Lecture Notes in Logistics

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Christiane Geiger *Editors*

Commercial Transport

Proceedings of the 2nd Interdisciplinary Conference on Production, Logistics and Traffic 2015

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Foreword

The Interdisciplinary Conference on Production, Logistics and Traffic (ICPLT) addresses the interfaces between the three eponymous disciplines. The second ICPLT in particular deals with economic, ecological and societal issues around commercial transport as the essential link for production, logistics and society. It took place during July 21–22, 2015, at TU Dortmund University, representing a joint effort by TU Dortmund University and TU Darmstadt University.

Today, transport and mobility are affected by manifold trends including new production technologies (like 3D printing or automation), urbanization and e-commerce. The international markets are integrating rapidly, promoting economic growth and in this way fulfilling a fundamental prerequisite for prosperity. To foster this development, technical, social and political barriers to international competition are more and more abolished, resulting in the development of intercontinental networks realizing an intensified division of labour. Starting and end point of the associated global passenger and goods flows are mostly agglomerations.

Worldwide, concentration tendencies of population and economic activities in cities are therefore observable. These flows are further marked by high-frequency small-scale deliveries, arising from retail and industry and their endeavour to reduce their inventory in order to save storage costs and valuable land and sales space. Besides, also e-commerce demands in particular of private households as well as offered e-commerce activities within most sectors are increasing.

All these forces again create an augmenting demand for commercial transport, especially in agglomerations, provoking a higher transport performance and putting pressure on traffic infrastructure.

Besides, conflicting goals of different interest groups fuel the discussion about commercial transport. On the one hand, commercial transport ensures adequate supply and distribution. Therefore, it is a fundamental prerequisite for economic actors to operate their business as well as for customers to receive goods and services. On the other hand, commercial transport has negative effects on environment and society, since it endangers the quality of life by external effects, e.g. air quality, noise and traffic safety.

In this way, the authorities of politics, municipalities and interdisciplinary planning, actors of production and logistics, habitants as well as all further groups of interests are involved and affected by this topic in various forms.

For this reason, this book comprises over 28 contributions examining trends and challenges for commercial transport as the essential link for production, logistics and society. Therefore, innovative technologies and strategies are presented and discussed to better understand the interdependencies and conflicts of interest between the areas of production, logistics and traffic.

Hence, the focus of this book is on the following core topics:

- Modelling of freight transport considering logistics, production and society
- Potentials for usage of e-mobility in commercial transport
- Balancing and reducing the environmental impacts (like noise, air pollution and greenhouse gases)
- Logistics hubs as interlinkages for intermodal commercial transport
- ICT system integration in production, logistics and traffic
- Supply chains and networks
- Empirical studies and data mining for analysing commercial transport
- Urban commercial transport
- Innovative approaches for production, logistics and transport systems

This book is addressed to all representatives of research and practice from the disciplines production, logistics as well as spatial and transport planning, who are interested in scientific and practice-oriented approaches.

The contributions had been evaluated and selected on the basis of a double-blind review process.

Acknowledgments

We as the editors of the book would like to thank all involved members of the scientific committee of the second ICPLT, who reviewed the presented contributions to assess their scientific and practical relevance, quality and originality.

The following professors were decisively involved in the selection of the following contributions:

- Prof. Dan Andersson, Chalmers University of Technology, Technology Management and Economics, NORTHERN LEAD Logistics Centre
- Dr.-Ing. Wulf-Holger Arndt, TU Berlin, Center for Technology and Society
- Prof. Dr.-Ing. Manfred Boltze, TU Darmstadt, Institute of Traffic and Transport
- Prof. Ph.D. Michael Browne, University of Westminster, Faculty of Architecture and the Built Environment
- Prof. Dr. Laetitia Dablanc, University of Paris-Est, French Institute of Science and Technology for Transport, Development and Networks
- Prof. Dr. Gerard DeJong, University of Leeds, Institute for Transport Studies
- Prof. Dr.-Ing. Jochen Deuse, TU Dortmund University, Institute of Production Systems, Professor for Operating and Production Systems
- Prof. Dr. Ralf Elbert, TU Darmstadt, Department of Management and Logistics
- Prof. Dr.-Ing. Heike Flämig, Hamburg University of Technology, Institute for Transport Planning and Logistics
- Prof. Dr. George A. Giannopoulos, National Centre for Research & Development, Hellenic Institute of Transport
- Prof. Ph.D. Genevieve Giuliano, University of California, Margaret and John Ferraro Chair in Effective Local Goverment, METRANS
- Prof. Dr.-Ing. Evi Hartmann, Friedrich-Alexander-University Erlangen-Nuremberg, Chair of Supply Chain Management
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Dortmund
Darmstadt
May 2015

Uwe Clausen
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Carina Thaller
Christiane Geiger

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About the Editors

Prof. Dr.-Ing. Uwe Clausen is Managing Director of the Institute of Transport Logistics at TU Dortmund University and—in joint appointment—also Director of the Fraunhofer-Institute for Material Flow and Logistics in Dortmund (since 2001) and Chairman of the "Fraunhofer Traffic and Transportation Alliance" (since 2003). He worked in the logistics service industry as European Operations Director at Amazon.com and Logistics Manager at Deutsche Post DHL. In July 1995 he achieved the title of Dr.-Ing. with his doctoral thesis on transportation network optimisation at TU Dortmund University.

He is member of the board of ECTRI European Conference of Transport Research Institutes, since 2012 (representative of Fraunhofer within ECTRI since 2005). He is Advisory Council Member of the Association of German Transportation Companies (VDV) and Member of the scientific advisory board of the Bundesvereinigung Logistik (BVL) e.V.

