COST ALLOCATION IN THE ESTABLISHMENT OF A COLLABORATIVE TRANSPORTATION AGREEMENT - AN APPLICATION IN THE FURNITURE INDUSTRY

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Abstract: Transportation is an important part of the Canadian furniture industry supply chain. Even though there are often several manufacturers shipping in the same market region, coordination between two or more manufacturers is rare. Recently, important potential cost-savings and delivery time reduction have been identified through transportation collaboration. In this paper, we propose and test, on a case study involving four furniture companies, a logistics scenario that allows transportation collaboration. Moreover, we address the key issue of cost-savings sharing, especially when heterogeneous requirements by each collaborating company impact the cost-savings. To do so, we propose a new cost allocation method that is validated through a case study. Sensibility analysis and details about the actual outcome of the case study complete the discussion.

Keywords: Collaboration, Cost allocation, Furniture industry, Game theory, Horizontal cooperation, Road transport

1. INTRODUCTION

The main export market of the Canadian furniture industry is the United States, with 95-96% of the total export value over the last decade (IC, 2008). Canada and the U.S. being neighbouring countries, most deliveries are made by truck over long distances. Increased competition from countries with low production costs, mainly China, together with escalating fuel prices, U.S. customs security and environmental concerns have created the need to improve transportation efficiency. The appreciation of the Canadian dollar against the U.S. dollar in recent years, as well as the request by furniture retailers to reduce delivery time have also put extra pressure on the Canadian furniture industry supply chain. Efficiency, velocity and agility in transportation operations are essential elements that constitute the furniture manufacturer of the future as described by (Archambault *et al*, 2006). Moreover, regardless of the three 2016 scenarios expected by the Furniture Foresight Centre (CEFFOR) for the furniture industry in high production costs countries such as Canada, the search for efficiency to cut costs will become an everyday issue (CEFFOR, 2008).

However, even when different furniture companies located in the same region ship to the same market regions, the same cities and/or the same furniture retailers, coordination in the transportation operations between two or more companies is rare. Two recent internal studies (Audy and D'Amours, 2008) demonstrating significant potential benefits for the industry have led to increasing interest in transportation coordination through collaborative planning. By exploring different collaborative logistics scenarios among a group of furniture companies, these studies identify cost and delivery time reductions as well as gain in coverage of regional markets.

However, even though a collaboration logistics scenario can provide substantial benefits for the group, each company needs to evaluate the scenario according to its own benefits. This individual evaluation can lead to a situation where the logistics scenario with the highest cost-savings for the group, named the *optimal cost-savings scenario*, does not provide the individual highest cost-savings to some companies or worse, provides one or more negative benefits. As a result, without any modifications, this *optimal cost-savings scenario* would be rejected in favour of another scenario that may not capture all the potential cost-savings and may eventually exclude some of the companies. This situation was reported by (Audy and D'Amours, 2008) in their case study involving four furniture manufacturers in the province of Quebec.

In this paper, we integrate in the *optimal cost-savings scenario* the modifications which satisfy the conditions allowing its establishment by the whole group. Moreover, since the establishment of this scenario relies on a negotiated collaboration agreement among the future partners, we study the key issue of cost-savings sharing. More specifically, we study how cost-savings should be shared to the satisfaction of all companies when heterogeneous requirements among the partners impact the total cost of the *optimal cost-savings scenario* and need to be taken into account. Based on two methods existing in the literature, we propose and compute a new method to achieve these goals. We then analyze the impact of different sharing strategies according to different results in the negotiation of the collaboration agreement.

The paper is organized as follows. First, we introduce the transportation operation modes and planning problem studied in the context of the Canadian furniture industry in Section 2. Then, in Section 3 we discuss the benefits of collaborative transportation planning and, in Section 4, we present a logistics scenario allowing an implementation of collaborative transportation planning in an industrial case study with four furniture companies. In Section 5 we discuss how to share cost-savings and how to share a reduction to these cost-savings. In both cases, we present a modified method to do so. In Section 6, numerical results of the two modified methods are illustrated and discussed using the case study as well as an impact analysis on two parameters in the negotiation. Finally, details about the actual outcome of the case study and concluding remarks are provided in Sections 7 and 8 respectively.

2. TRANSPORTATION OPERATION MODES

In the Quebec furniture industry, most furniture retailers' (i.e. the customers) orders are less-than-truckload size shipments and are delivered by truck to the U.S. To execute their transportation activities, furniture companies rely on carriers that operate mainly according to one of the two following modes.

The first mode is multiple-stop truckload (TL) operations. The TL carrier delivers a trailer to the shipping dock of the furniture company, who loads the trailer with many shipments. Occasionally, only one shipment will fill the trailer, but on average, 9 to 21 shipments are needed. Soon after the trailer is loaded, a TL carrier driver will leave for the delivery destination of its first customer. Since the shipments are not handled again before their delivery to the customer, loading of the trailer must respect the 'First In, Last Out' constraint.

Thus, loading decisions are tightly linked to truck routing decisions. Efficient truck routing is a key issue for short delivery time and reduced cost. This planning is commonly done on a weekly basis by the furniture company. Each planned delivery trip must respect operational constraints such as the truck capacity limit, the driver's hours of service regulations (i.e. working/driving time daily limits and minimum daily rest time) and the business hours of the customers. The cost of a delivery trip is proportional to the total one-way travelling distance with specific travelling distance rates according to the state of the last customer delivery. A cost by intermediate stop, a cost for customs documents preparation and a fuel surcharge is also charged on each delivery trip.

