Design and scenario assessment for collaborative logistics and freight transport systems

Jesus Gonzalez-Feliu, Joëlle Morana, Josep-Maria Salanova Grau, Tai-Yu Ma

▶ **To cite this version:**

Design and scenario assessment for collaborative logistics and freight transport systems

Jesus Gonzalez-Feliu[1], Joëlle Morana[2], Josep-Maria Salanova Grau[3], Tai-Yu Ma[4]

[1] Corresponding author: Laboratoire d'Economie des Transports, CNRS, 14, av. Berthelot - 69363 Lyon Cedex 07 – France, jesus.gonzales-feliu@let.ish-lyon.cnrs.fr

[2] Laboratoire d'Economie des Transports, Univeristy of Lyon 2, 14, av. Berthelot - 69363 Lyon Cedex 07 – France, joëlle.morana@let.ish-lyon.cnrs.fr

[3] Hellenic Institute of Transport – CERTH, P.O.Box: 60361 - 57001, Thermi, Thessaloniki - Greece

jose@certh.gr

[4] Laboratoire d'Economie des Transports, CNRS, 14, av. Berthelot - 69363 Lyon Cedex 07 – France, tai-yu.ma@let.ish-lyon.cnrs.fr

Abstract

Collaboration between partners is a very popular subject in both logistics and decision support research. However, transport management is often taken into account only as an external cost, without integration in collaborative reasoning. This paper proposes a framework to assess collaborative solutions in the context of logistics and freight transport, as well as to describe the links between freight transport and supply chain managementin terms of collaboration techniques. First the main concepts of collaborative logistics in the distribution and transport fields are presented, highlighting the links between collaboration, freight transport and supply chain management. Then, the method to assess collaborative logistics and freight transport solutions is proposed. This method includes a design scheme, a hierarchic clustering technique and a dominance analysis method to unify the assessment of each individual and prepare collaborative research for a common solution. After that, the method is applied to the assessment of five scenarios derived from a real situation for the urban area of Lyon, France) to illustrate how difficult convergence towards consensus is. The results show that a global optimal solution for the entire set of stakeholders is not easy to identify, and how the proposed method can be helpful for decision makers to achieve a consensus of common objectives.

Keywords: collaboration, resource sharing, logistics and transport design, simulation, scenario assessment

JEL classification: R42; M11

1. Introduction

Logistics and freight transport represent major sources of employment and are among the mainstays of national economic development. However, those sectors also produce external costs, such as for example environmental and social nuisances, which negatively affect the quality of life, particularly in urban areas (Crainic et al., 2004). New trends in retail and business organisation, along with technological innovations in supply chain and distribution planning have led decision-makers to consider collaborative strategies to reduce the overall cost of the supply process (Lambert, 2008). Although the main aspects of collaborative logistics have recently been reviewed (Roy et al., 2007; Simonot and Roure, 2007; Lambert, 2008), collaborative strategies in the field of freight transport have been given less attention, even if they are often implemented in reality (Gonzalez-Feliu and Morana, 2011; Gonzalez-Feliu, 2012a). Collaboration is based on both group reasoning and information sharing management. It takes place at different echelons of a supply chain even in a competitive environment (Gonzalez-Feliu and Morana, 2011).

In classical logistics research, most of the literature is focused on individual reasoning even when dealing with collaborative approaches. In tactical and operational planning – i.e. at medium-term and daily horizons – individual reasoning assumptions often prevail over group reasoning, mainly in real-time operations management (Crainic and Laporte, 1997). However, in long-term horizons (strategic planning), group decision-making can have a strong influence on the development of a common strategy. Such decisions have a direct impact on the project's duration, stability and sustainability (Gonzalez-Feliu and Morana, 2011). In any case, freight transport is often considered as an external cost and is not explicitly considered (Gonzalez-Feliu, 2013). Moreover, most works deal with the individual consequences of collaboration, and group reasoning in logistics and freight transport is only roughly presented without in-depth examination of the impacts collaboration has on individuals and as a group (Gonzalez-Feliu and Morana, 2011). Although collaborative decision making methods exist in other fields (Yearwood and Stranieri, 2011), they are based on optimization or on automatic solution selection, proposing a substitution to human relations and negotiation. In transport management, the human factor is crucial (Gonzalez-Feliu and Morana, 2010), and a decision making tools should not become a substitute but it would rather be considered a support to human choice making.

Furthermore, the current economic context is pushing the main decision-makers to adapt collaborative strategies (Danielis et al., 2010; Morana et al., 2013). Therefore, it is important to study collaborative transport from a global supply chain viewpoint, rather than from that of each separate component or stakeholder involved. However, the system optima usually differ from the sum of individual optima (Wardrop, 1952). For this reason, it seems appropriate to analyse both system and individual visions while taking decisions about collaboration alternatives.

The present paper describes collaborative freight transport, its links with supply chain management, and aims at framing an assessment method for such systems based on group decision-making algorithm. Therefore we propose a group decision model to help decision makers in strategic collaborative logistics, transport design and planning. More precisely, the paper presents a procedure to identify decision groups from q set of comparable solutions, given a set of stakeholders. This method aims not to give a unique choice (or a selection of solutions) but proposes classify classification of the solution space in order to get a clear description of the possible decision groups and their potential incompatibilities. The data inputs and the individual estimations of each solutions are not explicitly addressed here and are supposed as known and made comparable by the given stakeholders. The paper is

organised as follows. Section 2 introduces the main concepts of collaborative logistics and freight transport systems. Section 3 proposes a group decision support procedure for collaborative transport strategic planning. The proposed method aims at guiding decision-makers in the design of integrated collaborative logistics. To illustrate the proposed method, Section 4 assesses five scenarios related to cooperative logistics solutions for the urban area of Lyon (France). This section presents the simulations results for each scenario and discusses the possibilities of derived consensus. Finally the paper concludes with the main lessons learned from the scenario assessment results and proposes further developments of the proposed method.

2. An overview of collaborative logistics

Over recent years, several strategies and logistic models have been developed in order to increase supply chain efficiency. Collaboration is one of the most promising areas of study in supply chain management (Simatupang and Sridharam, 2002; Roy et al., 2006; Simonot and Roure, 2007; Lambert, 2008; Evrard Samuel and Spalanzani, 2009; Blanquart and Carbone, 2011; Gonzalez-Feliu and Morana, 2011). In logistics, a collaborative approach requires sharing common goals and resources throughout the life cycle of the collaboration (Blanquart and Carbone, 2011). This life cycle could be modelled into four stages (Simatupang and Sridharam, 2002): (1) engagement process, (2) inter-dependence management, (3) implementation of operations and (4) evaluation of collaboration.

2.1. Types of collaboration

Collaboration is seen all along supply chains (Brewer, 2001), at different horizons and levels (Gonzalez-Feliu and Morana, 2011). In general, two types of collaboration can be distinguished, i.e. vertical collaboration and horizontal collaboration.

2.1.1. Vertical collaboration

Vertical collaboration is defined as (Becker, 2003) "a *common process management in a supply chain by sharing complementary knowledge and resources in order to efficiently use synergies for planning, deployment, operation follow-up and control*". In vertical collaboration, three main approaches can be found:

1. Efficient Consumer Response (ECR) can be defined as a cooperative technique whose goal is maximizing total satisfaction of consumers by improving the economic performance of different actors within a supply chain. ECR is used first to promote automatic procedures to deal with supply chain links and thus reduce costs related to manual transactions such as command transmission and billing operations. In a second moment, all the processes are integrated in a unique procurement-distribution scheme for a better management of the entire supply chain (La Londe and Pohlen, 1996).

2. The Vendor Management Inventory (VMI) can be considered as the logical evolution of ECR (Roy et al., 2006). In this collaborative technique, the supplier is jointly responsible for warehouse re-supply on the basis of sales forecasts. This involves using collaborative actions (Waller et al., 1999). The Collaborative Planning, Forecasting and Replenishment[1] (CPFR) extends the VMI to the entire supply chain (Fliedner, 2003), mainly piloted by a supplier, who collaborates with a set of retailers and one or more logistics operators to coordinate sales, commands, stocks and shipments for a better operational management of the distribution supply chain.

---

[1] In 1998, the Voluntary Inter-Industry Commerce Standards committee® (VICS) published the VICS CPFR Guidelines, available online at: http://www.vics.org/committees/cpfr/

3. The Shared VMI technique has been developed in the UK and France (Simonot and Roure, 2007) and differs from the classic VMI in that it is developed and managed by a consortium of supply chain stakeholders sharing common destinations, i.e. retailers and/or facility areas. The shared CPFR extends the collaborative approach to a consortium of producers and/or grouped distribution stakeholders that pool their sales and logistics information to optimize their common resources (Rakotonarivo et al., 2009).

All these approaches have been mainly developed in grocery, textile and healthcare sectors (Roy et al., 2006), assume the use of outsourced transport. Transport carriers are seldom invited to discussions and strategic planning because they are considered only as subcontractors providing a specific service.

2.1.2. Horizontal collaboration

The second type of collaboration is the horizontal collaboration (Rakotonarivo et al., 2009). It is defined as the collaboration between a group of stakeholders of different supply chains acting at the same levels and having analogous needs. In the distribution supply chain, horizontal collaboration often takes place between two or more transport carriers (mainly small and medium sized companies), between two or more distribution companies (for example wholesalers), or between two or more retailers. To the best of our knowledge, this type of collaboration related to distribution logistics is not explicitly defined in the literature, in terms of typology and characterisation, since the concepts are new and start to be studied. We subdivide horizontal collaboration into three categories, which can be linked with the above vertical collaboration:

1. Bilateral collaboration is defined as the collaboration between two peers of the distribution supply chain, i.e. between two stakeholders belonging to the same echelon of the chain. Several types of bilateral collaboration can be observed. For example, producers can be associated for supply sharing in order to make bigger orders and reduce supply costs, or develop co-production strategies (TL&Associés and LET, 2009). Distribution companies can stipulate supply sharing agreements or common infrastructures like collaborative warehouses or shared cross-docking facilities (Rakotonarivo et al., 2009). Finally, retailers can perform minor actions more related to supply grouping than to logistics management.

2. Collaboration of logistics networks (Simonot and Roure, 2007): most logistics networks involve companies of the same type, as for example in the case of small transport operators, sales grouping networks for retailers or wholesalers associations. The main functions of these networks are related to supply coordination and logistics organization, and can be the organized extension of bilateral collaboration to three or more stakeholders.

3. Collaboration of open e-marketplace platforms: this form of collaboration is based on an electronic information exchange system by which potential customers for logistics services use to meet potential providers (Rakotonarivo et al., 2009). Specific services such as transport, storage, consolidation, or packaging, are offered by various providers.

