CIRRELT

Centre interuniversitaire de recherche sur les réseaux d'entreprise, la logistique et le transport

Interuniversity Research Centre on Enterprise Networks, Logistics and Transportation

Analysis of Building Coalitions and Savings Sharing – Application to Forest Transportation

Jean-François Audy
Sophie D'Amours
Mikael Rönnqvist

July 2009

CIRRELT-2009-26

Bureaux de Montréal :
Université de Montréal
C.P. 6128, succ. Centre-ville
Montréal (Québec)
Canada H3C 3J7
Téléphone : 514 343-7575
Télécopie : 514 343-7121

Bureaux de Québec :
Université Laval
2325, de la Terrasse, bureau 2642
Québec (Québec)
Canada G1V 0A6
Téléphone : 418 656-2073
Télécopie : 418 656-2624

www.cirrelt.ca

UNIVERSITÉ LAVAL UQÀM HEC MONTRÉAL ÉCOLE POLYTECHNIQUE MONTRÉAL Université de Montréal

Analysis of Building Coalitions and Savings Sharing – Application to Forest Transportation

Jean-François Audy[1,2,*], Sophie D'Amours[1,2], Mikael Rönnqvist[3]

[1] Interuniversity Research Centre on Enterprise Networks, Logistics and Transportation (CIRRELT)

[2] Département de génie mécanique, Pavillon Adrien-Pouliot, Université Laval, Québec, Canada G1K 7P4

[3] Norwegian School of Economics and Business Administration, Hellevein 30, NO-5045 Bergen, Norway and The Forestry Research Institute of Sweden, Uppsala Science Park, SE-75183 Uppsala, Sweden

Abstract. Transportation is an important part of the forestry supply chain. Typically, several forest companies operate in the same region. However, coordination of the wood flows between two or more companies is rare. The recent identification of important potential savings has raised interest in collaborative transportation planning to support coordination. Even though substantial savings can be realised, two key questions exist: (i) how should the potential savings be divided among a group of collaborating companies and (ii) among the potential collaborating companies, how should the collaborating group(s) be formed? In this paper, the two questions are studied in a specific context: among the potential collaborating companies, a subset, denoted the *leadings companies*, performs the collaborative transportation planning on behalf of the others. We use the concept of a business model to detail such context. Based on the literature on network formation where potential savings are modelled by a cooperative game, four business models in four different scenarios of leading companies are thus explored. We propose a longest path model as a new method to determine the stable and credible group(s) in each computation. A case study including eight forest companies is described and analysed.

Keywords. Game theory, OR in natural resources, transportation, graph theory, horizontal cooperation.

Acknowledgements. The authors wish to thank Philippe Marier of FORAC Research Consortium for his contribution to this work. The authors would also like to acknowledge the financial support of the Natural Sciences and Engineering Research Council of Canada (NSERC) and the private and public partners of the FORAC Research Consortium. Finally, the authors wish to thank the Forestry Research Institute of Sweden for the data used in the case study as well as the eight companies involved.

---

* Corresponding author: Jean-Francois.Audy@cirrelt.ca

Dépôt légal – Bibliothèque et Archives nationales du Québec,
Bibliothèque et Archives Canada, 2009

1. Introduction

Transportation is an important part of the wood flow chain in forestry. Large volumes and relatively long transport distances together with increasing fuel prices and environmental concerns create the need for improved transportation efficiency. Typically, several forest companies operate in the same region. Harvest areas supply mills that transform the round wood comprised of several assortments (defined by e.g. species, dimension and quality) into a basket of end-products (e.g. lumber, veneer) as well as by-products (e.g. chips, sawdust). These latter are then shipped to other mills for further transformation (e.g. pulp, paper). However, coordination of the wood flows between two or more companies is rare, even when supply (e.g. harvest areas) and demand (e.g. mills) points from different companies are evenly distributed geographically within a region. Forsberg et al. (2005) describe a Decision Support System (DSS) based on Operations Research (OR) methods that allows the coordination of the wood flows between companies. Two opportunities of coordination are computed in this DSS called FlowOpt.

Figure 1 illustrates the first opportunity: wood bartering between two companies. Four mills (i.e. two mills for company 1 and two mills for company 2) and a set of supply areas are considered. In the left part, each company operates by itself while in the right part both companies use all supply areas as a common resource. As a result, with wood bartering, volumes of some supply areas are exchanged between the companies to reduce the total travelling distance.

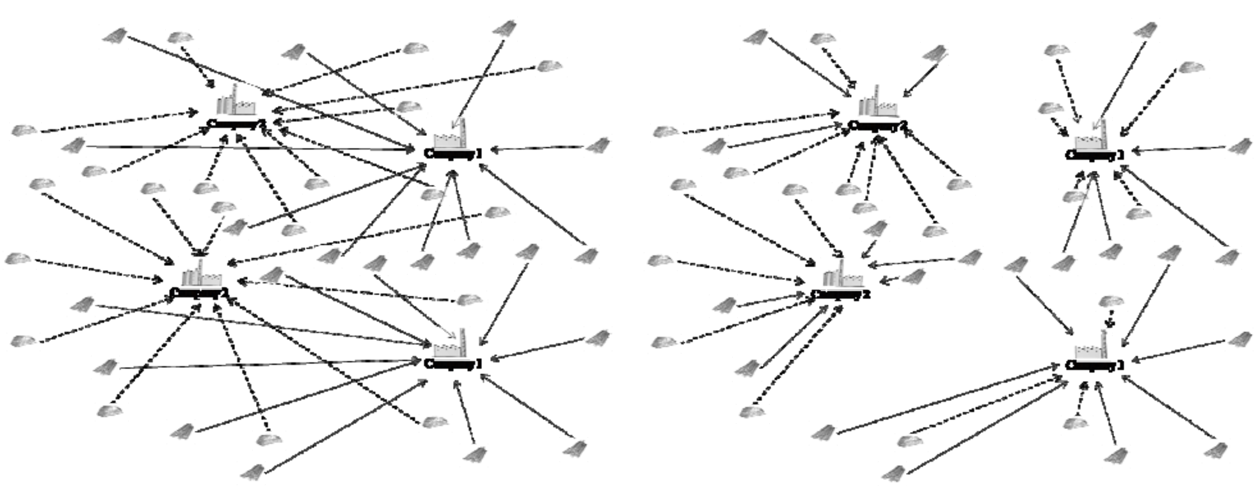

Figure 1: Improvements in transportation efficiency using wood bartering

Figure 2 illustrates the second opportunity: backhauling between two companies. Two mills (i.e. a sawmill and a papermill) and their respective delivery trips (sawlogs to sawmill and pulp logs to papermill) are considered. In the left part, each company uses an individual (back and forward) delivery trip while in the right part the companies combine their individual delivery trips into one to reduce the total unloaded travelling distance (i.e. broken lines).

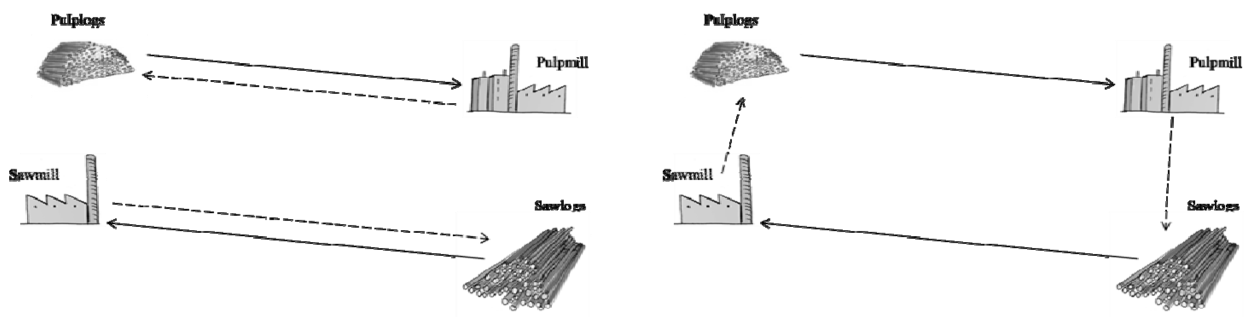

Figure 2: Improvements in transportation efficiency using backhauling

By improving transportation efficiency, this coordination leads to a reduction in transportation cost; see Forsberg et al. (2005) and Frisk et al. (2009) for industrial case studies conducted with the FlowOpt system. However, this coordination is conditional on collaboration between companies in transportation planning. As pointed out by Frisk et al. (2009), when coordination should be included in the integrated planning there is a number of questions that arise such as: (a) How to compute the potential savings of a coordination of the wood flows among a set of collaborating companies? (b) How should the potential savings be divided among the collaborating companies? We also add: (c) Among the potential collaborating companies, how should the collaborating group(s) be formed? For an empirical study of the three questions, we use an industrial case study with eight forest companies embedding potential savings with coordination of the wood flows. This case study is based on the same as described in Frisk et al. (2009).

To address question (a), we examine the literature on horizontal cooperation, see Cruijssen et al. (2007a) for a survey of this field. The European Union (2001) defines horizontal cooperation as "concerted practices between companies operating at the same level(s) in the market". These cooperating companies can be competitors or not but they should perform the same type of activities and/or services rather than performing complementary activities and/or services, which is related to vertical cooperation. See Simatupang and Sridharan (2002) for an in-depth discussion on vertical cooperation and Mason et al. (2007) on lateral cooperation, which is the combining of both horizontal and vertical cooperation. Moreover, the notion of "company" should not be considered too restrictively. For instance Barratt (2004) notes that horizontal cooperation can also be conducted among the business units (e.g. departments, divisions) inside a sole company that works as if they themselves were a company. Cruijssen et al. (2007a) provides a more logistics oriented definition where "horizontal cooperation is about identifying and exploiting win-win situations among companies that are active at the same level of the supply chain in order to increase performance."

In this paper, the latter definition is more relevant to address question (a). Indeed, in addition to the case studies in Forsberg et al. (2005) and Frisk et al. (2009), there exist several other cases studies in the literature where companies obtain savings with horizontal cooperation in road transport planning, see e.g. Caputo and Minonno (1996), Bahrami (2002), Cruijssen et al. (2005), Palander and Väätäinen (2005), le Blanc et al. (2007), Cruijssen et al. (2007b,c), Ergun et al. (2007), Krajewska et al. (2007), Mason et al. (2007), Audy et al. (2008) and Clifton et al. (2008). In many of these case studies, the common savings are defined as the difference between the cost of the common solution (i.e. transportation planning of all companies together) compared to the sum of the cost of each stand-alone solution (i.e. transportation planning of each company alone). A decision support system such as the above-mentioned FlowOpt system allows computing both common and stand-alone solutions which in turn allows computing the potential common savings obtained through collaboration by any group of two to all eight forest companies of our case study.

