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Conference Paper

Design of Sustainable Transportation Networks

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Wendelin Gross and Christian Butz

Abstract

The stakeholders of companies have increased their focus on sustainability of the business activities in the course of a societal paradigm shift towards inter-generational equity. The triple bottom line of economical, ecological, and social sustainability has become a standard model for the overall purpose of businesses. Therefore, companies in retail and manufacturing sectors tend to improve their carbon footprint and reduce emissions of Greenhouse Gas (GHG). The scope of this work is the strategic design of logistics network according to sustainability criteria by means of mathematical optimization methods. GHG emissions of road transportation for the delivery of goods to manufacturing sites or the point of sale are taken into account. The paper applies a facility location model to identify ecologically and economically efficient network configuration for given demands, road infrastructure, and equipment. The proposed research design provides insight into the trade-off between cost efficient and emission efficient network design, and presents metrics that can be applied to a facility location problem in order to pursue the ecological sustainability target. The application in two scenarios show the viability for real-world sized data sets.

Keywords: sustainability, network design, facility location, supply chain management

1. Introduction

The stakeholders of companies have increased their focus on sustainability of the business activities in the course of a societal paradigm shift towards inter-generational equity. The triple bottom line of economical, ecological, and social sustainability (Elkington 1998) has become a standard model for the overall purpose of businesses (Tacken et al. 2014, p. 56). Therefore, companies in retail and manufacturing sectors tend to improve their carbon footprint and reduce emissions of Greenhouse Gas (GHG), and set their strategic goals respectively.

Transportation of passengers and goods accounts for 24% of GHG emissions in Europe in 2012, and the trend is towards increasing emissions compared to most other sources such as electricity production (EEA 2014, p. 115). Despite the fact that transportation is a major cause of emissions and the increasing pressure from stakeholders on companies, planning of transportation networks is not yet commonly targeted for potential emission reduction (for the case of logistics planning in Germany see Horváth & Partners 2013, p. 11). Still, minimizing transportation costs remains essential for the company's competitiveness and remains the predominant network planning objective. However, over the recent years, sufficient standards for calculating costs and simulating GHG emissions in transportation have been developed, such as DIN/EN 16258, and empirical data on road vehicle emissions is available (DIN 2013, HBEFA 2010).

The purpose of the research behind this paper is to investigate the trade-off between transportation networks designed to a purely cost efficient approach with a network design that is optimized to minimal GHG emissions. Therefore, this work in progress paper aims at presenting, analyzing, and discussing an approach for sustainable network design, which will be derived from a standard cost efficient network design method. A facility location model is formulated and applied to two scenarios based on real-world data.

In the first section of this paper, the scope of work is further narrowed. Then, the existing body of literature on network design with a focus on facility location models with sustainability is briefly depicted, followed by the model description. Two scenarios are used for the evaluation of the approach. The scenarios serve for the calculation of trade-off and for the comparison of ecological and economical network design. Finally, conclusion and outlook close the paper.

2. Scope of work

The scope of this work is the strategic design of logistics network according to sustainability criteria by means of mathematical optimization methods. GHG emissions of road transportation for the delivery of goods to manufacturing sites or the point of sale are taken into account. The paper applies a facility location model to identify ecologically and economically efficient network configurations for given demands, road infrastructure, and transport equipment.

Seuring/Müller identified external pressure and incentives set by stakeholders as triggers for sustainable supply chain management in their deep literature analysis (Seuring and Müller 2008, p. 1703). Two groups of stakeholders are of particular relevance for the sustainability of the supply chain: Customers and public government.

Customer's perception of ecological sustainability becomes more important in industrialized countries and raises demand for sustainable products and services. Public governance tries to set incentives to reduce energy consumption and pollution such as emission dependant vehicle tax or penalties on electrical energy (Tacken et al. 2014, p. 56). As incentives and pressure by stakeholders apply to the focal company of the supply chain, according to Seuring and Müller, it will be assumed that the triggers are equally valid for the network design decision of a single company. This assumption is relevant because of this work's scope on the design of transportation or logistics networks - a planning task of a company or an enterprise. Still, transportation networks that perform the physical distribution are a connector of companies in

supply chains, but their design is not yet a cross company task. Further reading on the relation of logistics and supply chain management is vastly available (e.g. overview in Larson 2004).

The aforementioned triple-bottom-line comprises the economical, ecological, and social dimension of sustainability. However, again referring to Seuring and Müller, the focus in management related literature on sustainability lies on the ecological dimension or on the integration of economic and ecologic sustainability respectively (Seuring and Müller 2008, p. 1702). The following work covers ecological and economical sustainability with GHG emissions and costs of road transportation as indicator.

