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## Sustainable Logistic Scenarios in the NSR Region

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# Sustainable Logistic Scenarios in the NSR Region

Jacob Kronbak, Angela Münch, Liping Jiang and Lisbeth Brøde Jepsen

## Abstract

Freight transport between North Sea Region (NSR) countries presents high trade volumes in all Standard International Trade Classification (SITC) classes. Trade volume shifts over time depending, among others, on cost trends within the transport sector, which in turn are driven by, e.g. transport regulation. The recent EU regulations target the increase of intermodal transport in order to, among others, decrease the environmental impact of freight transport. This project provides a general approach for investigating the possible changes of transport cost within the NSR region under various future scenarios.

Firstly, three scenarios are proposed namely regulation, environment and competition scenarios which possess a different degree of including environmental cost into the transport cost calculation. After introducing the scenarios, the effects of the respective scenario on transport in terms of flows, modes and efficiencies is discussed. Secondly, generalized transport cost maps of intermodal transports scenarios (i.e. combination of road transport and short-sea-shipping) are calculated for 10 selected NSR ports/regions for the three different future cost developments. Maps are drawn which show the shift of transport costs and with this indicate the future stability of the trade flows. Thirdly, the shifts in the intermodal transport cost for the three scenarios are compared to changes in transport cost if only road transport is considered. Based on these calculations, management implications are drawn. It can be shown that establishing short-sea shipping links is cost stabilizing irrespective to the future cost development scenario if geographic distance is considered as major barrier to overcome.

**Keywords:** north-sea region, impedance distance, transport scenarios, intermodal transport

## 1. Introduction

Climate change leads to opportunities (e.g. the Northern Sea Route) as well as additional costs in the transport sector (e.g. road destruction, storm tides) due to the occurrence of more extreme weather events (Black and Sato, 2007). Some research is already conducted in order to calculate the general effects and shift in the cost structure in the transport sector considering climate change as well as to evaluate an optimal policy (Black and van Geenhuizen, 2006, Donaghy et al., 2005, Leinbach and Capineri, 2007, Rietveld and Stough, 2005). Additional to the external driven changes in the transport sector due to climate change, globalisation and market liberalization in the last decades led to an increase in trade flows which puts pressure on particular road and rail networks as well as causes pollution. Between 1970 and 2002, transport volume in the EU-15 surged about 181 percent on road networks, decreased about 16 percent on rail networks and increased about 166 percent on short-sea shipping lines. In 2010, in the EU-15 47.4 percent of goods (measured in tonne per km) are transported on roads, 39.8 percent on short-sea shipping lines, 6.8 percent by railway, 2.5 percent by pipelines and 3.5 percent by inland waterways (Leinbach and Capineri, 2007). This development is partly driven by the support of the EU for intermodal transport which includes growing unitisation (e.g. trailers and containers) within the transport sector. At the moment, the EU is intensively targeting a shift from road transport to intermodal transport in order to disburden the road networks. Moreover, it is expected that multi-user hub networks and horizontal bundling of freight transport will drive the development of the future EU transport sector (Leinbach and Capineri, 2007).

Numerous logistic models are proposed in order to organize freight resource efficient (De Jong et al., 2013). Ship transport has a potentially high economy of

scale while it offers higher fuel economy and lower emissions of harmful pollutants. Therefore, short-sea shipping is considered to be more sustainable and economically competitive than road transport (Medda and Trujillo, 2010). Recent policy of the EU seems to support this notion and a variety of research on the competitiveness of short-sea shipping as part of intermodal transport was conducted in recent years (Ng, 2009). In particular the integration of ports with transportation networks serving the 'Hinterlands' seems to be one key factor in the competitiveness discussion (Franc and Van der Horst, 2010, Frémont, 2008, Notteboom and Rodrigue, 2005). However, politico-economic variables have the ability to change the cost structure in this respect so that the combined transport becomes more competitive in terms of prices than road transport (Frémont and Franc, 2010, García-Menéndez and Feo-Valero, 2009) while spatial distance restricts the gains in cost efficiency of the intermodal transport by political regulations (Guerrero, 2014).

Part of the EU-Trade takes place between North Sea Region (NSR) countries. Also in this region, trade volumes shift over time depending, among others, on cost trends within the transport sector, which in turn are driven by, e.g. transport regulation. This paper provides a general approach for investigating the possible changes of transport costs in the NSR countries under various future policy scenarios. In the following, three scenarios are proposed namely Regulation, Environment and Competition scenarios. These scenarios present the background for the calculations of the changes in transport cost for 10 selected NSR ports/regions to indicate the future stability of the trade flows. Maps are drawn for each of the scenarios to present the location of cost shifts. Focus of the research is on intermodal transport, i.e. the combination of short-sea shipping and road transport. The aim is to identify critical features in the location of NSR ports which drives the transport cost structure in the NSR region and serve as basis for drawing finally management implications.

## **2. Methodology**

### **2.1 Development of three different scenarios**

The term scenario can be defined in many ways. In the context of this paper, a scenario defined by Ayres (1969) has been adopted ‘...a logical and plausible (but not necessarily probable) set of events, both serial and simultaneous, with careful attention to timing and correlation wherever the latter are salient’.

In 1995, the Danish Ministry of Transport and the Transport Council commissioned a scenario study from the Institute of Future Research in Copenhagen (Palludan et al., 1996). Based on this study report, three potential scenarios are identified to be critical for this study:

- The regulated/supra national scenario
- The environmental scenario
- The split-growth scenario

To simplify the name, the three scenarios are referred to as a) *Regulation*, b) *Environment*, and c) *Competition* scenarios hereafter. In the following, each of the scenarios is further elaborated:

#### **2.1.1 The Regulation scenario**

Referred to as the supra-national society (SUP) in Palludan et al. (1996), this scenario captures a development characterized by: “Strong political and economic integration continues within the European Union. At the same time a number of binding international agreements concerning, economic co-operation (budget co-ordinating) and the environment concerning CO<sub>2</sub>, NO<sub>x</sub>, SO<sub>2</sub>, etc. are ratified. The EU is appointed to monitor that the agreements are observed and is given authority to intervene. The transport sector is heavily regulated by the use of road pricing, making transport more expensive but less congested. Energy efficiency is central and rail and sea transport capacities are increased.”

