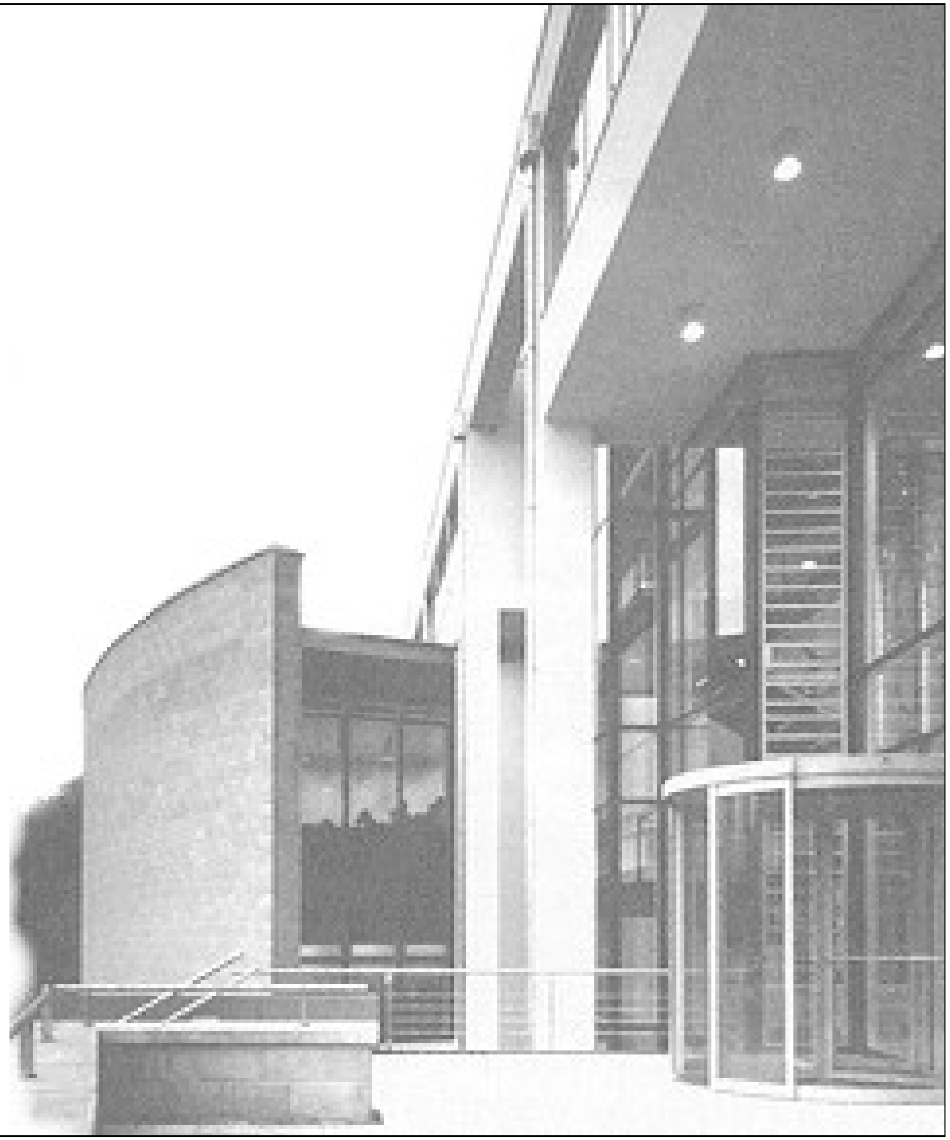
Institut für Logistik- &
Dienstleistungsmanagement
der FOM University of Applied Sciences

Total CO_2 Calculation in SCM

C. Wick, FOM ild

L. Koppers, FOM ild

M. Klumpp, FOM ild *



16th International Working Seminar on Production Economics

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Agenda

1. Introduction
2. Sustainability and Corporate Social Responsibility
3. Carbon Footprinting
4. Total CO_2 Calculation Modeling in SCM
5. Conclusions

