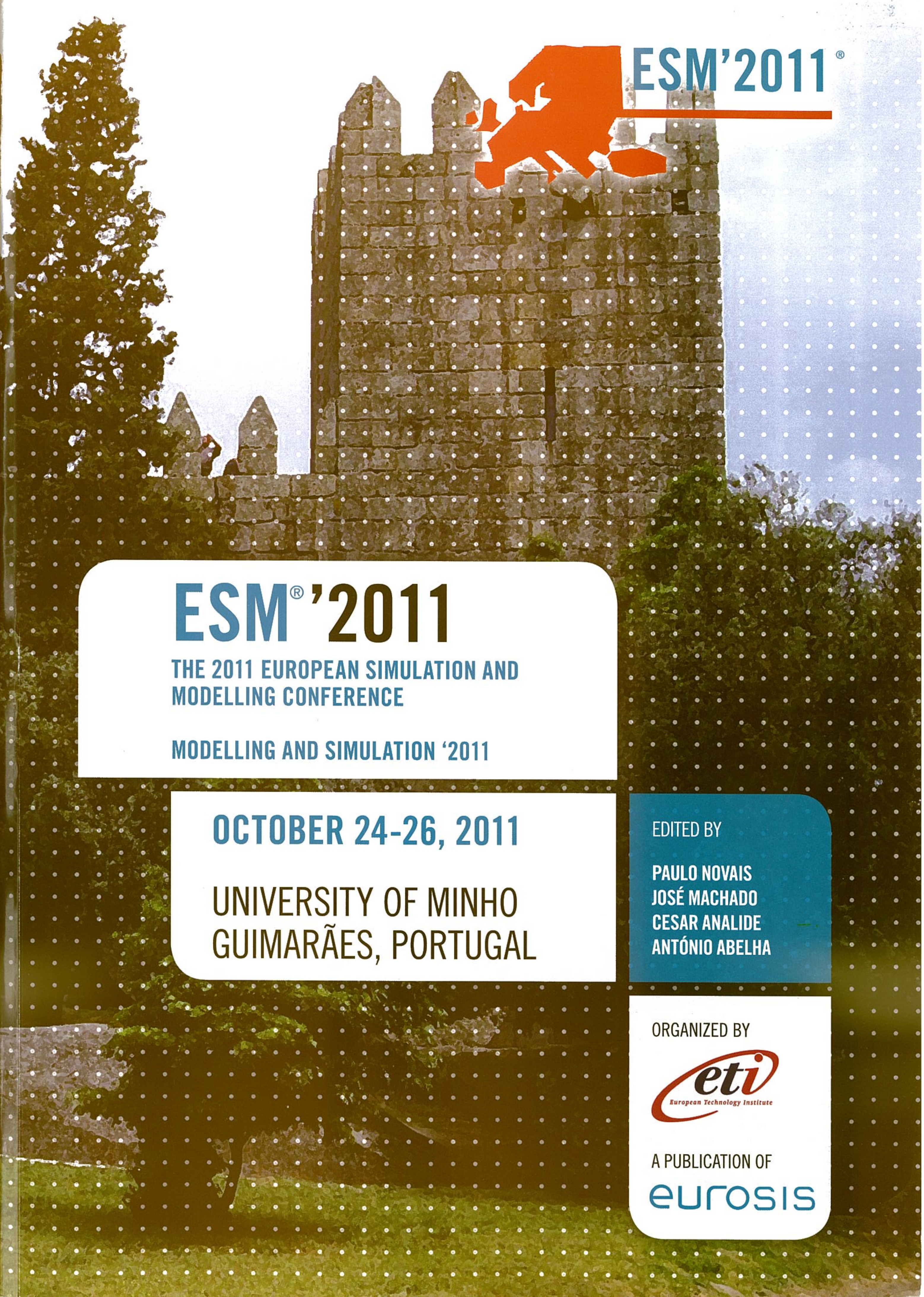

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SHAPLEY VALUE SIMULATION FOR ALLOCATING GHG EMISSION SAVINGS DUE TO LOGISTICS POOLING WITHIN ECR COOPERATIONS

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GHG emission allocation, SHAPLEY value, logistics pooling, Efficient Consumer Response (ECR), cooperation