### **2.1.2 The Environment scenario**

This scenario is a combination of an intimate society (INT) and a supra-national society (SUP), as outlined in Palludan et al. (1996). The scenario is defined as: “The family and home play a more central role in everyday life, and originality of e.g. food plays a predominate role in everyday life. Sustainability is very much in focus and each mode of transport “pays” for its own externality (full internalization). Politically, the society should also be in equilibrium, which influences both the economic, European and environmental policy.”

### **2.1.3 The Competition scenario**

This third scenario picks up the characteristics of the market oriented society (MKT) as circumscribed in Palludan et al. (1996) and is defined as: “Europe experiences an uneven economic growth. The open market is developed with deregulation in a number of sectors such as transport and agriculture. A common agricultural policy is abandoned. The opening towards Eastern and southern Europe is primarily of an economic nature. The stabilisation of the relationship with Eastern and southern Europe is obtained through free trade and economic support, which contributes to the economic growth in the region. Transport only pays direct costs and all externalities are ignored.”

## **2.2 The potential effects of each scenarios**

When using scenarios in transport planning, it is important to understand that each scenario not only influences all development variables, but also can have an impact on all levels of the planning process. Initially, a large number of variables were suggested to be incorporated into the analysis. However, in order to simplify by considering that not all the parameters are relevant, it was therefore decided to limit the scenarios to be described by the following three effect parameters:

- Flows (e.g. trade volumes)
- Modes (e.g. road, sea, rail)
- Efficiency (e.g. delivery time, clean tech)

The expected trend in the transport cost development depends on the combinations of scenarios and effects, which can be illustrated in a 3x3 matrix (Table 1). This extended matrix considers road transport (truck), shipping (sea), rail transport (train) as well as inland waterway transportation (inland navigations).

	a) Regulation Scenario			b) Environment Scenario			c) Competition Scenario		
	min	likely	max	min	likely	max	min	likely	max
Flows	0%	50%	100%	-25%	0%	25%	50%	100%	200%
Modes									
Truck	0%	50%	125%	25%	-25%	-50%	50%	150%	300%
Sea	-25%	50%	100%	-15%	50%	100%	0%	100%	300%
Train	0%	50%	75%	0%	50%	75%	0%	75%	150%
Inland navigation	0%	50%	100%	0%	100%	150%	0%	50%	100%
Efficiency									
Truck	-10%	10%	75%	10%	30%	75%	-10%	-25%	-50%
Sea	-25%	10%	50%	10%	20%	50%	0%	15%	30%
Train	-25%	10%	50%	5%	20%	50%	0%	-10%	-30%
Inland navigation	-25%	10%	50%	10%	20%	50%	0%	-10%	-30%

Tab. 1: Scenario Developments (General Freight Flow)

Thus, each scenario can be illustrated from three effect aspects. Due to future uncertainty, each effect is assumed to have an extreme minimum and extreme

maximum value, which present the boundaries of the development. The most likely value captures the most reasonable development until 2030. These tendencies are considered to be transparent, clear and acceptable for regional decision makers, EU politicians, retailers, shippers and logistics providers. The most likely as well as the extreme minimum and the extreme maximum values in Table 1 was based on consensus and where found at a single workshop with participants from the Food Port project.

### **2.3 Transport cost calculation**

Within the North Sea Region, there are various transport modes available for freight transport. In this research, focus is laid on the intermodal transport. In particular the combination of short-sea shipping and road transport are subject of the calculation as these are the two transportation modes which dominate the freight transport in the EU in terms of volumes (Leinbach and Capineri, 2007). In a first step, the intermodal transport cost alterations for the above-mentioned three scenarios are calculated. In a second step, the intermodal transport cost changes are compared to the road transport cost changes for the three scenarios with the help of maps.

In general, the output of the transport models can be time, cost or environmental parameters. In our model, generalised cost serves as mean to compare transport costs. In contrast to geographic distance, generalised cost (or impedance distance) is a weighted cost which includes all costs required to travel from one point to another (Sommer and Wade, 2006).

The calculation of the cost associated with the use of the intermodal transport system is based on the physical performance of the transport system. The modelling of the physical measurements and calculations of costs are calculated with a geographical information system. It is however not within the scope of this paper to give a thorough description of the functionalities of geographical information systems or the handling of digital multimodal networks as this can be found elsewhere in the literature (Jourquin and Beuthe, 1996, Jourquin and Limbourg, 2003, Kronbak, 2005, Kronbak and Brems, 1996).



As the purpose is to model the cost of freight transport, an important step in the modelling is the transformation of the physical measurements (transport distances and time) into monetary values. This is done by calculating a generalized cost for traversing each link in the network. The generalized cost for each link is composed of an addition of three cost contributions:

- Distance dependent costs
- Time dependent costs
- Fare and toll costs

The distance and time dependent costs normally apply to road transport whereas sea transport normally operates with fares.

The distance dependent cost components are for road transport typically vehicle operating costs (VOC) covering e.g. fuel consumption, maintenance, tires etc. For sea transport a distance dependent cost can also be used e.g. in cases where one lacks information on fares or when modelling tramp shipping. The distance dependent cost for each link within the network can be found as:

$$\mathbf{DDcost = (DDCC1 + DDCC2 + \dots + DDCCn) \cdot TransportDist}$$

Where *DDcost* is the total Distance Dependent cost for the link

*DDCC1 ... DDCCn* is the Cost Components

*TransportDist* is the length of the link

The *time dependent cost* components are for road transport typically e.g. wages or depreciation of the material (including e.g. financial costs). The time dependent cost for each road link is found as:

$$\mathbf{TDcost = (TDCC1 + TDCC2 + \dots + TDCCn) \cdot TransportTime}$$

Where *TDcost* is the total Distance Dependent cost

*TDCC1 ... TDCCn* is the Cost Components

*TransportTime* is the time used to traverse the link

In the modelling the distance and time dependent costs are modelled using a lookup table describing the costs for different link types or specific links. In the same way as for the calculation of the traverse time the calculation of the different costs elements can be made on an arbitrary classification of the

transport network based on e.g. country, region, road type, truck type, wages etc.