1. Introduction (I/II)

- Supply Chain Management (SCM):
  - encompasses the management of all activities undertaken by SC members between the point of origin and the point of sale
    → holistic and process based point of view
  - predominantly known as a methodology to reveal cost saving potentials and opportunities for an increase in revenues
- trends in SCM exceeding cost- and revenue-thinking have recently become of higher interest leading to new SC strategies
  → exemplary postulation: ‚greening the SC' → ‚Green SCM'

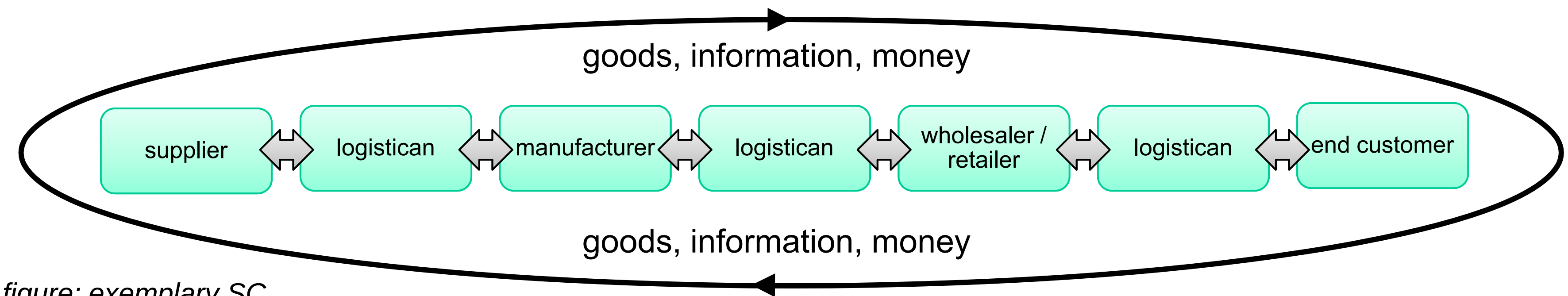


figure: exemplary SC

1. Introduction (II/II)

- Sustainability and Corporate Social Responsibility (CSR)
  - environmental needs, e.g. global warming limitation

- intrinsic vs. extrinsic motivated strategy implementation
  - hypothesis: (early) adoption of sustainable, particularly green issues influences a SC's economical success in a positive way

problem statement / research question:

→ development of new sustainable, especially environmental SC strategies

→ measurement of the economic impact on environment, particularly on global warming

→ realistic, effective and efficient calculation tools

2. Sustainability and Corporate Social Responsibility

- **Sustainability** meets the interests of future generations (‘long-term view’)
  → economic, environmental and social dimension
- sustainable strategies in SCM (extract):
  → reverse logistics
  → closed-loop SCs
  → extended producer responsibility
  → triple bottom line
  → product stewardship
  → eco-efficiency
  → carbon footprint
  → etc.

- **Corporate Social Responsibility** (CSR) appeals to the *voluntary commitment of businesses to incorporate sustainable belongings*
- corporations can be interpreted as social systems consisting of individual people being permanently linked to other systems as e.g. the environment
  → demonstrate corresponding respect for their surroundings
- Supply Chain Social Responsibility (SCSR)

3. Carbon Footprinting (I/III)

(A) carbon footprint

- no common definition exists both in theory and practice
- tool for calculating total GHG emissions along the entire SC
- represents a new stage of development concerning the ‚*ecological footprint*' first revealed by WACKERNAGEL/REES

→ measure indicating the impact of human activities by relating to the areas needed per capita

→ numerically illustrates the economical influence on certain ecological areas used to produce resources and store waste

