Multi-stage LTL transport systems in supply chain management

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Abstract: This chapter aims to unify concepts and to describe the multi-stage transport systems and their integratyion to supply chain management. Multi-stage distribution systems are common logistics management, and often they are assimilated to multi-stage transport strategies. However, transport is often considered as an external operation or a specific stage, even when it is a multi-stage system. First, the chapter presents the main concepts of multi-stage transport systems by defining the concept an making a typology of transport schemes. Then, an optimization analysis using the concept of accessibility is proposed to show the advantages and limits of such strategies. Then, an interview-based analysis includes a conceptual framework for the integration of multi-stage transport on supply chain management and a simulation shows the impacts of multi-stage transport on supply chain global costs and quality indicators.

Keywords: multi-stage freight transport, multi-echelon logistics, just-in-time, bundling, combinatorial optimization

Introduction

Freight transport is an important part of logistics systems, representing in average about 15% of the total cost of logistics operations (Toth and Vigo, 2002). Traditionally, the freight transport field has been often seen as an external or an adjustment variable for logistics planning and management (Beamon, 1998; Lambert, 2008). In the last years, transport takes another dimension since several works show the importance to include it into supply chain management decisions (Brewer et al., 2001; Gonzalez-Feliu, 2012). But freight transport schemes are "in se" complex systems that need to be defined and in-depth studied, and although several works start to include transport as a fundamental variable of supply chain management, only direct shipping FTL strategies are often used. In the last years, with new consumer's behaviors (mainly related to timetable flexibility), the use of new technologies in the current life (internet, smartphones, GPS devices, etc.) and the advantageous position of transport costs with respect to inventorying and warehouse management, multi-stage transport systems have been developed, more precisely when dealing with freight distribution schemes with cross-docking (Gonzalez-Feliu, 2012a). Moreover, multi-stage transport has not still clearly defined in research, sometimes using a terminology that can make confusion: to cite a representative example, when authors speak about multi-stage transport, the word "stage" has not the same signification than in supply chain management, as signaled in Gonzalez-Feliu (2011). However, FTL transport and linear systems have been defined via the bundling theory (Beuthe and Kreutzberger, 2001; Kreutzberger, 2006, 2010).

This chapter aims to present multi-stage transport systems and their insertion on supply chains, focusing on LTL schemes and providing a general framework for planning, optimization and management of such systems. First, multi-stage transport systems will be defined and related to supply chains and their multi-stage nature, making the distinction between a supply chain stage and a transport stage. After that, we will focus on the main LTL strategies. We will define them by extending Kreutzberger's (2008) work to LTL transport in the context of the outbound supply chain. We propose then to synthesize the main optimization objectives and methods to provide a framework to both researchers and practitioners that respect both the operability principles of Ackoff (1975) and Bonnafous (1989). Finally, research directions and applicability issues related to this subject are proposed and discussed.

Multi-Stage Transport and Supply Chain Management

The freight transportation sector is continuously changing as a consequence of the growth and transformation of the economic activity. However, and although it is often considered as a strong support to national economy, the logistics and freight transport field has a negative image related to the fact it is a source of congestion and environmental disturbance, which negatively affect quality of life (Crainic and Laporte, 1997). In recent years companies have changed their inventory and distribution strategies for better adapting them to the changing demand. Moreover, the new advances in technology have been a positive factor for the development of new markets and new consumer needs (Rodrigue, 2006), having a direct repercussion on logistics planning and management (Lambert, 2008). This has highlighted the importance of including transport management into supply chain planning and management issues (Crainic and Laporte, 1997; Toth and Vigo, 2002; Ghiani et al., 2004; Cordeau et al., 2007; Wieberneit, 2008; Gonzalez-Feliu, 2012a). However, to integrate a transport system into a supply chain it is important to first define it and identify its main variables and constraints; in another words, to model it[1]. A freight transport (as for personal trips) is defined by an origin, a destination and a purpose (Ortuzar and Willumsen, 2001). However, although in personal transport those three elements are necessary but also sufficient to define a trip, it is not the case for a transport of goods, mainly when dealing with LTL transport. Other elements that define a freight transport trip, path or route, are related to the following elements:

- Vehicle usage: As freight is loaded into vehicles, trips will be related to the usage that is made of those vehicles. The first vehicle usage strategy is that of Full Truck Load (FTL), which means that the entire vehicle's load at an origin will be delivered to the associated destination (Gonzalez-Feliu, 2008). Note that in FTL strategies vehicles can be not entirely loaded (i.e. it can present a residual capacity due to different reasons), but in any case they do not deliver more than one destination. Instead, in other real applications, like in city logistics, most of the vehicles are not full-loaded, so the applied policy is known as Less-than-Truck Load (LTL). The present document focus on LTL transport.

[1] Note that the definition of model made here does not automatically lead to a mathematical or quantitative expression. A model (Ackoff, 1979 ; Bonnafous, 1989) is a representation, or a reduction, of what is perceived to be a reality, but not the transcription of the reality itself. We will not enter on philosophic or epistemological aspects here, but we aim to note that the notion of model shown here answer to that definition, and not necessarily to a mathematical formalization of a reality.

- Transport mode: In freight transport, two modes are worldwide predominant: sea transport for intercontinental trips, and road transport for intra-continental paths. In some contexts (mainly in the U.S.A and Canada), railway transport is also one of the major modes. Moreover, three other modes can be seen: fluvial transport, which is not negligible in countries with navigable rivers, like France and The Netherlands, and soft mode transport, mainly in rural contexts of non-industrialized countries (animal traction) or in urban congested areas (cycling-based and chariot-based freight transport). Moreover, a path linking an origin and a destination to transport a quantity of goods can be monomodal (when only a mode of transport is used) or multimodal (when more than one mode are used).
- Hierarchical structure of the network: This aspect can be defined using two groups of strategies (direct shipping and multi-stage schemes). Single stage schemes represent the direct shipping strategy, and multiple stages systems deal with transport schemes with one or more ruptures of change. Note that in this work we will use the term "stage" and not "stage" to avoid confusion between transport strategies and global supply chains, and to explicitly include transport into supply chain management strategic and tactical decisions.
- Nature of demand/supply: in general, demand requests are made in advance, so the freight quantities are determined before the transportation system is optimized. In these cases, the decision problems are deterministic. However, in some real cases and for some freight categories, customers are defining the freight quantities of their request at the time of the arrival of the supplier's vehicle. In this case, decision problems are based on statistics and uncertainty modeling, and are noted as stochastic approaches.
- Transport system characteristics: In freight transport, vehicles are not isolated but are part of a system. In this system, one or more fleets of vehicles are defined. Those vehicles can have the same characteristics (i.e. the fleet of vehicles is homogeneous) or not (in this case the fleet of vehicles is known as heterogeneous). Moreover, one or more facilities are defined (in number and characteristics), mainly related to the following categories: vehicle depots (where vehicles are parked and its maintenance takes place), freight depots (the starting point of the freight and the link with the upstream supply chain stage), warehouses (if the transport system includes inventorying[2]), cross-docking facilities (where freight is temporally stored to be transferred, mostly within few hours, to another vehicle, being consolidated or split according to the distribution strategy), parking facilities and delivery areas.
- Transport frequency: A freight transport is also often associated to its frequency, i.e. it is not planned in an isolated way but related to the inventorying, stock management and distribution strategies that the producer (or distribution company) agrees with the customer. Two planning strategies related to transport frequency are used in real applications (Min et al., 1997). Single period problems represent the cases the distribution planning is made for one single specific configuration of requests (e.g. trip planning for a single day). If this configuration is defined

[2] In general, inventorying and transport are not jointly planned in supply chain management. Transport becomes a link and warehouses are related to transport systems when associated to the departure or destination of the transport trip chain.

not for a single moment but for a period of time (e.g. weekly planning where each day has a different request configuration).