The *fare* and *toll costs* are normally linked to either the use of a sea link, modal shift or the passage of a physical location like e.g. a toll bridge, a toll tunnel or a toll ring. The *fare* and *toll costs* for specific links are found as:

$$\textbf{Fare \& Tollcosts} = \textbf{FTC1} + \textbf{FTC2} + \dots + \textbf{FTCn}$$

As for the time and distance dependent costs the fare and toll cost calculations are controlled by lookup tables. The fare and toll cost file includes more information than the distance and time cost files but the principle is the same.

The NSR region covers numerous road and sea links. The following 10 ports/port regions have been selected as example points of origin for the transport model to enable a more focused display of cost shifts:

- Immingham/Humber estuary
- Esbjerg
- Zeebrugge/Oostende
- Hamburg
- Bremerhaven
- Gothenburg
- Kristiansund/Hitra
- Forth Ports Scotland
- Rotterdam
- Calais/Dover

These ports are not chosen only because of their location within the NSR region but rather due to their differences in the integration in the local transportation network as well as freight volumes they handle on an everyday basis. So, e.g. the Port of Rotterdam was the largest port regarding container throughput in Europe in 2008 with a 12 percent share of total container throughput in Europe. The Port of Hamburg was in 2008 the second largest port in the same statistic. Additionally, the Port of Bremerhaven and Zeebrugge can be found under the Top 15 ports in Europe considering container throughput (Notteboom, 2010). In contrast thereto, the ports of Forth Ports

Scotland or Kristiansund/Hitra are located rather remotely. Moreover, as the larger ports have a history of freight transport, the Port of Kristiansund/Hitra is under construction at the moment and will have to actively establish a future transportation network. The port region of Forth Ports Scotland is located in Northern England and seeks to actively outweigh remoteness by network integration as well as a diverse portfolio on good transport services. Moreover, the middle-sized port region of Immingham/Humber estuary is located on Central England's east coast with an immediate access to main big industrial cities in England and Scotland. Within a relatively short distance to the west coast of England it also provides connections with Ireland. In contrast, the middle-sized ports of Esbjerg and Gothenburg provide access to Northern Europe from Continental Europe and Great Britain, while the ports of Calais/Dover connect historically Continental Europe with Great Britain.

With the help of the GIS (Geographic Information System) software, ArcInfo, the visual output, the cost-points maps, are obtained for these 10 ports/port regions. Hence, the transport cost calculated above is transferred into cost-points which represent the cost of reaching every point of destination from the point of origin under consideration. Approximately 366.000 cost points are calculated in the whole of Europe. These first maps can also be referred to as baseline or 'before' model.

Based on the scenarios developed above in section 1 and 2 (see Table 1), the transport cost changes for each mode of transport (i.e. road or seaway) due to efficiency and flow differences. Table 2 displays the assumed changes for the different scenarios. So, for example, an increase in trade volume (i.e. flow) and efficiency is results in a general cost decline (i.e. *Regulation* Scenario). However, as the changes differ between the modes, it can be assumed further for the *Regulation* Scenario that seaway transport cost decreases slightly more than the costs for road transport – making intermodal transport more competitive to road transport.

	a) Regulation Scenario	b) Environment Scenario	c) Competition Scenario
Road	90%	120%	70%
Seaway	85%	90%	125%

Tab. 2: Scenarios – Assumed changes in cost structure

After the changes in the cost structure for the road and sea mode are implemented ('after' model), cost-point maps are drawn displaying the changes in the cost structure. The cost-point difference maps are generated by subtracting the 'before' and 'after' maps. The descriptive statistics of the difference maps of the absolute transport costs are shown in Table 3.

### 3. Results & Discussion

In the *Regulation* scenario, it is assumed that costs for both road and sea transport decline. However, in this scenario, as described above, the sea transport experiences a slightly higher cost decrease (i.e. 85 percent in 2030 of today's costs) than the road transport (90 percent in 2030 of today's costs). The areas closer to the selected point of origin gain only slight cost cuts, while with increasing distance the cost savings become more severe. The maximum change in transport cost varies highly between the selected NSR ports/regions. While Forth Ports Scotland shows the highest adjustment rate of transport cost (max. 546.32 Euros), Gothenburg reaches a comparable low change in transport cost (max. 336.41 Euros). However, although Gothenburg maximum change in transport cost is the lowest of all 10 NSR regions. The NSR region of Kristiansund/Hitra displays the highest average change in transport cost (mean: 271.68). Due to the rather non-central location, however, Gothenburg, Kristiansund/Hitra and Forth Ports Scotland changes in the transport costs are dominantly of larger scales. The lowest average cost gain is experienced for the region Calais/Dover (mean: 73.94). Considering the standard deviation in

the transport cost structure alteration, the NSR region Calais/Dover seems to be also the most stable one (Std. Dev. 46.26) while the NSR region Forth Ports Scotland experiences the highest variation in transport cost changes (Std. Dev. 67.38). Hence, in this scenario, ports which are more centrally located in the NSR region and with this more embedded in sea and road networks, reach lower transport cost gains but are also more stable in their cost structure than if located rather adjacent.