3. Literature review

3.1 Strategic network design

Three planning levels are generally distinguished depending on the time horizon: strategic, tactical and operational. Network design is a task that is bound to considerable capital investment in the case of production facilities, or bearing high planning and set-up efforts. Therefore, and because service quality depends on the location of the facilities in relation to other facilities, it is considered a strategic task (Melo et al. 2009, p. 403)(Klose and Drexel 2003, p. 4)(Owen and Daskin 1998, 424).

The general purpose of transportation and storage in logistics is the requirement for the transformation of physical goods in space and time. Production and consumption of goods usually do neither occur at the same place nor at the same time. Therefore, transformation in space (transportation) or time (storage) is necessary. Logistics aims at bundling these transformation processes regardless of company's divisions, markets, or product groups for the sake of efficiency (Weber 2008, p. 55). This results in transportation or logistics networks consisting of locations (nodes) and transport relations (arcs).

Planning tasks within network design and configuration comprise structural planning (location planning) including the number of active facilities, their

geographical location, and the respective productive steps to be undertaken at the location. Furthermore, all transport relations between sites for production, storage, and retail as well as stock levels and the assignment of transshipment points to productions sites are part of the network design and configuration (Ballou 1995, p. 40). The former of these tasks is also referred to as routing, the latter as allocation. As the input parameters undergo changes over time, e.g. rising energy costs and regionally fluctuating demands, the planning of these networks is a repetitive task of logistics or supply chain management (Wolff and Gross 2008, p. 127).

The task of location planning in logistics networks is to identify the most efficient network configuration that serves customer's demand for goods, which are generated or produced in facilities, through transshipment points. More general, a number of spatially distributed sinks and sources have to be connected via transshipment points. Thus, the result of the planning is a network configuration that defines the number and the location of transshipment points, and their connecting links to sources and sinks, so that all demand is satisfied and the goods are delivered via transshipment points.

The connecting links between sinks, transshipment points, and sources are measured by a given metric that represents distances or costs for instance. Additionally, constraints can be applied in order to model domain specific requirements (Melo et al. 2009, p. 401). In business practice, the task of location planning is divided into several steps within a standard process. According to a frequently applied concept of Butz et al. and others, the core process comprises the 3 steps modeling, optimization, and assessment of the results (Butz et al. 2010, p.24; see also Wolff and Nieters 2002, and Brauer et al. 2010).

The optimization step within the network design requires quantitative methods and the formulation of the input data such as demands and customer locations in a mathematical model. The resulting optimization problem is also referred to as facility location problem, which has been subject to intense studies within Operations Research (OR) and applied mathematics. The application of facility

location within supply chain management and logistics network design is a common approach since OR entered into SCM research (see ReVelle et al. 2008 and Klose and Drexl 2005 for a review and comprehensive description of different facility location problem types).

The abovementioned metric for measuring the arcs (connections between nodes) is a mathematical term for assessing (weighing) the individual good's flow between the nodes. The metric is of major importance for the outcome of the location planning because of two reasons. First, it highly influences the resulting network configuration. Second, it is a significant indicator for the model quality because it reflects the congruency of the model weighs and the real world weighs, e.g. costs. In the application domain of logistics networks, the metrics applied for measuring the arcs represent costs. That is for two reasons: first, to receive the predominantly relevant information from the network model; second, to base the decisions in network design on the predominantly relevant parameter. In strategic network design, however, costs are frequently assumed to be a linear function of distance. Then, spatial distances replace costs as metric for the network design.

3.2 Location planning

Facility location decisions (location planning) play a critical role in the strategic design of supply chain networks. While there is a broad body of literature on facility location in the application domain of transportation networks, the works that include ecological sustainability have only emerged recently. More specifically, the use of non-linear cost and emission metrics is still underdeveloped.

Within the vast body of literature on facility location, 7 journal papers have been selected according to the focus on non-linear metrics and ecological sustainability. Additionally, the coverage of uncertainty or robustness has been included because of relevance for further research (see Table 1 for summary). The origin of the investigated works in various disciplines such as operations

research, supply chain management, and applied mathematics illustrates relevance and multidimensionality of the subject network design.

Bookbinder and Reece propose an iterative 4-step approach for a facility location problem that includes the routing of vehicles in the outbound distribution. The facility location as first step in the approach deals with a linear metric, which is then refined by the outcome of the second step, the vehicle routing. Therefore, while the metric for the facility location is linear, the overall metric becomes non-linear (Bookbinder et al. 1988).

