Simulation and optimization methods for logistics pooling in the outbound supply chain

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SIMULATION AND OPTIMIZATION METHODS FOR LOGISTICS POOLING IN THE OUTBOUND SUPPLY CHAIN

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Abstract

Logistics pooling and collaborative transportation systems are relatively new concepts in logistics research, but are very popular in practice. This communication proposes a conceptual framework for logistics and transportation pooling systems, as well as a simulation method for strategic planning optimization. This method is based on a twostep constructive heuristic in order to estimate for big instances the transportation and storage costs at a macroscopic level. Four possible scenarios are explored and commented. Finally, a socio-economic analysis based on 20 semi-directive interviews is presented to propose the limitations and obstacles of logistics pooling

Keywords: Logistics pooling, supply chain management, optimization, group reasoning, simulation

1. Introduction

The freight transportation industry is a major source of employment and supports the economic development of the country. However, freight transportation has many negative aspects including congestion and environmental disturbance, which negatively affect quality of life, particularly in urban areas. Both the new trends in retail and commerce organization and the technological innovation in supply chain management and distribution planning have led decision makers to consider collaborative strategies to reduce overall cost and pollution emissions, and improve social management of the supply process (see papers concerned with sustainable development and transport and logistics management). In freight distribution, the most popular collaborative strategy is that of logistics sharing.

This can take place at the transport level, but also in warehousing, inventory and other operations. These strategies are based on collaborative decision making and information sharing. They usually take the form of agreements and partnerships. The main aspects of collaborative logistics in production and supply management have been recently reviewed, however logistics sharing in freight distribution remains a less explored subject in the literature, but commonly observed in several real-life cases.

The aim of this research is to provide a conceptual framework for collaborative transportation systems in the context of urban freight distribution. First, the background issues on collaborative transportation and logistics pooling planning and optimization are presented. Second we present a two-step constructive heuristic based on classical optimization algorithms for the VRP that will be adapted for simulating the proposed scenarios, presented after that.

Then, the computational results are presented and commented. Finally, in order to complete the optimization analysis by a socio-economic approach, the limitations and obstacles of these approaches are studied using a qualitative analysis on both documentary and interview-based data.

2. Background issues

In the last years, several strategies and logistics models have been developed in order to increase the supply chain effectiveness. Collaboration is one of the most promising areas of study in supply chain management (Lambert et al., 1996; Barrat, 2004; Min et al., 2005; Simatupang, & Sridharan, 2005; Lambert, 2008). In supply chain management, collaboration can take place at several stages of the chain and with different levels of interaction.

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According to Gonzalez-Feliu and Morana (2010), the different levels are the following:

• Transactional collaboration, i.e. coordination and standardization of administrative practices and exchange techniques.

• Informational collaboration, i.e. mutual exchange of information such as sales forecasts, stock levels and delivery dates. It is important to note that confidentiality and the process of competition can hinder collaboration.

• Decisional collaboration, or collaboration at the different horizons of logistics and transportation planning, which are:

o Operational planning: This planning stage is related to daily operations that can be coordinated or shared, like freight transportation or cross-docking.

o Tactical planning: The middle-term planning stage involves several tactical decisions, like sales forecasts, shipping operational decisions, stock and production management and quality control.

o Strategic planning: The highest collaboration stage is related to long term planning decisions such as network design, facility location, finance and production planning.

As we have seen above, information sharing is a basic requirement to assure the continuity of a logistics sharing service. For this reason, we can affirm that such services need an efficient shared information system to assure their good performance. Morana and Gonzalez-Feliu (2009) define the organizational bases of logistics sharing, based on the general model of Laudon and Laudon (2007) for information system conception. These bases can be resumed in the following chart, and are presented as five connected modules :