In the *Environment* scenario, it is assumed that cost increases for the road transport (i.e. 120 percent in 2030 of today's costs) while at the same time sea transport cost declines (i.e. 90 percent in 2030 of today's costs). Changes occur in two directions, cost increase and decrease. As the shift in transport costs are calculated as 'before' minus 'after', a negative difference is equivalent to a transport cost increase for this served area, while a positive value represents a cost decline for the area. The Port of Esbjerg is exposed in this scenario to the highest increase and the highest variation in transport cost changes (min: -691.12 Euros, Std. Dev. 100.39), while Kristiansund/Hitra display the lowest increase and the lowest variation in transport cost alteration (min: -560.92 Euros, max: 0 Euros, Std. Dev. 58.26). Hence, for this region, the cost increase for road transport is overruling the declining cost via sea links due to a lack of established sea routes. In contrast, the NSR region Immingham/Humber attains the highest cost gain (max: 187.05 Euros), while the NSR port of Gothenburg show the lowest average in transport cost changes (mean: -38.46) with also the majority of changes lower than the mean value (median: -36.36 Euros). Hence, all 10 NSR ports experience in this scenario in average an increase in transport cost due to the relatively high rise of the road transport costs which is also a part of the intermodal transport cost. The Port of Esbjerg suffers in this scenario not only from the highest transport cost increase but also exhibits the highest average of transport cost alteration (mean: -189.71). The more adjacent NSR ports which are well integrated into the road network gain here some advantage regarding the transport cost changes.

In contrast to the *Environment* scenario, the *Competition* scenario assumes a future decline of the road transport cost (i.e. 70 percent in 2030 of today's costs), while at the same time the transport cost via sea links raises (i.e. 125 percent in 2030 of today's costs). Also, in this scenario a negative difference in transport cost is equivalent to a cost increase, while a positive change in the transport cost represents a cost decline for the respective area. The highest cost increase is suffered in this scenario in the NSR region Immingham/Humber (min: -346.21 Euros), which, unsurprisingly, obtained in the former scenario the highest gain in the changes of the transport cost. However, in this scenario the Port of Hamburg displays the lowest increase in the transport cost (min: -61.20 Euros). The highest gain in transport cost can be observed for the Port of Rotterdam (max: 1207.38 Euros), while the NSR region Immingham/Humber also attains the lowest gain (max: 739.57 Euros) and the lowest average transport cost change (mean: 114.18). The highest average transport cost alteration can be observed for the port of Esbjerg (mean: 331.66). In regards to standard deviation of the shifts in transport cost, the NSR region Calais/Dover is the most stable area in our sample towards the changes (Std. Dev. 95.21) while the Port of Gothenburg shows the highest fluctuation in adaptation to the changes (Std. Dev. 187.99). Thus, in this scenario the NSR regions which are integrated well into short-sea-shipping transport networks gain the most of the transport cost alterations while central location (e.g. NSR region Calais-Dover) helps to outbalance future cost shifts.

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#### Regulation Scenario

NSR Port/Region	Min	Max	Mean	Median	Std.Dev.
Immingham/Humber	0.00	521.14	114.18	114.99	53.76
Esbjerg	0.00	423.64	126.27	115.66	53.94
Zeebrugge/Oostende	0.00	520.47	79.79	74.67	49.59

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Regulation Scenario

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NSR Port/Region	Min	Max	Mean	Median	Std.Dev.
Hamburg	0.00	459.43	98.31	87.37	53.11
Bremerhaven	0.00	473.56	94.93	85.50	51.50
Gothenburg	0.00	336.41	208.19	209.73	55.65
Kristiansund/Hitra	0.00	394.05	271.68	276.52	56.96
Forth Ports Scotland	0.00	546.32	181.01	193.83	67.38
Rotterdam	0.00	520.58	78.29	72.07	50.55
Calais/Dover	0.00	514.41	73.94	66.15	46.24

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Environment Scenario

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NSR Port/Region	Min	Max	Mean	Median	Std.Dev.
Immingham/ Humber	-571.51	187.05	-83.05	-72.77	83.96
Esbjerg	-691.12	61.68	-189.71	-180.12	100.39
Zeebrugge/ Oostende	-590.26	143.51	-95.05	-96.97	81.71
Hamburg	-610.44	75.49	-128.43	-116.49	96.44

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Environment Scenario

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NSR Port/Region	Min	Max	Mean	Median	Std.Dev.
Bremerhaven	-638.70	95.34	-120.86	-112.27	94.58
Gothenburg	-664.77	80.34	-38.46	-36.36	67.40
Kristiansund/Hitra	-560.92	0.00	-140.95	-130.15	58.26
Forth Ports Scotland	-658.24	137.06	-45.77	-46.01	66.33
Rotterdam	-589.29	150.37	-88.18	-93.03	84.35
Calais/Dover	-578.14	159.33	-108.25	-99.87	69.02

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Competition Scenario

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NSR Port/Region	Min	Max	Mean	Median	Std.Dev.
Immingham/Humber	-346.21	739.57	114.18	114.99	142.01
Esbjerg	-105.35	1130.50	331.66	311.48	135.31
Zeebrugge/Oostende	-244.46	1181.37	190.16	184.80	99.12
Hamburg	-61.20	1150.89	242.68	217.84	126.77
Bremerhaven	-90.20	1193.28	230.91	204.65	120.21
Gothenburg	280.76	997.16	173.22	218.63	187.99

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## Competition Scenario

NSR Port/Region	Min	Max	Mean	Median	Std.Dev.
Kristiansund/Hitra	-64.02	841.38	278.49	307.33	142.21
Forth Ports Scotland	-173.33	878.76	292.26	277.15	153.54
Rotterdam	-254.75	1207.38	186.02	182.31	101.13
Calais/Dover	-313.33	948.81	189.98	188.69	95.21

Tab. 3: Descriptive Statistics for each scenario and selected NSR port/region with marked extreme values (absolute difference in EUR)

A brief look at the absolute difference in transport cost suggests that the more detached regions have higher gains due to the longer distance, i.e. the further one transports the freight the more cost savings one can accumulate over the distance. In order to rule out such kind of effects the relative changes of the transport costs are examined in the following. Relative changes are calculated as:

$$\frac{'before' - 'after'}{'after' * 100}$$

Thus, with the help of this transformation the above described absolute transport cost shifts are transformed into a comparable measurement which neglects the geographic location of the NSR port/region within the NSR area. Results of the transformation are found in Table 4.

