Planning and Optimization Methods for Advanced Urban Logistics Systems at Tactical Level

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Planning and optimization methods for advanced urban logistics systems at tactical level

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Abstract This chapter aims to review and present the main combinatorial optimization problems recently introduced in literature, arising in urban logistics, in which distribution systems are involved as well as to make a critical analysis of the economic and environmental advantages obtained by following this kind of approaches. First we present the different categories of systems where, due to geographic or political constraints, there are access limitations to customers' area for vehicles which do not respect given requirements. Second, the main definitions and characteristics of advanced consolidation systems are presented. Third, the main combinatorial optimization problems associated to such systems are presented, as well as the main heuristics methods to solve them. Finally, to complete this study, a socio-economic analysis based on a set of interviews is proposed.

Keywords: Urban logistics, freight distribution, cross-docking, combinatorial optimization, tactical planning

1 Introduction

The sudden change of habits in the modern society, the advance of progress, the achievement of welfare and prosperity and a frenzy increase of life rhythms yielded to the need of finding new solutions for the management of freight distribution to reach a higher level of efficiency (Mancini, 2013a). This goal may be achieved through a better exploitation of presently available resources, a clever planning of the whole distribution process, a smart network design and a strictly collaboration among shipping companies. Such kind of approach implies the consolidation of loads of different shippers and carriers on the same vehicle, or, more generally, on the same service, and an efficient coordination of the resulting transportation activities. One of the most efficient ways to implement goods consolidation is to adopt multi-stage LTL transport systems (Gonzalez-Feliu, 2012a), which allow to split the transportation chains in different legs, in each one of which, goods are consolidated at facilities, where they are sorted and carried on other vehicles which perform the delivery to the customers or to another set of facilities.

The specificities of the last mile of the supply chains (mainly LTL transportation, with less optimized vehicles and confronted in many cases to big constraints and unexpected events related to the congestion of urban and peri-urban infrastructures) and the increase of customer satisfaction approaches in supply chain management make important to relate the quality to the logistics costs, making the economic aspects of the last mile an important component of supply chain design. In this context, the new advances in technologies have been a positive factor for the development of new markets and new consumer needs: the growth of e-commerce and postal shopping, as well as the pace of life, have reinforced the importance of “just in time” policies in freight distribution. Moreover, the service quality of a transportation carrier is often related to travel time, and can vary according to both socio-economics and trip characteristics. The total travel time of a vehicle trip depends on several aspects, like actual travel time, waiting and access time, congestion, deadlines or service features, etc. In addition, the new constraints of the generalised economic and financial crisis make a readjustment on the freight transportation strategies that have to be included in the main logistics tactical decisions. For these reasons, it is important for a distribution system to ensure the efficiency while maintaining a service quality defined by the time windows or other quality indices. For this reason, after defining the system, it is important to ensure that in a middle term period, the system is well-managed and controlled. To do this, a several methods from the operations research and combinatorial optimization can be defined (Crainic and Laporte, 1997).

The aim of this chapter is to propose a guide for researchers and practitioners on the main methods related to tactical planning in urban logistics. Two main families of problems will be addressed: vehicle routing with time windows and multi-stage vehicle routing. The chapter is organised as follows. Next section provides a brief background of freight transportation problems in urban logistics and motivates the aim and scope of the chapter. After that, a focus on two-stage VRP will be made, presenting the main issues, problems and variants. Finally, a qualitative analysis on the development of such systems will be carried out.

2 Urban consolidation and City Logistics systems

Urban logistics involves different stakeholders, like retailers and other urban commercial and service premises, wholesalers and distribution companies, transport and logistics carriers, public administrations and real estate actors among others (Ambrosini and Routhier, 2004). In order to deal with city logistics objectives (i.e. reduce congestion and environmental nuisances related to urban freight distribution without penalizing urban premises and inhabitants), several solutions and actions can be applied. Different types of actions can be defined in literature (Munuzuri et al., 2005; Benjelloun et al., 2010; Russo and Comi, 2010; Ville et al., 2012); we can group them on three main categories:

- Policy and planning actions, related to public authorities
- Organizational actions
- Technological actions

According to Gonzalez-Feliu et al. (2012a), the combination of all three categories of actions allows an efficient reduction of travelled distances then of congestion and environmental nuisances. However, we observe from their results that the impacts of each one are not the same. In other words, without organizational changes, both other categories have a limited impact on congestion reduction or transfer the problems to others sections of the city. So, innovative organizational strategies and models are needed, to improve the efficiency of freight transport (important for shippers, receivers and transport and logistics carriers), reduce vehicle flows and types (important for public authorities and citizens) and environmental issues (where most stakeholders are involved but public authorities are more sensible to). We have to note that those organizational changes have to be done without penalizing the economic activities of the city and ensuring the involvement of the different stakeholders related to urban logistics. For those reasons, city logistics offer great challenges and opportunities for operations research, management sciences and combinatorial optimization, in particular when dealing with vehicle routing and fleet management.