3. Carbon Footprinting (II/III)

(B) basic carbon footprint considerations

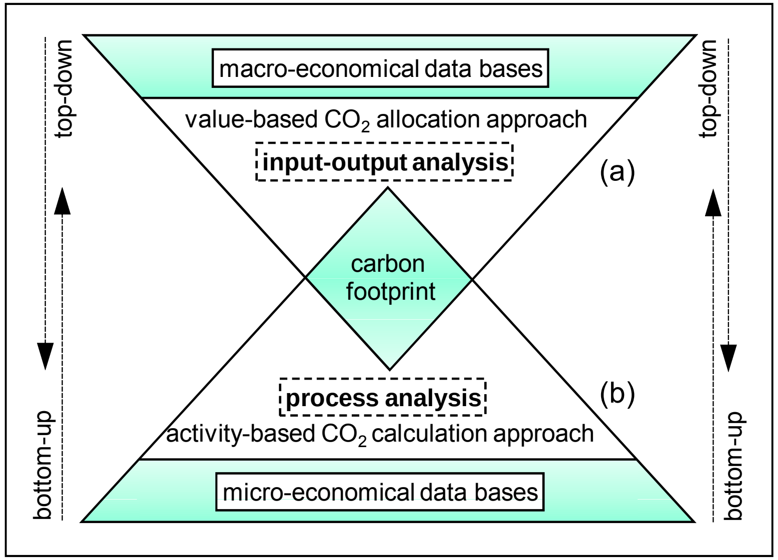
GHG species	scale of GHG emissions	reference parameters
▪ not only CO_2 emissions have to be taken into account, but ***all relevant GHG emissions*** ▪ important GHGs according to the *Kyoto Protocol*: (1) Carbon dioxide (CO_2) (2) Methane (CH_4) (3) Nitrous oxide (N_2O) (4) Hydrofluorocarbons (HFCs) (5) Perfluorocarbons (PFCs) (6) Sulphur hexafluoride (SF_6) ▪ non-carbon emissions can be converted into *carbon dioxide equivalents* (CO_2e) by using *Global Warming Potential* factors (GWP) as provided by the IPCC	▪ both ***direct and indirect GHG emissions*** have to be considered: → *direct GHG emissions* depend on *system boundaries*, i.e. usually a single corporation → *indirect emissions* on the other hand include those GHGs that *occur outside a single corporation,* although they *correspond to the use of energy or raw materials within the corporation* ▪ accurate definition of system boundaries → '*concept of scope*' as provided by WBCSD and WRI can be adopted	▪ in contrast to ecological footprints ***reference is*** no longer made to an ecological land area but a ***particular product or service*** ▪ an often used methodology to calculate a product's impact on nature: *life-cycle assessment* (LCA) → *holistic view* to products or services regarding full life-cycles, i.e. '*from cradle to grave*' → all corresponding *processes and activities* have to be taken into account measuring the total impact in terms of GHG emissions → SC-wide cooperation

A **carbon footprint** is a tool for *communicating environmental impacts of certain products* (or services) to the customer. *Measuring all direct and indirect GHGs in terms of* CO_2e it reveals the *total emission quantity* polluting our nature. Thus *all activities and processes along an entire SC are taken into account* ensuring that the product's entire life-cycle is included 'from cradle to grave'.

3. Carbon Footprinting (III/III)

(C) calculation methodologies:

- (a) input-output analysis vs. (b) process analysis vs. (c) hybrids



→ (a) recursive calculation methodology: lower labour-intensities and research costs
→ largely depends on estimations and allocations not implying a fair problem solution

→ (b) forwarding calculation methodology: higher labour-intensity and research costs
→ complex and comprehensive approach leading to accurate calculation results

4. Total CO_2 Calculation Modeling in SCM (I/IV)

methodical overview: six stage process cube footprint approach

[1] Identification of **core processes** along the entire SC	**[2]** Analysis of the identified core processes and segmentation into **sub-processes / process elements**		
	[3] Estimation / measurement of all sub-process / process elemtent related **GHG emissions per CO_2 driver** (e.g. driven km / used kwh)	**[4]** Identification of required CO_2 drivers and calculation of the **total CO_2 amount** caused by each **sub-process / process element**	
		[5] **Aggregation of all GHG emissions** concerning those sub-processes / process elements needed during the **entire life-cycle of a regarded product / service category**	**[6]** **Division of the sum of all GHG emissions** (caused by one specific category) **by the total number of** manufactured **products (or services)**