ABSTRACT

For a couple of years companies – and especially logistics transportation networks – are compelled by a number of new developments: Next to cost reduction efforts also considering 'green thinking' within logistics processes is of higher interest – constituting a critical success factor. Although companies are already legally forced to report sustainable – especially environmental – performance in certain extend voluntary reporting is important to several stakeholder groups. Currently, a couple of organisations work on standards for how to calculate and report greenhouse gas (GHG) emissions. If logisticians pool their transport capacities – as e.g. within Efficient Consumer Response (ECR) cooperation networks – not only costs but also GHG emissions can be saved ('eco-efficiency'). But up to the present the question of how to allocate such savings has widely been neglected. Thus, this paper provides a first problem solution on how to allocate GHG emission savings by the help of cooperative game-theory's SHAPLEY value concept. Therefore, operations research and computer aided simulation seem helpful.

INTRODUCTION

As within recent years companies are affected by rising competitive pressure new ways of differentiation are needed in order to secure sustainable company growth (Winkler et al. 2006). Especially, logisticians are addressed by such developments: Customers become aware of green delivery strategies next to a minimal level of costs (Delay 2007; Fiksel 2009). In order to fulfil customer's needs green strategies within logistics transportation networks are needed. *Saving greenhouse gas (GHG) emissions is just one – but a major – issue that needs to be addressed to in scientifical research* (cp. e.g. Beamon 1999; United Nations Framework Convention on Climate Change 1998; Wick and Klumpp 2010).
Calculating carbon footprints is actually of highest interest, but a very complex subject (BSI British Standards 2008; Schmidt 2009; Wackernagel and Rees 1996). As no standard has been established yet a number of companies, governments and non-governmental institutions work on problem solutions (e.g. BSI British Standards 2008; WBCSD and WRI 2004). One topic that has absolutely not been mentioned within this context is the way of *how to calculate and allocate GHG emission savings* within logistics transportation networks. This paper provides a first outlook on future developments as logistics pooling continuously gains more importance within global competition. Next to cost-savings this strategy especially effects GHG emission savings as physical transportation processes decrease (Pan et al. 2010).
But one question that remains unanswered in this field is the question of *how to report* these GHG emission savings towards customers. If several companies cooperate, which of them is responsible for GHG emission savings and therefore allowed to report them (Young 2010)? Thus, this paper provides a first problem solution of how to allocate GHG emission savings within logistics transportation networks operating logistics pooling. Therefore, operations research modelling is used (Maloni and Benton 1997): The mathematical and formal concept of SHAPLEY value – part of cooperative game theory – seems to be appropriate. As the whole subject is affected by high complexity computer aided simulation is consequently needed.

LOGISTICS POOLING, EFFICIENT CONSUMER RESPONSE AND ECO-EFFICIENCY

As due to globalisation merging markets are more and more common both international and national companies are threatened by new market conditions – e.g. division of labour and cost pressure (Middendorf 2008). Next to fierce competition also rising customer expectations – e.g. acting sustainably – have to be addressed in order to ensure continuous company growth. Thus, companies are often no longer able to work independently: *cooperative strategies within long-term partnerships are necessary*.
One strategy that recently has become of high interest for logisticians is *logistics pooling*. Here, a number of partners cooperatively plan and optimise own and shared transport capacities. Not only transport route and capacity optimisation are addressed, but also cooperative use of warehouses and transshipment centres. The aim is to operate vehicles at full capacities and reduce empty trips to a minimum. Finally, cost reductions are the overall aim. Despite a number of possible benefits in cooperative transport and unit load optimisation very little research deals with corresponding

effects (cp. e.g. Corsten 2004; Klumpp and Jasper 2007; Seifert 2006).

Logistics pooling is a sub-strategy of the *Efficient Consumer Response (ECR)* concept. ECR is a broad management philosophy – predominantly applied to the interface of producers and traders – that consists of two scopes: *ECR Supply Side* and *ECR Demand Side*. Supply Side strategies – as e.g. logistics pooling – cover those activities associated with the concept of *Supply Chain Management (SCM)* especially aiming at cost reduction potentials. Demand Side strategies on the other hand are part of *Category Management (CM)* – i.e. marketing activities. In extended relationships companies cooperate putting the focus on customers' needs (cp. e.g. Corsten 2004; ECR Europe 2006; Fernie 2004; Klumpp and Jasper 2007; Seifert 2006).

