



Anna Tatarczak

University of Maria Curie-Skłodowska in Lublin, Faculty of Economics,
Department of Marketing Research, anna.tatarczak@poczta.umcs.lublin.pl

A Framework to Support Coalition Formation in the Fourth Party Logistics Supply Chain Coalition

Abstract: The growing diversity of programmes concerning the solutions associated with the fourth party supply chain operations, the increasing pressure to optimise all resources and capabilities, as well as the continually increasing integration of different types of technologies are the driving force in the establishment of fourth party logistics supply chain coalition. Choosing the most rational and practical cost allocation mechanism in the fourth party logistics supply chain coalition, with the aim of reducing the overall operating costs, is the main condition ensuring companies' motivation to participate in collaboration. This paper addresses the concepts from the game theory combined with multi-criteria problems in order to introduce a realisable profit distribution mechanism, with the potential to establish practical collaborations among companies. The aim is to achieve the best conditions for collaboration. Case studies are used to demonstrate the utility of the framework.

Keywords: Fourth Party Logistics, game theory, Shapley value, innovation, supply chain

JEL: C71, O31, D85

1. Introduction

Fourth party logistics (4PL) has played a key role in supply chain management since it was put forward by the consulting group Accenture Inc. 4PL has been defined as “a supply chain integrator that assembles the capabilities, resources, and technology of its own company and other companies to design, build and run comprehensive supply chain solutions” (Bauknight, Miller, 1999). 4PL may be considered as a supply chain solution which combines the capability of management consulting, information technology and 3PL service providers (Büyüközka, Feyzioğlu, Ersoy, 2009: 112–120).

In recent years fourth party logistics has become increasingly popular in supply chain operations because it provides benefits in various areas (Saglietto, Cezanne, 2015: 461–486). Nissen and Bothe (2002: 16–26), Bhatnagar and Viswanathan (2000: 13–34) have described the advantages of 4PL. Many problems of activity assignment of 4PL have been proposed and solved (Li et al., 2003: 1241–1245; Huang et al., 2006: 3029–3034; Chen, Su, 2010: 3630–3637). Following the first 4PL model, the fourth party logistics supply chain coalition was introduced by Xu (2013). The basic idea is that “the fourth party logistics service providers make suggestions for the work and profit allocation among the member enterprises according to the overall situation, then supervise the performing of the contract, and take punishment measures for breach of contracts” (Xu, 2013), as shown in Figure 1. In this paper, we focus on the fourth party logistics supply chain coalition in which manufacturers and suppliers join forces.

In recent times, it has emerged that one of the major problems with supply chain coalitions is that of allocating cost savings among the member enterprises. Most cost sharing cases in the literature have been studied based on the cooperative game theory (Özener, Ergun, 2008: 146–165; Krajewska et al., 2008: 1483–1491). Moreover, a large number of papers have been published that proposed the game theory as a powerful tool for studying the problems by reporting on actual cases (Frisk et al., 2010: 448–458; Defryn, Vanovermeire, Sörensen, 2016: 75–89). In order to properly evaluate the problem of allocating fairly the common costs among the member enterprises in the fourth party logistics supply chain coalition, it is crucial to determine both the total gain and individual gains for each of the players. In the procedure presented in this paper, first cost allocation methods from the field of game theory were applied to determine the optimal strategy for cost savings calculations of the coalition. It was determined that there existed more than one cost allocation that would solve the problem. Based on this observation, the paper presents a definition of the coalition satisfaction degree for each proposed method and develops an algorithm for choosing one method based on coalition satisfaction. A two-step procedure that can help the fourth party logistics supply chain coalition to choose the appropriate allocation method is proposed.