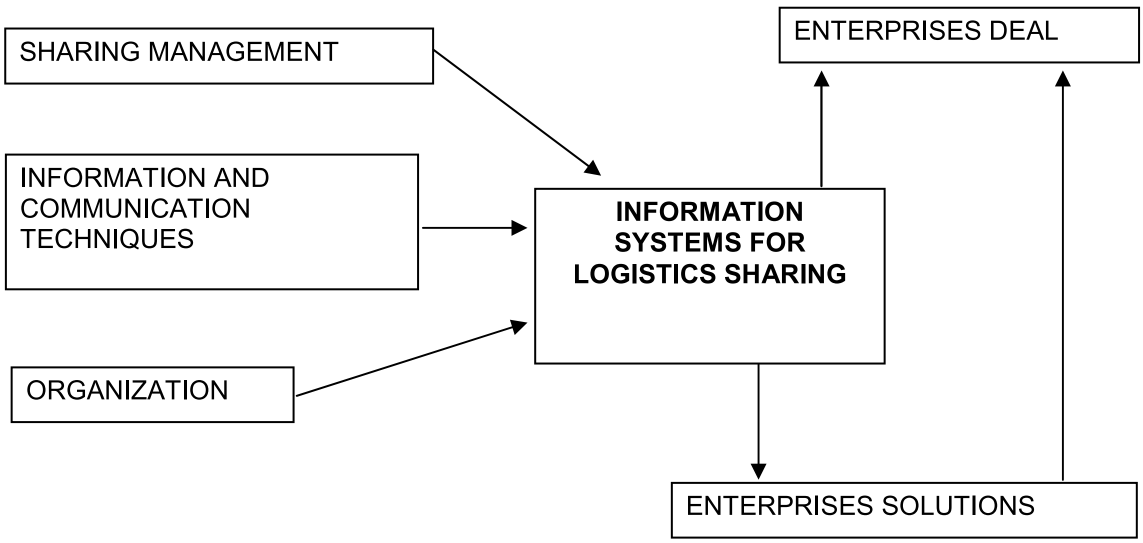

Figure 1: The five modules of freight transportation pooling strategic and tactical planning decision support (adapted from Laudon and Laudon, 2007)

The enterprise's deals module presents both the project's expectations and the risks that are studied in that project's preliminary developments. Considering the technologies and tools and their usage levels, several choices must be made in order to set up the best solution of logistic sharing services. In order to make these choices, it is important to formulate questions related to the goals and the risks of the project, and to find answers to these questions. In consequence, it is important to make a deep analysis of the possible risks that the project may encounter (Seiersen, 2006), that can be related to the project accounting (more precisely to the different type of resources that can be affected to the project), to the organization and continuity of the project, to the technological choices, to policies, processes and current practices, to the impact of the project organization in current and future operations and to dependence on the chosen technologies (in case of dysfunction of these technologies). For a more detailed survey, see Seiersen (2006).

The enterprise's solutions are the main objectives of the project and the evaluation of its performance (Laudon, & Laudon, 2007). Although at the end of the XXth century the notion of performance has been basically related to economic indicators, the notion of sustainability is nowadays a central element in transportation and logistics planning and management (Morana, & Gonzalez-Feliu, 2009). The sustainable development is the junction of three spheres: the first one deals with the economical aspects, the second one contains the social and the societal elements, and the third is related to the environment. Depoers et al. (2002) propose a set of indicators to evaluate the sustainable performance of an enterprise. In the logistics field, Marais, & Renaud, 2007 proposes a ranking table for the different components of Sustainable Development actions, based on an exhaustive literature review analysis. The authors propose 5 central subjects: Strategy, Enterprise's policy, organization, systems and key competences.

Moreover, Morana, & Gonzalez-Feliu (2010) present a reflection on how to evaluate the sustainability of a urban freight distribution system, considering all the three spheres in a global approach.