Nevertheless, for a couple of years trends exceeding cost- and revenue-thinking have become of higher interest. Due to the fact that a limited and short-term economic point of view does not meet the interests of all stakeholders, further considerations have to be taken into account. Recently, environmental – i.e. green – needs gained more attention both in literature and practice. As e.g. climate changes cause natural disasters, companies (will) have to develop common strategies by improving essential sustainable developments of economic activities (Lamsali 2006; Winkler et al. 2006).

Because companies are often afraid of rising costs and other disadvantages due to an implementation of environmental-friendly strategies it can be hypothesised that "… early or first movers, following the idea of Schumpeter's pioneer profit, can achieve financial gains by introducing new goods or methods of production as innovative action results in monetary benefits" (Wittneben and Kiyar 2009). In other words: *a company's economical success – e.g. rising shareholder value (SHV) – can be influenced by the (early) adoption these sustainable – particularly green – issues* (Franck 2008; Hutchins and Sutherland 2008; Lamming and Hampson 2008; Sen 2009). However, not only financial subjects are of interest. The continual improvement of intangible assets as e.g. company image has to be kept in mind as well.

One concept that broadly addresses just mentioned considerations is '*eco-efficiency*' (Fiksel 2009; Sen 2009). In reference to the World Business Council for Sustainable Development (WBCSD) (2000) "Eco-efficiency is achieved by the delivery of competitively-priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life-cycle to a level at least in line with the earth's estimated carrying capacity". If this verbal definition is expressed mathematically, one might shape the ratio as follows (WBSCD 2000):

$$\text{Eco} - \text{Efficiency} = \frac{\text{product or service [economic] value}}{\text{environmental influence}} \qquad (1)$$

As a product's or service's economic value ('efficiency') is nothing else than the ratio of revenues and costs, then eco-efficiency can also be formulated as:

$$\text{Eco - Efficiency} \uparrow = \frac{\frac{\text{revenues} \uparrow}{\text{costs} \downarrow}}{\text{environmental influence} \downarrow} \qquad (2)$$

ECR Supply Side strategies aim at a reduction of costs, while ECR Demand Side strategies aim at an increase in revenues. Thus, it is demonstrated that *ECR Supply Side – here: logistics pooling – and ECR Demand Side strategies may positively correlate with environmental needs – here: GHG emission saving activities – resulting in higher eco-efficiency* (Pan et al. 2010). Consequently, in a green context the concept of eco-efficiency becomes global part of the ECR concept.

This paper puts the focus on how to allocate GHG emission savings within cooperative logistics transportation networks using SHAPLEY value. As this operations research's issue is of high complexity computer aided simulation is necessary (Maloni and Benton 1997).

PROBLEM STATEMENT

Up to the present, *mathematical methods operationalising the impact of business processes on the environment – especially on global warming – are very rare.* A major question that remains unanswered in this context is the way of *how to realistic calculate the environmental impact of certain companies* respectively cooperative logistics transportation networks in terms of absolute GHG emissions. Moreover, the existence of inconsistent calculation approaches makes it almost impossible to benchmark carbon footprints of different companies (Olson 2010). As especially CO_2 emissions are likely to become a 'new currency' within the near future, a quick problem solution is necessary. Thereby, GHG emission calculation can be divided into two sections: (a) *GHG emission measurement or estimation* and (b) *GHG emission allocation.*

(a) An often used approach to measure or estimate GHG emissions is *process analysis*. It is characterised by a bottom-up approach (Wiedmann and Minx 2007). Therefore, it is necessary to identify all relevant processes that cause GHG emissions both within a company and even more important within the entire logistics transportation network. As there are lots of interdependencies among inter-company activities it has to be ensured that *system boundaries are explicitly defined* (Young 2010). Otherwise, the problems of under- and double-accounting could occur (BSI British Standards 2008; Schmidt 2009; Wiedmann and Minx 2007). After all processes have been mapped, their total impact on global warming has to be measured. If this is not possible in all cases – as e.g. due to the possibility that a certain product may be used in completely different ways or over varying time periods – reference values, i.e. generic values, are needed (Schmidt 2009). The final step is to sum up all GHG emissions set free due to all logistics network processes.