Cooperative game theory addresses both questions (b) and (c) in the study of *cooperative game with transferable utility (TU-game).* Any situation in which a group of companies, through cooperation (such as a collaboration in the transportation planning), can obtain a certain benefit (such as a savings) which can be divided without loss between them is described in such a TU-game. Moreover, in such a TU-game, a company is named a *player* and a group of cooperating companies a *coalition*. For a survey on the concepts and applications of game theory in the field of supply chain management, we refer to Leng and Parlar (2005), Cachon and Netessine (2006), Chinchuluun et al. (2008), Meca and Timmer (2008) and Nagarajan and Sošic (2008). In this paper, the case study embedding potential savings with coordination of the wood flows among the forest companies is described as a TU-game. However, given the requirement that coordination of the wood flows should be included in the planning, the TU-game is studied according to a specific context: among the eight companies, a subset, denoted the *leading companies* (LC), performs the planning on behalf of the others, denoted the *non-leading companies* (NLC). This context involves some modifications to the study of the TU-game and to describe them, we use the concept of a *business model*. A business model involves restrictions on question (b): the distribution of the benefit and, question (c): the formation of the coalition(s). To respect such restrictions in the study of the TU-game, we examine the literature on *network formation* where the potential cooperating savings are modelled by a TU-game such as the one described in our case study. By combining graph theory and both cooperative and non-cooperative game theory, the literature on network formation is well suited to address questions (b) and (c).

We explore four different business models and each of them is evaluated according to four *leadership scenarios* of distinct subsets of LC. The restrictions in the formation of the coalition(s) are the same among the four business models while there is a difference in the distribution of the benefits. Two business models follow a *savings allocation rule* to split the common savings among the collaborating companies while the two others follow a *cost allocation rule* to split the common cost among the collaborating companies. Moreover, in both the cost and the savings approaches, the *allocation rule* is customized according to a plausible altruistic or opportunistic behaviour by the LC. By adopting an opportunistic behaviour instead of an altruistic one, the LC aims to obtain additional benefit at the expense of the NLC. Thus, the comparison of the two business models within the same approach allows evaluating, question (b): how much additional benefit can the LC obtain by adopting an opportunistic behaviour instead of an altruistic one and, question (c): whether the final(s) coalition(s) that have been formed are the same or not?

Furthermore, the impact of the sequence in which the NLC are included in the coalition on the benefit of the LC is evaluated.

The research contribution of our paper is twofold. First, by including practical business considerations in our study of questions (b) and (c), we analyze both questions according to the self-interested objective of a subset of the players rather than all of them, and we demonstrate the impacts of such an objective on the results of both questions. Second, we propose a longest path model as a new method to determine the stable coalitions required by our analysis in the first contribution. The literature on horizontal cooperation in transportation almost never pays attention to the formation of stable coalitions, rather, most of the literature presumes that the grand coalition (i.e. the coalition of all potential cooperating players) always forms, while in practice the players, in making their coalition formation decisions, can face substantial limitations, such as the ones raised by our business models.

The paper is organized as follows. In Section 2 we introduce transportation planning in forestry and we describe the collaborative organisation managed by the LC. In Section 3 we describe the foundations of our TU-game while in Section 4 we describe the game through the field of network formation. In Section 5 we discuss the allocation rule for sharing the savings and we provide a tree representation of our game while in Section 6 we propose a longest path model to represent the game. In Section 7 we detail the case study and in Section 8 we present the numerical results. In Section 9 we discuss a number of practical aspects considering the proposed model and, finally, we make concluding remarks.

2. Transportation planning

Transportation planning in forestry is done in several steps and is commonly managed according to four time-perspective horizons: strategic, tactical, operational and real-time. Decisions at the strategic level often deal with forest management, wood procurement, road upgrade/building/maintenance considerations and transportation modes decisions. Tactical decisions mainly address planning issues from one week to one year (e.g. budget planning). On an annual basis, transportation is often integrated with harvesting planning, deciding on the catchment areas to supply the mills with the right wood assortments at the lowest cost. Operational decisions concern the planning of the entire route schedule for each individual truck for one or many days. Real-time decisions concern the dispatching of the next trip (or part of a route) to one truck in the present situation (e.g. when a truck completes a delivery). There exist many papers and case studies on different OR problems occurring in transportation planning in forestry, see review papers such as Rönnqvist (2003), Epstein et al. (2007) and D'Amours et al. (2008). In order to allow companies to deal with such OR problems, many decision support systems have also been developed, see e.g. routing system such as ASICAM (Weintraub et al., 1996), Åkarweb (Eriksson and Rönnqvist, 2003), MaxTour (Gingras et al., 2007), VTM (Audy et al., 2007) and RuttOpt (Andersson et al., 2008).

The case study in this paper is based on a classical problem in OR, the transportation model, with some modifications for the forestry context and to allow the use of backhauling. Thus, the OR problem consists in determining the destination-mill(s) of the wood assortments volume, that is, which supply point(s) should deliver to which demand point(s) in what volume. With a *common* planning of the OR problem (i.e. a planning with the supply and demand points of all collaborating companies), we obtain a solution which provides all the cost-effective wood bartering and backhauling coordination opportunities among the collaborating companies. A complete description of this OR problem and the decision support system, FlowOpt, use for its planning is found in Forsberg et al. (2005).

In the paper, the collaborating companies outsource the common planning of the OR problem to the LC. Thus, the LC acts as an organisation that manages the collaboration by, essentially, i) collecting the information (e.g. supply, demand), ii) performing the planning and, iii) providing each collaborating company with a 'collaborative plan' to put into practice. This 'collaborative plan' is specific to each company and is composed of two information parts. The first part advises the wood bartering and backhauling coordination opportunities within the supply and demand of the company. This information is easily extracted from the solution of the common planning of the OR problem. The second part concerns the monetary benefit obtained by the company in the collaboration. This information is computed with an allocation rule, which requires cost information obtained with common and stand-alone planning of the OR problem. More details on the allocation rule are provided in section 5. Our concept of a *business model* allows addressing both questions (b) and (c) according to the specific context of such a collaborative organisation.

The issues on how exactly, among the collaborating companies, the monetary exchanges are performed in order that each company reaches its monetary benefit is beyond the scope of this paper, as well as the definition of the exact information technology required by such a collaborative organisation. However, note that tailored allocation rules have recently been suggested in the literature to tackle the first issue, see e.g. Houghtalen et al. (2009) and Özener and Ergun (2008), while the second issue could be addressed by migrating the actual FlowOpt system to a web-based system such as the above-mentioned routing system Åkarweb and VTM.

3. Definition of the cooperative graph-restricted game

A TU-game is given by a pair (N,v), where N={1,2,3…,n} denotes a finite set of n players and v is the *characteristic function*, assigned to every coalition $S \subseteq N$ a *worth v(S)*, representing the total benefit of this coalition of players when they cooperate. The coalition with all players is called the *grand coalition* and each coalition with only one player, a *singleton coalition*. A *coalition structure* is a partition of the n players into distinct coalitions (a player cooperates in only one coalition). A *payoff* represents the individual benefit of a player for its cooperation on a coalition. In the literature, the notion of *n-person game with transferable utility* is also used to represent a *TU-game* and the notion of *utility* is also used to represent the *worth* of a coalition.

The worth of a coalition in a context of an OR problem with a minimization objective refers generally to a savings whereas with a maximization objective the worth refers to a profit. The OR problem of the case study has a minimization objective. Its solution provides the total transportation cost for the coalition while the worth of that coalition represents the total savings in transportation cost obtained through collaboration. Thus, the value of the *characteristic function* is computed from the solutions of the FlowOpt system. Specifically, the cost of a given coalition S, $c(S)$, is obtained from the system as well as the cost of the singleton coalition T_j of each company j in the coalition S, $c\left(T_j\right),\ \left|T_j\right|=1,\ T_j \subset S, j \in S$. The worth of that coalition S is easily computed by equation (1):

$$v(S) = \sum_{j \in S} c\left(T_j\right) - c(S) \qquad (1)$$

Obviously, *v(ø)* = 0 and *v(S)* = 0 if S is a singleton coalition. Also, the worth of a coalition does not depend on non-member players, i.e. there is no externality between the coalitions, and hence v(S) denotes the savings that the members of the coalition S can obtain on their own.

According to the solutions of the FlowOpt system on each coalition $S \subseteq N$, we can state certain properties of the studied game. The game is *superadditive*, since $v(S \cup T) \geq v(S) + v(T)$ for any disjoint coalitions $S, T \subseteq N$ such that $S \cap T = \varnothing$. In others words, a merge is always profitable (or at least not unprofitable). Also, the game is strictly *monotonic* increasing since $v(T) \succ v(S)$ for any coalitions $T \subset S \subset N$. Finally, the game is a *non constant-sum* since $v(S) + v(\overline{S}) \neq v(N)$ for all complementary coalitions S and $\overline{S}$ because all the savings provided by the opportunities in coordination of the wood flows between the players of the two distinct coalitions are lost.

In classical cooperative game theory, it is assumed that any and all coalitions are likely to form. However, in many specific contexts, it is possible that some coalitions cannot be formed due to certain social, hierarchical, economical, communicational or other restrictions, see van den Brink et al. (2007) for a list of papers on each. Introduced in cooperative game theory by Myerson (1977), graph theory provides a suitable tool for explicitly modelling these restrictions in the game. In Myerson graph theory formulation, a node represents a player and an undirected arc (i.e. link between two nodes) represents a potential to have a bilateral cooperative agreement between players *i* and *j*. Myerson defines a *cooperation structure* as all the feasible links between the potential agreeing players. The players "connected" on a non-directed graph *g* resulting from a given cooperation structure form a coalition. Even if two players do not have a direct bilateral agreement between each other, they may still be in the same coalition if they are "connected" through intermediate player(s). All the resulting "unconnected" graphs (i.e. the network structure) furnish the set of the distinct coalitions formed among the *N* players (i.e. the coalition structure). Following the works of Myerson, directed graph were then introduced in the literature. By using oriented arc from node *i* to *j* instead of undirected arc, we can represent more complex restrictions such as, e.g. player *i* can propose to player *j* to cooperate, whereas, player *j* cannot propose to player *i* to cooperate unless there exists an oriented arc *j* to *i*.

Our concept of business model introduces such graph restrictions in the study of the TU-game. Specifically, we impose a *cooperation structure* where one central player *i*, representing the leading(s) company(ies), is directly connected to every other non leading company *j* by an oriented arc *i* to *j* and there are no other arcs. Thus, the LC is the only one that can propose to a NLC to collaborate and only one coalition, necessarily including the LC, can be formed. Figure 3 shows an example of *cooperation structure* restricting a game with six players, player 1 being the leader. In the literature on network formation, this cooperative graph-restricted game without directed arcs is a special kind of cycle-free network called a 'star' in which there exists a node *i*, i.e. the centre of the star, such that every link in the network involves node *i* (Jackson, 2008).