In both vertical and horizontal collaborations, freight transport can be consolidated and pass through one or more warehouses and/or transhipment platforms (Iannone and Thore, 2010; Gonzalez-Feliu, 2012b, Lam et al., 2012). Moreover, the stakeholders including transport operators, warehouse keepers, logistics providers, producers, retailers, distribution companies and other agents can be involved in collaborative logistics at different levels. According to

Gonzalez-Feliu and Morana (2011), the first collaboration phase involves transactions. In this phase, the only collaboration is related to the correct execution of transactions by each involved stakeholder. Then, subsequent informational collaboration concerns information exchange that represents the basis of cooperation between stakeholders. Finally, the decisional collaboration phase involves decision making at different levels (i.e. operational, tactical and strategic planning) and is usually based on partnerships or cooperation agreements (Lambert, 2008).

2.2. The involvement of different stakeholders in collaboration

Since collaboration involves at least two different individuals, it is important to define the involved stakeholders in logistics and freight transport organizations to understand how the collaboration can affect current logistics schemes (Stathopoulos et al., 2011). All along each supply chain, several stakeholders interact to complete all the tasks necessary to produce and distribute a product. These stakeholders are of different nature and present different levels of involvement (Lambert et al., 1998).

First, the "shippers" are the stakeholders that are at the origin of a delivery (Marcucci et al., 2004, Lam et al., 2012). The stakeholders that act at deliveries' destinations are called "receivers" (Gonzalez-Feliu and Morana, 2011).They can be the different producers involved in the manufacturing phases of a product (mainly raw products, components, or machines) such as final product manufacturers, logistics providers, distribution and gross commerce enterprises. The retailers can be considered as the final destination of the products (Marcucci and Gatta, 2013a), except for home delivery services, where a new stakeholder (the end consumer) is added (Russo and Comi, 2006). The second category of stakeholders is that of the "transport providers", defined as the stakeholders that physically execute a transport operation (McKinnon, 2001). This category includes transport carriers that actually make a delivery and the shippers or receivers making own-account transport (Ambrosini and Routhier, 2004). A third category includes the involved value stakeholders all long of the supply chain (Brewer, 2001) such as platform management companies, logistics providers and transport management services (Danielis et al., 2005). Transport providers play a crucial role of collaborative logistics initiatives, mainly in urban areas (see, for instance, Muñuzuri et al., 2005; Dablanc, 2007; Paglione and Gatta, 2007; Marucci and Danielis, 2008; Marcucci et al, 2012; Morana et al., 2013). Yet other involved stakeholders can be considered: public administrations, highway companies or customs operators (Rakotonarivo et al., 2009). Their possible implication in logistics collaboration seems less important with respect to the three main categories since they are mainly seen as external actors of the supply chain. Their collaboration is mainly related to transactions and basic communication. In any case, the heterogeneity of the involved stakeholders and the different goals and degrees of implication for each member has to be considered (Marcucci et al., 2012; Gatta and Marcucci, 2013; Marcucci and Gatta, 2013a,b).

In cooperative process, the decision concerns the choice from a set of possible strategies or solutions implemented for middle and long-term strategies. In this context, two or more decision-makers collaborate at a decisional level to find a common organizational solution. These decision-making processes need to take into account not only individual but also the group viewpoint. This highlights the need for conciliation between each individual's viewpoint and a systemic perspective that is not always close to individual optima. In the past, the notions of *group decision-making* and *reasoning communities* have been studied in-depth in some fields such as healthcare or aeronautics (Yearwood and Stranieri, 2011) or household location choice (Marcucci et al., 2011). A reasoning community can be defined as a group or community of individuals that engage in dialogue with each other in order to reason toward

action (Yearwood and Stranieri, 2006). Moreover, this community engages in a process that involves three main phases (Yearwood and Stranieri, 2010):

- Individual reasoning: each individual seeks evidence, organises it and ultimately establishes claims that represent his or her preferred position or beliefs.

- Communication of reasoning: this phase describes the transmission of all aspects of individual and coalesced reasoning to others.

- Coalesced reasoning: this phase seeks to obtain an acceptable solution for the entire community. Coalesced reasoning does not mean that an agreement is reached but each individual's choice is understood and accepted as valid by the community even if the divergence of views is such that agreement is impossible.

3. Collaborative transport design and strategic planning: an integrated approach

Collaborative logistics involves several stakeholders. Moreover, transport management is often externalized and is not explicitly taken into account in logistics and supply chain management issues. This section describes the method to assist stakeholders in collaborative logistics and freight transport solutions, in a strategic planning horizon. This method aims at assisting both the communication of reasoning and the coalescent reasoning phases and at identifying whether consensus can be reached, or whether negotiation is necessary. The decision support methodology can be summarised as follows:

1. Strategy design: given a group of decision makers and their main goals, a set of envisaged strategies can be defined. For this purpose, patterns can be derived from the conceptual scheme proposed above[2].

2. Strategy simulation: each stakeholder calculates the decision function for each strategy envisaged by using existing tools in a comparable way. A global decision function taking into account a systemic approach is then estimated.

3. Individual clustering phase: this phase corresponds to individual reasoning. For each decision-maker, solutions are compared and grouped in order to define their main groups of interests. A clustering tree and decision ranking are built for this issue.

4. System clustering phase: by analogy to the individual clustering phase, the same clustering analysis for the value of the decision function is applied to the global system.

5. Dominance phase: for each solution, the dominance with respect to the other solutions is examined at individual and system levels.

6. Decision group identification: decision groups are defined based on the dominant solutions obtained at the previous phase. Then an analysis of solution selection is performed to help the decision-makers reach consensus or adapt their decision criteria to converge at a common position.

In the next section, more details of the proposed method are presented by providing a description of each of the phases defined above.

---

[2] In this study, and more precisely in the scenario simulation example, we assume a set of strategies, although in a more general framework strategy design would be supported by a dialog and analysis process that allows to identify a set of suitable solutions.

3.1. Collaborative transport design in the context of supply chains

The first phase includes designing suitable strategies of integrated logistics and freight transport. In this phase, the main elements of supply chain and transport management are combined to define an integrated solution that meets the targets of their potential users (Blanquart and Carbone, 2008). As seen in section 2, vertical and horizontal collaborations can take place complementarily on transportation, warehouse and platform management schemes. Then graphic presentation can be proposed in the form of a diagram. This diagram uses the concepts of geographical and institutional proximities (Blanquart and Carbone, 2008) and should aim at facilitating the optimization of the supply chain, inventories, freight transport and level of service at a strategic planning horizon (Crainic and Laporte, 1997; Gonzalez-Feliu and Morana, 2011). Although there is no general agreement on the design of the graphic presentation used, *"a well-executed map can enhance the strategic planning process, ease distribution on key information, facilitate supply chain redesign or modification, clarify channel dynamics, provide a common perspective, enhance communications, enable monitoring of supply chain strategy, and provide a basis for supply chain analysis"* (Gardner and Cooper, 2003). Consequently, the following diagram to link logistics and transportation collaboration (see Figure 1).

This diagram specifies the various relationships which bind the stakeholders in the supply chain. It is important to include transport management issues in strategic logistics planning. Although many authors have studied collaborative logistics (Lambert et al., 1996; Simatupang and Sridharam, 2002, Min et al., 2005; Simonot and Roure, 2007; Lambert, 2008), the main works are related to production coordination and inventorying-sales informational collaboration. However, transport management seldom takes into account other logistics operations (except for inventory). Therefore, in the current economic and legislative context Diaz-Hernandez et al., 2012), it seems vital for firms to associate (or re-associate) transport and logistics flows for both economic and policy reasons (Gonzalez-Feliu and Morana, 2011).

Figure 1. Collaborative practices connecting distribution logistics and freight transport
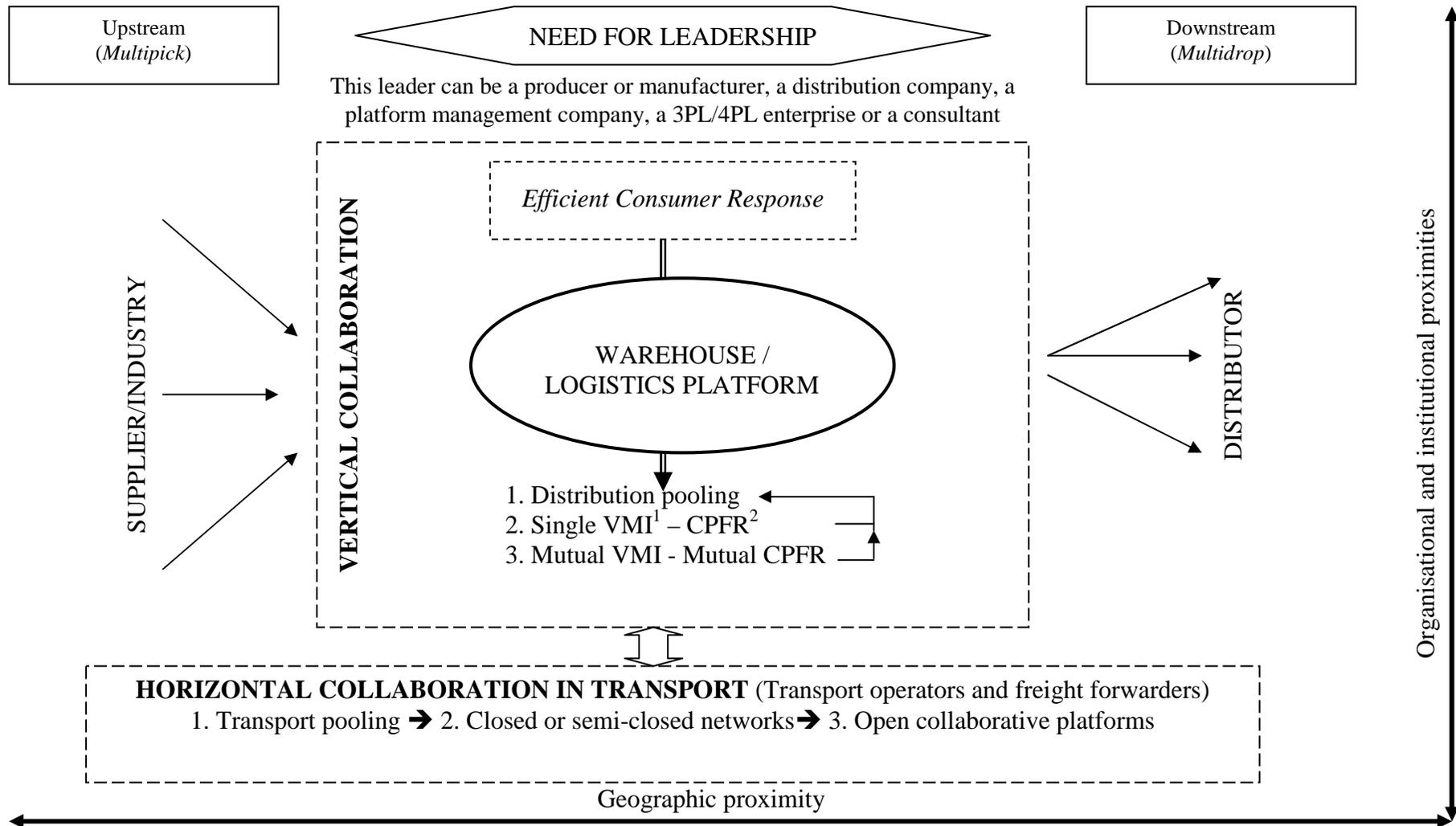
Remarks: [1]VMI: Vendor Management Inventory, [2]CPFR: Collaborative Planning, Forecasting and Replenishment