As this *subject is a very young discipline* just a few organisations as e.g. the British Standards Institution (BSI) (UK), the Carbon Trust (UK), the Department for Environment, Food and Rural Affairs (DEFRA) (UK), the DIN Deutsches Institut für Normung e.V. (D), the International Organization for Standardization (ISO) (CH), the World Business Council for Sustainable Development (WBCSD) (CH) and the World Resources Institute (WRI) (USA) have already discussed possible ways of standardisation. *As process analysis is based on micro-economical data it can be regarded to be very* *complex demanding for computer based simulation*. In order to reveal accurate GHG emission results this method seems to be most appropriate. Considerations made by above-mentioned organisations underline this assumption.

(b) After GHG emissions have been measured or estimated, *allocating them to single GHG emission objects* – e.g. companies – is necessary. Thereby, especially the question of how to *accurately respect system boundaries* within logistics transportation networks occurs. As due to the *application of cooperative strategies like ECR's logistics pooling* another problem needs to be solved.

The probably most known global GHG accounting and reporting standard is the '*Greenhouse Gas Protocol*' provided by the World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI). In order to accurately define system boundaries their '*concept of scope*' can be adopted. It consists of three scope categories standardised to achieve transparency and ensuring avoidance of double counting problems by different companies. *Scope 1* represents all direct GHG emissions caused by "… sources that are owned or controlled by the [regarded] company …" (WBCSD and WRI 2004). *Scope 2* then contains indirect GHG emissions generated by purchased electricity. Physically, these GHG emissions are set free outside the defined company's boundaries. Finally, *scope 3* refers to all other indirect GHG emissions caused by sources that are not under control of the company, e.g. GHG emissions emitted by third party logistics providers (WBCSD and WRI 2004).

While scope 1 and 2 GHG emission boundaries are a minor problem within logistics transportation networks, scope 3 GHG emission separation is a major one. Up to the present, there is *no discussion of how to realistic allocate GHG emissions if transportation capacities – as e.g. vehicles – are cooperatively used*. If there is no cooperation each company is able to separately measure and publish its scope 1 GHG emissions. *If on the hand transportation capacities get pooled a shift of several input* (resources as e.g. vehicles and staff) *and output parameters* (cost and GHG emission debits) *is likely* (mixture of scope 1 and 3 GHG emissions). This is an old problem always discussed when dealing with cooperative concepts like ECR (Seifert 2006; Wick and Klumpp 2009). In a two partner relationship it possibly might be that one partner is burdened with higher costs and GHG emissions while the other one is able to save costs and GHG emissions – compared to their recently non-cooperative work (Seifert 2006). Consequently, cost and GHG emission compensations are inevitable as otherwise there is no basis for cooperation (Dudek 2004). *Thus, the question of how to border* (Young 2010) *and allocate the overall GHG emission savings within logistics transportation networks needs to be answered as companies are forced to publish their environmental commitments more than ever* (Olson 2010).

One mathematical concept that has already been used to fairly allocate cost savings in n-person partnerships is *SHAPLEY value* (Maloni and Benton 1997; Thun 2005; Wick and Klumpp 2009). As each partner's contribution to all possible cooperation formations is respected this concept seems to be appropriate allocating GHG emission savings in logistics transportation networks. But *with a rising number of partners calculation becomes quickly difficult demanding for computer aided simulation*.

Finally, the problem of missing GHG emission calculation standards – generally accepted both in theory and practice – was demonstrated. Consequently, there is need to solve this problem by developing *global guidelines* on this subject. Otherwise, there won't be a feasible possibility to *publish and benchmark fair and realistic carbon footprints* of different companies – possibly implying distortions of competition (Olson 2010).

SHAPLEY VALUE

Introduced in 1953 by LLOYD S. SHAPLEY the *SHAPLEY value* is part of cooperative game theory. Compared to other cooperative game theory concepts – as e.g. the NASH-solution – it is generally applicable in *n*-person games. It allocates a definite solution to each player. SHAPLEY demonstrated that his concept is the only one that satisfies the following four axioms (Holler and Illing 2009; Shapley 1953; Thun 2005):

(1) *Symmetry*: All players are regarded as equal. I.e. if some players provide the same input, they also obtain the same output.