Because one of the most efficient ways to reduce the number of vehicles and improve their loading rates is commodity aggregation, urban consolidation has become one of the pillars of city logistics. Consolidation can take place at different stages of the urban supply chain (Danielis et al., 2013; Morana, 2013) and using the different urban logistics facilities that exist in urban areas (Boudouin et al., 2013). Although different forms of consolidation can be defined, we focus on multi-actor approaches, i.e. schemes where different actors will bring freight to consolidation platforms, mainly in the surroundings of a city, from where commodity needs to be transported to customers within the city (Crainic et al., 2012). The fundamental idea of such schemes arises on the facto of considering shipments, carriers, vehicles and consignees not individually, but rather as components of an integrated logistics system (Crainic, 2008). Then, the consolidation of shipments in a logistics pooling scheme (Gonzalez-Feliu and Morana, 2011) is needed, in order to deliver the different customers on better loaded, more energy efficient, less road occupancy impacting and eventually green vehicles. To do this, it is important to ensure the coordination of shipments, carriers and consignees into collaborative transport systems that need to be accepted by both public and private stakeholders (Morana et al., 2013).

The most popular example of such systems is that of the city distribution center, also known as urban consolidation or distribution center (Boudouin et al., 2013), which is defined by Allen et al. (2007) as *“a logistics facility situated in* *relatively close proximity to the geographic area that it serves (a city centre, an entire town or a specific site such as a shopping centre), to which many logistics companies deliver goods destined for the area, from which consolidated deliveries are carried out within that area, in which a range of other value-added logistics and retail services can be provided"*. Those urban terminals emerged in the 1990s, when there were more than one hundred of them, but they ran up against difficulties related to the difficulties of ensuring their economic balance without public funding support and the hesitancy by municipalities to continue subsidising them (Ville et al., 2012). Today, there are less than 20 genuinely significant consolidation terminals of this kind in Europe, notably in Italy (Morana et al., 2013), and less than 5 in Japan (Dablanc, 2010).

UCCs are also called City Distribution Centers (CDCs, van Duin et al., 2008) or Urban Distribution Centers (UDCs, Boudouin et al., 2013). Although many distribution companies and logistics service providers have at their disposal facilities where shipments are consolidated prior to distribution, defining and developing urban consolidation centres involving different companies, sometimes in competition, is not evident. Beyond the fact that an efficient use of such facilities implies changing habits and current organizations, which is not always easy for several carriers, the possible locations of this type of platforms do not belong to large sets of alternatives. Indeed, city centres are expensive, in terms of real estate prizes, and logistics activities take part in peripheral areas of the conurbation (Dablanc and Rakotonarivo, 2010; Adriankaja, 2012). This fact concerns also existing platforms that would be adapted to become urban consolidations facilities. The most usual UCCs in practice are located at intermodal platforms, logistics centres or former wholesaling facilities that are adapted to have enhanced functionalities to provide coordinated and efficient freight movements within the urban zone. Hey can also be part of terminals (mainly maritime or fluvial ports, airports and train stations). However such facilities are usually located at the outskirts of cities (Gonzalez-Feliu and Morana, 2010), close to highways. In any case, most UCCs are adapted facilities not originally built for City Logistics.

From those facilities, different distribution schemes can be defined. They can be grouped into two main categories (Benjelloun et al., 2010): single-tier systems derive from a direct shipping using LTL schemes to deliver customers from the UCCs; two-tier systems aim to better rationalise flows by grouping freight sent by well-loaded medium vehicles to cross-docking platforms call satellites, and then small vehicles deliver customers from satellites.

2.1 Single-tier distribution systems

Single-tier distribution systems are the most common strategies to deliver customers from regional logistics platforms from customers. In such systems, at urban consolidation platforms, freight is consolidated, then a set of *direct shipping* routes is planned to serve customers in the city centre by vehicles operating tours starting and finishing at an urban consolidation facility (Crainic et al., 2012). Tactical planning issues related to direct shipping schemes using LTL routes are well-studied in literature (Toth and Vigo, 2002; Cordeau et al., 2007; Golden et al., 2008).

As show in different works (Gonzalez-Feliu and Morana, 2010; Trentini and Malhéné, 2010; Allen et al., 2012; Crainic et al., 2012; Ville et al., 2012; Morana et al., 2013), urban consolidation platforms are often seen in small and medium cities and economically operational schemes are in general related to specific contexts of fields.

