COMPREHENSIVE GAIN SHARING MAXIMIZING SATISFACTION IN SUPPLY CHAIN COLLABORATIONS

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A major challenge in supply chain collaborations is the fair allocation of the coalition gain. In this paper, a comprehensive, yet simple gain sharing system with a special focus on the maximization of the parties' satisfaction using a minimax regret approach is developed. The gain sharing system is applied to a vertical SCC including one manufacturer, one logistics service provide and one retailer in the Dutch fast moving consumer goods industry. Results identify a fair and robust gain share allocation, which maximizes the parties' satisfaction and thus increases the probability of sustainable SCCs. We provide theoretical framework, which can be adapted, if necessary, to a particular SCC by using more practical satisfaction functions.

Keywords: supply chain collaboration, FMCG industry, gain sharing, satisfaction, minimax regret.

JEL: C61, C68, L81, M19, M29.

INTRODUCTION

Supply chain management (SCM) has long been regarded as a top priority for various sectors of the economy. Providing raw materials to manufacturers, keeping products in warehouses, and delivering final products to end customers on time at minimal cost and delays has been debated among academics and practitioners for a long time. In the course of the last decades, companies started to realize the potential of setting up supply chain collaborations (SCC). Various challenges such as scarce resources, increased competition among organizations and higher customer expectations forced companies to look outside their organizational boundaries to search for partners with whom they

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can collaborate [Lambert, Emmelhainz, Gardner, 1996; Cao, Zhang, 2011]. Several researchers [Lambert, Emmelhainz, Gardner, 1996; Boddy, Macbeth, Wagner, 2000; Cao, Zhang, 2011;] outline the sustainable competitive advantages that can be achieved through collaboration such as cost reduction, improved service performance and cycle time reduction [Daugherty et al., 2006; Stank, Keller, Daugherty, 2001]. Next to advantages, SCCs bring along theoretical and practical challenges. According to [Cruijssen, Cools, Dullaert, 2007; Leng, Parlar, 2009; Dahl, Derigs, 2011], one major challenge for the implementation and success of SCCs is the allocation of the coalition gain. If one party is not satisfied with its received amount or has the feeling that it does not receive a fair portion of the coalition gain, future SCCs are less likely to occur [Jap, 2001].

In order to solve this problem, researchers have developed diverse gain sharing methods to distribute the coalition gain among the collaborative parties [Vanovermeire et al., 2014]. The general idea of these methods is to allocate the gains in such a way that everyone is satisfied to ensure the implementation, success and sustainability of the SCC [Liu, Wu, Xu, 2010]. One well-known gain sharing method based on the foundation of game theory is the Shapley value [Shapley, 1953]. This value allocates to each participant the weighted average of his contribution to all (sub)coalitions, assuming the grand coalition is formed one party at a time. A more complex game theoretic sharing mechanism is the nucleolus. This procedure minimizes the maximal excess, which constitutes the difference between the total cost of a coalition and the sum of the costs allocated to its participants [Schmeidler, 1969]. More sophisticated and specialized gain sharing schemes are proposed in the literature [Tijs, Driessen, 1986; Özener, Ergun, 2008; Frisk et al., 2010; Xu, Pan, Ballot, 2013; Hezarkhani, Slikker, Van Woensel, 2016].

As each method has its specific benefits and drawbacks, it remains ambiguous which technique should be applied in a SCC compromised of parties with different objectives. Recently, a group of researchers [Jung, Peeters, Vredeveld, 2018] investigated the acceptance of several gain sharing methods in vertical SCCs in the Dutch fast moving consumer goods (FMCG) industry using a case study approach. Particularly, the acceptance of four gain sharing methods was studied: the Shapley value, the nucleolus and two methods based on the separable/non-separable cost division from [Tijs, Driessen, 1986], the weighted charge method (WCM) and equal charge method (ECM). It was observed that none of these allocation methods is accepted by all collaborative parties, which stresses the statements from other studies that there does not exist one universally preferred gain sharing method [Tijs, Driessen, 1986; Vanovermeire et al., 2014].

In addition, we interviewed several companies from the Dutch FMCG (Fast Moving Consumer Goods) industry, in cooperation with a Dutch logistics company specializing in efficient and sustainable solutions for supply chains, in order to get insights on how gain sharing is performed and perceived in practice. All interviewed companies participated in a logistics competition with the aim to reduce the truck cycle time at the retailer's distribution center through SCC. The interview guide as well as some information about the data collection are provided in the appendix. The interviews reveal that several participants do not see the need for complex gain sharing methods. In practice, simple rules which are easy to understand are preferred. This coincides with M. Leng and M. Parlar [Leng, Parlar, 2005] and Liu with coauthors [Liu, Wu, Xu, 2010] who describe the popularity of simple proportional allocation rules. Such simple methods are preferred in practice since, compared to the game theoretic allocation methods, they are: (1) easily implementable and computable, (2) understandable and transparent, and (3) not data-intensive. Furthermore, the COVID-19 pandemic highlighted the need for agile supply chains, because of the rapid market transformation especially in the FMCG segment. A widespread public health crisis, like a pandemic, can have significant negative consequences for businesses and supply chains, such as lowering efficiency and performance and propagating disruptions across supply chains (known as ripple effects), compromising their resilience and long-term sustainability [Guan et al., 2020; Ivanov, 2020]. This need for agility confirms the necessity of simple methods, which can be easily changed according to environmental changes [Chowdhury et al., 2021].