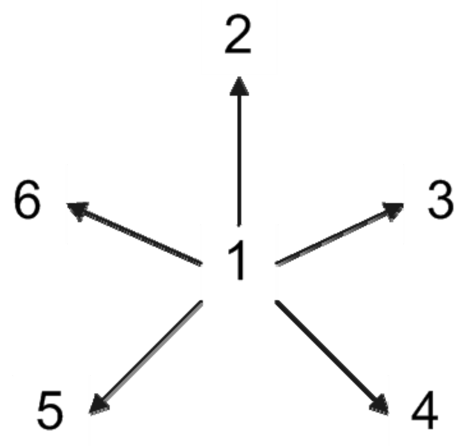

Figure 3: Example of a six-player cooperative graph-restricted game with player 1 being the LC

4. Description of the network formation game in extensive form

In classical cooperative game theory, the approach which is generally assumed during the formation of the coalitions is that any number of players can simultaneously join or abandon a coalition. However, in other contexts, only bilateral agreements to cooperate between players can occur and a player must maintain its previous agreement in any further bilateral agreement. For instance, Macho-Stadler et al. (2006) study the sequential merger among two companies, two groups of already merged companies or between a company and a group of already merged companies. Vidal-Puga (2007) studies a situation in which only one coalition is formed in the sequential inclusion of one new player. In a context similar to our case study, Cruijssen et al. (2005) study a procedure allowing a logistics service provider to form, with sequential offer to a set of potential collaborating shippers, the grand coalition. Finally, Cruijssen et al. (2007c) study the development of a hub distribution network (i.e. a distribution network in which transhipment is allowed at specific intermediate facilities called hubs) by a step-wise procedure in which only one shipper at a time joins the coalition, which is the jointly investing hub distribution network hub.

In this paper, our concept of business model imposes such approaches with permanent and sequential bilateral agreement in the study of the TU-game. Moreover, to respect the cooperative graph-restricted game such as the one in Figure 3, the bilateral agreement can only be proposed by the LC and the unique coalition is formed through a sequence of bilateral agreements between the LC and the NLC. In order to tackle such a sequential, permanent and player' restricted bilateral agreement in the coalition formation, we draw on the literature on *network formation* where all the potential cooperating worth are modelled by a TU-game in extensive form.

The literature on *network formation* incorporates, among other matters, the graph theory formulation supporting the modelling of the cooperative graph-restricted game; see Demange and Wooders (2005) and Jackson (2008) for exhaustive surveys on the network formation literature. Thus, the set of the "unconnected" graph g resulting from the links formed in the cooperative graph-restricted game (i.e. the network structure) provides the coalition structure. The modelling by a TU-game, instead of value functions on networks, of the worth obtained by each resulting coalition allows specifying the worth of the coalition represented by graph g on which players are connected with one another within the graph g and not on how exactly its players are connected within the graph g, see van den Nouweland (2005) for a survey of papers based on this modelling approach. Finally, the study of the game in extensive form, rather than in normal/strategic form, allows being more explicit about the issue of timing in the study of the game. Indeed, games in extensive form allow studying sequential bilateral agreements over many time periods while games in normal/strategic form are limited to bilateral agreements in one time period.

Network formation games in extensive form were introduced in the paper of Aumann and Myerson (1988), see Bloch and Dutta (2008) for a recent survey of the literature on sequential models of network formation. In the game of Aumann and Myerson, an exogenous rule gives the sequence of pairs of players that have an opportunity to make a bilateral agreement, i.e. to form a link between them. Bilateral agreements cannot be broken once they have been made. All players observe which pairs of players made or not an agreement when they have the opportunity to do so, i.e. we are in a game of perfect information. Mutual agreement is required to form a link and each player takes its decision with a look-ahead perspective, i.e. in addition to considering whether he will be better off with this link than without it, the player considers whether the formation of this link could end with a better or worse final payoff for him according to the further potential opportunities in links between other pairs of players. This look-ahead perspective is based on two assumptions in the game. First, the players take their decision in a self-interested way to maximize their own individual final payoff. Second, the worth of each resulting coalition (modelling by a TU-game) will be divided among its players according to an exogenous allocation rule, the Myerson value (Myerson, 1977). The Myerson value is an extension of the Shapley value (Shapley, 1953), a well-known allocation rule, to TU-game in which exactly how the players in a coalition are connected must be considered in the determination of the payoffs.

The game by Aumann and Myerson is finite in time: the game ends when, after the last link has been formed, all pairs of players without a bilateral agreement have, according to the sequence given by the exogenous rule, a last opportunity to make it, but do not agree. An equilibrium concept, the *subgame perfect Nash equilibrium (SPNE)*, is applied to provide a prediction about the decision of each player at each opportunity and thus, makes a prediction about the ending network structure. A SPNE is a refinement of the well-known *Nash equilibrium* (Nash, 1951) for a finite game of perfect information in game in extensive form. The network structure supporting a SPNE, and by extension each resulting coalition, is said to be *stable* and *credible*. A network structure is *stable* when the prediction about the set of decisions by each player is the 'best response' (i.e. allows the highest individual final payoff) against the sets of decision of the other players and, *credible* when these predictions hold at each 'step' of the game (i.e. at each opportunity to make a bilateral agreement). In a *stable* and *credible* network structure, no player, at any step of the game, could benefit from a modification in its predicted set of decisions.

Our concept of business model in the study of the TU-game imposes a similar approach with two main differences. First, to respect the cooperative graph-restricted game, the sequence of pairs of players that have an opportunity to make a bilateral agreement is determined by the LC and each pair involves a LC. Second, we do not follow a two-stage process in which the coalitions are formed and then the worth of each is divided among their players, rather, both are determined simultaneously. Thus, the proposition of bilateral agreement by the LC includes an immediate payoff for the NLC if this latter agrees and, in some business models, a description of the potential additional payoffs if other NLC also agree on further propositions by the LC. We put emphasis here on the word ‘potential’ since, in contrast to the immediate payoff, each of the additional payoffs for the NLC is conditional on the conclusion of a further bilateral agreement between the LC and other NLC’s. The procedure study by Cruijssen et al. (2005) involves such an announcement of the potential for additional payoffs within the proposition to collaborate. How are the immediate payoff and, in some business models, the potential additional payoffs computed by an allocation rule? Each of the four different business models explored in this paper uses a different allocation rule and each rule is described in the following section.

5. Allocation rule of each business model

Several cost/savings allocation rules exist in practice in the industry and in the field of cooperative game theory. An extensive review of cost allocation methods, mostly based on cooperative game theory such as the *Shapley value* and the *nucleolus*, can be found in Tijs and Driessen (1986) and Young (1994). The computing and analysis of some cost allocation methods on a case study similar to the one in the paper is presented in Frisk et al. (2009) as well as a new method, based on a linear programming model, that aims for proportionally equal payoff to each player.

There is no single and all-purpose method to achieve cost/savings allocation. Cooperative game theory provides a set of *properties* to study cost/savings allocation methods among a set of players. When choosing an existing method or developing a new one, we seek one that satisfies specific properties which are considered essential to meet in our context. In the context of our collaborative organisation, three of these properties must be satisfied by the allocation rule of each of the four business models. First, the propriety of *efficiency*, which requires that the common cost/savings of a coalition must be split entirely among its players. Second, the propriety of *individual rationality*, which requires that no player is worse off by collaborating on a coalition. Third, the *cross monotonic* propriety, which requires that the payoff of a collaborating player does not decrease with the conclusion of new bilateral agreements between the LC and other NLC. We had a fourth propriety recently introduced in the field of cooperation in transportation (see e.g. Audy et al. (2008), Özener and Ergun (2008), Perea et al. (2008)), which is a reinforcement of the *individual rationality*: no collaborating player can receive a null payoff. In other words, being a participant in a coalition must offer a positive benefit to the collaborating player.

The allocation rules of the four business models are based on the same allocation scheme: an allocation according to the stand-alone weighted cost of each player in the coalition. This allocation scheme is easy to understand and to compute. Thus, each allocation rule is a close version of the others according to i) a cost or a savings allocation approach and, ii) an *altruistic* or an *opportunistic* behaviour by the LC. In contrast to more advanced methods, the aim is to demonstrate through simple and easily customized allocation rules how the behaviour of the LC can affect benefit sharing among the collaborating players as well as the development and the size of the coalition.

Two business models follow a *cost allocation rule* while the two others follow a *savings allocation rule*. The cost approach consists in allocating the cost of a coalition *S* while the savings approach consists in allocating the worth of a coalition *S*. Thus, the payoff of a player *i*, v_i, is computed by equation (2) where y_i is the cost/savings-value allocated to player *i* by the cost/savings allocation rule:

$$v_i = c(T_i) - y_i \qquad (2)$$

In both the cost and the savings approaches, the *allocation rule* is customized according to a plausible *altruistic* and *opportunistic* behaviour of the LC. The distinction between both behaviours concerns the share of the *marginal worth increase* when a player *j* accepts a bilateral agreement proposed by the LC, which is the difference between the worth of the 'new' coalition S and the 'previous' coalition T, such that $T = \{S \setminus j\}$. The allocation rule coming from an altruistic behaviour shares the marginal worth increase among all the players of the 'new' coalition *S* while the one coming from an opportunistic behaviour shares the marginal worth increase only between player *j* and the LC. Thus, the proposition of bilateral agreement by an opportunistic' LC includes only one payoff for the NLC (i.e. the immediate payoff) while the proposition by an altruistic' LC includes the immediate payoff as well as a description of the potential additional payoffs. Sprumont (1990) introduces the notion of *population monotonic* *allocation scheme* to describe a situation in which, as with our two allocation rules customized to imitate an altruistic behaviour by the LC, the payoff to every player increases as the coalition to which he belongs grows larger (i.e. new player joins). The allocation rules of each of the four business model are:

Business model 1: the cost allocation approach with altruistic behaviour

According to the rule of this business model, each time a player *j* accepts the LC's proposition, the cost of the 'new' coalition S, c(S), is reallocated among all its players. The allocation is performed according to the proportion of the player's stand alone cost of the sum of all the players' stand alone cost in coalition S. The fundaments of this rule do not respect the *cross monotonic* propriety. However, by an appropriate selection of the sequence in which the LC makes its proposition of bilateral agreement to NLC, it is possible to respect the *cross monotonic* propriety in the case study.

Business model 2: the cost allocation approach with opportunistic behaviour

According to the rule of this business model, each time a player *j* accepts the LC's proposition, the cost allocated to the LC is recomputed while the cost allocated to the NLC is computed only once, that is, when the NLC accepts the proposition. Specifically, for each 'new' coalition S, the allocation of the cost of coalition *S* is computed in three steps. First, the cost allocated to player j is computed: this is the part of the cost of coalition S that corresponds to the proportion of its stand alone cost on the sum of all the players' stand alone cost in coalition S. Second, the remaining part of the cost of coalition S is computed by withdrawing the cost allocated to player j in the first step and all the cost allocated to the NLC in the previous iterations. Finally, the remaining cost is allocated among the LC according to the proportion of the LC's stand alone cost on the sum of all the LC' stand alone cost.

Business model 3: the savings allocation approach with altruistic behaviour

According to the rule of this business model, each time a player *j* accepts the LC's proposition, the *marginal worth increase* between the coalition *T* and the 'new' coalition *S* is allocated among all the players of coalition S. The allocation is performed according to the proportion of the player's stand alone cost on the sum of all the players' stand alone cost in coalition S.