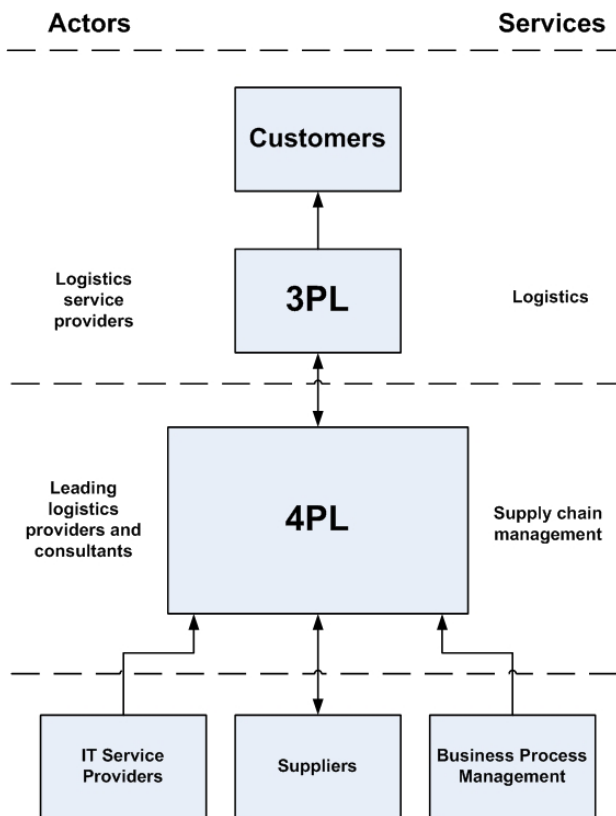


Figure 1. The fourth party logistics supply chain coalition
Source: own elaboration

The article focuses on an investigation of the game theory approach in relation to the problem of allocating the common costs to improve stability in the 4PL supply chain coalition. Using the game theory as the theoretical framework, the presented study proposes and tests a research model that investigates the following research questions:

1. How should the cost savings be shared among the coalition partners?
2. How can the optimal cost allocation scheme for the 4PL supply chain coalition be designed?

The intended purpose of this paper is to inform 4PL coalition members on the most practical cost allocation methods. Furthermore, it is our hope that 4PL manufacturers and suppliers will likewise incorporate our results in the planning process of future supply chain coalition projects.

The rest of the paper has been organised as follows. Section 2 presents the problem. In Section 3, the profit allocation problem is formally described, then an algorithm to choose one cost allocation method is developed. Section 4 pre-

sents a numerical example to illustrate a specific procedure of our algorithm and compare how different the results are when it is applied to different cost allocation methods. Finally, conclusions are drawn in Section 5.

2. Description of the problem

Although the fourth party logistics supply chain coalition offers potential benefits, the collaboration within the coalition also poses numerous challenges. Developing successful collaboration includes a number of questions such as:

1. How should the cost savings be shared among the partners?
2. Does an optimal cost allocation scheme which would satisfy the entire coalition exist?

As a result of several case studies involving collaboration in logistics, question 1) addresses the cost allocation problem which has grown in importance over the past decade and is of interest to researchers. The problem of how to fairly allocate profits has produced a large volume of literature. The main body of research on this topic is focused on how to share the benefits of collaboration among partners. Krajewska et al. (2008: 1483–1491) analysed the profit margins that resulted from horizontal cooperation among freight carriers. The paper presents the examined issue based on the cooperative game theory for a pickup and delivery problem with time windows. The paper shows that collaboration results in a considerable cost decrease and that these profit margins can be efficiently shared among the partners. Özener and Ergun (2008: 146–165) proposed a cost allocation mechanism using the cooperative game theory to study a collaborative transportation procurement network. Audy and D'Amours (2008: 519–532) proposed a methodology of sharing benefits for collaborative transportation through a case study of the furniture industry. Dai and Chen (2012: 633–643) developed three profit allocations mechanisms which are based on the Shapley value, a proportional allocation concept, and the contribution of each carrier to offering and serving requests, respectively. Lozano et al. (2013: 444–452) developed a mathematical model to allocate the profit among different transportation companies. Wang and Kopfer (2014: 357–380) used a collaborative transportation plan within a coalition of small and medium-sized freight carriers to improve the operational efficiency of the coalition members. Li, Rong and Feng (2015: 23–39) presented a request selection and exchange model in the carrier collaboration process, moreover, four profit allocation methods were discussed.

Based on the literature review presented above, a natural progression is to incorporate the profit allocation method into the fourth party logistics supply chain coalition. Unfortunately, only a small number of relevant studies have been conducted in this research domain. To this end, four well-known solution methods from the game theory are considered in this paper, namely, the Weighed Relative

Savings Model (Liu, Wu, Xu, 2010), the proportional method, the Shapley value (Shapley, 1953: 307–317), and the Nucleolus (Schmeidler, 1969: 1163–1170).