Main Author	Year	non-linear Metric	Ecological Sustainability	Uncertainty/ Robustness	Application in industry
Book-binder	1988	x	-	-	(Show case)
Wasner	2004	x	-	-	Parcel distribution
Hugo	2005	-	x	-	(Show case)
Shen	2007	x	-	-	4 generated data sets
Harris	2011	-	x	-	Automotive
Pishvaee	2012	-	x	x	Medical
Amin	2012	-	x	x	(Show case)

Tab. 1: Literature on location planning and sustainability (sorted by year of publication)

The work of Wasner and Zäpfel as well is an approach of integrating the vehicle routing and the facility location. They further developed the iterative approach to a parallel approach by the introduction of variables that link the routing and facility location. Within the inbound transports, they apply a metric that is non-linear towards lot size. For the outbound tours, a linear metric is used (Wasner and Zäpfel 2004).

Hugo and Pistikopoulos set up a planning model for the location of plants with regard to market demands, raw material supply, and production technologies.

They aim at minimizing the environmental impact of the resulting network. As their focus is on the decision how to produce goods in the network, they do not apply transportation emissions. Also, their cost metric is linear (Hugo and Pistikopoulos 2005).

Shen and Qi formulate a standard facility location model (p-median). Their approach for the outbound transportation costs is the use of a formula for the approximation of the distance from the transshipment point to the sink that assumes delivery tours. Therefore, the outbound cost metric turns non-linear (Shen and Qi 2007).

The work of Harris et al. aims to assess the impact of the traditional cost optimization approach to strategic modeling on overall logistics costs and emissions. Their approach uses linear metrics for cost and emission. The latter is modeled with fuel consumption and conversion rates taking truck utilization as parameter into account. Note that emissions are calculated for assessment only after the designing the network purely on cost base (Harris et al. 2011).

Pishvaee et al. set up a facility location model of a production network that comprises the decision about production sites based on costs and emissions in production and transportation, and uncertainty. The applied metrics for transportation costs and emissions are linear. In order to deal with uncertainty, they use a fuzzy logic approach to solve the bi objective (cost and emission) model (Pishvaee et al. 2012).

Amin and Zhang investigate facility location comprising the decision on plant and collection centers for recyclables (closed loop network). They apply a linear cost metric. The extension of the model they propose to multi objectives includes the environmental impact. However, the environmental impact excludes transportation aspects (Amin and Zhang 2012).

4. Research design

Research is designed to investigate the difference between transportation network design that is purely cost efficient and on that is purely eco efficient in the sense of GHG emissions. The design comprises commonly applied mathematical modeling and optimization of transportation networks.

The first step comprises gathering and preparing the input data for the scenarios. This resulted in two scenarios, one based on a hypothetical supply and demand structure, and one based on real-world data of a company. The second step is to formulate the general mathematical model of the transportation network including demand, costs, and target function. Two metrics representing the costs are formulated: One for cost optimization, and the other for emission optimization. Then, the model with both metrics is applied to the scenarios resulting in two optimal network configurations each: the cost optimal and the emission optimal. For reference and validation, a third network configuration has been generated for each scenario, which is optimized without a metric, i.e. on transportation distance, in this step. That is for the purpose to show that the trivial solution without any metric is not dominant.

Finally, total transport costs and emissions of the resulting network configuration are assessed using the same metrics in order to receive the four key indicators for each of the scenarios that allow comparison of cost and emission efficient network configurations. The indicators are displayed normalized. Also, the number of transshipment points in the resulting network configuration is provided (see Table 2 for the scheme of results).

Scenario	Total Cost	Total Emission	# of transshipment points
Cost efficient network configuration (cost optimization)	100%	%	#
Emission efficient network configuration (emission optimization)	%	100%	#
Reference network configuration (distance optimization)	%	%	#

Tab. 2: Key indicators for network assessment and comparison of solutions (scheme)

5. Model formulation

5.1 Network layout

The network design problem is formulated as a facility location program in a 2-echelon-layout. This is a standard model for the distribution of goods from sources, e.g. production sites, to sinks, i.e. customers. Two metrics for assessing and measuring the arcs cover cost and GHG emissions. Both metrics distinguish between transportation from source to transshipment point (inbound) and from transshipment point to sink (outbound). The costs metric is derived from real world transportation tariffs. GHG emissions are modeled according to DIN/EN 16258 and the HBEFA database (DIN 2013, HBEFA 2010) of emission factors. For modeling and optimization, the commercial planning software 4flow vista (version 4.2) has been applied.

The general type of model is a facility location model with a given set of allowed transshipment points (nodes) between sources and sinks (Figure 1). In terms of OR, the model represents a p-median problem (Klose and Drexl 2005 p. 7).