At this point, a key element appears in the implementation of collaborative practices, namely the need for all the individuals in the supply chain to be involved in its operations. These collaborative practices highlight the "relational structure of the supply chain" (Lambert et al, 1998). Little can be proposed without considering the role of power and influence in relationships between two or more individuals (Bonet-Fernandez, 2009); however, recognition of the work of each member of the supply chain facilitates the success of collaboration.

3.2. Strategy simulation method

The strategy simulation is an important stage of the decision support methodology since in this phase the different solutions defined in phase 1 are assessed by each stakeholder. To do this, it is important to have an integrated tool that estimates the costs[3] (and or benefits) of each solution for each stakeholder in a similar way in order to make possible a comparison not only among solutions for a single stakeholder but also among different stakeholders. At this stage, several simulation methods can be used. In general, these methods need to follow three general steps to support a collective solution search:

1. Scenario construction: from the solution set defined in phase 1, a set of scenarios is defined. Each scenario represents a realistic situation where the corresponding strategy is deployed. Therefore the resulting logistics and transport system is assumed operational. In order to compare these scenarios, the logistics demand must be the same for all of them, as well as the decision variables, i.e. the measure or measures used by each stakeholder to compare two or more solutions.

2. Decision function definition: from the decision variables, a standard decision function is chosen. This function should meet the needs of each decision maker to assess and evaluate the possibilities of each strategy with respect to his or her goals and stakes. Moreover the chosen decision function is estimated for each stakeholder on the same assumptions and estimation methods to make it transferable to each decision maker.

3. Transport service simulation: in order to simulate the scenarios, it is suitable to estimate the transport plans related to the organizational and technical choices. For each scenario, the different stakeholder's transport services are simulated using a tactical planning tool and the decision variables are calculated.

4. Decision function estimation: to prepare the communication among partners and support the search of consensus, it is important to provide a unified evaluation based on the same decision function for each involved decision maker. For this reason, from the results of the transport service simulation, the decision function is estimated for each solution and stakeholder.

The decision function associates to each solution a decision value. In other words, it is the result of a decision support analysis that quantifies the suitability of a solution for a decision maker. Note that the decision function can be issued of different decision support methods. In this paper we do not aim at making an extensive literature review on this subject but at proposing a set of the most common methods in transport sciences. Combinatorial optimization is often used in freight transport planning (Crainic and Laporte, 1997; Nemhauser and Wosley, 1999; Barnhart

---

[3] These costs are defined by the group of collaborating stakeholders that need to agree into a standard cost estimation in order to support the search of a consensus (Raifa et al., 2002)

and Laporte, 2007), mainly dealing with strategic and tactical planning. Economic analysis methods are used in strategic and long term issues assessment, for instance in cost-benefit analysis approaches for infrastructure and high-investment project evaluation (Prest and Turvey, 1965; Layard and Glaister, 1994; Tudela et al., 2006; DG REGIO 2008). Econometric methods are also used in forecasting studies (Johnston, 1972; Mannering and Hensher, 1987; Washington et al., 2003). Moreover, multi-criteria decision support is also used in project assessment or in pilot evaluation (Velton and Stewart, 2002; Tudela et al., 2006; Campos Gouvêa et al., 2009). Other methods are adopted in more pluri-disciplinary approaches, such as empirical and statistical methods (Wonnacott and Wonnacott, 1990; Nijkamp and Blaas, 1994) or mathematical modelling (Ortuzar and Willumsen, 2001; Hensher and Button, 2001; Kutz, 2003; Wadell and Ulfarsson, 2004; Marcucci and Musso, 2010; Portoghese, 2011).

3.3. Individual clustering phase

Once the strategies envisaged are defined and discussed, each decision-maker starts his/her individual reasoning phase. At this point, each decision-maker analyses and assesses each solution in order to define priorities and orientate the goals in a further phase of discussion and quest for consensus. Therefore, it is important to define a homogeneous set of decision variables in order to compare each individual's choices. More precisely, the goal of the individual reasoning support method is to group the solutions into homogeneous clusters, then to provide a key for comparison. This is done by carrying out a hierarchical cluster analysis (Ward, 1963). According to Tan et al. (2006), two types of methods are distinguished. *Agglomerative approaches* begin with *n* clusters, one for each solution, and merge them iteratively until one cluster consisting of all *n* objects remains (Kaufman and Rousseeuw, 1990; Davidson and Ravi, 2005). *Divisive approaches* (Boley, 1998; Hastie et al., 2009) work in an opposite way. Indeed, these approaches begin with one cluster of *n* objects; then it is split iteratively until *n* singleton clusters are defined.

To identify these decision groups, it is necessary to explore each decision-maker's solution space and group the alternatives into solution clusters, i.e. subsets of solutions considered close or equivalent by the decision-maker. The next step is to perform a group analysis to find similarities and synergies between each decision-maker's solution clusters. In this paper we chose an adapted agglomerative nesting algorithm, also known as Agnes algorithm (Struyf et al., 1996), for the following reasons. The Agnes cluster method allows making groups by aggregating step by step the solutions in a more intuitive way than divisive approaches (Lattin et al., 2003). Moreover, it is possible to evaluate the distance between two clusters at each step, making it easy to find a set of clusters that meet the decision makers' constraints. The details of the Agnes clustering method are presented in Appendix.

3.4. Group clustering phase

Analogously to the individual clustering phase, a clustering analysis can be carried out on a systemic perspective. In this case, the same decision function is used on both the individual clustering phase and on the overall system. Then, the Agnes clustering algorithm is used on the system decision function set in the same way as for individual clustering.

3.5. Dominance phase

The dominance phase is performed after defining the similarity clusters to analyse the dominance relations between clusters. Each solution is examined in comparison to the others on the basis of the value of the decision function. A table showing the dominances between solutions is used to report all the solutions for each strategy and each decision-maker. This is done by extending the concept of dominance used by Wierzbicki (1980) and Brans and Vincke (1985), which is very common on several families of non-additive multi-criteria methods. However, additive functions or operators are not used to define dominance but use the clustering analysis to find the dominant solutions to make the method suitable for both quantitative and qualitative definitions of the decision function. Given two strategies *A* and *B* for each decision maker *k*, where *A* and *B* are included in different clusters *i* and *j*[4], we can state that *A* dominates *B* if the distance between these two clusters is greater than the corresponding decision threshold δ^k. That can be formalised mathematically as follows:

$$A > B \text{ if } A \in i, B \in j, i \neq j \text{ and } d_{ij} > \delta^k \ \forall k$$

, where $A > B$ means *A* dominates *B*. Then, for each strategy and decision-maker, all the other strategies dominated by the one considered can represented in a dominance tree (Cimitile and Visaggio, 1995) or in a dominance table.

3.6. Decision group identification

Afterwards, the decision groups can be defined by crossing all the data of the dominance table. To do this, the Agnes algorithm is applied to the data issued from the dominance phase. The algorithm is used to group the stakeholders under one or more groups of envisaged solutions. In other words, a set of decision groups is identified, and the distances between these groups. If only one decision group is found, the selected solutions are Pareto optimal, i.e. are considered as equivalent for each stakeholder. In the case two or more groups are found, a further analysis of consensus mechanisms or compensation strategies is necessary to find a consensual decision for the entire set of stakeholders.

4. An example of application

To illustrate the method proposed, five scenarios are formulated for assessing collaborative strategic transport planning. Although the proposed method is designed to support decisions in general supply chain and transport management, the proposed application aims to focus on last mile distribution for two reasons. The first is that last mile optimization is one of the most challenging subjects in both research and practice (Toth and Vigo, 2002). The second is that several collaborative approaches have started to be developed in this context, mainly in the last years (Muñuzuri et al., 2006; Allen et al., 2007; Benjelloun et al., 2010; Gonzalez-Feliu and Morana, 2010; Russo and Comi, 2011). Collaboration seems to be an important issue for urban goods transport optimization, but currently the existing studies related to urban logistics and transport management deal mainly with individual reasoning (Crainic, 2008; Russo and Comi, 2011). For all these reasons, the example of application will deal with LTL distribution in urban areas.

---

[4] If *A* and *B* are in the same cluster, *A* and *B* are considered as equivalent, so no dominance can be defined

4.1. Scenario description

The proposed scenarios involve five LTL transport operators. Each operator has a depot, several satellites for consolidating the cargo, and two fleets of trucks, which are different for each company (one fleet of light goods vehicle and one fleet of standard trucks)[5]. The total number of customers is 408, and there are 12 satellites. Moreover, each customer can be served by more than one carrier.

We simulate a total of five scenarios, described below:

S0. *No collaboration with distribution using current vehicles.* The reference situation represents a non-collaborative strategy where only big trucks are used. A large number of customers are visited due to the bigger capacity of the vehicles. This scenario is the reference situation.

S1. *VMI strategy with usage of small vehicles instead of the current big vehicles.* In this scenario it is assumed that each operator follows a VMI strategy. No horizontal collaboration is supposed, and vertical collaboration leads to a more frequent delivery service. The demand to deliver is then lower than that of S0, which makes possible the use of small vehicles. This results on a larger number of small routes due to the smaller capacity of the vehicles.

S2. *VMI strategy with two-echelon transport and cross-docking systems.* Starting with the assumptions of S1, the transport system is modified to introduce a two-echelon schema where the big trucks are used for distributing the cargo to the satellites, and from them to the final customers using the smaller vehicles. As for S1, no horizontal collaboration is supposed, and the vertical collaboration presents also the co-ordination between the two transport echelons.