2.2 Two-tier distribution systems

Two-tier systems (Crainic et al., 2004, 2009, 2010) are mainly planned for large cities, based on a so-called *consolidation-distribution* strategy, which uses a second stage of facilities and different vehicle fleets in order to avoid the presence of large vehicles in the city centre, reducing in that way the number and length of empty trips (Crainic, 2008).

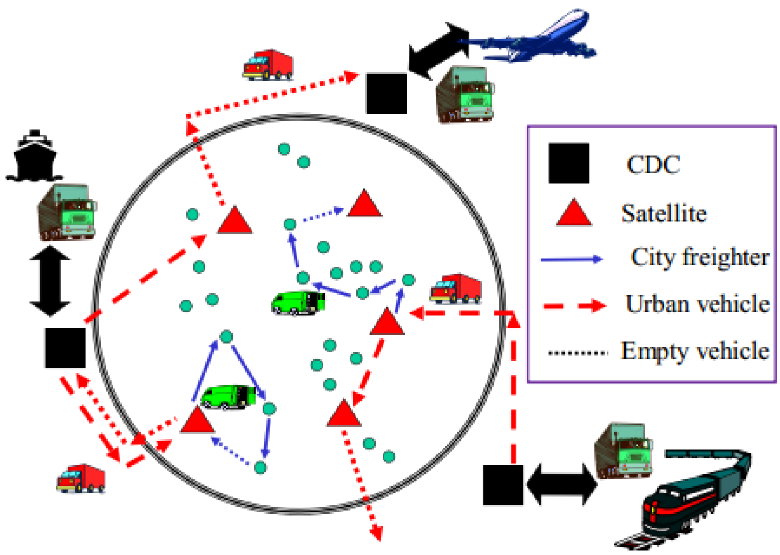

Fig. 1. An example of two-tier distribution system (Crainic et al., 2012)

The different operations in two-tier CL systems (command preparation, consolidation, sorting, etc.) are performed at facilities organized into a hierarchical structure, as illustrated in Fig. 2: major logistics terminals and depots are located in the urban periphery, in urban consolidation platforms, called here *city distribution centers* (Crainic et al., 2012) where it is loaded into urban trucks, which are of medium dimensions (ideally 9-12 t) ; then freight is transported city freighters (3.5) at *crossdocking satellites*, strategically located close to or within the city centre, from where final customers are delivered. Satellites are generally intended to be simple transhipment facilities like vehicle reception points (Boudoin et al., 2013) and operate according to a vehicle-synchronization and cross-dock transhipment model (Drexl, 2012), i.e., urban vehicles and city freighters meet at satellites at appointed times, with only short waiting times being permitted. Indeed, no intermediate storage is allowed at satellites if not for a very small time (in general less than half an hour).

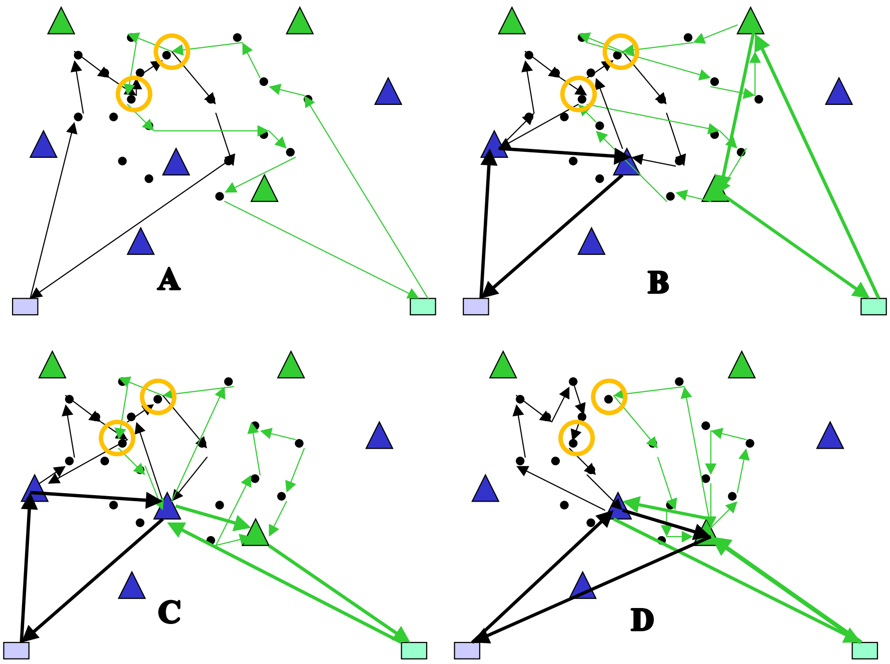

Fig. 2. A comparison between a single-tier (A) and three two-tier (B, C, D) distribution systems

2.3 Challenges & Opportunities

Although urban consolidation centers have been studied by many researchers, the derived systems present several challenges and opportunities for city logsitcs research, more precisely related to operations research and management sciences.