- Transport constraints: Due to different reasons (vehicle characteristics, driving regulation, accessibility constraints, etc.) one or more constraints can be associated to freight transport (Nagy and Sahli, 2007). The most common are the following: distance limitations, customer's time availability for goods reception (that are defined as hard or soft time windows[3]).
- Bundling strategy: when dealing with LTL transport, the question of how freight can be bundled into a vehicle appears (Kreutzberger, 2008). The main strategies of the bundling theory are: direct networks (i.e., no bundling is applied), hub and spoke networks which are three-stage FTL transport systems), linear networks (which are in general transport systems with a unique LTL route), multi-linear networks (classic LTL transport systems), trunk feeder schemes (two-stage systems defined by a central unique LTL route and several FTL trips to deliver or pick-up the freight at each stop of the LTL route) and trunk collection and distribution schemes (respectively two and three-stage systems where consolidation is made at the first rupture of charge and distribution at the second).

As presented above, multi-stage transport systems are characterized by one or more groups of intermediary stages where various operations can be achieved. In these intermediary facilities, some operations take place, to help the distribution process, reduce costs, give a higher quality service or offer some additional services to vehicle drivers. One of the most important group of activities that take place at the intermediary platforms is related to cross-docking operations (Lowe, 2005). In most of multi-stage transportation cases, the main characteristics are related to vehicle changing at least in one intermediary terminal. In these cases, freight is unloaded from the arriving vehicle, then loaded into a different vehicle. This freight can be exposed to package or organization changes, or can change vehicle without submitting changes on the measure unit (i.e., the entire load does not change nature, form and content in the trans-doc operation). Other important operations, which are common in many distribution fields, deal with freight reorganization. In some real applications, as for example newspaper or fresh alimentary products distribution, the companies have to deliver products coming from different producers to each destination point (Jacobsen and Madsen, 1980).

[3] Hard time windows are time periods within which the freight can be delivered to the customer. If a vehicle arrives too soon or too late, it is supposed that it cannot deliver the freight. Soft time windows allow flexibility, i.e. if the time window is not respected, it is still possible to deliver freight but a penalty has to be paid. For more information, see Braysy and Gendreau (2005a,b)

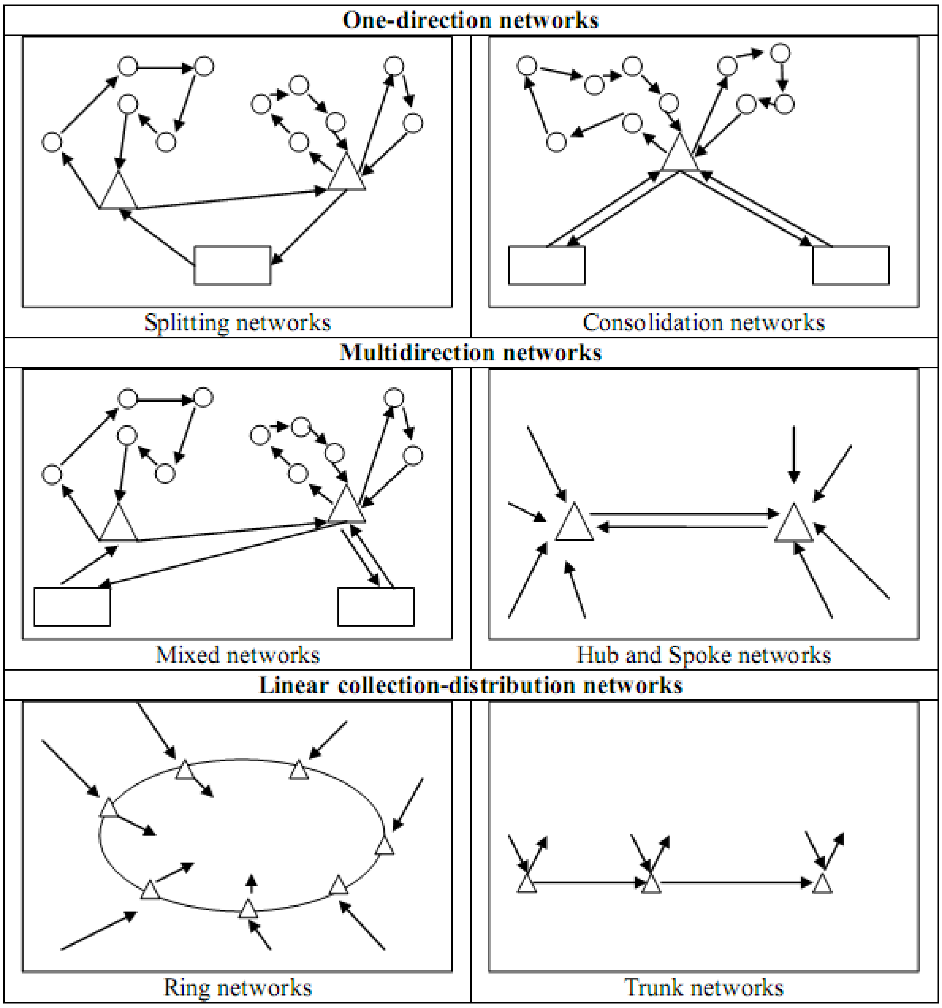

Figure 1. Main multi-stage bundling strategies (adapted from Gonzalez-Feliu, 2008 and Kreutzberger, 2008).

To reduce costs, this freight is reorganized at the intermediary points, where each customer's request is composed by aggregating its demand from each producer, and then the vehicles are loaded. Note that the concepts of bundling (co-habitation of freight belonging to different destinations in the same vehicle) and pooling (common simultaneous usage of resources by various stakeholders that know and consent that usage) are different (the second is a particular sub-family of the first) and have to not be confounded (For more information about logistics pooling, see Gonzalez-Feliu et al., 2010).

Another aspect associated to these facilities is the freight storage (Ackerman and Brewer, 2001). Freight can be deposed at the terminals for a small period of time (the necessary to complete the other operations); in these cases, the system can be modeled without considering inventory aspects. When freight is stocked and distributed gradually in function of demand trends and requests, inventory systems can model the whole system. Although in transportation systems production activities are not considered, some additional operations and services can take place at intermediary platforms. For example, labeling, control, package making or the preparation of promotional and special offer products that are not realized by the producers but by the distribution companies.

In this work we will focus on multi-stage LTL transport. In precedent works (Gonzalez-Feliu, 2008, 2011, 2012) it has been stated that two types of multi-stage transport can be defined: multi-stage transport with warehousing refers to systems made by one or more factories, a number of storage areas, known as warehouses, and the final destination of freight (Ackerman and Brewer, 2001); multi-stage transport with cross-docking differs from the warehousing strategy in the fact that cross-docking platforms don't have the possibility to stock, but consent the consolidation and transshipment operations (Gonzalez-Feliu, 2012). This classification is pertinent when related to transport management, but when dealing with the interactions between transport and supply chain management, solely multi-stage transport with cross-docking is an only-transport management strategy. Let's explicate it. In transport and warehousing schemes, freight requests are made to warehouses, which have a stock of freight. These warehouses command freight in big quantities to factories. In other words, such strategies show a direct interaction between supply chain management and transport planning. In other words, a systemic planning and optimization approach for such systems needs to take into account both transport and inventory management (the transport planner depends on the inventory management if a good collaboration is required). In transport and cross-docking schemes, commands are made directly to the origin of the freight, which is in general a factory or a warehouse. To manage and plan such transport systems, the transport system can be isolated from the origin and the destination, i.e. if demand and constraints are given with the origin and the destination, the transport routes can be planned. This work deals consequently with multi-stage LTL transport with cross-docking.