S3. *Collaborative VMI with transport pooling between two carriers, and S3 strategies for the other three carriers.* This scenario presents a shared VMI approach involving two operators, the others implementing a classic VMI approach as in the second scenario. The collaborating customers share their satellites, and consolidate cargo destined for the same customers which also share their fleets of small trucks.

S4. *Collaborative VMI among all carriers with a transport pooling system.* The last scenario assumes a collaborative transportation sharing network where all the operators collaborate, using all the cross-docking platforms to consolidate the cargo destined for the same customers and sharing their fleet of small trucks.

Each transport company is supposed to assess the solutions on the basis of its yearly operational cost. To do this, a yearly distribution profile is defined (mainly two period: regular weeks and holiday weeks), and standard routes are planned for each week. Thus, we define two demand profiles, i.e., two typical delivery days, one for each period. Although these scenarios are analysed from the viewpoint of transport companies, their integration in global logistics systems have been taken into account. More precisely, scenario S0 is built on the basis of regular routes without a link with sales forecast and inventory management while scenarios S1 to S4 result from VMI approaches that lead into a more complex transport schema presenting two main periods and more frequent routes.

---

[5] A light vehicle is assumed to have a maximum total weight of 3.5 tones. The total weight of a standard truck is between 7 tones and 12 tones.

The demand used to define the non-VMI and the VMI profiles is issued from estimation following the estimations provided in Rakotonarivo et al. (2009). The demand is estimated on the basis of standard censorial data from the French Institute of Statistics (SIRENE file of year 2005) using the Freturb model (Gonzalez-Feliu et al., 2012, 2013), to generate the number of deliveries corresponding to a set of establishments. The study area is Lyon's urban region. In 2006, this area consisted of about 2.000.000 inhabitants and 800.000 households. The application database derives from the 2006 household trip survey of Lyon urban area (Sytral, 2006), from which related demography information can be extracted. Then from the SIRENE file of year 2005 the information related to retailing activities is related to each zone of the urban area (the overall surveyed territory has been divided into a set of about 750 zones. From the SIRENE file the data corresponding to the small grocery retailers of Lyon and Villeurbanne is extracted (about 400 establishments). These retailers will be the final destinations of the freight to be delivered and are grocery retailers with a total surface lower than 400 m². Then 12 cross-docking platforms are created and located in the near periphery of city, mainly in industrial zones, extracted from the SIRENE file. The depots are located in the peri-urban area, also known as the far periphery of the city. After that, a quantity of freight is associated to each delivery as on Gonzalez-Feliu and Salanova (2011).

To simulate the freight routes distribution, each company's transport plan is estimated using the fast heuristic algorithm designated for two-echelon transport optimization in urban areas (Gonzalez-Feliu and Salanova, 2011). First, a non-hierarchical clustering method is applied to assign customers to a set of vehicles. Second, the routes are built based on a semi-greedy algorithm. The cost of the routes are fixed costs (driver basically) and variable costs (length, time, consume and contamination). To estimate the travel time, average speeds are used, with higher values for the access to the route, and lower values for the in-route travel.

4.2.   Results of analysis

We present below the main simulation results as well as a collaborative decision making analysis. To assess the scenarios, we defined the decision function as the yearly cost by converting the distance travelled of each route to a monetary cost, using the ratios of Generalitat de Catalunya (2011)[6]. The values of the decision function are shown in Table 1. From this table, it is difficult to decide what the best solution for all transport operators is. By applying the method proposed, we obtain the following decision function values for each transport operator (see Table 1):

---

[6] We consider fuel costs, maintenance and vehicle insurance (related to the distance travelled) and crew costs, related to travel time (in hours). This travel time estimated from the distances travelled and average urban speeds (Gonzalez-Feliu et al., 2012)

Table 1. Values of the decision function[7] for each transport operator

	Scenario	Operator 1	2	3	4	5	Total
S0	Big vehicles	84 963	112 114	121 066	99 713	139 439	557 295
S1	Small vehicles	97 784	110 395	103 740	81 569	138 862	532 349
S2	Single VMI	103 185	139 660	106 755	104 069	102 962	556 632
S3	Bilateral Pooling	100 774	139 660	78 040	104 069	102 962	525 505
S4	Network	98 919	154 276	91 604	62 304	75 052	482 154

We observe that each transport operator has different priorities and costs. For example, transport operator 1 seems to perceive a loss in all the solutions, with respect to the reference situation whereas transport operator 5 has a strong preference for scenario S4 (a collaborative network between all the partners), but the global "optimum" that satisfies every decision-maker cannot be found without more detailed analysis.

4.2.1. Individual reasoning phase

To pursue the analysis for each individual transport operator, we calculate the dissimilarity matrixes for each decision-maker as the percentage variation of each solution's cost with respect to S0. The same is done for the entire system. Moreover, each transport operator defines a decision threshold[8] δ^k, reported in Table 2.

Table 2. Decision threshold values of the function for each transport operator

Operator	Decision threshold δ^k
1	10%
2	15%
3	10%
4	5%
5	15%

We apply the Agnes algorithm on each decision maker's dissimilarity matrix and construct their corresponding cluster tree and decision ranking. The results of the clustering phase are synthesised below. Note that for transport operators 2, 4 and 5, solutions 2 and 3 present the same cost, since these solutions assume collaboration only between transport operators 1 and 3. Therefore, in the clustering analysis, solutions 2 and 3 are already grouped for these three operators, resulting in 4 starting clusters instead of five.

---

[7] Annual costs in euros estimated from the simulation results (travelled distances and travel times) using the cost tables proposed by Generalitat de Catalunya (2011)

[8] The decision treshold defines the margin within what two solutions can be considered as equivalent by a decision maker. Their inclusion on the Agnes method is explained in Appendix 1.

Transport operator 1 (Figure 2): The clustering analysis shows two main solution clusters whose average radius r^c is less than the decision threshold δ^1. The first contains only solution 0, and the second includes all the other solutions. Moreover, we observe that these two clusters are not close: the radius of a cluster grouping all the solutions is about 18%. On the other hand, solutions 1 to 4 are very close: their cluster radius is about 2%, very far from the decision-maker's limits (5%). When observing the decision ranking, it can be seen that solution 0 is preferable to the other solutions, showing that all the proposed alternatives result in significant cost increases.
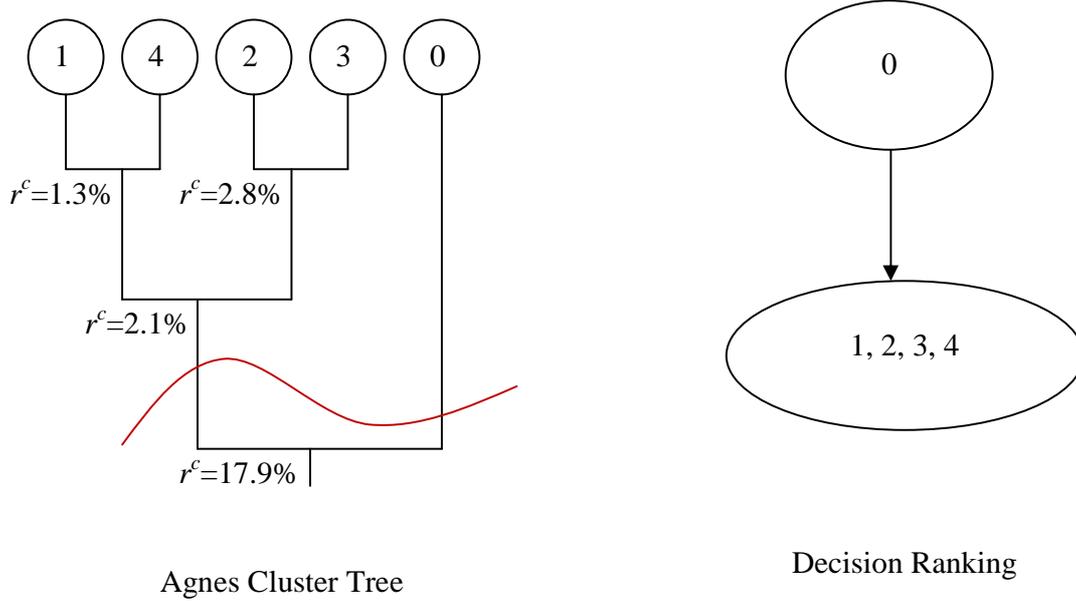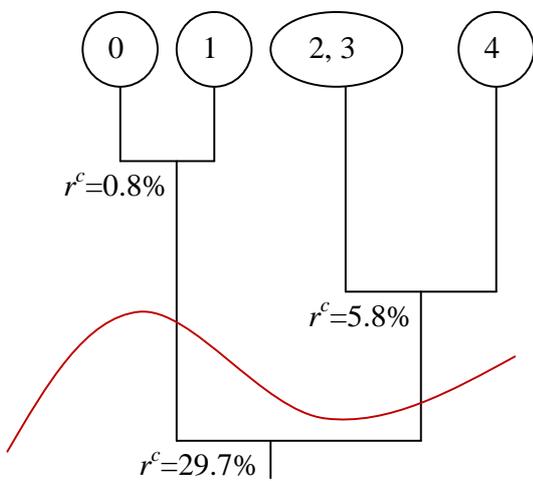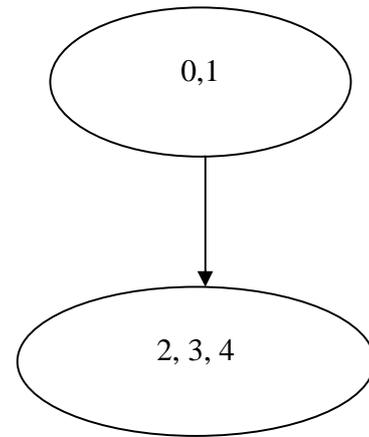