In the *Regulation* scenario, the NSR region Forth Ports Scotland possessed the highest maximum changes in absolute term. However, in relative terms the NSR region Immingham/Humber experiences the highest increase in transport cost. While before the lowest absolute difference was reached by the NSR port of Gothenburg, in relative terms the NSR region of Kristiansund/Hitra obtains

the lowest maximum difference. The maximum absolute average transport cost alteration was achieved before by the NSR region of Kristiansund/Hitra, which is now in relative terms higher for the NSR port of Gothenburg. The NSR region Calais/Dover acquires in absolute and relative terms, however, the lowest average loss in transport costs. Thus, changing focus from absolute terms into relative terms changes the picture slightly. Moreover, it becomes obvious that the changes in transport costs are driven mainly for the NSR ports/regions Gothenburg, Kristiansund/Hitra, and Forth Ports Scotland by the cost decrease in the sea transport, while the others NSR regions are affected mainly by changes in the road cost structure (i.e. the median of the first mentioned three NSR ports/regions are close to the 15 percent cost decrease in the sea transport which signalize that the majority of the observations are close to this cost alteration, while for the other NSR ports/regions the median is closer to the 10 percent cost decrease of the road transportation). Furthermore, due to the combination of road and sea transport, except the NSR region of Kristiansund/Hitra, the other NSR ports/regions actually realize relative cost gains above the maximum cost decrease of 15 percent (for sea links).

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#### Regulation Scenario

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NSR Port/Region	Min	Max	Mean	Median	Std.Dev.
Immingham/Humber	0.00	17.64	12.92	11.11	2.02
Esbjerg	0.00	16.87	11.69	11.11	1.25
Zeebrugge/Oostende	0.00	17.55	12.09	11.11	1.87
Hamburg	0.00	16.89	11.89	11.11	1.59
Bremerhaven	0.00	17.28	11.93	11.11	1.68
Gothenburg	0.00	17.16	14.74	14.79	1.21
Kristiansund/Hitra	0.00	14.99	13.92	14.04	0.80

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Regulation Scenario					
NSR Port/Region	Min	Max	Mean	Median	Std.Dev.
Forth Ports Scotland	0.00	17.54	14.32	14.67	1.68
Rotterdam	0.00	17.62	12.15	11.11	1.99
Calais/Dover	0.00	17.36	11.39	11.11	1.09
Environment Scenario					
NSR Port/Region	Min	Max	Mean	Median	Std.Dev.
Immingham/Humber	-16.66	11.05	-7.99	-7.97	7.16
Esbjerg	-16.66	7.11	-14.13	-16.66	5.00
Zeebrugge/Oostende	-16.66	10.60	-12.64	-16.66	7.57
Hamburg	-16.66	7.16	-13.23	-16.66	6.50
Bremerhaven	-16.66	9.16	-13.06	-16.66	6.90
Gothenburg	-16.66	8.53	-2.42	-2.32	4.93
Kristiansund/Hitra	-16.66	0.00	-6.16	-5.63	3.06
Forth Ports Scotland	-16.66	10.55	-3.94	-2.85	6.78
Rotterdam	-16.66	10.98	-12.26	-16.66	8.27
Calais/Dover	-16.66	9.61	-14.09	-16.66	5.28

Competition Scenario					
NSR Port/Region	Min	Max	Mean	Median	Std.Dev.
Immingham/Humber	-19.88	42.86	34.16	42.86	13.26
Esbjerg	-8.03	42.86	39.82	42.86	7.83
Zeebrugge/Oostende	-16.52	42.86	39.09	42.86	8.90
Hamburg	-4.33	42.86	38.87	42.86	9.35
Bremerhaven	-6.71	42.86	38.74	42.86	9.68
Gothenburg	-14.25	42.86	14.33	18.78	14.30
Kristiansund/Hitra	-2.19	42.86	15.91	17.62	9.90
Forth Ports Scotland	-7.25	42.86	28.69	28.44	12.02
Rotterdam	-17.50	42.86	39.35	42.86	8.70
Calais/Dover	-15.48	42.86	40.83	42.86	8.56

Tab. 4: Descriptive Statistics for each scenario and selected NSR port/region with marked extreme values (relative difference in percent)

While in the *Regulation* scenario some changes occur if instead of absolute difference in transport cost the relative changes are considered, in the *Environment* scenario only one alteration in the results of the extreme values can be observed. The highest variation in transport cost change is in relative terms detected for the NSR port of Rotterdam instead for the NSR port Esbjerg. While in the *Regulation* scenario the combination of road and sea transport led to higher cost gains (measured in transport cost) than the actual cost changes, in the *Environment* scenario the increase in road transport is offset by the cost decrease in the sea transport. As in the *Regulation* scenario, the observation for the NSR ports/regions Gothenburg, Kristiansund/Hitra, and Forth Ports

Scotland are also driven mainly by cost changes in the sea transport. However, in this scenario additionally the NSR region of Immingham/Humber offsets the increase in road transport cost by shifting towards sea links (see median) and therewith reaches the highest gains in the transport cost.

In the *Competition* scenario, the lowest minimum difference in relative terms is attained by the NSR region Kristiansund/Hitra instead of the NSR port Hamburg. Furthermore, the highest and lowest average relative changes in transport cost is measured for the NSR port/region Calais/Dover and Gothenburg, and not as in absolute terms for the NSR port/region Esbjerg and Immingham/ Humber. While the NSR port of Gothenburg also in relative terms scores the highest variation in transport cost changes, the lowest variation is observed in relative terms for the NSR port of Esbjerg, instead of the NSR region Calais/Dover which appear more stable in absolute terms. Examining, the median of the observations, it becomes obviously that the assumed cost increase of 25 percent for the sea transport and at the same time cost decrease of 30 percent in the road transport is translated into higher cost gains than assumed in the scenario by apparently shifting parts of the more expensive sea transport towards the more cheaper road transport. In this scenario, as well as above, the NSR ports/regions Gothenburg, Kristiansund/Hitra, and Forth Ports Scotland appears to lack the option to shift and with this maintain in the more expensive sea transport network which leads to the results that the majority of the cost points are distributed around the minimum change which is equal to a transport cost increase, i.e. cost increase for the majority of the observation which needs to be offset and therefore result in lower average transport cost gains.