As it will be presented below, some studies have considered multi-stage system cost optimization, but the main difficulty of individuating an classing them is that each field uses a different notation and no standard vocabulary has already be proposed. To deal with it, we propose a general definition of a multi-stage distribution system, presenting the vocabulary and notation which will be followed in this work. In a multi-stage transport system, it is not possible to deliver the freight directly from the origin to the final destination of the request. In fact, freight goes to one or more intermediary facilities, where some of the operations presented above take place. If we define an N-stage distribution system, N intermediary stages are considered. Each stage e has a number of k-stage intermediary facilities associated to it. The overall transportation network can then be decomposed into N stages. The first connects the depots to the 1st-stage intermediary facilities. Then, N-2 intermediate stages inter-connect the different intermediary facilities and define the structure of each intermediary transport. Finally, the N^{th} stage represents the subsystem in which freight is delivered from the (N-1)th stage intermediary facilities to the final destinations. The depots are then the starting points of the distribution chain. They represent mainly a manufacturing plant or a general warehouse, and are easily identifiable into a supply chain stages. We define as e-intermediate facility (e-IF) a logistics platform associated to the stage e. At each e-IF, the freight is transshipped (and, eventually, complementary operations like consolidation, splitting, labeling, re-packaging or customs and quality controls take place). The customers are defined as the final destinations of the freight.

The potential customers in a supply chain integration are various: traditionally they are seen as stores or retailers, but also households in some home-delivery services; however, in supply chain integrated approaches we can also consider manufacturing plants and warehouses if the N-stage transport connects two intermediary stages and does not concern last mile transport).

We use this definition analogously to vehicle routing optimization. To deliver the freight, a number of vehicle fleets are defined. Each stage e usually has its own fleet of vehicles, defined by different characteristics (capacity, dimensions, speed), and can be heterogeneous or homogeneous. An e-stage vehicle is a vehicle belonging to stage e, i.e. travelling from an e-1-IF to an e-IF. Because of a lack of unification (Gonzalez-Feliu, 2011), several mathematical formalizations of the optimization problems are found in relation to multi-stage LTL transport optimization.

Most of them deal with two-stage delivery systems with splits at cross-docking platforms. Such problems are mainly related to route construction (Semet, 1995; Drexl, 2007; Gonzalez-Feliu, 2008; Zegordi and Nikbakhsh, 2009; Jepsen et al., 2012 or Nguyen et al., 2012) or to problems where a set of routes are already defined (Gendron and Semet, 2008; Crainic et al., 2009; Dondo et al., 2011).

The main conclusions of such theoretic and mathematics analyses is that the problem is difficult (noted as NP-hard in mathematical disciplines) and formulations representing a simplified reality are useful to identify the optimization deals and challenges, such as the systemic nature of the problem and the need of overall approach that do not split the problem in subsystems is such systemic nature aims to be conserved (Drexl, 2007; Gonzalez-Feliu, 2008); those works help also to give benchmarks and references for the development of applied tools for decision support concerning multi-stage transport planning, but cannot be used to optimize them in real-size cases (which count hundreds or thousands of transport requests, mainly in urban areas, according to Gonzalez-Feliu and Salanova, 2012).

Moreover, according to Ackhoff's (1979) considerations, it is important to meet real needs and question on how a given tool can better answer's the practice's requirements and well represent the "observed reality". It is then important to find a balance between the "problem solving" (finding the optimum of the represented optimization problem" and the "solution probleming" (finding the implications, applications and real feasibility conditions of the given solution, or revise the problem and solving methods to reach such feasibility). For those reasons, we will focus on existing solving methods for multi-stage LTL transport optimization and how they can reach what we intend by practical feasibility.

3. Planning, Management and Optimization for Multi-Stage LTL Transport Systems

In outbound logistics planning and management, decisions on the transport schemes and their effectiveness have direct impacts on both operational costs and service quality. Consequently, it is important to adapt transport networks to the different logistics and territorial constraints without forgetting their links to the supply chain and the logistics management actions of organizations. Since direct shipping strategies are easy to integrate into supply chains, they are often included in logistics planning and management as fixed or variables to be planned, but with a small control margin at the global supply chain stage).

However, multi-stage transport systems present the difficulty of managing two or mre transport schemes connected by a rupture of charge where crossdocking and synchronization need to be carried out. In this section we aim to focus on the systemic management of such systems, focusing on tactical planning (Crainic and Laporte, 1997). Operational and execution planning levels deal with short and real time decisions that need a good focus on the single operations and their internal organizations, so a decomposition approach is the most adapted way to process and understand them. At the strategic level (i.e., long term), approximations on the transport network structure, relating it to an estimated cost are suitable representations to plan the global supply chains.

However, at a tactical level (which is middle term-based), the differences between approximation approaches, decomposition approaches and systemic approaches can be easily seen and analyzed. In this section we do not present in-depth the different algorithms and methods (for which comprehension a knowledge of operations research is required, and will be briefly presented in an appendix) but discuss their operability conditions and issues in the sense of Bonnafous (1989) by identifying their main advantages and disadvantages.

Decomposition Approaches

In this chapter we do not aim to focus on the different categories of models and methods that can be used in decomposition approaches, but it is important to study how they relate multi-stage LTL transport systems to optimization tools. For that reason we focus only on existing works dealing with multi-stage LTL systems by decomposing them on separately solved subsystems, which can be called pseudo-systemic two-stage vehicle routing optimization methods. Indeed, such methods are mainly constructing routes by a logical separation of the overall system into a set of connected subsystems (in general, by assigning transport demands to IF, then constructing 2nd stage routes to finally obtain the 1st stage routes). Most methods stop at the construction phase, i.e., routes are not post-optimized, either because of technical limitations (for methods before 1990) or to represent a “realistic” optimization, i.e. to simulate an optimization logic that is close from current practices. As stated in Ambrosini and Routhier (2004), practical optimization is far from theoretical optimums and solutions obtained by complex meta-heuristic methods. Moreover, Gonzalez-Feliu and Morana (2011) confirmed that classical heuristics (most of them developed between 1950 and 1970) are the basis of the most deployed commercial tools for vehicle routing in real LTL transport. Furthermore, few works, mainly on the context of city logistics (Crainic, 2008) are developed to simulate urban splitting networks. In such works (Crainic et al., 2010, 2011) use either IF-based post-optimization (i.e., no customer exchange between IF is allowed, like Crainic et al. 2010, 2011) or route-based post-optimization (once routes are defined, they can be re-optimized but their composition in term of customers to visit does not change. Such methods are adaptations of vehicle routing problem altghorithms without proposing sistemic views in the problem solving process.

The Vehicle Routing Problem (VRP) is the generic name given to a whole class of combinatorial optimisation problems in which a set of routes for a fleet of vehicles based at one or several depots must be determined for a number of geographically dispersed points, called customers.

These vehicles are operated by a set of crews, known as drivers, and are travelling to customers using an appropriate road network. In particular, the solution of a VRP is obtained by the determination of a set of routes, each performed by a single vehicle that starts and ends at its own depot, such that each customer's requirement is fulfilled, all the operational constraints are satisfied, and the overall transportation cost is minimised. For a detailed definition of the problem and the several models used to define the basic versions, see Toth and Vigo, (2002).

