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January 2011

CIRRELT-2011-04

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An Educational Game in Collaborative Logistics

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Abstract. We describe an educational game in collaborative logistics. The game is based on an award-winning application in cost allocation in transportation. The purpose of the game is to acquire an understanding of negotiation, coalition building and cost/profit sharing when the players have different power and hold different levels of information. The game is played with each player representing a single company. The objective of the game is to find an efficient plan and to share the benefits of the collaboration. We describe the underlying case study, basic concepts in game theory, and outline the game and discuss experiences from running the game in several countries and those with students registered in business schools, engineering and forestry faculties.

Keywords. Collaborative logistics, cost sharing, cooperative game, logistics.

Acknowledgements. We thank Philippe Marier for developing Excel files supporting this game. We also acknowledge the financial support of Natural Sciences and Engineering Research Council of Canada (NSERC) and the FORAC Research Consortium. Finally, we thank the Forestry research institute of Sweden for providing the industrial case.

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1 Introduction

In order to outdo the competition, access new markets and respect operational, social and environmental constraints, enterprises are establishing more and more collaborations with many other business entities. Furthermore, with costs and information sharing, organizations have the opportunity to optimize their logistics activities. However, each enterprise has its own objectives and typically makes its own planning decisions to maximize individual profit. Therefore, it becomes crucial to determine how business entities will work together, the value of the collaboration and how to share the benefits. In order to illustrate the behavior when companies are faced with the task of sharing information and agree on sharing of benefits, we have developed an educational game, based on an industrial case described in Frisk *et al.* (2010). This article won the EURO Management Science Strategic Innovation Prize 2007. The game is easy to understand and can be used in many logistics or quantitative courses and for many different students. We have used it with Master's students at business schools, engineering schools and with professionals in transportation planning. In addition, we have utilized it in several countries including Sweden, Norway, Canada, France and Chile.

A popular and often-employed educational game is the "beer distribution game" (beer game) developed at MIT (Sterman, 1989). It is a simulation game to illustrate the impact of the bullwhip effect in supply chains and it serves to identify best practices in supply chain management. As well, electronic versions of the game exist, see e.g. Simchi-Levi et al. (2003). The beer game has also been adopted and implemented for different sectors, for example, the FORAC Research Consortium developed an online version for the forest industry. The importance and positive effect of making use of business games as teaching tools in Management Science (MS) and Operations Research (OR) courses are discussed in Griffin (2007) and Ben-Zvi and Carton (2007). It is argued that business games are an effective way to engage students in MS/OR topics. They provide an understanding of the real problems and the practical situations faced by companies or organizations with such problems. There exist games for several industrial sectors. Recently, Talluri (2009) described a game for teaching revenue management and Allon and Mieghem (2010) described one for supply chain sourcing. A general list of on-line simulation games is described in Wood (2007). A short and limited version of the game in this paper is also described in D'Amours and Rönnqvist (2010).

In this paper, we describe the case study and its history, and some basic concepts in game theory, the game, how it is played and report some general observations. A lecture where the game is played is divided into four parts. In the first part, the background of the case study and setting of the game is introduced. In the second and third parts, the game is played in two runs. In the first run, a restricted game is played, where the number of participants in the collaboration is limited. In the second run, any collaboration is allowed. In the last fourth part, the results and experiences of the real case study are described and discussed. The outline of the paper is as follows. In Section 2, we describe the case study used in the game. In Section 3, we provide some basic concepts in game theory. In Section 4, we describe what happened in the real case. In Section 5, we describe some material used to play the game. In Section 6, we describe experiences from running the game in different settings. We end with some concluding remarks.

2 Case study

The data used in this paper have been taken from a study done by the Forestry Research Institute of Sweden for eight participating forest companies. These companies operate in the southern part of Sweden as shown in Figure 1. The green area is the location of supply areas and the stars are industries. In total there are 898 harvest areas and 101 industries. The total number of products (or assortments) is 39. A product is a log with a specific combination of species, diameter, length and quality. Demand is either expressed as a volume per product or as a volume of a mix of products (there are 12 possible products mix).

Fig. 1. Illustration of geographical area where the companies operate in southern Sweden.

In our case, we consider the problem of coordinating fibre procurement and transportation for several companies. It is common that transport costs can be decreased if companies use wood bartering. However, this is difficult as planners do not want to reveal supply, demand and cost information to competitors. In practice, this is solved by deciding on wood bartering of specific volumes. Today, this is typically done in an ad-hoc manner and is mostly dependent on personal relations. In Figure 2, we illustrate the potential benefits of wood bartering when two companies are involved. Here, we have four mills at two companies (two mills each) together with a set of supply points for each company. On the left-hand side, each company operates by itself. The transportation distances are relatively long as compared to the right side where all supply and demand points are used by both companies. Since the overall cost is more or less proportional to the distance, it is clear that the solution to the right side with collaboration is much better than the left side without collaboration.