Concerning strategic planning, the first issue we observe is that of culturally and socially-aware organization and business models, as for cultural impacts[1] of such schemes and need for somewhat tailored solutions (for example in North America). Then, we observe questions related to public policy (Dablanc, 2010; Ballantine and Lindholm, 2013), stakeholders behavior (Marcucci and Gatta, 2013), partnerships and collaboration (Gonzalez-Feliu et al., 2013a; Morana et al., 2013), which have impacts on supply models. Another important questions is that of demand identification, using modeling techniques (Ambrosini et al., 2008; Anand et al., 2012; Comi et al., 2012; Gonzalez-Feliu and Routhier, 2012). Another category of challenges is that of defining suitable on models and tools to evaluate city logistics impacts, to pursuit before-after analysis and study long-term implications of city logistics actions and solutions (Gonzalez-Feliu et al., 2012a,b).

In tactical planning, it is important to develop comprehensive urban transportation planning, taking into account the integration with personal and public transport, the impacts of ITS and the main issues related to day-before planning. The main issues in operations research refer to system, service and operations planning, including models, algorithms and instruments to support practitionners in their tasks.

Complementarily to strategic planning (related to system design, platfom location and resource dimensioning) and to operational planning (real-time and short term organization, optimization and follow-up), tactical planning is related to service network design (Crainic, 2000), to crew and vehicle scheduling, time issues and vehicle routing. Although such questions are in-depth studied for several versions of single-tier systems, it is not the same for multi-tier schemes (Gonzalez-Feliu, 2012b, 2013a). In next section, tactical planning issues related to two-tier city logistics schemes are presented in order to support city planners and carrier managers in their tactical choices and planning issues.

3 Tactical planning issues for advanced city logistics systems

In city logistics, when focusing on inter-establishments, we study the transport flows related to commodities into, out of and within the city or the urban area. Since the main component of third party transport is made of LTL circuits, the main combinatorial optimization problem related to city logistics is the vehicle routing, and this at all planning levels (refs.)

In single-tier systems, vehicle routing problems are close to classical problems studied in the literature (Toth and Vigo, 2002; Golden et al., 2008). The main issues related to vehicle routing in city logistics arise on the dynamic and time-

[1] In other words, the impacts of government actions on people and business, on business models, taxation and refunding mechanisms, among others.

dependent nature of transport (Taniguchi et al., 1999, 2001; Taniguchi and Thompson, 2002), on access restrictions (Munuzuri and Van Duin; 2013) and on pickup and delivery strategies, among others. Since one-tier systems are well studied in the literature, we aim to extend Crainic's (2008) work for two-tier systems. Note that this chapter is directed to both researchers and practitioners of different disciplines so instead of an in-depth overview of operations research algorithms it presents the main categories of problems and methods. Detailed literature reviews on the subject are found in Drexl (2012), Gonzalez-Feliu (2013b) and Mancini (2013b).

In two-tier systems, two fleets of heterogeneous vehicles synchronize to deliver time-dependent freight demands within customer time windows, with little or no waiting room at (most) transfer stations. To deal with such systems, several new problems and challenges can be observed, but they can be grouped into two main categories. The first derives from the multi-stage nature of the transportation system, and all questions related to connexion among stages (Gonzalez-Feliu, 2012a) and synchronization (Drexel, 2012) and seeks to study the problem as a two-stage system following the concept of multi-stage transport systems (Kreutzberger, 2008; Gonzalez-Feliu, 2013a). The second is related to the multi-trip nature of second-stage transport schemes (Nguyen et al., 2013) and consists on taking into account different e tactical planning (Crainic, 2008). Indeed, in such systems it is considered that the first tier vehicles are planned in a first time, giving an overall idea of the second tier, and this last is refined in a second time (Crainic et al., 2009). Other issues are the different types of transport modes, vehicles and routes that can be involved in such schemes (Crainic et al., 2012), collaboration among partners (Gonzalez-Feliu et al., 2013b) or the integration of new services like time-constrained deliveries or pickup and delivery services (Crainic et al., 2012) but they can be included in the two main categories of approaches.

We present below both categories of approaches, presenting the main concepts and assumptions related to them and the most popular solving methods shown in the literature.