The VRP is considered as one of the most challenging combinatorial optimisation problem and is studied for more than 50 years (Gonzalez-Feliu, 2008). Many works and surveys related to VRP can be found in literature (for mode details about this problem, see Golden, 1988; Laporte, 1992; Toth and Vigo, 2002; Cordeau et al., 2007; Golden et al., 2008).

Table 1. Main decomposition approaches and solving methods

Authors	Type of algorithm	Size	Type of system	Real context
Wren (1971)	Construction heuristics	One depot, multiple IF and 200 customers	Consolidation Collection	Yes
Jacobsen and Madsen (1980)	Construction heuristics	One depot, three IF and 4510 customers	Splitting Distribution	Yes
Brunswicker (1986)	Construction heuristics	One depot, 52 IF and 739 customers	Consolidation Collection	Yes
Vahrenkamp (1989)	Construction heuristics	Multiple depots and IF and 200 customers	Consolidation Collection	Yes
Crainic et al. (2010)	Construction heuristics with IF-based LS[4] post-optimization	One depot, five IF and 250 customers	Splitting Distribution	No
Gonzalez-Feliu et al. (2010)	Construction heuristics	Three depots, seven IF and 310 customers	Consolidation Distribution	No
Crainic et al. (2011)	Multi-start heuristics with IF-based TS post-optimization	Test cases from Crainic et al. (2010)	Splitting Distribution	No
Gonzalez-Feliu and Salanova (2012)	Construction heuristic with route-based LS post-optimization	Five depots, 9 IF and 1450 customers	Mixed Distribution	Yes

The advantages of such approaches are that the reality representation is close to the current practices, i.e. to the logical strategies of "dividing the system" into a set of "easily understandable and controllable" subsystems. Moreover, construction heuristics are easy to explain to non-experts and intuitive to understand.

Finally, they are quick to implement and to transfer into specialized and general fleet management tools. The main disadvantages of such systems derive from the fact the systemic nature of multi-stage LTL transport is not really integrated into the solving method, making such methods a direct application of classical VRP heuristics with a small adaptation. However, they correspond to a current practice philosophy in terms of optimization and are very popular in practice, although little diffused in scientific publications.

[4] Local Search

Systemic Approaches

System route optimisation proposed to simultaneously optimise all the routes belonging to the various stages, as well as the demand assignment to each intermediary platform. These approaches often follow the findings of Jacobsen and Madsen (1980), who defined the two-stage version of the problem. According to the authors, the problem consists of determining the location of the satellites, allocating the customers to the best satellites and determining both first and second-stage routes.

A sub-family of system optimization problems is that of hierarchical arc routing problems. In these problems, the second stage is not represented by a vehicle routing problem (where demand is assigned to nodes) but by an arc routing problem (where demand is distributed on an arc).

These problems can deal with post distribution, waste collection or other road maintenance problems, like painting or repairing operations. Although in its single stage version (the Capacitated Arc Routing Problems) they are very popular, its two-stage version is a new variant only studied by few authors.

The problem often combines a vehicle routing problem to serve intermediary depots or facilities and an arc routing problem to deliver the final customer sections. However, only three works have been found on such sub-variant.

Both sub-variant (vehicle routing and arc routing approaches) have similar advantages and disadvantages, on a real operability viewpoint. Their strengths are that both take into account the systemic nature of multi-stage LTL transport, and propose in many cases adapted tools that are easy to implement and become operational tools.

However, most works remain theoretical or conceptual for vehicle approaches. Indeed, only one vehicle routing work is applied to real context, and considering the “realistic” applications, the percentage of applicable algorithms remains small (which represents less than 25%).

This is not the case for arc routing approaches, because all three are solving practical problems. However, no real practices are, in our knowledge, using one of such approaches, and the systemic optimization remains for the moment a tool of research, where several theoretical optimums have been recently found (Contardo et al., 2012; Jepsen et al., 2012). Remain however to find a framework that should be easily adapted for practitioners, at different planning horizons, in order to support their decisions and management issues.

Table 2. Main systemic approaches and solving methods – VRP

Authors	Type of algorithm	Maximum size	Type of system	Real context
Jacobsen and Madsen (1980)	Construction heuristic with systemic LS post-optimization	Test cases from Jacobsen and Madsen (1980)	Splitting Distribution	Yes
Madsen (1983)	Construction heuristic with systemic LS post-optimization	One depot, three IF and 4510 customers	Splitting Distribution	Yes
Semet and Taillard (1993)	Construction heuristic with systemic TS[5] post-optimization	One depot, nine IF and 45 customers	Splitting Distribution	No
Semet (1995)	Lagrangian relaxation-based heuristic algorithm	One depot, 50 IF and 100 customers	Splitting Distribution	No
Gerdessen (1996)	Construction heuristic with systemic LS post-optimization	One depot, 200 IF and 200 customers	Splitting Distribution	No
Chao (2002)	Construction heuristic with systemic TS post-optimization	One depot, 150 IF and 199 customers	Splitting Distribution	No
Scheuerer (2006)	Construction heuristic with systemic TS post-optimization	Test cases from Chao (2002)	Splitting Distribution	No
Tan et al. (2006)	Construction heuristic with systemic hybrid post-optimization	Test cases from Chao (2002)	Splitting Distribution	No
Drexl (2007)	Mathematical formulation solved by exact methods	One depot, eight IF and eight customers	Splitting Distribution	No
Gonzalez-Feliu et al. (2007)	Mathematical formulation solved by LP[6] commercial tools	One depot, four IF and 50 customers	Splitting Distribution	No
Gonzalez-Feliu (2008)	Mathematical formulation solved by LP commercial tools	One depot, five IF and 50 customers	Splitting Distribution	No
Hoff and Lokketangen (2008)	Construction heuristic with systemic TS post-optimization	Real size instances	Mixed Distribution	Yes

[5] Tabu Search
[6] Linear Programming

Table 2bis. Main systemic approaches and solving methods – VRP

Authors	Type of algorithm	Maximum size	Type of system	Real context
Lin et al. (2009)	Construction heuristic with systemic SA[7] post-optimization	Test cases from Chao (2002)	Splitting Distribution	No
Zegordi and Nikbakhsh (2009)	Construction heuristic with systemic SA post-optimization	10 depot, 50 IF and 100 customers	Mixed Distribution	No
Boccia et al. (2010)	Construction heuristic with systemic TS post-optimization	Five depot, 20 IF and 200 customers	Mixed Distribution	No
Nguyen et al. (2010)	Construction heuristic with systemic LS post-optimization	One depot, 10 IF and 250 customers	Splitting Distribution	No
Perboli et al. (2010)	Exact method using Gonzalez-Feliu et al.'s (2007) formulation	Test cases from Gonzalez-Feliu (2008)	Splitting Distribution	No
Villegas et al. (2010)	Construction heuristic with systemic LS post-optimization	Test case from Nguyen et al. (2010)	Splitting Distribution	No
Nguyen et al. (2011)	Construction heuristic with systemic VNS[8] post-optimization	One depot, 10 IF and 250 customers	Splitting Distribution	No
Wang et al. (2011)	Construction heuristic with systemic SA post-optimization	Test cases from Gonzalez-Feliu et al. (2006)	Splitting Distribution	No
Contardo et al. (2012)	Mathematical formulation solved by an exact method	Test cases from Nguyen et al. (2010)	Splitting Distribution	No
Jepsen et al. (2012)	Mathematical formulation solved by an exact method	Test cases from Gonzalez-Feliu (2008)	Splitting Distribution	No