After comparing the intermodal transport cost alterations between the scenarios, in a second step, the transport cost changes are compared to changes in road transport cost for the same scenarios (i.e. assuming a world without short-sea shipping links). This step is taken to point out the part of the transport cost changes driven by short-sea shipping lines. Therefore the cost changes in the three scenarios of a world containing only road transport costs

are deducted by an intermodal world. In the following, the relative changes are reported (see table 5). Negative changes indicate that intermodal transport achieve higher transport cost savings under the respective scenario than the mere road transport. If the road transport is less costly than the intermodal transport under the scenario for the point of destination from the point of origin, transport cost changes are positive.

In the *Regulation* scenario, due to the assumption that sea transport cost are decreasing further than road transport, relative high cost gains for intermodal transport can be achieved compared to the road transport cost. So, from the point of origin, the NSR port Gothenburg, transportation cost can be reduced to up to 49 percent if intermodal transport is considered rather than only road transport (i.e. maximum relative change). If the point of origin is within Continental Europe, also at least 31 percent of transport cost can be saved if intermodal transport is preferred to road transport (i.e. minimum cost saving, NSR port Bremerhaven). However, in average, intermodal transport outcompetes road transport considering the rather adjacent NSR ports/regions Gothenburg, Kristiansund/Hitra and Forth Ports Scotland. Hence, the relative disadvantage of being located further away from economic important areas can be balanced out by establishing sea links to these hub centres. Regarding the variation in cost saving switching from road transport to intermodal transport, the already mentioned three NSR ports/regions Gothenburg, Kristiansund/Hitra and Forth Ports Scotland together with the NSR region Immingham/Humber display relatively high variation in cost changes (max. Std. Dev: 14.12; NSR port Gothenburg) compared to the other NSR ports/regions in our analysis (min. Std. Dev: 6.29, NSR port Esbjerg).

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#### Regulation Scenario

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NSR Port/Region	Min	Max	Mean	Median	Std.Dev.
Immingham/Humber	-41.67	11.11	4.19	11.11	10.84

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Regulation Scenario					
NSR Port/Region	Min	Max	Mean	Median	Std.Dev.
Esbjerg	-44.09	11.11	8.71	11.11	6.29
Zeebrugge/Oostende	-48.29	11.11	8.15	11.11	7.05
Hamburg	-39.94	11.11	7.97	11.11	7.44
Bremerhaven	-31.28	11.11	7.88	11.11	7.65
Gothenburg	-49.44	11.11	-12.85	-7.93	14.12
Kristiansund/Hitra	-37.20	11.11	-11.43	-8.62	10.06
Forth Ports Scotland	-41.90	11.11	-0.46	-0.10	10.88
Rotterdam	-49.04	11.11	8.36	11.11	6.90
Calais/Dover	-42.07	11.11	9.51	11.11	6.79
Environment Scenario					
NSR Port/Region	Min	Max	Mean	Median	Std.Dev.
Immingham/Humber	-56.25	0.00	-21.86	-16.67	8.13
Esbjerg	-58.07	0.00	-18.43	-16.67	4.71
Zeebrugge/Oostende	-61.22	0.00	-18.88	-16.67	5.28
Hamburg	-54.96	0.00	-19.02	-16.67	5.58
Bremerhaven	-48.46	0.00	-19.09	-16.67	5.74
Gothenburg	-62.08	0.00	-34.64	-30.95	10.59

Environment Scenario					
NSR Port/Region	Min	Max	Mean	Median	Std.Dev.
Kristiansund/Hitra	-52.90	0.00	-33.57	-31.47	7.55
Forth Ports Scotland	-56.42	0.00	-25.35	-25.08	8.16
Rotterdam	-61.78	0.00	-18.73	-16.67	5.17
Calais/Dover	-56.56	0.00	-17.87	-16.67	5.09
Competition Scenario					
NSR Port/Region	Min	Max	Mean	Median	Std.Dev.
Immingham/Humber	-25.01	42.86	33.95	42.86	13.93
Esbjerg	-28.12	42.86	39.78	42.86	8.09
Zeebrugge/Oostende	-33.52	42.86	39.06	42.86	9.06
Hamburg	-22.78	42.86	38.82	42.86	9.57
Bremerhaven	-11.64	42.86	38.70	42.86	9.84
Göteborg	-35.00	42.86	12.05	18.37	18.16
Kristiansund/Hitra	-19.26	42.86	13.88	17.48	12.94
Forth Ports Scotland	-25.30	42.86	27.97	28.44	13.99
Rotterdam	-34.49	42.86	39.32	42.86	8.87
Calais/Dover	-25.52	42.86	40.80	42.86	8.73

Tab. 5: Cost comparison for each scenario and selected NSR port/region between road transport and intermodal transport with marked extreme values (relative difference in percent)



In the *Environment* scenario, intermodal transport is by definition always more cost-efficient than road transport and will be therefore not discussed further in detail. The extreme values in this scenario are the same NSR ports/regions as in the other scenarios. In contrast thereto, in the Competition scenario by assumption road transport should outcompete intermodal transport in regards to transport cost. But, looking at the calculations, it can be shown that each port of origin has at least some points of destination which are still more cost-efficient to reach by intermodal transport than by road transport. Although sea shipping transport cost in this scenario differs about 55 percent to road transport cost regarding our assumptions, the intermodal transport cost is at maximum ca. 43 percent more expensive than only road transport. Hence the combination of sea with road transport can offset extreme cost increases for one transport mode.