He was member of the DFG (German Research Foundation) experts board "System technology" on the subject "Traffic and transportation systems, logistics, quality management", from 2004 to 2012. From July 2002 till July 2005, Prof. Clausen was Dean of the Engineering Faculty at TU Dortmund University.

His research areas include green logistics, commercial transport modelling, intermodal transportation, mathematical optimization, network optimization and distribution systems.

Prof. Dr. Hanno Friedrich studied Industrial Engineering at the Karlsruhe Institute for Technology (KIT). After having finished his studies in 2004, he worked for six years at McKinsey & Company, a strategic management consulting firm. Within this time, he did his Doctorate, which he finished in 2010 at the KIT under the supervision of Prof. Dr. Werner Rothengatter. After working for one year as a Postdoc at the KIT he received a call for a Junior Professorship in the area of commercial transport at the TU Darmstadt in 2011. Since September 2015 he is Assistant Professor at the Kühne Logistics University (KLU) in Hamburg. His research topics include freight transport demand modelling, transport economics, risk management in transport and logistics and food logistics.

Dipl.-Geogr. Carina Thaller studied Human Geography at the Ludwig-Maximilans-University in Munich. Her study focus was in the fields of transport planning und traffic techniques, as well a urban and rural planning. While her study she worked on transport planning projects for motorized individual and public transport as a student assistant at gevas humberg & partner. In addition, she absolved internships successfully as a trainee for Transport Politics and Transport Concepts at ADAC e.V. in the Section “Representation of Interests in Transport” as well as at BMW AG in the Department of Traffic Techniques and Transport Management in Munich. In the framework of her diploma thesis she has researched in the field of intermodalility in individual transport. Her main focus was on the potentials of public bikes in suburban areas. Her recommendation served the principal Munich Public Transports (MVV) as a preparatory study to implement public bikes projects in the suburbs of Munich.

Since 2011 she has been working as a PhD student and research assistant at the Institute of Transport Logistics, TU Dortmund University, Germany. Carina Thaller’s research focuses on freight transport planning, modelling and analysing as well as green logistics. Thereby, she concentrates on the effects of interactions between society, economy, transport and environment and evaluates the impacts on freight transport flows. She is working in the group “Process Management” at the Institute of Transport Logistics. In this role, she assumes control and research work of national and international research and transfer projects.

Dr.-Ing. Christiane Geiger is Chief Engineer and a Member of the Executive Board of the Institute of Transport Logistics at TU Dortmund University. She is responsible for the administrative management of the Institute as well as she coordinates and supports project work. Additionally, in this position, she holds lectures on waste logistics, planning and optimizing logistics nodes and logistics and traffic management.

Christiane Geiger studied logistics at TU Dortmund University. She joined the Institute of Transport Logistics as scientific assistant in June 2008. Her methodical focus lies on process analysis and optimization from a cost, performance and ecological perspective. With this expertise, she took over the leadership of the group “process management” in October 2011. In technical terms she is engaged in contract logistics and environmentally sustainable freight transport. In November 2014, she completed her doctorate on resource rough dimensioning for launching automotive contract logistics services.

Part I
Modelling of Freight Transport Considering Logistics, Production and Society

Chapter 1
Redeveloping the Strategic Flemish Freight Transport Model

Stefan Grebe, Gerard de Jong, Dana Borremans, Pieter van Houwe and Hans-Paul Kienzler

1.1 Introduction

The Flemish authorities use a strategic freight model to forecast the demand for freight transport in the future and to support the decision making process for large infrastructure investments. In addition, the estimated truck matrix is input for the Flemish strategic passenger transport model.

The freight model is a classical four-step traffic model with several additions. One of the additions is a time-period choice model, which takes into account shifts from peak periods to off-peak periods due to congestion and allows for instance simulations of policies with congestion charges during peak hours. Another extension is a module for the use of logistical hubs (by mode).

Recently, a new version of the freight model (version 4.1.1) has been developed. In this paper we will discuss the Flemish freight model version 4.1.1 with a main focus on the mode and vehicle type choice. We discuss the model structure, the cost functions, the results of logit model estimations and present the elasticities. Furthermore, we briefly discuss the time-of-day choice model.

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1.2 Model Description

The model starts with the application of production and attraction multipliers on socio-economic data (for future year these are forecasts themselves) for each zone. The model uses 518 zones within Belgium and 96 larger external zones in Europe. Given the productions and attractions per zone, the distribution is modelled by using a gravity model.

Mode choice and vehicle type choice are integrated in one model and are estimated simultaneously. The mode and vehicle-type choice part of the model considers three road vehicle types, three train types and ten inland waterways (IWW) vessel types as direct and intermodal transport modes. Air transport and short sea shipping are not modelled. To compensate for this, the zones hosting harbors or airports attract and produce the amounts of cargo that is shipped further away in reality.

There are three separate network assignments: for IWW transport, for rail transport and for road transport (the latter takes place simultaneously with the assignment of the cars in the strategic passenger transport model).

Goods are distinguished in 20 product groups (NST 2007 classes) following the classification system for transport statistics by the Economic Commission for Europe by the United Nations. For three of the commodities (NST 15, 18 and 20) no data is available and no model can be estimated. Table 1.9 in the Appendix gives an overview of the classification of goods per NST class. During the estimations and the model calculations the commodities are treated independently. In this way, different demands for the different product groups can be taken into account and different trends between them are incorporated correctly.