Although simple methods are appealing, some studies (e. g. [Cruijssen, Dullaert, Fleuren, 2007]), point out that these methods might systematically undervalue a party's true share in the SCC success. This might lead in the long run to a party's frustration and collaboration abandonment. In contrast, game theoretic allocation methods objectively take into account each player's contribution and produce allocations that distribute the benefits of cooperation based on clear fairness properties [Cruijssen, Dullaert, Fleuren, 2007]. However, alsothegametheoretic gain sharing methods are not commonly accepted by all collaborative parties due to e.g. a different influence of behavioral aspects, such as available information [Leng, Parlar, 2005; Jung, Peeters, Vredeveld, 2018].

In summary, the problem of existing gain sharing methods is that some of them are too complex for implementation into real SCC, while others — which are simpler — could undervalue party's true share. Since mathematical simplicity, applicability and transparency constitute key allocation characteristics in practice, this paper introduces a comprehensive, yet simple gain sharing method. Therefore, the goal of this paper is to develop a comprehensive, yet simple gain sharing system with a special focus on the maximization of the parties' satisfaction using a minimax regret approach. We achieve this goal through the following tasks: (1) work out and test the gain sharing system; (2) provide a sensitivity analysis in order to verify the model stability; (3) discuss the main findings and possible implications. In order to ensure allocation simplicity, its intuitive understanding and fair acceptance, the new gain sharing system focuses on the maximization of the parties' satisfaction. Here, we understand satisfaction as a gain share of a party because all companies mainly care about profit [Smith, Gonin, Besharov, 2013]. To the best of our knowledge, none of the previous gain sharing methods focused on such criteria. Furthermore, our novel gain sharing system requires only limited input data, while providing a complete and robust gain sharing solution and many related and useful key performance indicators (KPIs).

The remainder of the paper is structured as follows. Section 1 introduces the gain sharing system followed by the application of the system to a vertical SCC in the Dutch FMCG industry in Section 2. In Section 3, the system's stability/robustness is discussed and a sensitivity analysis is presented. Finally, Section 4 concludes the paper, with key findings, theoretical and managerial implications as well as further research directions.

1. GAIN SHARING SYSTEM

As stressed in the introduction, practical appreciation requires a gain sharing system that is simple to understand and to use, while producing a fair and robust allocation of the coalition gain. In this section, a comprehensive and simple gain sharing system is introduced.

The goal of the system is to maximize the satisfaction of all collaborative parties through a minimax regret approach. In Figure 1, the proposed gain sharing system is illustrated in a block diagram.

The gain sharing system consists of three parts: input, gain sharing algorithm and output. Furthermore, the dynamic character of SCCs has been taken into consideration. The input factors of the gain sharing system may change during the SCC. Therefore, the gain sharing (re)allocation should be recomputed

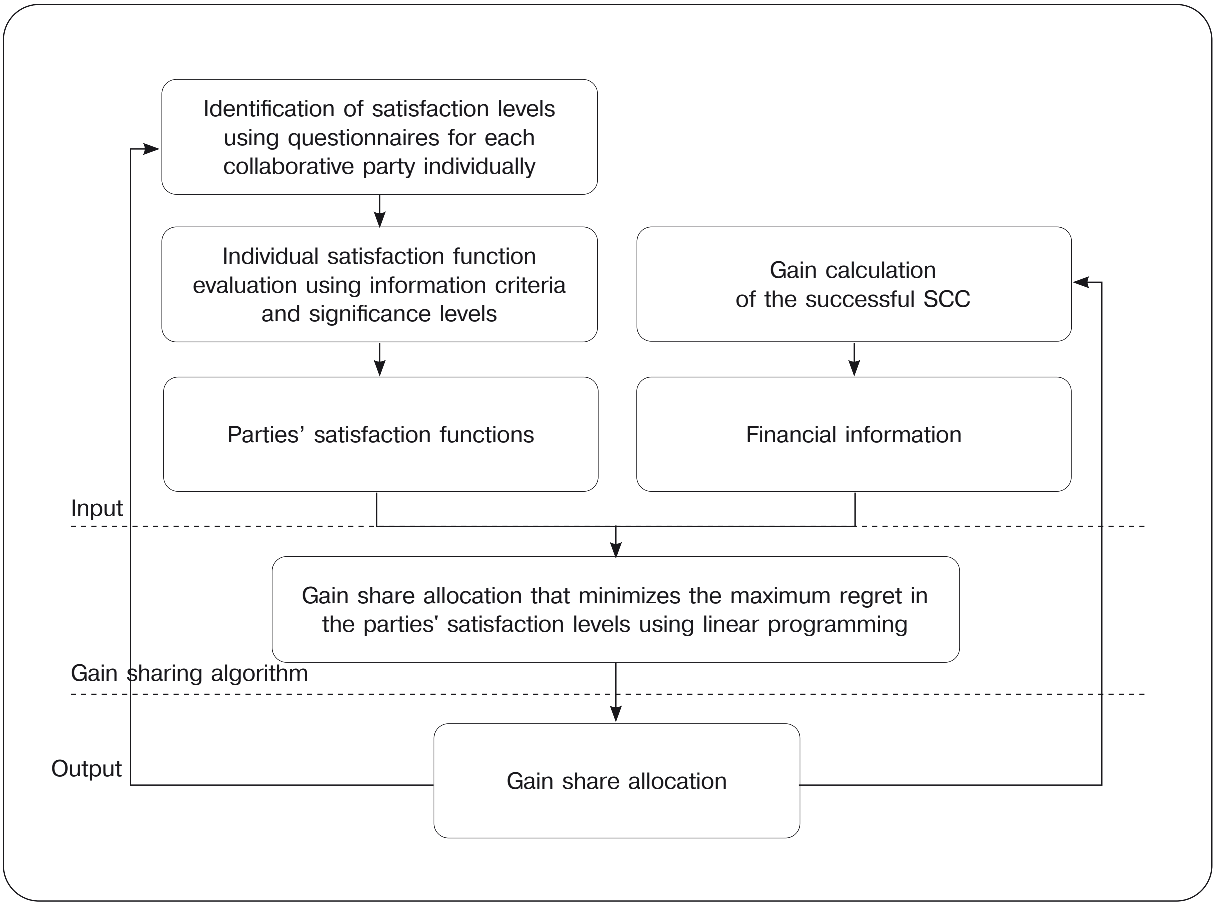

Fig. 1. The block diagram of the comprehensive gain sharing system

when necessary. In the following sections the three system parts are explained in more detail. Section 1.1 explains the input factors, followed by the introduction of the gain sharing algorithm in Section 1.2. Finally, the output is discussed in Section 1.3.