All the long of a supply chain, several stakeholders interact in order to complete all the tasks necessary to produce and distribute a product to a retailer. The organization module describes these stakeholders. We will focus on those related to urban goods movement (Ambrosini, & Routhier, 2004). The "loaders" are the actors that send or receive the freight, who can be producers (industrial or artisan activities), logistics providers (4PL, LLP) or retailing activities. These actors can be considered as "senders" if they act at the origin of the transport, and "receivers" if they are at its destination. Another important category is the "transporters". The transporters can be the "loaders" that make self-transport operations, or the third-party transportation companies. These companies can be artisans that have only one vehicle, small and medium enterprises or big companies and multinational groups, as well as postal and courier operators, and integrated logistics solutions providers like TNT, DHL, FedEx or UPS, among others. A third category is the logistics real estate actors, that are the "owners and management companies" of warehouses, cross-docks, intermodal platforms and other logistics infrastructures. Nonetheless, other actors, like public administrations, highway companies, customs operators can also be included in this classification since their possible implication as logistics sharing partners are much less important respect to the three main categories.

The management module contains all the elements of the management of sharing services and collaboration. In the case of collaborative freight distribution, a focus on the elaboration of new business models based on the collaboration is primordial. Moreover, the research of new customers can be also included in this module. Several organizational schemas are related to collaborative supply chains, like the Efficient Consumer's Response (ECR) and other similar approaches, like the Quick Response (textile industry), and the Efficient Healthcare Customer's Response (Roy et al., 2006), the Vendor Managed Inventory (Waller et al., 1999) and the Collaborative Planning Forecasting and Replenishment (Roy et al., 2006). Other schemas can be defined in the freight distribution field, like the transportation pooling (Gonzalez-Feliu and Morana, 2010) and the transportation networks (Simonot and Routre, 2007). An overview on the collaborative freight distribution schemas will be presented in next section.

Information is a central key of sharing. Without information sharing, the other levels of sharing cannot take place. In transport management, the role of ICT has been recently overviewed (Fabbe-Costes, 2007). Two types of information technologies are identified by the author: the transportation management modules, related to transportation planning, and the information exchange tools, that allow transportation to be integrated into the supply chain.

In logistics planning, decisions on the transportation network settings have a direct impact on the service quality but also on their costs. It is then important to adapt the transportation network to the economical, geographical, organizational and quality constraints (Crainic and Laporte, 1997; Wieberneit, 2008). Literally, the questions in freight distribution tactical and operational planning are related to supply and inventory policies (warehousing), vehicle routing and scheduling (transportation management), vehicle assignment to a route and crew assignment to each operation. The two last points derive from the two first, and take place after them. In research, both inventory and vehicle routing and scheduling problems are very popular, and several algorithms are proposed in recent surveys (Goetschalckx et al., 2002; Toth and Vigo, 2002; Leung, 2004; Dullaert et al., 2007; Golden et al., 2008). Moreover, a periodic survey on operative software for vehicle routing management can be found (for the last version of the survey, see Hall and Partyka, 2008). A special attention has to be made to multi-echelon transportation systems (Madsen, 1982; Naghi and Sahli, 2007), where collaboration is necessary to assure a good performance in the whole system. To deal with cost optimization issues, two-echelon systems have been recently studied (Naghi and Sahli, 2007; Gonzalez-Feliu, 2008; Gendreau and Semet, 2008).

In transportation planning and management, ICT play an crucial role, and are usually combined with the optimization modules in order to improve the performance of the different operations. A special attention has to be given to the main technologies which allow the freight transport operations to be included in the global supply chain of a product. Fabbe-Costes (2007) individuates three categories of IS, i.e. document's exchange systems, communication systems and traceability systems. The document exchange systems assure the communication among actors and memorize several transactions. Then, the communication systems assure the enterprise flow's guide. Finally, the traceability systems are developed to find and follow freight movement.

3. Organizational schemas in collaborative freight transportation

In this section we will describe the main organizational schemas related to collaborative freight distribution, focusing on the last mile issues in urban areas.