Business model 4: the savings allocation approach with opportunistic behaviour

According to the rule of this business model, the *marginal worth increase* when player *j* accepts the LC's proposition is allocated only between the player *j* and the LC. Specifically, for each 'new' coalition S, the allocation of the *marginal worth increase* between coalitions *T* and *S* is computed in three steps. First, the part of the *marginal worth increase* allocated to player *j* is computed: it is the part of the *marginal worth increase* that corresponds to the proportion of its stand alone cost on the sum of all the players' stand alone cost in coalition S. Second, the remaining part of the *marginal worth increase* is computed by withdrawing the part allocated to player j in the first step. Finally, the remaining part of the *marginal worth increase* is allocated among the LC according to the proportion of the LC' stand alone cost on the sum of all the LC' stand alone cost.

5.1. Tree representation of the network formation game in extensive form

A finite game of perfect information in extensive form such as the one in our paper can be represented by a simple tree where a node has a player's label and the outgoing edge(s) of this node corresponds to the available decision(s) for the player at this step of the game. At each step, the player can make only one decision, i.e. select only one of the available outgoing edge(s). Figure 4 shows a small example of simple tree with three players, player 1 being the LC, in which the cost of coalition *S*, $c(S)$, are: $c(\{1\}) = 4$, $c(\{2\}) = 8$, $c(\{3\}) = 5$, $c(\{1,2\}) = 10$, $c(\{1,3\}) = 8$, $c(\{2,3\}) = 10$, $c(\{1,2,3\}) = 13$.

The *root node* corresponds to the first player that must make a decision and, according to its decision, the subsequent node, if any, corresponds to the next player that would have to make a decision, and so on. For instance, the tree starts with player 1 that must take a decision among three outgoing edges: one is labelled 'E' while the two others are labelled 'P'. In this paper, our concept of business model imposes the LC at the root nodes and the available decisions to the LC and the NLC must be different. Thus, the LC is allowed to propose ('P') a new bilateral agreement to a specific NLC or to end ('E') the game by not proposing any new bilateral agreement. The NLC are allowed to accept ('A') or refuse ('R') the proposition of bilateral agreement by the LC. When the NLC accept the LC' proposition, a link is formed between them and individual payoffs are obtained. In our network formation game, only the outgoing edges labelled 'A' can form links and provide individual payoffs. To keep the tree as short as possible, we represent the end of the game when a NLC refuses the offer by the LC while, according to any of our four business models, the LC has the opportunity to continue the game with the other NLC's without bilateral agreement or, even later, proposes again a bilateral agreement to a NLC that has previously refused.

A sequence of decisions by the players determines a path through the tree. The individual final payoffs (computed with the allocation rule of business model 4 in Figure 4) for the respective players are given at the end of each potential path, labelled 'a' to 'i' in Figure 4. Each path provides an answer to both questions (b) and (c). For instance, path 'c' corresponds to, question (b): the formation of coalition {1,2} and the singleton coalition {3}, and, question (c): a individual final payoff of 0.67 for player 1, 1.33 for player 2 and zero for player 3. Moreover, a path tells us details about the issue of timing in the answers to both questions (b) and (c). For instance, path 'e' tells us that player 1 first takes the decision to make a proposition to player 2 and then to player 3, while in path 'i' it is the opposite case. And, as we can see by comparing the individual final payoffs of paths 'e' and 'i', the choice of the sequence to reach the same coalition (the grand coalition in paths 'e' and 'i'), has an impact on the individual final payoff of player 1 as well as the two other players.

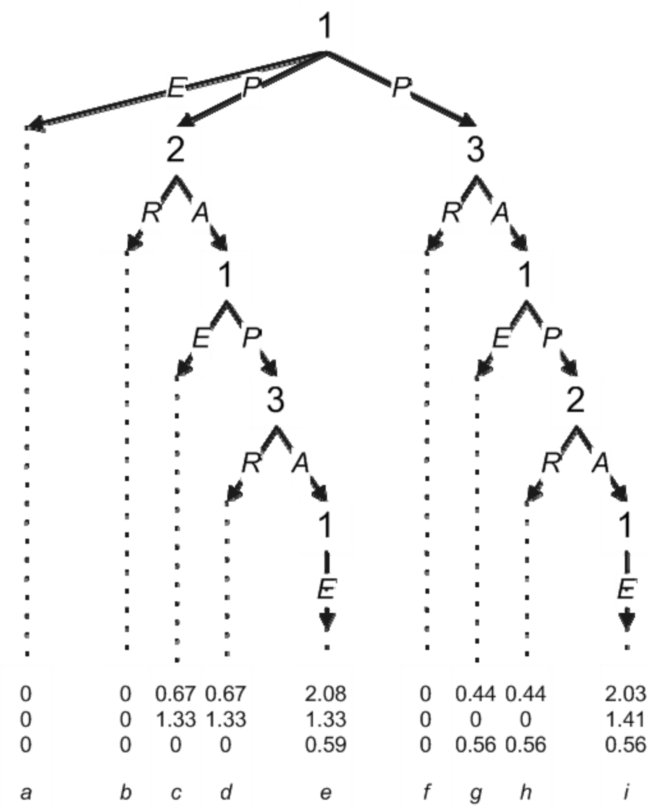

Figure 4: Example of a three-player network formation game in extensive form with player 1 being the leading company

By providing a prediction about the decision of each self-interested player at each node, the solution concept of *subgame perfect Nash equilibriun* (SPNE) allows identifying which path, among all potential paths, will be taken and thus, to answer to questions (b) and (c). The method of *backward induction* could be used to determine the path supported the SPNE in the game. Essentially, this method consists in starting the predictions at each decision node without successor and reaching back in the tree to the root node. For instance, path 'e' supports the SPNE in the game represented by Figure 4. In this paper, a longest path model is proposed as a new method to determine the path supported the SPNE, i.e. to determine the *stable* and *credible* coalitions.

6. Longest path model to represent the network formation game in extensive form

The objective of the LC is the formation of a stable and credible coalition in such a way that they will maximize their individual final payoff, as opposed to that of each of the players. To determine the *optimal* path according to this objective, we can formulate our network formation game in extensive form by an OR problem: the longest path problem. Given a network of oriented arcs from node *i* to node *j* with each a length value, the objective in this OR problem is to find the longest path in the network to reach a sink node *0** starting by a source node *0*. The indexes, sets, parameters and decision variables used in the longest path model are defined in Table 1.

Table 1: Indexes, sets, parameters and decision variables

Indexes	
S	: a coalition
T	: a coalition, such that $T = \{S \setminus j\}$
0	: the pseudo-player source
*0**	: the pseudo-player sink
Sets	
A	: set of all oriented arcs to go from coalition S to T
A'	: set of all oriented arcs to go from coalition S to T, such that the pseudo-player sink is excluded from the coalition T, $A' \subset A$
Parameter	
$M_{S,T}$	: *marginal payoff increase* for the LC from coalition S to T

Decision variable	
$x_{S,T}$	: 1 if the *optimal* path goes from coalition *S* to *T*, 0 otherwise

The longest path problem [LPP] can be formulated as following:

$$\text{[LPP]} \quad \text{MAX} \sum_{(S,T)\in A'} M_{S,T} x_{S,T}$$

s.t.

$$x_{S,T} - \sum_{(T,U)\in A} x_{T,U} = 0 \quad \forall (S,T)\in A' \tag{3}$$

$$\sum_{(S,T)\in A|S=0} x_{S,T} = 1 \tag{4}$$

$$\sum_{(S,T)\in A\setminus A'} x_{S,T} = 1 \tag{5}$$

$$x_{S,T} \in \{0,1\} \quad \forall (S,T)\in A$$

In this context, a node represents an 'ordered' coalition, e.g. the coalition '1,2' is different from the coalition '2,1' even if they regroup the same players. The value of the oriented arcs represents the *marginal payoff increase* for the LC when player *j* accepts the proposition of bilateral agreement and thus, coalition *T* is formed from coalition *S*, such that $T = \{S \setminus j\}$. Each of these values is computed according to the allocation rule of a specific business model. All oriented arcs starting from the pseudo-player source or arriving at the pseudo-player sink have a null marginal worth increase. The objective of the [LPP] is to find the path traversed in the network (i.e. from the pseudo-player source to the pseudo-player sink) that allows the total maximal payoff to the LC, which is the sum of each of the oriented arc values on this path. The constraints (3) ensure that the formation of the coalition is made by sequential bilateral agreement. The constraints (4) and (5) ensure that only one coalition is created.

An illustrative numerical example

In order to illustrate the formation of the coalition following the [LPP] formulation, we reconsider the small example of three players in Figure 4 and in which the worth of coalition *S*, *v(S)*, are: $v(\{1\}) = 0$, $v(\{2\}) = 0$, $v(\{3\}) = 0$, $v(\{1,2\}) = 2$, $v(\{1,3\}) = 1$, $v(\{2,3\}) = 2$, $v(\{1,2,3\}) = 4$. Since player 1 is the LC and he (or she) can only propose a bilateral agreement to one NLC at the time without the obligation to make a proposition to all of them, the set A is equal to ((0,01), (01,012), (01,013), (01,010*), (012,0123), (012,0120*), (013,0132), (013,0130*), (0123,01230*), (0132,01320*)) while the set A' is equal to ((0,01), (01,012), (01,013), (012,0123), (013,0132)). Figure 5 shows the graph on which the [LPP] must be solved. The value on each oriented arc represents the marginal payoff increase for the LC if player *j* accepts their proposition and the coalition *T* is formed from coalition *S*, such that $T = \{S \setminus j\}$. In order to follow the logic of the tree representation of our game in Figure 4, we deliberately represent the graph of the [LPP] with a top-to-bottom orientation of the source and the sink, rather than a right-to-left as in the OR literature. Moreover, the letters in parentheses on each of the pseudo-players' sink entering arcs refers to the paths ending with an edge labelled 'E' in the tree representation of the game in Figure 4.