1.3 Mode and Vehicle Type Choice

1.3.1 Model Specification

The mode choice and the vehicle-type choice are integrated within one model. An overview of the structure and the alternatives is shown in Fig. 1.1. The three modes are road, rail and inland waterways. The latter is split further into direct and intermodal transport. On the lowest level are the different vehicle types. For rail and the two IWW branches substitution between specific alternatives is taken into account by including nesting coefficients. For road transport a deterministic model is estimated, due to lack of observations on road vehicle type at the OD level.

In the estimation process, first multinomial logit (MNL) models have been estimated per NST class. The probability P_i of each alternative i can be calculated from the utilities U_i

Model specification

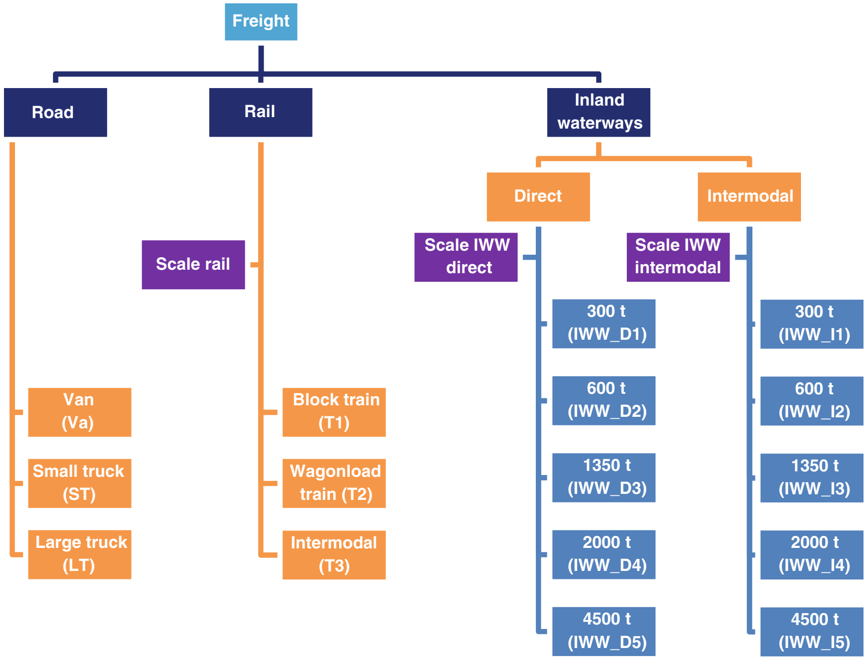

Fig. 1.1 Schematic overview of the mode and vehicle-type choice model

$$P_i = \frac{e^{U_i}}{\sum_{j=1}^{n} e^{U_j}}.$$

The utility function U_i consists of two terms, the observed utility component $\tilde{U}_i$ and the random (or error) term ε_i: $U_i = \tilde{U}_i + \varepsilon_i$.

The error term follows the extreme value distribution type 1 (Gumbel) and will not be further discussed in the rest of this paper. The observed utility consists of an alternative specific constant ASC_i, a number of coefficients c_i times continuous variables K_i and d_i coefficients times dummy variables $D_i(=0 \vee 1)$

$$\tilde{U}_i = \text{ASC}_i + c_i \cdot K_i + d_i \cdot D_i.$$

The problem of a classical MNL model is that it does not take into account correlations between alternatives, which are very often present in reality. Nested logit models take the substitution between specific alternatives into account. The nesting coefficient describes the correlation between the alternatives. The coefficient has a value between 0 and 1. A value outside this range is not consistent with utility maximization and indicates a problem with the estimated model. A coefficient of 1

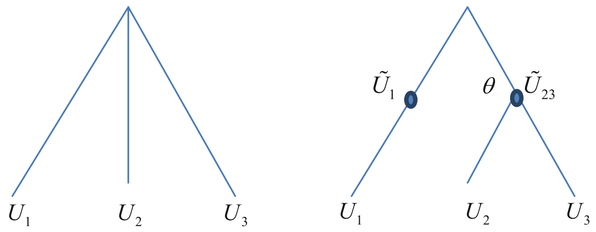

Fig. 1.2 Example of a simple MNL model with 3 alternatives (*left*) and a nested logit model (*right*). Θ is the nesting coefficient

means no correlation and 0 full correlation between the alternatives. A schematic comparison of a MNL model without nesting and a nested model is shown in Fig. 1.2.

In a nested model the probability for an alternative with utility H within a nest with m alternatives is calculated with a similar formula as in the MNL model.

Within a nest the probability of each alternative compared to the *m* alternatives is calculated analogously to a MNL model

$$P_{<i|A,k>} = \frac{e^{H_i/\theta}}{\sum_{j=1}^{m} e^{H_j/\theta}}$$

with H_i the observed utility component, Θ the nesting coefficient and k the number of alternatives on the higher level. The probabilities one level higher in the decision tree with n alternatives are calculated with

$$P_{A,k} = \frac{e^{G_k+\theta_k \cdot L_k}}{\sum_{l=1}^{n} e^{G_l+\theta_l \cdot L_l}}$$

with G_k the utility term of the top level and the "logsum"-term within the nest

$$L_k = \ln \sum_{i=1}^{m} e^{H_i/\theta}$$

The probability of alternative i is the product of the probabilities of the two levels

$$P_i = P_{A,k} \cdot P_{<i|A,k>}.$$

For more details about nested and MNL models see (Train 2003).

In the Flemish freight model only utilities on the lowest level are estimated. This means that in the formulas above $H_i = \tilde{U}_i$ and $G_k = 0$. By multiplication of all utilities with all nesting coefficients in the model, costs and times have the same meaning for all alternatives.

