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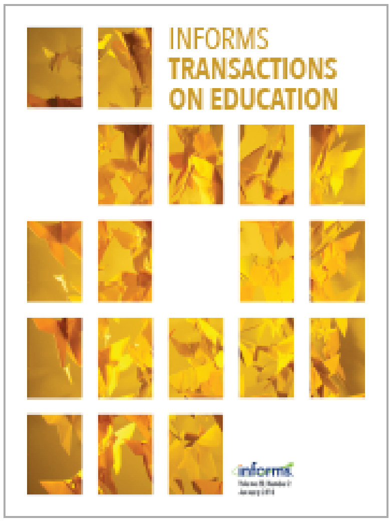

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An Educational Game in Collaborative Logistics

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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 powers and hold different levels of information. The game is played with each player representing a single company. The challenge for the players is to find an efficient coalition and to share the benefits and costs of the collaboration. We describe the underlying case study, review basic concepts in game theory, outline the teaching case, and discuss experiences from running the game in several countries and with students in business, engineering, and forestry.

Key words: collaborative logistics; cost sharing; cooperative game; logistics
History: Received: December 2010; accepted: November 2011.

1. Introduction

As enterprises are specializing and diversifying, they rely more on collaborations with other business entities (Audy et al. 2011). Organizations are adopting these strategies in order to outdo the competition; access new markets, while being mindful of operational, social, and environmental constraints. Furthermore, by sharing costs and information, organizations are able 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 anticipate how business entities can work together, how they can value their collaboration, and how they can share the benefits of collaboration. In order to illustrate the behavior when companies are faced with the task of sharing information and agree on sharing benefits, we have developed a teaching case based on an industrial case study described in Frisk et al. (2010). This article won the EURO Management Science Strategic Innovation Prize in 2007. The teaching case is run as a 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 and engineering schools, with professionals in transportation planning, and with business executives. In addition, we have utilized it in several countries, including Sweden, Norway, Canada, France, and Chile.

A popular 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 students to understand how supply chain work and has motivated research on supply chains integration and synchronization challenges. Electronic versions of the game also 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 (Wood Supply Game 2012). The importance and positive effects 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 with MS/OR topics. They provide an understanding of the real problems and the practical situations faced by companies or organizations. There exist games for several industrial sectors. Recently, Talluri (2009) described a game for teaching revenue management and Allon and Van Mieghem (2010) described one for supply chain sourcing. A taxonomy of online simulation games is described in Wood (2007). Cochran (2005) is also a reference for classroom games and related literature. Sniedovich (2002) discusses the importance and use of educational games. A short and limited version of the game in this paper is also described in D'Amours and Rönnqvist (2010a).

In this paper, we describe the case study and its history, review some basic concepts in game theory, describe the game and how it is played, and we provide some general observations. A two-hour lecture where the game is played is divided into four parts. In the first part, the background of the industrial case study and settings of the teaching case and game rules are 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 each coalition is limited to two at most. In the second run, any collaboration and size of one or several coalitions are allowed. In the fourth and final part, the results and experiences of the industrial case study are described and discussed as well as a review of the theoretical background.

The outline of the paper is as follows. In §2, we describe the case study used in the game. In §3, we provide some basic concepts in game theory for instructors not familiar with game theory. We present these concepts to the students after playing the game. In §4, we describe what happened in the real case. In §5, we describe some material used to play the game. In §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 case 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 shaded areas are the locations of supply areas and the stars are mills. In total there are 898 harvest areas and 101 mills. The total number of products is 39. A product is a log type with a specific combination of species, diameter, length, and quality. Demand is expressed as a volume per product.