The second mode is less-than-truckload (LTL) operations. The LTL carrier always keeps a trailer at the furniture company in order to allow the company to load its shipment as it becomes ready. Each day or so, the LTL carrier comes with a new trailer and leaves with the previous one to collect these shipments and bring them to its terminal. The LTL carrier handles these transportation/consolidation operations with many furniture companies in order to consolidate a large number of shipments at its terminal and to achieve truck routing several times a week and dispatch drivers regularly. After a shipment has been collected at the company, the LTL carrier guarantees its delivery inside a specific time range by destination zone.

The furniture company is charged on each of its shipments rather than on a delivery trip basis. The cost is proportional to the shipment volume, with specific rates by volume range and destination state. The cost of shipment is subject to a minimum charge in addition to a fuel surcharge.

When it is really cost-effective, a furniture company operating with the first mode could use a regional LTL carrier located in the U.S. (e.g. the terminals network of carrier USF). In this case, rather than planning the shipment delivery up to customer location, the delivery is planned up to one of the regional LTL carrier terminals who offer the service to the customer. The cost charged by a regional LTL carrier is usually proportional to the shipment weight and subject to a minimum charge in addition to a fuel surcharge.

3. COST-SAVINGS WITH COLLABORATION

Currently, the companies in the case study realize their transportation operations with the carrier/mode they judge to be most beneficial for them. (Caputo *et al*, 2005) report that although different criteria may influence the selection of a carrier, cost is often the most important as is the case for the four companies. Therefore, the case study focuses on the cost reduction benefit, although delivery time is also measured. Meeting delivery time is a critical criterion for the companies.

According to (Cruijssen *et al*, 2007a), identifying and exploiting win-win situations among companies at the same level of the supply chain in order to increase their performance is about horizontal cooperation. Group purchasing organizations are a typical example of horizontal cooperation among buyers. Our case study can be considered as an example of horizontal cooperation. The literature provides interesting case studies where companies obtain savings with horizontal cooperation in road transport planning, see e.g. (Bahrami, 2002), (Cruijssen *et al,* 2005), (Forsberg *et al*, 2005), (Palander and Väätäinen, 2005), (le Blanc *et al.* 2007), (Cruijssen et al, 2007b), (Ergun *et al*, 2007), (Krajewska *et al*, 2007), (Mason *et al*, 2007) and (Frisk *et al*, 2009). In this paper, when the companies accomplish collaborative planning, cost-savings derive from two coordination opportunities: improved delivery trips and better transportation rates.

By planning the delivery trips of the four companies' shipments together, improvements in efficiency can be achieved, such as reduction in travelling distance and increase in the loading rate of the trailer. A savings of 5% by such improved efficiencies with multi-stop delivery trips among half a dozen manufacturing plants are reported by (Brown and Ronen, 1997). (Cruijssen *et al*, 2007b) report a 30.7% savings in a case study involving the planning of multi-stop delivery trips among three collaborating entities. Moreover, according to a sensitivity analysis on average order size, (Cruijssen *et al*, 2007b) report that collaborative planning appears to be more profitable in sectors where orders are small (i.e. less-than-truckload size shipments) than in sectors where the average order is large (i.e. truckload or close size shipments).

By negotiating their transportation rates with the carrier together rather than individually, companies obtain, at the least, better transportation rates among the four actual rates of the companies. (Kuo and Soflarsky, 2003) report discounts in the range of 20-45% by negotiating with several carriers, with up to 70% discount from some large firms. The existence of discounts, but in lower percentages, has been confirmed in our case study by a comparison of the actual rates of the four companies as well as a quotation study done by a consulting firm among several LTL and TL carriers operating in Quebec.

4. ESTABLISHMENT OF THE COLLABORATION

In the study by (Audy and D'Amours, 2008), collaborative planning was explored under four different logistics scenarios. For each scenario, Table 1 identifies the service provider to which the coalition outsources their operations of i) transportation upstream to the terminal, ii) consolidation-warehousing at the terminal, and iii) transportation downstream from the terminal. Note that the only difference between scenario #3 and #4 is the location of the terminal, which has an impact on the total travelling distance and, consequently, the total cost.

Table 1: The service provider of the logistics scenario #1-5

Logistics scenario	Service provider		
	Transportation upstream to the terminal	Consolidation and warehousing at the terminal	Transportation downstream from the terminal
1	LTL carrier		
2	TL carrier	Company A	TL carrier
3 and 4	LTL carrier		TL carrier
5	LTL carrier (Only the shipments that will have a delivery time delayed by more than two days)		
	TL carrier	Company A	TL carrier

Scenarios #2-4 result in more cost-savings than scenario #1. However, even though they reduce the delivery time average of the group, these three scenarios increase the delivery time average of two of the four companies, while this was not the case with scenario #1. For some shipments, this increase means a delivery time delayed by three days or more, which is not acceptable for almost all customers of the four companies. However, scenario #1 leads to the exclusion of company A from the transportation coalition (i.e. obtains a negative saving) and, consequently, a logistics scenario #5 is proposed.

Scenario #5 combines a carrier of both the TL and LTL operation modes. (Caputo *et al*, 2005) report attractive benefits by using both modes. We will thus assign to an LTL operation mode all the shipments that will have a delivery time delayed by more than two days in a TL operation mode. By outsourcing these shipments to an LTL carrier directly from the shipping dock of the companies, we ensure that the customers' delivery time expectations are respected. The other shipments, which represent the majority, are assigned to a TL carrier. Among the three scenarios without an LTL carrier (i.e. #2, 3 and 4), scenario #2 results in the highest cost-savings and consequently, in scenario #5, the terminal is located in the factory of company A. In fact, scenario #5 should not be considered as a totally new scenario but as the *optimal cost-savings scenario* (i.e. the name of scenario #2 in the introduction) to which more flexibility in the transportation operation is allowed in order to meet the requirements in delivery times of each company.