1.3.2 Data on Transport Flows and Costs

For the modes and vehicle types the distances and travel times between Origin-Destination (OD) pairs are estimated by skimming each of the three networks. The results are level-of-service files per vehicle type that contain per OD pair distance, travel time, (road charge) and accessibility. For intermodal transport the travel times and travel distances are given for both modes. All zones are accessible by road transport, but not all zones can be reached by rail and IWW. If an alternative is not available, it is excluded during the estimation process.

Furthermore, OD matrices for the base year 2010 have been constructed based on data from available transport statistics. These are aggregate data (zonal level) which are split in the 20 NST classes. For rail and IWW this information is available for all vehicle types. For road transport only a national vehicle type split is available. Therefore, a deterministic road vehicle-type choice model was built and calibrated to match the overall shares per vehicle type. Based on the costs the best vehicle per OD-pair is chosen. The method will be discussed in the next section.

The cost functions used in the mode and vehicle-type choice model include transport-time dependent cost, transport-distance dependent cost, toll fees, resting periods, as well as costs for loading, unloading and transshipment. The general formula is:

$$Costs = \tilde{\alpha} + \beta_1 \cdot t_1 + \gamma_1 \cdot d_1 + \tilde{\Delta} + \beta_2 \cdot t_2 + \gamma_2 \cdot d_2 + \varepsilon.$$

- $\tilde{\alpha}$ is the sum of the loading costs α_1 in the origin zone and the unloading costs α_2 in the destination zone. We assume that loading and unloading costs are equal and only depend on the vehicle type. As time and distance costs scale linearly, threshold effects are also incorporated in the costs for loading and unloading.
- β_1 and γ_1 are the time and distance dependent costs for rail or IWW. They are multiplied with the transport time t_1 and transport distance d_1 with one of these modes. The times and distances are vehicle type dependent.
- $\tilde{\Delta}$ are the transshipment costs for intermodal transports. In the model the assumption is made that these costs have to be paid once if the origin or destination zone is a harbor and otherwise twice. This implies that non-harbor zones require pre- and post-carriage by road transport.
- β_2 and γ_2 are the time and distance dependent costs for road transport (either direct or serving as access to and egress from rail or IWW). They are multiplied with the transport time t_2 and transport distance d_2 with this mode. Road user charges ε can add to the transport cost of the road shipment. The distances and times are vehicle type dependent.

For direct trips the equation simplifies:

$$Costs = 2 \cdot \alpha_{1,2} + \beta_{1,2} \cdot t_{1,2} + \gamma_{1,2} \cdot d_{1,2}(+\varepsilon).$$

The cost functions are determined based on data from studies in Scandinavia, the Netherlands and Belgium. In addition to the determination of the $\alpha, \beta, \gamma, \Delta$ and ε special attention has been given to also determine the shares of fuel, taxes, personal, insurances and other important contributions to the total costs per hour and per km. This is important in the forecast of future years and for the simulation of policy effects (Table 1.1). An overview of the unit cost inputs per ton is given in Fehler! Verweisquelle konnte nicht gefunden werden.

The capacities and the cost indicators take the average load factors into account. All costs have to be paid for integer numbers of vehicles, wagons or containers. For road transport the minimum shipment size is one truck. For (wet en dry) bulk ships it is the capacity of a ship. For container ships and intermodal rail transport costs are per containers of 12 tons. Carriage trains have a minimum shipment size of 20 ton (one wagon) and for block train only whole trains can be booked. Note that for intermodal shipments (IWW and rail) the road transport part is exclusively with heavy trucks (with containers) in the model.

For IWW the model distinguishes direct and intermodal shipments. For intermodal shipments the cost indicators of container ships are applied. For direct transport, the assumption is made that all NST classes except 2, 7 and 8 are dry bulk goods. For the other three classes we assume a mixture of wet and dry bulk with percentages of 50 % (NST 2), 75 % (NST 7) and 100 % (NST 8) wet bulk.

1.3.3 Deterministic Road Transport Model

For road transports five vehicle types are considered (the three that are in Fig. 1.1, but with container and non-container for small and large trucks). However, the information which vehicle is used for specific ODs is lacking (which is required to estimate a logit model). Therefore, the choice of the road-vehicle-type is estimated using a deterministic model. Based on the transport costs the cheapest vehicle is chosen for each OD pair and NST class. To match the fraction of containerized and non-containerized transports an intermediate step is introduced.

The amount of containerization per NST class is deduced from the Dutch BasGoed (Significance, NEA en DEMIS (2010)) in which the containerization is determined for 10 NSTR classes. Under the assumption that the amount of containerization is the same in both countries the containerization can be approximated for the 20 NST classes (see Table 1.2).

For small and large trucks the container-type and the non-container type are merged into a single vehicle type each. Thus, the deterministic model is estimated for three vehicle types only: vans, small trucks and large trucks. For small and large

Table 1.1 Overview of the cost indicators (in Euro per ton) for 2010 in the cost functions of all transport modes in the freight model