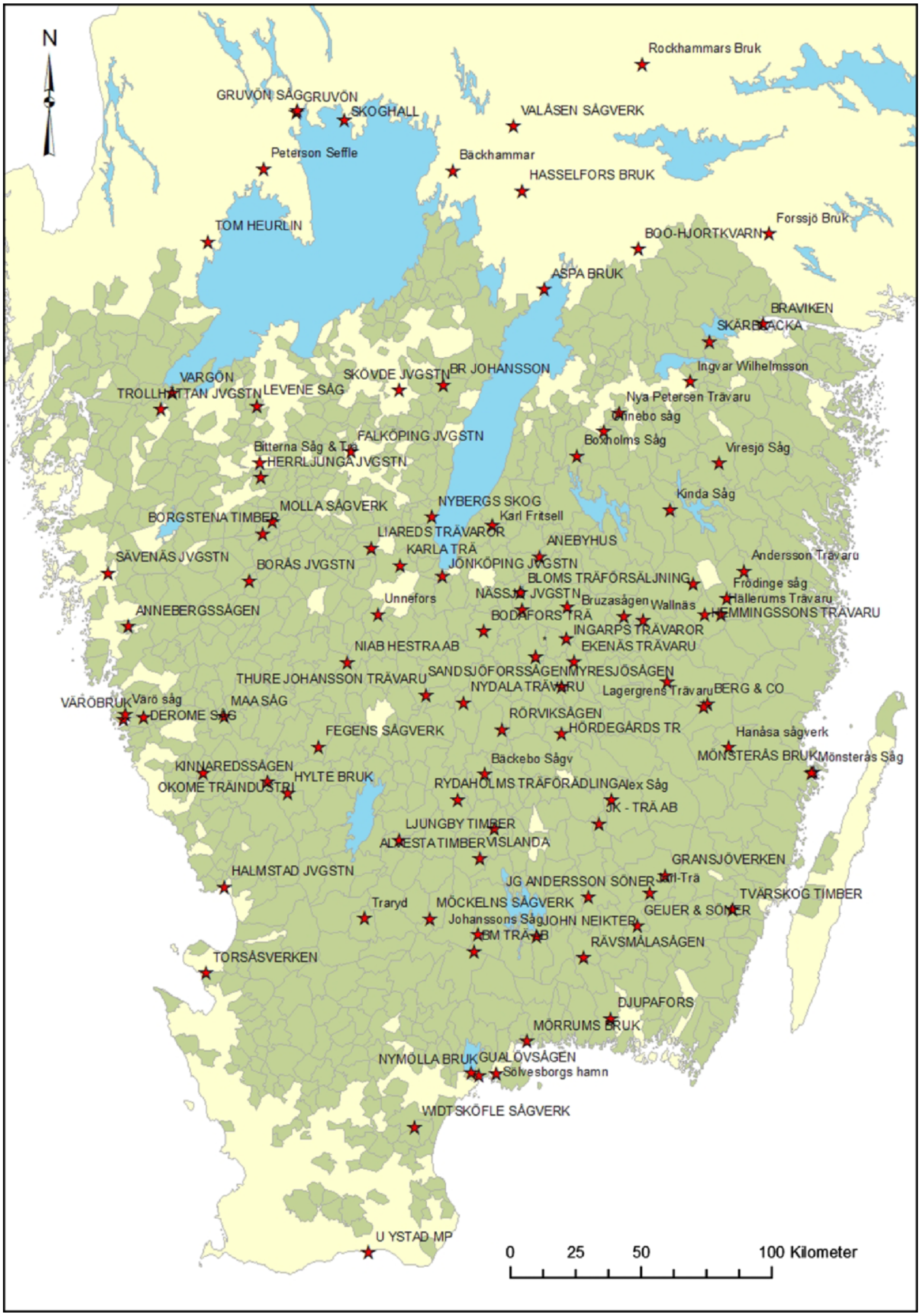
In our case we consider the problem of coordinating fiber procurement and transportation for all or some of the eight companies. It is common that transport costs can be decreased if companies use wood bartering. However, this is difficult because planners do not want to reveal supply, demand, and cost 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 (each company is responsible for two mills) 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 jointly by both companies. Because the overall cost is more or less proportional to the distance, it is clear that the solution on the right side with collaboration is much better than the left side without collaboration.

The data to support the case study are taken from companies records reporting on fiber procurement and transportation carried out during one typical month. They involve all transports from the eight companies and include information on time, origin destination, volume, and product. The level of activity varies within the companies. Table 1 shows the volume transported and the proportion of the total transported volume for each of the companies. Companies are of different sizes, for example, company 2 is much larger than company 8. While playing the game, the players typically experience the power of the larger companies in the negotiation process. For example, player holding company 8 rarely gets any attention from the other players.

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 mills. Some companies cover the entire region (e.g., company 2) and others only a part (e.g., company 1). There is a correlation between the overlap in coverage, between two companies and the potential for cost savings from collaboration. For example, if companies 2 and 3 collaborate, the cost savings can be large whereas if companies 1 and 3 collaborate, the cost savings would be smaller.

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 247 (2^8–1–8) coalitions possible. Transportation costs for all coalitions were computed with the system FlowOpt (Forsberg et al. 2005). This is a decision support system that 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 points. 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, for consistency we use only the optimized values. We do not use the actual costs because the companies might differ in how effectively the plan their operations.