The model is also referred to as hub location model in literature (Klose and Drexl, 2005 p. 20).

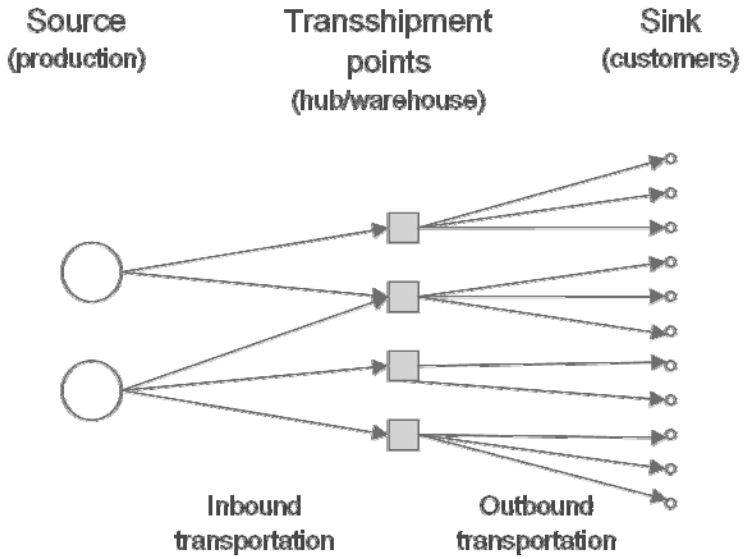

Fig. 1: Network (scheme)

The parameters for the hub location (p-median) comprise in general the demand at each sink and the distance between each possible relation of sink and node, and source and node (Owen and Daskin 1998, p. 425). However, to receive good results for the transport network planning, further parameters are used. First, instead of using solely distance, non-linear metrics for transportation costs and GHG emissions are applied. Second, the distances between the nodes are derived from real world road infrastructure (road distance).

The set of possible transshipment points has been derived from publicly available information bases, aiming at a representative coverage of the relevant European regions. Existing transshipment points of larger logistics service providers have been identified and included in the model. In total, there are 376

transshipment points available (see Figure 2 for the spatial distribution of possible transshipment points). For the sake of uniformity, 2 reference locations have been added. The scenarios presented in section 6 contain the very same reference locations in terms of latitude and longitude (see Figure 3). This allows the comparison of the spatial distribution of transshipment points and network sinks.

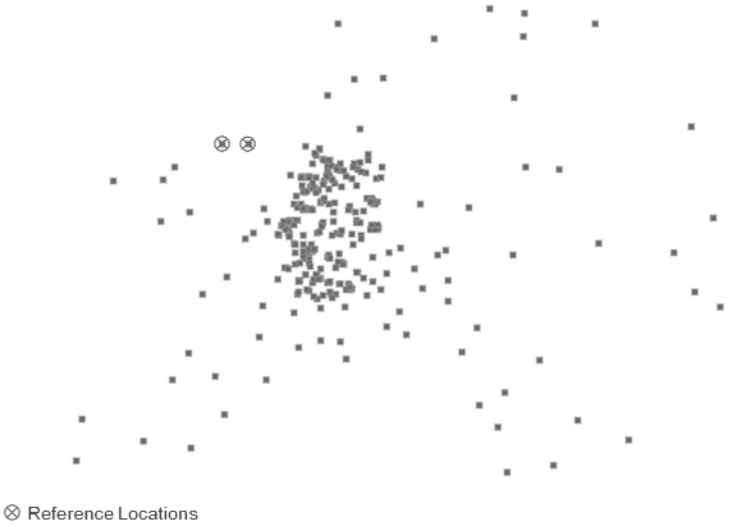

Fig. 2: 376 possible European transshipment points in the model (spatial distribution in the 2-dimensional plane)

The facility location model objective is minimizing total 'costs', which in this case can be costs or emissions. Therefore, inbound and outbound costs build the target functions, (1) for costs, and (2) for emissions.
Target functions:

$$min! \sum_{\substack{Inbound \\ relations}} cost_{Inbound,i} + \sum_{\substack{Outbound \\ relations}} cost_{Outbound,j} \quad (1)$$

$$min! \sum_{\substack{Inbound \\ relations}} emission_{Inbound,i} + \sum_{\substack{Outbound \\ relations}} emission_{Outbound,j} \quad (2)$$

As mentioned above, the cost and emission metrics are crucial for the model outcome (see next section). Note, that the model does not yet comprise costs and emissions for the facilities themselves. However, assuming that costs and emissions per shipped article are equal in all locations, the location costs and emissions are not relevant for the optimization result. Thus, economies of scale for locations are not included in the model for the sake of rigidness. This can be subject of further enhancement of the model.