[7] Simulated Anenaling
[8] Variable Neighborhood Search

Table 3. Main approaches and solving methods for category 2

Authors	Type of algorithm	Maximum size	Type of system	Real context
Del Pia and Filippi (2006)	Construction heuristic with systemic VND[9] post-optimization	One depot, multiple IF and customer streets	Consolidation Collection	Yes
Amaya et al. (2007)	Systemic heuristic from trunked exact methods	One depot, 5 IF and 595customer streets	Consolidation Distribution	Yes
Amaya et al. (2010)	Construction heuristic with systemic LS post-optimization	Test cases from Amaya et al. (2007)	Consolidation Distribution	Yes

Approximated Approaches and Other Related Works

In these problems, the main goal is not to precisely design each route plan but to give a general detailed definition of the two-stage transport system. For this reason, costs are approximated, creating groups of customers that are then assigned to routes. Although the test cases remain small for several problems, results show that they can be applied to bigger instances, and be used in real-life. The major advantages of such approaches is that they take into account the systemic nature of systems (works focusing on one stage without including the other in the optimization are not taken into account since they are not systemic); readers can refer to Bard et al. (1998a,b) and Agnelelli and Speranza (2002) for different variants and applications of such approaches. Moreover, the approximations arise of the simplification of one of the two stages, mainly by considering a fixed set of possible routes or by associating a fixed cost to each route independently of the number of customers but taking into account the capacity and distance constraints; in this ways, the representation of the observed reality meets the practitionners expectatives and are easy to understand. However, such approaches are not easy to communicate into the scientific community, since their scientific contribution is not computational or mathematically formal, but methodological and multidisciplinary, which makes difficult to be communicated to operations research communities (Ackhoff, 1979).

The scientific literature includes other examples from several disciplines and fields of research that also deal with multi-stage LTL transport, including operations research, business, management, socio-economics and transport engineering. One of the main research subjects deals with vehicle management at terminals (Wang and Regan, 2008; Soltani and Sadjadi, 2010, Larbi et al. 2011).

Another important subject is that of intermodal transport management at both transport engineering (Lowe 2005, Dalla Chiara et al. 2008) or operations management. In any case, most works belonging to those categories are related to terminal and infrastructure management, not to the transportation

[9] Variable Neighborhood Descent

system itself. Also, operations research deal with the optimization of facility locations (Aikens 1985, Hinojosa and Puerto, 2003; Klose and Drexl 2004).

Table 4. Main approximation approaches and solving methods

Authors	Type of algorithm	Maximum size	Type of system	Real context
Crainic et al. (2004)	Mathematical formulation solved by LP commercial tools	One depot, 12 IF and 51 customers	Splitting Distribution	No
Ambrosino and Scutellà (2005)	Mathematical formulation solved by LP commercial tools	One depot, five IF and 25 customers	Splitting Distribution	No
Crevier et al. (2007)	Construction heuristic with systemic TS post-optimization	One depot, six IF and 216 customers	Consolidation Distribution	No
Gendron and Semet (2008)	Mathematical formulation solved by LP commercial tools	93 depot, 320 IF and 722 customers	Mixed Distribution	Yes
Huart et al. (2010)	Construction heuristic with systemic TS post-optimization	One depot, five IF and 50 customers	Splitting Distribution	No
Dondo et al. (2011)	Mathematical formulation solved by LP commercial tools	One depot, two IF, 25 customers	Splitting Distribution	Yes

These categories of research works are not detailed here because they refer to technical aspects of a part of a system and are not related to the management of multi-stage LTL transport systems and issues related the interconnections of stages, as for example transshipment and synchronization.

4. SOCIO-ECONOMIC ISSUES

In addition to the above works are qualitative studies that deal with supply chain management and which can be related to multi-stage transportation with cross-docking, but they are not directly related to the optimization approaches (Gonzalez-Feliu, 2012a). Concerning multi-stage LTL transport, Yang et al. (2010) identified the factors affecting cross-docking operations in the context of terminal management including the impacts of other supply chain stages such as delays on production and distribution. Beuthe and Kreutzberger (2001) and Kreutzberger (2006, 2008, 2010) analyzed different multi-stage transport schemes and estimated the changes in their costs in order to compare them and show which are the most suitable bunling strategies from different perspectives. However, most systems are FLT schemes and only linear systems show one limited LTL route (which corresponds to a train line with some collection/delivery points feed by FTL transport). Simonot and Roure (2007) examined of transport network typologies in terms of constitution, objectives and organizational behavior. TLandAssociés and LET (2009) identified and analyzed the main leverages involved in changing transportation demand on the loader's point of view (for both consigners and consignees), observing that transport management and modal split were considered as leverages for transportation carriers, not for loaders. Gonzalez-Feliu and Morana (2011) performed a case study on press distribution to examine the limits to possible changes in their distribution schemes. A similar approach is followed in Gonzalez-Feliu (2012a) to extend such works to the consolidation and cross-docking LTL transport systems. Although it is often said that freight transport is an important component of supply chian management (Toth and Vigo, 2002), the relations between them are not often studied. For that reason, we aim to propose a qualitative analysis to both illustrate the practical forms of LTL multi-stage transport and how it is seen by practitioners. To this purpose, we propose a qualitative analysis based on a set of 50 interviews. Since a first set of potential stakeholders (mainly 2PL and 3 PL) has been identified between 2009 and 2010 (Gonzalez-Feliu and Morana, 2011), resulting on a set of 20 interview, a complementary campaign has been carried out focusing on industrial and distribution stakeholders between 2011 and 2012. The synthesis of the interviewed stakeholders is the following (Table 5):

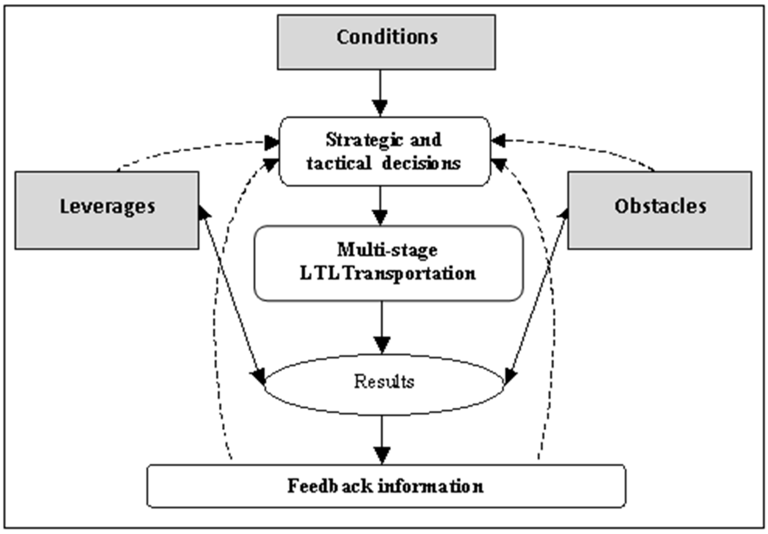

Figure 2. Conceptual Model for A Socio-Economic Analysis in Multi-Stage Freight Distribution Planning and System Design (adapted from Gonzalez-Feliu and Morana, 2011).

To complete the different information that is needed to characterize muilti-stage transport in supply chains, different categories of stakeholders were interviewed: manufacturers (from automotive, textile and agro-food industry), distribution specialists (grocery and press), urban distribution specialists (urban consolidation centres, e-commerce operators and public authorities) as well as logistics operators (3PL, 4PL and 5PL).