Agnes Cluster Tree

Decision Ranking

Figure 2. Cluster Tree and Decision Ranking for transport operator 1

Transport operator 2 (Figure 3): From the clustering results, two solution clusters can be defined. The first contains solutions 0 and 1, which are less close and the second includes all the other solutions. The second includes solutions 2, 3 and 4. The first cluster presents a very small radius, whereas the second is near the decision-maker's limits. Indeed, the second cluster's radius is almost 6%, which corresponds to $\delta^2/2$. Moreover, these two clusters are less close than those of transport operator 1, i.e. the radius of a unique cluster grouping all the solutions is close to 30%, which is almost twice that observed for transport operator 1. The decision ranking shows similar results: solution 0 is preferred, although transport operator 2 also includes solution 2 in the first cluster.
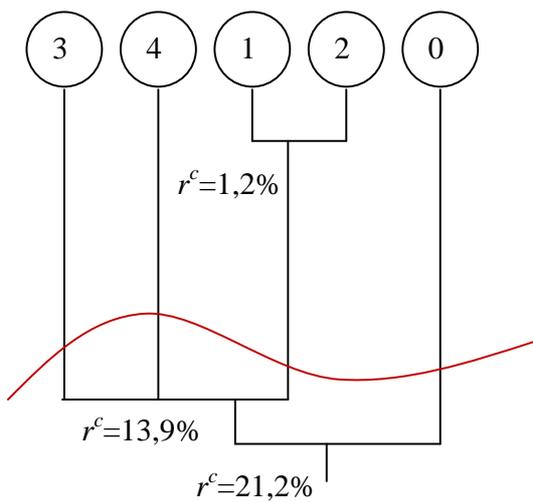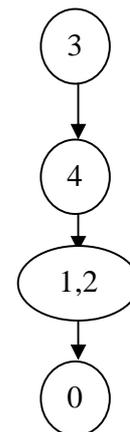
Agnes Cluster Tree

Decision Ranking

Figure 3. Cluster Tree and Decision Ranking for transport operator 2

Transport operator 3 (Figure 4): In this case, four solution clusters are identified. Indeed, a result with fewer clusters presents at least one cluster whose radius is higher than the decision-maker's limits. The decision ranking shows that solution 3 is the most efficient in terms of annual cost, followed by solution 4. Solutions 1 and 2 are less good but they still represent a significant improvement with respect to solution 0.

Agnes Cluster Tree

Decision Ranking

Figure 4. Cluster Tree and Decision Ranking for transport operator 3

Transport operator 4 (Figure 5): The resulting decision tree is different from the other operators. We observe three solution clusters, but two of them contain only one solution. The cluster containing all the solutions presents a large radius (about 30%). Regarding the decision ranking, strategy no. 4 is the most efficient, followed by solution 1, both of which are better than the other alternative strategies.
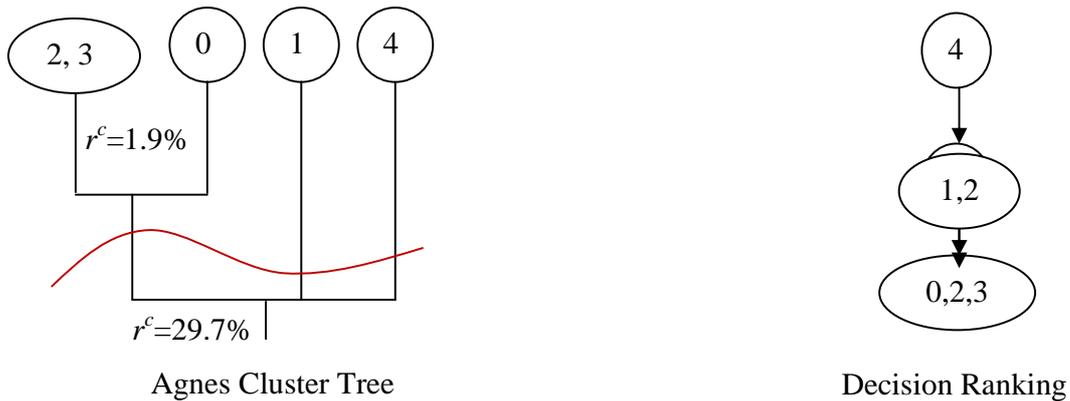

Figure 5. Cluster Tree and Decision Ranking for transport operator 4

Transport operator 5 (Figure 6): In this case, also three clusters are defined. Indeed, grouping solutions into two clusters leads to a cluster with a large radius (20%), and a unique cluster would present the largest radius (more than 30%). When examining the decision ranking, it can be seen that solution 4 is the best solution, followed by the cluster containing solutions 2 and 3, then by solutions 0 and 1.
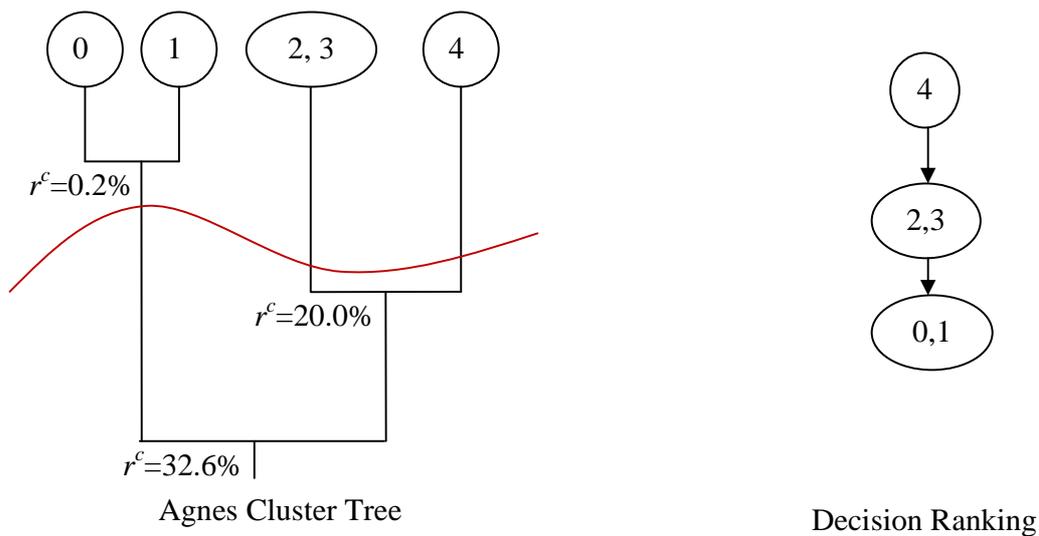

Figure 6. Cluster Tree and Decision Ranking for transport operator 5

4.2.2. Group clustering results and dominance analysis

Finally, to analyse the system's viewpoint, we repeat the same analysis taking into account the global costs for the system (Figure 7). In order to establish a set of suitable clusters, we consider the lowest threshold of all the decision-makers, i.e. 5%. Two groups are then identified: the first contains solution 4; the second includes all the others, with a radius of about 2%. The radius of a cluster containing all the solutions is about 10%. Regarding the decision ranking, we observe that the cluster of solution 4 surpasses the other cluster, so it can be said that solution 4 is more suitable than the others.
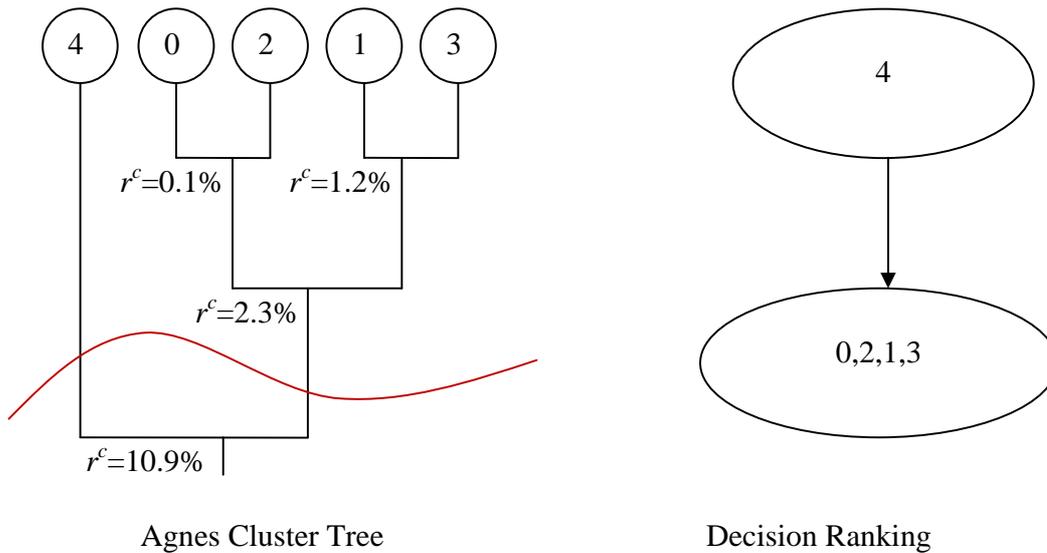

Agnes Cluster Tree   Decision Ranking

Figure 7. Cluster Tree and Decision Ranking for the overall system

In order to group the transport operators before the consensus research phase, we propose to synthesize the clustering analysis results in Table 3:

Table 3. Dominance table.

	Transport operator					System
	1	2	3	4	5	
S0	>All	>2,3,4	ND	ND	ND	ND
S1	ND	>2,3,4	>0	>0,2,3	ND	ND
S2	ND	ND	>0	ND	0,1	ND
S3	ND	ND	>All	ND	0,1	ND
S4	ND	ND	>0,1,2	>All	>All	All
Envisaged solutions for considered operator	S0	S0,S1	S3,S4	S1,S4	S2,S3,S4	S4

Remark: ND means non-dominance

According to table 3, we can establish two main decision groups and select two main strategies to be discussed by different decision makers in their consensus research phase. S4 seems a good solution for operators 3, 4 and 5 and S0 seems the most efficient for operators 1 and 2. Regarding S3 (which mainly concerns operators 1 and 3, since it is based on their bilateral collaboration), *a priori* it is a good alternative for operator 3 but not for operator 1, so it seems preferable to abandon it. Let us examine them more precisely. Whereas operators 3, 4 and 5 seem to reach easy agreement on strategy S4, it will be more difficult for operators 1 and 2. For operator 1, S4 leads of an 18% cost increase, whereas for operator 2, this increase is about 20%. On the other hand, operator 3 makes 13% savings on costs, and operators 4 and 5 make respectively 40% and 60% savings on costs. A strong-dominating solution is not identified, but strategy 4 seems to be the preferred by both a slight majority of the decision makers and by the system. Negotiation (Raifa et al., 2001) is then required to make the decision-makers converge to a consensual choice.