	Category	Capacity	β	γ	α	$\tilde{\Delta}$
Road	Van	1.5	20.087	0.086	14.400	14.400
Road	Small truck	12	3.128	0.019	2.700	2.700
Road	Small truck (co)	12	2.954	0.019	2.167	1.500
Road	Large truck	27	1.741	0.014	1.481	1.481
Road	Large truck (co)	27	1.656	0.014	1.541	0.970
IWW	dry bulk	600	0.163	0.004	0.800	
IWW	Wet bulk	600	0.171	0.004	1.000	
IWW	Container	600	0.120	0.004	0.600	
IWW	Dry bulk	1350	0.090	0.002	0.700	
IWW	Wet bulk	1350	0.111	0.002	0.800	
IWW	Container	1350	0.071	0.002	0.500	
IWW	Dry bulk	2000	0.075	0.002	0.654	
IWW	Wet bulk	2000	0.095	0.002	0.754	
IWW	Container	2000	0.060	0.002	0.454	
IWW	Dry bulk	4500	0.058	0.001	0.600	
IWW	Wet bulk	4500	0.077	0.001	0.700	
IWW	Container	4500	0.047	0.001	0.400	
IWW	Dry bulk	9000	0.038	0.001	0.600	
IWW	Wet bulk	9000	0.050	0.001	0.700	
IWW	Container	9000	0.031	0.001	0.400	
Rail	Carriage	501	0.898	0.021	1.500	
Rail	Intermodal	765	0.598	0.014	1.500	
Rail	Blok train	765	0.598	0.014	1.435	

The two vehicle types with the addition (co) are trucks with containers

Table 1.2 Average containerization per NST class for road transport

NST	% Cont	NST	% Cont	NST	% Cont	NST	% Cont
1	2.9 %	6	5.1 %	11	6.8 %	16	6.8 %
2	1.5 %	7	1.6 %	12	6.8 %	17	6.8 %
3	1.2 %	8	2.5 %	13	6.8 %	18	–
4	4.5 %	9	2.2 %	14	3.1 %	19	6.8 %
5	4.3 %	10	4.3 %	15	–	20	–

trucks the costs depend on the amount of containerization per NST class δ_{NST} and are calculated as:

$$Costs = \delta_{NST} \cdot Costs_{Container} + (1 - \delta_{NST}) \cdot Costs_{No-Container}.$$

Fig. 1.3 Overview of driving times (*light grey*) and resting times (*dark grey*) for road transport. For shipments longer than 24 h the pattern repeats

In the mode and vehicle choice model congestion is not considered as freight transport takes place only to a small extent during peak hours. Much more important to consider during mode choice are the mandatory rest periods for truckers. In the model they are added to the transport times for road-shipments longer than 270 min. Figure 1.3 gives an overview of the implemented resting periods. In the calculation of the time-dependent costs the short breaks of 45 min are considered, the long breaks during the night are not.

A not trivial choice in the deterministic model is the trip frequency. The OD matrix contains the flows of goods between zone pairs in the base year. This corresponds to a trip frequency ω equal to 1. Per NST class there are many zone pairs where several shippers and receivers are situated. For most of them the trip frequency will be higher than once per year. Both effects are arguments for a higher trip frequency. Counteracting this is consolidation of shipments from different zones. By comparing the amount of ton kilometers per vehicle type in Belgium (see Table 1.3), the optimum trip frequency is determined. It is 2.6 for national transports and 1.04 for international transports. After the calibration the determined and observed shares per vehicle type are in good agreement (Federale Overheidsdienst Economie, ADSEI 2010).

Taking into account the containerization per NST class, the rest times and the trip frequencies, the costs for the three vehicle types can be calculated for each OD pair. Per vehicle type also the minimum number of vehicles is determined. The total costs are the product of the costs per vehicle and the minimum number of vehicles (integer number) required. For each OD pair the cheapest type is chosen and its price is used in the logit model.

1.3.4 Estimation Results

The logit model is estimated with the ALOGIT software. In the estimations process observations are weighted by their shipment size. To normalize all shipments are normalized by the average shipment size per NST class (see Table 1.4).

Table 1.3 Observed and modelled distribution (after the calibration) of freight in ton kilometers transported in vans, light and heavy trucks for national and international shipments

Mode	Observed		Deterministic model	
	National (%)	International (%)	National (%)	International (%)
Van	0.5	0.0	0.82	0.08
Light	5.5	1.0	4.45	0.91
Heavy	94.0	99.0	94.73	99.01

Table 1.4 Average flow of goods per OD pair and NST class

NST	Ton per transport	NST	Ton per transport
1	203.9	10	381.9
2	143.6	11	104.1
3	258.9	12	97.5
4	187.9	13	24.8
5	46.5	14	109.9
6	119.4	16	47.1
7	268.9	17	39.9
8	189.8	19	31.0
9	321.5	Average	159.9

The model includes a cost term that consists of the monetary transport costs and shadow costs to account for the transport time that is related to the commodities (e.g. for interest on the capital in transit, deterioration, safety stock). For the transport time different valuation estimates have been tested and compared. In the final model the transport time is valuated with 10 % of the transport costs for non-containerized goods and 20 % for containerized goods, which means that transport time is valuated as shadow costs of 10 of 20 % respectively (Significance et al. 2013).

In the model cost coefficients are estimated for road, rail, direct IWW and intermodal IWW. The utilities of all alternatives have the structure

$$\tilde{U}_i = \mathrm{ASC}_i + \mathrm{cc}_i \cdot \left(\frac{C}{TonTot} + 0.1 \cdot \frac{C}{TonTot}\right) + D_i^{\mathrm{int}} + D_i^{\mathrm{Hav}},$$

with ASC the alternative specific constants, cc the cost coefficients, C the transport costs and TonTot the size of the transport. D^{int} is a dummy for international transports and D^{Hav} the dummy for trips to harbor zones. The 0.1 in the formula is a 0.2 for containerized shipments. As reference category road transport has been chosen. Therefore, the ASC for road transport has been fixed to zero.

An overview of all results is given in Table 1.5. The model contains individual cost coefficients for road, rail plus direct and intermodal IWW transport. All cost coefficients have negative values. The absolute values for road transport are the smallest, for rail transport in the middle and for IWW transport the largest. This is in agreement with our expectations. In addition, significant dummy coefficients have been found for international IWW and rail transports and transports by rail to or from harbor zones.