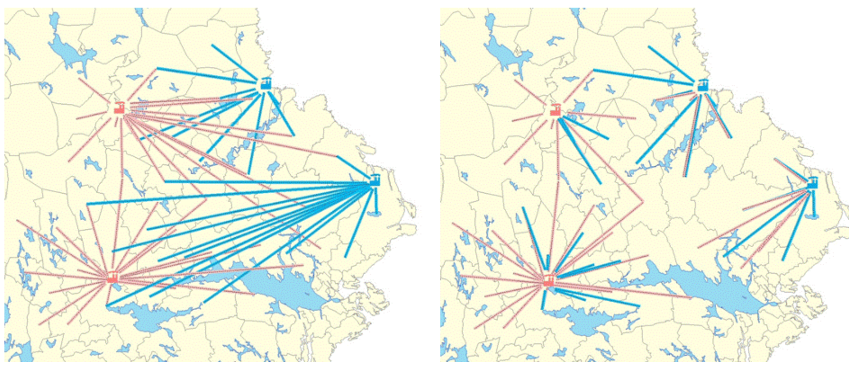

Fig. 2. Illustration of wood bartering between two companies. In the left part, two companies (indicated in blue and red) work with their own supply and demand. In the right part, the companies treat their supply and demand as common.

The data to support the case study is taken from transportation files reporting on activities carried out during one typical month. It involves all transports from the eight companies and includes information on time, from/to nodes, volume and product. The level of activities varies within the companies. Table 1 shows the volume transported and the proportion over the total transported volume for each of the companies. It is clear that company 2 is much larger than company 8. This aspect and its consequences will be very clear in the game.

Table 1. Monthly volumes (cubic metres) for each of the eight companies.

Company	Volume	Proportion
Company 1	77361	8.76%
Company 2	301660	34.16%
Company 3	94769	10.73%
Company 4	44509	5.04%
Company 5	232103	26.29%
Company 6	89318	10.12%
Company 7	36786	4.17%
Company 8	6446	0.73%

The companies operate in southern Sweden and cover different geographical areas; see Figure 3 where the green areas show the supply areas and the red circles denote the industries. Some companies cover the entire region (e.g. company 2) and others only a part (e.g. company 1). A good coverage, i.e. they work in the same region, between two companies indicates high potential for savings. For example, if companies 2 and 5 collaborate, the cost savings can be large. At the same time, if companies 1 and 5 collaborate, the cost savings would be small.

From the case study, we had detailed information on all transports made by the eight companies. With this information, we can compute the optimal cost for each company as well as the cost if all eight companies work together. In addition, we can also compute the cost of all possible coalitions. There are 245 (2^8-1-8) coalitions possible. The new transportation costs were computed with the system FlowOpt (Forsberg et al. 2005). This is a decision support system which includes a Geographical Information System, the Swedish road database NVDB and optimization routines to solve the OR models. The transportation planning problem is to decide how to transport logs from supply to demand point. The transportation can be done directly or indirectly through terminals. Moreover, there are several transportation modes including trucks, trains and ships. In Table 2, we provide information on the actual cost of the transportation activities, the cost when transportation is optimized within the company and finally, the cost when all companies are working together. The total saving when all companies are working together is 8.6%. In the game, we use only the optimized values as the companies may have different efficiency in their own planning.