4. Total CO_2 Calculation Modeling in SCM (II/IV)

stage 1: identification of core processes

- development of a common understanding along the entire SC
  → idealised and standardised process categories escorting a product or service from ‚cradle to grave'
- implementation of helpful SC frameworks, e.g. SCOR model
- identification of five core process categories (P_{total}):
  → Source (S), Make (M), Deliver (D), Consumption (C), Return (R)
  → $P_{total} = \{S; M; D; C; R\}$

stage 2: process analysis and process segmentation

- process mapping concerning the regarded product or service life-cycle as e.g. supposed by BSI British Standards, UK
  → transparency of all process interdependencies
- checking volume and content for each sub-process and its elements
  → $P_{total} = \sum_{i=1}^{n}(S_i + M_i + D_i + C_i + R_i) = \sum_{i=1}^{n}(s_i + m_i + d_i + c_i + r_i) \quad \forall \quad i, n \in \mathbb{N}^+$

4. Total CO_2 Calculation Modeling in SCM (III/IV)

stage 3: measurement or estimation of GHG emissions per CO_2 driver

- identification and analysis of process element related CO_2 drivers
  → e.g. km or tkm for different transport modes within delivery processes
- decision whether particular basis data should be measured (field research / primary data) or estimated (desk research / secondary data)
- mathematically calculation values can be expressed as vector ($\vec{u}$) indicating the CO_2 amount caused by a single CO_2 driver *i* concerning all process elements *s, m, d, c* and *r*:

$$\rightarrow \vec{u} = \left(u_{si;} ; u_{mi} ; u_{di} ; u_{ci} ; u_{ri}\right) \qquad \forall \qquad i = (1,\ldots, n) \in IN^{+}$$

stage 4: calculation of total GHG emissions per process element

- identification of required CO_2 drivers within product or service life-cycles
  → absolute number of demanded CO_2 driver units per process element

$$\rightarrow \vec{a} = (a_{si} ; a_{mi} ; a_{di} ; a_{ci} ; a_{ri}) \qquad \forall \qquad i = (1,\ldots,n) \in IN^{+}$$

- calculation of the total GHG emissions (e_{ki}) per process element

$$\rightarrow e_{ki} = u_{ki} \bullet a_{ki} \qquad \forall \qquad k = s,m,d,c,r \wedge i = (1,\ldots,n) \in IN^{+}$$

4. Total CO_2 Calculation Modeling in SCM (IV/IV)

stage 5: calculation of total GHG emissions per product / service category

- consolidation of already calculated figures (stages 3/4) indicating the outcome as total CO_2 amount per product or service category ($E_{category}$):

(1) simple aggregation of all CO_2 emissions caused by each process element needed for revealing a certain product or service category

$$\rightarrow \quad E_{category} = \sum e_{ki} \qquad \forall \qquad k = s, m, d, c, r \wedge i = (1, \ldots, n) \in IN^+$$

(2) multiplication of vector ($\vec{u}$) [CO_2 amount caused by a single CO_2 driver *i* per process element *s, m, d, c* or *r*] (stage 3) by vector ($\vec{a}^{\,T}$) [absolute number of demanded CO_2 driver units per process element] (stage 4)

$$\rightarrow \quad E_{category} = \vec{u} \bullet \vec{a}^{\,T} \qquad \forall \qquad k = s, m, d, c, r \wedge i = (1, \ldots, n) \in IN^+$$

stage 6: calculation of product or service related GHG emissions (per unit)

- division of the category based values already calculated on stage 5 by the total number of offered products or services (*x*)
  → ratio represents the final product or service carbon footprint ($E_{product/service}$):

$$\rightarrow \quad E_{product\,/\,service} = \frac{E_{category}}{x} \qquad \forall \qquad x \in IN^+$$