To avoid possible conflict of interest, the truck routing from the terminal is done by a computer application and company A must follow the transport plan obtained. 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. In practice, possible conflict of interest or the appearance of such still remains. Companies B, C and D must accept this risk, since company A must be considered as a kind of third party logistics (3PL) provider of consolidation-warehousing, truck routing and logistics services. Indeed, the offer of multiple and bundled services from an asset-based company, rather than just single and isolated transportation or warehousing service, refers to a 3PL provider in the literature, see (Selviaridis and Spring, 2007) for a review. For its services, company A charges companies B, C and D a cubic foot flat rate on their total volume of shipments that transit by the terminal. This type of rate reflects how a service is charged in this industry. Other types of rate are reported in the literature, e.g. in (Cruijssen *et al,* 2005) the 3PL levy a pre-determined percentage of the cost-savings obtained through the cooperation in transportation.

Transportation operations upstream/downstream to/from the terminal are outsourced to a TL carrier. The shipments of companies B, C and D are delivered, separately for each company, to the terminal during the week using only full truckload delivery except when a partial delivery is necessary on Friday afternoons to clear the shipments inventory at the company. During the weekends, trucks are routed and start their delivery trips from the terminal at company A. Note that the TL carrier in the scenario should not be considered only as a transportation service provider operating alone. The carrier could belong to a group of collaborating carriers such as World Wide Logistics, an ongoing founding organization of six specialized furniture carriers (Thomas, 2008).

Finally, furniture companies B, C and D request another modification to the initial delivery trips planning. Indeed, if these companies grant the delivery to a regional LTL, this means that some of their shipments will be handled three times instead of twice, thus increasing the risk of potential damage. However, with some of their customers, furniture companies B, C and D have delivery agreements that specifically do not allow more than one transit operation, with the precise aim of reducing the risk of damage as well as problems caused by damage. Thus, to meet the requirements of some of the customers of furniture companies B, C and D, the use of regional LTL carriers is prohibited on all the shipments specified by these companies.

5. SHARING THE COST-SAVINGS OF THE COLLABORATION

Collaboration brings up the following question. How should the cost-savings obtained through collaboration among a group of companies be shared between the companies? To address this problem, cooperative game theory provides a natural framework.

In cooperative game theory, a situation in which a group of companies, through cooperation, can obtain a certain benefit (such as a cost-savings) that can be divided without loss between them, can be described in an n-person game with transferable utility. Moreover, in such a game, a company is named a player, and a group of companies, a coalition. As mentioned by (Hadjdukavá, 2006), there are two fundamental questions that need to be answered in such a game: (1) which coalitions can be expected to be formed? (2) How will the players of coalitions that are actually formed apportion their joint benefit?

By studying a situation in which we aim to implement logistics scenario #5, we address the first question in a very restricted way. Indeed, we limit to one the number of coalitions that can be formed, namely the *grand coalition,* which includes all players. This limitation must be taken into account in studying the second question in order to guarantee that no player or subset of players will obtain a higher cost-savings by acting outside the *grand coalition*. A coalition whose sharing of the cost-savings satisfies this condition is said to be *stable*.

Instead of splitting the savings of the coalition among the players, we address the second question by using a cost allocation method in which the cost of the collaborative planning is split between the players. Several cost allocation methods exist in the literature, an extensive list of papers and applications on cost allocation methods, which are partly based on cooperative game theory such as the Shapely value and the nucleolus, can be found in (Tijs and Driessen, 1986) and in (Young, 1985, 1994). In its literature survey on cost allocation, (Young, 1994) indicates that cost allocation is a practical problem in which the salience of the solution depends on contextual and institutional detail and there are various ways of modelling a cost allocation situation.

In a case study involving cooperation in transportation, the Shapley value was used as a cost allocation method by certain authors, e.g. (Cruijssen *et al,* 2005) and (Krajewska *et al*, 2007). More recently, (Frisk *et al*, 2009) propose a new cost allocation method called *Equal Profit Method* (EPM). This method aims at finding a stable allocation, such that the maximum difference in relative savings between all pairs of two players is minimized. A linear programming model (LP) must be solved to find this stable allocation. The authors propose this new cost allocation principle because, in their case study involving eight companies, they found certain disadvantages with most well-known allocation models in the literature when it came to the acceptance of the cost allocation among the companies. They report that it was difficult to not show that all companies had a similar relative cost-savings compared to the stand alone cost. Thus, they suggest that in a negotiation situation, it would be beneficial to have an initial allocation where the relative savings are as similar as possible for all players. Since in our case study the companies will reach a collaboration agreement after a negotiation based on a proposition elaborated by company A, the EPM is meaningful and was computed. However, according to our business context and how transportation operations are performed in the furniture industry, two modifications to the EPM have been necessary.

The first modification was the introduction of a minimum cost-savings percentage in the EPM. The business logic behind such a modification is that being a participant in a coalition must be profitable to the collaborating player. An allocation method ensuring that each player receives a strictly positive benefit from collaborating referred to the *positive benefits* propriety (Agarwal *et al*, 2009). Such propriety has recently been introduced by some authors in case studies involving cooperation in transportation, see e.g. (Özener and Ergun, 2008), (Perea *et al*, 2008). How much minimum savings percentage is enough to convince each player to join the coalition? At the lowest, the percentage must be greater than zero; in other words the cost allocated to a player must be less than its stand alone cost. However, in practice this issue is much more complex and it is based on negotiation between the companies that goes beyond the scope of this paper, see (Nagarajan and Sošić, 2008) for a review of cooperative bargaining models in supply chain management.

The second modification was the introduction in the EPM of three non transferable costs for each company. As previously mentioned, for its services, company A charges companies B, C and D a cubic foot flat rate on their total volume and this is the first non transferable cost. The second non transferable cost concerns the additional cost incurred in the collaborative planning to satisfy all the special requirements of a specific company. A special requirement is about the respect of tight delivery time and/or the prohibition on using a regional LTL carrier on a specific shipment, both of which are the modifications integrated in scenario #5. To calculate the value of these additional costs for each company, a method is proposed in the following section. The last and third non transferable cost is for the transportation upstream to the terminal, i.e. the transportation from the company to the terminal of its shipment assigned to a TL operation mode.

