not taken into consideration, is presented.

Other costs found in the papers / Number of presences
-Structural costs of distribution centre and stores / 3
-Backordered costs / 2
-Idle ship costs / 2
-Goods picking costs / 2
-Initial shelf filling costs / 1
-Fixed costs for ship / 1
-Costs for product write-off and necesssary price-reduction / 1

Figure 4.8 *List of other costs not considered in the papers classification.*

5 Papers and Archetypes Analysis

This last chapter is the core of the thesis, because its aim is to group the twenty-six papers into several archetypes, which represent the problem of determining the delivery frequency in the distribution management under different dimensions.
As already stated, the papers have been chosen after having studied their content, and this selection has been carried out paying particular attention to specific parameters, already described in chapter 4. It is important to state that every single paper has its own structure, supply chain considered, aim, method of research and so on; this is why finding a model for a determined group of papers would have been extremely hard without the utilization of specific parameters. While the reason why each of them has been selected has already been described in the chapter 3, at the end of the methodology of research, here the new goal is to explain how these parameters can influence the frequency of the delivery in a generic supply chain.

The aim of this thesis is to present an overview of the different approaches aimed to determine the delivery frequency in the distribution management, and expose their limits and capabilities but, in addition to this, also to outline the factors which play a role in the delivery frequency determination. This thesis must be helpful for future research regarding this topic, giving some models which can be used to support decision-making on delivery frequency. It must be said that every paper has its own method with specific equations and it is not possible to analyze all them, for this reason, only the general approach, used to resolve a delivery pattern, has been taken into consideration.

As it is demonstrated in this chapter, the relationships between this factors and the way in which the papers have been grouped is not casual, in fact every archetype described in this section is well defined by specific parameters. Furthermore, in order to make this thesis more complete as possible, many papers, taken from the most disparate fields, have been taken into account but, obviously, because of their diversity, not all their characteristics coincide perfectly.

5.1 Factors Which Play a Role

After a careful review of all the articles taken into account, four factors, which play an important role in the determination of the delivery frequency have been found. Some of them are explicitly mentioned in several papers while others have been logically deducted, and the papers confirmed this.
It is useful, as Figure 5.1 shows, to divide them into two categories:

-Primary Factors: the most influent factors in the determination of the delivery frequency in distribution management. Every kind of company must consider them.

-Secondary Factors: important factors which can influence the delivery frequency, but not strictly needed to be faced by all the business firms.

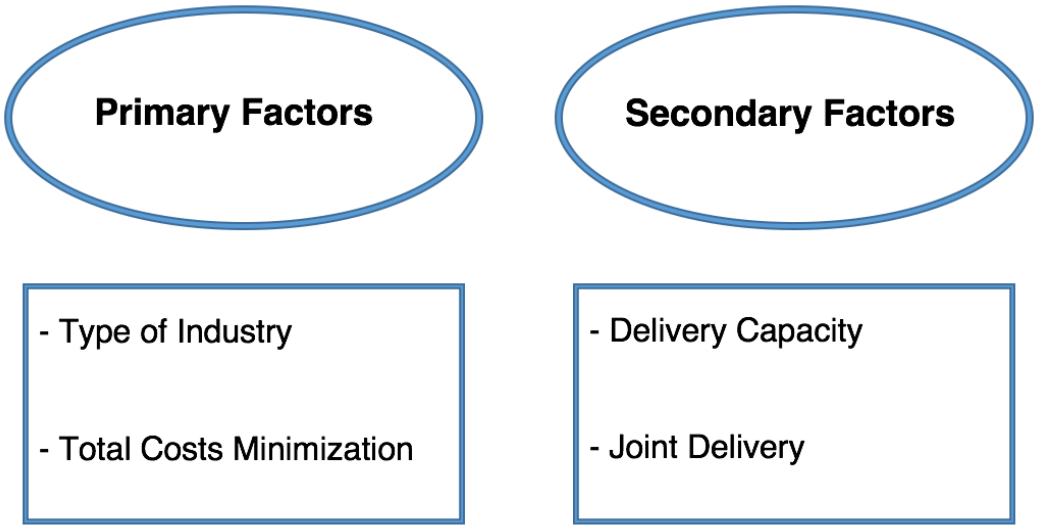

Figure 5.1 *Subdivision of the factors which play a role in the delivery frequency determination.*

Here, every factor, and the reason why it has been selected, are described:

5.1.1 Type of Industry: The type of industry is one of the primary factors which play a role in the determination of the delivery frequency in a company. It is a very important parameter from which several delivery schemes depend, in fact, when an author proposes a new method to suggest delivery decision-making, states immediately for which type of industry he is addressing, usually already in

the abstract or even in the title of the paper. It was not by chance that this parameter has been used in the research of the papers and for the creation of an archetype.

The type of industry is fundamental for the determination of the delivery frequency, because every kind of industry has its own specific characteristics, time schedule, type of products delivered, geographical areas of employment, limits to be respected and so on. The best way to explain this topic is making some references to the papers analyzed in this thesis. As already shown in the Figure 4.1, many types of industry occur in this research; they can mainly be divided into four groups:

- Food industry (fresh foods in particular)
- Vehicle industry
- Maritime shipping industry (such as natural gas or crude oil for example)
- Generic manufacturing industry

Other types of industry occur, including batteries, bulk cement, fashion retailer and others, but they are treated only in one article.

If the food and maritime shipping industry are taken into consideration, the differences in the delivery frequency are distinct. The food industry can not have the same delivery pattern of the crude oil industry, for example. Especially for the fresh foods, such as salads or milk for instance, the delivery frequency is very high due to the elevated perishability of these kinds of products. If the Van Der Vorst et al. (1999), which deal with fresh salads supply chain in particular, is considered, they increases ordering and delivery frequencies in the supply chain between producer and distribution centre from 2 to 3, 4 or 5 times a week and between DC to retailers from 3 to 4, 5 or 6 times a week. After an analysis, applied to a real case study (Salads industry in Netherlands), the best scenario is when the products are delivered 3 times a week from the producers to the distribution centre and 4 times a week from the distribution centre to the retailers. This confirms that the delivery frequency, in a type of industry like this, must be high. In Masson et al. (2015), the frequency with which the collection centre, or distribution centre, is supplied, is daily. In fact, the milk must be immediately refrigerated and delivered to the collection centre, where it is analyzed before being delivered to the different retailers as soon as possible, in order to maintain

its own properties unchanged until consumption by the customers.

On the other hand, a maritime shipping industry can deliver the goods, such as crude oil or natural gas for instance, not as often as the fresh food industry. The fuels, for instance, have not a so strict time limit as the fresh foods but their demand is very high anywhere in the world. The exactly delivery frequency of a maritime shipping industry depends on each paper, but it is possible to find only one article in which the delivery scheme is composed by one shipment per day. It must be said that Lin and Tsai (2014) deal with a particular transportation area, in fact its numerical results show that Shanghai, Hong Kong and Singapore are ports that are ideal for carriers in establishing daily frequency operations along the Pacific Rim, a very intense maritime traffic zone.

Other example can be made, such in the vehicle industry for instance, but, for the moment, it is important to understand why a type of industry can influence the delivery frequency in a supply chain, and, consequently, why this parameter has been chosen to group the papers in several archetypes.

5.1.2 Total Costs Minimization: Another primary factor which determines the delivery frequency in the distribution management is the economic aspect. As already stated in this thesis, it is not easy to find a model which deals only with the delivery frequency determination, because this topic is strictly related to a more general issue: developing a model which aims to minimize the total costs of the supply chain considered. In all the papers, in addition to specific goals proper to each one of them, the final objective is to present an equation, or a system of equations, in which the entire model is set, and it is successively implemented in a software. The goal of this equation is therefore, mainly, to minimize the total costs. Once the model has been solved, many variables of the equation, or system of equations, are determined, including the variable regarding the delivery frequency. Often, many scenarios are available, and each of them present different parameters settings; after having tested all of them, the scenario, which presents the best improvement in total costs saving, is chosen as the best solution given by the model.

In addition to this, the economic aspect, and then the minimization of the total costs, consists principally in the balance between two costs: the transportation costs and the storage costs. It is mathematically and logically demonstrated that, as Sternbeck and Kuhn (2014) state, a high delivery frequency corresponds to an

increase of the transportation costs, due to the many trips taken by the trucks or ships, and to the continue route planning. Meanwhile, a low delivery frequency leads to lower transportation costs but higher holding and inventory costs, because the goods are stored in the manufacturing centres or, more usual, in the distribution centres. This choice implies higher costs for the products maintenance such as electricity and heating for instance, but also for the interests on the not sold goods and all the other costs already mentioned in chapter 4.
Other costs are involved in the papers analyzed in this thesis, but transportation costs and holding costs are the most frequent (as Figure 4.7 shows) and most important to take into consideration to determine delivery frequency. Mathematically, a right balancing between these two costs leads to the perfect configuration of a delivery pattern.

5.1.3 Delivery Capacity: The capacity of delivery has been classified as a secondary factor which play a role in the determination of delivery frequency, because it represents such a constraint in the supply chain of the companies, but it is not faced by all of them. The delivery capacity is defined as the maximum rate at which a generic seller, such as a supplier or distribution centre, can deliver its products to a generic buyer, a retailer for instance, into the supply chain. Consequently, this factor can influence the delivery frequency between two plants, especially in the daily frequency case. For example, if this kind of delivery scheme has been selected, but the capacity of delivery is not enough to handle it because of the lack of trucks available, the company has the possibility to reduce the delivery rate or to rely on third-party logistics service providers (3PLs) to transport distribution centre pallets to the stores. In an empirical study, as Sternbeck and Kuhn (2014) state in their article mentioned in this thesis, 61% of companies confirmed that they use 3PL services at least for some of the distribution tasks. In particular, roughly 40% of grocery retail companies have outsourced all their store deliveries to 3PLs.
The advantages of this choice are the higher bundling potential with other customers of the service providers and capacity compensation effects between the companies shipping via the 3PL, in addition to a higher delivery capacity through the whole supply chain (Sternbeck and Kuhn, 2014). It must be said that this technique is not always convenient, in fact the real economic gain of this choice should be evaluated; sometimes it is preferable to adopt the first solution, that is a

lower delivery rate, rather than hiring a third-party logistics service provider for a simply economic reason. The same situation can occur also in the opposite case, in which the delivery frequency is low and the delivery load is therefore very high; as a result of this, the company can evaluate to rely on third-party logistics service providers, always if the economic aspect is advantageous, or to divide the moved load into more shipments, increasing the delivery frequency.