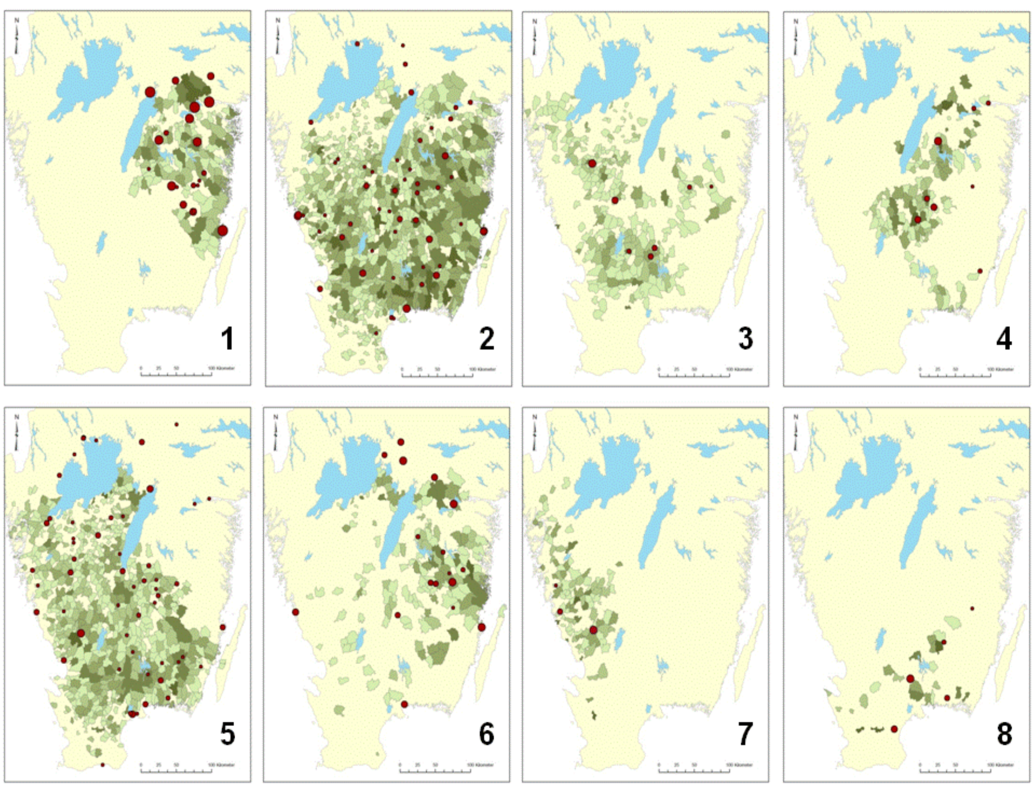

Fig. 3. Supply areas (indicated with green) and demand points or mills (indicated with red circles) for the companies.

Table 2. Real and optimized costs associated with each company and when all work together. All cost units are given in kSEK (thousand of Swedish kronor).

Company	Cost - real	Cost - opt	Cost - all
Company 1	3,894	3,778	
Company 2	15,757	14,859	
Company 3	4,828	4,742	
Company 4	2,103	2,067	
Company 5	10,704	10,340	
Company 6	5,084	4,959	
Company 7	1,934	1,884	
Company 8	333	333	
Companies 1-8			39,253
Total	44,637	42,963	39,253

3 Basic concepts in collaboration

One important aim of the game is to provide an understanding of the negotiation process, cost sharing mechanisms and an understanding of issues to make it happen in practice. Some important concepts needed for this are found in game theory literature. This section is based on the description found in D'Amours and Rönnqvist (2010). We will describe a number of sharing principles once the coalition has been formed and agreed. We start by introducing some basic notation used in game theory. We will discuss sharing principles based on cost allocation methods. We have a set of business entities N . A *coalition S* is a subset of business entities i.e. $S \subset N$.The *grand coalition* is the set of all entities i.e. N . The cost of a coalition is denoted $c(S)$.

A cost allocation method distributes (or allocates) the total cost of a coalition to the entities. In many cases there is an assumption that we use the grand coalition as a basis but below we may have any coalition as a basis for the allocation. This aspect is important as it is often needed to establish any contribution when coalitions are formed. Each entity *j* will be allocated the cost y_j.

Since the total cost is to be distributed among the entities, we have

$$\sum_{j \in s} y_j = c(S) \qquad (1)$$

A cost allocation which satisfies the above constraint is said to be *efficient*. There are other properties that can be associated with a cost allocation. One property which requires that the entity not be allocated a higher cost than its own cost is called individual rationality. This is simply expressed as

$$y_j \le c(\{j\}) \qquad (2)$$

Another important concept is to ensure that there are no incitements for a coalition to break out and work independently. This implies that the cost allocated to a particular coalition of entities cannot exceed the actual cost of the coalition. There are many potential coalitions and this means that we have one constraint for each possible coalition. This can be expressed as

$$\sum_{j \in S'} y_j \le c(S) \quad \forall \ S' \subset S \tag{3}$$

Constraint set (1) and (3) define what is called the *core*. Any solution which is feasible with respect to the core is called *stable*. In general, there is no guarantee that there exists a feasible solution to the core. The game is said to be monotone if

$$c(S') \le c(S), S' \subset S \tag{4}$$

This means that if one new entity is included in a coalition, the cost never decreases. The game is said to be *proper* if

$$c(S) + c(T) \ge c(S \cup T), S \cap T = \emptyset \tag{5}$$

This implies that it is always profitable (or at least not unprofitable) to form larger coalitions. The properties discussed above are not satisfied for all classes of games. Some may be guaranteed and others not. For each coalition, S , and a cost allocation, y , we can compute the *excess*

$$e(S, y) = c(S) - \sum_{j \in S} y_j \tag{6}$$

which expresses the difference between the total cost of a coalition and the sum of the costs allocated to its members. For a given cost allocation, the vector of all excesses can be thought of as a measure of how far the cost allocation is from the core. If a cost allocation is not in the core, at least one excess is negative.