3.1 Problem definition and variants

We observe in the literature several declinations of the problem, arising on two main questions of vocabulary. The first is related to the hierarchic nature of the problem (Min et al., 1997): several terms, like level, echelon, tier or stage are used. To make practitioners more familiar with the problems, and avoid confusion with multi-echelon logistics systems, we will use the definition of Min et al. (1997) and Gonzalez-Feliu (2013a), calling them multi-stage transport systems. The second is the name of the combinatorial optimization problem that can be defined to optimise such systems. Three main problems have been defined in literature (multi-stage vehicle routing, multi-stage location routing and truck-andtrailer vehicle routing). However, all three problems are declinations of the same model, as stated in Nagy and Salhi (2007). For that reason, we will call such problems multi-stage vehicle routing optimization problems (m-VRP). Such problems have been introduced for the first time in Laporte (1988) but formally presented in Gonzalez-Feliu (2012a). In urban logistics, the attention is focused on the Two-Stage version of the problem (2-VRP), a simplified version frequently arising in the context of Two-Stage distribution systems design. This system is composed by three interacting levels, linked by different vehicle fleets performing delivery operations:

- Primary Facilities, also called depots : high capacitated facilities generally located far from the urban area, where freight is loaded on first stage vehicles
- Secondary Facilities, also called satellites : low capacitated facilities devoted to transhipment operations, in which freight arriving from primary facilities is transferred into smaller vehicles, referred as second stage vehicles, which perform the distribution to the final customers
- Customers : End points of the distribution, which must be served by at least one second stage vehicle

Given this structure, the 2-VRP consists in defining number and location of primary and secondary facilities, performs the allocation operations, i.e. assign each final customers to an open secondary facility, and each secondary facility to an open primary facility, satisfying capacity facility constraints, and solve the resulting routing problem, identifying how many vehicles, for each fleet, are used, by which vehicle each customer is served, and in which order the vehicle performs its deliveries. From a physical point of view, a General Two-Stage Capacitated Vehicle Routing system (G 2-VRP) operates as follows (see also Figure 1):

- Freight arrives at an external zone, one depot, where it is consolidated into the 1st-stage vehicles, which constitute heterogeneous fleets;
- Each 1st-stage vehicle travels to a subset of satellites that will be determined by the model and then it will return to the depot;
- At each satellite, freight is transferred from 1st-stage vehicles to smaller, environmental friendly vehicles, belonging to 2nd-stage fleets (also heterogeneous);
- Each 2nd-stage vehicle performs a route to serve the designated customers, and then travels to a satellite (not necessarily its departure point).

The basic version of the problems is called Two-stage capacitated VRP (2-CVRP). This is the simplest version of multi-stage VRPs. At each stage, all vehicles belonging to that stage have the same fixed capacity. The size of the fleet of each stage is fixed and known in advance, and there exists an upper bound on the number of vehicle which can start from the same satellite. The objective is to serve customers by minimizing the total transportation cost, satisfying the capacity constraints of the vehicles. There is a single depot and a fixed number of capacitated satellites. All the customer demands are fixed, known in advance, and must be compulsorily satisfied. Moreover, no time window is defined for the deliveries and the satellite operations. For the 2nd stage, the demand of each customer is smaller than each vehicles capacity and cannot be split in multiple routes of the same stage. This problem can present several variants (Gonzalez-Feliu, 2008; Mancini, 2011, 2013a). Note that in more realistic situations, the basic version needs to be extended to a multi-depot, multi-carrier heterogeneous fleet case. In other words, more than one starting depot (corresponding to a CDC) is defined (Nguyen et al., 2011), and vehicles can be of different characteristics for the same stage (Gonzalez-Feliu and Salanova, 2012). Moreover, more than one carrier can share platforms or even vehicles (Gonzalez-Feliu et al., 2010; Gonzalez-Feliu and Salanova, 2012; Thompson and Hassall, 2012). From those extensions of the basic version, other variants can be defined to include different constraints related to urban freight transport (Deflorio et al., 2012). More in details, variants may be grouped following a classification where we consider three main aspects: network and service features, and route limitations.

Route limitations are applied to one or more routes, on one or more stages. Two types of limitations can be considered, and are distance and time constraints. A 2-stage distance constrained VRP is a variant of the basic problem of the same family where one or more k-stages present maximum distance limits. These limits are expressed in terms of maximum distance that vehicles can travel, and they will be related to the vehicle's characteristics. This distance can be explained in terms or travel distance (in km), or in terms of travel time. In this second group of constraints, different factors like, times related to loading and unloading operations, and slack pauses can be considered, and represent the maximum time a vehicle can be on service, for maintenance, crew working hours and other reasons.

In network features variants, the main important problem should be the 2-stage multi-depot VRP. This problem, analogously to classical VRP, presents more than one depot, so the starting point of each 1st-stage route can be different to the others. In these problems, two main policies are considered. The first is that the freight type is the same for all customers and all depots have an enough quantity of freight to serve all customers. Analogously to MDVRP, in ME-MDVRP, freight requested can be assigned to one of the available depots. Additional constraints can be added to the depot availability, as for instance the depot capacity, time period for service (defined by the opening and closing hours which correspond to the limits beyond which it is not possible to arrive to the depot), but in all cases it is supposed that all customers can be assigned to all depots.