5.1.4 Joint Delivery: This is the last factor which plays a role in the determination of the delivery frequency. It is important to remember that, in the decision for a specific delivery pattern, two figures are involved; usually, they can be the suppliers and the distribution centre, or this last one and the retailers. The equations, developed in the papers of this thesis, take both figures into consideration in order to find the best solution for them. As a result of this, the costs related to the distribution centre, for instance, the costs related to the transportation of goods, and the costs related to the retailers are included in the functions which minimize total costs. The objective is to find the best delivery frequency for both figures involved, in order to satisfy the shipping plant and the receiving plant at the same time. In the event that a big deliveries company and a smaller one are considered, more attention is paid to the bigger one's necessities, otherwise, if it is possible, an agreement is tried to be reached through a stipulation of a contract.

5.2 Papers Archetypes

After all this discussion about the factors which influence the delivery frequency in the distribution management, the final part of this thesis is presented. This section consists in the creation of several archetypes under two particular dimensions: the type of industry and the method used to choose the best delivery frequency in a supply chain. In addition to this, the costs taken into consideration and other parameters, are combined with the study of the papers, in order to find more relationships between several archetypes.

The reason why the type of industry has been selected for grouping the papers has been already explained in the first part of this chapter, in fact this parameter is essential to determine the delivery rate in a company and influences the structure of a paper, such as the supply chain considered, and its equations.

For the same reason, the method or technique, used to find the best delivery

pattern, has been selected to create some models or groups. It is one of the goals of this thesis to understand the differences between several approaches used in this topic, their limits, and capabilities.

Every type of relationship between the different archetypes, and even among the papers that constitute them, is, when it is possible, explained, such as the use of a specific software or the costs considered for example.

5.2.1 Type of industry

The first grouping has been made with the type of industry. As already stated the most common types of industry found are:

- Food industry (fresh foods in particular)
- Maritime shipping industry (such as natural gas or crude oil for example)
- Generic manufacturing industry
- Vehicle industry
- Other types of industry (batteries, fashion retailer, bulk cement, and others treated in only one article)

The frequency, at which the type of industry is present in this thesis, is presented in Figure 5.2

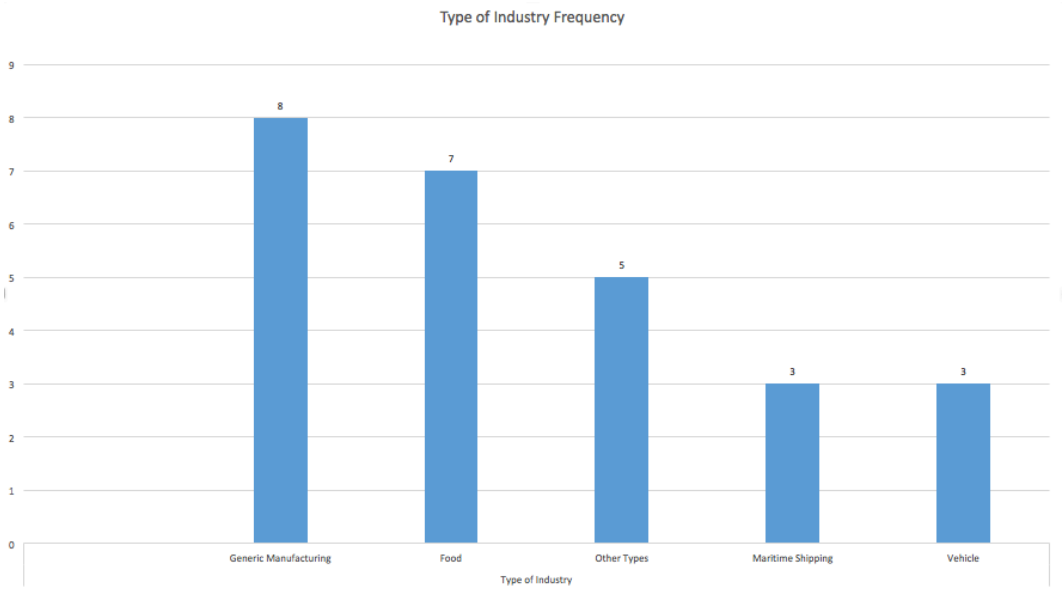

Figure 5.2 *The number of papers dealing with a specific type of industry*.

5.2.1.1 Food Industry

Table 5.3 *The first archetype: 7 papers which deal with the food industry*.

PAPER (YEAR)	INDUSTRY (CASE STUDY)	SUPPLY CHAIN CONSIDERED	METHOD USED	SOFTWARE USED	TRANSPORTATION	HOLDING/ INVENTORY	LOADING/ UNLOADING	GOOD RECEIPT	ORDER GENERATION	PENALTY (EARLY,TARDY, UNDER OR OVER SUPPLY)	PRODUCTION (SET-UP, MATERIAL..)
Van Der Vorst et al. (1999)	Multi-Echelon Food Systems (Salads Supply Chain in Netherlands)	Producers→Manifacturers→ D.C.→Outlets→Customers	Simulation (Discrete events)	Petri Net	✓	✓	✓	✓		✓	
Jansen et al. (2000)	Contract Catering (Fresh,Chilled,Dry and Frozen Foods in a Dutch Company)	Suppliers→Wholesalers→Cat erers→Customers	Simulation (Discrete events)	Arena	✓	✓	✓	✓	✓		
Sternbeck and Kuhn (2014)	Grocery Retailing (Major European Retail Company)	Central D.C.→Regional D.C.→Internal Consolidation Point →Store	Binary integer selection model	CPLEX	✓	✓		✓	✓		
Zanoni and Zavanella (2006)	Perishable Goods (Numerical Example)	Single Origin (Production node) → Single Destination (Distribution node)	MILP + Heuristic	CPLEX	✓	✓					✓
Bruzzone and Longo (2012)	Fresh Foods (Italian Fresh Fish Foods Company)	Supplier → D.C. → Store → Customer	Simulation	Marlin	✓	✓		✓		✓	
Dabbene et al. (2008)	Fresh Foods (Salads Supply Chain)	Single Vendor → Many Retailers	Local search (Stochastic hybrid discrete event model)	Not Stated	✓					✓	
Massona et al. (2015)	Diary Industry (PLQ, Les Producteurs de lait di Quebec)	Producers→ Collection Plant	Simulation + Local search	CPLEX	✓					✓	

(Table 5.3) Relationships between Food Industry and:

-Publication Date: The publication dates of these papers are between 1999 and 2015. Van Der Vost et al. (1999) and Jensen et al. (2000) are the oldest papers taken into consideration in this thesis; this leads to the conclusion that the problem, regarding the delivery frequency determination of food goods, has been studied for many years. In fact, the food supply chain is one of the most difficult issue to be addressed because of the perishability of some kinds of food.

-Supply Chain Considered: The food industry has the typical configuration of a generic supply chain. Four articles out of seven have the same structure of the supply chain presented in the second chapter of this thesis. Sternbeck and Kuhn (2014) do not consider the suppliers while Van Der Vost et al. (1999)" make a distinction between producers and manufactures, nowadays not very considered. Dabbene et al. (2008) consider another type of supply chain, regarding one vendor and many retailers, while Masson et al. (2015), as already stated, take many producers and one collection centre into consideration.

-Method Used: Many methods used have been considered for the development of these papers. In particular, four articles out of seven have chosen the simulation as the best technique to reach the objective function aimed to find the best delivery frequency. Local search method is used in two papers, because Masson et al. (2015) make use of both simulation and local search. MILP and heuristic are used

only by Zanoni and Zavanella (2006), and a binary integer selection model has been used by Sternbeck and Kuhn (2014).
While a detailed description of every method used occurs in the next section of this chapter, here only a brief comment, about the use of simulation, is given. The food industry, fresh foods in particular, is affected by many stochastic variables which represent the perishability of the goods. In fact, this last aspect is very variable from a food to another one, and according to some conditions of transportation. For example, if there is a temperature loss in one of the separate compartments, the quality of the food can be not at the required quality at the time of delivery, therefore it must be discarded; this represents a variability in the supply chain. The food expiration is not completely governed by mathematical rules, sometimes a prolonged exposure to sunlight, or treatment outside of a protective atmosphere, even for a few minutes, can compromise the quality. This is the reason why the simulation is the best method aimed to represent this phenomenon, affected by aleatoric nature.

-Software Used: The software used in the food industry are not very related to the technique chosen or to the characteristics of this type of industry. The software are mainly CPLEX, which has already been described as the most popular software in this thesis, Arena, Petri Net, used only by Van Der Vost et al. (1999), Marlin, which has been adopted by Bruzzone and Longo (2012), and Dabbene et al. (2008), that have not declared the software used.

-Costs Considered: After a brief review of the papers of this archetype, it is immediately noticeable that the transportation costs are always considered. This is easily explained, because the transportation is a main component of a delivery scheme, in the case of perishable goods in particular. Determining delivery frequency, without considering the costs involved during the trip of goods, is not reasonable.
The storage costs are not considered in both Dabbene et al. (2008) and Masson et al. (2015). In fact, they deal with fresh foods, such as salads and milk for instance, which can not be stored in a backroom. The first three papers of this model consider the storage costs only because they analyze also dry and frozen goods, which can be stored for a long period before being delivered and sold. Zanoni and Zavanella (2006) and Bruzzone and Longo (2012), even if they consider mainly

fresh foods, decided to take also the storage costs into consideration, only for completeness, and to make the model more flexible as possible in the case that other products would have been considered.
The other costs, present in these articles, are not particularly relevant, with exception of the penalty costs. This last parameter has been used, particularly, in all the four papers, dealing with fresh foods, except for Zanoni and Zavanella (2006). The reason is that the penalty for the food delivery is very important, because of its perishability; a delay in the milk delivery, or even an excess of product for example, can be very damaging for its quality and, especially, for its saleability.