Table 5. Synthesis of the proposed interviews

Set of stakeholders	Total number of interviews	Semi-directive interviews	Non-directive interviews
Grocery distribution	5	2	3
Urban consolidation centers	6	3	3
Public local authorities	4	2	2
Press distribution	2	1	1
Parcel distribution 3PL	5	2	3
Classical distribution 3PL	6	2	4
Automotive industry	4	2	2
Clothes industry	3	0	3
Agro-food industry	5	2	3
4PL/5PL	6	3	3
E-commerce operators	4	1	3
Total	*50*	*20*	*30*

Moreover, two different interviews have been carried out. The first was a set of semi-directive interviews, in the context of a project concerning demand control by senders and logistics operators.

The second was a set of open interviews, i.e., non-directive, with a pseudo-directive mechanism to orient the interviewed people when the answers where not directly related to the subject or an information or issue was not in-depth discussed. Such interviews were developed to introduce the different socio-economic factors related to the deployment and operational management of multi-stage LTL transport systems. A chart summarizes the conceptual framework, adapting Gonzalez-Feliu and Morana's (2011) work to general LTL transport:

We identify three categories of elements: the conditions, the leverages and the obstacles. Conditions can be defined as the factors that contribute to the development of a multi-stage LTL transport system; those factors are mainly defined from the socio-economic and legislative contexts of practices, grouped into the following families:

- Economic, environmental and value conditions, defined as the factors related to economic efficiency, the prestige of the partners, and image. Sustainable performance is an important element to be included in this category (Gonzalez-Feliu and Morana, 2011).
- Legislation and jurisprudence issues related to collaboration in transport, known as legislative motivators. Nowadays, the most important aspects in this category are the different local laws

that help the development of multi-stage transportation systems in urban and regional freight transportation (Ville et al. 2013).

- Relation conditions are closely related to habits and inter-personal relational behavior (Yearwood and Stranieri, 2011). When actors have already been involved together in such schemes since linked by common interest, and when this collaboration has a positive impact on their logistics performance, transportation sharing is more naturally taken into account than in cases where such conditions are not met. Moreover, non-competing and complementary companies are more concerned with these types of approaches in the absence of legislative or financial conditions (Gonzalez-Feliu and Morana, 2011).
- Financial conditions are related to the funding strategies and the possible financial support provided by public, private or semi-public companies. Several approaches have emerged from research and innovation projects financed (totally or partially) by public organizations, in forms of subsidies or Public-Private Partnerships.
- Transport context conditions, mainly related to geographic and demographic contexts, for example urban goods transport and city access and parking conditions (Ville et al., 2012), regional contexts, in geographical and local economy terms, international exchanges that justify intermodal transport (Kreutzberger, 2008, 2010), or mountain pass crossing that can be a development factor of railroad systems (Lowe, 2005).

We also observe that such conditions are strongly related to three connected elements. First is the *monomodality or mulitmodality nature of the transport*. Indeed, multimodal networks are in fact multi-stage, and train-based of urban soft modes-related systems include LTL transport sub-systems). The second is the *nature of the global management operator*. Freight-forwarder and transport commitment companies are in general subcontracting and 4PL-5PL integrators often propose multi-stage systems, not always of LTL nature but that can be interfaced to LTL transport for the last mile. Last but not least, the third is the activity sector. Some fields seem more susceptible to multi-stage LTL transport than others, like the press distribution sector, the clothes sector, the spare parts and the grocery distribution companies, among others. Press distribution and grocery distribution are studied by many authors.

Concerning clothes distribution, with the adoption of quick response strategies, combined with the European franchising sales strategies, regular deliveries, managed by manufacturers, impose a zero-stock inventory strategy. In other works, all the clothes available are exposed or temporarily stored at the retailer's location, and weekly-monthly deliveries are ensured by the franchiser. Concerning spare parts, since the service quality (a quick delivery and a high availabily of commanded goods has to be ensured to reduce the waiting time, since such parts are related to automotive reparations) is directly related to the logistics systems and their costs, a supranational network with a few number of centralized warehouses (one per sub-area) and a spread network of transshipment facilities is being adopted by most manufacturers. That strategy leads to the development of hub and spoke networks managed by sub-contractors, mainly specialized 4PL or 5PL) Such logistics systems need multi-stage LTL transport networks to ensure its quality and efficiency.

The leverages are the conditions and situations that have a positive impact on the daily operations of multi-stage LTL transport networks. They are similar to those of collaboration and logistics partnerships (Lambert 2008).

These factors are not only related to logistics organization but also to the evolution of the strategic planning relationships between partners. A history of relations between two actors can facilitate a durable partnership. Closely related to the leverages are the obstacles, i.e. factors that can impede the successful development of strategies concerning multi-stage transportation with cross-docking. For that reason, they are associated when defining them. Several families of leverages/obstacles and obstacles were identified from the feedback and are summarized as follows:

- *Commercial strategies*. Multi-stage systems need the coordination and cooperation of different stakeholders to be operations. Each organization has its own commercial interests, which are not the same for loaders and for transport operators. In fact, aggressive strategies and disregard for transport plans to favor “friends” or customers have been identified by many transport operators as a brake on the development of collaborative multi-stage networks. On the other side, friendly behaviors or clear collaboration agreements can help the deployment of collaborative systems, including multi-stage LTL transport networks.
- *Economic and cost management issues*. They can be related to the implementation of a multi-stage system, or more precisely investment costs for the construction or adaptation of cross-docking platforms, depots or other infrastructures. Another source of disagreement usually concerns the “ownership” or the central management of an infrastructure (or the management issues related to them) once it is operational.
- *Logistics management practices and acceptability*. Each stakeholder’s practices in terms of operational planning and management have a direct impact on the efficiency of a transport network. Moreover, the potential or real changes that an organization based on a multi-stage LTL transport system may become important obstacles to its development. The physical and organizational conditions for freight compatibility, like dimensions, freight, type of packaging, loading unit and the main characteristics of loading operations are important. These are not only related to legislation but also to organizational issues, equipment and habit. Another factor is the acceptability of organizational changes, which also has to be taken into account when defining the main characteristics of a multi-stage system. This can lead to malfunctions, delays or employees’ strikes and complaints liable to harm the image and reputation of the multi-stage system.
- *Responsibility and confidentiality*. The main transactions in freight transportation are regulated by several commercial contracts. However, sub-contracting is not always well defined (Ville et al. 2013). Moreover, not all transport operators agree to let subcontractors

> take charge of the last miles if issues of responsibility are not well defined. In the case of conflicts, the transfer of responsibility clause of a contract plays an important role because it defines the physical and moral responsibilities for product loss or damage, and it determines who pays if either occur. Moreover, confidentiality can become an obstacle to multi-stage systems when two competing actors decide to collaborate to reduce their transport costs. Since information is the base of good collaboration, if one or more partners manage confidential information that they do not want to share for competitive reasons, the efficiency of the multi-stage approach can be considerably reduced. These issues come to light in most of the initiatives involving competing enterprises not supported by public entities.

Moreover, other factors have to be considered. For example, transport cost optimization is seen by loaders as a competence of the transport operator. Moreover, multi-stage systems entail the participation of several operators, so that coordinated optimization is not easy to organize.

Conclusions and Research Guidelines

In this chapter we have overviewed the main optimization problems and issues for multi-stage LTL transport systems, focusing on tactical and operational planning horizons. We observe a lack of unification in the terminology used, as well as on the comparative approaches to validate the proposed methods. Since two-stage LTL optimization problems, based on hierarchical VRP variants, seem to be the most prominent problems to be studied, it is important to watch at their applicability and operability issues. For those reasons, it is important to see at the application level which leverages and limitations to the deployment of such systems are seen.

Finally, the role of multidiciplinarity will be important to make the different figures related to multi-stage LTL transport communicate and reach a consensus to the acceptation of those approaches.