1.1. Input

The gain sharing algorithm demands two input elements: the satisfaction functions of each party and the financial information of the SCC.

In the literature there are many definitions for the term satisfaction, which is the first input element of the algorithm. One of the accepted definitions states "…satisfaction is the customer's fulfillment response. It is a judgment that a product/service feature or the product or service itself provided (or is providing) a pleasurable level of consumption — related fulfillment, including levels of under — and over-fulfillment" [Oliver, 2014]. In the context of gain sharing methods, satisfaction of a (sub)coalition is usually defined as the excess of cost savings of the grand coalition minus the total gain of a (sub)coalition [Lozano et al., 2013]. In this paper, we assume that the satisfaction of a party depends on the gain share which is assigned to the party. We are aware that the gain share is not the only aspect that has an influence on the parties' satisfaction levels therefore, in Section

4 additional aspects that could be considered in further research are proposed. In order to derive the parties' satisfaction functions, we have to identify the satisfaction levels of the parties for different possible gain shares. For this purpose, questionnaires have to be distributed to the collaborative parties. Using questionnaires as a research instrument is useful since they are usually inexpensive to administer, little training is required to develop them and they are easy and quick to analyze [Wilkinson, Birmingham, 2003]. This contributes to the simplicity of the gain sharing system.

In the questionnaire, the parties are asked how satisfied they are with a certain gain share. An example question would be "How satisfied are you with a gain share of 20% of the coalition gain?". The responses of a party are elicited on a five-point Likert scale ranging from "very dissatisfied" to "very satisfied". Using a Likert scale to measure the satisfaction is common practice. Examples can be found in [Mueller, McCloskey, 1990; Traynor, Wade, 1993], which both measure the job satisfaction of employees on a five-point Likert scale. In order to receive valid responses, it is necessary to indicate how many parties are involved in the SCC. After conducting the questionnaires, they have to be analyzed and the parties' satisfaction functions have to be derived from the data. In order to identify the most appropriate satisfaction function for each party individually, several non-linear regressions could be performed. For the purpose of narrowing down the possible functions it is advisable to plot the data first. In order to evaluate the performance of the different functions, next to the investigation of the significance levels of the coefficients, the H. Akaike information criterion (AIC) [Akaike, 1974] and the G. Schwarz with coauthors information criterion (SIC) [Schwarz et al., 1978] are compared. These two statistical criteria, which are both founded on information theory, are often used when selecting the most appropriate model for the underlying data [Sin, White, 1996]. The function with the least AIC and SIC value should be preferred [Ludden, Beal, Sheiner, 1994].

The second input factor is the financial information of the collaboration. Important information in this context is the overall coalition gain achieved by the grand coalition as well as the gain for each possible subcoalition.

1.2. Gain sharing algorithm

The gain sharing algorithm aims to increase the satisfaction of the collaborative parties through the minimization of the maximum regret. According to [Loulou, Kanudia, 1999; Mausser, Laguna, 1999], the minimax criterion is a reliant criterion for evaluating and selecting decisions under uncertainty and imperfect information. We use the minimax regret approach in order to put more weight on the least satisfied party and thereby, increase the probability that no party leaves the SCC, which in turn results in an increased chance of having a sustainable SCC. In this study, the regret represents the difference between the best possible satisfaction level, when 100% of the gain is assigned to a party, and the actual satisfaction level of that party.

Let N be the set of collaborative parties. For each party $i \in N$, let $0 \leqslant x_i \leqslant 1$ denote the gain share of party i and let $s_i(x_i)$ represent the satisfaction level of party $i \in N$ when x_i share of the gain is allocated to i. We propose the following, simple and intuitive, gain sharing model:

$$min_{0 \le x \le 1}\, max_{i \in N} \left\{ s_i\left(1\right) - s_i\left(x_i\right) \right\}, \qquad (1)$$

subject to

$$\sum\nolimits_{i \in N} x_i = 1, \qquad (2)$$

$$\sum\nolimits_{i \in S} x_i \ge \upsilon\left(S\right) / \upsilon\left(N\right) \ \forall S \subset N,$$

where $v(S)$ and $v(N)$ represent the gain share of a sub-coalition $S \subset N$, $S\ 6 = \varnothing$ and the gain share of the grand coalition, respectively.

Clearly, the objective function is to minimize the maximum regret of the collaborative parties. Constraints (1) and (2) ensure that the gain allocation is in the core and thus stable. Being in the core guarantees that no party can increase its share/profit by leaving the grand coalition [Leng, Parlar, 2009]. We include these constraints to ensure that there is no rational incentive for any party to leave the SCC.

1.3. Output

The output of the gain sharing model is the gain allocation, which minimizes the maximum parties' regret or, in other words, it distributes the gain to satisfy all parties. Particularly, the objective function represents one of the KPIs that will support managers to evaluate the performance of the gain sharing system. Other outputs are the satisfaction levels/functions for each party as well as the corresponding regrets.