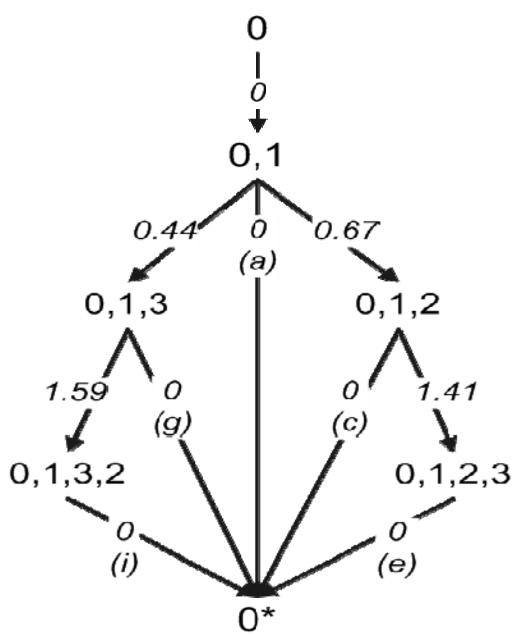

Figure 5: the [LPP] representation of network formation game in extensive form

The mathematical model based on the [LPP] can be stated as:

$$\text{MAX } 0.67x_{01,012} + 0.44x_{01,013} + 1.41x_{012,0123} + 1.59x_{013,0132}$$

s.t.

$$\begin{aligned}
&x_{0,01} - (x_{01,012} + x_{01,010*} + x_{01,013}) = 0 \\
&x_{01,012} - (x_{012,0123} + x_{012,0120*}) = 0 \\
&x_{01,013} - (x_{013,0132} + x_{013,0130*}) = 0 \\
&x_{012,0123} - (x_{0123,01230*}) = 0 \\
&x_{013,0132} - (x_{0132,01320*}) = 0
\end{aligned} \tag{3}$$

$$x_{0,01} = 1 \tag{4}$$

$$x_{01,010*} + x_{012,0120*} + x_{013,0130*} + x_{0123,01230*} + x_{0132,01320*} = 1 \tag{5}$$

$$x_{S,T} \in \{0,1\} \quad \forall (S,T) \in A$$

In Figure 5, we can see that the optimal path for the LC is the longest path 0, 1, 2, 3, 0* with a total individual final payoff of 2.08 for the LC. This total individual final payoff corresponds to a reduction of 52% of the LC's stand-alone cost (i.e. $c(\{1\}) = 4$) as well as a catch by the LC of 52% of the worth generated by the final coalition (i.e. $v(\{1,2,3\}) = 4$). Obviously, the optimal path is the path supporting the SPNE, i.e. the path which determines the *stable* and *credible* coalition(s).

Moreover, by following the optimal path, instead of the one we denote by the *worst path* (i.e. in Figure 5, the path 0, 1, 3, 2, 0* with a total final payoff of 2.03), the LC obtain a 0.05 (2.5%) additional payoff. The worst path must leads to the exact same final coalition as the optimal path (in Figure 5: the grand coalition) but with the sequence providing the lower total final individual payoff to the LC. Finding the worst path is equivalent to solving the *shortest path problem* with the constraint to connect all the companies connected by the optimal path.

Finally, as for a path in the tree representation of the game in Figure 4, the answer, with the timing issue, on both questions (b) and (c) can be deduced.

7. Numerical results

The numerical results are based on a case study involving eight forest companies operating in Sweden. For an average Swedish mill, the one-way delivery distance for round wood is 80 km and transportation operations account for 27% of its supply cost (Frisk, 2008). Moreover, transportation represents up to 0.45 billion €/year for the Swedish forest companies and approximately a third of this cost is fuel (Frisk, 2008). Given this large amount of money spent on transportation, a small cost reduction can lead to important savings. Furthermore, transportation is not a core activity for the wood processing mills and, consequently, this reduces the level of risk associated with the collaboration. These conditions (i.e. high potential return, low risk, not core activity) provide a good business context for the establishment of a collaborative organization in transportation.

7.1. Description of the case study

The data has been taken from a case study done by the Forestry Research Institute of Sweden for eight participating forest companies. The companies operate in southern Sweden and cover different geographical areas. Figure 6 shows the operation areas of the eight companies. The darker polygons indicate high volume supply areas of one or more supply points while bigger circles represent high volume demand points. Company 2 covers the entire region while the others only one or more parts. The data represent the transports carried out during one month for a total of 898 supply points, 101 demand points and 12 wood assortments (depending on e.g. species and dimensions).

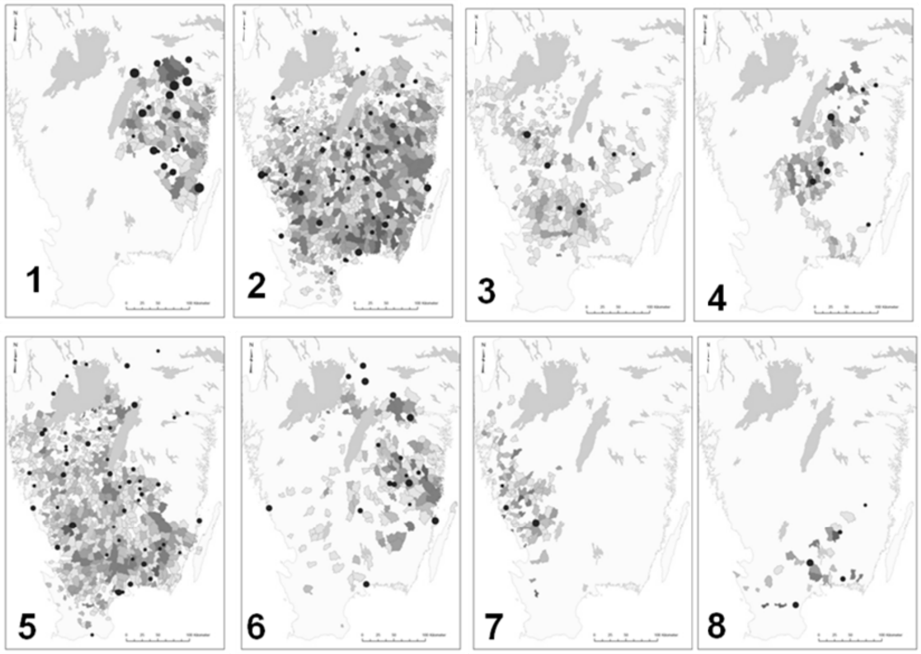

Figure 6: The operation areas for the eight companies

The companies are different volumes and Table 2 shows the company weighted volume transported and their stand alone weighted cost. We see that the company weighted volume is strongly linked to the company stand alone weighted cost.

Table 2: Proportion of volume and stand alone cost per company

Company	Volume	Stand-alone cost
1	8.8%	8.6%
2	34.2%	34.8%
3	10.1%	11.1%
4	5.0%	4.8%
5	26.3%	24.0%
6	10.7%	11.4%
7	4.2%	4.5%
8	0.7%	0.8%

To be able to solve the [LPP] according to the four business models and with any leadership scenario among the eight forest companies, upstream work on the data in the case study is required. First, we need to compute, with equation (1), a worth for every coalition $S \subseteq N$. To use equation (1), the common planning of the OR problem of all combinations of coalition involving 2 to 8 of the companies has been done with the FlowOpt system in order to provide the cost of 247 (2^8-8-1) distinct combinations of a coalition. Also, to obtain the stand alone cost of each player (e.g. the eight singleton coalitions), the planning of the OR problem with only the supply and demand points of the company has also been done with the FlowOpt system. Second, according to the above-mentioned allocation rule in each of the four business models, we need to compute the value for each oriented arc, which is the *marginal payoff increase* for the LC from coalition *S* to *T*, such that $T = \{S \setminus j\}$.

7.2. Description of the leadership scenario

Each business model has been evaluated according to four leadership scenarios in which one, two or four companies among the eight are the LC. The choice of these four leadership scenarios is based on the below-mentioned hypothesis and other leadership scenarios could be evaluated.

Leadership scenario 1: the larger player

According to the two opportunities in coordination of the wood flows in Figures 1 and 2, the companies with a large volume evenly distributed over different geographical areas are usually the companies who can generate the greatest savings by collaborating with any other company. Thus, it appears realistic to suppose that one or more LC's with a large volume and a fairly good geographical cover (in both harvest areas and mills) could reach a 'critical size' to initiate the collaboration with initial propositions including enough payoffs to convince a few first players to accept to collaborate. Then, with a greater size, substantial payoff can be generated with any player outside the actual coalition and thus facilitate the snowball effect on the growth of the collaborative organisation. With more than a third of the total volume carried and harvest areas and mills covering the entire region, company 2 alone surpasses our notion of 'critical size' and it is the LC in this first scenario.

Leadership scenario 2: the second largest player with a player completing its coverage

In this second scenario, companies 1 and 5 are jointly the LC. The sharing of leadership by the two companies is mutually advantageous. They obtain together a weighted volume and a cover of the different geographical areas almost equal to company 2 and thus, together they reach a business position to initiate the collaboration that is as advantageous as that of company 2. Also, for the second largest company 5, a shared leadership with company 1 specifically is highly strategic from the point of view of the geographic cover. Both companies do not operate within the same geographical areas and the combination of their respective geographic cover fits like two pieces of a puzzle. Their collaboration only generates a modest savings of 0.8% ($110,146) which is not surprising for two players with adjacent geographic cover.

Leadership scenario 3: the two mid-size players

In this third scenario, companies 3 and 6 are jointly the LC. These two companies are the two mid-size players among the eight players. Together, they increase their weighted volume and obtain a partial, but well distributed coverage of the entire region. Their similarities (i.e. volume and dispersed cover) favour a joint leadership while together they generate a savings of 1.3% ($121,897).

Leadership scenario 4: the four smaller players

In this last scenario, companies 1, 4, 7 and 8 are jointly the LC. These companies are the four smaller players among the eight companies. Together, they become the third largest weighted volume and obtain coverage in many geographical areas. Their similarities (i.e. small volume, narrow and isolated coverage) favour a joint leadership while they generate together a savings of 1.7% ($134,188).

8. Results analysis

Table 3 shows the results with leadership scenario 1 computed according to the four different business models. Tables 4, 5 and 6 show the same results for, respectively, leadership scenario 2, 3 and 4. In the columns “Optimal path” and “Worst path” we provide, respectively, the more and less lucrative paths for the leading company(ies). The optimal path is the path that supports a SPNE while the worst path leads to the exact same final coalition as the optimal path but with the sequence providing the lower total final individual payoff to the LC. The difference between both optimal and worst paths is provided, in percentage and cost value, in the column “Difference”.

In business model 1, all paths which lead to the final coalition maximizing the total individual final payoffs of the LC are optimal paths. Consequently, we indicate the number of optimal paths that are available for the LC to form this final coalition. In leadership scenario 4 (i.e. the four smaller players), we should note an exception to the previous statement. In order to respect the *cross monotonic* propriety in the allocation, two paths (i.e. 3, 5, 2, 6 and 3, 5, 6, 2) among the entire 24 potential paths to reach the grand coalition are not allowed since, in both, the payoffs of player 3 are reduced by 0.19% ($9,079) when player 5 joins the coalition. In the three other leadership scenarios, all the available optimal paths respect the *cross monotonic* propriety.

Column “LC total final payoff” shows, in percentage (compared to the total stand-alone cost of the LC) and in cost value, the total final payoff of the LC. The last column shows the percentage of the worth of the final coalition taken by the LC or, in other words, the percentage part the final payoff of the LC represented on the sum of the final payoff obtained by all the collaborating companies. The case study highlights several results. In the next subsections, we analyse a number of them.