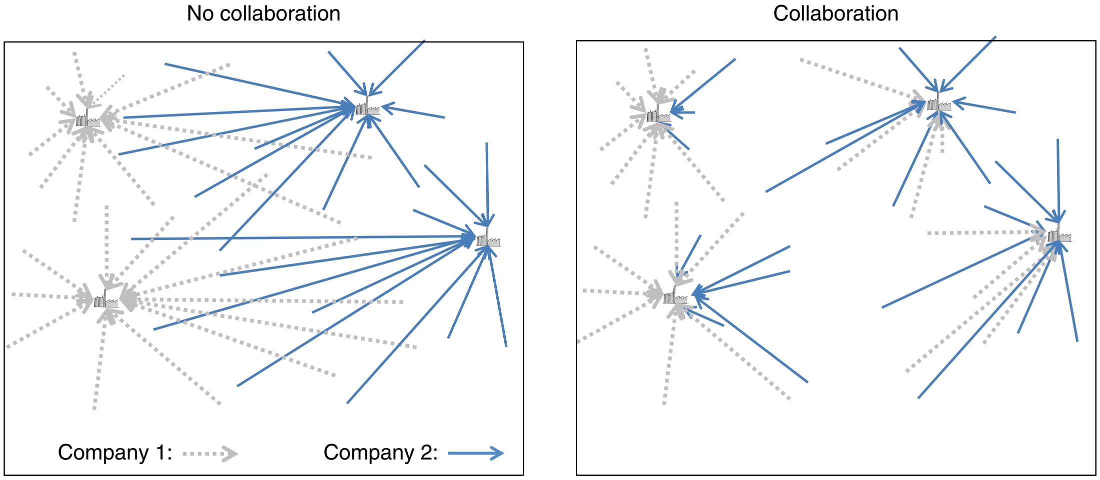
Figure 1 Illustration of Geographical Area Where the Companies Operate in Southern Sweden



3. Basic Concepts in Collaboration

One important aim of the game is to provide an understanding of the negotiation process of cost sharing mechanisms, and the importance of trust and fairness. Some important concepts needed for this are found in the game theory literature. This section is provided for the instructors who might want to review these concepts with the students at the end of the game. It is based on the description found in D'Amours and Rönnqvist (2010b). We will describe a number of sharing principles once the coalition has been formed and agreed upon. We start by introduc-

Figure 2 **Illustration of Wood Bartering Between Two Companies**



Notes. On the left, the transportation flows for two companies (indicated in dotted and dark lines) work with their own supply and demand. On the right, the companies treat their supply and demand as common. The total distance is about 50% shorter using a common wood bartering.

ing 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 because it is often needed to establish the contribution of all possible coalitions. Each entity j will be allocated the cost y_j. A coalition set consisting of only one entity j is denoted $\{j\}$. Because the total cost is to be distributed among the entities, we have

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

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

$$y_j \le c(\{j\}). \tag{2}$$

Another important concept is to ensure that there is no incentive 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 sets (1) and (3) define what is called the *core*. Any solution in the core is called *stable*. In general, there is no guarantee that there exists a solution in to the core. The game is said to be monotone if

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

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

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

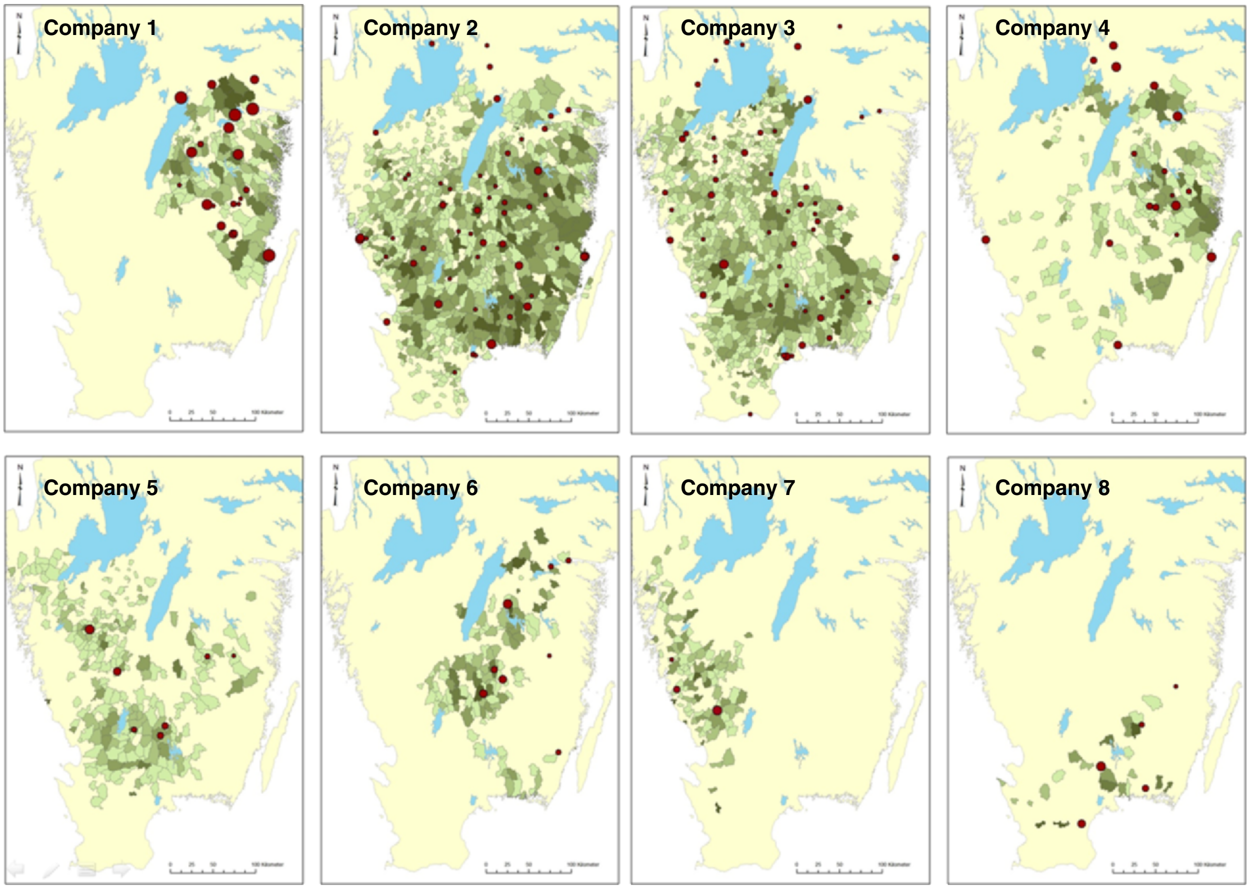
This implies that it is always profitable (or at least not unprofitable) to form larger coalitions. The properties discussed above are not satisfied for all classes of games. Some may be guaranteed and others not. For each coalition, S, and a cost allocation, y, we can compute the *excess*