Different patterns of substitution between different modes were tested by specifying different nesting structures and testing whether the nesting coefficients were significant. Per NST class zero, one or two nesting coefficients are estimated.

Table 1.5 Overview of the estimated coefficients of the final model

File	NST01.F12	NST02.F12	NST03.F12	NST04.F12	NST05.F12	NST06.F12
Title	VrachtModel	VrachtModel	VrachtModel	VrachtModel	VrachtModel	VrachtModel
Converged	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE
Observations	275389	156103	233731	274571	220612	267109
Final log (L)	−69989.2	−92727	−208866.9	−49407.1	−88370.8	−116294.7
D.O.F.	20	16	20	20	7	18
$Rho^2(0)$	0.845	0.675	0.605	0.892	0.7	0.78
$Rho^2(c)$	0.083	0.124	0.134	0.102	0.088	0.06
Estimated	14-Jan-15	14-Jan-15	14-Jan-15	14-Jan-15	14-Jan-15	14-Jan-15
Scaling	1	1	1	1	1	1
ASC_Road	0 (*)	0 (*)	0 (*)	0 (*)	0 (*)	0 (*)
ASC_Rail1	−25.11 (−13.6)	−8.097 (−56.2)	−9.367 (−88.4)	−97.36 (−4.4)	−2.004 (−120.4)	−5.487 (−5.1)
ASC_Rail2	−27.93 (−13.6)	−10.15 (−57.6)	−10.71 (−88.6)	−98.70 (−4.5)	−2.998 (−186.3)	−6.989 (−5.1)
ASC_Rail3	−34.42 (−13.6)	−13.63 (−55.1)	−13.42 (−82.7)	−101.1 (−4.6)	−4.174 (−150.6)	−9.883 (−5.1)
ASC_IWW_D1	0 (*)	0 (*)	0 (*)	0 (*)	0 (*)	0 (*)
ASC_IWW_I1	0 (*)	0 (*)	−12.51 (−28.3)	0 (*)	0 (*)	0 (*)
ASC_IWW_D2	−14.09 (−13.8)	−5.712 (−42.5)	−4.274 (−99.7)	−60.63 (−4.5)	0 (*)	−13.98 (−5.0)
ASC_IWW_I2	−21.99 (−16.0)	0 (*)	−7.124 (−51.6)	−135.1 (−4.4)	0 (*)	0 (*)
ASC_IWW_D3	−12.45 (−13.6)	−2.214 (−32.7)	−2.336 (−76.1)	−43.68 (−4.5)	0 (*)	−7.054 (−5.1)
ASC_IWW_I3	−16.87 (−13.9)	0 (*)	−4.715 (−45.9)	−98.48 (−4.4)	0 (*)	−7.206 (−5.0)
ASC_IWW_D4	−14.16 (−13.8)	−2.176 (−33.2)	−2.561 (−80.9)	−59.29 (−4.5)	0 (*)	−7.780 (−5.1)
ASC_IWW_I4	−18.94 (−15.2)	0 (*)	−4.173 (−41.8)	−152.7 (−4.4)	0 (*)	−4.593 (−3.6)
ASC_IWW_D5	−13.77 (−13.8)	0.8681 (15.9)	−1.203 (−40.4)	−49.80 (−4.5)	0 (*)	−11.71 (−5.1)
ASC_IWW_I5	−14.54 (−12.6)	−0.5718 (−0.2)	−3.891 (−41.3)	−172.4 (−4.3)	0 (*)	−3.963 (−3.1)
InternRail	1.540 (6.8)	0.8425 (12.5)	2.305 (43.0)	10.08 (4.1)	−0.2126 (−13.7)	−0.8602 (−5.0)
InternIWW	4.401 (13.2)	−1.309 (−25.2)	2.506 (73.8)	21.12 (4.4)	0 (*)	1.030 (4.4)

(continued)

Table 1.5 (continued)

File	NST01.F12	NST02.F12	NST03.F12	NST04.F12	NST05.F12	NST06.F12
Title	VrachtModel	VrachtModel	VrachtModel	VrachtModel	VrachtModel	VrachtModel
Converged	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE
HarborRail	5.283 (12.4)	−1.531 (−23.0)	2.617 (50.3)	21.19 (4.3)	0.5161 (36.1)	1.142 (5.0)
cc_Road	−0.09306 (−12.8)	−0.1354 (−43.6)	−0.1286 (−62.1)	−0.2872 (−5.6)	−0.04490 (−76.2)	−0.1086 (−5.1)
cc_Rail	−0.05573 (−7.9)	−0.1323 (−29.1)	−0.08025 (−29.8)	−0.1694 (−11.3)	−0.07660 (−65.7)	−0.1610 (−5.1)
cc_IWW_D	−0.4522 (−13.7)	−1.066 (−46.3)	−0.5832 (−72.8)	−5.026 (−4.6)	0 (*)	−1.172 (−5.1)
cc_IWW_I	−1.540 (−11.7)	−3.432 (−5.3)	−0.7038 (−49.8)	−4.139 (−4.1)	0 (*)	−2.096 (−4.8)
Theta_IWW_I	0.6734 (14.7)	1.000 (*)	1.000 (*)	1.000 (*)	1.000 (*)	0.4269 (5.1)
Theta_IWW_D	0.3291 (38.0)	0.3574 (63.3)	0.4905 (99.4)	0.5811 (37.6)	1.000 (*)	1.000 (*)
Theta_Rail	1.000 (*)	1.000 (*)	1.000 (*)	0.09426 (4.6)	1.000 (*)	1.000 (*)
File	NST07.F12	NST08.F12	NST09.F12	NST10.F12	NST11.F12	NST12.F12
Title	VrachtModel	VrachtModel	VrachtModel	VrachtModel	VrachtModel	VrachtModel
Converged	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE
Observations	168950	250690	264028	248535	229675	201072
Final log (L)	−80577.3	−183076.1	−99886.4	−155781.1	−99952.1	−125041.1
D.O.F.	21	18	19	19	14	15
$Rho^2(0)$	0.668	0.707	0.807	0.626	0.754	0.604
$Rho^2(c)$	0.103	0.057	0.079	0.041	0.062	0.15
Estimated	16-Jan-15	14-Jan-15	16-Jan-15	14-Jan-15	14-Jan-15	14-Jan-15
Scaling	1	1	1	1	1	1
ASC_Road	0 (*)	0 (*)	0 (*)	0 (*)	0 (*)	0 (*)
ASC_Rail1	−12.83 (−5.3)	−6.500 (−73.7)	−4.903 (−35.1)	−3.799 (−24.3)	−3.316 (−3.8)	−1.969 (−111.2)
ASC_Rail2	−16.14 (−5.3)	−7.668 (−74.3)	−5.578 (−35.1)	−5.032 (−24.3)	−4.388 (−3.8)	−2.741 (−141.8)