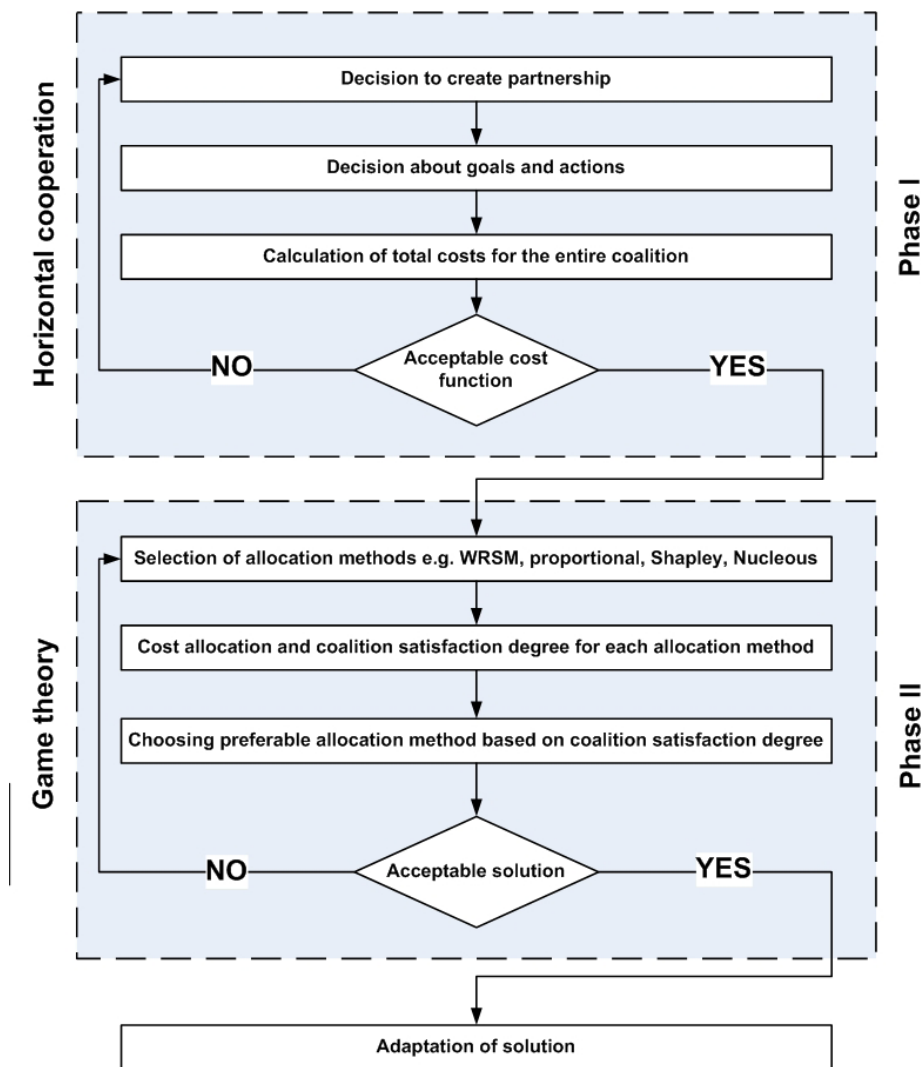


Figure 2. Research model
Source: own elaboration

Profit allocation is one of the crucial problems in the fourth party logistics supply chain (Xu, 2013) However, since the literature produced to date is in agreement that no single cost allocation method works best in all situations (Defryn, Vanovermeire, Sörensen, 2016: 75–89), choosing one favourable allocation method is another important problem directly linked to question 2). Therefore, it is the

task of the partners to choose the optimal method in terms of satisfying the entire coalition.

This study considers the problem of the fourth party logistics supply chain coalition (Xu, 2013) and the collaboration life cycle (Simatupang, Sridharan, 2002: 15–30). Consequently, our study's principal objective is to take this problem a step further by constructing a general structure for the collaboration-relationship process based on the game theory. For a better understanding of the process, the subsequent process phases are presented in Figure 2. Compared with previous studies, this study makes several contributions to the existing knowledge base in the following ways. Firstly, cost allocation methods that award positive benefits to all members of the fourth party logistics supply chain coalition are presented. Secondly, a measurement formula is established to better understand the satisfaction of each member that enters into the collaboration and to apply an allocation mechanism. In addition to the general guidelines for managing collaboration provided by the cooperative game theory, an algorithm based on multiple-criteria methods is proposed. Thirdly, a numerical study is undertaken to demonstrate the applicability of the proposed method.

3. Profit allocation

This section presents the existing profit (cost) allocation methods based on game theory concepts, namely, the core, Weighted Relative Savings Model (WRSM), proportional allocation, Shapley value, and Nucleolus.

A *cooperative game* with transferable utility (TU game) is a pair (N, v) , where $N = \{1, 2, \dots, n\}$ is a player set, and $v: 2^N \rightarrow R$ is a function such that $v(\emptyset) = 0$ is called the *characteristic function* of the game. A subset $S \subset N$ is called a coalition, and N is called the *grand coalition*. The number of all subsets of N excluding the null set is equal to $2^n - 1$. When coalition S cooperates, the total cost $C(S)$ is generated and it is expressed as

$$v(S) = \sum_{i \in S} C(\{i\}) - S, \quad \forall_{S \subset N}. \quad (1)$$

A game (N, v) is superadditive if $v(S) + v(T) \leq v(S \cup T)$ for all S and $T \subset N$ such that $S \cap T = \emptyset$.