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

Table 1 **Monthly Volumes (Cubic Meters) for Each of the Eight Companies**

Company	Volume	Proportion (%)
Company 1	77,300	8.8
Company 2	301,300	34.2
Company 3	232,100	26.3
Company 4	89,300	10.1
Company 5	94,770	10.7
Company 6	44,509	5.0
Company 7	36,786	4.2
Company 8	6,446	0.7

Figure 3 **Supply Areas (Indicated with Green) and Demand Points or Mills (Indicated with Red Circles) for the Companies**



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.

Many quantitative allocation rules exist 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

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

Table 2 **Real and Optimized Costs Associated with Each Company and when All Work Together**

Company	Cost-real	Cost-opt	Cost-all
Company 1	3,894	3,780	
Company 2	15,757	14,860	
Company 3	10,704	10,340	
Company 4	5,084	4,960	
Company 5	4,828	4,740	
Company 6	2,103	2,067	
Company 7	1,934	1,884	
Company 8	333	333	
Companies 1–8			39,253
Total	44,637	42,964	39,253

Note. All costs, are given in kSEK (thousands of Swedish kronor).

This allocation method is intuitive but can often lead to an allocation that does not satisfy the core conditions. A more advanced method is based on dividing the allocation into two parts. One is associated with a separable cost and the other a nonseparable cost. The separable cost or the marginal cost (7) of entity j and the nonseparable cost (9) can be expressed as

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

$$g_S = c(S) - \sum_{j\in S} m_j \tag{9}$$

The separable cost for an entity j is simply the cost difference between the case when the entity is included in the grand coalition or not. This is a measure of the overall impact by including entity j or not. If this marginal cost is added for all entities we do not obtain, in general, the cost of the grand coalition. This latter difference is the nonseparable cost. Methods based on separable and nonseparable costs allocate the costs according to

$$y_j = m_j + \frac{w_j}{\sum_{j\in S} w_j} g_S. \tag{10}$$

Depending on which weights are chosen, there are different versions of the method. The two most straightforward methods are called the equal charge method, which distributes the nonseparable cost equally, and the alternative cost avoided method, which uses the weights $w_j = c(\{j\}) - m_j$. The latter method expresses 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 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

$$y_j = \sum_{S'\subset S-\{j\}} \frac{|S'|!(|S|-|S'|-1)!}{|S|!}(c(S'\cup\{j\}) - c(S')). \tag{11}$$

Here $|\cdot|$ 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 of the flow conservation constraints for the supply and demand constraints, respectively. Here, i and j are the indices of the supply nodes (i) and demand nodes (j), respectively. The supply in supply node i is denoted s_i and demand at demand node j is denoted d_j. The set of supply nodes are denoted I and the set of demand nodes J. When we solve the transportation model for the coalition $S = N$, we get $c(N)$. The optimal dual solution has the property

$$c(N) = \sum_{i\in I} u_i s_i + \sum_{j\in J} v_j d_j. \tag{12}$$

A distribution of costs in linear production models, and our model is a special case, has been proposed by Owen (1975), who shows that the core is nonempty and that a solution can be obtained from the associated linear program (LP) problem. The solution is based on market prices, which correspond to the shadow prices in the linear program. 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. Here we assume that the supply of each supply node, s_i, is the summation of all companies, i.e., $s_i = \sum_c s_i^c$. The same splitting also applies for the demand nodes. Then we can compute its contribution as

$$y_c = \sum_{i\in I} u_i s_i^c + \sum_{j\in J} v_j d_j^c. \tag{13}$$

In many applications the entities wish to share the relative savings equally. One such approach, called equal profit method (EPM), is suggested in Frisk et al. (2010). In this approach, the following LP is solved

$$\begin{aligned} \min\ & f \\ \text{s.t. } & f \ge \frac{y_i}{c(\{i\})} - \frac{y_j}{c(\{j\})}, \quad \forall i,j \\ & \sum_{j\in S} y_j \le c(S), \quad \forall S\subset N \\ & \sum_{j\in N} y_j = c(N) \end{aligned} \tag{14}$$