(continued)

Table 1.5 (continued)

File	NST07.F12	NST08.F12	NST09.F12	NST10.F12	NST11.F12	NST12.F12
Title	VrachtModel	VrachtModel	VrachtModel	VrachtModel	VrachtModel	VrachtModel
Converged	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE
ASC_Rail3	−22.60 (−5.3)	−10.38 (−72.2)	−7.148 (−34.8)	−8.369 (−24.4)	−6.344 (−3.8)	−4.126 (−123.3)
ASC_IWW_D1	−10.31 (−5.1)	0 (*)	0 (*)	0 (*)	−14.18 (−4.7)	0 (*)
ASC_IWW_I1	0 (*)	0 (*)	0 (*)	0 (*)	0 (*)	0 (*)
ASC_IWW_D2	−10.47 (−5.3)	−4.299 (−89.0)	−5.576 (−48.4)	−9.062 (−26.4)	−15.09 (−4.8)	0 (*)
ASC_IWW_I2	2.421 (1.2)	−11.78 (−28.3)	−1.528 (−3.4)	−20.62 (−12.0)	0 (*)	0 (*)
ASC_IWW_D3	−1.931 (−5.0)	−3.069 (−75.5)	−4.278 (−41.0)	−7.621 (−23.3)	−10.99 (−3.8)	−2.946 (−61.0)
ASC_IWW_I3	2.550 (1.4)	−7.419 (−31.2)	−4.354 (−8.0)	−14.74 (−15.3)	0 (*)	−0.8200 (−7.1)
ASC_IWW_D4	−2.452 (−5.1)	−3.081 (−79.8)	−3.977 (−37.3)	−8.194 (−25.9)	−11.70 (−4.2)	−2.203 (−56.5)
ASC_IWW_I4	−2.684 (−1.5)	−9.643 (−33.5)	−2.745 (−6.0)	−16.48 (−15.4)	0 (*)	3.255 (60.6)
ASC_IWW_D5	4.323 (5.3)	−1.553 (−46.4)	−3.725 (−42.5)	−7.669 (−24.4)	0 (*)	−1.058 (−34.3)
ASC_IWW_I5	−6.126 (−3.5)	−5.345 (−26.7)	−0.8786 (−2.2)	−15.27 (−15.7)	0 (*)	4.271 (84.6)
InternRail	0.2285 (1.7)	0.1395 (4.2)	0.4618 (16.8)	−1.429 (−21.7)	−0.5841 (−3.7)	−0.3324 (−17.2)
InternIWW	−2.836 (−5.3)	0 (*)	−0.1630 (−4.1)	−1.747 (−13.1)	−5.571 (−3.6)	−0.7909 (−40.7)
HarborRail	−2.507 (−5.2)	0.8848 (27.9)	1.516 (31.9)	0.8522 (19.5)	0.8282 (3.7)	0 (*)
cc_Road	−0.1220 (−5.3)	−0.02492 (−29.6)	−0.04757 (−29.9)	−0.09695 (−24.6)	−0.07789 (−3.7)	−0.01900 (−34.6)
cc_Rail	−0.1033 (−5.1)	−0.01958 (−16.7)	−0.03777 (−20.4)	−0.1073 (−23.0)	−0.1247 (−3.7)	−0.03124 (−33.1)
cc_IWW_D	−1.960 (−5.3)	−0.4238 (−59.4)	−0.2638 (−25.3)	−0.3779 (−23.6)	−0.04960 (−2.2)	−0.2932 (−38.1)
cc_IWW_I	−4.213 (−5.3)	−0.6024 (−20.7)	−1.133 (−14.4)	−0.5089 (−6.0)	0 (*)	−0.8211 (−91.6)
Theta_IWW_I	0.2770 (5.3)	1.000 (*)	1.000 (*)	1.000 (*)	1.000 (*)	1.000 (*)
Theta_IWW_D	0.7381 (68.3)	0.5082 (79.2)	0.8011 (35.5)	0.4052 (24.8)	0.6153 (3.8)	1.000 (*)
Theta_Rail	1.000 (*)	1.000 (*)	1.000 (*)	1.000 (*)	1.000 (*)	1.000 (*)

(continued)

Table 1.5 (continued)