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References

Ackerman, K.B., Brewer, A.M. (2001). Warehousing: a Key Limit in the Supply Chain. In Brewer, A M., Button, K.J., Hensher, D.A. (eds.), *Handbook of Logisitcs and Supply Chain Management*, Amsterdam: Pergamon, pp. 225-237.

Ackoff, R.L. (1979). The future of operational research is past. *Journal of the Operational Research Society* 30 (2):93-104.

Aikens, C.H. (1985). Facility Location Models for Distribution Planning. *European Journal of Operational Research* 22 (3): 263-279.

Amaya, A., Langevin, A., Trépanier, M. (2007). The capacitated arc routing problem with refill points, *Operations Research Letters*, 35: 45-53.

Amaya, A., Langevin, A., Trépanier, M. (2010). A heuristic method for the capacitated arc routing problem with refill points and multiple loads. *Journal of the Operational Research Society* (2010) 61: 1095-1103.

Ambrosini, C., Routhier, J.L. (2004). Objectives, methods and results of surveys carried out in the field of urban freight transport: an international comparison. *Transport Reviews* 24 (1): 57-77.

Ambrosino, D., Scutellà, M.G. (2005). Distribution network design: new problems and related models. *European Journal of Operational Research* 165: 610-624.

Angelelli, E., Speranza, M.G. (2002). The periodic vehicle routing problem with intermediate facilities. *European Journal of Operational Research* 137: 233-247.

Bard, J. F., Huang, L., Jaillet, P., Dror, M. (1998). A Decomposition Approach to the Inventory Routing Problem with Satellite Facilities. *Transportation Science* 32 (2): 189-203.

Bard, J., Huang, L., Dror, M., Jaillet, P. (1998). A branch and cut algorithm for the VRP with satellite facilities. *IIE Transactions* 30: 821-834.

Beamon, B.M. (1998). Supply Chain Design and Analysis: Models and Methods. *International Journal of Production Economics* 55: 281-294.

Beuthe, M., Kreutzberger, E. (2001). Consolidation and Trans-Shipment. In A.M. Brewer, K.J. Button and D.A. Hensher (eds.), *Handbook of Logistics and Supply Chain Management*, Amsterdam: Pergamon, pp. 239-252.

Boccia, M., Crainic, T. G., Sforza, A., Sterle, C. (2010). A Metaheuristic for a Two Echelon Location-Routing Problem. *Lecture Notes in Computer Science* 6049: 288-301.

Bonnafous, A. (1989). *Le siècle des tenèbres de l'économie*, Economica, Paris.

Brewer, A.M., Button, K.J. Hensher, D.A. (2001). *Handbook of Logisitcs and Supply Chain Management.* Amsterdam: Pergamon.

Brunswicker, J. (1986). Optimale Standort- und Tourenplanung fur die Rohmilcherfassung eines Molkereibetriebes Lit, Munster.

Chao I. (2002). A tabu-search method for the truck and trailer routing problem. *Computers and Operations Research* 29: 33-51.

Cordeau, J.F., Laporte, G., Savelsberg, M., Vigo, D. (2007). Vehicle Routing. In Barnhart C. and Laporte G. (eds.), *Transportation*, Amsterdam: North Holland, pp. 367-428.

Crainic, T.G., Laporte G. (1997). Planning models for freight transportation. *European Journal of Operational Research* 97: 409-438.

Crainic, T.G., Ricciardi, N., Storchi, G. (2004). Advanced freight transportation systems for congested urban areas. *Transportation Research Part C* 12: 119-137.

Crainic, T.G. (2008). City Logistics. In Chen, Z.L. and Raghavan, S. (eds.), *Tutorials in Operations Research 2008. State-of-the-Art Decision Making Tools in the Information-Intensive Age*, INFORMS, pp. 181-212.

Crainic, T.G., Ricciardi, N., Storchi, G. (2009). Models for evaluating and planning city logistic transportation systems. *Transportation Science* 42(4): 432-454.

Crainic, T. G., Mancini, S., Perboli, G., Tadei, R. (2010). Two-echelon vehicle routing problem: a satellite location analysis. *Procedia Social and Behavioural Sciences* 2(3): 5944-5955.

Crainic, T. G., Mancini, S., Perboli, G., Tadei, R. (2011). Multi-start heuristics for the Two-Echelon Vehicle Routing Problem. *Lecture Notes in Computer Science* 6622: 179-190.

Crevier, B., Cordeau, J.F., Laporte, G. (2007). The multi-depot vehicle routing problem with interdepot routes. *European Journal of Operational Research* 176: 756-773.

Del Pia, A., Filippi, C. (2006). A variable neighborhood descent algorithm for a real waste collection problem with mobile depots. *International Transactions in Operational Research* 13(2): 125-141.

Dondo, R., Méndez, C.A., Cerdá, J. (2011). The multi-echelon vehicle routing problem with cross docking in supply chain management. *Computers and Chemical Engineering* 35(12): 3002-3024.

Drexl, M. (2007). *On some generalized routing problems*. PhD. Thesis, University of Nuremberg, Germany.

Gendron, B., Semet, F., Strozyk, C. (2002). Adaptive Distribution Systems. *TRANSTECH: Transport Technology Product and Process Innovation Management*, Presses Universitaires de Valenciennes, pp. 36-42.

Gerdessen, J. (1996). Vehicle routing problem with trailers. *European Journal of Operational Research* 93: 135-147.

Ghiani, G., Laporte, G., Musmanno, R. (2004). *Introduction to Logistics Systems Planning and Control*, New York: Wiley.

Golden, B.L., ed. (1988). *Vehicle routing: methods and studies*, Amsterdam: North-Holland.

Golden, B. L., Raghavan, S. et Wasil, E. A. (2008). *Vehicle routing: Latest advances and challenges*, Boston: Kluwer.

Gonzalez-Feliu J., Perboli G., Tadei R., and Vigo (2007). The two-echelon capacitated vehicle routing problem. 22nd EURO Conference on Operational Reseal Research, Prague, Czech Republic, June 2007.

Gonzalez-Feliu, J. (2008). *Models and Methods for the City Logistics: The Two-Echelon Capacitated Vehicle Routing Problem*. PhD. Thesis. Politecnico di Torino, Turin, Italie.

Gonzalez-Feliu, J., Peris-Pla, C., Rakotonarivo, D. (2010). Simulation and optimization methods for logistics pooling approaches in the outbound supply chain. In Romano, C.A. (ed.), *Towards a sustainable development and corporate social responsibility strategies in the 21st Century Global Market. Valencia: UPV Publications*, pp. 394-401.

Gonzalez-Feliu, J. (2011). Two-echelon transportation optimisation: unifying concepts via a systematic review. *Working Papers on Operations Management* 2(1): 18-30.

Gonzalez-Feliu, J., Morana, J. (2011). Collaborative Transportation Sharing: From Theory to Practice via a Case Study from France. In Yearwood, J.L., Stranieri, A. (eds.) *Technologies for Supporting*

Reasoning Communities and Collaborative Decision Making: Cooperative Approaches, Hershey, PA: Information Science Reference, pp. 252-271.

Gonzalez-Feliu, J. (2012a). Freight distribution systems with cross-docking: a multidisciplinary analysis. *Journal of the Transportation Research Forum* 51(1): 93-109.

Gonzalez-Feliu, J. (2012b). Cost optimisation in freight distribution with cross-docking: N-echelon location routing problem. *Promet – Traffic and Transportation* 24(2): 143-149.