The first constraint set is to measure the pairwise 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 zero (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. (2010), 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, 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, Dual Prices, and EPM

Company	Volume	Shapley	Dual	EPM
Company 1	9.0	5.1	4.1	6.7
Company 2	9.7	9.0	12.7	8.8
Company 3	0.2	5.7	−1.8	8.8
Company 4	19.9	9.2	11.7	8.8
Company 5	11.2	13.5	14.2	8.8
Company 6	4.3	8.6	12.3	8.8
Company 7	13.2	15.8	15.6	8.8
Company 8	14.0	6.9	9.1	8.8

4. What Happened with the Companies

The research project provided the expected savings of each potential coalitions between the eight companies. The expected savings were interesting however the sharing of it was not simple. The results of the study 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 meter. 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 3, but it was not acceptable that the second largest company (Company 5) would gain only 0.2%. This difference in savings between the companies 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 its 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 and the individual impact of each company.

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 nonseparable costs, shadow prices, and volume weights were tested and analyzed. As part of the analysis, the 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 the explicit mathematical formulation of the method was presented in §3. This approach was acceptable to 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.

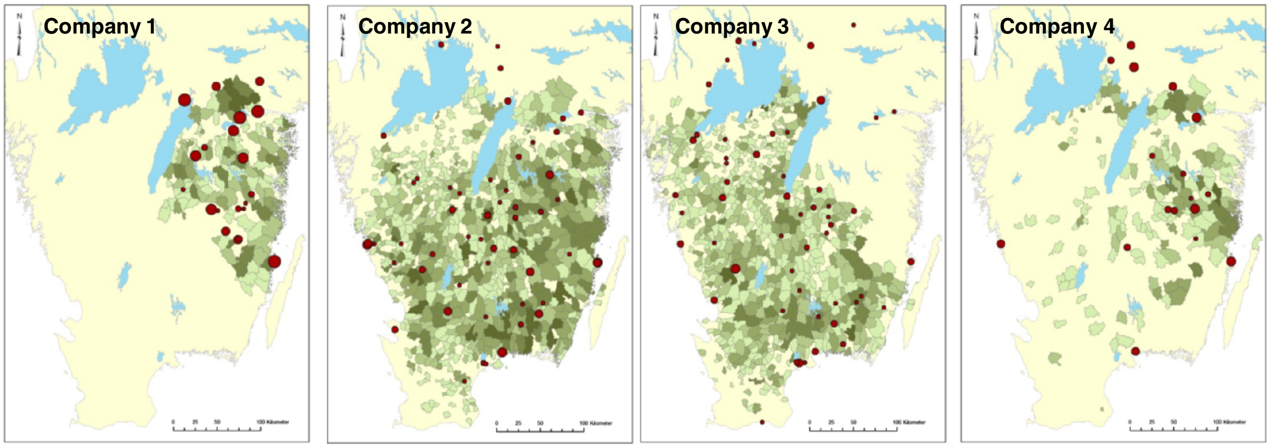
As a result of the case study, three companies started collaborating in 2008 by coordinating their planning on a monthly basis. Before each month, each company provided the information about supply and demand to a third party logistics, provider in this case the Forestry Research Institute of Sweden. Then an integrated plan (i.e., common plan) was made 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 such as 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, core conditions were not included. With this revised model, it was not possible to guarantee a stable solution, but the companies were of the opinion that this part was not that important. More important however, was that they could trust each other in the long term. The approach was tested during four months in 2008 and the potential savings were 5%–15% each month. Currently in development is a web-based application for common plans where a third party logistics provider is not required.

5. Game

The game can be played in three versions. The first version has four companies and four players the second includes five companies (five players) and the third, all eight companies (eight players). In the versions with four and five companies, more information is provided to the players. Here, all actual costs of all the possible coalitions are provided. All versions of the game are played during a two- to three-hour lecture. In a standard class, there will be a set of groups of four (or five) students. The best layout is to have the students of each group gathered together around a table. Each group should have space to move around the table. Each participant will receive a document explaining the game and providing the needed information. Students are not expected to prepare in any way. It is better to have them read papers on game theory after they experienced the game. The information provided for the students in version 1 (four companies/four players) is described below.