The notation used in the LP model to solve the modified EPM is defined in Table 2.

Table 2: Indexes, sets, parameters and decision variable in the modified EPM

Sets	
N	: the set of players, $N=\{\text{A, B, C, D}\}$
S_N	: all subsets (i.e. coalitions) of N, $S_N=\{\{\text{A}\}, \{\text{AB}\}, \{\text{AC}\}, \{\text{AD}\}, \{\text{ABC}\}, \{\text{ABD}\}, \{\text{ACD}\}, \{\text{ABCD}\}, \{\text{B}\}, \{\text{BC}\}, \{\text{BD}\}, \{\text{BCD}\}, \{\text{C}\}, \{\text{CD}\}, \{\text{D}\}\}$
Parameters	
A_i	: non- transferable cost of player $i\in N$ for all its special requirements
B_i	: non-transferable cost of player $i\in N$ for its transport upstream to the terminal
$C^{sa}(i)$	: stand-alone cost of player $i\in N$
$C(s)$	: cost of collaborative planning for player(s) in $s\in S_N$ without any special requirement
$C_R(s)$	: cost of collaborative planning for player(s) in $s\in S_N$ with the special requirement of all player $i\in R,\ R\subseteq s$
P	: minimum savings percentage for all players
T	: volume flat rate charges at the terminal
V_i	: total volume in shipment of player $i\in N$ who transit by the terminal
Decision variable	
z_i	: cost allocated to player $i\in N$

The modified EPM is formulated in the following LP model:

min f

s.t.≥

$$f \geq \frac{z_i}{C^{sa}(i)} - \frac{z_j}{C^{sa}(j)} \quad \forall i, j \in N \mid i \neq j \qquad (1)$$

$$\sum_{i \in s} [z_i + T \times V_i + A_i + B_i] \leq C_{\{s\}}(s) \quad \forall s \in S_{N \setminus \{A\}} \qquad (2)$$

$$\sum_{i \in N} z_i = C(N) \qquad (3)$$

$$\frac{[C^{sa}(i) - (z_i + T \times V_i + A_i + B_i)]}{C^{sa}(i)} \geq P, \quad \forall i \in N \qquad (4)$$

The first constraint set is to measure the difference in savings between all pairs of players. The variable f is used in the objective function to minimize the largest difference. The second constraint set allows for an allocation ensuring a *stable* coalition, that is, no company or subset of companies will obtain a higher cost-savings by acting outside the *grand coalition*. Company A is excluded from all these partial coalitions because company A aims to bring all companies into its coalition. The third constraint is to obtain an *efficient* allocation (also referred to in the literature as the *budget balance* propriety), i.e. the total cost of the collaborative planning is divided among the players. Finally, the fourth constraint set allows company A to grant to each company the minimum saving percentage agreed upon during the negotiation.

5.1. SHARING THE ADDITIONAL COST INCURRED TO SATISFY SPECIAL REQUIREMENTS

By modifying the collaborative planning in order to respect the special requirements of the companies, the cost of the collaborative plan increases. Since some companies have more requirements than others and the impact on the cost increase between two requirements is almost never the same, this raises a new question: how should the additional cost incurred to satisfy the special requirements be shared between the companies?

To address this question, we modified the *Alternative Cost Avoided Method* (ACAM) presented in (Tijs and Driessen, 1986). In the ACAM, the total cost to be allocated is divided into two parts: the separable and the non-separable costs. The method first allocates to each player his separable cost and then distributes the residual part of the total cost, i.e. the non-separable cost, among the participants according to given weights. The separable cost of each player is the marginal cost increase obtained when player $i \in N$ joins the coalition $S_{N\setminus\{i\}}$. The non-separable cost is then allocated using the weights expressing the marginal savings that are made by each player by joining the grand coalition instead of operating alone.

In the modified ACAM, we allocate the additional cost incurred in the collaborative planning to satisfy the special requirements instead of the total cost. Specifically, we allocate the difference between the cost of the collaborative planning satisfying the special requirements and the cost of the collaborative planning without the special requirements. The cost of the collaborative planning without the special requirements is allocated among the players with the modified EPM described previously.

The modified ACAM aims to allocate to the company with the most expensive requirements the greatest part of the additional cost incurred in the collaborative planning. The business logic behind this allocation modulated by the impact of the individual requirements of each company is to make each company aware that, in general, the more numerous and restrictive their requirements are, the more this has an impact on the collaborative planning and, in turn, on the increase in the additional transportation cost. Thus, the modified ACAM encourages each company to keep the number and degree of restrictions of their transportation requirements to a strict minimum. As in the original ACAM, the modified ACAM first allocates its separable cost to each player and then distributes the non-separable cost. The decision variables used in the following detailed step by step description of the modified ACAM are defined in Table 3.