In a superadditivity game, it is always beneficial for two disjointed coalitions to cooperate and form a grand coalition. A game (N, v) is convex if $v(S \cup \{i\}) - v(S) \leq v(T \cup \{i\}) - v(T)$ for all $i \in N$ and for all $S \subset T \subset N \setminus \{i\}$.

An allocation function is denoted by $x_i(v)$ that is used to assign a payoff x_i to player $i \in N$. The core of the game (N, v) is defined as

$$Core(n, v) = \left\{ x \in R^n : \sum_{i \in N} x_i = v(N) \text{ and } \sum_{i \in N} x_i \geq v(S), \text{ for all } S \subset N \right\}.$$

The core divides the total payoff of the grand coalition among all the players, and the sum of the payoffs to the players of each coalition S is no less than the payoff of the coalition S .

3.1. Weighted Relative Savings Model

The Weighted Relative Savings Model WRSM (Liu, Wu, Xu, 2010: 143) is introduced first. Let the contribution ratio weight w_i be expressed as

$$w_i = 1 - \frac{\sum_{i \in S} v(S) - v(S \setminus \{i\})}{\sum_{i \in N} \sum_{i \in S} v(S) - v(S \setminus \{i\})}, \tag{2}$$

where expression

$$\sum_{i \in S} v(S) - v(S \setminus \{i\}), \quad \forall i \in N \tag{3}$$

is defined as the *contribution of partner i to the grand coalition*. The WRSM is mathematically formulated as the following linear programming problem:

Minimise f

$$s.t. \frac{w_i x_i}{C(\{i\})} - \frac{w_j x_j}{C(\{j\})} \leq f, \quad \forall i, j \in N$$

$$\sum_{i \in S} x_i \geq v(S), \quad \forall S \subset N$$

$$\sum_{i \in S} x_i = v(N).$$

For any (N, v) and w_i calculated using (2), the WRSM can be derived using the following algorithm:

Algorithm 1. Calculation of the WRSM

Step 1.

Solve the linear programming problem $LP_1 \min f_1$ subject to

$$\frac{w_i x_i}{C(\{i\})} - \frac{w_j x_j}{C(\{j\})} \leq f_1, \quad x \in R^n \quad \forall i, j \in N$$

set iteration counter $k = 2$.

Step 2.

Let \hat{f}_{k-1} denote the optimal value of f_{k-1} in LP_{k-1} problem and let

$$O_{k-1} = \left\{ x \in R^n : \text{an optimal solution to } LP_{k-1} \right\},$$

$$A_{k-1} = \left\{ S \subset N : \frac{w_i x_i}{C(\{i\})} - \frac{w_j x_j}{C(\{j\})} = \hat{f}_{k-1}, \forall x \in O_{k-1} \right\}$$

if LP_{k-1} gives a unique solution, then stop, **otherwise** solve the problem $LP_k : \min f_1$ subject to

$$\frac{w_i x_i}{C(\{i\})} - \frac{w_j x_j}{C(\{j\})} \leq f_k, \quad x \in R^n \quad \forall i, j \in N, S \subset N \setminus \bigcup_{l=1}^{k-1} A_l,$$

$$\frac{w_i x_i}{C(\{i\})} - \frac{w_j x_j}{C(\{j\})} = f_l, \quad x \in R^n \quad \forall i, j \in N, S \subset A_l, l = 1, \dots, k-1.$$

if set $k = k + 1$, go to Step 2.

3.2. Proportional allocation

The second method is *proportional allocation*. This allocates a proportional share of the initial contributions of each partner and is defined by the equation

$$\varphi_i(v) = \frac{C(i)}{\sum_{j \in N} C(j)} v(N).$$

The method is commonly used in practice by companies, due to its easy interpretation and transparency (Frisk et al., 2010: 448–458).

3.3. Shapley value

The Shapley value (Shapley, 1953: 307–317) is defined by the formula

$$\varphi_i(v) = \sum_{S \subset N \setminus \{i\}} \frac{|S|!(n-|S|-1)!}{n!} (v(S \cup \{i\}) - v(S)), \text{ for all } i \in S.$$

It is simple to implement, hence it is widely used in both economics and logistics (Krajewska et al., 2008: 1483–1491; Vanovermeire et al., 2014: 339–355).

3.4. Nucleolus

The last commonly used solutions concept is *Nucleolus*, defined by Schmeidler (1969: 1163–1170). Define the set X by all the allocation vectors which satisfy the efficiency condition $\sum_{j \in N} x_j = v(N)$ and also the individual rationality constraint $x_j \leq v(\{j\})$, $\forall j \in N$. The nucleolus is an allocation vector $x \in X$ whose excess vector is lexicographically greatest.