Table 3: Main results of leadership scenario 1 - the larger player

Business model	Optimal path	Worst path	Difference		LC total final payoff		LC proportion of the total worth of the final coalition
1	All the 720 paths that lead to the final coalition {2,3,4,5,6,7,8}				9.5%	$1,400,519	38.0%
2	1, 5, 8, 4, 6, 7, 3	3, 7, 6, 4, 8, 5, 1	5.2%	$761,378	16.2%	$2,383,788	60.5%
3	3, 7, 8, 4, 6, 5, 1	5, 1, 6, 8, 4, 7, 3	2.9%	$426,256	15.0%	$2,201,067	55.8%
4	4, 1, 6, 3, 8, 7, 5	3, 5, 6, 7, 4, 1, 8	1.1%	$161,356	22.4%	$3,282,559	83.3%

Table 4: Main results of leadership scenario 2 - the second largest player with a player completing its coverage

Business model	Optimal path	Worst path	Difference		LC total final payoff		LC proportion of the total worth of the final coalition
1	All the 720 paths that lead to the final grand coalition				9.3%	$1,286,565	32.6%
2	2, 8, 4, 6, 7, 3	7, 3, 2, 4, 6, 8	3.1%	$432,052	16.2%	$2,239,878	56.8%
3	7, 3, 4, 8, 2, 6	2, 6, 8, 4, 7, 3	1.6%	$218,603	13.5%	$1,868,065	47.4%
4	2, 8, 4, 7, 6, 3	3, 2, 6, 7, 8, 4	1.6%	$214,011	22.1%	$3,049,227	77.4%

Table 5: Main results of leadership scenario 3 - the two mid-size players

Business model	Optimal path	Worst path	Difference		LC total final payoff		LC proportion of the total worth of the final coalition
1	All the 120 paths that lead to the final coalition {2,3,4,5,6,7,8}				9.5%	$908,812	24.7%
2	1, 5, 8, 4, 2, 7	7, 4, 2, 8, 5, 1	8.6%	$818,603	19.8%	$1,889,297	47.9%
3	7, 4, 2, 8, 5, 1	5, 1, 2, 8, 4, 7	4.0%	$377,708	16.9%	$1,606,806	40.8%
4	1, 5, 8, 4, 7, 2	2, 1, 4, 5, 7, 8	3.0%	$288,121	29.5%	$2,807,986	71.2%

Table 6: Main results of leadership scenario 4 - the four smaller players

Business model	Optimal path	Worst path	Difference		LC total final payoff		LC proportion of the total worth of the final coalition
1	All the 24 paths that lead to the final grand coalition except the paths 3, 5, 2, 6 and 3, 5, 6, 2				9.3%	$736,118	18.7%
2	5, 2, 6, 3	3, 6, 2, 5	10.6%	$838,410	24.9%	$1,963,205	49.8%
3	3, 6, 2, 5	5, 2, 6, 3	3.4%	$267,622	16.5%	$1,305,700	33.1%
4	2, 6, 5, 3	3, 6, 2, 5	3.9%	$309,085	36.3%	$2,863,558	72.6%

8.1. Business model 1 and player 1

If player 1 is one of the LC in business model 1 (i.e. leadership scenarios 2 and 4), the grand coalition will form with a 9.3% final individual payoff for each of the eight players. On the other hand, if player 1 is not one of the LC (i.e. leadership scenarios 1 and 3), the final coalition {2, 3, 4, 5, 6, 7, 8} will form and player 1 will end in a singleton coalition {1}. Alone in its singleton coalition, player 1 is therefore the loser of this result with a null payoff while the seven other players receive a 9.5% final individual payoff. The reason for this exclusion is simple: even the addition of player 1 to coalition {2, 3, 4, 5, 6, 7, 8} results in a marginal worth increase of 0.61%, according to the altruistic cost allocation rule in business model 1, its addition reduced by 0.2% the payoffs of the seven other players. In other words, in business model 1, at the expense of the other players, player 1 receives more benefits than its volume can generate in the grand coalition. Overall, the exclusion of player 1 in leadership scenarios 1 and 3 leads to final coalitions that do not capture the entire economic potential in collaboration. The loss of overall supply chain profitability because of self-interested players has been greatly studied in the literature on vertical cooperation in supply chain management, see e.g. Simatupang and Sridharan (2002).

If for any reason, excluded player 1 has an influence on the LC (e.g. player 1 assumes a portion of the supply of one or several of the mills of leading player 2 in the leadership scenario 1), player 1 can use its influence to force leading player 2 to make a bilateral agreement proposition. Such a notion of influence of a potential user, of an on-going implementation inter-organizational system, against another potential user has been studied in the field on information systems, see e.g. Boonstra, A., and J. de Vries (2008). To maintain its final individual payoff, leading player 2 must propose a final individual payoff to player 1, which is, at the maximum, equal to the marginal worth increase of 0.61%. By accepting an individual payoff equal to its marginal worth increase, player 1 obtains 76.2% (a loss of $80,820) of the individual payoff that he would have obtained if he had been one of the LC or if we had addressed the formation of the coalition according to a maximization objective of the coalition's worth rather than the total final individual payoff of the LC (i.e. a subset of the players).

8.2. Altruistic versus opportunistic behaviour

In the four computed leadership scenarios, by adopting an opportunistic behaviour rather than an altruistic one in the same cost/saving allocation approaches, the leading companies have obtained an additional individual payoff of 6.9-19.7%. The greater difference belongs to the last leadership scenario in which the four smaller players have increased their total individual payoff by 15.6% (a gain of $1,227,087) and 19.8% (a gain of $1,557,858) in respectively, the cost and saving allocation approaches. Obviously, this additional benefit for the LC with an opportunistic behaviour was made at the expense of the benefit share for the NLC but, as with the adoption of altruistic behaviour, all the above-mentioned proprieties in the allocation (e.g. *individual rationality*) were respected with the opportunistic behaviour.

In 2008, three of the eight companies involved in the case study started a collaboration where monthly coordinated planning was done (Lehoux et al., 2009). Based on this recent development, we note that an altruistic behaviour seems more suitable to a collaborative organization driven by one or a set of shipping companies (as in our leadership scenarios) while an opportunistic behaviour seems closer to a collaborative organization driven by one or several carriers or third party logistics. More details on the latter collaboration organization are provided in Table 7.

8.3. Optimal and worst sequence

In business models 2 to 4 in the four computed leadership scenarios, by taking to their advantage the decision on the sequence in which to propose a bilateral agreement to the NLC, the LC have obtained a 1.1-10.6% additional total payoff. For instance, in business model 2 with the leadership scenario 1, leading player 2 obtains an additional individual payoff of 5.2% (a gain of $761,378) by following the (optimal) sequence 1, 5, 8, 4, 6, 7, 3 rather than the (worst) sequence 3, 7, 6, 4, 8, 5, 1. Figure 7 shows both optimal (left) and worst (right) paths for this specific case.

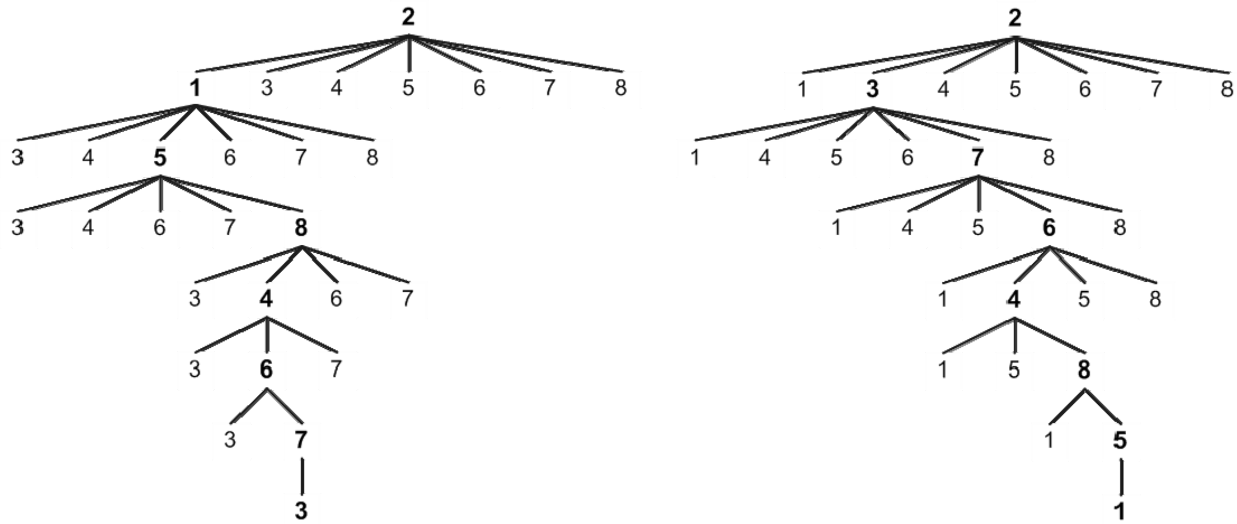

Figure 7: Optimal and worst paths for leading player 2 in business model 2

Among the four leadership scenarios, it is interesting to note that in business models 2 and 3, the sequence of the worst path is (or almost) the reverse of the optimal path (e.g. Figure 7). The reason for this is different for the two business models.

In business model 2, there are players with important volumes and dense covers on their respective geographical areas (i.e. players 1, 2 and 5, which for the sake of clarity we denoted as the α players) in the beginning of the optimal sequence of the four computed scenarios. The transportation planning of the volume belonging to the α players with the volume belonging to the LC will generate new coordination opportunities with any LC or α player. In this business model, the proposition to the NLC includes only one individual payoff (i.e. the immediate payoff). Thus, it is advantageous for the LC to fix the individual payoff of the α players as early as possible in the sequence in order to avoid sharing later with them the savings coming from the synergies generated with their volume.

In business model 3, the players with small volume and lean, partial and dispersed geographic cover are (e.g. players 4, 7 and 8, which for the sake of clarity we denoted as the β players) at the beginning of the optimal sequence of the four computed scenarios while the α players are predominantly at the end of the optimal sequence. In this business model, the marginal worth increase of the 'new' coalition S is shared with all players of coalition T ($T = \{S \setminus j\}$) and player j

using the stand alone weighted cost of the player. Thus, it is more advantageous for the LC to start with the β players and player 3 than the α players. Together with the volume of the LC, the volume of the β players and player 3 (see discussion in next paragraph) will generate smaller marginal worth increase than the volume of the α players. However, the LC will obtain a higher part of this small marginal worth by not starting the sequence with the α players that, with their relative high stand-alone cost, received a larger part of the further marginal worth increases.

Players 3 and 6 are similar players both in their volume and stand-alone cost percentages (compared to the grand coalition, see Table 2) and the characteristics of their geographic cover. However, in business model 3, player 3 is at the beginning of the sequence while player 6 is at the end of the sequence or just before the α players. The difference in the location of the main operation areas of players 3 (i.e. in the south-west) and 6 (i.e. in the north-east) mostly explains the results. With its location, player 3 provides to the LC with more synergies than player 6. At the bottom line, these additional synergies allow to the LC more benefits than the larger part of the further marginal worth increases player 3 will receive with its higher (compared to the β players) stand alone weighted cost.

8.4. The value of being a leading player

By being a leading player, a company improves its final individual payoff. For each of the four business models, Figure 8 illustrates the final payoff of player 2 according to the four leadership scenarios. We see that player 2 obtains higher payoffs by being an LC (i.e. leadership scenario 1) rather than being a NLC (i.e. leadership scenarios 2, 3 and 4). Especially, by taking alone the leadership in scenario 1, player 2 improves by 1.5% ($20,488), 59.9% ($1,427,215), 45.3% ($996,870) and 80.4% ($2,638,443) for, respectively, the business models 1, 2, 3 and 4, if we compare to its average final payoff in scenarios 2-4. These values represent the opportunity cost of not being, alone or with another specific player, a LC in each business model.