Service features variants refer to some aspects which the distribution service company offers in the transportation service. Two main families of variants are presented, analogously to classical VRP. The first of, and maybe the most important, due to time limitations, is the ME-VRP with Time Constraints. Several types of time constraints, which represent different temporal aspects of multi-echelon transport organization, can be considered. We will describe those which can be observed in most real applications where time constitutes one of the main factors describing the proposed service features.

The most common time limitation, analogously to classical VRP and distribution problems, is the Time Window (TW) in which the vehicle can visit a facility. The problem is called NE-CVRP with time windows (NE-VRPTW), and the TW are associated to nodes (usually, time limitations are not directly associated to arcs, but to customers or k-stage satellites, even if TW can also be associated to the depot). When the TW are associated only to customers, only the second stage follows VRPTW logics whereas for the first, time constraints will not influence it directly, but indirectly assuring that the freight arrives on time to satellites. When TW are associated to satellites, the complexity of the problem increases. This complexity increase can be directly imputed to connexion constraints between stages.

Other time constraints, which are more restrictive, are vehicle synchronization at satellites. In some real applications, satellites are not projected to store freight even for a small time interval, and vehicles cannot wait for a long time at satellites, waiting to be loaded or unloaded. We can formulate a problem that represents these cases, which can be noted as 2-stage Capacitated VRP with Satellites Synchronization (2E-CVRP-SS). In this problem, time constraints on the arrival and the departure of the vehicles at the satellites are considered. In fact, the k-1 stage vehicles arriving in a satellite unload their freight, which must be immediately loaded into a k-stage vehicle. These constraints can be of two types: hard and soft. In general, a small time interval, called synchronization margin T_s, is defined. In hard SS, every time a k-1 stage vehicle unloads its freight, k-stage vehicles must be ready to deliver it. This is represented as follows: k-1 stage vehicles cannot wait more than T_s, and this is expressed by a very restrictive pseudo-TW, which does not have a fixed EAT but, when a k-stage vehicle arrives at a k-stage satellite at a time t, the corresponding complementary k-1 stage vehicles must arrive at most at time $t' = t + T_s$, and vice versa. In soft SS, when k-1 stage vehicles arrive, if k-stage vehicles are not available, the demand is lost and a penalty is paid.

A more complex version which derives from Multi-depot 2-VRP but consider feature services which are different from time constraints is Multi-depot multi-request NE-VRP (MD-MR NE-VRP). This problem is only considered if freight can be merged at satellites. In this case, given a k-stage satellite, the freight coming from k-1 stage routes assigned to different depots can be merged or reorganized to put on the same k-stage vehicle freight with different origin depot and having to be delivered to the same customer. The main difficulty of this variant arises in the fact of selecting the k-stage satellites to merge the freight which allow to minimize the overall costs.

Another service feature policy represents services with Pickup and Deliveries (2-CVRP-PD). Pickup and deliveries, are not presented here, detailed surveys can be found in literature (Berbegia et al., 2007; Parragh et al., 2008) but we can define three types of operations: in VRP with Backhauls vehicles first make all deliveries then they make a second route starting from the last customer and ending on the depot to make pickups; in VRP with Mixed PD a vehicle can, at a customer, even deliver, even pickup or both, but can also first deliver a customer, continue its route and return to customer for picking-up freight; in VRP with Simultaneous PD, vehicles must deliver then pick-up freight at each customer, without the possibility to return, so the vehicle must have enough capacity when visiting a customer to pick-up the corresponding freight after delivering it. In this case we can consider the satellites as intermediate depots to store both the freight that has been picked-up from or must be delivered to the customers. PD constraints are applied only to customers, satellites being organised as in basic versions (1^{st}-stage vehicles deliver freight to satellites then 2^{nd}-echelon vehicles pick up the corresponding goods from them), so the VRP-PD approach is applied only for the second stage.

A particular case of 2-VRP is obtained when considering a transportation system where taxi services are considered (2-VRP-TS). In this variant, direct shipping from the depot or a k-stage satellite to customers is allowed if it helps to decrease the cost, or to satisfy time and/or synchronization constraints, without passing through the rest of the stages.