5.2.1.2 Maritime Shipping Industry:

Table 5.4 *The second archetype: 3 papers which deal with the maritime shipping industry.*

PAPER (YEAR)	INDUSTRY (CASE STUDY)	SUPPLY CHAIN CONSIDERED	METHOD USED	SOFTWARE USED	TRANSPORTATION	HOLDING/ INVENTORY	LOADING/ UNLOADING	GOOD RECEIPT	ORDER GENERATION	PENALTY (EARLY,TARDY, UNDER OR OVER SUPPLY)	PRODUCTION (SET-UP, MATERIAL..)
Mutlua et al. (2015)	Liquefied Natural Gas (Numerical Example)	Loading Ports → Artificial Ports → Customer Ports	Heuristic	CPLEX	✓		✓			✓	
Lin and Tsai (2014)	Maritime Liner Shipping (Shanghai, Hong Kong and Singapore ports)	Not Stated	Local search + Heuristic (Lagrangian relaxation technique)	CPLEX	✓		✓			✓	
Siddiqui et al. (2013)	Crude Oil (Vela International Marine Limited)	Single Supplier → Many Customers	MILP + Heuristic	CPLEX	✓		✓				

(Table 5.4) Relationships between Maritime Shipping Industry and:

-Publication Date: The maritime shipping industry is very hard to manage, because of its very long distances covered and its many customers involved. In addition to this, this type of industry is steadily growing, especially in the Asian continent, thanks to the constantly increase of goods necessity. For these two reasons, the papers have been developed recently, in the last 3 years.

-Supply Chain Considered: In the maritime shipping industry the supply chain considered is basically the same. From a loading port, in proximity of production/extraction plant in the fuel case, to many customers ports, through an artificial port with a sorting function as in Mutlua et al. (2015). Lin and Tsai (2014) do not specify the supply chain taken into consideration but propose only a numerical example.

-Method Used: It is very interesting to note that in all the papers grouped under this archetype, a heuristic technique has been chosen. As stated before, this kind of industry covers very long distances, between different lands and also continents, and never considers only one customer, but a lot of them, often very far from each other. Determining the delivery frequency, making a model to solve this problem, and facing the Vehicle Routing Problem can be extremely hard, and reasonable solutions can be obtained only after a lot of time. Heuristic method is therefore used when, in order to face a complicated problem, an optimal solution can not be found, but a satisfactory one is preferred in very less time.

-Software Used: The most used software in thesis, CPLEX, has been chosen, in all the papers here considered, to perform the models proposed. This software can manage all the methods, aimed to determine the delivery frequency, and, as Table 4.4 shows, heuristic in particular.

-Costs Considered: In this archetype, the costs taken into consideration are nearly the same. The transportation costs are, obviously, always considered. The holding/inventory costs are never taken into consideration because of their negligibility in comparison with the transportation costs. It is interesting to note that the loading/unloading costs, which are normally not very present in the papers of this thesis, are here always considered. In fact, in the maritime shipping industry, this cost represents relevant operations in the supply chain, which can not be ignored. The products loading and unloading can be not so significant in a case of a truck, but extremely important and weighty in the liner case.
In all the papers, with the exception of Siddiqui et al. (2013), the penalty costs are included in the system of equations aimed to determine the delivery frequency. With very long routes, stipulating penalties for early or tardy delivery, or else under or over supply, can be a smart choice for the customers.

5.2.1.3 Generic Manufacturing Industry:

Table 5.5 *The third archetype: 8 papers which deal with a generic manufacturing industry.*

PAPER (YEAR)	INDUSTRY (CASE STUDY)	SUPPLY CHAIN CONSIDERED	METHOD USED	SOFTWARE USED	TRANSPORTATION	HOLDING/ INVENTORY	LOADING/ UNLOADING	GOOD RECEIPT	ORDER GENERATION	PENALTY (EARLY,TARDY, UNDER OR OVER SUPPLY)	PRODUCTION (SET-UP, MATERIAL..)
Hariga et al. (2013)	Generic Supply Chain (Numerical Example)	Single Vendor → Many Retailers	MINP + Heuristic	Not Stated	✓	✓		✓	✓	✓	✓
Jauhari (2014)	Generic Manifacturing Company (Numerical Example)	Single Vendor → Single Buyer	Iterative Procedure	Not Stated	✓	✓			✓	✓	✓
Kurz and Zapfel (2013)	Generic Manifacturing Company (Numerical Example in a Company in Linz, Austria)	Single Supplier → Many Customers	MILP (2 objectives mathematical model) + Heuristic	CPLEX	✓	✓				✓	
Békés et al. (2014)	Generic Industry (French Firms)	Firm → Warehouse → Many Customers	Deterministic + Stochastic inventory model (Empirical methodology)	Not Stated	✓	✓		✓		✓	
Ho et al. (2013)	Generic Industry (Numerical Example)	Single Supplier → Many Retailers	Local Search (Replenishment cycle division method)	Not Stated	✓	✓			✓		✓
Amin and Zhang (2014)	Generic Manifacturing Company (Copier Remanifacturing Company)	Plants → Retailers → Collection Center → Disposal Center → Plants	MILP	CLPEX	✓						✓
Bahri and Tarokh (2013)	Generic Supply Chain (Numerical Example)	Single Vendor → Single Buyer	Simulation + Stochastic integrated model	Matlab		✓			✓	✓	✓
Schuh et al. (2015)	Generic Manifacturing Company (Numerical Example)	Supplier → Manifacturing → Customers	Simulation	Anylogic		✓			✓		

(Table 5.5) Relationships between Generic Manufacturing Industry and:

-Publication Date: In all these papers, a generic manufacturing industry is presented. The authors have not specified for which industry the paper has been addressed, but they just want to take a generic industry for example, and they prefer to focus on the technique aimed to determine a delivery pattern.
The publication dates are very recent, in fact, in the case of a generic manufacturing, a preference for new papers with modern models has been made.

-Supply Chain Considered: The types of supply chain present in this archetype are various, from the single vendor - single buyer to the generic supply chain already described. To be more precise, in four of the eight articles here analyzed, it is possible to find a supply chain which consists of a single vendor and many retailers. In fact, if a generic manufacturing supply chain, without any particular reference to a specific type of industry, must be taken into consideration, the best way to represent it through a model is the utilization of a simple but effective supply chain, consisting of a vendor, which can be compared with a distribution centre, and many retailers or, directly, customers.

-Method Used: Because of the variety of cases handled, without taking into consideration any particular type of industry or specific case, a lot of methods and

techniques have been used in this model. In addition to MILP, simulation, local search, and heuristic, which are present in the same amount, also an iterative procedure and a deterministic + stochastic inventory model can be found, in Jauhari(2014) and Békés et al. (2014) respectively.

-Software Used: Any particular relationship can be here found; in fact, in addition to CPLEX, Matlab, and Anylogic, half of the articles have not specified the software used.

-Costs Considered: The first interesting aspect of the costs considered is that Bahri and Tarokh (2013) and Schuh et al. (2015) do not include the transportation costs in the model. They are the only two papers of this thesis which made this choice and, not casually, are included in the same archetype. The first paper deals, in particular, with a model which aims, instead of regarding the shipments, to determine Joint Economic Lot Sizing. This article has been chosen, mainly, for the important role that the Joint Delivery factor plays in the delivery frequency determination, as stated at the beginning of this last chapter. On the other hand, the second paper aims to simulate the assessment of a real-time capable disturbance management in a manufacturing supply chain, and is mainly focused on the effects of an increasing sensibility to disturbances on the delivery date of a generic company, instead of the goods transportation.
All the papers consider the holding costs, with exception of Aming and Zhang (2014), and none of the eight articles has included the loading/unloading costs. More than half of the papers has taken the penalty costs into consideration, and, especially, it has considered the order generation costs, which are often ignored in all the other archetypes. It is also interesting to note that five papers out of eight have included the production costs in the mathematical model; this is due to the fact that manufacturing and delivery companies are considered, and production costs, as already explained, can partially influence the delivery frequency.

5.2.1.4 Vehicle Industry:

Table 5.6 *The fourth archetype: 3 papers which deal with vehicle industry*.

PAPER (YEAR)	INDUSTRY (CASE STUDY)	SUPPLY CHAIN CONSIDERED	METHOD USED	SOFTWARE USED	TRANSPORTATION	HOLDING/ INVENTORY	LOADING/ UNLOADING	GOOD RECEIPT	ORDER GENERATION	PENALTY (EARLY,TARDY, UNDER OR OVER SUPPLY)	PRODUCTION (SET-UP, MATERIAL..)
Memaria et al. (2015)	Automotive (Malasyan Automaker)	Manifacturers → Distributors → Dealers	MILP + MOGA (Multiple objective genetic algorithm)	Matlab	✓	✓				✓	✓
Meng et al. (2015)	Automobile Industry (Shanghai Automobile Industry Corporation)	Manifacture → D.C., Storage Center	Simulation + Stochastic programming model (Lagrangian relaxation technique)	CPLEX	✓	✓					
Tang et al. (2013)	Aerospace Manifacturing (Aerospace System Design Laboratory in Georgia)	Suppliers → Fabrication/Assembly → Customers	MILP	GNU Linear Programming Kit	✓						✓

(Table 5.6) Relationships between Vehicle Industry and:

-Publication Date: Usually, the vehicle industry is not particularly related to the delivery frequency determination problem, but the increase of the global competition led the companies to evaluate this aspect for a cost-saving. This is why the publication dates are very recent. Two papers have been published in the last year, and Tang et al. (2013) is still recent. The first two papers deal both with the automobile industry; on the other hand, the third paper analyzes the aircraft industry, the wing-box in particular, and it has been grouped in this archetype because of its similarity of the supply chain considered with the other papers.

-Supply Chain Considered: The supply chain of these three papers is basically the same, from a producer to the customers, involving a distribution centre or an assembly centre in the case of the aircraft wing-box. The production and, successively, the shipment of a wing-box is less frequent than an automobile, but it is composed by a high components quantity, like in the case of a car.

-Method Used: Meng et al. (2015) use, basically, a simulation approach, while the other two papers have chosen a MILP to solve their model. MILP is therefore used when variables represent quantities that can only be integer. For example, it is not possible to deliver 5,4 cars or wing-boxes (Wikipedia. 2016. Mixed Integer Linear Problem. Accessed 24.02.2016).

-Software Used: In this archetype, three different software have been used, CPLEX, Matlab, and GNU, therefore there is not a particular relationship between them, but there is a wide possibility of choice.