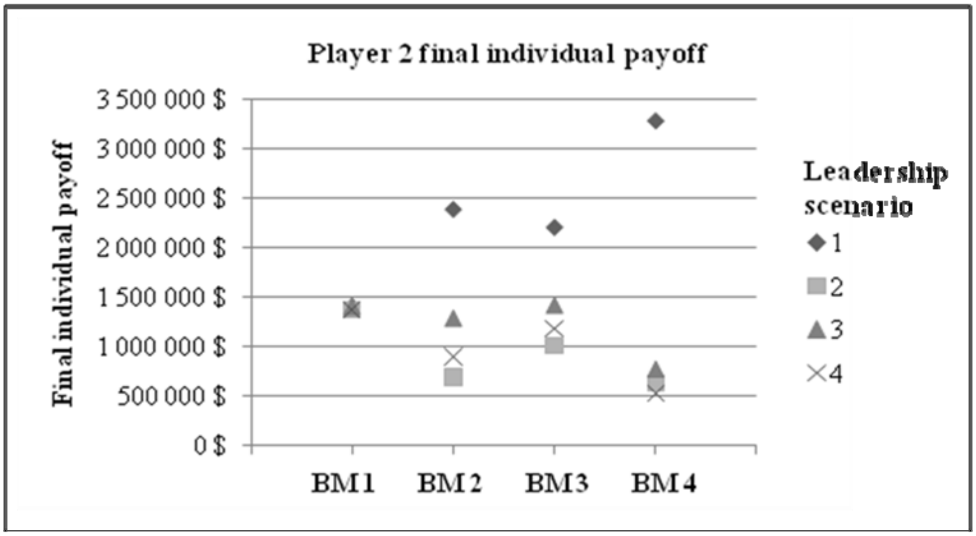

Figure 8: The opportunity cost for the player 2 of not being the sole LC in each business model

In business model 1, a refinement of the latter statement must be noted according to the impacts of player 1 on the results (see discussion in 8.1): if a player shares the leadership with player 1, this player will not improve its final individual payoff in business model 1.

8.5. Discussion

As reported in our case study as well as in other above-mentioned case studies with horizontal cooperation in transport planning, there are important savings with collaborative planning. In this paper, we study the allocation of these savings as well as the formation of the collaborating groups according to one perspective of a collaboration organization. However, there are other perspectives of collaboration organization that could be evaluated, see e.g. Wang et al. (2007). Among the stakeholders that could be involved in different OR problems occurring in transportation planning in forestry, we can identify five potential categories of who can perform the common planning. They are presented in Table 7 and some examples are provided.

Table 7: The five categories of organisations that can perform the common planning

Category	Description
1	A shipping company performs the planning. An example is the Swedish forest companies Holmen Skog (HS) and Norra Skogsägarna (NS) (Eriksson and Rönnqvist, 2003). By using the decision support system ÅkarWeb, HS advises the backhauling opportunities among both its under-contract carriers and some of NS in order to allow coordination among the carriers in the truck routing.
2	More than one shipping company performs the planning. An example is the buyers' network of the Canadian wood logs supplier Groupe Transforêt (Audy et al., 2007). By using the decision support system VTM prototype, truck routing is performed on all the volume to delivery in the network in order to schedule shared routes among two or more buyers.
3	A carrier or a third party logistics (3PL) performs the planning. An example is the Swedish forest products carrier Skogsåkarna (http://www.skogsakarna.se/) who furnishes the transport activities of several forest companies. Another example is the Swedish company Sydved (http://www.sydved.se/) who organises the purchase and transport of logs for its owners, the forest companies Stora Enso and Munksjö.
4	More than one carrier or 3PL performs the planning. An example is the Swedish logging and transportation company VSV (http://www.vsv.se/english.html) who collaborates in its transport operations with other carriers.
5	Shipper(s), Carrier(s) and 3PL(s) perform the planning.

There are also a number of practical aspects to consider for successful collaborating groups. Below we discuss a number of them and we refer to Frisk et al. (2009) for a discussion on other relevant aspects on the case study (e.g. valuation of wood, legality, tactical versus operational planning and shared information and quality).

Sequential bilateral agreement

We study sequential bilateral agreement for the formation of the coalition since, in practice the evaluation of the potential benefit is often realized between two companies at a time. Each company uses its internal planning system to anticipate the potential benefit of the collaboration without revealing it to the other company and to negotiate a bilateral collaboration agreement.

The main reasons why the information about the potential benefit is not shared are that this information may include sensitive business information and provide insights that could substantially affect the negotiation. It appears realistic to suppose that the proposition of collaboration by the LC must also be evaluated on a 'two companies' basis' while considering the previously collaborating companies as only one company dealing with another potentially collaborating company. Then, the larger group of collaborating companies can continue the bilateral evaluation and so on until the final coalition is formed.

Conflict of interest

The collected information for collaborative planning may include sensitive business information. To avoid possible conflict of interest, the 'collaborative plan' to put in practice by each company is generated with the two OR models and the LC must follow the obtained solutions. In a discussion on inter-organizational systems, Kumar and van Dissel (1996) identify possible risks of conflict and strategies for minimizing the likelihood of such conflicts. More recently, Clifton et al. (2008) use cryptographic techniques to perform the transportation planning among potential competitors' carriers without the requirement of a central broker and with a strictly minimum share in information. However, possible conflict of interest or the appearance of such still remains, essentially because the collaborative organization of the LC is not an independent one. In the paper, we consider that the NLC accepts this risk since the collaborative organization of the LC must be considered as a kind of specialized logistics service provider.

Coalition establishment and management costs

No cost was calculated for the establishment and then the management of the coalition while, in practice, both will reduce the final payoff.

Establishment cost has been studied by some authors in the literature on network formation. Slikker and van den Nouweland (2000) introduce a 'connecting' cost when players forming links and study how different values of that fixed cost influence the formation of the network. Galeotti et al. (2006) also use a 'connecting' cost but this cost varies across the players and, in addition, for the same player, the cost is sensitive to the identity of the potential partner-player. In practice, this variable 'connecting' cost makes sense since some players in the case study have more affinity together such as e.g. for the connection of their own IT system. However, the drawback of such a bilateral approach excludes the complete coalition structure which, according to Macho-Stadler et al. (2006), should be considered since the authors note that the establishment cost of a coalition seems much higher when more companies are involved.

In contrast to establishment cost, management cost refers to a repeating cost of running the collaboration over time. Some authors (e.g. Audy et al., 2008) use a fixed unit cost which is e.g. link to the volume to delivery, while other (e.g. Cruijssen et al., 2005) levy a part of the savings.

Cost-reduction perspective and negotiation

In this paper, the decision to collaborate or not strictly focusses on a cost-reduction perspective while, as detailed in the literature review of Cruijssen et al. (2007a), there exist several other potential benefits (e.g. faster delivery time) than cost-reduction to perform horizontal cooperation in transportation and logistics. However, cost-reduction is usually by far the most important of the potential benefits, but a question still remains: how much is enough in payoff to convince a player to accept to collaborate? At the least a payoff is just slightly greater than zero but, in practice, this issue is much more complex and it is based on a negotiation between the companies. Nagarajan and Sošic (2008) provide an exhaustive review of cooperative bargaining models in supply chain management that could support such payoffs fixation in a negotiation context. In such bargaining models, one notion is highly relevant: the negotiation power of each player. For instance, when two players negotiate, we should expect that the player with the higher negotiation power receives a larger payoff than the weaker counterpart.

Moreover, before engaging in costly and time-consuming establishment work, a more strategic oriented reflexion must be considered by the potential collaborating players. For instance, based on a total of 58 key performance indicators found through in-depth interviews and a literature study, Naesens et al. (2007) propose a framework to address, at a low cost and in a short period of time, such issues for reflection. Sometimes, even with large potential benefits, two companies can face insurmountable practices (e.g. difference in culture) that inhibit their collaboration. Several impediments and threats to horizontal cooperation are also detailed in the literature review of Cruijssen et al. (2007a).

9. Conclusion

It has been shown that coordination of the wood flows among companies within the same region can lead to an important transportation cost reduction. There exist decision support systems that can establish transportation plans including such coordination opportunities and thus quantify the value of the savings by any group of collaborators in the region. However, these systems raise questions of how to share the obtained savings among the collaborating companies and how the collaborating group(s) will be formed. We study both questions within a network formation game in extensive form to take into account in the game several restrictions raised by our notion of business model. This business model approach allows the integration of practical considerations in defining the allocation rule (e.g. altruistic or opportunistic behaviour) as well as the coalition formation process (e.g. leading position of some players). To find the stable and credible group(s) and payoffs in the studied game, we propose a longest path model. This model has been applied in a case study with eight companies involved in forest transportation in Sweden. A total of four distinct business models have been considered in the paper and each have been evaluated with the model according to four distinct leadership scenarios. The tests highlight several results.

In the four computed leadership scenarios, by adopting an opportunistic behaviour rather than an altruistic one, the leading companies have obtained an additional individual payoff of 6.9-19.7%. Furthermore, among the four computed scenarios, the savings allocation approach (i.e. business models 3 and 4) has been more advantageous for the leading companies than the cost allocation approach (i.e. business mode1s 1 and 2) by allowing a larger part of the worth of the final coalition to the leading players than the non-leading ones.

It was shown that in a group of companies, specific business models could lead to the formation of final coalitions that do not capture the entire economic potential of the group.

By taking the decision on which optimal sequence to propose bilateral agreement to the same set of non leading companies, the leading companies have obtained a total 1.1-10.6% additional payoff.

The opportunity cost of not being a leading company (alone or with other specific companies) as also been evaluated, for company 2 this could resolve in a loss of 80.4% of its best final payoff as a leader.

As future research, we want to study different business models in which the LC can develop their coalition in various ways. Another issue to be addressed relates to evolution of the formed coalition(s) as time goes by and thus more planning periods are considered. The formation of the coalitions without complete or accurate information should also be addressed. Finally, the additional payoffs for a company to join more than one coalition (i.e. overlapping coalitions) by splitting its demand/supply should be investigated.

10. Acknowledgments

The authors wish to thank Philippe Marier of FORAC Research Consortium for his contribution to this work. The authors would also like to acknowledge the financial support of the Natural Sciences and Engineering Research Council of Canada and the private and public partners of the FORAC Research Consortium. Finally, the authors wish to thank the Forestry Research Institute of Sweden for the data used in the case study as well as the eight companies involved.

11. References

Andersson, G., Flisberg, P., Lidén, B., Rönnqvist, M., 2008. RuttOpt: a decision support system for routing of logging trucks. Canadian Journal of Forest Research, 38 (7), 1784-1796.

Audy, J.-F., D'Amours, S., Rousseau, L.-M., Favreau, J., Marier, P., 2007. Virtual transportation manager: a web-based system for transportation optimization in a network of business units. In: Gingras, J.-F., (Ed.). 3rd Forest Engineering Conference, 1-4 October 2007, Mont-Tremblant, Canada. Montreal: FPInnovations-FERIC.