We first outline the purpose of the game and give a printout map, shown in Figure 4, of supply points and demand points for each of the four companies.

Figure 4 **Maps for Companies 1, 2, 3, and 4**



Note. Supply areas are shaded and dark circles are plants.

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.

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 1 and 2 work individually, the overall cost is 3,780 (Company 1) + 14,860 (Company 2) = 18,640 kSEK. However, if they work together, the cost is 18,300 kSEK, which represents a savings of 340 kSEK (18,640 − 18,300). One question is how these 340 kSEK should be divided between the two companies, 1 and 2. There are many possible coalitions, and Table 5 summarizes the costs and savings for all possible conditions. The improvement in the table is given as percentage, i.e., savings divided by the aggregated individual cost. For example, the improvement for coalition (Company 1 + Company 2 + Company 3) is computed as $1{,}270/28{,}980 = 4.38\%$.

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). The decision on how the overall savings should be divided within the companies in a coalition is part of deciding which companies should work together. In phase 1, only two companies can work together. In phase 2, any coalition structure is possible. For example, all companies can work together, no companies work together, or any group of two or three companies can work together. Each company can only participate in one coalition in each of the game.

Once the first phase 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 all groups) that the students have agreed on. This discussion is often interesting and provides a good basis for the second phase. To support this discussion, we have developed an Excel sheet where each group solution is inserted through an easy input form (Results_4companies.xlsx is provided as a supplementary file). Figure 5 gives an example from phase 2 when eight groups have

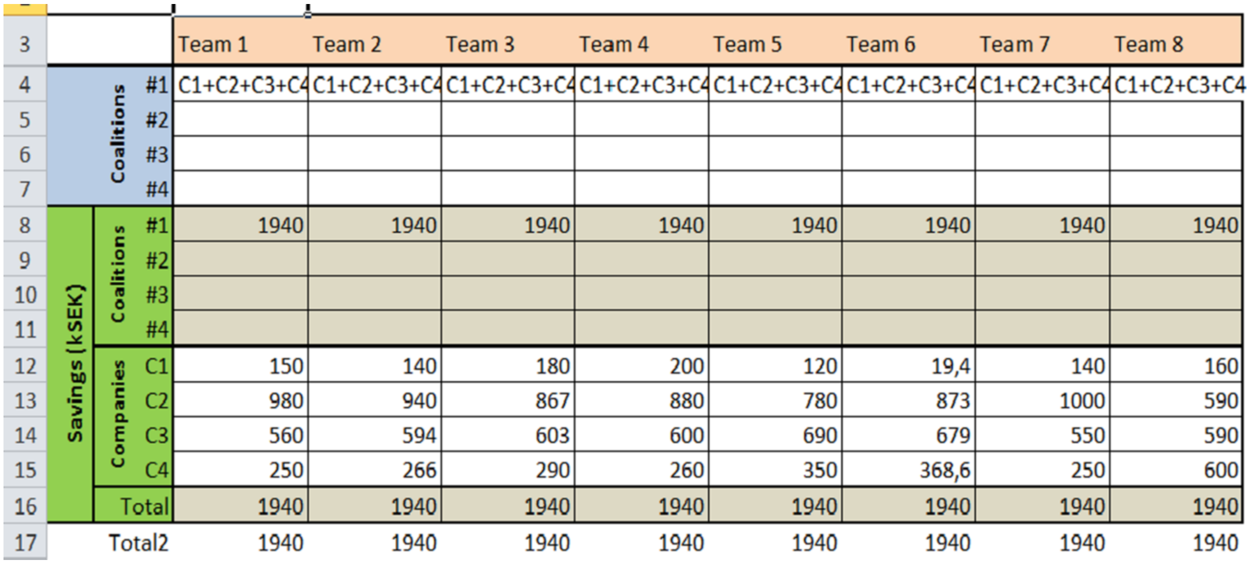
Table 4 **Summary of the Four Companies and Their Transportation Volume (m^3), Transportation Cost (kSEK), and Average Transportation Distance (km)**

Company	Volume	Individual cost	Average distance
Company 1	77,300	3,780	70.3
Company 2	301,300	14,860	56.8
Company 3	232,100	10,340	68.5
Company 4	89,300	4,960	68.5
Total	700,000	33,940	—

Table 5 **Summary of Possible Coalitions and Their Cost if They Work Together, Summed Individual Cost, and Savings and Improvement**

Coalition (companies)	Cost (kSEK) (collaboration)	Cost (kSEK) (individual)	Savings (kSEK)	Improvement (%)
1 + 2	18,300	18,640	340	1.82
1 + 3	14,000	14,120	120	0.85
1 + 4	8,510	8,740	230	2.63
2 + 3	24,210	25,200	990	3.93
2 + 4	19,040	19,820	780	3.94
3 + 4	15,060	15,300	240	1.57
1 + 2 + 3	27,710	28,980	1,270	4.38
1 + 2 + 4	22,490	23,600	1,110	4.70
1 + 3 + 4	18,580	19,080	500	2.62
2 + 3 + 4	28,400	30,160	1,760	5.84
1 + 2 + 3 + 4	32,000	33,940	1,940	5.72