-Costs Considered: The costs considered are, basically, the same, with exception of Tang et al. (2013). While the cars can be stored in a distribution centre, or by the vendors stores, for long time, the aircraft wing-box is usually designed and built for a specific aeroplane, after that its construction has been ordered. For this reason, in this Made To Order case, the holding costs have been omitted.
The production costs, which are relevant in this type of industry, are described in two papers out of three.

5.2.1.5 Other Types of Industry

Table 5.7 *The fifth archetype: 5 papers which deal with other types of industry*.

PAPER (YEAR)	INDUSTRY (CASE STUDY)	SUPPLY CHAIN CONSIDERED	METHOD USED	SOFTWARE USED	TRANSPORTATION	HOLDING/ INVENTORY	LOADING/ UNLOADING	GOOD RECEIPT	ORDER GENERATION	PENALTY (EARLY,TARDY, UNDER OR OVER SUPPLY)	PRODUCTION (SET-UP, MATERIAL..)
Pujawan and Arief (2015)	Bulk Cement Industry (Indonesian Company)	Distribution Port → Customers and Fabrics	Simulation	Arena	✓	✓					
Dong and Turnquist (2015)	Inbound Material Industry (Dayton Company in Ohio)	Suppliers → Consolidation Center → Manifacture Plants	MILP + Heuristic	Lingo	✓	✓					
Anne and Jan Kramer (2010)	Logistics Service Providers (Numerical Example)	Single Supplier → Many Retailers	Simulation	Not Stated	✓	✓					
Chen et al. (2014)	Fashion Retailer Chain and Multi Plant Manifacturing Network (Numerical Example)	Many Retailers , 1 Depot	Local search + Heuristic	CPLEX	✓		✓				
Amin and Zhang (2014)	Battery Industry (Company in North India)	Disassembly Center → Recycling Center → New Battery Manifacturing → Distributer, Retailer, Factory, Outlet	Simulation	Arena	✓						

In Table 5.7, all the other types of industry, which are not related to any of the other archetypes, are only briefly described, because finding relationships between these papers is not consistent with the aim of the section of this chapter.
This last group of papers includes five types of industry, very different from each other, and several supply chains are taken into account. All the main methods are here used, but there is a preference for heuristic technique, and, especially, simulation. Different software have been used, including Arena, CPLEX, and Lingo. The costs taken into consideration are about the same, and the transportation costs, as almost always happens in the topic of this thesis, are included in each paper.

5.2.2 Method used

The second grouping has been made with the method used. Different techniques, or approaches, have been chosen, by the authors of the papers, in order to determine the delivery frequency in the distribution management. In this case, it was not possible to find the same amount of relationships of the first case, because the different methods involve many types of industry and supply chain, which are

often not related to each other. On the other hand, some relationships have been found between the method used and the software used, and the costs considered. The relation, between a specific technique and a particular software, is fairly evident, while the relation, between the different approaches and the costs included in the model, is very clear, but it can be the result of particular circumstances; it is interesting, for a future research, to extend the selection of the papers, in order to verify this topic.

Another important distinction that must be outlined is the difference between a deterministic approach and a stochastic one. A deterministic model is one in which every set of variable states is uniquely determined by parameters in the model and by sets of previous states of these variables; therefore, a deterministic model always performs the same way for a given set of initial conditions. Conversely, in a stochastic model, usually called a "statistical model", randomness is present, and variable states are not described by unique values, but rather by probability distributions.

The methods, or approaches, used in this thesis are mainly four, as already stated, and they are:

-Simulation
-MILP
-Heuristic
-Local Search

The frequency, at which the method used is present in this thesis, is presented in Figure 5.8

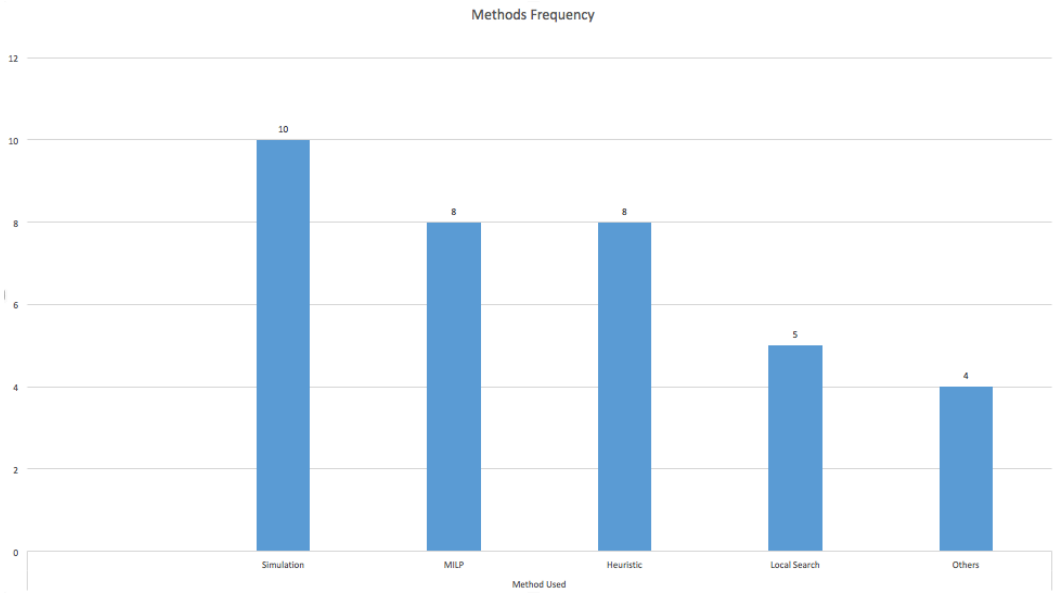

Figure 5.8 *The number of papers dealing with a specific method used*.

Looking at Figure 5.8, it is noticed that more than twenty-six papers occur. This occurs because many articles use two techniques to determine delivery frequency. This choice is justified by the fact that, when the model proposed is very complicated, the best solution is to divide it into two or more parts, and solve each of them with a different method, according to the structure of the problem. In particular, the heuristic technique is the best way to obtain approximated results in few time, and it is therefore very useful to solve the hardest part of the problem, which can require also many hours or, sometimes, even days.

5.2.2.1 Local Search:

Table 5.9 *The use of local search in 4 papers of the thesis*.

PAPER (YEAR)	INDUSTRY (CASE STUDY)	SUPPLY CHAIN CONSIDERED	METHOD USED	SOFTWARE USED	TRANSPORTATION	HOLDING/ INVENTORY	LOADING/ UNLOADING	GOOD RECEIPT	ORDER GENERATION	PENALTY (EARLY,TARDY, UNDER OR OVER SUPPLY)	PRODUCTION (SET-UP, MATERIAL..)
Ho et al. (2013)	Generic Industry (Numerical Example)	Single Supplier → Many Retailers	Local Search (Replenishment cycle division method)	Not Stated	✓	✓			✓		✓
Dabbene et al. (2008)	Fresh Foods (Salads Supply Chain)	Single Vendor → Many Retailers	Local search (Stochastic hybrid discrete event model)	Not Stated	✓					✓	
Lin and Tsai (2014)	Maritime Liner Shipping (Shanghai, Hong Kong and Singapore ports)	Not Stated	Local search + Heuristic (Lagrangian relaxation technique)	CPLEX	✓		✓			✓	
Chen et al. (2014)	Fashion Retailer Chain and Multi Plant Manifacturing Network (Numerical Example)	Many Retailers , 1 Depot	Local search + Heuristic	CPLEX	✓		✓				

Description: In computer science, local search is a metaheuristic method for solving computationally hard optimization problems. Local search can be used on problems that can be formulated as finding a solution maximizing a criterion among a number of candidate solutions. Local search algorithms move from solution to solution in the space of candidate solutions (the search space) by applying local changes, until a solution deemed optimal is found or a time bound is elapsed. In the case of this thesis, the criterion, which must be maximized, is usually the best economic gain for the delivery company; in other words, the minimization of total costs.
Generally, a metaheuristic is a higher level procedure designed to find, generate, or select a heuristic (partial search algorithm) that may provide a sufficiently good solution to an optimization problem, especially with incomplete or imperfect information or limited computation capacity. Metaheuristics sample a set of solutions which is too large to be completely sampled. Metaheuristics may make few assumptions about the optimization problem being solved, and so they may be usable for a variety of problems (Wikipedia. 2016. Local Search (optimization). Accessed 03.03.2016).

(Table 5.9) Relationships between Local Search and:
-Software Used: Usually, CPLEX is the typical software used for the local search in this thesis. Two papers out of four have chosen it, while the other two have not specified the software used.

-Costs considered: The main relationship, between the local search technique and the costs taken into account in this archetype, consists in the almost complete lack of holding costs; only one paper out of four has taken them into consideration. In addition to this, the good receipt costs are completely absent.

Limits and Capabilities: As stated before, local search algorithms work until a solution deemed optimal is found or a time bound is elapsed. This last case is very useful for complicated problems in this thesis, such as Lin and Tsai (2014) for example, which deals with maritime shipping industry. Another solution to face the complexity of a proposed mathematical model is to terminate the local search process when the best solution, found by the algorithm, has not been improved in a given number of pre-determined steps. In addition to this, local search is a very

versatile technique because it can give a valid solution even if it is interrupted at any time before its end (Wikipedia. 2016. Local Search (optimization). Accessed 03.03.2016).

On the other hand, local search algorithms are typically approximation or incomplete algorithms, because the search may stop even if the best solution found by the algorithm is not optimal, such the heuristic technique for instance.

In Table 5.9 there are some details about the local search methods used, such as lagrangian relaxation technique or replenishment cycle division method for instance, but they are specific of each paper and therefore are not here described.

5.2.2.2 Simulation:

Table 5.10 *The use of simulation in 10 papers of the thesis*.