## 4. Management Implications

Based on these results, characteristics are discussed which makes a port region more vulnerable towards future changes than other regions. For this purpose, two different kinds of policy directions are considered: the risk-averse versus the risk seeking port manager.

A *risk-averse port manager* is assumed to target long-term stability of the costs irrespective of future development. For this kind of manager two options are opened up: either examining in more detail the NSR regions/port which did not score any kind of extreme value (max or min) in any of the categories described above, or analysing the ports with the lowest changes in transport costs and/or lowest standard deviation.

Regarding the first option for the *risk-averse port manager* to avoid extreme values, the NSR-ports/regions of Zeebrugge/Oostenende, Hamburg and Bremerhaven match best this criterion. Thus, these regions seem to balance out any extreme future development with the help of their geographic location, and the therewith connected embeddedness into the sea and road networks

within the NSR. Regarding the short sea lines, the port of Bremerhaven possesses the highest number of shipping lines (18) in our analysis of which the majority links the region with Scandinavian regions (17). In contrast, the NSR region of Zeebrugge/Oostenende holds in our analysis only an average number of shipping links (10) which connects the region mainly with GB ports. The NSR port Hamburg is linked in our analysis with 14 other ports in the NSR region of which the majority (13) are located in Scandinavia. The one sea link, however, which connects the NSR port Hamburg outside Scandinavia, is the one to the NSR port of Bremerhaven, hence, another port with a majority of sea links to Scandinavia. Apparently, the combination of being integrated due to the geographic location into the continental European road network and at the same time via sea to Scandinavia leads to the comfortable situation to be capable to balance out any kind of future cost trends.

The second option for the *risk-averse port manager* is to target the lowest standard deviation or lowest minimum change in transport cost. Regarding the lowest standard deviation in our three scenarios, the NSR ports/regions Kristiansund/Hitra and Esbjerg display in relative terms the lowest standard deviation in the calculation of the transport cost changes. While, the NSR region Kristiansund/Hitra is relatively well able to offset price alterations in road transport (*Regulation* and *Environment* Scenario), the NSR port of Esbjerg counterbalance relatively well price increase for sea transport with price declines in the road transport (Competition scenario). Considering the lowest minimum change in transport cost, the NSR region Kristiansund/Hitra scores the best result in relative terms in the Competition scenario and in absolute terms in the *Environment* scenario. The NSR port Hamburg obtains the lowest minimum change in absolute terms in the Competition scenario. The low standard deviation in relative and absolute terms (see the *Environment* scenario) as well as the low relative change in the transport cost for the NSR region Kristiansund/Hitra seems surprisingly as this region is mainly connected via road to sea links; i.e. can be considered as rather detached and peripherally located within the NSR region. The low relative change can be seen as

expression of almost non existing modal shift for the NSR region Kristiansund/Hitra given the tree scenarios. The region has due to its geographical location an extremely solid truck based hinterland and almost any destination outside this hinterland can only be served by ship.

In opposition to the risk-averse port manager, the risk-seeking port manager aims to reach the highest transport cost decline by assuming the predictability of future cost development. Thus, this kind of manager takes a chance of gaining cost reductions. Assuming the future will look like the *Regulation Scenario* (i.e. cost of sea and road transport declines); the highest gain in the transport cost difference is accumulated in the NSR region of Forth Ports Scotland in absolute terms due simply to distance to served areas. In relative terms, however, the NSR region Immingham/Humber reaches the highest gain in this scenario. If supposedly the sea transport costs decrease while at the same time the road transport costs increase as in the *Environment Scenario*, the NSR port of Immingham/Humber would be the port to examine in more detail. Despite its geographic location in the middle of GB and close to major cities, the NSR port of Immingham/Humber operates in our analysis on 12 sea links of which 3 connects the area with Scandinavian Ports, while the others bond the area with continental Europe. If, however, the opposite development is supposed to take place (i.e. cost of sea transport increase while at the same time the cost for the road transport decrease as in the *Competition Scenario*), the NSR port of Rotterdam would be here the example to achieve highest gains in transport costs in absolute terms. This port is located centrally in the NSR region and with this also embedded into the regional sea and road network. The latter characteristic is supported by the fact that 17 sea routes are incorporated in our analysis, of which 8 links this port to Scandinavian regions, while the other links are to GB or continental Europe.

As discussed above, the NSR ports/region Gothenburg, Kristiansund/Hitra, and Forth Ports Scotland tend to react differently towards the changes in transport costs than the other NSR ports/region selected in our analysis. Despite of Gothenburg's sea connection to 15 NSR ports of which only 3 are located in

Scandinavia, it is apparently on the same track as the rather detached and peripherally located NSR regions Kristiansund/Hitra and Forth Ports Scotland. Although, in our analysis, the latter two are only connected via road to either Bergen or Rosyth which possess some sea links but do not appear to be connected very well within the NSR region neither. Hence, these NSR ports/regions are interesting cases as by theory they should be subject to rather high transport cost increases instead of declines. However, by combining the few sea links with the rather less developed road network of the Scandinavian region (compared to continental Europe) cost gains are still possible for these regions irrespective of future price development.

In general, comparing intermodal transport cost with road cost it was shown that for each scenario establishing sea links with other NSR ports/regions creates at least some kind of transport cost advantages compared to only road transport. Certainly, the more adjacent NSR ports have a higher stake in establishing these short-sea links, however, if hinterlands should be served, cost-efficiency gains are also realized by NSR ports in Continental Europe.