3.2 Exact methods

Exact methods seek to find the exact optimum of the entire system, i.e. to prove that the best solution found is optimal. The main limits of such approaches are of two types: first is a strong simplification of the mathematical models, that assume one depot and all satellites and vehicle fleets (for each stage) having the same capacity; second is that the instance solved by such methods are very small (up to 5 satellites and 50 customers, according to Baldacci et al., 2013). The first model of this type is found in Gonzalez-Feliu et al. (2007) and a small set of works propose methods to solve this problem. Branch-and-Cut (Perboli et al., 2010; Jepsen et al., 2013) and Branch-and Price (Santos et al., 2012) allow to solve instances up to two satellites and 32 customers, although Jepsen et al.'s (2012) method obtains better results than the others. However, a recently proposed Branch-and-Bound method (Baldacci et al., 2013) is able to solve almost all instances up to 5 satellites and 50 customers. Such instances, introduced in Gonzalez-Feliu et al. (2007) and Mancini (2011) are available in the OR-library of Beasley (1990).

3.3 Systemic heuristic approaches

According to Gonzalez-Feliu (2013b), two types of heuristics are proposed to solve such problems. The first is that of systemic approaches that see the multi-stage transport problem as a whole system and the second includes methods that separate the problem into a set of sub-problems, one per stage, that are solved separately. Concerning systemic approaches, they need to deal with simplified problems, in a similar way than exact methods, in order to be deployed but allow finding near-optimal solutions for bigger instances, some of them being near to real size problems. According to Mancini (2013b) we can group those heuristics in different categories. We adapt this classification to city logistics problems.

First is that of construction heuristics, which aim to find initial solutions. In other words, such algorithms find a sub-optimal solution to the problem and stop once the first feasible solution is found. Although they are far from theoretical optima (10-25% in average for medium size instances), they have the interest to be easy to understand and implement and be applied to very large instances (Jacobsen and Madsen, 1980). The most used algorithms are the savings algorithm of Clarke and Wright (1965), often combined with allocation algorithms (Madsen, 1983), cluster-first route second algorithms, mainly using greedy or semi-greedy algorithms (Gonzalez-Feliu et al., 2010; Gonzalez-Feliu and Salanova, 2012). In the two last cases, multi-depot multi-stakeholder problems were solved, the first with homogeneous fleets per stakeholder, the second involving heterogeneous fleets.

Local Search (LS) algorithms are procedures that, starting from an initial solution (mainly found using a construction heuristic method), iteratively analyze a neighborhood surrounding S' in the solution search space (Aarts and Lenstra, 1997). The neighborhood's exploration can be exhaustively carried out then the best solution in the neighborhood is taken as current best and the algorithm is restarted (Best Improvement) or the exploration can be interrupted immediately after an improving solution is found and immediately restarted from the new current best (First Improvement). Although LS is not directly used in many works, it is broadly and usefully applied as an intensification tool into a metaheuristic framework as Multi Start heuristics (Crainic et al., 2011) or combined with Evolutionary Algorithms in hybrid or memetic heuristics, (Xu et al., 2013).

The Greedy Randomized Adaptive Search Procedure (GRASP) is a multistart two-phase metaheuristic algorithm based on adapted greedy procedures (Resende and Ribeiro, 2010). In a first phase, an initial solution is obtained using a greedy randomized procedure, whose randomness allows solutions in different areas of the solution space to be obtained. The second phase is a local search phase that improves these solutions. This algorithm is often hybridated with path-relinking post-optimization (Nguyen et al., 2012; Crainic et al., 2013).

Alternate Large Neighborhood Search (ALNS) is an iterative post-optimization algorithm (i.e. that needs an initial solution as input) that at every iteration, a number customers are removed by a destroy operator, put in a customer pool and then re-inserted by a repair operator (Hemmelmayr et al., 2012). Several local search operators are used, selected by a roulette wheel mechanism based on their past success. ALNS was first developed by Ropke and Pisinger (2006) for the pickup and delivery problem and adapted to two-stage transport systems by Hemmelmayr et al. (2012) .

Last but not least, classical methaheuristic methods, like tabu search (Boccia et al., 2010) or simulated annealing (Zegordi and Nikbakhsh, 2009; Wang et al., 2011) or variable neighborhood search (Schwenger et al., 2011) are also used. For a more in-depth description of such methods applied to two-stage systems, see Mancini (2013b).

3.4 Decomposition heuristic approaches

An alternative to systemic approaches is that of decomposition methods that are based on a logical separation of the overall system into a set of connected subsystems (in general, by assigning transport demands to satellites, then constructing 2nd stage routes to finally obtain the 1st stage routes). It is not very easy to identify all such works, since some of them do not show directly then multi-stage nature of transport systems, but a general separation method can be found in Crainic (2008) and Crainic et al. (2009). The main advantage of such methods is that they can deal with more specific aspects of urban distribution such ad dynamic travel times, access time windows or multi-trip systems, among others.