5.2 Cost and emission metric

The metrics for assessing and measuring the transports in the network were designed as non-linear functions in the first place. The reason behind non-linearity in transportation lies in economies of scale. Firstly, non-linearity applies towards the lot size of the shipment in order to reflect the fact that cost and emission per pallet and kilometer depend on truck utilization. In simple words, the less packed a truck is, the higher the costs and emissions for each pallet are. Secondly, non-linearity applies towards the total spatial distance of the transport. Here, the case is different for costs and emissions. While costs are modeled as non-linear towards distance according to observations in the real world, emissions are modeled as linear towards distance. That is due to the assumption that GHG emissions of a truck remain constant per kilometer no matter how far the transport goes.

For inbound transportation in distribution networks, that is the transports from the sources to the transshipment point full utilization is assumed. In terms of logistics, full truck loads (FTL) deal with the transportation. Therefore, the cost and emission metrics turn linear towards lot size for inbound transportation. Table 3 summarizes the main characteristics of the cost and emission metric.

The cost metric (3) and (4) is based on several real world tariffs that have been collected from industry, retail, and logistics service providers, and combined to form a representative cost metric. The metric allows for full truck load (FTL)

transportation, which is basically a price per truck per kilometer, and less than truck load (LTL) transportation. LTL tariffs refer to a single shipment, which is a price per lot size per kilometer. Both, FTL and LTL tariffs are non-linear towards distance.

	Inbound	Outbound
Cost	Linear (lot size), non-linear (distance); region-specific, truck-specific; real world tariff (FTL)	Non-linear (distance, lot size); region-specific, truck-specific; real world tariff (LTL)
Emission	Linear (distance, lot size); truck-specific, traffic-dependant; emission data base (FTL)	Linear (distance), non-linear (lot size); truck-specific, traffic-dependant; emission data base (LTL)

Tab. 3: Characteristics of metric for inbound and outbound transportation

The lot size can be either provided as weight or volume, depending on the more critical constraint of the truck, which is payload or volume. Because the goods that are used in the scenarios are light weight, the lot size refers to volume as more critical constraint. Additionally, regionally differing prices in Europe are covered in the metric on a country level.

For the emission metric (5) and (6), standard approaches for assessing transportation emissions have been applied. According to the norm DIN EN 16285, emissions should be derived from the real fuel consumption of the truck fleet, which is computed into GHG emissions with a fuel-to-emission conversion rate. As this approach is not applicable in a planning environment with real fuel consumption not available, the norm supports the calculation of emission based on distance and emission factors (DIN 2013). Emission factors are empirical functional relations between pollutant emissions and the activity that causes them, which is in this case road transportation (Franco et al. 2013, p. 84).

For the emission metric, these factors have been derived from the emission database HBEFA, which is based on extensive empirical studies (see De Haan and Keller 2004 for detailed insight on the first edition of HBEFA). The database provides emission factors according to truck type and truck utilization.

Furthermore, road type and traffic situation are included. Here, according to the planning environment of strategic network design, highways and a dense free flow traffic situation are applied.

Concerning the truck utilization, the relevant criterion for emissions is the weight of the truck load, as the filling degree of the loading bay does only affect the emissions if it adds weight to the truck. Therefore, lot size within the emission metric refers to weight. However, the metric ensures that the volumetric capacity of the truck cannot be exceeded even if a larger shipment would be possible by the maximum payload.

Cost metric:

$$\mathrm{cost}_{\mathrm{Inbound,i}} = \mathrm{d_i} * \mathrm{V_i} * \mathrm{cvol}_{\mathrm{T,R}} \quad (3)$$

$$\mathrm{cost}_{\mathrm{Outbound,j}} = \mathrm{d_j} * \mathrm{V_j} * \mathrm{cvol}_{\mathrm{T,R,D,L}} \quad (4)$$

Emission metric:

$$\mathrm{emission}_{\mathrm{Inbound,i}} = \mathrm{d_i} * \mathrm{M_i} * \mathrm{evar}_{\mathrm{T}} \quad (5)$$

$$\mathrm{emission}_{\mathrm{Outbound,j}} = \mathrm{d_j} * \left(\frac{\mathrm{M_j}}{\mathrm{capm}_{\mathrm{T}}} * \mathrm{evar}_{\mathrm{T}} + \mathrm{efix}_{\mathrm{T}}\right) \quad (6)$$

Indices:

i: index of relation inbound

j: index of relation outbound

T: index of truck type

R: index of region of origin and destination (matrix)

D: index of distance class

L: index of lot size class

Parameters:

d: road distance

cvol: cost per volume unit

capm: capacity (weight) of truck

evar: variable GHG emissions per truck (utilization dependant)

efix: fix GHG emissions per empty truck

Variables:

M: mass (weight) of goods on relation

V: Volume of goods on relation

The facility location model as described above has been modeled and solved in the commercial planning tool set 4flow vista (version 4.2).