## **5. Conclusion**

Sustainability of nowadays transport costs in the NSR is evaluated in this paper. After discussing three different scenarios on potential changes in the cost structure of inter-modal transport, *Regulation*, *Environment* and *Competition* scenario, cost points are calculated in order to display the effects of the scenarios in geographic maps for 10 different NSR port/regions. It could be shown that due to location and/or integration in local transportation networks ports can balance out cost changes driven by policy decisions. Hence, future road transportation cost increase can be balanced out by sea transport cost decrease and the other way around. Advanced integration into transportation networks can offset geographic adjacency. Although, central points are more accessible than peripheral ones (considering a closed system) politically driven changes in transport cost structure is able to counterbalance geographic

disadvantages. This we can show, e.g., for the NSR ports/regions Gothenburg, Kristiansund/Hitra, and Forth Ports Scotland. These NSR ports/regions are located away from central points and are mainly connected by sea links. In the *Environment* scenario, in which road transportation becomes more expensive while sea transport is the preferred mode of transport, these adjacent NSR-ports suffered the lowest average transport cost burden. However, in the Competition scenario, in which the road transport outcompete the sea transport regarding future transportation cost shifts, the three NSR ports/regions Gothenburg, Kristiansund/Hitra, and Forth Ports Scotland still could realize an average net transport cost gain. Due to the lack the option to shift from sea to road entirely, however, these gains were smaller than the ones for the other NSR ports/regions in this analysis. Hence, the ability of a port to offset transport cost changes depends on the preferred mode of transport network they are integrated in.

Based on transport cost modelling results, implications for port management are drawn. It is pointed out that a risk-averse manager of a Continental European port will be able to balance out future cost changes if he makes use of established sea links to Scandinavia and European road network. However, by combining the few sea links with the rather less developed road network of the Scandinavian region (compared to continental Europe) cost gains are still possible for these regions irrespective of future price development.

The analysis is based on established sea and road networks. However, it is shown that investing in creating new sea routes from a port management point of view might be worth as it compensates for increases in road transport cost. Hence, attracting more sea routes lead to further efficiency gains which can offset future transport cost uncertainties.

Future research should also take the rail and inland water transport into consideration, so as to provide a holistic view of transport cost development. Moreover, general freight flows are here considered only. The picture is subject to change if volumes are taken into account as well as a differentiation between fresh food transport (incl. temperature control) and other goods.



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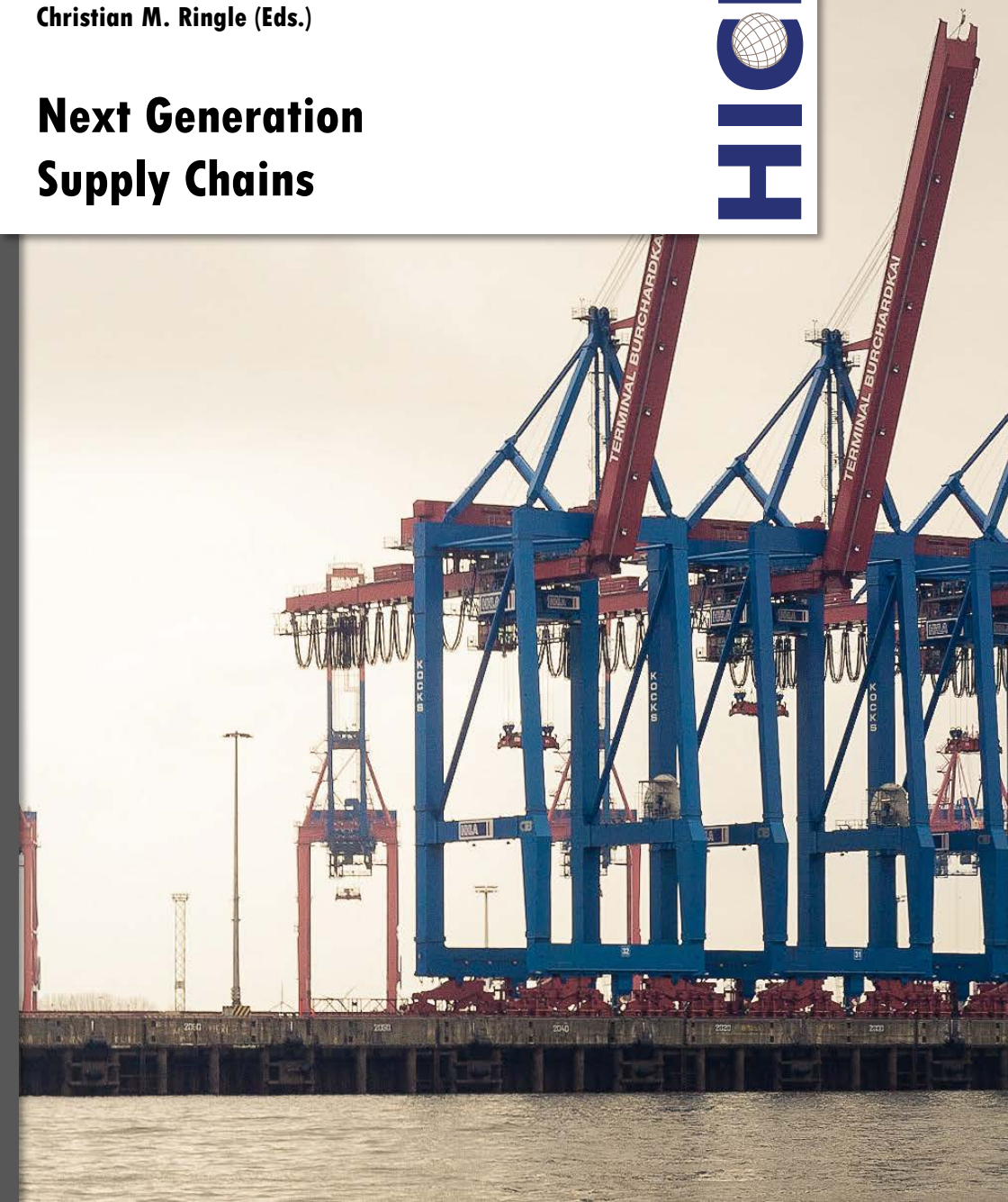
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**Wolfgang Kersten, Thorsten Blecker and  
Christian M. Ringle (Eds.)**

# **Next Generation Supply Chains**



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Prof. Dr. Christian M. Ringle  
*(Editors)*

# **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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