Gonzalez-Feliu, J., Salanova, J. (2012). Defining and evaluating collaborative urban freight distribution systems. *Procedia – Social and Behavioral Science* 39: 172-183.

Hinojosa Y., Puerto J., Fernández F. R. (2003), A multiperiod two-echelon multicommodity capacitated plant location problem, *European Journal of Operational Research* vol. 23 pp. 271–291.

Hoff, A., and Løkketangen, A. (2008), A Tabu Search Approach for Milk Collection in Western Norway. In *Proceedings of the Sixth Triennial Symposium on Transportation Analysis*, TRISTAN, Pukkett, Thailand.

Huart, A., Brotcorne, L., Semet, F. (2010). Optimisation of multimodal transportation chains in city logistics. *Proceedings of the VII Triennial Symposium on Transport Analysis*, Tromso, Norway.

Jacobsen, S.K., Madsen, O.B.G. (1980). A Comparative Study of Heuristics for a Two-Level Routing-Location Problem. *European Journal of Operational Research* 5: 378-387.

Jepsen, M, Spoorendonk, S, Ropke, S. (2012). A branch-and-cut algorithm for the Symmetric two-echelon capacitated vehicle routing problem. *Transportation Science*, http://dx.doi.org/10.1287/trsc.1110.0399.

Klose, A., Drexl, A. (2005). Facility Location Models for Distribution System Design. *European Journal of Operational Research* 162 (1): 4-29.

Kreutzberger, E. (2006). The shipper's perspective on distance and time and the operator (intermodal goods transport) response. *European Transport / Trasporti Europei*, 25-26: 99-113.

Kreutzberger, E. (2008). *The Innovation of Intermodal Rail Freight Bundling Networks in Europe. Concepts, Developments, Performances*, TRAIL Thesis Series nr. T2008/16, Delft, The Netherlands.

Kreutzberger, E. (2010). Lower Cost Intermodal Rail Freight Transport Bundling Networks: Conceptual Structuring and Identification. *European Journal of Transport and Infrastructure Research* 10 (2): 158-180.

Lambert, D.M. (2008). *Supply Chain Management: Processes, Partnerships, Performance. 3rd edition*., Sarasota, FL: Supply Chain Management Institute.

Laporte, G. (2002). The Vehicle Routing Problem: An Overview of Exact and Approximate Algorithms. *European Journal of Operational Research* 59: 345-358.

Larbi, R., Alpan, G., Baptiste, P., Penz, B. (2011). Scheduling Cross Docking Operations Under Full, Partial and No Information on Inbound Arrivals. *Computers and Operations Research* 38 (6): 889-900.

Lin, S. W., Yu, V.F., Chou, S.Y. (2009). Solving the truck and trailer routing problem based on a simulated annealing heuristic. *Computers and Operations Research* 36: 1683-1692.

Lowe, D. (2005). *Intermodal Freight Transport*. Butterworth-Heinemann.

Madsen, O.B.G. (1983). Methods for solving combined two level location-routing problems of realistic dimensions. *European Journal of Operational Research* 12 (3): 295-301.

Min, H., Jayaraman, V., Srivastava, R. (1997). Combined location-routing problems: A synthesis and future research directions. *European Journal of Operational Research* 108: 1-15.

Nagy, G., Salhi, S. (2007). Location routing: Issues, models and methods, *European Journal of Operational Research* 177: 649-672.

Nguyen, V.P., Prins, C., Prodhon, C. (2010). A Multi-Start Evolutionary Local Search for the Two-Echelon Location Routing Problem. *Lecture Notes in Computer Science* 6373: 88-102.

Nguyen, V.P., Prins, C., Prodhon, C. (2011). A multi-start iterated local search with tabu list and path relinking for the two-echelon location-routing problem. *Engineering Applications of Artificial Intelligence* 25(1): 56-71.

Nguyen, V.P., Prins, C., Prodhon, C. (2012). Solving the two-echelon location routing problem by a GRASP reinforced by a learning process and path relinking. *European Journal of Operational Research* 216: 113-126.

Ortuzar, J.d.D., Willumsen, L.G. (2001). *Modeling Transport. Third Edition*. Chichester: John Wiley and Sons.

Perboli, G., Tadei, R., Masoero, F. (2010). New Families of Valid Inequalities for the Two-Echelon Vehicle Routing Problem. *Electronic notes in discrete mathematics* 36: 639-646.

Rodrigue, J.P. (2006). Transportation and the Geographical and Functional Integration of Global Production Network’s. *Growth and Change* 37: 510-525.

Scheuerer, S. (2006). A Tabu Search Heuristic for the Truck and Trailer Routing Problem. *Computers and Operations Research* 33: 894-909.

Semet, F., Taillard, E. (1993). Solving real-life vehicle routing problems efficiently using tabu search. *Annals of Operations Research* 41: 469-488.

Semet, F. (1995). A two-phase algorithm for partial accessibility constrained vehicle routing problem. *Annals of Operations Research* 61: 45-65.

Simonot, P.Y., Roure, J. (2007). *Logistique collaborative. Une question d’avenir*. Paris: Economica.

Soltani, R., Sadjadi, S.J. (2010). Scheduling Trucks in Cross-Docking Systems: A Robust Meta-Heuristics Approach. *Transportation Research Part E* 46(5): 650-666.

Tan, K.C., Chew, Y.H., Lee, L.H. (2006). A hybrid multi-objective evolutionary algorithm for solving truck and trailer vehicle routing problems. *European Journal of Operations Research* 172: 855-885.

TL&Associés, LET (2009). *FIDES: **Flexibilité** et Impact de la Demande de Transport des Différents Secteurs Economiques et Simulation de Scénarios d’Evolution. Rapport final*. Paris: PREDIT.

Toth P., Vigo D. (2002). *The vehicle routing problem*, Philadelphia: Society for Industrial and Applied Mathematics.

Vahrenkamp, R. (1989). Transportation logistic in rural setting: the case of milk collection. Technical Report 5/1989. Kassel: Fachbereich Wirtschaftswissenschaften.

Ville, S., Gonzalez-Feliu, J., Dablanc, L. (2012). The limits of public policy intervention in urban logistics: Lessons from Vicenza (Italy), *European Planning Studies,* doi: 10.1080/09654313.2012.722954.

Villegas, J.G., Prins, C., Prodhon, C., Medaglia, A.N., Velasco , N. (2010), GRASP/VND and multi-start evolutionary local search for the single truck and trailer routing problem with satellite depots. *Engineering Applications of Artificial Intelligence* 23(5): 780-794

Wang, J.F., Regan, A. (2008). Real-Time Trailer Scheduling for Crossdock Operations. *Transportation Journal*, 47 (2): 5-20.

Wang, M., Xuhong, T., Chang, S., Wu, S. (2011). Hybrid ant colony optimization algorithm for two echelon vehicle routing optimization, *Procedia Engineering* 15: 3361-3365

Wieberneit, N. (2008). Service Network Design for Freight Transport: A Review. *OR Spectrum* 30: 77-112.

Wren A. (1971). *Computers in Transport Planning and Operations*, London: Ian Allan.

Yang, K.K., Balakrishan, J., Cheng, C.H. (2010). An Analysis of Factors Affecting Cross Docking Operations. *Journal of Business Logistics* 31 (1): 121-148.

Yearwood, J.L., Stranieri, A. (2011). *Technologies for Supporting Reasoning Communities and Collaborative Decision Making: Cooperative Approaches*. Hershey, PA: Information Science Reference.

Zegordi S., Nikbakhsh, E. (2009). A heuristic and a lower bound for the two-echelon location-routing problem. *International journal of industrial engineering and management* 20(1): 1-14.