3.1. Vendor Managed Inventory

The Vendor Managed Inventory (VMI) can be considered a next step respect the ECR. In this collaborative approach, the supplier is co-responsible of the warehouses' re-supplying using the sells database, using collaborative actions. This approach implies an involvement of the distribution company to give real time information to the producer, which will be able to make a re-supplying proposal and then make his previsions in order to adapt his production phases and his resources to these previsions. A new form of VMI, which can be called "shared VMI", is developed in UK and France, and involves several producers, which agree to work with the same distribution company and share with him their information (Simonot and Roure, 2007). This is a form of collaboration with a high level of information sharing, which takes place at both tactical and operational phases.

3.2. Platform sharing and infrastructure logistics pooling

In freight distribution, shared platforms and infrastructures are very common. However, most of them are only physically shared, and the actors that operate in these platforms do not collaborate. The manager of the platform assures the functionalities of the platforms. This is the case of warehouses that rent their space (and sometimes have also several services to propose) to several distribution companies. Multimodal transportation is also a field where infrastructures and platforms are shared (Dalla Chiara, 2009). Another model of shared platform is the "collaborative warehouse", where several producers and distribution companies share a physical space and logistics information to improve the global performance of the overall distribution processes (Global Commerce Initiative, 2008). This idea can also be found in consolidation platforms, like classical cross-docks, regional platforms, urban consolidation centers or urban logistics spaces.

3.3. Freight transportation pooling

In freight transportation, collaboration between two operators is an action that is usually informal and not documented. These actions are taken to increase the loading rate of a vehicle, or to make a "friend" company deliver a customer that the contracted operator is not able to do (Patier, 2004 ; Morana and Gonzalez-Feliu, 2009). In frequent collaboration cases, the approaches can be formalized by agreements.

3.4. Networks of logistics providers and transportation operators

Another form of collaboration is the networks of transportation companies. Most of these networks involve small and medium companies. A network is presented as an association, although some of them assume the form of a cooperative company (Simonot and Roure, 2007). A more collaborative sharing approach is the open e-marketplace.

This approach is based on an electronic information exchange system, where the transportation offer actors meet the transportation demand ones. The offer comes from transport companies, and the demand can come from "loaders" or from transporters that do not have enough quantity of goods to transport in a considered area.

4. Optimization analysis

In this section we present the proposed method for strategic cost analysis in order to evaluate the gains of collaborative transportation systems as a logistics approach in a macroscopic simulation approach. Then, we propose several contrasted scenarios. Finally, computational results issued of the simulation framework are proposed and commented.

4.1. Simulation procedure

The simulation procedure has as main objectives to estimate, in a macroscopic perspective, the transportation costs of the different schemas that will derive from the scenarios. Although in classical VRP several methods are proposed (Toth, & Vigo, 2002; Golden et al., 2008), two-echelon systems are started to be deeply explored recently (Drexl, 2006; Gonzalez-Feliu, 2008; Gendreau, & Semet, 2008; Crainic et al., 2010) and most works deal with theoretical and exact approaches that are limited to cases with few destinations, in general up to 50. Moreover, although it has been hypothesized (Gonzalez-Feliu, 2008), collaborative two-echelon distribution systems have not already been modeled. We propose a Clustering-first routing-second algorithm (Toth and Vigo, 2002) that can be adapted to collaborative multi-echelon transportation systems.

The algorithm work as follows: given a set of destinations, a set of cross-docking facilities and a set of depots (origins), the objective of the algorithm is to construct the routes of the system that will deliver the destinations from the origins making cross-docking operations at the intermediary facilities. Two types of vehicles can be defined: the first level ones will deliver the intermediary facilities, and the second level ones the destinations. First, a clustering phase will group the destinations and assign them to a second-level vehicle. For this, we will use a k-means algorithm (Hartigan, 1975), taking into account the distances to the depot but also to the closest intermediary facility. The second phase (routing) will use a greedy algorithm (Resende, & Ribeiro, 2003), i.e. a procedure that, starting from an intermediary facility, assigns the closest destination to the route. Then, in an iterative way, the closest destination is assigned to the route until no destinations are unassigned in the cluster. The first level routes are then build using dynamic programming, since the number of intermediary facilities is small. In order to postoptimize, an iterative procedure is run to test if changing the intermediary facilities the overall cost is reduced. The procedure solves instances of more than 200 destinations and 5 satellites in less than 1 second.

