

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

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1. Introduction
2. GHG Emission Savings: Measurement/Allocation Problem
3. Case Study and SHAPLEY Value Simulation
4. Conclusions

- companies are forced to **assimilate market developments**
 - cooperative strategies within long-term partnerships
 - green business strategies in logistics transportation networks
- hypothesis: (early) adoption of green strategies influences companies' **economical success** positively
- calculating **carbon footprints** is actually of highest interest
 - lack of world-wide consistent calculation guidelines



problem statement/research question:

- how to measure and allocate GHG emission savings within logistics transportation networks operating logistics pooling? → complexity calls for computer aided simulation
- application of operations research: cooperative game theory's SHAPLEY Value

1. Introduction (II/III)

– Cartoon: Carbon Footprint –



1. Introduction (III/III)

– ECR, Logistics Pooling, Eco-Efficiency –



- complex management philosophy that aims at putting the **focus on customers' (green) needs**
- **ECR Supply Side** (Supply Chain Management) **vs. ECR Demand Side** (Marketing)

ECR

- Logistics Pooling**
- **cooperative planning and optimisation** of own and shared **transportation capacities** and routes
 - operate vehicles at full capacities and reduce empty trips to a minimum



- “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” (WBCSD 2000)
- **logistics pooling is positively correlated with GHG emission saving activities**

Eco-Efficiency



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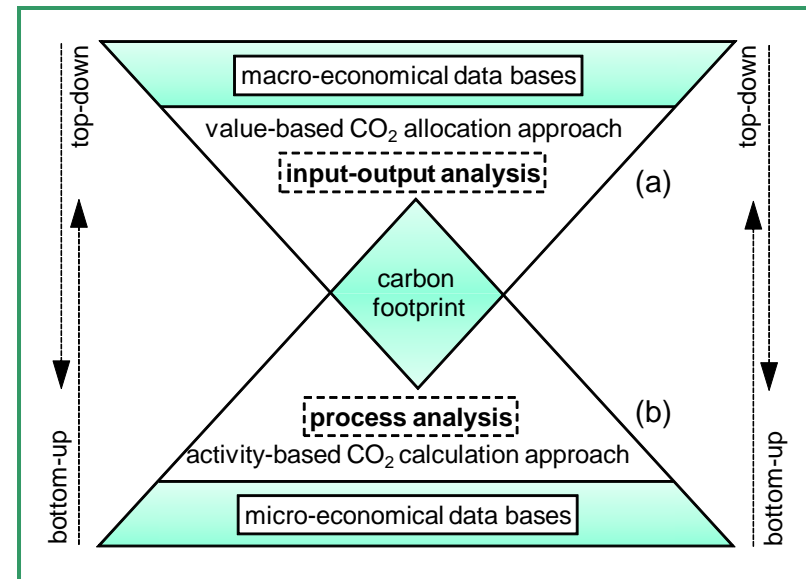
2. GHG Emission Savings (I/II)

– Measurement Problem –

“what you can't measure
you can't manage”