There exist many quantitative allocation rules and we will discuss some that have been used in different applications. A simple and straightforward allocation is to distribute the total cost of the coalition among the participants according to a volume or a cost weighted measure. This allocation is called *weighted costs* and is expressed by the formula

$$y_j = \frac{c(\{j\})}{\sum_{j \in S} c(\{j\})} c(S) \tag{7}$$

It is intuitive but can often lead to an allocation that does not satisfy the core conditions, for example. A more advanced method is based on dividing the allocation into two parts. One is associated with a separable cost and the other a non-separable cost. The separable cost or the marginal cost (8a) of entity *j* and the non-separable cost (8b) as can be expressed as

$$m_j = c(S) - c(S \setminus \{j\}) \tag{8a}$$

$$g_S = c(S) - \sum_{j \in S} m_j \tag{8b}$$

Methods based on separable and non-separable costs allocate the costs according to

$$y_j = m_j + \frac{w_j}{\sum_{j \in S} w_j} g_S \tag{9}$$

Depending on which weights are chosen, there are different versions of the method; the two most straightforward methods are the *Equal Charge Method*, which distributes the non-separable cost equally, and the *Alternative Cost Avoided Method*, that uses the weights $w_j = c(\{j\}) - m_j$, expressing savings that are made for each participant by joining the grand coalition instead of operating alone. These allocations satisfy the efficiency and symmetry properties. However, they are not necessarily in the core. These and other additional versions are discussed in Tijs and Driessen (1986).

The *Shapley value* (Shapley, 1953) is a solution concept that provides us with a unique solution to the cost allocation problem. The underlying idea is based on the assumption that the grand coalition is formed by entering the entities into this coalition one at a time. As each entity enters the coalition, it is allocated the marginal cost, and this means that its entry increases the total cost of the coalition it enters. The amount an entity receives by this scheme depends on the order in which the entities are entered. The Shapley value is just the average marginal cost of the entity, if the entities are entered in completely random order. The cost allocated to entity *j* is equal to

$$y_j = \sum_{S' \subset S \setminus \{j\}} \frac{|S'|!(|S| - |S'| - 1)!}{|S|!} \left(c(S' \cup \{j\}) - c(S') \right) \qquad (10)$$

Here |.| denotes the number of entities in the considered coalition. The quantity, $c(S \cup \{j\}) - c(S)$, is the amount by which the cost of coalition *S* increases when entity *j* joins it, here denoted by the marginal cost of entity *j* with respect to the coalition *S*. The Shapley value satisfies the efficiency property but does not necessarily satisfy the stability or the individual rationality properties.

When solving the transportation model used in the case study, we get dual or shadow prices for each of the supply and demand constraints. We define u_i and v_j as the shadow prices for the supply and demand constraints respectively. When we solve the transportation model for the coalition $S=N$, we get $c(N)$. The optimal dual solution has the property

$$c(N) = \sum_{i \in I} u_i s_i + \sum_{j \in J} v_j d_j \qquad (11)$$

The distribution of costs in linear production models, and our model is a special case, has been proposed by Owen (1975). They show that the core is non-empty and that a solution can be obtained from the associated LP-problem. The solution is based on market prices, which in the LP-model are represented by the shadow prices. Each company's contribution can be found by computing its contribution to the dual objective function value. We assume that company *c* has contribution s_i^c to supply constraint *i* and d_j^c to demand constraint *j*. Then we can compute its contribution as

$$y_c = \sum_{i \in I} u_i s_i^c + \sum_{j \in J} v_j d_j^c \qquad (12)$$

In many applications the entities wish to share the relative saving equally. One such approach, called *Equal Profit Method* (EPM), is suggested in Frisk *et al.* (2006). In this approach a Linear Programming (LP) model is solved where the model can be formulated as

$$\begin{aligned}
&\min f \\
&s.t. \\
&f \geq \frac{y_i}{c(\{i\})} - \frac{y_j}{c(\{j\})}, \forall i,j \\
&\sum_{j \in S} y_j \leq c(S), \forall S \subset N \\
&\sum_{j \in N} y_j = c(N)
\end{aligned} \tag{13}$$