2. IMPLEMENTATION OF THE GAIN SHARING SYSTEM

In this section, the proposed gain sharing system is applied to a real data set received from the logistics company for a vertical SCC including one manufacturer, one LSP and one retailer in the Dutch FMCG industry. The goal of this section is to apply the gain sharing system in order to theoretically illustrate the potential and high performance of the system. The implementation of the gain sharing system in practice is not part of this paper. Also notice that the new gain sharing system is not limited to vertical SCCs. It can be easily applied to a horizontal or a lateral SCC as well.

2.1. Satisfaction functions and financial information

In order to identify the most appropriate satisfaction function for each of the three parties individually, information about the satisfaction levels of different gain shares is needed for each party individually. In this study, the results from [Jung, Peeters, Vredeveld, 2018] are used. They have investigated the influence of different behavioral aspects on the parties' acceptance levels of selected gain sharing methods in a vertical SCC between one manufacturer, one LSP and one retailer in the Dutch FMCG industry by conducting questionnaires. One aspect the researchers investigate is the influence of the gain share on the parties' acceptance levels of the corresponding gain sharing method. Assuming that the acceptance levels are equal to the parties' satisfaction levels, the results from [Jung, Peeters, Vredeveld, 2018] are taken as a basis for the relationship between the assigned gain share and the satisfaction levels of the three parties.

Based on this information, the satisfaction levels for different gain shares are simulated with 100 runs and 50 trials per run. Examples of these simulations are provided in Table 1.

For various gain shares the corresponding satisfaction levels of the three parties on a five-point Likert scale are displayed.

Plotting the data shown in Table 1 reveals the characteristic S-shape curve, also known as the sigmoid curve. In order to identify the most appropriate sigmoid function to represent the parties' satisfaction levels for the different gain shares, several non-linear regressions have been performed using the software EViews 9 SV. EViews uses the Gauss-Newton algorithm [Levenberg, 1944; Marquardt, 1963]. It turns out that the straightforward logit model, also known as logistics regression, demonstrated the best fit to represent the satisfaction of all parties (based on the significance levels and the AIC and SIC):

$$s_i(x_i)=\frac{a_i}{b_i+e^{c_i x_i}}, \qquad (3)$$

where x_i represents the gain share assigned to each party $i = m, l, r$. Here, the index m

Table 1

Satisfaction levels of the three parties for various gain shares

Gain share, %	Satisfaction level*		
	Manufacturer	LSP	Retailer
10	2	4	1
20	3	4	1
30	4	5	1
40	5	5	2
50	5	5	3
60	5	5	3
70	5	5	3
80	5	5	4
90	5	5	4
100	5	5	5

N o t e: *on Likert scale (1–5).

Table 2

Output of the non-linear regression

Non-linear regression coefficient	Manufacturer		LSP		Retailer	
	Coefficient	Probability	Coefficient	Probability	Coefficient	Probability
a_i	1.23	0.00	8.48	0.00	0.72	0.00
b_i	0.24	0.00	1.69	0.00	0.13	0.00
c_i	–9.0	0.00	–9.0	0.00	–3.50	0.00

N o t e: output of the non-linear regression (reported in "Coefficient" are highly significant on a 1 % significance level, see columns "Probability").

refers to the manufacturer; l refers to the LSP and r to the retailer; coefficients *a*, *b* and *c* are determined by the non-linear regression. The corresponding outputs of the non-linear regressions for the three parties are depicted in Table 2 For all parties the coefficients.

Table 2 shows the plotted satisfaction functions. The LSP is the party, which is most easily satisfied. It was observed that the LSP is influenced by a cognitive bias; the so-called choice-supportive bias [Jung, Peeters, Vredeveld, 2018]. Here, people tend to always think positively about a decision they made, even if the decision has a flaw [Mather, Johnson, 2000]. In the Dutch FMCG industry, the LSP often takes the initiative to start the SCC. Therefore, no matter what gain share is assigned to the LSP, this party is always satisfied. Unlike the LSP, the retailer has typically very low acceptance/satisfaction levels. Even if the largest portion of the gain is assigned to the retailer, this party is not satisfied, which might be the result of the power position of the retailer in the Dutch FMCG industry [Jung, Peeters-Rutten, Vredeveld, 2017]. Regarding the manufacturer, the satisfaction function shows a steep increase from the beginning until a gain share of around 50 % is received. Above that amount the manufacturer is generally satisfied.