There are other methods worth mentioning, such as the τ -value (Tijs, Driessen, 1986: 1015–1028) or minimax core (Drechsel, Kimms, 2011: 2643–2668), that can also be used.

3.5. Coalition satisfaction degree

In Subsection 3.1–3.4, the allocation methods are presented. In this section, the coalition satisfaction degree (CSD) is introduced to measure the fairness of an allocation plan at the level of the coalition.

It may be expected that the cost allocation method should be chosen in such a way that the partners find the solution desirable from an individual point of view. Based on the allocation method φ_i defined above, the coalition satisfaction degree is expressed as follows:

Definition 1. *The coalition satisfaction degree of φ_i concerning the profit allocation is given by the formula*

$$s_i = \frac{\varphi_i - \varphi_i}{\varphi_i - \varphi_i}, i \in S. \quad (4)$$

The coalition satisfaction degree s_i is assigned a range of values from 0 to 1. If s_i is equal to 1, then player i is completely satisfied with the cost allocation method φ_i . On the contrary, if $s_i = 0$, then the allocation method is assigned the minimum value φ_i . Therefore, the larger the value of s_i , the more preferable the allocation for each player is.

Based on the introduction above, a seven step procedure is presented in order to develop an optimal allocation scheme for fourth party logistics chain coalitions. This scheme depends implicitly on well-known profit allocation concepts: WRSM, proportional allocation, Shapley value, and Nucleolus. The procedure assumes that the total coalition cost is lower than the sum of stand-alone costs for all the companies involved, which is a superadditive property. The algorithm may be described in the following way:

Algorithm 2.

N – number of partners in the grand coalition,

k – partner indices,

I – number of allocation methods,

i – allocation method indices, $i > 1$,

φ_i^k – cost allocated to partner k according to i -th allocating method,

s_i^k – coalition satisfaction degree for partner k according to i allocating method,

$\pi(k)$ – rank of partner k in sequence π .

Step 1. Apply profit allocation concepts φ_i^k to obtain the allocation for each player k of the fourth party logistics chain grand coalition.

Step 2. For each applied i -th method (e.g. WRSM, proportional allocation, Shapley value, Nucleolus), use formula (4) to calculate the *coalition satisfaction degree*.

Step 3. Coalition members decide their rank in sequence π (e.g.: a coalition established through the sequence $\pi = X_1 X_2 X_3$ means that player X_1 is the first in the coalition, followed by player X_3 , and the last one is player X_2 player).

Step 4. Set $k = 1$ and $i = 1$.

Step 5. The method that produces the lowest s_i^k value for each player k is eliminated.

Step 6. Increase k and i by one. Then if $k < N$ or $i < I$, go to Step 5; otherwise, go to Step 7.

Step 7. The remaining allocation concept will be considered as the candidate for the profit allocation method for the fourth party logistics supply coalition.

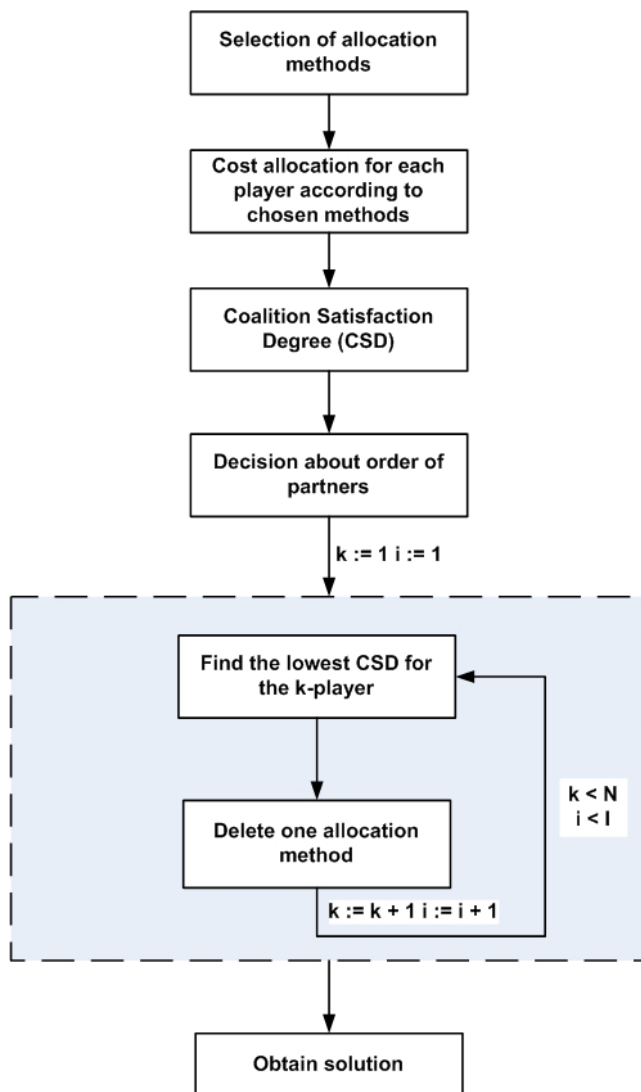


Figure 3. A schematic representation of Algorithm 2 used to solve the allocation problem for 4PL
 Source: own calculations