4.2.3. An argument discussion for research of consensus and negotiation

To initiate the discussion on negotiation, we can say that each adoption of a solution will lead to a compensation mechanism if all the partners are to join in a consortium agreement. Focusing on solution 4, transport operators 1 and 2 will require compensations to accept the solution proposed since it is more costly for them than the current situation. Using the method proposed, we will assess four compensation strategies, and compare them to a reference situation. Each compensation strategy is noted as a "hypothesis" that should not be confused with the solutions examined above (as we focus on solution 4 in this phase). The hypotheses proposed are the following (the results of this simulation are presented in table 4 after the description of the hypotheses):

- H0: Reference, i.e. a hypothesis of no compensation. It is assumed that each transport operator accepts the cost increases or gains as they are stated in the simulation of solution 4. This hypothesis has a strong impact on decision makers 1 and 2, since solution 4 represents a non-negligible cost increase for them.
- H1: equal distribution of cost savings. This hypothesis assumes that all the partners communicate their cost increases or savings, they calculate the overall cost savings with respect to solution 0 and then they divide them into 5 equal parts. The impact is strong for all the partners but in different ways: transport operators 1 and 2 and 3 have small cost savings with this hypothesis, since the distribution of the overall savings compensates their respective cost increases. Transport operator 3 has a slightly lower cost saving in comparison to hypothesis H0, but transport operators 4 and 5 have significant differences: their cost savings are bout half those of hypothesis H0.
- H2: compensation of cost increases without other distribution of savings. In this hypothesis, cost increases are compensated by cost savings, proportionally. In other words, the amount of the overall cost increases of transport operators 1 and 2 is deducted, proportionally, from the cost savings of the remaining operators. The remaining savings are not re-distributed, so operators 1 and 2 present neither cost increases nor savings, and operators 3 to 5 conserve a large part of their savings.
- H3: compensation of cost increases with equal distribution of remaining savings. The last hypothesis assumes the same compensation mechanism of cost increases as for H3 but adds an equal distribution of the remaining savings. This hypothesis leads to a

homogeneous distribution of savings (all operators present savings from 15 to more than 18%), but it mainly penalises the operators whose operational costs are lower (operators 4 and 5).

Table 4. Cost savings in comparison to the current situation (Solution 0), for each transport operator and in averages (in percentage)

	H0	H1	H2	H3
Operator 1	-18.2%	8.6%	0.0%	18.4%
Operator 2	-20.0%	3.1%	0.0%	16.0%
Operator 3	22.0%	13.4%	9.0%	15.2%
Operator 4	40.1%	22.0%	27.7%	15.5%
Operator 5	59.9%	23.1%	41.5%	15.8%
Average	16.1%	15.8%	15.6%	16.2%

Remark: Percentages are estimated according to the assumption that prices of freight transport services will remain unchanged for each operator.

We apply the proposed method and report the results of the dominance phase in table 5. In this case, it can be seen that one of the solutions matches all the decision-makers' dominant solution set. Indeed, since the marginal savings are high for transport operators 3 to 5, we observe that all the transport operators consider hypothesis H2 as one of the dominant solutions. Moreover, decision makers 1 and 2 can adopt all the compensation schemes, the only unsuitable hypothesis being H0.

Table 5. Dominance table for compensation situations.

	Transport operator				
	1	2	3	4	5
H0	ND	ND	>All	>All	>All
H1	>0	>0	ND	>3	>1, 3
H2	>0	>0	ND	>3	ND
H3	>All	>All	ND	ND	ND
Situations envisaged for operator considered	1, 2, 3	1, 2, 3	0, 1, 2, 3	0, 1, 2	0, 2

Remark: ND means non-dominance

We can conclude that in this situation consensus can be reached, but it requires a discussion and information exchange phase that is difficult to simulate. Whatever the case, the method proposed would guide and support this discussion, by enabling group decision-making and the quest for consensus by all the decision makers.

5. Conclusion

In this paper we defined vertical and horizontal collaborative logistics and freight transportation, and proposed a framework to support the main strategic planning decisions from a group

viewpoint. After reviewing the main forms of collaboration, we proposed a method to assist each stakeholder for analysing each solution and communicating with the other stakeholders in order to reach consensus. This framework is based on a hierarchical cluster analysis and a decision ranking method. To illustrate the method, we proposed an assessment of five possible strategies for collaborative transportation in last-mile freight distribution. The simulation results show two identified decision groups, and a consensus seems to be difficultly reached without negotiation (the convergence towards a unique solution for all operators is not explicit). To support negotiation, three compensation hypotheses are proposed and assessed using the proposed algorithm. The results show an application of the method and how it can support a group of heterogeneous decision makers in the choice of a common collaborative freight distribution strategy. However, the method is not able to substitute real negotiation, but can be a decision support tool for dialogue and communication in the search of agreement or consensus.

In conclusion, collaborative logistics and freight transport systems appear to be interesting strategies but each involved decision maker can diverge from the others on the best form of collaboration. Consequently, it is necessary to develop decision support systems that involve all the decision makers concerned, by preparing them to be predisposed to discussion and convergence through consensus. The proposed method can assist decision makers but it is important to note that the final decision has to be taken by these stakeholders. Although private stakeholders often have a cost-reasoning orientation in strategic decision making, other criteria, such as quality and service accuracy, are elements that cannot be neglected. Moreover, real estate and public authorities' stakeholders often adopt a multi-criteria viewpoint when dealing to strategic decision making. Further extension includes applying the proposed framework to cost-benefit analysis and multi-criteria decision-making under stochastic demand (Carrillo Murillo, 2011) in order to introduce tactical decisions in strategic planning.

Acknowledgements

References

ALLEN, J., THORNE, G., BROWNE, M. (2007), *Good Practice Guide on Urban Freight*, Bestufs, Rijswijk, The Netherlands.

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*, Vol. 24, n°1, pp. 57 – 77.

BARNHART, C., LAPORTE, G., (2007), *Transportation*, Handbooks in operations research and management science vol. 14, North Holland, Elsevier, Amsterdam.

BECKER D. (2003), *Le développement des implantations logistiques en France et ses enjeux pour les politiques d'aménagement. Rapport final,* Conseil Général des Ponts et Chaussées, Paris.

BENJELLOUN A., CRAINIC, T.G., BIGRAS, Y. (2010), Towards a taxonomy of City Logistics projects, Procedia Social and Behavioral Sciences, Vol. 2, n° 3, pp. 6217-6228.

BLANQUART C., CARBONE V. (2010), Pratiques collaboratives et démarche environnementale dans la supply chain : mythe ou réalité ?, *The 8th International Conference on Logistics and SCM Research*, 29-30 sept., 1er oct., Bordeaux, France.

BLANQUART C., CARBONE V. (2008), La place du transport dans les organisations logistiques durables, *Les cahiers scientifiques du transport*, Vol. 54, pp 11-24.

BOLEY D. (1998), Principal direction divisive partitioning, *Data Mining and Knowledge Discovery*, Vol. 2, n° 4, pp. 325-344.

BONET-FERNANDEZ D. (2009), Pouvoir et leadership dans la supply chain, *Humanisme et Entreprise*, n° 294, pp. 1-13.

BRANS, J.P., VINCKE, P. (1985), A preference ranking organisation method: The PROMETHEE method for MCDM. *Management Science*, Vol. 31, n° 6, pp. 647–656.

BREWER, A.M.,(2001), The concept of value: symbolic artefact or useful tool? In BREWER, A.M., BUTTON, K.J., HENSHER, D.A. (Eds.), *Handbook of Logisitcs and Supply Chain Management*, Pergamon, Oxford, UK, pp. 127-139.

CAMPOS GOUVÊA, V.B., RODRIGUES RAMOS, R.A., DE MIRANDA, D., CORREIA, S. (2009), Multi-criteria analysis procedure for sustainable mobility evaluation in urban areas, *Journal of Advanced Transportation*, Vol.43, n°4, pp.371-390.

CARRILLO MURILLO, D.G. (2011), Stochastic Distribution of Intermodal Transport Freight Flows in Hinterlands, *International Journal of Transport Economics*, Vol. 38, n° 1, pp. 9-38.

CIMITILE, A., VISAGGIO, G. (1995), Software salvaging and the call dominance tree, *Journal of Systems and Software*, Vol. 28, n° 2, pp. 117–127.

CRAINIC, T. G. (2008), City Logistics. In CHEN, Z. L., 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. (2004), Advanced Freight Transportation Systems for Congested Urban Areas, *Transportation Research Part C*, Vol. 12, pp. 119-137.

CRAINIC, T.G., LAPORTE, G. (1997), Planning models for freight transportation, *European Journal of Operational Research*, Vol. 97, pp. 409-438.

DABLANC, L. (2007), Urban goods transport, difficult to modernize, difficult to optimize, *Transportation research Part A*, Vol. 41, n° 3, pp. 280-285.

DANIELIS R., ROTARIS L., MARCUCCI E. (2010), Urban freight policies and distribution channels: a discussion based on evidence from Italian cities, *European Transport/Trasporti Europei*, Vol. 46, pp. 114 - 146.

DANIELIS, R., MARCUCCI, E., ROTARIS, L. (2005), Logistics managers' stated preferences for freight service attributes, *Transportation Research Part E*, Vol. 41, n° 3, pp. 201-215.

DAVIDSON, I., RAVI, S.S. (2005), Agglomerative hierarchical clustering with constraints: Theoretical and empirical results. In J. Alípio, L. Torgo, P. Brazdil, R. Camacho and J.Gama, *Knowledge Discovery in Databases: PKDD 2005*, Lecture Notes on Computer Science Vol. 3721, Springer, Berlin, pp. 59-70.

DG REGIO (2008), *Guide to Cost Benefit Analysis of Investment Projects*, European Commission, Directorade General Regional Policy, Brussels, Belgium.

DIAZ-HERNANDEZ, J.J., MARTINEZ-BUDRIA, E., JARA-DIAZ, S. (2012), The Economic efficiency in stevedoring determinants industry, *International Journal of Transport Economic*s, Vol. 39, n° 3, pp. 369-396.

EVRARD SAMUEL K., SPALANZANI A. (2009), Developing collaborative competencies within supply chains, *International Journal of Information Technology and Management*, Vol. 8, n°2, pp. 146-160.

FLIEDNER, G. (2003), CPFR: an emerging supply chain tool, *Industrial Management & Data Systems*, Vol. 103, n° 1, pp. 14-21.

GATTA, V., MARCUCCI, E. (2013), Urban freight distribution policies: joint accounting of non-linear attribute effects and discrete mixture heterogeneity, Research in Transportation Economics, forthcoming.

GARDNER J.T., COOPER M. (2003), Strategic supply chain mapping approaches, *Journal of Business Logistics*, Vol. 24, n° 2, pp. 37-64.

GENERALITAT DE CATALUNYA (2011), *Observatori de costos del transport de mercaderies per carretera a Catalunya, Butlletí de transports Número 58 – Març 2011*, Direcció General de Transports i Mobilitat, Generalitat de Catalunya, Barcelone, Spain.