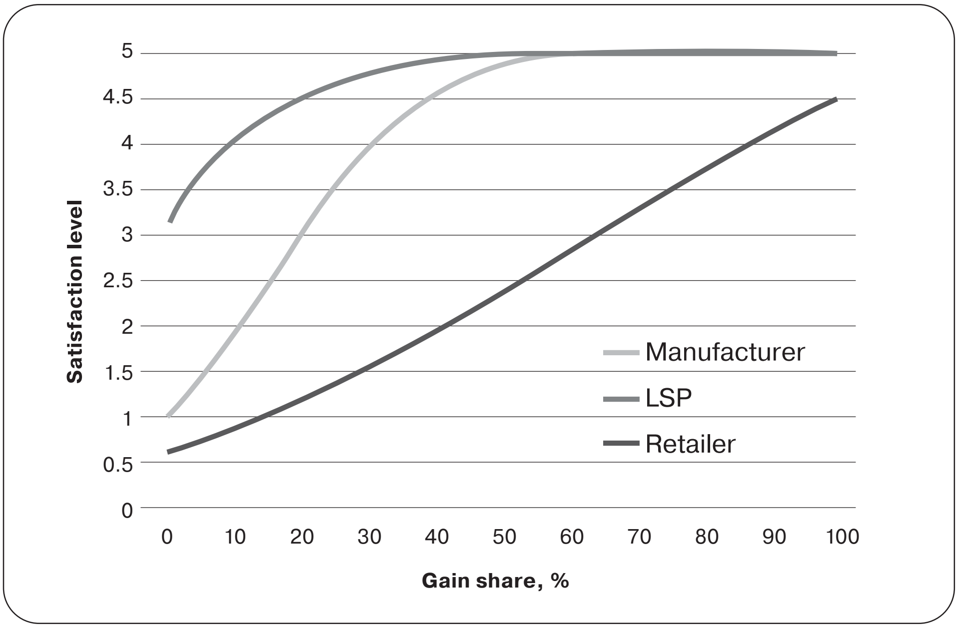

Fig. 2. Graphical illustration of the satisfaction functions

Table 3

Expected benefits, costs and resulting profits of the vertical SCC, €

Expected gain	Manufacturer	LSP	Retailer	Overall
Benefits	80 000	50 000	250 000	380 000
Costs	85 000	10 000	80 000	175 000
Profits	–5 000	40 000	170 000	205 000

In order to perform the gain sharing algorithm, the financial information of the SCC is required. In the supply chain under study, the LSP ships the final products produced by the manufacturer from the production site to the retailer to satisfy the orders placed by the retailer. The retailer itself meets the demand of multiple end-customers. Table 3 provides an overview of the expected benefits, costs and the resulting profits of the vertical SCC.

The data were provided by the logistics company.

As already outlined in Section 1.1 and 1.2, next to the grand coalition gain, the subcoalition gains have to be provided. The gain for a coalition between the manufacturer and the LSP is equal to 9000€ whereas a collaboration between the manufacturer and the retailer results in a coalition gain of 99 000€. A gain of 150 000€ can be achieved by a coalition between the LSP and the retailer. If the parties are not collaborating with each other, no gain can be achieved for any party. Also, these values have been provided by the logistics company.

Based on the input data described above, the gain sharing algorithm for the vertical SCC between the manufacturer, LSP and

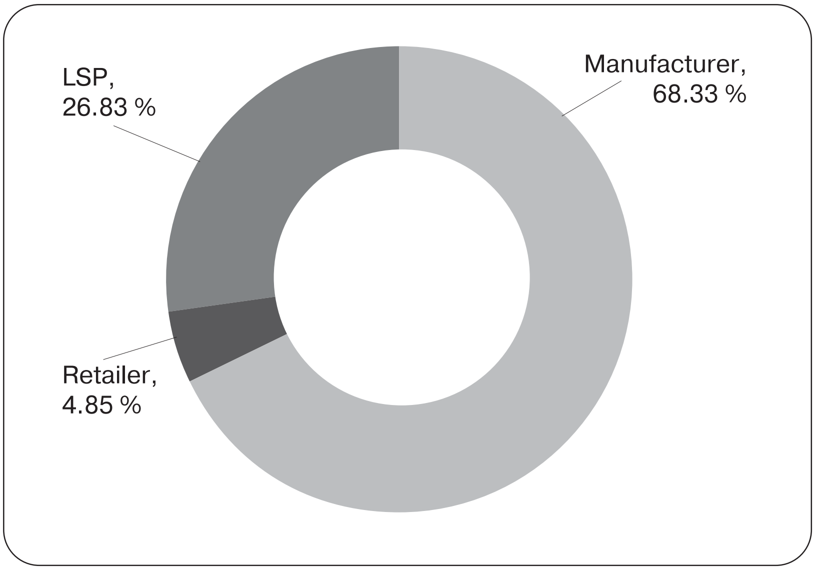

Fig. 3. Gain share allocation

Table 4

Satisfaction levels and regrets of all parties

Involved party	Gain share, %	Satisfaction level	Regret
Manufacturer	26.83	50 000	380 000
LSP	4.84	10 000	175 000
Retailer	68.33	40 000	205 000

Note: satisfaction level and regret are presented in Likert scale (1–5).

retailer from the Dutch FMCG industry can be specified as follows:

$$min_{0\le x_m, x_l, x_r \le 1} max \begin{Bmatrix} 5.12-\dfrac{1.23}{0.24+e^{-9x_m}}; \\ 5.02-\dfrac{8.48}{1.69+e^{-9x_l}}; \\ 4.49-\dfrac{1.23}{0.13+e^{-3.5x_r}} \end{Bmatrix} \quad (4)$$

$$x_m + x_l + x_r = 1 \quad (5)$$

$$x_m + x_l \geqslant 0.04 \quad (6)$$

$$x_m + x_r \geqslant 0.48 \quad (7)$$

$$x_l + x_r \geqslant 0.73 \quad (8)$$

2.2. Output discussion

In Figure 3, the gain allocation for the vertical SCC in the Dutch FMCG industry is depicted. The retailer receives with 68.33 % the largest portion of the gain, followed by the manufacturer with 26.83 %. The remaining part of 4.84 % is assigned to the LSP.

Table 4 presents the satisfaction levels on Likert scale (1–5) corresponding to the assigned gain shares and regrets. The latter one is calculated by subtracting the actual satisfaction level of the assigned gain share from the maximum possible satisfaction level. The manufacturer's satisfaction level for the assigned gain share of 26.83 % is the largest one with 3.73. There retailer possesses

Table 5

Satisfaction levels and regrets for the Shapley value and nucleolus

Involved party	Shapley value			Nucleous		
	Gain share, %	Satisfaction level	Regret	Gain share, %	Satisfaction level	Regret
Manufacturer	17.72	2.78	2.34	2.11	1.15	3.97
LSP	30.16	4.83	0.19	26.99	4.77	0.25
Retailer	51.63	2.45	2.04	70.89	3.37	1.12

the lowest satisfaction level with 3.25 for the largest gain share. Nevertheless, the retailer has the lowest regret with 1.24. When looking at the manufacturer's and the LSP's regret, it can be observed that the regret is the same with 1.39 for both parties, see column "Regret". Comparing this regret with the retailer's regret, no big difference can be observed, which leads to the conclusion that the optimum is reached.