Single-echelon systems can be represented as two-echelon systems with one intermediary facility that has no transportation costs to be reached from the depot.

4.2. Contrasted scenarios

We propose four contrasted scenarios, built from the instances proposed by Fisher (1994) for the Capacitated Vehicle Routing Problem that can be used to reproduce hypothetical transportation plans.

The first scenario represents the case where each company follows a direct shipping distribution schema. To estimate the transportation costs, we use the simulation method on a CVRP for each company and we calculate the overall transportation cost resulting as the sum of each company's cost. The second scenario is that of a two-echelon distribution system, but with separate infrastructures and vehicle fleets. The companies are not collaborating, but follow a cross-docking strategy. To estimate the transportation costs, we use the simulation method on a 2E-CVRP for each company and we calculate the overall transportation cost resulting as the sum of each company's cost. The third scenario present a first form of collaboration, that of sharing the cross-docking facilities. To estimate the transportation costs, we use the simulation method on a 2E-CVRP for each company but with common satellites, then we can calculate the overall transportation cost as the sum of each company's cost. The fourth scenario supposes a complete collaboration among partners. To estimate the transportation costs, we create a multi-depot 2ECVRP instance resulting of the aggregation of the thee companies into the same system then we solve it to obtain the transportation cost.

4.3. Computational results

The different scenarios have been tested using our simulation approach programmed in Python. The clustering phase can give us an idea of the number of second-level routes that are used, so a first measure of performance. Using twoechelon systems means an increase on the number of vehicles, because of the multi-level nature of the system. In these approaches, if transportation is not shared, we observe that the number of vehicles does not change. When the three companies share their vehicles, they can be better optimized, and we observe an important gain in the number of vehicles (Table 1).

The routing phase have permitted to simulate the different travels for each level. In scenarios 2 and 3, the algorithm finds a first solution that uses many satellites and routes, but after a small post-optimization phase the costs decrease. However, the algorithm is able to solve all the instances in less than one second. We observe that wthout a vehicle optimization, the cost reduction is less important. Two echelon strategies are efficient if there is freight rationalization, and to do this it is important to have important volumes to transport. We observe also that only when a vehicle sharing approach is used, the platforms are better used, and we find three unused cross-docking facilities.

Table 1: Number of vehicles, cross-docking platforms and transportation costs (km) gain of each scenario respect to the reference situation

	Vehicles	Platforms	Gain
0	15	0	-
1	22	7	-5%
2	21	7	-10%
3	14	4	-22%

The cost gains, which are related to the kilometers travelled by the vehicles, remain however small, if we consider than other costs, mostly related to consolidation, are added but have not been considered in this study. Future developments of the simulation approach will take into account these costs, as well as the costs of opening a new logistics platform or adapting the existing facilities to develop sharing approaches.

In order to complete the study, a socio-economic analysis on the main limits to transportation sharing and collaboration is proposed in next section.

5. The obstacles to logistics pooling: a documentary-based discussion

As we have seen from simulation, collaboration is an interesting approach to reduce the transportation costs, as well as the environmental effects of freight distribution, mostly in urban areas. However, it is not always possible to follow this type of logistics schemas in an economical and social continuity. The limitations and obstacles are those factors that can become an impediment to the successful development of a logistics sharing approach.

In order to study these limitations, we propose a quick study on 20 experiences' feedbacks. As it is not always easy to identify and interview the main stakeholders of collaborative transportation systems (mainly because of the lack of information and of their manager's availability reasons), we have made a preliminary documentary study based on both scientific literature and specialised publishing analysis (Patier, 2004; Roy et al., 2006; Simonot et Roure, 2007; Stratégie Logistique 20084; L'officiel des transporteurs, 2008-2009; Le journal de la logistique, 2009; Agrion, 2009; Bestufs, 2009; TL&Associés an LET, 2009). We have identified 20 interesting cases, and we have completed the missing information by semi-directive and open interviews to the main stakeholders involved in collaborative transportation planning. These experiences can be grouped as follows:

• Collaborative VMI (6 cases): all concern the grocery field, and we have found 1 from the USA, one from Canada, one in the European Union and 4 in France.