The first constraint set is to measure the pair-wise difference between the profits of the entities. The variable f is used in the objective to minimize the largest difference. The two other constraint sets define all stable allocations. In cases where the objective is not 0 (no difference between the entities) the reason is that there is a coalition that has an incentive to break out, i.e. the core constraints must be satisfied. The EPM is related to a weighted version of the Constrained Egalitarian Allocation (CEA) method (Dutta and Ray, 1991). The CEA method seeks to pick a point in the core where the allocated amounts are as equal as possible. We can also define a weighted version of the CEA method (Koster, 1999). In order to relate the weighted CEA method to the method of Frisk et al. (2006), we set the weight of player i equal to $1/c(\{i\})$.

In Table 3, we show the results when we use a volume weighted allocation, Shapley values, Nucleolus, Dual prices, and EPM. It is clear that the results are very different for the applied methods.

Table 3. Relative savings in percentage with sharing principles: volume, Shapley values, Nucleolus, Dual prices, and EPM.

Company	Volume	Shapley	Nucleoulus	Shadow	EPM
Company 1	9.0	5.1	3.4	4.1	6.7
Company 2	9.7	9.0	11.1	12.7	8.8
Company 3	11.2	13.5	14.0	14.2	8.8
Company 4	4.3	8.6	6.4	13.3	8.8
Company 5	0.2	5.7	4.8	-1.8	8.8
Company 6	19.9	9.2	8.3	11.7	8.8
Company 7	13.2	15.8	11.5	15.6	8.8
Company 8	14.0	6.9	4.6	9.1	8.8

4 What happened with the companies

Once the first analysis for the eight companies was done, the results were presented to the managers. Each participating company was pleased and impressed with the large savings in both cost and CO_2 emissions. There was a discussion on how the overall cost and/or cost reduction should be split. In the forestry business, the cost is often based on average price per metric ton or cubic metre. Hence, a natural way of splitting the cost is for each company to take a share of the total cost corresponding to its proportion of volume. The result of a volume-based weighting is viewed in Table X. The fact that the second largest company (Company 5) would gain only 0.2% was not acceptable. This difference was too high and it was impossible to reach an agreement. The reasons for this difference in relative savings are twofold. First, each company takes responsibility for their own supply and makes sure it is delivered to the new destinations (coupling between supply and demand points). Secondly, the geographical distribution differs between companies and this affects the new distribution solution.

In order to come up with a sharing principle that the companies could agree on, several sharing principles based on economic models including Shapley value, the nucleolus, separable and non-separable costs, shadow prices and volume weights were tested and analyzed. As part of the analysis, a new approach called Equal Profit Method (EPM), was developed. The motivation was to get an allocation that provided an as equal as possible relative profit among the participants. In addition, it satisfies core constraints from cooperative game theory and is a stable solution. This approach was acceptable among the forest companies. It was further extended in a two-stage process where the first stage identified volumes that made a contribution to the collaboration i.e. volumes in the integrated solution that were not the same as in the individual solutions. Then the EPM was applied to these identified volumes.

As a result of the case study, three companies started collaborating in 2008 by coordinating their planning on a monthly basis. Before each month, each company provided the information about supply and demand to a third party logistics, in this case the Forestry Research Institute of Sweden. Then an integrated plan (i.e. common plan) was done and the result was given back to the forest companies for their own detailed transportation planning. The sharing principle was based on having the same relative savings applied to each company's own supply. In addition, there were some constraints making sure that each company was the main supplier for its own mills, and that pairwise exchange flows were the same. The latter is to avoid financial exchanges between companies. Moreover, some core conditions were not included. With this revised model, it was not possible to guarantee a stable solution. The approach was tested during four months in 2008 and the potential savings were 5-15% each month. Currently, there is a development of a platform for common plans where a third party logistic provider is not required.

5 Game

The game can be played in three versions. The first and second versions include four or five companies and the third all eight companies. In the versions with four and five companies more information is provided to the players. Most important are the actual costs of all the possible coalitions. All versions of the game are played during a 2-3 hour lecture. In a standard class, there will be a set of groups of four students. The information provided for the students in version 1 (four companies) is described below.

We first outline the purpose of the game and give a map, see Figure 4, of supply points and demand points for each of the four companies. Each company can work individually and has a specific transportation cost. A summary of the companies when they are working individually during one month is given in Table 4.