The retailer has the most power in the Dutch FMCG supply chain and, in addition, in this setting the retailer has the highest financial contribution to the coalition gain, which results in low satisfaction levels for all gain shares. In turn, this results in the allocation of the largest portion of the coalition gain to the retailer. As already mentioned, the LSP is influenced by the choice-supportive bias [Mather, Johnson, 2000; Jung, Peeters, Vredeveld, 2018]. The influence of this bias results in a high acceptance/satisfaction level for all possible gain shares. Obviously, this leads to the smallest gain share.

In order to proof the advantage of our proposed gain sharing system, we compare it with the two most referred (and preferred) game theoretic allocation methods, the Shapley value and the nucleolus [Moulin, 1991]. Table 5 shows the satisfaction levels and the regrets for these two methods. Here, the manufacturer receives the smallest portion of the gain and, compared to our gain sharing system, the satisfaction level is lower resulting in a higher regret.

The LSP receives a larger portion of the gain resulting in a very high satisfaction level and in a small regret. The retailer receives a larger portion of the coalition gain according to the nucleolus and a lower portion according to the Shapley value. As a whole, the maximum regrets in the two game theoretic methods are much higher than in our proposed gain sharing system. This might result in a decreased probability of a long-term sustainable SCC, which is, however, very important for every party in any supply chain [Jap, 2001].

3. SYSTEM STABILITY

In this section, the gain sharing system stability is investigated. First, fairness properties of allocation methods, which represent interesting KPIs, are introduced and the satisfaction of these properties for the developed gain sharing system is investigated. This is followed by a sensitivity analysis of the uncertain parameter of our system, the satisfaction functions.

3.1. Fairness properties

Considering the characteristics of a SCC, it is essential that any proposed sharing mech-

Table 6

Allocation properties of gain sharing methods

Property	Definition
Efficiency	The total coalition gain is shared as the grand coalition forms: $\sum_{i \in N} x_i = v(N)$
Individual rationality	No partner gains less than his stand-alone gain: $x_i \geq v(\{i\})$
Subgroup rationality	Parties are never better off forming a subgroup by excluding other parties: $\sum_{i \in S} x_i \geq v(S)$
Stability	No single participant or (sub)coalition of participants of the collaboration would benefit from leaving the grand coalition: $\sum_{i \in N} x_i = v(N)$ and $\sum_{i \in S} x_i \geq v(S)$
Additivity	The profit allocation of a combination of several separate coalitions is equal to the sum of the separate allocation values of these coalitions: $x(i \cup j) = x(\{i\}) + x(\{j\})$

Table 7

Collaborative profit and allocated profit for all (sub)coalitions, €

(Sub)coalition	Allocated profit	Collaborative profit
M	54 999.45	0.00
L	9 930.20	0.00
R	140 070.35	0.00
ML	64 929.65	9 000.00
MR	195 069.80	99 000.00
LR	150 000.55	150 000.00
MLR	205 000.00	205 000.00

N o t e s: manufacturer (M); LSP (L); retailer (R); manufacturer — LSP (ML); manufacturer — retailer (MR); LSP — retailer (LR); manufacturer — LSP — retailer (MLR).

anism is desirable on a collaborative and individual level. Not only should the overall collaborative profit level improve, also the individual profitability levels of all participating parties need to be maintained or, even better, enhanced. In addition, it is important to ensure that the applied sharing technique is perceived by the cooperating parties as reasonable and easy to understand. Accounting for these challenges, a general definition of a fair sharing mechanism is difficult to develop. As such, Table 6 provides an overview of the basic fairness properties desirable in the SCC context [Guardiola et al., 2007; Leng and Parlar, 2009; Liu et al., 2010; Verdonck, 2018].

Since the fairness properties of the developed allocation system may have a significant

Table 8

Gain share allocation for two-level collaborations

Coalition	x_m	x_l	x_r
ML	0.6082	0.3918	
MR	0.2963		0.7037
LR		0.1668	0.8332

Notes: manufacturer — LSP collaboration (ML), manufacturer — retailer collaboration (MR), LSP — retailer collaboration (LR); x_m, x_l, x_r are the coefficients showing the remaining part of the gain which has to be split among two parties manufacturer, LSP, and retailer respectively.

influence on the SCC sustainability, we test the satisfaction of these properties for the proposed gain sharing system by means of an illustrative numerical example. The example relates to the already outlined vertical SCC between the manufacturer (M), LSP (L) and retailer (R) from the Dutch FMCG industry. The third column of Table 7 lists the collaborative profits for all possible (sub)coalitions. The second column lists the profits allocated by the developed gain sharing algorithm when the grand coalition is formed.

Analyzing this example, we can state that our proposed gain sharing system is efficient. The total coalition gain is shared as the grand coalition forms (205 000 = 205 000). Moreover, constraint (2) of the gain sharing system satisfies the efficiency property. The proposed gain sharing system also satisfies the *individual rationality* property. The standalone gain for each party is 0, while the allocated gain for each individual party is larger than 0. In addition, the *subgroup rationality* property is satisfied. No subcoalition has the incentive to leave the grand coalition and be better-off when acting alone. This is because the collaborative profit of subcoalitions is smaller than its allocated profit in case the grand coalition is formed. Constraints (1) and (2) guarantee *stability* of the allocation defined by the proposed system. Finally, the *additivity* property is satisfied. The profit allocation of any (sub)coalition is equal to the sum of the separate allocation values of the (sub)coalition members, e.g., for M and L, 64 929.65 = 54 999.45 + 9930.20. The analysis indicates the fulfillment of all fairness properties. Therefore, it can be stated that the proposed gain sharing system can be perceived as fair and will likely result in sustainable SCCs.