Table 3: Decision variables in the modified ACAM

Decision variables	
t	: non-separable cost to allocate among all players in the grand coalition
r_i	: marginal cost increase when player $i \in N$ joins the coalition.
w_i	: relative weight of player $i \in N$
x_i	: non transferable cost of player $i \in N$ for all its special requirements (becomes the parameter A_i in the modified EPM)
y_i	: separable cost of player $i \in N$

Step 1: the separable cost of each player $i \in N$ must be calculated with:

$$y_i = C_{\{i\}}(N) - C(N) \quad \forall i \in N \tag{5}$$

Step 2: the non separable cost must be calculated with:

$$t = C_{\{N\}}(N) - C(N) - \sum_{i \in N} y_i \tag{6}$$

Step 3: the relative weights to distribute the non-separable cost among the players must be calculated with one of these two equations:

$$t \geq 0 \quad w_i = C_{\{N\}}(N) - C_{\{N \setminus \{i\}\}}(N) \quad \forall i \in N \tag{7}$$

$$t<0 \quad r_i = C_{\{N\}}(N) - C_{\{N \setminus \{i\}\}}(N) \quad \forall i \in N$$

$$w_i = \begin{cases} r_i = 0 & w_i = 0 \\ r_i > 0 & \sum_{j \in N} r_j - r_i \end{cases} \quad \forall i \in N \tag{8}$$

When the non separable cost is negative, equation (8) becomes necessary to respect the cost allocation principle of the modified ACAM, i.e. allocate to the company with the most expensive requirements the greatest part of the additional cost incurred in the collaborative planning. Indeed, with equation (8), the method distributes to the players with the lowest marginal cost increase the greatest reductions on their non separable cost, while on the other hand, the player with the highest marginal cost increase receives the lowest reductions.

Step 4: the non transferable cost of each player $i \in N$ for its special requirements must be calculated with:

$$x_i = y_i + \frac{w_i}{\sum_{j \in N} w_j} t \quad \forall i \in N \tag{9}$$

5.1.1. An illustrative numerical example

In order to illustrate the modified ACAM, we consider a small example including three players. The cost of collaborative planning of the grand coalition *N* without any special requirement, $C(N)$ = 20, while the cost of the grand coalition with all special requirements, $C_{\{1,2,3\}}(N)$ = 30. The cost of collaborative planning with only the special requirements of player 1, $C_{\{1\}}(N)$ = 21, player 2, $C_{\{2\}}(N)$ = 22, and, finally, player 3, $C_{\{3\}}(N)$ = 24. The cost of collaborative planning with the special requirement of all players except player 1, $C_{\{2,3\}}(N)$ = 28, player 2, $C_{\{1,3\}}(N)$ = 26, and, finally, player 3, $C_{\{1,2\}}(N)$ = 24.

Step 1: the separable cost of player 1, y_1, is calculated by $C_{\{1\}}(N)-C(N)$ = 21 -20 = 1 while y_2 = 2 and y_3 = 4.

Step 2: the non separable cost, t, is calculated by $C_{\{1,2,3\}}(N)-C(N)-(y_1+y_2+y_3)$ = 30 – 20 – (1 + 2 + 4) = 3

Step 3: the non separable cost being greater than zero, the relative weights of player 1, w_1, is calculated by equation (7): $C_{\{1,2,3\}}(N)-C_{\{2,3\}}(N)$ = 30 – 28 = 2 while w_2 = 4 and w_3 = 6.

Step 4: the non transferable cost of player 1 for its special requirements, x_1, is calculated by $y_1+\frac{w_1}{(w_1+w_2+w_3)}t$ = $1+\frac{2}{(2+4+6)}\times 3$ = 1.5 while x_2 = 3 and x_3 = 5.5.

Once this non-transferable cost is calculated for each player, the modified EPM can now be used to allocate to players the $C(N)$ = 20, i.e. the cost of the collaborative planning of the grand coalition *N* without any special requirement.

6. NUMERICAL RESULTS

The data used in the case study were collected weekly in the billing system of the four furniture companies during four consecutive weeks in 2008. The results are thus based on a comparison between the sum of the stand alone cost (delivery time) of each company and the cost (delivery time) of the collaborative transportation plan in the logistics scenario. Moreover, the cost-savings of each player is the difference between the player's stand alone cost and its allocated cost according to the modified EPM.

Two regions in the U.S. have been targeted by the companies for the collaborative planning of their shipments: first, the states on the West Coast (characterized by a wide territory, a small density road network and clustered customers) and second, the states bordering the Great Lakes (characterized by a high density road network and a relatively homogeneous geographic distribution of the customers). The case represents a total of 363 shipments to 256 different customers for a percentage of 44.6% of the total volume shipped in the U.S. The representation of the volume shipped during the simulation compared to the rest of the year has been validated (e.g. not in a seasonal peak or down). Companies shipped, respectively, 66.6%, 17.5%, 9.3% and 6.7%, of the total volume shipped while the distribution of the stand alone cost is 59.7%, 21.8%, 10.4% and 8.2%.

6.1. Cost allocation

For each of the four weeks, collaborative planning was performed eight times in order to compute the modified EPM, i.e. collaborative planning with the grand coalition and with the seven coalitions without company A, $\forall s \in S_{N\backslash\{A\}}$. The collaborative planning was done with a Microsoft Excel spreadsheet as well as the modified ACAM while the modified EPM was programmed using ILOG OPL. Road information (i.e. distance and time) was obtained with PC*MILER. Table 4 shows the provisional and final (i.e. respectively, without and with the three non transferable costs) cost and savings per company according to the allocation by the modified EPM.

Table 4: Provisional/final cost and savings per company according to the modified EPM

Company	Stand-alone cost ($CAD)	Provisional (only z_i)		Final ($z_i + T \times V_i + A_i + B_i$)	
		Cost ($CAD)	Savings (%)	Cost ($CAD)	Savings %
A	71 695	58 817	18.0	58 817	18.0
B	26 149	15 394	41.1	25 111	4.0
C	12 445	8 133	34.6	10 853	12.8
D	9 806	7 221	26.3	9 806	0.0
Sum	120 095	89 565	25.4	104 587	12.9

We see first that company D goes from a provisional savings of 26.3% to a 0.0% final savings. The total cost of its three non separable costs takes its entire provisional savings. By setting the minimum savings percentage parameter at greater than zero in the modified EPM, we can avoid this situation. Thus, we ensure that the allocation would provide not only a *stable* coalition (i.e. no company or subset of companies will obtain a higher cost-savings by acting outside the *grand coalition*) but also a *profitable* coalition (i.e. no company or subset of companies will obtain a higher *or equal* cost-savings by acting outside the *grand coalition*). Moreover, we ensure that the individual rationality condition is satisfied for each company (i.e. no company pays more than its stand-alone cost). According to the solution concepts in cooperative game theory, a cost allocation that satisfies the two previous conditions is said to be in the core.