PAPER (YEAR)	INDUSTRY (CASE STUDY)	SUPPLY CHAIN CONSIDERED	METHOD USED	SOFTWARE USED	TRANSPORTATION	HOLDING/ INVENTORY	LOADING/ UNLOADING	GOOD RECEIPT	ORDER GENERATION	PENALTY (EARLY,TARDY, UNDER OR OVER SUPPLY)	PRODUCTION (SET-UP, MATERIAL..)
Amin and Zhang (2014)	Battery Industry (Company in North India)	Disassembly Center → Recycling Center → New Battery Manifacturing → Distributer, Retailer, Factory, Outlet	Simulation	Arena	✓						
Schuh et al. (2015)	Generic Manifacturing Company (Numerical Example)	Supplier → Manifacturing → Customers	Simulation	Anylogic		✓			✓		
Bruzzone and Longo (2012)	Fresh Foods (Italian Fresh Fish Foods Company)	Supplier → D.C. → Store → Customer	Simulation	Marlin	✓	✓		✓		✓	
Anne and Jan Kramer (2010)	Logistics Service Providers (Numerical Example)	Single Supplier → Many Retailers	Simulation	Not Stated	✓	✓					
Pujawan and Arief (2015)	Bulk Cement Industry (Indonesian Company)	Distribution Port → Customers and Fabrics	Simulation	Arena	✓	✓					
Van Der Vorst et al. (1999)	Multi-Echelon Food Systems (Salads Supply Chain in Netherlands)	Producers→Manifacturers→ D.C.→Outlets→Customers	Simulation (Discrete events)	Petri Net	✓	✓	✓	✓		✓	
Jansen et al. (2000)	Contract Catering (Fresh,Chilled,Dry and Frozen Foods in a Dutch Company)	Suppliers→Wholesalers→Cat erers→Customers	Simulation (Discrete events)	Arena	✓	✓	✓	✓	✓		
Masson et al. (2015)	Diary Industry (PLQ, Les Producteurs de lait di Quebec)	Producers→ Collection Plant	Simulation + Local search	CPLEX	✓					✓	
Bahri and Tarokh (2013)	Generic Supply Chain (Numerical Example)	Single Vendor → Single Buyer	Simulation + Stochastic integrated model	Matlab		✓			✓	✓	✓
Meng et al. (2015)	Automobile Industry (Shanghai Automobile Industry Corporation)	Manifacture → D.C., Storage Center	Simulation + Stochastic programming model (Lagrangian relaxation technique)	CPLEX	✓	✓					

Description: The simulation of supply chain systems is used mainly to examine the effect of improvements or investments in a production a delivery system. Most often this is done using a static spreadsheet with process times and transportation times. For more sophisticated simulations, as it sometimes occurs in this thesis, Discrete Event Simulation (DES) is used with the advantages to simulate dynamics in the production system. A production system is very much dynamic depending on variations in manufacturing processes, assembly times, delivery or receiving orders delays, machine set-ups, breakdowns and small stoppages (Wikipedia. 2016. Simulation. Accessed 03.03.2016).

(Table 5.10) Relationships between Simulation and:

-Software Used: There are lots of software commonly used for simulation approach and discrete event simulation, such as CPLEX, Matlab, Anylogic and others but, in particular, Arena, which has already been associated with this method in chapter 4. All these software differ in usability and markets but do often share the same foundation in the case of simulation.

-Costs Considered: The simulation approach, in this thesis, considers, in all most cases, the holding costs, as opposed to the local search. The two papers, which are the only that have not taken the transportation costs into account, are grouped in this archetype. In addition to this, the good receipt costs, not considered in the local search at all, and the order generation costs, which do not occur many times in the articles of this thesis, are quite present here.

Limits and Capabilities: The simulation, as already mentioned, is particular useful when there is a need to plan the production and the delivery of goods in a company. In this thesis, this approach has been particularly used in the food industry, in order to take the perishability of the goods into account, as already discussed in the first section of this chapter. This is not the only advantage, because simulation is preferred to the other approaches when some dates are incomplete and, sometimes, even not stated. For example, if the delivery frequency from a distribution centre to some retailers must be evaluated, it can be reasonable, especially at the beginning of the activity, considering to build a consolidation point in order to manage the shipments, directed to the retailers, with more efficacy. This choice represents an additional cost, and the simulation can take this into consideration.
The fact that the simulation consider many variable factors of the model is, on the other side, a limit. In fact, the results, sometimes, can not correspond to the real expectations. It must be also said that the accuracy and reliability of the results depends on the quantity and variability of input data in the model.
Another consideration is that, in Table 5.10, is possible to note that the simulation approach is often used without the integration of any other method, highlighting its independent utilization.

5.2.2.3 MILP:

Table 5.11 *The use of MILP in 8 papers of the thesis*.

PAPER (YEAR)	INDUSTRY (CASE STUDY)	SUPPLY CHAIN CONSIDERED	METHOD USED	SOFTWARE USED	TRANSPORTATION	HOLDING/ INVENTORY	LOADING/ UNLOADING	GOOD RECEIPT	ORDER GENERATION	PENALTY (EARLY,TARDY, UNDER OR OVER SUPPLY)	PRODUCTION (SET-UP, MATERIAL..)
Kurz and Zapfel (2013)	Generic Manifacturing Company (Numerical Example in a Company in Linz, Austria)	Single Supplier → Many Customers	MILP (2 objectives mathematical model) + Heuristic	CPLEX	✓	✓				✓	
Zanoni and Zavanella (2006)	Perishable Goods (Numerical Example)	Single Origin (Production node) → Single Destination (Distribution node)	MILP + Heuristic	CPLEX	✓	✓					✓
Dong and Turnquist (2015)	Inbound Material Industry (Dayton Company in Ohio)	Suppliers → Consolidation Center → Manifacture Plants	MILP + Heuristic	Lingo	✓	✓					
Siddiqui et al. (2013)	Crude Oil (Vela International Marine Limited)	Single Supplier → Many Customers	MILP + Heuristic	CPLEX	✓		✓				
Hariga et al. (2013)	Generic Supply Chain (Numerical Example)	Single Vendor → Many Retailers	MINP + Heuristic	Not Stated	✓	✓		✓	✓	✓	✓
Amin and Zhang (2014)	Generic Manifacturing Company (Copier Remanifacturing Company)	Plants → Retailers → Collection Center → Disposal Center → Plants	MILP	CLPEX	✓						✓
Tang et al. (2013)	Aerospace Manifacturing (Aerospace System Design Laboratory in Georgia)	Suppliers → Fabrication/Assembly → Customers	MILP	GNU Linear Programming Kit	✓						✓
Memaria et al. (2015)	Automotive (Malasyan Automaker)	Manifacturers → Distributors → Dealers	MILP + MOGA (Multiple objective genetic algorithm)	Matlab	✓	✓				✓	✓

Description: The Mixed Integer Linear Problem (MILP) is a mathematical optimization or feasibility program in which some or all of the variables are restricted to be integers. These variables, such as the case of this thesis, involve service and vehicle scheduling in transportation networks. For example, a problem may involve assigning buses or subways to individual routes so that a timetable can be met, and also to equip them with drivers. Usually, binary decision variables indicate whether a bus or subway is assigned to a route and whether a driver is assigned to a particular train or subway (Wikipedia. 2016. Mixed Integer Linear Problem. Accessed 04.03.2016).

(Table 5.11) Relationships between MILP and:

-Software Used: In this archetype, different software have been used, but four papers out of eight have preferred CPLEX. As already stated in chapter 4, this software is very versatile, with a preference for MILP and heuristic.

-Costs Considered: The only interesting relationship, between this type of approach and the costs taken into account, is the high number of articles which have included the production costs. In fact, this kind of parameter is not very frequent in the papers of this thesis, but here five papers out of eight have chosen to include this cost in their systems of equations.

Limits and Capability: With heuristic and simulation, MILP is one of the most used method to determine the delivery frequency in distribution management. It is used, mainly, for two reasons. Firstly, as already mentioned, when the integer variables represent quantities that can only be integer (it is not possible to deliver 6,5 cars). Secondly, when the integer variables represent decisions and so should only take on the value 0 or 1, for instance (Wikipedia. 2016. Mixed Integer Linear Problem. Accessed 04.03.2016).

These two considerations assume value after an accurate analysis of the papers of this archetype. In fact, in this model, there is the highest number of articles which deal with the Vehicle Routing Problem: three papers out of eight, while, for example, in all the ten papers of the simulation approach, only two have considered this issue. This method provides therefore excellent results, and has many capabilities.

On the other hand, MILP is know as NP-hard, that is an acronym of "non-deterministic polynomial-time hard", which means, in other words, that the polynomial algorithms, that constitute it, are hard to solve (Wikipedia. 2016. NP-hardness. Accessed 04.03.2016).

For this reason, MILP is often used in combination with a heuristic technique, and the problem is therefore divided into two steps in order to make it easier to be solved.

5.2.2.4 Heuristic:

Table 5.12 *The use of heuristic in 8 papers of the thesis*.

PAPER (YEAR)	INDUSTRY (CASE STUDY)	SUPPLY CHAIN CONSIDERED	METHOD USED	SOFTWARE USED	TRANSPORTATION	HOLDING/ INVENTORY	LOADING/ UNLOADING	GOOD RECEIPT	ORDER GENERATION	PENALTY (EARLY,TARDY, UNDER OR OVER SUPPLY)	PRODUCTION (SET-UP, MATERIAL..)
Kurz and Zapfel (2013)	Generic Manifacturing Company (Numerical Example in a Company in Linz, Austria)	Single Supplier → Many Customers	MILP (2 objectives mathematical model) + Heuristic	CPLEX	✓	✓				✓	
Zanoni and Zavanella (2006)	Perishable Goods (Numerical Example)	Single Origin (Production node) → Single Destination (Distribution node)	MILP + Heuristic	CPLEX	✓	✓					✓
Dong and Turnquist (2015)	Inbound Material Industry (Dayton Company in Ohio)	Suppliers → Consolidation Center → Manifacture Plants	MILP + Heuristic	Lingo	✓	✓					
Siddiqui et al. (2013)	Crude Oil (Vela International Marine Limited)	Single Supplier → Many Customers	MILP + Heuristic	CPLEX	✓		✓				
Hariga et al. (2013)	Generic Supply Chain (Numerical Example)	Single Vendor → Many Retailers	MINP + Heuristic	Not Stated	✓	✓		✓	✓	✓	✓
Lin and Tsai (2014)	Maritime Liner Shipping (Shanghai, Hong Kong and Singapore ports)	Not Stated	Local search + Heuristic (Lagrangian relaxation technique)	CPLEX	✓		✓			✓	
Chen et al. (2014)	Fashion Retailer Chain and Multi Plant Manifacturing Network (Numerical Example)	Many Retailers , 1 Depot	Local search + Heuristic	CPLEX	✓		✓				
Mutlua et al. (2015)	Liquefied Natural Gas (Numerical Example)	Loading Ports → Artificial Ports → Customer Ports	Heuristic	CPLEX	✓		✓			✓	

Description: The heuristic technique, often called simply a heuristic, is an approach to problem solving, learning, or discovery that employs a practical method not guaranteed to be optimal or perfect, but sufficient for the immediate goals. Where finding an optimal solution is impossible or impractical, such as in the models which involve a lot of variables, heuristic methods can be used to speed up the process of finding a satisfactory solution. Heuristics can be, when the available time is not much, mental shortcuts that ease the cognitive load of making a decision (Wikipedia. 2016. Heuristic Technique. Accessed 05.03.2016).