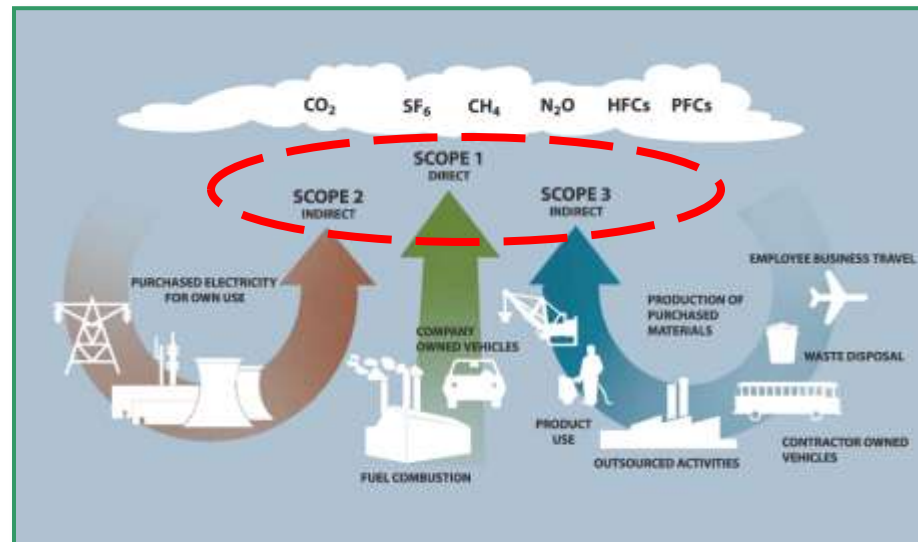
- **inconsistent** GHG emission measurement
→ benchmark problems (e.g. companies, products)
- preparation of **standardised guidelines**
→ e.g. BSI and Carbon Trust (UK), DIN (D), ISO (CH), WBCSD (CH), WRI (USA)
- (a) process analysis vs. (b) input-output analysis vs. (c) hybrids



2. GHG Emission Savings (II/II)

– Allocation Problem –

- start: amount of GHG emissions has been measured
→ allocation to GHG emission objects (e.g. companies)
- how to accurately **define system boundaries** within logistics transportation networks?
→ **concept of scope** by World Business Council for Sustainable Development (WBCSD) and World Resources Institute (WRI)



Source: http://www.wri.org/image/view/11233/_original, 14.10.2011.

- how to accurately **allocate GHG emission savings** if transportation capacities (e.g. vehicles) are **pooled**?
→ problem: shift of input (resources; e.g. vehicles/staff) and output parameters (costs/GHG emission debits)
 ➔ mixture of scope 1 and 3 GHG emissions!
- **SHAPLEY Value** has already successfully been used to fairly allocate cost savings in *n*-person partnerships
→ with rising number of partners calculation becomes difficult: high demand for computer aided simulation!



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3. SHAPLEY Value Simulation (I/IV)

– Basics –

Lloyd S. SHAPLEY (*1923)



Source: http://en.wikipedia.org/wiki/Lloyd_Shapley

Application:	<i>n</i> -person games																
Aim:	calculating fair and rational negotiation solutions																
Axioms:	(a) Pareto-Optimality (b) Symmetry (c) Dummy-Player (d) Additivity																
Solution/Formula:	$\Phi_i(v) = \sum_{K \ni i; K \subset N} \frac{(k-1)!(n-k)!}{n!} [v(K) - v(K - \{i\})]$																
	<table border="0"> <tr> <td><i>K</i>:</td> <td>Sub-coalition</td> <td>$\Phi_i(v)$:</td> <td>SHAPLEY Value player <i>i</i></td> </tr> <tr> <td><i>k</i>:</td> <td>number of players in <i>K</i></td> <td><i>n</i>!:</td> <td><i>n</i> factorial (1 • 2 • ... • <i>n</i>)</td> </tr> <tr> <td><i>N</i>:</td> <td>Coalition</td> <td><i>i</i>:</td> <td>single player</td> </tr> <tr> <td><i>n</i>:</td> <td>number of players in <i>N</i></td> <td><i>v</i>:</td> <td>characteristic function</td> </tr> </table>	<i>K</i> :	Sub-coalition	$\Phi_i(v)$:	SHAPLEY Value player <i>i</i>	<i>k</i> :	number of players in <i>K</i>	<i>n</i> !:	<i>n</i> factorial (1 • 2 • ... • <i>n</i>)	<i>N</i> :	Coalition	<i>i</i> :	single player	<i>n</i> :	number of players in <i>N</i>	<i>v</i> :	characteristic function
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- ECR/logistics pooling cooperation of three logisticians (L_I , L_{II} and L_{III})