By using a chosen allocation algorithm, the total cost savings of the coalition might be allocated among the partners in a way that is optimal from the point of the coalition’s interests. As a consequence, it implies that companies are encouraged

to take part in the collaboration. The algorithm makes use of the coalition satisfaction degree. The proposed algorithm is based on an iterative search where the allocation method with the lowest satisfaction degree for player k is deleted from the list until k is equal to the number of partners in the grand coalition. In this way, the best allocation method is chosen. It is crucial to decide in Step 3 in what sequence the companies are to be placed, since different sequences generate different cost allocation methods as a solution for the algorithm above. The algorithm is presented in Figure 3.

4. Simulation result and analysis

A formal description of the problem is the following. It considers a fourth party logistics chain coalition $N (N = 4)$ in which two manufacturers and two suppliers (labelled $X_1 - X_4$) join forces. In order to show the effectiveness of the algorithm proposed in Section 3.5 and determine which measures will be the most adequate for the fourth party logistics chain coalition, results are compared for WRSM, proportional, Shapley, and Nucleolus methods. The simulation is based on the existing test instances in Xu (2013). All of the relevant information is summarised in Table 1. The results were obtained by running the algorithm and applying the cost allocation methods introduced in Section 3. The Cost Savings of Coalition are calculated using (1) the Contribution to the Grand Coalition based on (3) formula and the Contribution Ratio Weight based on (2) formula.

As the sum of all stand-alone costs (19 765.9) is larger than the cost of the grand coalition (15 238.4), forming a coalition would be profitable. However, the profit function is not convex since we have:

$$CostSavings(\{X_1, X_2, X_3\}) = 2770.6 < CostSavings(\{X_1, X_3\}) +$$

$$CostSavings(\{X_1, X_2\}) - CostSavings(\{X_1\}) = 1768.3 + 1216.7 = 2985$$

Indeed, contrary to the superadditivity property, in many practical logistics issues (as it is in the case of our example), complexity is too exigent (Lozano et al., 2013: 444–452).

In order to establish a grand coalition, the partners have to make a decision about the selection of an effective cooperation strategy for cost savings allocation. Table 2 and Figure 4 summarise the computations of the proposed allocation methods. For each allocation concept, cost allocation is calculated according to the definitions and formulas discussed in Section 3. The results listed in Table 2 prove that each player can earn a greater profit after cooperation than that the profit ob-

tained before cooperation. To sum up, we can see that individual X_2 receives the maximum Cost Allocation according to Proportional allocation while individual X_4 receives the maximum CSD according to Nucleolus. In addition, for exploratory purposes, a comparison of the resulting cost allocations is shown in Figure 4.

Table 1. Test instances and related calculations

Coalition S	Cost savings of coalition	Cost	Contribution to the grand coalition	Contribution ratio weight
$\{X_1\}$	0.0	5 603.7	7 191.6	0.8
$\{X_2\}$	0.0	4 156.9	9 078.2	0.8
$\{X_3\}$	0.0	4 598.4	11 770.0	0.8
$\{X_4\}$	0.0	5 406.9	9 894.8	0.8
$\{X_1, X_2\}$	1 216.7	8 543.9		
$\{X_1, X_3\}$	1 768.3	8 433.8		
$\{X_1, X_4\}$	1 174.0	9 836.6		
$\{X_2, X_3\}$	975.3	7 780.0		
$\{X_2, X_4\}$	629.7	8 934.1		
$\{X_3, X_4\}$	1 516.9	8 488.4		
$\{X_1, X_2, X_3\}$	2 770.6	11 588.4		
$\{X_1, X_2, X_4\}$	2 772.9	12 394.6		
$\{X_1, X_3, X_4\}$	3 123.6	12 485.4		
$\{X_2, X_3, X_4\}$	2 881.1	11 281.1		
$\{X_1, X_2, X_3, X_4\}$	4 527.5	15 238.4		