• Transportation pooling agreements (6 cases): half of them for the food industry (1 in Western Europe and North-West Africa , for international transportation to UK and The Netherlands destinations, and 2 in France, for regional transportation), 2 for press distribution (1 in France and 1 in The Netherlands), and 1 for spare parts distribution (France-Spain).

• Networks and consortiums of transportation companies (6 cases): all for road LTL transportation (1 in Italy, 1 in The Netherlands and 4 in France).

• Open e-marketplaces for freight transportation (2 cases): one for container transportation and another for road LTL transportation (both in France).

From these experiences' feedbacks, we identify find several types of limitations and obstacles, which can be grouped into the following categories:

1. Commercial strategies. Each enterprise has its own commercial interests. If they are not a major source of conflicts among producers, retailers and logistics operators, they can become an important handicap for the transportation operators. In fact, aggressive strategies and the non-respect of the transportation plans to advantage the "friends" or their own customers can be actions that are not appreciated by the partners of collaborative transportation systems.

2. Financial questions. In collaborative transportation, it can happen that new platforms or other infrastructures have to been created or adapted. One source of disagreement is usually related to financing these investments, then to the "ownership" of them once they are operative.

3. Logistics strategies. In this category we find the physical and organisational conditions for freight compatibility, like dimensions, freight, type of packaging, loading unit and loading operations main characteristics. Another organisational factor is the acceptability of the sharing approach, which also has to be taken into account when defining the main characteristics of the collaboration for logistics sharing.

4. Legislation. Restrictive legislation to sharing approaches is legislation that is related to freight compatibility, i.e. the norms and laws that forbid the loading of a vehicle with products of different sorts (for example dangerous goods, fresh food, waste, raw materials, etc.) or to competition laws that can limit the development of collaborative transportation approaches.

5. Confidentiality. The main issues related to confidentiality that can become an obstacle to logistics sharing are when two competing actors decide to collaborate in a distribution system that implies sharing some of their logistics resources. Since information is the base of good collaboration, if one or more partners manage confidential information that they don't want to share for competition reasons, the efficiency of the sharing approach can decrease considerably. These issues are seen in most of the initiatives involving competing enterprises that do no have the support of public entities.

6. Responsibility. The factors related to the transportation operation's responsibility are strictly derived from the contract between the different actors of these operations. If the collaborations for logistics sharing follow a contract or a chart where the questions of responsibility are well defined, these questions will not constitute an obstacle to sharing. On the other hand, if these questions are not clearly specified in a contractual document, legal disputes related to responsibility can easily occur or the quality of service decreases because of these questions.

6. Conclusion

In this paper we have presented a multidisciplinary analysis to logistics pooling including an optimization analysis and a socio-economic discussion. The optimization analysis show the potential of logistics pooling, and the need to increase the vehicles' load and the platform usage rates in order to better use the resources and reduce costs. The socio-economic discussion has allowed us to identify the main limits of logistics pooling, which are mainly commercial strategies, financing, organization and habits, legislation, confidentiality and responsibility are the main obstacles to multi-echelon and collaborative transport. Since the transport is made by humans, social aspects are important and can be the keys of success of a transport system. Finally, we have to note that not all the drivers follow all the instructions written in the transport plans (Deflorio et al. 2009). For these reasons, optimization methods are useful but have to meet the operational needs and limits, most of them related to habitude, which is difficult to change.

In conclusion, logistics pooling has a big potential and can be well accepted by practitioners and public authorities, but the structural changes have to be implemented in a middle-long term perspective, after individuating and analyzing the potential obstacles to the development of a project in order to ensure its continuity at an economic point of view. Moreover, a strong implication of public administration in terms of incentives and subventions to develop such systems seems important to ensure their economic durability.

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