Figure 5 Input Information from Eight Groups with Their Agreed Upon Coalition and Agreed Upon Savings



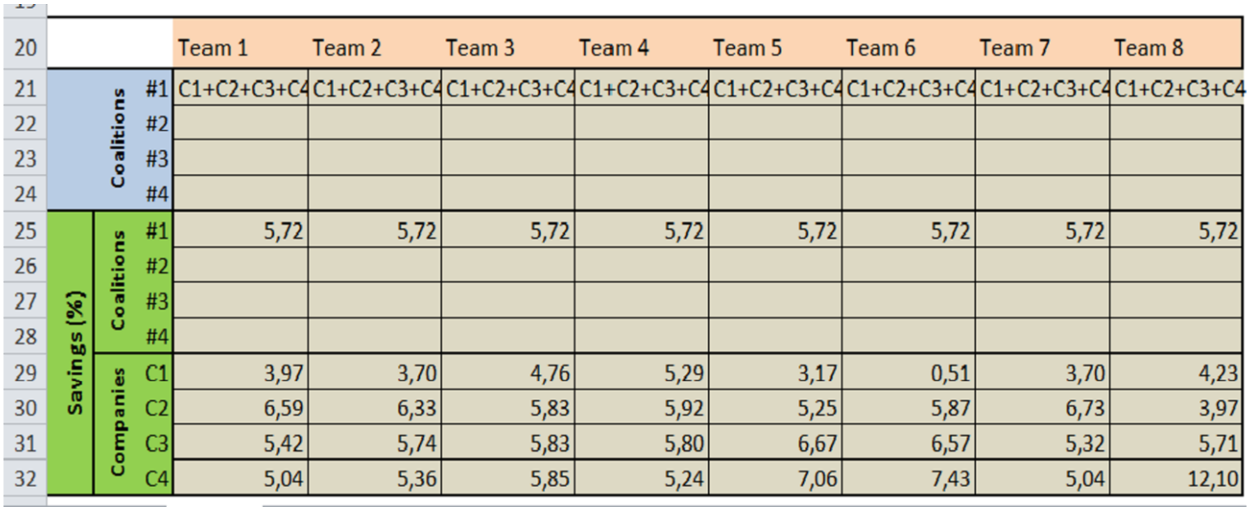
3				Team 1	Team 2	Team 3	Team 4	Team 5	Team 6	Team 7	Team 8
4	Coalitions		#1	C1+C2+C3+C4	C1+C2+C3+C4	C1+C2+C3+C4	C1+C2+C3+C4	C1+C2+C3+C4	C1+C2+C3+C4	C1+C2+C3+C4	C1+C2+C3+C4
5			#2								
6			#3								
7			#4								
8	Savings (kSEK)	Coalitions	#1	1940	1940	1940	1940	1940	1940	1940	1940
9			#2								
10			#3								
11			#4								
12		Companies	C1	150	140	180	200	120	19,4	140	160
13			C2	980	940	867	880	780	873	1000	590
14			C3	560	594	603	600	690	679	550	590
15			C4	250	266	290	260	350	368,6	250	600
16			Total	1940	1940	1940	1940	1940	1940	1940	1940
17			Total2	1940	1940	1940	1940	1940	1940	1940	1940

Note. In this case all eight groups agreed on the grand coalition, but the agreed upon savings are quite different.

inserted their solution. First the coalitions agreed are inserted and then the agreed savings for each company within each coalition. The coalitions are selected in the white area of rows 4–7 using a dropdown list and the agreed savings are inserted in the white area of rows 12–15. All input is done in the white areas whereas the grey areas are information computed based on the input. Based on the input, two results are generated. In the Excel sheets, the companies are denoted C1 (Company l), C2 (Company 2) etc. First, we compute the relative savings for each company. This is viewed in a table which 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 in an Excel graph, shown in Figure 7. These results typically generate a lively discussion among the students about rationality, fairness and trust.