Source: own calculations

Table 2. Results for test instances

Enterprises	WRSM		Proportional allocation		Shapley value		Nucleolus	
	Cost allocation	CSD	Cost allocation	CSD	Cost allocation	CSD	Cost allocation	CSD
$\{X_1\}$	1361.7	1.0	1283.6	0.6	1220.3	0.4	1137.8	0.0
$\{X_2\}$	921.4	0.5	952.2	1.0	916.6	0.4	895.3	0.0
$\{X_3\}$	1012.6	0.0	1053.3	0.2	1273.3	1.0	1246.1	0.9
$\{X_4\}$	1231.8	0.9	1238.5	0.9	1117.4	0.0	1248.3	1.0
Sum	4527.5	2.3	4527.5	2.7	4527.5	1.7	4527.5	1.9

Source: own calculations

The core is an important set solution for the cooperatives game. Within an allocation in the core of the game, no player can receive more without lowering the payoff of another agent. Applying the definition of the core produces the following set of inequalities that describes the core:

$$\begin{aligned}
 &x_1, x_2, x_3 \geq 0 \\
 &x_1 \leq 5603.7 \\
 &x_2 \leq 4156.9 \\
 &x_3 \leq 4598.4 \\
 &x_1 + x_2 \leq 8543.9 \\
 &x_1 + x_3 \leq 8433.8 \\
 &x_2 + x_3 \leq 7780.0 \\
 &x_1 + x_2 + x_3 = 11588.
 \end{aligned}$$

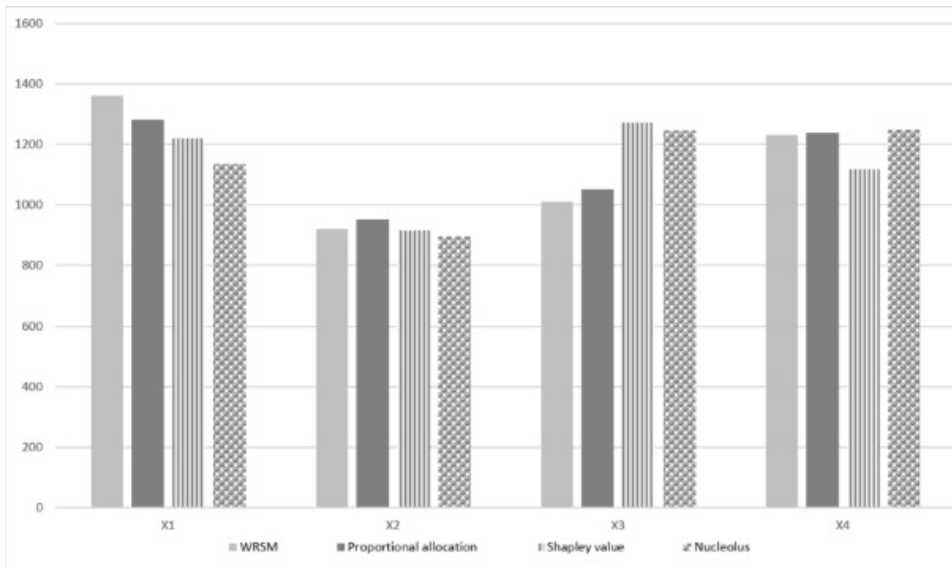


Figure 4. Allocation of cooperation profits for 4-players
 Source: own calculations

Figure 5 displays a graphical illustration of the core for the 4-players coalition as computed by TU Glab (<http://tuglabweb.uvigo.es/TUGlabWEB2/index.php>). Note that, as this illustration shows, only the profits allocated to players X_1, X_2, X_3 are shown. The gain allocated to X_4 could be calculated from the efficiency condition. The core is nonempty which means that a grand coalition will form. Therefore, Nucleolus is an element of the core. The WRSM, Shapley value and cost proportional allocation methods are also in the core for this instance.

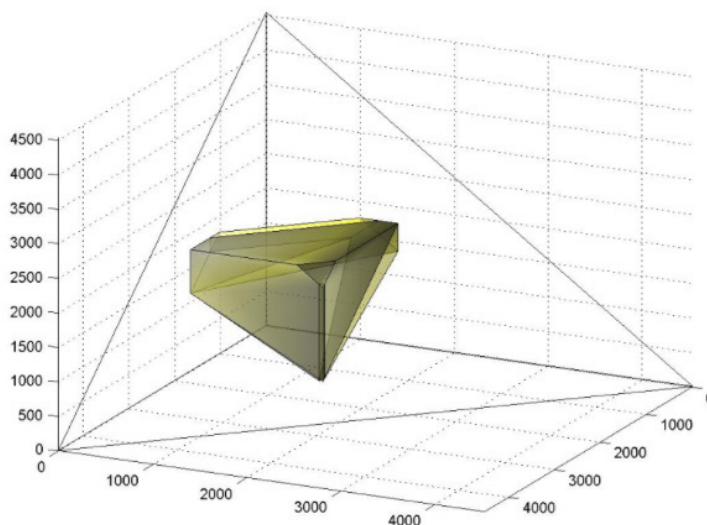


Figure 5. Core for the 4-players coalition example

Source: own calculations

When applying the proposed Algorithm 2, we want to obtain the optimal cost allocation for the grand coalition. Recalling that we start with a selection of allocation methods (WRSM, proportional, Shapley value, Nucleolus), next we have to calculate the Cost Allocation according to each chosen method and the coalition satisfaction degree (values are presented in Table 2). Let the order of partners be $\pi = (X_1, X_2, X_3, X_4)$.