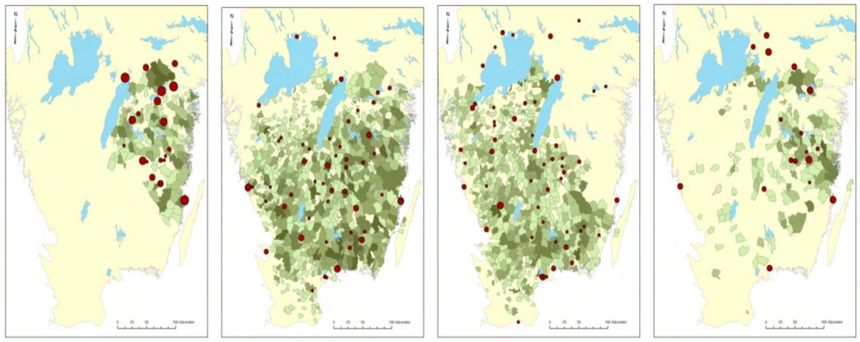

Fig. 4. *Maps describing each of the four companies C1 – C2 – C3 – C5. Green areas describe supply areas and red circles industries with demand.*

Table 4. *Summary of the four companies and their transportation volume, transportation cost and average transportation distance.*

Company	Volume	Individual cost	Average distance
Company 1	77,300 m^3	3,780 (kSEK)	70,3 km
Company 2	301,300 m^3	14,860 (kSEK)	56,8 km
Company 3	232,100 m^3	10,340 (kSEK)	68,5 km
Company 5	89,300 m^3	4,960 (kSEK)	68,5 km
Total	700,000 m^3	33,940 (kSEK)	-----

The companies can form one or several coalitions (a set of companies working together). If they work in a coalition, they simply treat their supply and demand as common, and can find a solution that lowers the overall transportation cost. For example, if companies C1 and C2 work individually, the overall cost is 3,780 (C1) + 14,860 (C2) = 18,640 kSEK. However, if they work together, the cost is 18,300 kSEK which represents a saving of 340 kSEK (18,640-18,300). One question is how these 340 kSEK should be divided between the two companies, C1 and C2. There are many possible coalitions and Table 5 summarizes their costs and savings. The improvement in the table is given as percentage i.e. savings divided by the aggregated individual cost. For example, the improvement for coalition (C1+C2+C3) is computed as 1,270/28,980=4.38%.

Table 5. *Summary of possible coalitions and their cost if they work together, summed individual cost, savings and improvement.*

Coalition	Cost (kSEK) (collaboration)	Cost (kSEK) (individual)	Saving (kSEK)
C1 + C2	18,300	18,640	340
C1 + C3	14,000	14,120	120
C1 + C5	8,510	8,740	230
C2 + C3	24,210	25,200	990
C2 + C5	19,040	19,820	780
C3 + C5	15,060	15,300	240

C1+C2+C3	27,710	28,980	1,270
C1+C2+C5	22,490	23,600	1,110
C1+C3+C5	18,580	19,080	500
C2+C3+C5	28,400	30,160	1,760
C1+C2+C3+C5	32,000	33,940	1,940

In the collaboration game, each group consists of four players. Each player is responsible for one company. The objective for each player is to improve its own cost/profit as much as possible. The task is to discuss and agree which companies should work together (if any). In part A, only two companies can work together. In part B, any coalition structure is possible. For example, all companies can work together, no companies work together, any group of two or three companies can work together. Each company can only participate in one coalition (in both part A and part B). Given the agreed coalitions in the two parts, how should the overall savings be divided among the participating companies?

Once the first part is played, we have a discussion on how the participants made their decisions, their thinking and their bargaining power. We also discuss the different results (displayed for groups) that the students have agreed on. This discussion is often interesting and provides a good basis for the second part. To support this discussion, we have developed an Excel tool where each group solution is inserted through an easy form. Figure 5 gives an example when eight groups have inserted their solution. First the coalitions agreed are inserted, and then the agreed savings for each company within each coalition. The Excel sheet includes some controls so that the correct savings are indeed inserted. Based on the input, two results are generated. First, we compute the relative savings for each company. This is inserted into a new table and is illustrated in Figure 6. Here it is easy to see how fair the distribution is. For example, group 1 selected a full coalition which gives an average saving of 5.76%. However, the agreed savings for the companies turned out to be 3.97%, 6.59%, 5.42% and 5.04%. Second, the same relative savings are also shown also in an Excel graph, see Figure 7. These results are very easy to discuss and compare among the student groups.