(Table 5.12) Relationships between Heuristic and:

-Software Used: The most used software, in the heuristic approach, is CPLEX. It as already been stated that this software is particular flexible, and indicated for this kind of method used.

-Costs Considered: With regard to the costs taken into consideration, it is interesting to note that only one half of the papers have included the holding costs in their model, while the other half has taken the loading/unloading costs into account, which are usually not frequent in the papers of this thesis.

Limits and Capabilities: The main advantage in the utilization of a heuristic procedure is the rapidity with which the results are obtained. This can be very useful in the short term decisions, and it can give to the managers support in the decision-making on delivery frequency, when the available time to make a choice is very short.
Another important aspect of the heuristic approach is the way in which it solves the most complicated problems. In the previous archetype and as Table 5.12 shows, MILP has been associated to a heuristic procedure five times; in fact, this last method is generally used to solve problems, which can require a lot of time, and, sometimes, can not even be resolved. The heuristic approach finds, always and quickly, a solution, that is not guaranteed to be perfect, but sufficient for immediate goals (Wikipedia. 2016. Heuristic Technique. Accessed 05.03.2016).
The advantage of this kind of procedure is also its weakness, in fact, usually, the best or optimal solution is not found, and this limits its utilization only for not detailed action planning.

Table 5.12 shows also that the heuristic approach is also associated with the local search, in two papers, and can even be used without the integration of other approaches, as Mutlua et al. (2015) state.

5.2.2.5 Other Methods Used

In Table 5.13, the remaining methods used are presented but not described, because they do not represent any archetype, and their analysis is not closely related to the aim of this thesis.

Table 5.13 *The remaining methods used in this thesis*.

PAPER (YEAR)	INDUSTRY (CASE STUDY)	SUPPLY CHAIN CONSIDERED	METHOD USED	SOFTWARE USED	TRANSPORTATION	HOLDING/ INVENTORY	LOADING/ UNLOADING	GOOD RECEIPT	ORDER GENERATION	PENALTY (EARLY,TARDY, UNDER OR OVER SUPPLY)	PRODUCTION (SET-UP, MATERIAL..)
Sternbeck and Kuhn (2014)	Grocery Retailing (Major European Retail Company)	Central D.C.→Regional D.C.→Internal Consolidation Point →Store	Binary integer selection model	CPLEX	✓	✓		✓	✓		
Békés et al. (2014)	Generic Industry (French Firms)	Firm → Warehouse → Many Customers	Deterministic + Stochastic inventory model (Empirical methodology)	Not Stated	✓	✓		✓		✓	
Jauhari (2014)	Generic Manifacturing Company (Numerical Example)	Single Vendor → Single Buyer	Iterative Procedure	Not Stated	✓	✓			✓	✓	✓

In this thesis, any mathematical formula has been presented so far, and this fact is due, in particular, to two main reasons.

Firstly, as stated in the introduction of this thesis, the aim is to describe the decision problem in general, outline which factors play a role, and present an overview different quantitative operations management approaches that can provide decision support for this. As a result of this, since every paper presents its model with specific equations to determine the delivery frequency, the analysis of each of them does not head back to the objectives of this thesis. The way to determine the delivery frequency is already described, in details, in each paper. In addition to this, the length of the thesis would have been extremely long.

Secondly, a mathematical model, which represents a specific archetype, could have been developed by grouping together all the mathematical models of that archetype. This means taking all the equations of each paper into account, and creating a model which represents all them. As already stated, in most cases, the problem of determining delivery frequency can not be separated from the rest of the equations included in the model of the paper. As a result of this, handling a high number of equations, in most cases very complicated, is not manageable, at least within this thesis.

6 Conclusions

In this thesis, the problem of determining delivery frequency in the distribution management has been faced. As this thesis demonstrates, this issue is addressed by different authors in several ways. The main aim of this thesis has been, in fact, to group various and different papers into specific archetypes, which are characterized by particular parameters.

The general decision problem and a generic supply chain have been described in chapter 2. Chapter 3 is completely dedicated to the research methodology, which is extremely important in order to get good material on which to work. In particular, the research keys and the parameters, searched in the papers, have been described and justified. Chapter 4 presents an overview of all the papers found through research, moreover an accurate analysis of some aspects of the papers, such as the costs considered or software used for example, has been given. Chapter 5 is the most important part of the thesis, in which the factors that play a role in the delivery frequency determination have been analyzed. In addition, several archetypes have been created, analyzing two fundamental dimensions: the type of industry and the method used. Especially in the first case, many relationships have been found, which affect different parameters, the supply chain and costs considered in particular. In the second case, more attention has been paid to the different types of approaches aimed to determine the delivery frequency, outlining their limits and capabilities.

As already stated at the end of chapter 5, any formula is presented in this thesis, because the latter is mainly focused on an overview of the different approaches used and on their relationships, instead of analyzing every single paper mathematical model.

The goal is therefore to provide a sort of guidelines to support the decision-making on delivery frequency. Depending on the type of industry, certain costs or methods are preferred; or, in accordance with a specific approach, its limits and capabilities, to determine the delivery frequency, are exposed, paying attention to the factors which can play a role.

In conclusion, the development of a mathematical model, that incorporates a specific group of papers, starting from the archetypes already created in this thesis, can be an interesting starting point for future researches.

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Appendix

Here, every single paper is briefly presented, for this reason any deepening process will be described in this section. However, a short presentation of each paper is important to give the reader a more specific idea of the issues involved.

-Paper 1: Modelling and simulating multi-echelon food systems / Jack Van Der Vorst, Adrie Beulens, Paul van Beek / 1999

Description: This paper presents a method for modelling the dynamic behaviour of food supply chains and evaluating alternative designs of the supply chain by applying discrete-event simulation. The modelling method is based on the concepts of business processes, design variables at strategic and operational levels, performance indicators, and business entities, as these concepts allow relevant aspects of a food supply chain to be described and modelled. This simulation model is based on timed coloured Petri-nets to support decision-making when redesigning a supply chain for chilled food products. Scenario analysis allows to evaluate the potential benefits of alternative designs for this supply chain in terms of logistical performance. In the case study analyzed, major benefits were identified.

Keywords: Supply Chain Modelling; Discrete-Event Simulation; Modelling Method.

-Paper 2: Simulation model of multi-compartment distribution in the catering supply chain / Derrien Jansen, Arjen Van Weert, Adrie Beulens, Ruud Huirne / 2000

Description: An efficient distribution system of high performance is needed to anticipate market developments in the catering supply chain (CSC) in the Netherlands. A simulation model was developed to analyse a multi-compartment distribution system which should satisfy customer demands for shorter lead times, increased delivery frequency and improved quality of process and product. The simulation model quantifies logistic and financial performances in various alternative logistic scenarios for multi-compartment distribution in the catering supply chain. This stochastic simulation model was constructed on the basis of a value chain analysis yielding activities and performance indicators (PIs). The model proved to be accurate in its predictions when applied to a case situation

taken from the Dutch CSC. It is concluded that discrete event simulation is an effective tool to evaluate promising logistic scenarios. The new, multi compartment method of distribution allowed for a 14% decrease in total costs in the Dutch CSC while satisfying customer demands.
Keywords: Simulation; Stochastic Processes; Multi-Compartment Distribution; Catering Supply Chain; Performance Measurement.

-Paper 3: An integrative approach to determine store delivery patterns in grocery retailing / Michael Sternbeck, Heinrich Kuhn / 2014
Description: This article focuses on the tactical problem of selecting delivery patterns according to which grocery stores are repetitively supplied with products from different order segments by retail-owned distribution centres. The research environment considered consists of logistics processes in DCs, transportation and instore logistics. Dependencies are identified on the delivery patterns selected and specify the relevant costs. These costs are reflected in the objective function of a binary selection model. Implementing and applying the model to the real case of a major European retail company yields substantial cost savings potential of 5.3%, amounting to tens of millions of euros per annum.
Keywords: Grocery Retailing; Store Delivery; Retail Operations; Planning Interdependencies.

-Paper 4: Single-vendor single-buyer with integrated transport-inventory system: Models and heuristics in the case of perishable goods / Simone Zanoni, Lucio Zavanella / 2006
Description: This article deals with the problem of shipping a set of products from a single origin (the vendor) to a common destination (the buyer) with the objective of minimizing the sum of the inventory and transportation costs, when a set of shipping frequencies is given and products are assumed to be perishable.
A mixed integer linear programming model is provided for the problem and the modification of known heuristic algorithms is proposed to solve it. Extensive computational results show how some of the modified heuristics are extremely efficient and effective.
Keywords: Production; Inventory; Lot-Sizing; Heuristics; Perishable Good; Single-Vendor; Single-Buyer.

-Paper 5: An Integrated Production-Distribution Planning in Green Supply Chain: A multi-objective evolutionary approach /Ashkan Memaria, Abdul Rahim, Robiah Ahmadb / 2015

Description: The goal of this research is to develop a novel multi-objective mathematical model in a green supply chain network consisting of manufacturers, distribution centres and dealers in an automotive manufacture case study. The main objectives considered are: minimizing the costs of production, distribution, holding and shortage cost at dealers as well as minimizing environmental impact of logistic network. In addition to minimizing the costs and environmental impacts particularly the emission of CO2, the model can determine the green economic production quantity using Just-In-Time logistics. Furthermore, multi-objective genetic algorithm is applied in order to minimize these two conflicting objectives simultaneously. Finally, the performance of the proposed model is evaluated by comparing the obtained Pareto fronts from MOGA and goal attainment programing solver in Matlab.