GONZALEZ-FELIU, J. (2013), Multi-Stage LTL Transport Systems in Supply Chain Management. In CHEUNG, J., SONG, H. (eds.), *Logistics: Perspectives, Approaches and Challenges*, Nova Science, New York, pp. 65-86.

GONZALEZ-FELIU, J., TOILIER, F., AMBROSINI, C., ROUTHIER, J.L. (2013), Estimated data production for urban goods transport diagnosis. The Freturb methodology. In GONZALEZ-FELIU, J., SEMET, F., ROUTHIER, J.L. (eds.), *Sustainable Urban Logistics: Concepts, Methods and Information Systems*, Springer, Berlin.

GONZALEZ-FELIU, J. (2012a), Freight distribution systems with cross-docking: a multidisciplinary analysis, *Journal of the Transportation Research Forum*, Vol. 51, n° 1, pp. 93-109.

GONZALEZ-FELIU, J. (2012b), Cost optimisation in freight distribution with cross-docking: N-echelon location routing problem, *Promet – Traffic & Transportation*, Vol. 24, n° 2, pp. 143-149.

GONZALEZ-FELIU, J., AMBROSINI, C., PLUVINET, P., TOILIER, F., ROUTHIER, J.L. (2012), A simulation framework for evaluating the impacts of urban goods transport in terms of road occupancy, *Journal of Computational Science*, vol. 3, n. 4, pp. 206-215.

GONZALEZ FELIU, J., SALANOVA, J. (2012), Defining and evaluating collaborative urban freight transport systems, *Procedia – Social and Behavioral Science*, Vol. 39, pp. 172-183.

GONZALEZ-FELIU J., MORANA J. (2011), Collaborative transportation sharing: from theory to practice via a case study from France. In YEARWOOD J., STRANIERI, A. (Eds.), *Technologies for Supporting Reasoning Communities and Collaborative Decision Making: Cooperative Approaches*, Information Science Reference, Hershey, PA, pp. 252-271.

GONZALEZ-FELIU, J., MORANA, J. (2010), Are City Logistics Solutions Sustainable? The Cityporto case, *TeMA. Journal of Land Use, Mobility and Environment*, Vol. 3, n° 2, pp. 55-64.

HASTIE, T., TIBSHIRANI, R., FRIEDMAN, J. (2009), *The Elements of Statistical Learning: Data Mining, Inference, and Prediction*, Second Edition, Springer, New York.

HENSHER, D.A., BUTTON, K.J. (2001), *Handbook of transport modelling*, Pergamon, Oxford.

IANNONE, F., THORE, S. (2010), An Economic Logistics Model for the Multimodal Inland Distribution of Maritime Containers, *International Journal of Transport Economics,* Vol. 37, n° 3, pp. 281-326.

LAM, J.S.L., MEERSMAN, H. VAN DE VOORDE, E. (2012), Unveiling Supply Chain Integration and its Value in Container Shipping, *International Journal of Transport Economics*, Vol. 39, n° é, pp. 275-298.

JOHNSTON, J. (1972) *Econometric Methods*, Second Edition, McGraw Hill, New York.

LA LONDE, B., POHLEN, T. (1996), Issues in supply chain costing, *The International Journal of Logistics Management*, Vol. 7, n° 1, pp. 1-12.

KAUFMAN L., ROUSSEEUW P. (1990), *Finding Groups in Data*, New York: John Wiley and Sons.

KUTZ, M. (2003), *Handbook of transportation engineering*, McGraw-Hill, New York.

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

LAMBERT, D.M., COOPER, M., PAGH, J. (1998), Supply Chain management: Implementation Issues and Research Opportunities, *The International Journal of Logistics Management*, Vol. 9, n° 2, pp. 1-19.

LAMBERT, D.M., EMMELHAINZ, M. A., GARDNER, J. T. (1996), Developing and Implementing Supply Chain Partnerships, *The International Journal of Logistics Management*, Vol. 7, n° 2, pp. 1-17.

LATTIN, J., CARROLL, J.D., GREEN, P.E. (2003), *Analyzing Multivariate Data, Thomson Learning*, Inc., Publishing, California.

LAYARD, R., GLAISTER, S. (1994), *Cost-benefit analysis*, Cambridge University Press, Cambridge.

MANNERING, F., HENSHER, D.A. (1987), Discrete/continuous econometric models and their application to transport analysis, *Transport Reviews*, Vol. 7, n° 3, pp. 227-244.

MARCUCCI, E., GATTA, V. (2013a), Behavioral modeling of urban freight transport. Testing non-linear policy effects for retailers. In GONZALEZ-FELIU, J., SEMET, F., ROUTHIER, J.L. (eds.), *Sustainable Urban Logistics: Concepts, Methods and Information Systems*, Springer, Berlin.

MARCUCCI, E., GATTA, V. (2013b), Intra-agent heterogeneity in urban freight distribution: the case of own-account operators, *International Journal of Transport Economics*, forthcoming.

MARCUCCI, E., STATHOPOULOS, A., GATTA, V., VALERI, E. (2012), A Stated Ranking Experiment to Study Policy Acceptance: The Case of Freight Operators in Rome's LTZ, *Scienze Regionali – Italian Journal of Regional Science*, Vol. 11, n° 3, pp. 11-30.

MARCUCCI, E., STATHOPOULOS, A., ROTARIS, L., DANIELIS, R. (2011), Comparing single and joint preferences: a choice experiment on residential location in three-member households, *Environmental and Planning part A*, Vol. 43, pp. 1209–1225.

MARCUCCI, E., MUSSO, E. (2010), Urban Freight Modelling and Policy Analysis. In VAN DE VOORDE, E., VANELSLADER, T. (Eds.), *Applied Transport Economics. A Management and Policy Perspective*, de Boeck, Antwerpen, pp. 385-406.

MARCUCCI, E., DANIELIS, R. (2008), The Potential Demand for a Urban Freight Consolidation Centre, *Transportation*, Vol. 35, n° 2, pp. 269-289.

MARCUCCI, E. DANIELIS, R., MASSIANI, J. (2004), Heterogeneity in freight shippers' preferences. Proceedings of European Transport Conference, annual conference of the Association for European Transport, 4-6 Oct., Strasbourg.

MCKINNON, A. (2001), Integrated logistics strategies. In BREWER, A.M., BUTTON, K.J., HENSHER, D.A. (Eds.), *Handbook of Logisitcs and Supply Chain Management*, Pergamon, Oxford, UK, pp. 157-170.

MESNARD, X., DUPONT A. (1999), Votre logistique est-elle à la pointe ?, *L'Expansion*, n° 94, pp. 52-58.

MIN, S., ROATH, A. S., DAUGHERTY, P. J., GENCHEV, S. E., CHEN, H., ARNDT, A. D., RICHEY, R. G. (2005), Supply Chain Collaboration: What's Happening, *International Journal of Logistics Management*, Vol. 16, n° 2, pp. 237-256.

MORANA, J., GONZALEZ-FELIU, J., SEMET, F. (2012), Urban consolidation and logistics pooling. Planning, management and scenario assessment issues. In GONZALEZ-FELIU, J., SEMET, F., ROUTHIER, J.L. (eds.), *Sustainable Urban Logistics: Concepts, Methods and Information Systems*, Springer, Berlin.

MUÑUZURI, J., LARRAÑETA, J., ONIEVA, L., CORTÉS, P. (2005), Solutions applicable by local administrations for urban logistics improvement, *Cities*, Vol. 22, n° 1, pp. 15-28.

NEMHAUSER, G.L. AND WOSLEY, L.A. (1999), *Integer and Combinatorial Optimization*, John Wiley and sons, Chichester.

NIJKAMP, P., BLAAS, E. (1994), *Impact assessment and evaluation in transportation planning, Kluwer*, Dordrecht, The Netherlands.

ORTUZAR, J. DE D., WILLUMSEN, L. (2001), *Modelling Transport*, John Wiley and sons, Chichester.

PAGLIONE, G., GATTA, V. (2007), Le preferenze degli attori economici verso l'installazione di un Centro di Distribuzione Urbana (CDU): il caso di Pesaro, IX Riunione Scientifica SIET, http://www.sietitalia.org/siet9/papers/Paglione-Gatta_SIET%202007.pdf

PORTOGHESE, A., SPISSU, E., BHAT, C.R., ELURU, N., MELONI, I. (2011), A Copula-Based Joint Model of Commute Mode Choice and Number of Non-Work Stops during the Commute, *International Journal of Transport Economics*, Vol. 38, n° 3, pp. 337-364.

PREST, A.R., TURVEY, R. (1965), Cost-Benefit Analysis: A Survey, *The Economic Journal*, Vol. 75, pp. 683-735.

RAIFA H., RICHARDSON J., METCALFE D. (2002), *Negotiation analysis - The science and art of collaborative decision making*, Harvard University Press, Harvard, Etats Unis.

RAKOTONARIVO D., GONZALEZ-FELIU J., AOUFI A., MORANA J. (2009), La mutualisation. In Semet, F. (coord.), *Logistique Urbaine Mutualisée Durable. Etat de l'art scientifique et technique. Rapport final*. Prestaliss-Advancity, Paris.

ROUTHIER J. L., TOILIER F. (2007) FRETURB V3, a Policy Oriented Software of Modelling Urban Goods Movement. In *Proceedings of the 11th World Conference on Transport Research*, 24-28 June 2007, Berkeley, USA.

Roy J., Landry S., Beaulieu M. (2006), Collaborer dans la chaîne logistique : où en sommes-nous ?, *Gestion. Revue Internationale de Gestion*, Vol. 31, n° 3, pp. 70-77.

Russo, F., Comi, A. (2006), Demand models for city logistics: a state of the art and a proposed integrated system. In Taniguchi, E., Thompson, R.G. (eds.), Recent advances in city logistics, Elsevier, Amsterdam, pp. 91-105.

Russo, F., Comi, A. (2011), Measures for sustainable freight transportation at urban scale: expected goals and tested results in Europe, *Journal of Urban Planning and Development*, Vol. 137, n° 2, pp. 142-153.

Simatupang T.M., Sridharam R. (2002), The Collaborative Supply Chain, *The International Journal of Logistics Management*, Vol. 13, n° 1, pp. 15-30.

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

Stathopoulos, A., Valeri, E., Marcucci, E., Gatta, V., Nuzzolo, A., Comi, A. (2011). Urban freight policy innovation for Rome's LTZ: A stakeholder perspective. In Melo, S. and Macharis, C. (Eds.), *City distribution and urban freight transport: multiple perspectives*, Edward Elgar Publishing, Cheltenham, U.K., pp. 75-100.