Secondly, we see that the final cost and savings of company A remains unchanged. Obviously, company A does not charge itself a volume flat rate and has no transportation operations upstream the terminal adjacent to its factory. The zero non transferable cost for special requirements is explained by the absence of special requirements by company A. As for companies B, C and D, they had special requirements which increased the cost of the collaborative planning by 9 737 $CAD. To compute the modified ACAM that distributed this additional cost among the companies, collaborative planning of the grand coalition was performed according to nine variations of special requirements to satisfy. With a 7 811 $CAD allocated cost, Company B assumes the greatest part (80.2%) of the additional cost, which makes sense since company B is the company that has the largest number of shipments with special requirements and thus is more likely to affect the rise of the cost in the collaborative planning. Companies C and D assume the balance of the additional cost, with respectively a 749 $CAD (7.7%) and 1 177 $CAD (12.1%) allocated cost by the modified ACAM.

6.2. Comparison between the original and modified methods

Table 5 shows the results on both the modified EPM proposed in this paper and the original EPM proposed by (Frisk *et al*, 2009). Note that in the modified EPM, the value of the minimum savings percentage was set to 1% in order, as discussed in the previous subsection, to obtain not only a *stable* coalition but also a *profitable* coalition.

Table 5: Comparison between the original and the modified EPM methods

Company	Modified EPM		Original EPM		Difference	
	Cost ($CAD)	Savings (%)	Cost ($CAD)	Savings (%)	Cost ($CAD)	Savings (%)
A	58 817	18.0	62436	12.9	3 619	-5.1
B	25 111	4.0	22773	12.9	-2 338	8.9
C	10 951	12.0	10838	12.9	-113	0.9
D	9 708	1.0	8540	12.9	-1 168	11.9
Sum	104 587	12.9	104 587	12.9	0	0

The original EPM provides a similar cost-savings of 12.9% to the four companies and thus, results in a zero f value. Company A has the most to lose with the original EPM. Indeed, the savings increases of companies B (+8.9%), C (+0.9%) and D (+11.9%), are gained from the savings of company A (-5.1%), which is allocated a higher cost of 3 619$CAD by the original EPM. Companies B and D are the two companies that benefit most from the original EPM by massively transferring to company A the additional costs incurred by the group to meet their special requirements in the collaboration. Finally, note that without the addition of a minimum savings percentage in the modified EPM, company B would obtain a zero savings.

6.3. Influence of the minimum savings percentage on the cost allocation

As detailed in the following section, these research works lead to a pilot project aiming to put simulated logistics scenario #5 into practice. To do so, companies must reach a negotiated collaborative business agreement that details the collaboration setting, especially all the monetary-related parameters. As the direct (i.e. consolidation-warehousing and logistics) or indirect (i.e. truck routing) services provider for the group, company A was mandated to first define an agreement proposition to negotiate. Before submitting its proposition of collaborative agreement to the other companies, it would be beneficial for company A to evaluate the impact on the allocation results of different values of the minimum savings percentage parameter on which the group could agree. Figure 1 shows the savings per company according to all the integer values the parameter may take.

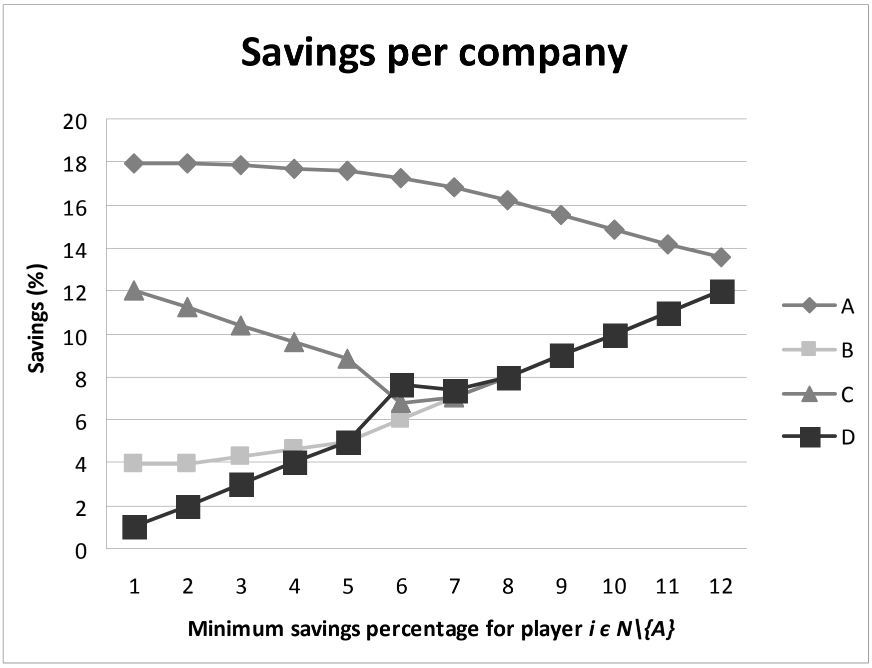

Figure 1 – Savings per company according to the minimum savings percentage

We see that each increase of the minimum savings percentage is funded from the savings of companies A and C. It is therefore beneficial for company A and C (except for company C if the group agrees to a minimum savings of 12%) that the group agree to a minimum savings percentage nearest to 1%. On the x axis, the values of the minimum savings percentage stop at 12%, since beyond this integer value of savings (or more precisely beyond 12.914%), the savings of company A will be less than the savings of companies B, C and D. Moreover, from an 8% minimum savings percentage (or more precisely 7.1539%), companies B, C and D always obtain the same savings. However, an agreement by the group to 8% or more is contrary to the cost allocation principle of fairness imbedded in the modified EPM and ACAM since the savings of companies B and D is funded by companies A and C.