(2) *Pareto-Optimality*: Due to an arrangement made all players will be awarded with an output that is superior to that they actually achieve ('status quo'). Further, no player may achieve a better output without downgrading another player. The sum of all individual payoffs is equal to the overall payoff that is allocated.

(3) *Dummy-Player*: If a player achieves the same output within all coalition formations possible – compared to the output gained by working independently – she or he will also just be awarded with the original output. I.e. marginal benefits achieved by player i in all possible coalition formations are constant and are equal to those achieved working in isolation.

(4) *Additivity*: If a game is divided into sub-games, the sum of a player's outputs within these sub-games is equal to that within the overall game. I.e. if there is a special coalition formation each player achieves the quota equal to the output within several sub-coalition formations.

The SHAPLEY value is mathematically formulated within equitation (3):

$$\Phi_i(v) = \sum_{K \ni i; K \subset N} \frac{(k-1)!(n-k)!}{n!}\left[v(K) - v(K - \{i\})\right], \tag{3}$$

whereby:

$\Phi_i(v)$	SHAPLEY value for player i,
K	Sub-coalition,
k	Number of players in K,
N	Coalition,
n	Number of players in N.

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Moreover, player *i* is part of coalition N. Letter K then represents possible sub-coalitions in N, i.e. K is proper subset of N ($K \subset N$). The term $K \ni i$ expresses that for any player *i* all sub-coalitions K are included in calculation if they are a proper subset of N and if *i* is even part of it. [v(K) – v(K – {*i*})] represents the marginal contribution of player *i* to an existing coalition K. Furthermore, there are n! different combinations of how all players *n* may join coalition N. I.e., the probability of all possible orders joining an existing coalition is always the same. Thereby, exact (k – 1)!(n – k)! combinations exist in which *i* joins the coalition lastly. Finally, ∑ means that all marginal contributions of player *i* weighted by the term $\frac{(k-1)!(n-k)!}{n!}$ have to be summed up, if *i* joins sub-coalition K (Holler and Illing 2009; Shapley 1953; Thun 2005).

CASE STUDY SIMULATION

In order to become more practical a brief fictitious case study approach is provided demonstrating *high need for computer aided calculation in the broad field of operations research* (Maloni and Benton 1997). Therefore, it is assumed that three logisticians (L_I, L_{II} and L_{III}) – providing road transportation services – cooperate. Each vehicle fleet causes an already measured amount of GHG emissions if there is no partnership. After a *logistics pooling cooperation* between L_I, L_{II} and L_{III} has been initiated, the amount of GHG emissions decreases due to an optimisation in vehicle capacity use (Pan et al. 2010). Several values of absolute GHG emissions are needed: For all possible cooperation formations absolute GHG emissions in tons (t) per year are given as follows (sample numbers):

v({L_I}) = 60.00, v({L_{II}}) = 15.00,
v({L_{III}}) = 25.00, v({L_I / L_{II}}) = 52.50,
v({L_I / L_{III}}) = 68.00, v({L_{II} / L_{III}}) = 35.00,
v({L_I / L_{II} / L_{III}}) = 82.50.

If the players work individually L_I is charged with 60.00 tons of GHG emissions per year, L_{II} with 15.00 tons and L_{III} with 25.00 tons. If there is a coalition between logistician L_I and logistician L_{II} the total annual amount of GHG emissions is only 52.50 tons instead of 75.00 tons [[v({L_I}) = 60.00] + [v({L_{II}}) = 15.00]]. Thus, the cooperation saves 22.50 tons of GHG emissions per year. If player L_I and L_{III} cooperate there is a new GHG emission value of 68.00 tons per year constituting a decrease of 17.00 tons per year. And if finally player L_{II} and L_{III} are in partnership 5.00 tons of GHG emissions are saved per year. Last but not least a cooperation of all three logisticians (L_I, L_{II} and L_{III}) secures GHG emissions amounting to 17.50 tons per year. If there is a three player coalition 3! = 6 different combinations of how to join an existing sub-coalition exist. As marginal GHG emission saving values for all theoretical cooperation combinations player *i* is part of are needed, *calculation quickly becomes complex*. Therefore, *computer assisted calculation is necessary*. If there would just be a cooperation consisting of 10 players – which is not unlikely in logistics transportation networks – already 10! = 3,628,800.00 different joining combinations are possible. The exemplary marginal GHG emission savings and the corresponding SHAPLEY value for each player *i* are shown within table 1:

Table 1: Marginal GHG emission savings/SHAPLEY values.

	marginal GHG emissions savings (in t/year)		
permutations	**L_I**	**L_{II}**	**L_{III}**
L_I / L_{II} / L_{III}	00.00	22.50	-05.00
L_I / L_{III} / L_{II}	00.00	00.50	17.00
L_{II} / L_I / L_{III}	22.50	00.00	-05.00
L_{II} / L_{III} / L_I	12.50	00.00	05.00
L_{III} / L_I / L_{II}	17.00	00.50	00.00
L_{III} / L_{II} / L_I	05.00	12.50	00.00
total (Σ)	57.00	36.00	12.00
SHAPLEY-Value	**09.50**	**06.00**	**02.00**

The first line in table 1 (L_I / L_{II} / L_{III}) illustrates that logistician L_I initially works independently. Consequently, no GHG emissions can be saved as there is no cooperation [[v({L_I}) = 60.00] – [v({L_I}) = 60.00] = 0.00]. Then, logistician L_{II} joins logistician L_I. Thus, an annual GHG emission reduction of 22.50 tons per year is achieved [[v({L_I / L_{II}}) = 52.50] – [[v({L_I}) = 60.00] + [v({L_{II}}) = 15.00]] = -25.00]. As this reduction is only possible because logistician L_{II} gets in cooperation with logistician L_I the reduction amount is completely dedicated to logistician L_{II}. If finally logistician L_{III} joins the cooperation of the logisticians L_I and L_{II} the new partner (L_{III}) gets charged with 5.00 annual tons of GHG emissions as L_{III} does not effect a marginal benefit in this constellation [[v({L_I / L_{II} / L_{III}}) = 82.50] – [[v({L_I / L_{II}}) = 52.50] + [v({L_{III}}) = 25.00]] = +5.00]. This does not mean that the overall three player coalition is inefficient. If all marginal savings (or debits) for all theoretical joining combinations are calculated and the sum for each player *i* is divided by the number of total combination possibilities (here: 3! = 6) positive savings (in tons per year) for all players are generated (SHAPLEY value L_I = 9.50, SHAPLEY value L_{II} = 6.00 and SHAPLEY value L_{III} = 2.00]. Thus, an overall GHG emission saving of 17.50 tons per year is achieved (cp. sum of values in each line provided in table 1). Finally, it has to be outlined that the concept of SHAPLEY value is *fair and realistic* – as already demonstrated by the description of its associated axioms. Nevertheless, there are a number of barriers that need to be addressed. For instance, only GHG emissions are taken into account. Thus, cause (input) and effect (output) relations are neglected. If e.g. just one player invests in new technologies – implying less GHG emissions – it is the only player that has to be awarded. As faultless measurement of GHG emission can currently not be guaranteed, values that should be allocated are imprecise probably effecting calculation bias. Only if correct input parameters are given a correct allocation is possible. Moreover, calculating SHAPLEY value is very complex as all theoretical marginal GHG emission savings for all companies are needed. Depending on the number of players this leads to a high workload. Thus, cost-benefit analysis is necessary. Otherwise, considering marginal GHG emission savings is fair as different players contribute to different extents – SHAPLEY value provides a unique problem solution for each player.

CONCLUSIONS

This paper highlighted a number of aspects that logistics transportation networks are confronted with:

- Today in logistics operations not only *economic* (e.g. cost and revenue considerations), but also *ecologic* (e.g. green thinking) aspects become critical success factors.

- In order to secure existence and sustainable growth, companies are often forced to implement new strategies: Cooperation concepts as e.g. ECR are one opportunity.
- Green thinking has to be understood as chance of differentiation and not only as negative impact: The concept of eco-efficiency shows that economic and ecologic needs can be linked positively.
- ECR's cooperative strategy of logistics pooling is just one example for successful eco-efficiency actions.
- Up to the present no global (reporting) standard for measuring and allocating GHG emissions exists. A number of organisations work on problem solutions.
- In order to maintain cooperations a fair and realistic solution on how to allocate cost and GHG emission savings is needed. One concept that seems appropriate to solve allocation problems is SHAPLEY value.
- As the application of SHAPLEY value within logistics transportation networks is very complex operations research and computer based simulation are necessary.

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