3.2. Sensitivity analysis

We perform a sensitivity analysis to examine the effect of the uncertain satisfaction functions on the satisfaction levels of the parties. Depending on the satisfaction function, the assigned amount to the party will get smaller or larger and the remaining part has to be split among the other two parties. For example, if the gain share assigned to the manufacturer will change from the current 26.83 % to 20 % of the coalition gain, 6.83 % of the collaborative profit has to be split among the LSP and retailer. In order to assign the remaining gain share to the LSP and retailer in a fair way, we ran the gain sharing system for a SCC between the LSP and retailer. Depending on the outcome of the gain sharing system for xl and xr, the remaining part will be split among the two parties. The same holds for the reverse case, so if the assigned gain share to the manufacturer increases. The results of the gain sharing system for the two-level collaborations are shown in Table 8. A collaboration between the manufacturer and LSP results in an allocated share of 60.82 % to the manufacturer and the rest would be assigned to the LSP. The gain share assigned to the manufacturer is halved (29.63 %), if the manufacturer and retailer are collaborating. The highest gain share is assigned to the retailer (83.32 %), if the retailer is engaged in a two-level collaboration with the LSP.

Figures 4, 5 and 6 show the results of the sensitivity analysis for a change in the manufacturer's, the LSP's and the retailer's satisfaction function, respectively. The parties' satisfaction levels vary in relation to a change in the satisfaction functions.

A change in the LSP's satisfaction function has the highest impact on the satisfaction levels of the manufacturer and retailer, see Figure 5. If the assigned gain share to the LSP increases, the satisfaction levels of the manufacturer and retailer decrease rapidly. Both satisfaction functions follow an S-shape and do not cross each other. This indicates that, in comparison to the manufacturer, the retailer is always less satisfied.

The LSP is the party who is always satisfied no matter what gain share is assigned to this party. As a result, the satisfaction levels of the LSP are not highly influenced by a change in the retailer's and manufacturer's satisfaction function, as demonstrated in Figures 4 and 6.

Concluding this section, especially the retailer's and the manufacturer's satisfaction levels are highly influenced by a change in the satisfaction functions. Therefore, in order to assure the SCC sustainability, the precise determination of the satisfaction functions is important. One essential aspect to achieve the precise determination of the satisfaction functions are honest answersing the questionnaires. However, if the survey questions demand responses which are too revealing, people tend to refuse to answer or even lie [Warner, 1965; Clark, Desharnais, 1998]. Anonymity is one option, which might increase the probability of receiving honest answers [Mühlenfeld, 2005]. In the survey by [Jung, Peeters, Vredeveld, 2018], anonymity has been guaranteed. Through the use of an online survey, no personal interaction be-

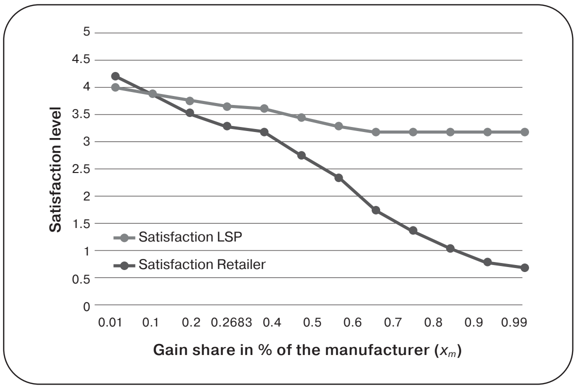

Fig. 4. Sensitivity analysis for the manufacturer's satisfaction function

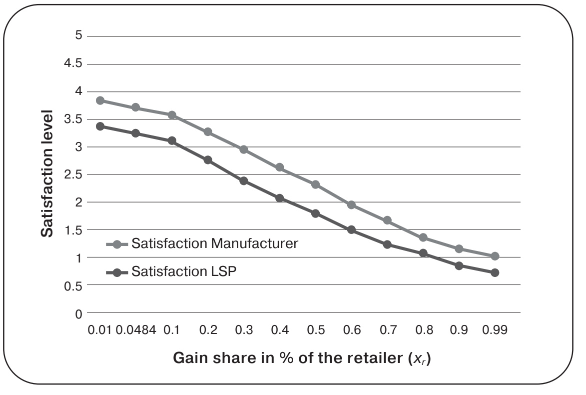

Fig. 5. Sensitivity analysis for the LSP's satisfaction function

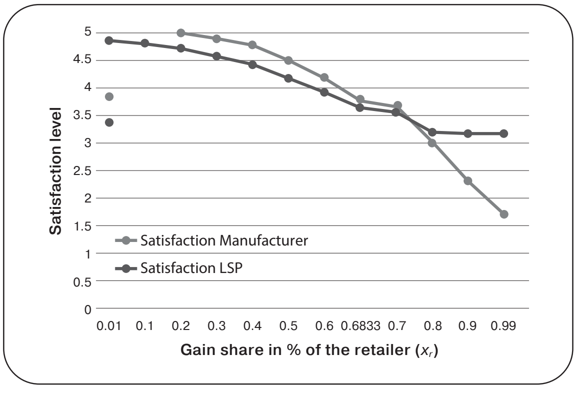

Fig. 6. Sensitivity analysis for the manufacturer's satisfaction function

tween the interviewer and the interviewee took place. Furthermore, except for the question which supply chain position the respondent has, no personal questions were asked. Through the use of self-administered questionnaires and therefore, the absence of an interviewer, the probability of getting truthful answers can also be increased [Nederhof, 1985]. In addition, according to [Mühlenfeld, 2005], instructing people to answer truthfully before and during the survey might be another idea to increase honesty.