6.4. Influence of the volume flat rate on the savings of company A

Another monetary-related parameter that could be interesting to evaluate by company A before the negotiation is the impact on the allocation of both an increase and decrease of the volume flat rate. An increase of the cost could be the consequence of a significant decrease in the total volume shipped by the companies during a period of time while a decrease could be reached with an investment in the handling and warehousing equipment at the terminal. Company A estimates the cost of its 3PL provider services to a volume flat rate of 0.20 \$CAD/cubic foot and this, with virtually nil profit. It is this volume rate that was used in the previous numerical results. Figure 2 shows the savings of company A according to the current volume flat rate and with both an increase and decrease of 0.05 \$CAD/p^3 to the current volume flat rate. Since the savings of the other companies remain unchanged they are not shown.

Figure 2 – Distribution of company A savings according to different volume flat rate

Whatever the minimum savings percentage on which the group could agree, Figure 2 illustrates two crucial issues for company A. If the volume flat rate is more than the rate estimated, it is company A that assumes this difference by a reduction of its savings. Specifically, an increase by 0.05 \$CAD/p^3 means a reduction of 1.0% of company A's savings. On the other hand, a decrease of 0.05 \$CAD/p^3 means an increase of 1.0% of company A's savings. Consequently, this allows company A to evaluate further than the two regions and the periods of time of the study, the return on investment of any project, e.g. to renew handling or warehousing equipment.

7. OUTCOMES

Aiming at the implementation of logistics scenario #5 proposed in this paper, a pilot project was initiated by the companies with the support of their industrial association. To demonstrate some of the expected key issues in the pilot project, a simulation game, named the *Cost allocation game*, was played with the companies at the beginning of the project. This game, developed by two professors (Rönnqvist and D'Amours, 2008), is based on the industrial case study involving horizontal cooperation in transportation that is reported in (Frisk *et al*, 2009). The purpose of the game is the creation of the *grand coalition* with a cost allocation method agreed on by each participant. The *grand coalition* is the coalition leading to the maximum benefit in this game (i.e. cost-savings). In a pre-determined number of rounds in which asymetric information on the potential cost-savings of some coalitions is individually and confidentially revealed to each participant, negotiation takes place between the participants to form or break coalition(s) and define, in each coalition, a cost allocation method to agree on. The key issues relevant for the pilot project that was demonstrated with the simulation game was: i) the difficulty of defining a cost allocation method that is agreed on by all participants of a coalition; ii) the difficulty of sharing individual information in the negotiation; iii) the large gap in the collaboration synergy (mainly, cost-savings) obtainable between different participant(s); iv) the merger of two disjoint coalitions is always profitable (i.e. *superadditive* propriety); v) the loss in cost-savings if the *grand coalition* is not formed (i.e. *non constant-sum* propriety).

As mentioned in Section 6.3, to put logistics scenario #5 into practice the companies must reach a collaborative business agreement that details the collaboration setting and, as the services provider, company A was mandated to define a first proposition of agreement to negotiate. Company A was highly involved and motivated by the pilot project, mainly for two reasons. First, the additional volume from the three other companies will allow company A to serve again the entire U.S. on a weekly basis. The gradual decrease in demand (and therefore the volumes shipped) has, in some regions, forced delayed shipments in order to maintain the transportation costs economically viable and competitive. This has been done by moving to a fortnightly service in these regions. Second, as was agreed by the four companies at the beginning of the pilot project, company A projected, in a second phase, to recruit new collaborating companies to the limit of its internal capacities (i.e. warehousing and reception/shipping docks). This additional volume would increase (or at the least, maintain) the cost-savings, the delivery time and the future transportation rate negotiation power position of the furniture companies against the carriers.

The definition of the agreement by company A was delayed for many reasons (e.g. U.S. customs security approbation, renewal of the employees' collective agreement at company A). When companies B, C and D receive the proposition of agreement, company B left the negotiation early. Company B was suspected, by the other companies, of opportunistically using the monetary-related parameters inside the proposition of agreement to renegotiate downward its current transportation rates with its carriers. The negotiations between the three other companies were slowed but continued. In growing financial difficulty, company C delayed its commitment to the pilot project and later on declared bankruptcy. Since the shipping volume of companies B and C represented 80% of the volume brought to company A for the collaboration, the sole volume of companies A and D did not provide enough coordination opportunities and the pilot project was suspended.

Since then, several factors (e.g. reduction of the fuel surcharge by the decrease of the fuel record prices, transportation rates discounts by the carriers' competition on the reduced shipping volume in the slowdown economic period) have reduced the pressure of transportation expenses on companies' profitability. This in turn reduces the priority of any effort (such as the pilot project) deployed by the companies and their industrial association to reduce transportation expenses. Nevertheless, company A has recently joined an ongoing founded local organization regrouping several companies from different industrial sectors. The feasibility of transportation collaboration is one of the avenues the members want to evaluate.

8. CONCLUDING REMARKS

Using a case study of four Canadian furniture companies shipping to the U.S., it has been demonstrated that collaboration in transportation can provide cost-savings as well as delivery time reduction. To establish a collaboration meeting companies' requirements on certain shipments (i.e. tight delivery time and/or prohibition of the use of regional LTL carrier), a logistics scenario with more flexibility in the transportation operations has been proposed and tested. The result obtained in this improved logistics scenario satisfies the requirements of the furniture companies and thus, makes the collaboration with this logistics scenario acceptable to all companies.