Struyf A., Hubert, M., Rousseeuw P.J. (1996), Clustering in an Object-Oriented Environment. *Journal of Statistical Software* Vol. 1, n° 4, 30 p.

Sytral (2006), *Enquête ménages déplacements 2006 de l'aire métropolitaine lyonnaise*, Sytral, Lyon, France.

Tan P.N., Steinbach M., Kumar V. (2006), *Introduction to data mining*, Pearson Addison Wesley, Boston, MA.

TL&Associes, LET (2009), *Flexibilité et Impacts de la Demande de transport des différents secteurs Economiques, et simulation de Scénarios d'évolution. Rapport final*, TL&Associés, Paris.

Toth, P., Vigo, D. (2002), *The Vehicle Routing Problem*, SIAM Monographs on Discrete Mathematics and Applications 9, SIAM, Philadelphia.

Tudela, A., Akiki, N., Cisternas, R. (2006), Comparing the output of cost benefit and multi-criteria analysis An application to urban transport investments, *Transportation Research Part A*, Vol. 40, pp. 414–423.

Velton, V., Stewart, T.J. (2002), *Multiple criteria decision analysis: an integrated approach*, Kluwer, Norwell, MA.

WADELL, P., ULFARSSON, G.F. (2004), Introduction to urban simulation: design and development of operational models. In Hensher, D.A., Button, K.J., Haynes, K.E., Stopher, P.R., *Handbook of transport geography and spatial systems*, Elsevier, Oxford, pp. 203-236.

WALLER M., JOHNSON M., DAVIS T. (1999), Vendor managed inventory in the retail supply chain, *Journal of Business Logistics*, Vol. 20, n° 1, pp. 183-203.

WARD, J. H. (1963), Hierarchical Grouping to Optimize an Objective Function, *Journal of the American Statistical Association*, Vol. 58, pp. 236–244.

WARDROP, J. G. (1952). Some theoretical aspects of road traffic research, *Proceedings of the Institute of Civil Engineers, PART II*, Vol.1, pp. 325–378.

WASHINGTON, S., KARLAFTIS, M., MANNERING, F. (2003), *Statistical and econometric methods for transportation data analysis*, CRC Press, Boca Raton FL.

WIERZBICKI, A. (1980), The use of reference objectives in multiobjective optimization. In Fandel, G. Gal, T. (eds.), *MCDM Theory and Application*, Springer-Verlag, Berlin, 468-486.

WONNACOTT, T.H., WONNACOTT, R.J. (1990), *Introductory statistics for business and economics*, 5th edition, John Wiley & sons, New York.

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

YEARWOOD, J., STRANIERI, A. (2010). Group Structured Reasoning for Coalescing Group Decisions, *Group Decision and Negociation*, Vol. 19, n° 1, pp. 77-105.

YEARWOOD, J., STRANIERI, A. (2006). The generic/actual argument model of practical reasoning, *Decision Support Systems*, n° 41, pp. 358-379.

Appendix: Adaptation of an Agnes clustering algorithm to collaborative decision support

The Agnes clustering method proposed in section 3 is derived from Struyf et al.'s (1996) method. It can be defined as follows.

Take a group of *M* decision-makers discussing the development of collaborative logistics and a transport system, and a set of *N* possible strategies. Each decision-maker is considered as an individual and each strategy to be assessed can be identified as a solution of the decision problem envisaged, i.e. the objective of group reasoning. In this context the decision problem is to reach consensus on choosing the best strategy for the group, but this solution does not necessarily lead to an optimal system. It is assumed that each solution will be examined by each decision-maker and that each of the latter has the same information concerning the potential costs and benefits of each strategy, in order to assess if it is advantageous for them. Moreover, each decision-maker uses the same techniques and assumptions in order to ensure the use of a homogeneous decision scale. To assist each decision-maker to find the most suitable solution and examine the difficulties preventing convergence to consensual decision, the paper proposes to analyse the main decision groups in the community. A decision group is defined as a group of individuals converging to the same solution. In other words, it is a subset of decision-makers who consider the same solution as good for them, even if it is not always the best alternative, and agree to implement it.

Denote the set of decision-makers as $V_D=\{1; \ldots; k; \ldots; M\}$, and the set of strategies as $V_S=\{0; \ldots; i; \ldots; N\}$. Each strategy i is then assessed by decision-maker k on the basis of the decision function $f^k(i)$. Each decision-maker k defines a vector F^k of the decision functions as follows:

$$F^k = \begin{bmatrix} f^k(1) \\ \vdots \\ f^k(i) \\ \vdots \\ f^k(N) \end{bmatrix} \text{ where } f^k(i) \text{ is the value of the decision function for strategy i.}$$

Therefore each decision maker k defines their dissimilarity matrix D^k as follows:

$$D^k = \begin{bmatrix} 0 & \ldots & D_{1j}^k & \ldots & D_{1N}^k \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ D_{i1}^k & \ldots & 0 & \ldots & D_{iN}^k \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ D_{N1}^k & \ldots & D_{Nj}^k & \ldots & 0 \end{bmatrix} \text{ where } D_{ij}^k \text{ is the distance between solutions } i \text{ and } j.$$

Given F^k and D^k, we can then explore the solution space of each decision-maker, using the agglomerative nesting algorithm which works as follows. First, in the initialization phase, we define N clusters (one for each solution of decision vector F^k). We define each cluster's centroid c_i as a dummy solution whose decision function is the average of the values for each solution included in the cluster. In the initialization phase, this centroid is characterized by $f(c_i)=f(i)$ and $D_{ci-i}=0$. Then, at iteration e, we compare all the clusters and merge the two that are closest to each

other. In other words, given set V_e of clusters at iteration e, we merge clusters i and j if $D_{ij}^k < D_{gh}^k; g,h \in V_e$.

This cluster is denoted as c and then the cluster's centroid is associated to the decision function $f^k(c)$ as follows:

$$f^k(c) = \underset{i \in c}{Average}\left[f^k(i)\right].$$

Next, each distance to the cluster's centroid is recalculated in the following way:

$$D_{ci}^k = f^k(k) - f^k(c)$$

We define the cluster radius r^{kc} as the average distance between a solution in the cluster and its centroid, i.e. $r^{kc} = \underset{i \in c}{Average}\left[D_{ci}^k\right]$.

Although the main clustering methods merge clusters by pairs, we consider that the situation where a cluster has the same or a very similar distance to two others can occur. Consequently, we define the incomparability threshold u for each decision-maker k, and given a cluster i, compared to other two clusters j and l.

If $\left|D_{ij}^k - D_{il}^k\right| < u$, we merge clusters i, j and l, and calculate all the corresponding attributes of the new cluster (decision function, centroid and, for each solution, its distances to the centroid).

The iterations are repeated until it is found a single cluster grouping all the solutions. Then, for each decision-maker, we select the number of decision clusters to be retained for analysis. To do this, each decision-maker k defines a comparability threshold δ^k as the distance between two solutions under which he/her considers that they can belong to the same cluster. In other words, we consider that clusters i and j have to be taken into account separately if $r^{kc} > \dfrac{\delta^k}{2}$.

Once the number of solution clusters has been defined, we build a solution ranking diagram in which the priorities are represented.
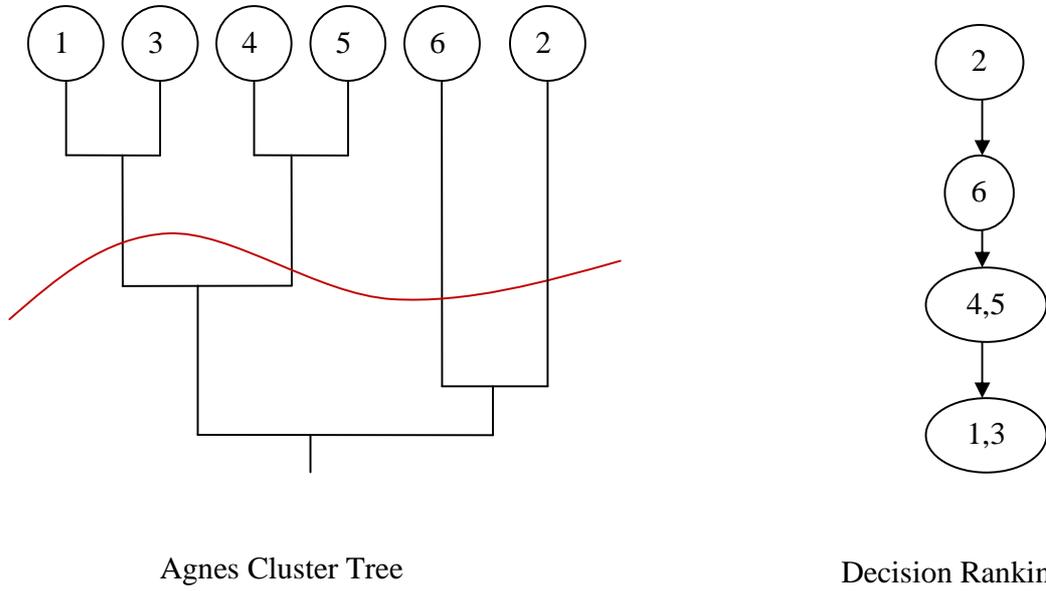
Agnes Cluster Tree   Decision Ranking

Figure 8. Example of a cluster tree and a decision ranking for a decision-maker having a set of six solutions

Analogously to the individual clustering phase, we can define the decision function vector F and dissimilarity matrix D by taking a systemic view. Indeed, if we aggregate the values of each decision-maker's decision function for solution i, we obtain the value of decision function $f(i)$ for the global system:

$$F = \begin{bmatrix} f(1) \\ \vdots \\ f(i) \\ \vdots \\ f(N) \end{bmatrix} \quad \text{where } f(i) \text{ is the value of the decision function.}$$

Then, the dissimilarity matrix can be defined as follows:

$$D = \begin{bmatrix} 0 & \dots & D_{1j} & \dots & D_{1N} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ D_{i1} & \dots & 0 & \dots & D_{iN} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ D_{N1} & \dots & D_{Nij} & \dots & 0 \end{bmatrix} \quad \text{where } D_{ij} \text{ is the distance between solutions } i \text{ and } j.$$

Then, hierarchical clustering is carried out in a similar way for each decision maker. The function values are, therefore, those corresponding to a systemic approach integrating all the individuals. In other words, the values of F for the system do not show explicitly which decision-makers are the most advantaged or disadvantaged, but only show the value of the decision from a system viewpoint. The Agnes cluster Tree and the Decision Ranking are then calculated using the same algorithm as for individual clustering but on a systemic perspective.