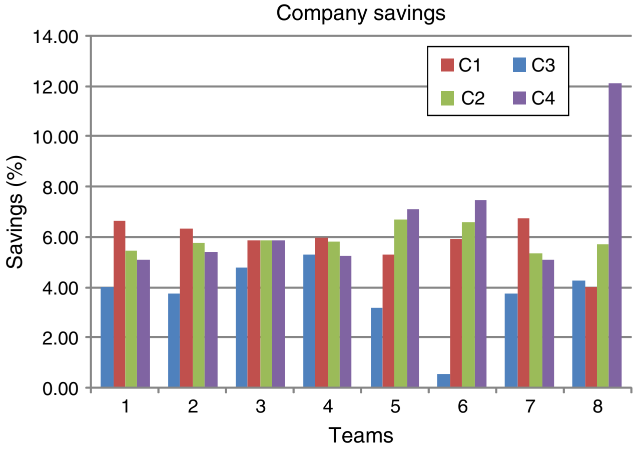
Version 2 of the game is identical to version 1 except that a fifth company is added. This makes the first phase a bit more complicated because at least one company must be left outside a coalition. Moreover, the new fifth company has spread of its resources, providing high potential for collaboration and therefore, raising its power. The supplementary file for version 2 is Results_5companies.xlsx.

Figure 6 Relative Savings for Each Company Based on the Inserted Solution



20				Team 1	Team 2	Team 3	Team 4	Team 5	Team 6	Team 7	Team 8
21	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
22			#2								
23			#3								
24			#4								
25	Savings (%)	Coalitions	#1	5,72	5,72	5,72	5,72	5,72	5,72	5,72	5,72
26			#2								
27			#3								
28			#4								
29		Companies	C1	3,97	3,70	4,76	5,29	3,17	0,51	3,70	4,23
30			C2	6,59	6,33	5,83	5,92	5,25	5,87	6,73	3,97
31			C3	5,42	5,74	5,83	5,80	6,67	6,57	5,32	5,71
32			C4	5,04	5,36	5,85	5,24	7,06	7,43	5,04	12,10

Figure 7 Relative Savings for Each Company Based on the Inserted Solutions from the Eight Groups



The information provided for the students in version 3 (eight students and 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. In Table 6, we provide the information for one company. Version 3 also has two phases. In the first phase, coalitions of at most two companies should be found. This is more difficult, compared to versions 1 and 2 because there are many more alternatives. Also, here it is very clear that companies 2 and 3 have much higher negotiation power. In the second phase, any coalition and principle for sharing the benefit may be used. In this version of the game, the students do not know the savings when they decide to collaborate. They need to define the coalition and set the principle they will follow for the splitting of the savings. Only the real benefits of the agreed coalitions are announced to the agreed groups. They finish the game by computing the savings following the principle they have agreed on.

Once the game is played, we follow up with what happened in the industrial case study 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 values and the shadow price approach. We also show results when using a simple "volume" based allocation method, which is often used in practice. Finally, we present the retained approach called the equal profit method. Essentially we make a quick run through material similar to §4 in this paper.

Table 6 Costs and Savings (kSEK) When Company 1 Works Together with a Second (2–8) Company

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

There is also a discussion of other drivers for the collaboration. These are the effects of CO_2 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 behavior and how the coalitions can be formed. More information and results based on the case study can be found in Audy et al. (2012).

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 because 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 students developing key competencies for establishing higher quality collaboration in logistics.

6. Experiences

We have played this game with students, business people, and researchers in France, Sweden, Norway, Chile, and Canada. All information (PDF documents, Excel sheets, and PowerPoint presentation) are provided on a password-protected part of the ITE website, accessible only to the instructors. We first developed version 3 of the game where eight players are provided with the company information and information 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 case study because there are eight companies involved in the real case. However, we 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. As a group, they are perceived as an interesting "larger" player. Then others start discussing collaboration with them as a group. 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 because they illustrate strategies in dealing with the case. North Americans tend to build their coalition one by one, which is in contrast with 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. 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 a smaller number of companies and provides more information. Each player knows the potential benefit of paring with all other companies. The players are rapidly challenged because no equilibrium exists and they need to negotiate an incentive to get the maximum out of the grand coalition. The discussions are easier to manage than in version 3 of the game because only four players are involved in each group. The players focus more on the sharing mechanism than on coalition building. We then developed version 2 (with five companies/players) as we wanted to create a more difficult negotiation situation in the first phase. In this version, one company must be left outside as only two coalitions of two companies can be made in phase 1. This creates more discussions and negotiations among the participants. This version is the one we use most frequently today. We have also developed an Excel sheet for versions 1 and 2 to illustrate the results and characteristics of the most common sharing principles. In the version with four and in particular with five companies, it is clear how much bargaining power the largest company has. All others have an incentive to collaborate with this company, which often can come up with very good agreements. It is also interesting to note when all companies are working together, much of this bargaining power of the largest company is lost and the agreements provide relative savings of the same order.

7. Conclusions

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

Business games are often used for developing complex competences. This is the case for this game because the participants integrate advanced game theory knowledge as well as develop their negotiation skills. Moreover, it also provides an insight into how differently the bargaining power can be based on the size and location of the companies.

To be efficient, business games need to be simple and meaningful. The game proposed in this paper 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 an industrial case study 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.

Supplementary Material

Files that accompany this paper can be found and downloaded from http://dx.doi.org/10.1287/ited.1120.0090.

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