5. Conclusions

- rising importance of sustainable strategies within SCM
  → e.g. Green SCM, Supply Chain Social Responsibility (SCSR)
- not only single corporations are faced with the needs of society, as e.g. environmental protection, but also entire SCs
  → intensification of cooperation among SC members
- lack of academic action linking CO_2 measurement of common SC processes and product or service carbon footprinting
  → academic articles predominantly consider CO_2 calculation within logistics as e.g. in road and rail transportation
  → manufacturing, consumer use and disposal often neglected
- proposed six stage total CO_2 calculation model in SCM can be interpreted as a first step towards an efficient problem solution
  → further detailing and evaluation seem to be necessary

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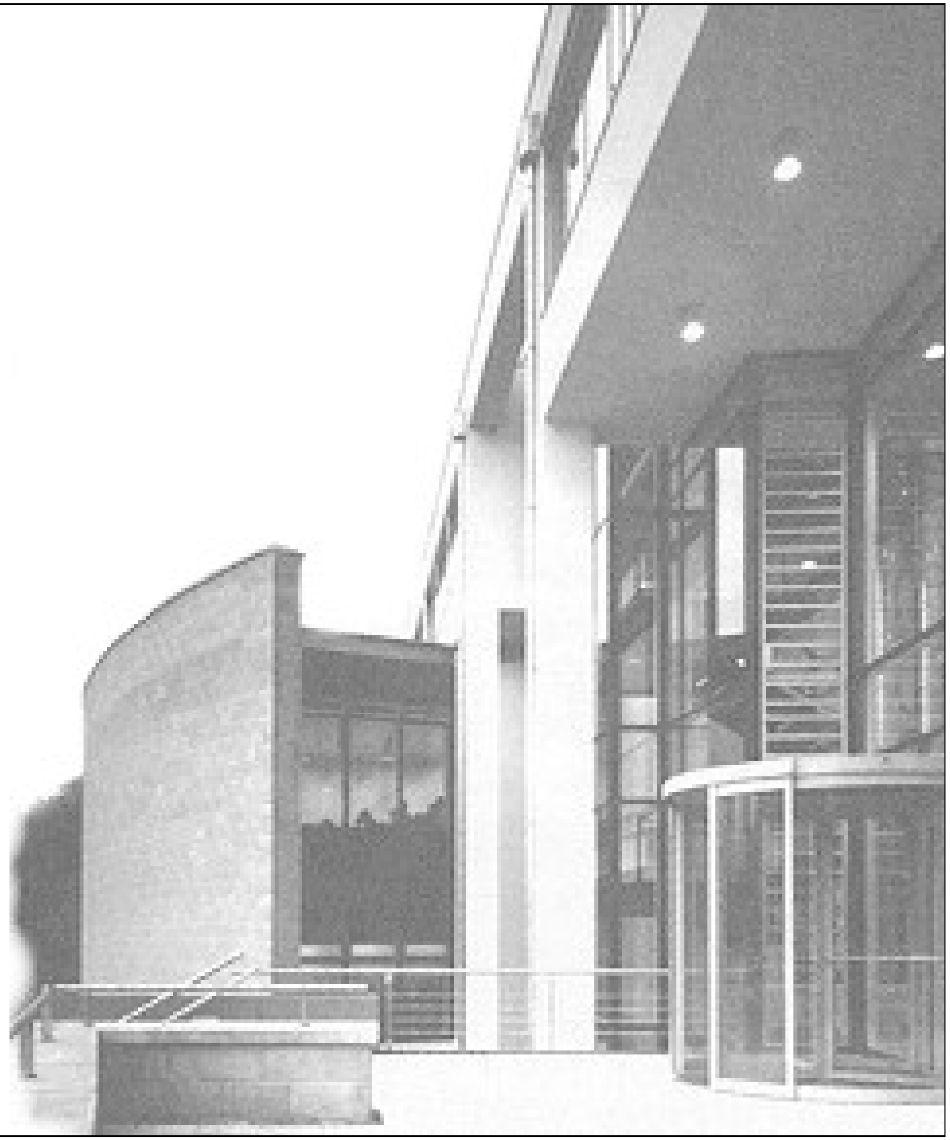

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