4 Socio-economic and practical implications of two-tier schemes

As shown above, two-tier city logistics systems can be an interesting approach to reduce transport cost. However gains on transport cost are not alone in ensuring the success of these schemes (Gonzalez-Feliu, 2012b). Indeed, the socio-economic context has to be taken into account because the feasibility of multi-stage transport systems depends also on other factors (Gonzalez-Feliu, 2013a). According to Gonzalez-Feliu and Morana (2011), three types of factors can be defined. The motivators are the factors that contribute to the development of a transportation system with cross-docking. According to Gonzalez-Feliu (2012b), four groups of motivators can be defined:

- *Performance motivators*, on an economic, environmental and value viewpoints. They are 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*, mainly related to collaboration but also to transactions and formal or informal sub-contracting.
- *Financial motivators*, related to funding mechanisms of such systems (Gonzalez-Feliu et al., 2013a). Those factors are still few studied but they

can constitute key success factors if well identified and analysed, as shown in Gonzalez-Feliu and Morana (2011).
- *Relation motivators*, closely related to habits and inter-personal relations. When stakeholders have already been involved together in collaborative or cooperative schemes resulting on positive impacts on their logistics performance, collaborative transportation 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 motivators.

The facilitators are the conditions and situations that have a positive impact on the daily operations of a multi-echelon transportation scheme. 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. The boundary between motivators and facilitators is not always clear but, according to Gonzalez-Feliu (2012b), these two categories can be distinguished by the fact that motivators appear in strategic planning and facilitators at tactical and operational levels. Closely related to the facilitators are the limitations and obstacles that can impede the successful development of strategies concerning multi-stage transport systems (Gonzalez-Feliu and Morana 2011). Both facilitators and limitations can be couples and summarized as follows:

- *Commercial strategies*. Each enterprise has its own commercial interests, which are not the same for loaders and for transport operators. Although they are not a major source of conflict among producers, retailers and logistics operators, they can become an major handicap for transport operators. In fact, aggressive strategies and disregard for transport plans to help “friends” or customers have been identified by many transport operators as a brake on the development of collaborative multi-echelon networks.
- *Ownership and savings management issues*. Although at a strategic level the investment costs can be easily shared by partners, the benefits resulting from the tactical and operational management of the system are less easy to share if no solid contracts and agreements have been signed. Moreover, the ownership of the system of some of its parts (facilities, vehicles, crews) can be a factor of success or a main brake to the system’s deployment.
- *Logistics strategies of each stakeholder*. More precisely, the potential or real changes that an organization based on a multi-stage system may introduce are a source of obstacles to its development, but can also be a catalyser in case of good adaptation of crews. A special attention has to be given to the *acceptability of organizational changes*, because it can lead to malfunctions, delays or employees’ strikes and complaints liable to harm the image and reputation of the multi-echelon system.

- *Physical and organizational conditions for freight compatibility*. Some characteristics and conditions related to commodity 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.
- *Acceptability of organizational changes*, which also has to be taken into account when defining the main characteristics of a multi-echelon system. This can lead to malfunctions, delays or employees' strikes and complaints liable to harm the image and reputation of the multi-echelon system.
- *Responsibility and confidentiality*. The main transactions in freight transportation are regulated by several commercial contracts. Moreover, confidentiality can become an obstacle to multi-stage systems. Indeed, 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 system can be considerably reduced.

Furthermore, other factors have to be considered, like for example transport cost optimization is seen by loaders as a competence of the transport operator. Finally, it is important to note that multi-stage transport systems entail the participation of several operators, so that coordinated optimization is not easy to organize but can be the key of success is well-managed.

5 Conclusion

Urban freight data serves a wide range of uses and is extremely important in helping public and private sector decision-makers to ensure that urban freight transport takes place in as efficient and sustainable a manner as possible. Without such freight data, it is extremely difficult for national, regional and urban authorities to make decisions on issues including road space allocation and congestion, freight transport's role in energy consumption and air quality, safety and security issues associated with freight transport, modal shift, and land use planning.

The extent of urban freight data collection varies significantly between the European countries surveyed. In addition, even in countries with the greatest quantity of urban freight data, most of this is derived from the disaggregation of data collections that take place at a greater geographical scale than the urban area. Freight data is currently collected by a large number of different organizations including: national, regional and urban governments, other public sector bodies and agencies on behalf of these governments, as part of one-off studies and projects, and by private sector organizations including industrial, retail, service and transport companies, trade associations and market research companies. These urban freight data collection efforts are not currently co-ordinated, and this results in many different data sources and data sets that vary widely in quality and methodology, making comparisons and combinations of them difficult or impossible. Even in the countries in which the greatest quantity of urban freight data is collected, when all of this urban freight data is brought together, it still does not provide a comprehensive picture of the urban freight transport system. Instead, the picture provided is patchy and unreliable.

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