4. CONCLUSIONS

In this paper, a comprehensive, simple and robust gain sharing system has been introduced. In order to ensure the acceptance and satisfaction of the collaborative parties and to increase the probability of a sustainable SCC, the system focuses on the maximization of the parties' satisfaction by using a minimax regret approach. The proposed gain sharing system has been tested on real data for a vertical SCC in the Dutch FMCG industry. Results show the increase in the parties' satisfaction and decrease in their regrets. Furthermore, the system stability analysis proved the fairness of the gain allocation and revealed the importance of the accurate determination of the satisfaction functions.

4.1. Practical implications

The new gain sharing system requires only limited input data to provide robust output for the gain sharing decision. In addition, the proposed gain sharing system provides all key characteristics which are appreciated in practice: mathematical simplicity, applicability and transparency. Furthermore, important KPIs such as the optimal gain share allocation and the fairness properties have been introduced in order to support managers to evaluate the performance of the proposed gain sharing system. Moreover, the sensitivity analysis revealed the importance of the satisfaction functions precision. In order to achieve this, honest questionnaire replies are essential.

4.2. Limitations

Our gain sharing system has several limitations. Firstly, we provide theoretical framework, which shows the algorithm maximizing the satisfaction of the collaborative parties. Secondly, we chose simple satisfaction functions. These functions may also include non-financial aspects of satisfaction like, for instance, parties' objections which could more significant factor determining cooperation or rejection of it. Straightforwardly taking into account all these limitations, we can improve the system and achieve more realistic results, while the main goal of this paper is to introduce a new algorithm for gain sharing.

4.3. Theoretical implications

First, the existing gain sharing methods are not accepted by or satisfactory for the collaborative parties, while the proposed scheme focuses on the maximization of the parties' satisfaction. Second, known game theoretic allocation methods are perceived as too hard to understand and too complex to implement, while the presented method is intuitive and simple. Another contribution is the application of the gain sharing system to a vertical three-echelon SCC, while the contemporary SCM literature addresses the applications of gain sharing methods in horizontal, two-echelon collaborations.

4.4. Further research

This paper offers several opportunities for further research. Firstly, it has been assumed that the only influencing aspect on the parties' satisfaction is the gain share. Further research should include additional influencing aspects such as the amount and the quality of information for parties to share. Secondly, the relation between the assigned gain share and the profit a party can achieve on its own needs to be investigated. Thirdly, testing the gain sharing system on horizontal and/or lateral SCCs as well as in real-life applications may result in stronger support for the new gain allocation. Fourthly, the acceptance of the gain sharing system could be observed in practice. The implementation of the new gain sharing system into practice requires the precise determination of the satisfaction functions for each collaborative party individually. Here, we theoretically illustrated the performance of the system based on the satisfaction levels of the parties from [Jung, Peeters, Vredeveld, 2018], who show the satisfaction levels of the Dutch FMCG industry by conducting questionnaires. Thus, it is of high importance to further implement the techniques, that ensure and/or improve the honesty in the questionnaire replies. Moreover, market structure could vary in different countries, and satisfaction functions might change depending on the market segment. Therefore, it is worth to test the sharing system on data from other geographical regions and market segments in order to make it more adapted to local conditions.

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Комплексный подход к распределению выигрышей для максимизации удовлетворенности от сотрудничества в цепочке поставок

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Основной проблемой сотрудничества в цепочке поставок является справедливое распределение прибыли коалиции. В статье разработана комплексная, но простая система распределения прибыли с особым акцентом на максимизацию удовлетворенности сторон с использованием подхода минимаксного сожаления. Система разделения прибыли применяется к вертикальному типу сотрудничества в цепочке поставок, включающему одного производителя, одну логистическую компанию и одного розничного продавца быстроразвивающейся отрасли потребительских товаров. Результаты определяют справедливое и надежное распределение доли прибыли, которое максимизирует удовлетворенность сторон и, таким образом, увеличивает вероятность устойчивого сотрудничества. В работе представлена теоретическая основа, которая при необходимости адаптируется к конкретному типу коалиции.

Ключевые слова: сотрудничество в цепочке поставок, отрасль FMCG, распределение прибыли, уровень удовлетворенности, минимаксное сожаление.

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Appendix

INTERVIEW GUIDE

The preliminary study was conducted with 20 companies including seven manufacturers, six LSPs and seven retailers from the Dutch FMCG industry, which all participated in a logistics competition with the goal to reduce the costs at the retailer's distribution center through SCC. For the data collection individual, semi-structured interviews were conducted mostly face-to-face with the supply chain managers of the companies.

The following questions concerning the gain sharing methods were asked to the interviewees:

1) what does "fair gain sharing" mean for you and your company;
2) to what extent are you willing to share gains among the entire supply chain? (answer on a 5-point Likert scale);
3) would it be a problem for your company to share gains with coalition parties that are achieved by your company, but are a result of a collaboration; to what extent and why? If so, why are you willing to share gains;
4) in your experience, how do other parties within your supply chain react to gain sharing;
5) before you start a collaboration, is the transparency of how much each party needs to invest in collaboration an important issue;
6) before you start a collaboration, is it crucial information for you to know how parties will benefit? To what extent and why?