(a) GHG emissions in tons per year (sample numbers):

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

(b) GHG emission **savings** (*) in tons per year (sample numbers):

$v(\{L_I\})^* = 00.00$	$v(\{L_{II}\})^* = 00.00$	$v(\{L_{III}\})^* = 00.00$	$v(\{L_I / L_{II}\})^* = 22.50$
$v(\{L_I / L_{III}\})^* = 17.00$	$v(\{L_{II} / L_{III}\})^* = 05.00$	$v(\{L_I / L_{II} / L_{III}\})^* = 17.50$	

$$v(\{L_I\})^* = v(\{L_I\}) / v(\{L_I\}) = 60.00 / 60.00 = \underline{00.00}$$

$$v(\{L_I / L_{III}\})^* = v(\{L_I / L_{III}\}) / [v(\{L_I\}) + v(\{L_{III}\})] = 68.00 / [60.00 + 25.00] = \underline{-17.00}$$



$$v(\{L_I / L_{II} / L_{III}\})^* = v(\{L_I / L_{II} / L_{III}\}) / [v(\{L_I\}) + v(\{L_{II}\}) + v(\{L_{III}\})] = 82.50 / [60.00 + 15.00 + 25.00] = \underline{-17.50}$$

3. SHAPLEY Value Simulation (III/IV)

– Case Study: Solution –

		marginal GHG emission savings [in tons/year]		
		L_I	L_{II}	L_{III}
<p>marginal GHG emission savings L_I $= v(\{L_I\}) \text{ ./. } v(\{L_I\}) =$ <u>00.00</u></p>	permutations			
	$L_I / L_{II} / L_{III}$	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	

marginal GHG emission savings L_{II}
 $= v(\{L_I / L_{II}\}) \text{ ./. } [v(\{L_I\}) + v(\{L_{II}\})]$
 $= 52.50 \text{ ./. } [60.00 + 15.00] = \underline{-22.50}$

marginal GHG emission savings L_{III}
 $= v(\{L_I / L_{II} / L_{III}\}) \text{ ./. } [v(\{L_I / L_{II}\}) + v(\{L_{III}\})]$
 $= 82.50 \text{ ./. } [52.50 + 25.00] = \underline{+05.00}$

SHAPLEY-Value L_I
 $= \frac{\text{sum column } L_I}{n!}$
 $= \frac{57.00}{6} = \underline{09.50}$

- axioms secure **fair and realistic allocation** values
 - marginal contribution of each player is considered
 - unique problem solution

- only absolute GHG emissions are taken into account (**input-output relations are neglected**)
 - also investments in environment-friendly assets need to be addressed
 - who is responsible for further GHG emission savings?

- as input values may not measured exactly **calculation bias** may exist
 - problems in GHG emission measurement need to be solved firstly

- **high complexity** as all theoretical marginal GHG emission savings have to be calculated
 - 10 player cooperation already stands for 3,628,800.00 different joining combinations

- suggested problem solution needs to be tested in daily operations (**practical evaluation**)





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- 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: **chance of differentiation** / not only negative impact → logistics pooling → eco-efficiency
- 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 **fair and realistic solutions** on how to allocate cost and GHG emission savings are needed → 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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Thank you for your kind attention!



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Chapter: CASE STUDY SIMULATION:

Then, logistician L_{II} joins logistician L_I . Thus, an annual GHG emission reduction of 22.50 tons per year is achieved $[[v(\{L_I / L_{II}\}) = 52.50] - [[v(\{L_I\}) = 60.00] + [v(\{L_{II}\}) = 15.00]] = -25.00$.

Then, logistician L_{II} joins logistician L_I . Thus, an annual GHG emission reduction of 22.50 tons per year is achieved $[[v(\{L_I / L_{II}\}) = 52.50] - [[v(\{L_I\}) = 60.00] + [v(\{L_{II}\}) = 15.00]] = -22.50$.

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