Keywords: Green Supply Chain Network; Integrated Production-Distribution; Multi-Objective Optimization; Genetic Algorithm, JIT.

-Paper 6: Closed-loop supply chain network configuration by a multi-objective mathematical model / Saman Amin, Guoqing Zhang / 2014

Description: Integration of forward and reverse channels results in closed-loop supply chain networks. In this research, a mixed-integer linear programming model is proposed to configure a closed-loop supply chain network. The network includes multiple products, plants, recovery technologies, demand markets, and collection centres. The objective function is minimization of the total cost. The model can determine number and locations of open facilities, and flows of products in the network. In addition, we develop the model to multi-objectives by considering minimisation of defect rates and time of operations in collection centres. To solve the model, weighted-sums and distance methods are applied in copier remanufacturing example and the results are analysed. Moreover, value path approach is applied to compare the results of different methods.

Keywords: Closed-Loop Supply Chain; CLSC; Multi-Objective Programming; Reverse Logistics; RL; Mixed-Integer Linear Programming; MILP.

-Paper 7: Design of a simulation model for the assessment of a real-time capable disturbance management in manufacturing supply chains / Günther Schuh, Michael Schenk, Nikolaos Servos / 2015

Description: The steady increasing of supply chain complexity due to a rising global cross-linking of production and sales regions leads to an increasing sensitivity to disturbances while in the meantime the requirements of the availability, the time of delivery and the security of supplies within the supply chain increases. To meet this challenge the security of the supply chain infrastructure and the feasibility of supply chain processes need to be ensured, despite of the high specialization within the supply chain partners, the low stock and time buffers, and the information shortcoming between supply chain partners. In this research, a System Dynamics simulation model, based on the manufacturing supply chain model of Sterman, has been developed for representing the actual complexity and dynamic in manufacturing supply chains. Therefore, the modelled manufacturing supply chain shows the processes of a four level supply chain focusing the processes and interactions of the mid-positioned two supply chain participants. The main contribution of the work described in this paper, is the description and implementation of necessary additional modules and parameters to Sterman's basic model for the diagnosis of disturbance impacts as well as for the realization of supply chain adjustments. Finally, the model has been simulated and examined for realistic values.

Keywords: Supply Chain; Simulation; Disturbance Management; System Dynamics.

-Paper 8: Modelling-based Design of Strategic Supply Chain Networks for Aircraft Manufacturing / Zilin Tang, Marc Goetschalckxb, Leon McGinnisb / 2013

Description: The aerospace supply chain network has evolved and become more complex over the years. New methods are needed to design and analyze the system, and to establish the interactions between aircraft (product) design and supply chain (process) design. This paper aims to introduce a strategic multi-product, multi-period design model for the manufacturing and distribution of an aircraft wing-box with a planning horizon of the full program duration. The supply chain systems consist of a number of external suppliers, candidate manufacturing sites, and a number of customers at fixed locations. The design

model is a mixed-integer linear programming optimization routine that minimizes the total time-discounted network cost. The model generates a system configuration that specifies the location and capacity of the manufacturing sites, the material flow, and the transportation routes within the network. The model is implemented using open-source tools, and has a comprehensive and flexible data structure to support the decision-making process during the early aircraft design stages.

Keywords: Aerospace Manufacturing; Supply Chain Design; Mixed-Integer Linear Programming.

-Paper 9: A Cooperative Inventory Model for Vendor-Buyer System with Raw Material Decisions, Deterministic Lead Time and Stochastic Demand / Wakhid Ahmad Jauhari / 2014

Description: This study investigates integrated inventory problem for a two-stage supply chain consisting of a single vendor and single buyer. A model is developed for coordinating the replenishment decisions for raw material procurement, production, and shipment under stochastic environment. For attaining the model objective, an algorithm has been developed to determine the optimal shipment-sized, safety factor, number of shipment and number of raw material replenishment based on minimum expected total cost. Furthermore, numerical examples are given to illustrate the effect of primary parameters on the lot size, safety factor, number of batches and expected total cost. The results from numerical examples shows that making production-inventory decisions jointly can reduces expected total cost comparing with making decisions individually.

Keywords: Supply Chain; Replenishment Decision; Raw Material Procurement; Production; Shipment; Stochastic.

-Paper 10: An application methodology for logistics and transportation scenarios analysis and comparison within the retail supply chain / Agostino Bruzzone, Francesco Longo / 2012

Description: The article proposes the development of an application methodology, named MARLIN, for logistics and transportation scenarios analysis and comparison within the fresh food supply chain. The MARLIN application methodology consists of the development of a dedicated simulation-based software tool for scenarios analysis and comparison and its inclusion in a

methodology framework. After the description of the cooperating simulators and methodology framework, a case study on a real FFSC is presented to showcase the MARLIN application methodology; the case study provides analytical and numerical results for five scenarios and selects the optimal one.
Keywords: Logistics; Transportation; Retail Supply Chain; RSC; Industrial Engineering; Simulation.

-Paper 11: The ship routing and freight assignment problem for daily frequency operation of maritime liner shipping / Dung-Ying Lin, Yu-Yun Tsai / 2014

Description: To cope with excess capacity and improve service quality, maritime international liner carriers have recently adopted a new operational model known as daily frequency. In this new model, carriers provide daily pickup and delivery service to customers at major ports along the Pacific Rim. The ship routing and freight assignment problem is investigated for daily frequency operation of liner shipping. A solution procedure that incorporates a Lagrangian relaxation technique and local search was proposed. The numerical results show that Shanghai, Hong Kong and Singapore are ports that are ideal for carriers in establishing daily frequency operations along the Pacific Rim. In this paper the delivery frequency is not calculated but it is already chosen in order to give more attention to the other components of the delivery pattern model.
Keywords: Daily Frequency; Maritime Liner Shipping; Lagrangian Relaxation; Local Search; Ship Scheduling; Freight Routing.

-Paper 12: Model and algorithm for an unpaired pickup and delivery vehicle routing problem with split loads / Qingfeng Chen, Kunpeng Li, Zhixue Liu / 2014

Description: This paper addresses the routing problem with unpaired pickup and delivery with split loads. An interesting factor of this problem is that the quantity and place for pickup and delivery are decision variables in the network. An easy-to-implement heuristic is developed in order to gain an efficient and feasible solution quickly. Then, a local search algorithm based on the variable neighborhood search method is developed to improve the performance of the heuristic. Computational results show that the proposed method is able to obtain an optimal or near optimal solution in reasonable time for the

formulated problem.
Keywords: Logistics; Vehicle Routing; Transport; Pickup and Delivery; Variable Neighborhood Search.

-Paper 13: Carrying capacity procurement of rail and shipping services for automobile delivery with uncertain demand / Qiang Meng, Xiuling Hei, Shuaian Wangc, Haijun Mao / 2015
Description: The determination of the optimal carrying capacity procurement of rail and shipping services in the automobile intermodal network with unique characteristics is essential to save automobile delivery cost. In this research a two-stage stochastic programming model is developed for the tactical-level decision problem arising in the special automobile intermodal network. Furthermore, the sample average approximation algorithmic procedure is improved to solve the model. The model and solution method are applied to a case study associated with the Shanghai Automobile Industry Corporation. In conclusion, this study deals with an emerging new research topic with practical significance for the automobile industry.
Keywords: Automobile Delivery; Carrying Capacity Procurement; Intermodal Freight Transportation; Uncertain Delivery Demand; Two-Stage Stochastic Programming Model.

-Paper 14: Closed-loop supply chain network configuration by a multi-objective mathematical model / Saman Amin, Guoqing Zhang / 2014
Description: Integration of forward and reverse channels results in closed-loop supply chain networks. In this research, a mixed-integer linear programming model is proposed to configure a closed-loop supply chain network. The network includes multiple products, plants, recovery technologies, demand markets, and collection centres. The objective function is minimisation of the total cost. The model can determine number and locations of open facilities, and flows of products in the network. In addition, the model is developed to multi-objectives by considering minimisation of defect rates and time of operations in collection centres. To solve the model, weighted-sums and distance methods are applied in copier remanufacturing example and the results are analysed. Moreover, value path approach is applied to compare the results of different methods.

Keywords: Closed-Loop Supply Chain; CLSC; Multi-Objective Programming; Reverse Logistics; RL; Mixed-Integer Linear Programming; MILP.

-Paper 15: Optimisation of fresh-food supply chains in uncertain environments / Fabrizio Dabbene, Paolo Gay, Nicola Sacco / 2008

Description: The design of the supply chain, and in particular of the distribution phase, for fresh-food products, such as fresh and fresh-cut produce, fruit or meat, cannot be achieved without considering the perishable nature and the variability of the products entering the chain. Motivated by these considerations, this paper presents a novel approach for the optimisation of fresh-food supply chains that manages a trade-off between logistic costs and some indices measuring the quality of the food itself as perceived by the consumer, such as ripeness, microbial charge or internal temperature. The supply chain and the behaviour of the product during its delivery are described using a hybrid model consisting of two specific parts. The first part takes into account event-driven dynamics (typically product handling) while the second one describes time-driven dynamics (the dynamics of some parameters characterising the food product in the supply chain). The performance of the supply chain, expressed in terms of both logistic costs and final product quality, are then enhanced using a specific optimisation algorithm that uses the model to assure the feasibility of the proposed optimal solutions.

-Paper 16: A seller-buyer supply chain model with exponential distribution lead time / Mehrab Bahri, Mohammad Tarokh / 2013

Description: Supply chain is an accepted way of remaining in the competition in today's rapidly changing market. This paper presents a coordinated seller-buyer supply chain model in two stages, which is called Joint Economic Lot Sizing. The delivery activities in the supply chain consist of a single raw material. The delivery lead time is assumed to be stochastic and follows an exponential distribution. Also, the shortage during the lead time is permitted and completely back-ordered for the buyer. With these assumptions, the annual cost function of Joint Economic Lot Sizing is minimized. At the end, a numerical example is presented to show that the integrated approach considerably improves the costs in comparison with the independent decisions by seller and buyer.

Keywords: Integrated Inventory Model; Stochastic Lead Time; Supply Chain Coordination; Cost, Optimization.