We also studied one of the key issues in a collaboration agreement among the companies: how cost-savings should be shared among them. Based on two cost allocation methods in the literature, the *Equal Profit Method* and the *Alternative Cost Avoided Method*, we propose a new method imbedding modifications for the business context of the case study. We first introduce in a modified EPM the presence of three non transferable costs: (i) volume flat rate for 3PL provider services, (ii) special requirements cost and (iii) transport cost for transportation upstream to the terminal. As for the second cost, we propose a modified ACAM to determine the non transferable cost allocated to each of these companies. This modified ACAM aims to allocate to the company with the most expensive requirements the greatest part of the additional cost incurred in the collaborative planning with the special requirements. Secondly, to ensure an allocation providing a stable and profitable coalition, we introduce in the modified EPM the notion of having to guarantee a minimum savings percentage to all companies. We computed a set of values that can take this percentage to show the impact on the allocation among the companies. We also evaluated the impact on the cost-savings of company A in an increase or decrease of its volume flat rate as 3PL service provider in the collaboration. Details about the actual outcome of the case study complete the discussion.

There are many research directions that can be pursued in the future. For instance, in the case study, considerable geographic coverage benefit could be achieved by a company through the collaboration, raising the question of how much this access to new markets is worth. A way to study this question could be found by considering the coverage benefit in the cost allocation method. This could be a challenging problem also for other benefits from collaboration, see e.g. (Cruijssen *et al,* 2007a) for a review of papers identifying different benefits revealed with collaboration.

Typically, the decision on the savings distribution among the companies is determined simultaneously with the decision on which coalitions can be expected to form (Greenberg, 1994). In the paper, the approach chosen to address these two issues simultaneously is static, i.e. we expected that the *grand coalition* would be formed according to the negotiated minimum savings percentage and remain unchanged. This approach is justifiable considering the high transaction costs of implementing such a collaboration. (Macho-Stadler *et al,* 2006) note that the transaction costs seem to increase with the number of companies involved. However, these two issues should be addressed using a more dynamic approach allowing modifications to the coalition as time goes by.

In the case study, company A wants to bring all companies into its coalition and, in further steps, other companies as well. However, the issues on the optimal size of the coalition, for all players of the coalition or only a subset, should be addressed. Moreover, in a context of transportation such as in the case study, this issue should be addressed according to delivery regions instead of only on a company basis. For instance, this geographic perspective would allow adding the shipments of a new company to the collaborative planning only in regions with transport capacity to fulfill.

Economics does provide a rich understanding of the fundamentals behind these issues, the next step is to validate the knowledge in field work.

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References

Agarwal, R., Ergun, Ö., Houghtalen, L. and O.Ö. Ozener, (2009). Collaboration in cargo transportation. In: Chaovalitwongse, W., Furman, K.C. and Pardalos, P.M. (eds). *Optimization and Logistics Challenges in the Enterprise*. Springer: New York, pp 373-409.

Archambault, G., Carle, D., Caron. M. and R. Vézina (2006). The furniture manufacturer of the future, executive summary [In French]. FPInnovations-Forintek, Canada.

Audy, J.-F. and S. D'Amours (2008). Impact of benefit sharing among companies in the implantation of a collaborative transportation system – An application in the furniture industry. In: Camarinha-Matos, L. and Picard, W., (eds). *IFIP International Federation for Information Processing, Volume 283, Pervasive Collaborative.* Networks. Springer: Boston, pp 519-532.

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

Brown, G.G. and D. Ronen (1997). Consolidation of customer orders into truckloads at a large manufacturer. *The Journal of the Operational Research Society* 48 (8): 779-785.

Caputo, A.C., Fratocchi, L. and P.M. Pelagagge (2005). A framework for analyzing long-range direct shipping logistics. *Industrial Management and Data Systems* 105 (7): 876-899.

CEFFOR (2008). The furniture industry in 2016 – Competitive scenarios: strategic trends and implications, executive summary. Furniture Foresight Centre, Spain.

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

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

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

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

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

Greenberg, J (1994). Coalition structures. In: Aumann, R.J. and Hart, S. (eds). *Handbook of Game Theory with Economic Applications*. North-Holland: Amsterdam, pp 1305-1337.

Hadjdukavá, J. (2006). Coalition formation games: a survey. *International Game Theory Review* 8 (4): 613-641.

IC (2008). Trade Data Online, requests on NAICS based code #337. Industry Canada, Government of Canada. Available from: http://www.ic.gc.ca/, accessed 25 January 2008.

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

Kumar K and van Dissel H G (1996). Sustainable collaboration: Managing conflict and cooperation in interorganizational systems. *MIS Quarterly* 20 (3): 279-300.

Kuo, C.-C. and F. Soflarsky (2003). An automated system for motor carrier selection, *Industrial Management and Data Systems* 103 (7): 533-539.

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

Macho-Stadler, I., Pérez-Castrillo, D. and N. Porteiro (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. and R. Boughton (2007). Combining vertical and horizontal collaboration for transport optimisation. *Supply Chain Management: An International Journal* 12 (3): 187-199.

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

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

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

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

Rönnqvist, M. and S. D'Amours (2008). Cost allocation game. *5th CEMS Research Seminar: Supply Chain Management – Recent Trends and Future Perspectives*, January 23-27 2008, Riezlern, Autria.

Selviaridis, K. and M. Spring (2007). Third party logistics: a literature review and research agenda. *International Journal of Logistics Management* 18 (1): 125-150.

Thomas, L. (2008). Six furniture trucking firms to merge. Furniture Today. Available from: http://www.furnituretoday.com/, accessed 30 April 2008.

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

Young, H.P. (1985). Cost allocation: methods, principles, applications. North-Holland: Amsterdam.

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