			Team 1	Team 2	Team 3	Team 4	Team 5	Team 6	Team 7	Team 8
	Coalitions	#1	C1+C2+C3+C4	C1+C2+C3+C4	C1+C2+C3+C4	C1+C2+C3+C4	C1+C2+C3+C4	C1+C2+C3+C4	C1+C2+C3+C4	C1+C2+C3+C4
		#2								
		#3								
		#4								
Savings (kNOK)	Coalitions	#1	1940	1940	1940	1940	1940	1940	1940	1940
		#2								
		#3								
		#4								
	Companies	C1	150	140	180	200	120	19,4	140	160
		C2	980	940	867	880	780	873	1000	590
		C3	560	594	603	600	690	679	550	590
		C4	250	266	290	260	350	368,6	250	600
	Total		1940	1940	1940	1940	1940	1940	1940	1940
	Total2		1940	1940	1940	1940	1940	1940	1940	1940

Fig. 5. *Input information from eight groups with their agreed coalition and the agreed savings. In this case all eight groups agreed on the grand coalition but the agreed savings are quite different.*

			Team 1	Team 2	Team 3	Team 4	Team 5	Team 6	Team 7	Team 8
	Coalitions	#1	C1+C2+C3+C4	C1+C2+C3+C4	C1+C2+C3+C4	C1+C2+C3+C4	C1+C2+C3+C4	C1+C2+C3+C4	C1+C2+C3+C4	C1+C2+C3+C4
		#2								
		#3								
		#4								
Savings (%)	Coalitions	#1	5,72	5,72	5,72	5,72	5,72	5,72	5,72	5,72
		#2								
		#3								
		#4								
	Companies	C1	3,97	3,70	4,76	5,29	3,17	0,51	3,70	4,23
		C2	6,59	6,33	5,83	5,92	5,25	5,87	6,73	3,97
		C3	5,42	5,74	5,83	5,80	6,67	6,57	5,32	5,71
		C4	5,04	5,36	5,85	5,24	7,06	7,43	5,04	12,10

Fig. 6. *Relative savings for each of the companies based on the inserted solution.*

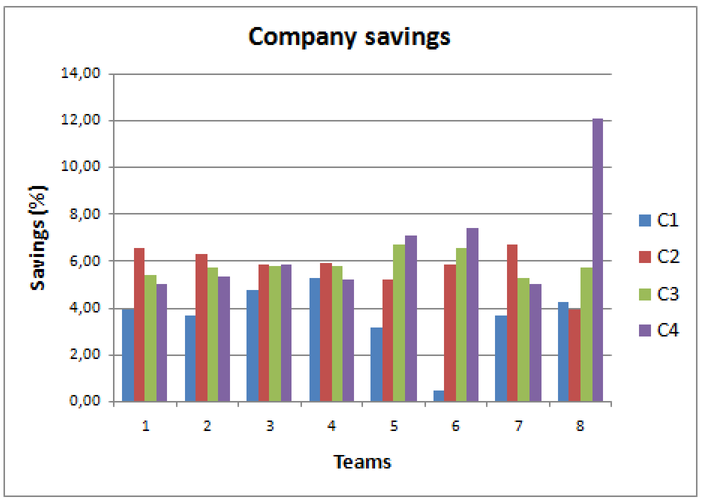

Fig. 7. *Relative savings for each of the companies based on the inserted solutions from the eight groups.*

The information in version 2 (five companies) is very similar to that in version 1. The only difference is that a fifth company is introduced. This makes the first part a bit more complicated as at least one company must be left outside a coalition. Moreover, the new fifth company has a good bargaining power.

The information provided for the students in version 3 (eight companies) is different. Each company has information about its total cost together with the information about collaborating with one other company. There is no information on collaborating with three or several companies. In this version, it is more important to find agreements without knowing the real benefits. Below in Table 6, we provide the information for one company. Version 2 also has two parts. In the first part, coalitions of at most two companies should be found. This is more difficult, as compared to version 1, as there are many more alternatives. Also, here it is very clear that companies 2 and 5 have much higher negotiation power. In the second part, any coalition and principle for sharing the benefit are to be found. At the end, the real benefits of the agreed coalitions are provided to the agreed groups and they need to split the savings according to agreed principles.

Table 6. Costs and savings (kSEK) when company 1 works together with a second (2-8) company.