Iteration 1: For player X_1 the lowest CSD is for Nucleolus and is equal to zero. Hence, Nucleolus is eliminated from the set of allocation methods. Now, we consider only WRSM, proportional, and Shapley value methods.

Iteration 2: Now, we look at the CSD of player X_2 player, and we find that its lowest value is for the Shapley value (equal to 0.37). As a result, the Shapley value is removed from the set of allocation methods.

Iteration 3: We examine the CSD for X_3 , which means finding its lowest value. In this case, it is for WRSM, and it is removed from the allocation set.

The optimum solution is the proportional allocation. Hence, the algorithm terminates. We can easily check what the result would be if the order of players was different. For four players, there are 24 possible sequences for the grand coalition. Applying Algorithm 2 for each of the possible sequences, we conclude that in 22 cases out of 24, the optimal solution is the proportional allocation, while in two cases, it is WRSM.

Table 3. Illustrative example of the method for choosing algorithm

Enterprises	WRSM	Proportional	Shapley	Nucleolus
$\{X_1\} \leftarrow$	1.0	0.6	0.4	0.0
$\{X_2\}$	0.5	1.0	0.4	0.0
$\{X_3\}$	0.0	0.2	1.0	0.9
$\{X_4\}$	0.9	0.9	0.0	1.0
$\{X_1\}$	1.0	0.6	0.4	0.0
$\{X_2\} \leftarrow$	0.5	1.0	0.4	0.0
$\{X_3\}$	0.0	0.2	1.0	0.9
$\{X_4\}$	0.9	0.9	0.0	1.0
$\{X_1\}$	1.0	0.6	0.4	0.0
$\{X_2\}$	0.5	1.0	0.4	0.0
$\{X_3\} \leftarrow$	0.0	0.2	1.0	0.9
$\{X_4\}$	0.9	0.9	0.0	1.0
Final solution	Proportional allocation			

Source: own calculations

5. Conclusions

This paper investigates the behaviour of a cost allocation scheme for the fourth party logistics supply chain coalition in a collaborative environment. First, it takes a look at four well-known allocation concepts. Then, it introduces the concept of coalition satisfaction degree which demonstrates how the levels of satisfaction among partners differ when different methods are applied to the same problem. In order to support the incentive to cooperate, the mechanism for selecting one allocation method by the coalition is applied. In addition, an example is presented to illustrate the allocation scheme. The analysis of this approach produces recommendations for solutions to more complex problems which may occur in real life. The approach seems to be useful and is a promising area for further research. A direction of further research worth considering is to test large-scale instances that are able to better represent 4PL problems. Further studies may also take into account the risks arising (investment, information divulging and failure risks) among partners. The third research problem may concern designing a profit allocation mechanism according to other solution concepts (e.g.: τ – value, minimax core) and comparing the coalition satisfaction degree among them. These issues will be studied in our future research.

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Tworzenie koalicji między operatorami 4PL

Streszczenie: Operator logistyczny 4PL (Fourth Party Logistics Provider) oferuje nowe i innowacyjne rozwiązania, mające na celu obniżenie kosztów, udostępnienie usług i usprawnienia w zarządzaniu złożonymi łańcuchami dostaw. Celem artykułu jest przedstawienie najlepszych warunków do współpracy między wyspecjalizowanymi podmiotami zajmującymi się zarządzaniem łańcuchem dostaw – operatorami 4PL. Rozważania dotyczące czynników wpływających na tworzenie koalicji przez operatorów 4PL, a także konkluzje z zakresu trwałości współpracy stały się podstawą do zaprojektowania dwustopniowej procedury, zbudowanej w oparciu o pojęcia z teorii gier. Celem przedstawionej procedury jest wybór metody alokacji kosztów/zysków przez koalicjantów. Analizy przeprowadzono na podstawie danych pochodzących z literatury.

Słowa kluczowe: operator 4PL, teoria gier koalicyjnych, wartość Shapleya, innowacje, łańcuch dostaw

JEL: C71, O31, D85

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