6. Scenarios

The model with cost and emission metric respectively as stipulated above is applied to two data sets, referred to as scenarios in the following. The scenarios are based on real-life data (see Figure 3 for the spatial distribution of sinks on a 2-dimensional plane).

Network #1 represents a hypothetical data set with typical demand distribution over Europe according to the economical strength of regions, and a single source (see Gross et al. 2010 for details on the data generation).

Network #2 is derived from a real world company that maintains several own production sites and as well delivers goods directly from suppliers within the network.

The two scenarios have been selected in order to provide indication on some relevant directions for further research, and on applicability of the approach in different settings and prerequisites. Therefore, one scenario network represents a hypothetical, generated data set and the other one was derived from a company's real-world data. Also, the networks are of different size in terms of the number of sinks, total throughput, and the number of sources (see Table 4 for key parameters).

In both scenarios, the transportation distance is calculated as the shortest path on the existing European road infrastructure. Commonly available commercial service has been used for distance calculation.

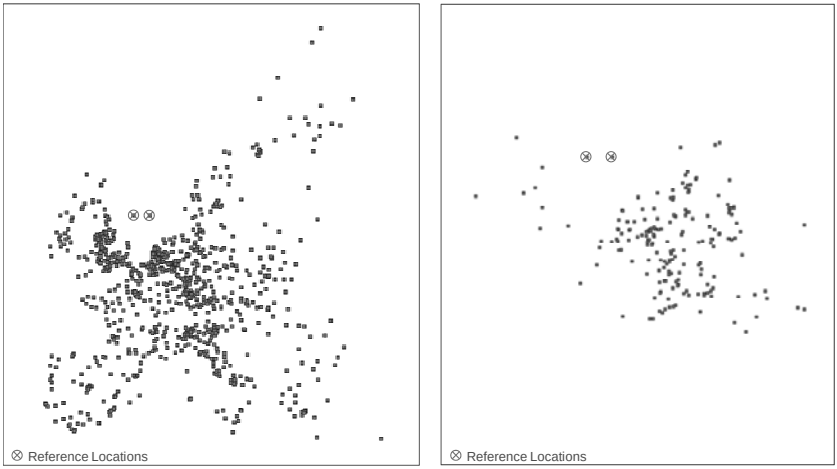

Fig. 3: Spatial distribution of sinks in Europe in the scenario networks in the 2-dimensional plane (left: Network #1, right: Network #2)

	Network #1	Network #2
# of sources	1	18
# of sinks	939	304
# of articles	1	424
Total throughput	8,535,490 m³/y	2,019,316 m³/y
Inbound frequency	1/w	1/w
Outbound frequency	1/w	1/w
Traffic situation	Dense free flow	
Road type	Highway	
Truck type	Euro-V truck with standard trailer	

Tab. 4: Key parameters of scenario networks

7. Results

The facility location model shows the difference between the outcome of network design focused on costs and emissions respectively. The trade-off between the cost efficient and the emission efficient network configuration is between 2% and 54%. Comparing the scenarios, the Network #2 (based on a real-world situation) effectuates the higher trade-off than Network #1 (based on a hypothetical, generated situation). The reference network configuration without metric for the network arcs (based on distance) bears in all cases higher cost and emission than the cost and emission efficient network configuration. Besides the figures of total cost and emission, the number of transshipment points in use in the network configurations is of interest.

In Network #1 (see Table 5 for key indicators), the trade-off between cost efficient and emission efficient network is 3% in costs and 2% in emissions. The sustainable network design results in 3% higher total costs than the standard approach of cost efficiency. The total emissions in the cost efficient network are 2% higher than in the sustainable network design. Roughly 25% more transshipment points are in use in the sustainable network compared to the cost efficient one (194 compared to 154). This indicates a major structural difference in two network configurations.

The scenario Network #2 shows greater divergence between the cost efficient and the emission efficient network configuration than Network #1 (see Table 6 for key indicators). The trade-off in total costs is 54%, and 16% in total emissions. A sustainable network design approach would save 16% of emissions at a cost increase of 54% compared to the cost efficient network configuration. Similar to Network #1, the number of active transshipment points is higher in the emission efficient network configuration than in the cost efficient one; in this scenario by 39% (167 compared to 120).