-Paper 17: Storage constrained vendor managed inventory models with unequal shipment frequencies / Moncer Hariga, Mehmet Gumus, Abdelkader Daghfous / 2013

Description: A supply chain is considered where a vendor manages its multiple retailers' stocks under a vendor managed inventory (VMI) contract that specifies upper stock limits at the retailers' premises and over stock costs for exceeding those limits. A mixed integer non linear program is formulated to minimize total supply chain costs and to allow unequal shipment frequencies to the retailers. An algorithm is developed to solve its relaxed version which provides a lower bound cost solution. A cost efficient heuristic procedure is proposed to generate delivery schedules to the retailers. A sensitivity analysis is conducted to provide insights on the performance of the proposed heuristic. Results show that the heuristic finds optimal or near optimal solutions, and it proposes substantial savings compared to the total supply chain cost in the cases where there is no VMI and where there is VMI but with equal shipment frequencies to retailers.

Keywords: Single Vendor; Multiple Retailers; Vendor Managed Inventory; Storage Contract; Heuristic Procedure.

-Paper 18: A comprehensive annual delivery program for upstream liquefied natural gas supply chain / Fatih Mutlua, Mohamed Msaknia, Hakan Yildizb, Erkut Sönmezc ,Shaligram Pokharel / 2015

Description: Developing a cost effective annual delivery program (ADP) is a challenging task for liquefied natural gas (LNG) suppliers, especially for LNG supply chains with large number of vessels and customers. Given significant operational costs in LNG delivery operations, cost effective ADP scan yield substantial savings, adding up to millions. Providing an extensive account of supply chain operations and contractual terms, this paper aims to consider a realistic ADP problem faced by large LNG suppliers; suggest alternative delivery options, such as split-delivery; and propose an efficient heuristic solution which outperforms commercial optimizers. The comprehensive numerical study in this research demonstrates that contrary to the common belief in practice, split-delivery may generate substantial cost reductions in LNG supply chains.

Keywords: Maritime Industry; Annual Delivery Planning Problem; LNG Supply Chain; Large-Scale Optimization.

-Paper 19: Combining service frequency and vehicle routing for managing supplier shipments / Zhijie Dong, Mark Turnquist /2015

Description: This paper proposes a new approach to designing inbound material collection routes that considers pick-up frequency and spatial design as joint decisions to minimize total logistics (transportation plus inventory) cost. The clustering-based optimization uses an approximation to the actual cost of a routing solution without actual route construction. We show that the problem is analogous to a single-source fixed-charge facility location problem, and near-optimal solutions can be found using an efficient heuristic algorithm. Tests show the effectiveness of how this model is formulated and a case study demonstrates that substantial total cost savings can be achieved in realistic applications.

Keywords: Capacitated Clustering; Frequency Location Clustering; Inventory Routing Problem; Vehicle Routing Problem; Single-Source Fixed Charge Facility Location Problem.

-Paper 20: A periodic planning model for maritime transportation of crude oil / Atiq Siddiqui, Manish Verma, David Tulett / 2013

Description: Crude oil is primarily transported through sea using very large tankers. Efficient scheduling of these tankers is challenging as well as critical given long lead times, tight delivery time windows and high operational costs. This paper attempts to solve such a scheduling problem for an oil supplier facing supply quota and port capacity constraints. A mixed-integer programming formulation and two times dependent solution techniques are proposed. Numerical results suggest that computing time was a function of the number, starting location, and time to availability of tankers at the supply sources. Finally, a time-based decomposition technique is presented to solve large problem instances, illustrating substantial reductions in computing time for marginally worse-off solutions.

Keywords: Crude Oil Tankers; Marine Transportation; Mixed-Integer Programming; Periodic Planning; Scheduling.

-Paper 21: Modelling cost-delivery trade-offs for distribution logistics by a generalized PVRP model / Andrea Kurz, Gunther Zapfel / 2013

Description: This article provides a mathematical model to support management

in making decisions about cost-delivery trade-offs in the case of cost-delivery flexibilities in distribution logistics. The optimization problem can be modelled as a bi-objective periodic vehicle routing problem, which is known as NP-hard. In the periodic vehicle routing problem considered in this study, no delivery patterns are pre-defined, instead the patterns are the result of the optimization process of the model. In addition, delivery time flexibilities are incorporated in the model. A heuristic solution method for realistic problem sizes is based on the tabu search procedure, and a real case study illustrates the applicability of the solution concept.

Keywords: Cost-Delivery Trade-Offs; Logistics; Periodic Vehicle Routing; Tabu Search Metaheuristic.

-Paper 22: An Optimal Mixed Batch Shipment Policy for Multiple Items in a Single-Supplier Multiple-Retailer Integrated System / Wen-Tsung Ho, Shu-Fang Lai, Yun-Kuei Huang / 2013

Description: This study addresses mixed batch shipment policy with common replenishment cycle for multiple items in a single-supplier multiple-retailer integrated system. The supplier produces multiple items on a single facility under a common replenishment cycle and delivers products to retailer utilizing a mixed batch shipment policy. The objective is to determine the optimal replenishment cycle, the number of shipments, and the structure of mixed shipment, all of which minimize the integrated total cost per unit time. The single-item isolation model is constructed first, and the single item isolation model is then integrated into the single-item integration model. Moreover, the single-item integration model is integrated into the multi-item integration model. The minimum total cost model is transformed into a maximum replenishment cycle model to optimize the structure of the mixed batch shipment. The replenishment cycle division method is then developed to obtain the optimal solutions to the subject problem. Examples are presented to illustrate the procedures involved in the replenishment cycle division method.

Keywords: Inventory; Common Replenishment Cycle; Replenishment Cycle Division Method; Mixed Batch Shipment.

-Paper 23: Flexibility of Delivery Frequency in Logistics Competition / Anne & Jan Kramer / 2010

Description: The strategic impact of flexible delivery frequencies is investigated on the competition of logistics service providers (LSPs) in a supply chain. LSPs compete for customers who choose an exclusive service provider based on their individual preference, prices and inventory costs. The service provider which offers the higher delivery frequency is more attractive to customers, because inventory holding costs are kept low. In reverse, higher delivery frequencies entail higher transportation costs for the LSPs (frequency effect), which is only partially offset by a community cost effect that captures the economies of scale from larger market share and synergies from increased load efficiency. A scenario is considered in which only one of the two LSPs can choose its delivery frequency strategically. The main result is that flexibility in frequency choice is only a strategic advantage for the LSP if customers' inventory holding costs are relatively high compared to transportation costs. In this case customers especially appreciate the high delivery frequencies and the flexible LSP is able to satisfy this demand. However, when inventory holding costs are comparably small with respect to the LSPs' transportation costs, the inflexible LSP is at an advantage. In this case, inflexibility acts as a credible strategic commitment which the flexible LSP can only react to. Furthermore, low inventory holding costs lead to a situation in which the LSP with the delivery frequency faces the dilemma whether to choose its optimal delivery frequency and to make less profit than his competitor or to forfeit some of its own profits in order to make larger profits than the other LSP.
Keywords: Transportation; Supply Chain; Delivery Frequency; Price and Service Competition; Logistics Service Provider; Inventory Costs.

-Paper 24: An integrated shipment planning and storage capacity decision under uncertainty / Nyoman Pujawan, Mansur Maturidi Arief / 2015
Description: In transportation and distribution systems, the shipment decisions, fleet capacity, and storage capacity are interrelated in a complex way, especially when the authors take into account uncertainty of the demand rate and shipment lead time. While shipment planning is tactical or operational in nature, increasing storage capacity often requires top management’s authority. The purpose of this paper is to present a new method to integrate both operational and strategic decision parameters, namely shipment planning and storage capacity decision under uncertainty. The ultimate goal is to provide a near optimal solution that leads to a striking balance between the total logistics costs and product

availability, critical in maritime logistics of bulk shipment of commodity items.
The authors use simulation as research method. The authors develop a simulation model to investigate the effects of various factors on costs and service levels of a distribution system. The model mimics the transportation and distribution problems of bulk cement in a major cement company in Indonesia consisting of a silo at the port of origin, two silos at two ports of destination, and a number of ships that transport the bulk cement. The authors develop a number of "what-if" scenarios by varying the storage capacity at the port of origin as well as at the ports of destinations, number of ships operated, operating hours of ports, and dispatching rules for the ships. Each scenario is evaluated in terms of costs and service level. A full factorial experiment has been conducted and analysis of variance has been used to analyze the results. The results suggest that the number of ships deployed, silo capacity, working hours of ports, and the dispatching rules of ships significantly affect both total costs and service level.
Keywords: Uncertainty; Indonesia; Transportation; Simulation; Efficient Frontier; Shipment Planning; Storage Capacity.

-Paper 25: Shipment Frequency of Exporters and Demand Uncertainty / Gabor Békés, Lionel Fontagné, Balazs Murakozy, Vincent Vicard / 2014
Description: Firms adjust to differences in market size and demand uncertainty by changing the frequency and size of their export shipments. In this inventory model, transportation costs and optimal shipment frequency are determined on the basis of demand as well as inventory and per shipments costs. Using a cross section of monthly firm-product-destination level French export data it is confirmed that firms adjust on both margins for market size. In a stochastic setting, firms adjust to increased uncertainty by reducing their sales and, for a given export volume, by reducing their number of shipments and increasing their shipment size.
Keywords: Gravity; Transport Costs; Frequency of Trade; Inventory Model; Firms.

-Paper 26: A two-stage solution method for the annual dairy transportation problem / Renaud Masson, Nadia Lahrichi, Louis-Martin Rousseau / 2015
Description: The annual dairy transportation problem involves designing the routes that collect milk from farms and deliver it to processing plants. The

demands of these plants can change from one week to the next, but the collection is fixed by contract and must remain the same throughout the year. While the routes are currently designed using the historical average demand from the plants, this paper shows that including the information about plants demands leads to significant savings. A two stage method, based on an adaptive large neighborhood search (ALNS), is proposed here. The first phase solves the transportation problem and the second phase ensures that the optimization of plant assignment is performed. An additional analysis based on period clustering is conducted to speed up the resolution.
Keywords: Dairy Transportation Problem; Two Stage Method.

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Declaration of Authorship

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Milo Scramoncin, Munich, 24 March 2016