Company	Company	Cost (separate)	Cost (together)	Saving
1	2	18,640	18,300	340
1	3	8,520	8,490	30
1	4	5,840	5,770	70
1	5	14,120	14,000	120
1	6	8,740	8,510	230
1	7	5,660	5,660	0
1	8	4,110	4,100	10

Once the game is played, we follow up with what happened in the real case and what sharing mechanisms were tested and used. We introduce the students to basic game theory including the core conditions, efficient allocation and individual rationality concepts. We then go through well-known methods such as the Shapley value, the shadow price approach, the nucleolus approach. We also show results when using a simple "volume" based allocation method which often is the one used in practice. Finally, we present the retained approach named the equal profit method. Essentially we make a quick run through material similar to Section 4 in this paper.

There is also a discussion of other drivers for the collaboration. These are: the effects of CO2 emissions, trust and long term relationships. To form any coalition is also highly dependent on which company is the driver and which business model each company has. Therefore, we discuss different business models and behaviour and how the coalitions can be formed. More information and results based on the case study can be found in Audy et al. (2010).

The closing discussion always brings up the challenges of building long term relationships between the players. Key aspects of the transaction cost theory and the agency theory are used to sustain the discussion. Finally, we tend to use this discussion to reinforce the contribution of game theory to assess the potential of collaborative logistics as well as provoke reflection on other aspects of long-term relations such as trust, communication, coordination mechanism and contracts. We also provide extra reading. For example, the papers by Audy *et al.* 2010 and Lehoux *et al.* 2009 are good complements to the game as they report on collaborative logistics cases. It is clear that this game does not cover all the important issues but we believe that it contributes to developing key competencies for establishing higher quality collaboration in logistics.

6 Experiences

We have been playing this game with students, business people and researchers in France, Sweden, Norway, Chile and Canada. All information (PDF documents, Excel sheets and PPT presentation) can be provided by the authors. We first developed version 3 of the game where 8 players are provided with the company information and on the impact of partnering with another company. For example, company 1, knows its cost, average transportation distance and the geographical location of its catchment areas and industries.

Company 1 also knows the potential benefit of pairing with company 2, 3, 4, 5, 6, 7 and 8 respectively. It does not know the benefit of being part of a larger coalition. For us this was the replication of the real case as there are eight companies involved in the real case. We however found that the players with the smallest companies were rapidly put aside. The only way they could really be heard by the others was to join forces with them even though they did not have any incentive at first sight. Only once, as a “larger” player, would the others start discussing with them. This was difficult for the students to realize; very few participants saw the potential of this strategy and were capable of using its power in the negotiation process.

Running the game in different countries permitted us to capture cultural differences. These observations cannot be generalized but are interesting to discuss here as they illustrate strategies in dealing with the case. North Americans tend to build their coalition one by one, which is in opposition to Scandinavians who typically start with the grand coalition and rarely eliminate a company from the grand coalition. Participants from France and Chile used mixed strategies mainly based on relations – pairing with their friends. In Chile, one group decided to eliminate the smallest company and gave the player the responsibility of mediating the grand coalition. These are only a few examples of how the participants approach the challenges of this game and again no generalization is possible. In this game the players focus more on coalition building than on designing the sharing mechanism.

We then developed version 1 of the game. This version deals with only four companies and provides more information. Each player knows the potential benefit of paring with one, two and three companies. The players are rapidly challenged by the fact that no equilibrium exists and that they need to negotiate an incentive to get the maximum out of the grand coalition (four companies). The discussions are easier to manage than in version 3 of the game as only four players are involved in each group. The players focus more on the sharing mechanism than on coalition building. We have also developed an Excel sheet for versions 1 and 2 to illustrate the results and characteristics of the most common sharing principles.

7 Conclusions

Collaboration in supply chain is attracting interest from academic and industrial communities. It is seen as a new approach to increase the value created through better cross-chains coordination. However, most agree on the fact that establishing efficient and sustainable collaborations requires highly-skilled and competent people. This is why we developed this game.

Business games are often used for developing complex competences. This is the case of this game as the participants integrate advanced knowledge on game theory as well as develop their negotiation skills.

To be efficient, business games need to be simple and meaningful. The game proposed focuses on two aspects of collaboration in logistics: coalition building and sharing mechanism. It is simple to explain and to run. Moreover, the game builds on a real industrial case providing a meaningful background in terms of the data (e.g. maps, costs, distances and volumes) and human behavior. It also shows that the theories learned through the exercise are relevant to students.

Acknowledgement

We thank Philippe Marier for developing Excel files supporting this game. We also acknowledge the financial support of NSERC and the FORAC Research Consortium. Finally, we thank the Forestry research institute of Sweden for providing the industrial case.

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