Network #1	Total Cost	Total Emission	# of transshipment points
Cost efficient network configuration (cost optimization)	100%	102%	154
Emission efficient network configuration (emission optimization)	103%	100%	194
Reference network configuration (distance optimization)	127%	113%	54

Tab. 5: Key indicators for cost and emission efficiency of Network #1

Network #2	Total Cost	Total Emission	# of transshipment points
Cost efficient network configuration (cost optimization)	100%	116%	120
Emission efficient network configuration (emission optimization)	154%	100%	167
Reference network configuration (distance optimization)	149%	127%	195

Tab. 6: Key indicators for cost and emission efficiency of Network #2

8. Conclusion and Outlook

The proposed research design has provided insight into the trade-off between cost efficient and emission efficient network design, and showed metrics that can be applied to a facility location problem in order to pursue the ecological sustainability target. The application in two scenarios show the viability for real-world sized data sets.

The scenario Network #1 shows only limited differences between cost and emission efficient network. Reasons for that are assumed to stem from the single source network structure because this provides limited options for the assignment of transshipment points to sinks. Significantly larger difference can be observed in the real-world scenario Network #2. This can underline the relevance of both data sets in order to identify the critical input parameters in further investigations.

The increase in the number of active transshipment points in both scenarios forms a trend towards more decentralized network configurations when sustainability is taken into account. This trend points towards the importance of truck utilization, which is generally higher in inbound transportation, for emission efficiency. In the cost efficient network configuration, the effect of shorter, less efficient outbound transportation distances might level the effect of higher inbound utilization.

Further analysis of the solutions is required in order to understand, which input parameters are most important for the outcome. Also, the applicability of the resulting network configuration in the real world requires investigation. Therefore, the effect of cost and emission of the transshipment points should be integrated in the first place. As well, operational constraints, such as a maximum number of active transshipment points need to be covered. Different truck types are another possible enhancement in order to close the gap between model and reality. The assumption of linearity of emissions towards total distance of the transport relation can be another aspect for further research. Here, a promising approach might be the inclusion of different average truck speed for shorter distances. Different truck types for inbound and outbound transportation or even for the single relations, e.g. depending on the distance, can also be applied within a model extension. For the calculation of outbound transportation distance, approaches that aim at including or approximation a vehicle routing model could be of interest.

Another question of interest would be, if and how a transition from one configuration to the other is possible. The resulting effort and costs should be of

utmost relevance. Finally, the integration of cost and emission metric into a single, multi-objective metric should be the paramount goal. The considerations on risk management and uncertainty of the input parameter can be included into the model in order to anticipate the volatility of demand and external factors during the planning horizon.

Still, the strategic sustainability targets of companies are not transferred to operations such as logistics management and network design. After first methodical research on sustainable network design has been provided in this paper, further research is required to design a framework that includes sustainability in the paramount strategic and operational planning and performance measurement.

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Wolfgang Kersten, Thorsten Blecker and
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Next Generation Supply Chains