Audy, J.-F., D'Amours, S., Rousseau, L.-M. 2008. Cost allocation in the establishment of a collaborative transportation agreement - An application in the furniture industry. CIRRELT Research Paper 2008-50, Canada. Submitted to Journal of the Operational Research Society.

Aumann, R., Myerson, R., 1988. Endogenous formation of links between players and of coalitions: An application of the Shapley Value. In: Roth, A. E., (Ed.). The Shapley Value: Essays in Honor of Lloyd Shapley, Cambridge: Cambridge University Press, 175-191.

Bahrami, K., 2002. Improving supply chain productivity through horizonal cooperation – the case of consumer goods manufacturers. In: Seuring, S., Goldbach, M., (Eds.). Cost Management in Supply Chains. New York: Physica Verlag, 213-232.

Barratt, M., 2004. Understanding the meaning of collaboration in the supply chain. Supply Chain Management: An International Journal, 9 (1), 30-42.

Bloch, F., Dutta, B., 2008. Formation of networks and coalitions. Available from: http://www.vcharite.univ-mrs.fr/PP/bloch/papers/networksurvey.pdf [Accessed 24 March 2009].

Boonstra, A., de Vries, J., 2008. Managing stakeholders around inter-organizational systems: A diagnostic approach. Journal of Strategic Information System. 17 (3): 190-201.

Cachon, G.P., Netessine, S., 2006. Game theory in supply chain analysis. In: Johnson, M. P., Norman, B., Secomandi, N., (Eds.). Tutorials in Operations Research: Models, Methods and Applications for Innovative Decision Making. Hanover: Institute for Operations Research and the Management Sciences, 200-233.

Caputo. M., Mininno, V., 1996. Internal, vertical and horizontal logistics integration in Italian grocery distribution. International Journal of Physical Distribution and Logistics Management, 26 (9): 64-90.

Carlsson, D., Rönnqvist, M., 2007. Backhauling in forest transportation: models, methods, and practical usage. Canadian Journal of Forest Research, 37 (12), 2612-2623.

Chinchuluun, A., Karakitsiou, A., Mavrommati, A., 2008. Game theory models and their applications in inventory management and supply chain. In: Chinchuluun, A., Pardalos, P. M., Migdalas, A., Pitsoulis, L., (Eds.). Pareto Optimality, Game Theory And Equilibria, Vol. 17., Springer: NewYork, 833-865.

Clifton, C., Iyer, A., Cho, R., Jiang, W., Kantarcioglu, M., Vaidya, J., 2008. An approach to securely identifying beneficial collaboration in decentralized logistics systems. Manufacturing & Service Operations Management, 10 (1), 108-125.

Cruijssen, F., Borm, P., Fleuren, H., Hamers, H., 2005. Insinking: a methodology to exploit synergy in transport, CentER Discussion Paper 2005-121, Tilburg University, Netherlands.

Cruijssen, F., Dullaert, W., Fleuren, H., 2007a. Horizontal cooperation in transport and logistics: a literature review. Transportation Journal, 46 (3), 22-39

Cruijssen, F., Bräysy, O., Dullaeert, W., Fleuren, H., Salomon, M., 2007b. Joint route planning under varying market conditions. International Journal of Physical Distribution and Logistics Management, 37 (4), 287-304.

Cruijssen, F., Borm, P., Dullaert, W., Hamers, H., 2007c. Joint hub network development. CentER Discussion Paper 2007-76, Tilburg University, Netherlands.

D'Amours, S., Rönnqvist, M., Weintraub, A., 2008. Using operational research for supply chain planning in the forest products industry. Information System and Operational Research, 46 (4), 265-281.

Demange, G., Wooders, M., 2005. Group Formation in Economics: Networks, Clubs and Coalitions. Demange, G., Wooders, M., (Eds.). Cambridge: Cambridge University Press.

Epstein, R., Karlsson, J., Rönnqvist, M., Weintraub, A., 2007. Forest transportation. In: Weintraub, A., Romero, C., Bjorndal, T., Epstein, R., (Eds.). Handbook on Operations Research in Natural Resources, International Series in Operations Research and Management Science, Vol. 99, Chapter 20. New York: Kluwer Academic Publishers, 391-403.

Eriksson, J., Rönnqvist, M., 2003. Transportation and route planning: Åkarweb - a web-based planning system. In: Iwarsson Wide, M., Hallberg, I., (Eds.). 2nd Forest Engineering Conference, 12-15 May 2003, Växjö, Sweden. Uppsala: SkogForsk. 48-57.

Ergun, O., Kuyzu, G., Savelsbergh, M., 2007. Reducing truckload transportation costs through collaboration. Transportation Science, 41 (2), 206-221.

European Union, 2001. Guidelines on the applicability of Article 81 of the EC Treaty to horizontal cooperation agreements. Official Journal of the European Communities, 2001/C 3/02. Available from: http://europa.eu/scadplus/leg/en/lvb/l26062.htm [Accessed 24 March 2009].

Forsberg, M., Frisk, M., Rönnqvist, M., 2005. FlowOpt: a decision support tool for strategic and tactical transportation planning in forestry. International Journal of Forest Engineering, 16 (2), 101-114.

Frisk, M., 2008. Forestry Research Institute of Sweden, personal communication, November.

Frisk, M., Jörnsten, K., Göthe-Lundgren, M., Rönnqvist, M., 2009. Cost allocation in collaborative forest transportation. Forthcoming in European Journal of Operational Research.

Galeotti, A., Goyal, S., Kamphorst, J., 2006. Network formation with heterogeneous players. Games and Economic Behavior, 54 (2): 353-372.

Gingras, C., Cordeau, J.-F., Laporte, G., 2007. Un algorithme de minimisation du transport à vide appliqué à l'industrie forestière. Information System and Operational Research, 45 (1), 41-47.

Houghtalen, L., Ergun, Ö., Sokol. J., 2009. Designing mechanisms for the management of carrier alliances. Forthcoming in Management Science.

Jackson, M.O., 2008. Representing and Measuring Networks. Social and Economic Networks. Princeton: Princeton University Press. 20-53.

Krajewska, M.A., Kopfer, H., Laporte, G., Ropke, S., Zaccour, G., 2007. Horizontal cooperation among freight carriers: request allocation and profit sharing. Journal of the Operational Research Society. 59 (11): 1483-1491.

Kumar, K., van Dissel, H.G., 1996. Sustainable collaboration: managing conflict and cooperation in interorganizational systems. Management Information Systems Quarterly. 20 (3): 279-300.

Leng, M., Parlar, M., 2005. Game theoretic applications in supply chain management: A review. Information System and Operational Research, 43 (3), 187-220.

le Blanc, H.M., Cruijssen, F., Fleuren, H. A., de Koster, M.B.M., 2007. Factory gate pricing: an analysis of the Dutch retail distribution. European Journal of Operational Research, 174 (3): 1950-1967.

Lehoux, N., Audy, J.-F., D'Amours, S., Rönnqvist, M., 2009. Issues and experiences in logistics collaboration. Forthcoming in IFIP, a Springer Series in Computer Science, for the 10th IFIP Working Conference on Virtual Enterprises, 7-9 October 2009, Thessaloniki, Greece.

Macho-Stadler, I., Pérez-Castrillo, D., Porteiro, N., 2006. Sequential formation of coalitions through bilateral agreements in a Cournot setting. International Journal of Game Theory, 34 (2): 207-228.

Mason, R., Lalwani, L., Boughton, R., 2007. Combining vertical and horizontal collaboration for transport optimisation. Supply Chain Management: An International Journal, 12 (3): 187-199.

Meca, A., Timmer, J., 2008. Supply Chain Collaboration. In: Kordic, V., (Ed.). Supply Chain, Theory and Applications. Vienna: I-Tech Education and Publishing.

Myerson, R.B., 1977. Graphs and cooperation in games. Mathematics of Operations Research, 2 (3): 225–229.

Naesens, K., Gelders, L., Pintelon, L., 2007. A swift response tool for measuring the strategic fit for resource pooling: a case study. Management Decision, 45 (3): 434-449.

Nagarajan, M., Sošic, G., 2008. Game-theoretic analysis of cooperation among supply chain agents: review and extensions. European Journal of Operational Research, 187 (3): 719-745.

Nash, J.F., 1951. Non-cooperative games. The Annals of Mathematics 54 (2), 286–295.

Özener, O.Ö., Ergun, Ö., 2008. Allocating costs in a collaborative transportation procurement network. Transportation Science, 42 (2), 146-165.

Palander, T., Väätäinen, J., 2005. Impacts of interenterprise collaboration and backhauling on wood procurement in Finland. Scandinavian Journal of Forest Research, 20 (2). 177-183.

Palmgren, M., Rönnqvist, M., Varbrand, P., 2004. A near-exact method to solve the log truck scheduling problem. Transactions in Operations Research. 11, 447-464.

Perea, F., Puerto, J., Fernández, F.R., 2008. Modeling cooperation on a class of distribution problems. European Journal of Operational Research, 198 (3), 726-733.

Rönnqvist, M., 2003. Optimization in forestry. Mathematical Programming, 97 (1-2), 267-284.

Simatupang, T.M., Sridharan, R., 2002. The collaborative supply chain. International Journal of Logistics Management, 13 (1):15-30.

Slikker, M., van den Nouweland, A., 2000. Network formation models with costs for establishing links. Review of Economic Design, 5 (3): 333-362.

Slikker, M., van den Nouweland, A., 2001. Social and Economic Networks in Cooperative Game Theory, Theory and Decision Library C, Vol. 17, Boston: Kluwer Academic Publishers.

Sprumont, Y., 1990. Population monotonic allocation schemes for cooperative games with transferable utility. Games and Economic Behavior, 2 (4): 378-394.

Tijs, S. H. and T. S. H. Driessen, 1986. Game theory and cost allocation problems. Management Science, 32 (8), 1015-1058.

Young, H.P., 1994. Cost allocation. In: Aumann, R.J., Hart, S., (Eds.). Handbook of Game Theory with Economic Applications. Amsterdam: North-Holland, 1193-1235.

van den Brink, R., van der Laan, G. , Casil'ev, V., 2007. Component efficient solutions in line-graph games with applications. Economic Theory, 33 (2): 349-364.

van den Nouweland, A., 2005. Models of network formation in cooperative games. In: Demange, G., Wooders, M., (Eds.). Group Formation in Economics: Networks, Clubs and Coalitions. Cambridge: Cambridge University Press, 58-88.

Vidal-Puga, J.J., 2008. Forming coalitions and the Shapley NTU value. European Journal of Operational Research, 190 (3), 659-671.

Wang, Y., Potter, A., Naim, M., 2007. Electronic marketplaces for tailored logistics. Industrial Management & Data Systems, 107 (8): 1170-1187.

Weintraub, A., Epstein, R., Morales, R., Seron, J., Traverso, P., 1996. A truck scheduling system improves efficiency in the forest industries. Interfaces, 26 (4):1-12.