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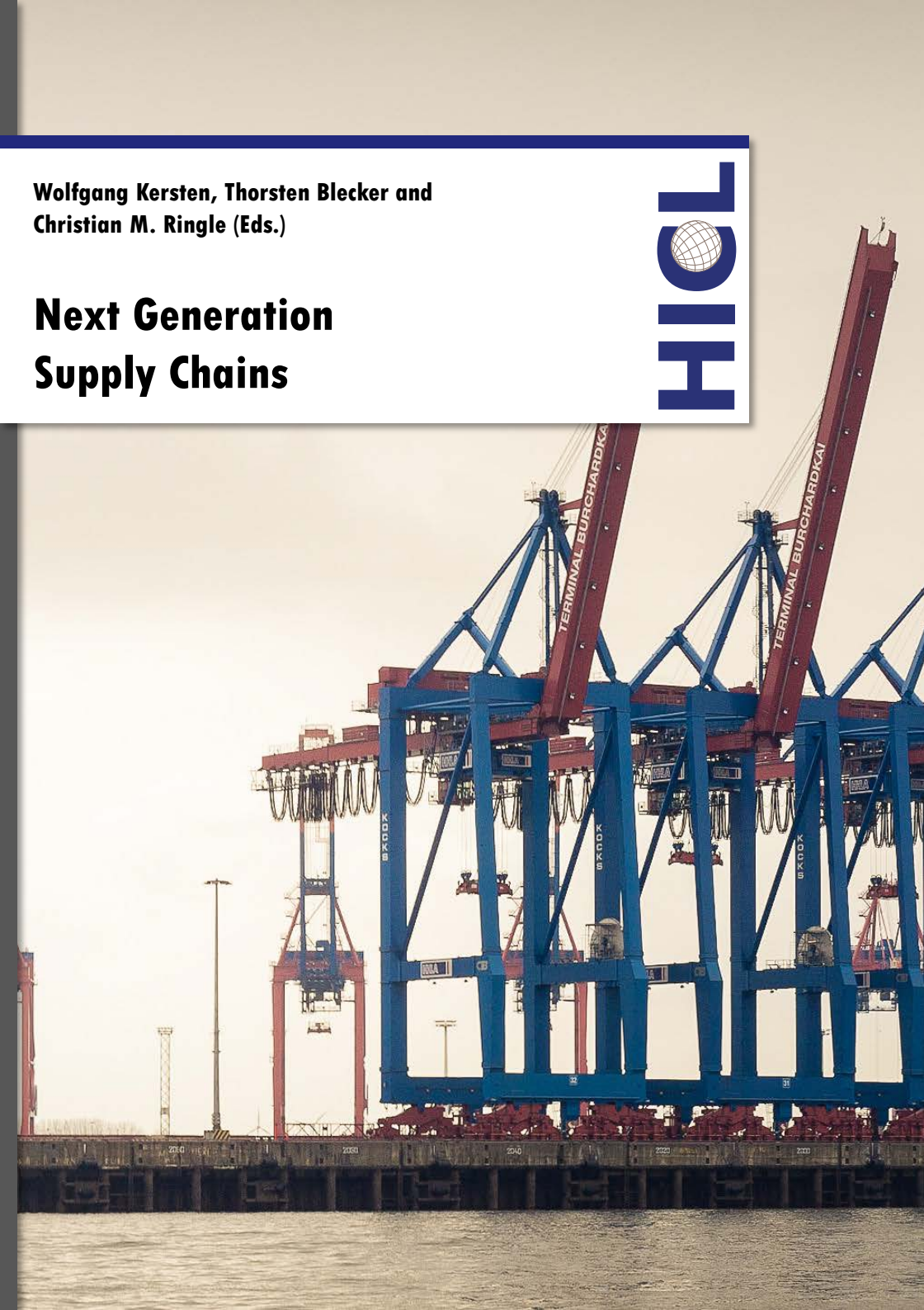

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Next Generation Supply Chains

Trends and Opportunities

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Preface

Today's business environment is undergoing significant changes. Demand patterns constantly claim for greener products from more sustainable supply chains. Handling these customer needs, embedded in a sophisticated and complex supply chain environment, are putting the players under a constant pressure: Ecological and social issues arise additionally to challenges like technology management and efficiency enhancement. Concurrently each of these holds incredible opportunities to separate from competitors, yet also increases chain complexity and risks.

This book addresses the hot spots of discussion for future supply chain solutions. It contains manuscripts by international authors providing comprehensive insights into topics like sustainability, supply chain risk management and provides future outlooks to the field of supply chain management. All manuscripts contribute to theory development and verification in their respective area of research.

We would like to thank the authors for their excellent contributions, which advance the logistics research progress. Without their support and hard work, the creation of this volume would not have been possible. We would also like to thank Sara Kheiravar, Tabea Tressin, Matthias Ehni and Niels Hackius for their efforts to prepare, structure and finalize this book.

Hamburg, August 2014

Prof. Dr. Dr. h. c. Wolfgang Kersten
Prof. Dr. Thorsten Blecker
Prof. Dr. Christian Ringle

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About HICL

Since 2006 the annual conference Hamburg International Conference of Logistics (HICL) at Hamburg University of Technology (TUHH) is dedicated to facilitate the exchange of ideas and contribute to the improved understanding and practice of Logistics and SCM. HICL creates a creative environment which attracts researchers, practitioners, and industry thinkers from all around the world.

Innovation is increasingly considered as an enabler of business competitive advantage. More and more organizations focus on satisfying their consumer's demand of innovative and qualitative products and services by applying both technology-supported and non technology-supported innovative methods in their supply chain practices. Due to its very characteristic i.e. novelty, innovation is double-edged sword; capturing value from innovative methods in supply chain practices has been one of the important topics among practitioners as well as researchers of the field.

This volume, edited by Thorsten Blecker, Wolfgang Kersten and Christian Ringle, provides valuable insights into:

- Innovative and technology-based solutions
- Supply chain security management
- Cooperation and performance practices in supply chain management

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