Observations	NST13.F12	NST14.F12	NST16.F12	NST17.F12	NST19.F12
Final log (L)	VrachtModel	VrachtModel	VrachtModel	VrachtModel	VrachtModel
D.O.F.	TRUE	TRUE	TRUE	TRUE	TRUE
Observations Final log (L) D.O.F. $Rho^2(0)$	NST13.F12 VrachtModel TRUE 153914	NST14.F12 VrachtModel TRUE 238610	NST16.F12 VrachtModel TRUE 175107	NST17.F12 VrachtModel TRUE 174826	NST19.F12 VrachtModel TRUE 189694
$Rho^2(c)$	−47506.3	−149214.4	−122599.9	−60910.3	−93221.3
Estimated	7	19	17	7	16
Scaling	0.671	0.66	0.619	0.655	0.737
ASC_Road	0.14	0.088	0.168	0.107	0.13
ASC_Rail1	14-Jan-15	14-Jan-15	14-Jan-15	14-Jan-15	14-Jan-15
ASC_Rail2	1	1	1	1	1
ASC_Rail3	0 (*)	0 (*)	0 (*)	0 (*)	0 (*)
ASC_IWW_D1	−0.8534 (−36.0)	−7.181 (−50.8)	−5.570 (−35.7)	−1.360 (−67.8)	−1.314 (−74.0)
ASC_IWW_I1	−2.455 (−117.8	−8.941 (−51.4)	−8.711 (−38.3)	−2.565 (−136.1	−2.572 (−155.6)
ASC_IWW_D2	−3.568 (−99.1)	−12.21 (−50.7)	−12.94 (−37.8)	−3.765 (−116.9	−3.733 (−131.4)
ASC_IWW_I2	0 (*)	0 (*)	0 (*)	0 (*)	0 (*)
ASC_IWW_D3	0 (*)	0 (*)	0 (*)	0 (*)	0 (*)
ASC_IWW_I3	0 (*)	−6.138 (−60.2)	−2.948 (−25.9)	0 (*)	−3.151 (−46.2)
ASC_IWW_D4	0 (*)	−14.55 (−18.7)	0 (*)	0 (*)	0 (*)
ASC_IWW_I4	0 (*)	−3.915 (−47.6)	−0.6739 (−8.0)	0 (*)	−1.649 (−36.1)
ASC_IWW_D5	0 (*)	−3.330 (−16.7)	5.436 (22.5)	0 (*)	−2.095 (−7.9)
ASC_IWW_I5	0 (*)	−3.885 (−47.4)	−2.907 (−30.5)	0 (*)	−1.540 (−30.8)
InternRail	0 (*)	−6.428 (−25.7)	8.068 (30.0)	0 (*)	0 (*)

(continued)

Table 1.5 (continued)

Observations	NST13.F12	NST14.F12	NST16.F12	NST17.F12	NST19.F12
Final log (L)	VrachtModel	VrachtModel	VrachtModel	VrachtModel	VrachtModel
D.O.F.	TRUE	TRUE	TRUE	TRUE	TRUE
InternIWW	0 (*)	−3.045 (−38.5)	0 (*)	0 (*)	−1.699 (−27.2)
HarborRail	0 (*)	−2.279 (−12.7)	12.54 (35.9)	0 (*)	−1.269 (−5.3)
cc_Road	−0.2298 (−11.2)	0.8343 (19.3)	−0.3640 (−6.0)	−0.2179 (−11.8)	−0.1915 (−11.8)
cc_Rail	0 (*)	0.1790 (3.8)	−1.744 (−21.9)	0 (*)	−0.8982 (−20.6)
cc_IWW_D	0.1482 (7.7)	2.200 (40.0)	−0.4334 (−7.6)	0.3794 (22.5)	0.3510 (23.7)
cc_IWW_I	−0.03393 (−59.5)	−0.06251 (−39.6)	−0.06911 (−31.3)	−0.04064 (−64.9)	−0.04324 (−81.6)
Theta_IWW_I	−0.07170 (−60.7)	−0.07476 (−32.2)	−0.1271 (−31.2)	−0.07788 (−61.3)	−0.08366 (−76.7)
Theta_IWW_D	0 (*)	−0.5087 (−46.0)	−1.018 (−41.6)	0 (*)	−0.3163 (−48.4)
Theta_Rail	0 (*)	−1.068 (−32.3)	−2.698 (−37.3)	0 (*)	−0.6184 (−16.2)
Observations	1.000 (*)	1.000 (*)	1.000 (*)	1.000 (*)	1.000 (*)
Final log (L)	1.000 (*)	0.3983 (53.1)	0.3157 (40.2)	1.000 (*)	1.000 (*)
D.O.F.	1.000 (*)	1.000 (*)	1.000 (*)	1.000 (*)	1.000 (*)

The Theta coefficients are the nesting coefficients. t-ratios are given within brackets

1.3.5 Time and Cost Elasticities

Time and cost elasticities have been calculated using the estimated model. This has been done by increasing the transport time or the transport costs in one of the three modes (road, rail, IWW) with 10 % and keeping the rest constant. In the calculations of the cost elasticities only the real cost are increased and not the 10 or 20 % of the time valuation. By comparing the mode shares (in ton and ton kilometers) before and after the adjustment the elasticities are calculated

$$\sigma = \frac{N_{(+10\,\%)} - N}{N \cdot 10\,\%},$$

with N the number of ton or ton kilometer. The results are displayed in Tables 1.6 and 1.7. The cross elasticities are calculated for all NST classes. Due to the huge amount of elasticities we have chosen to present the full set of own and cross elasticities only for one commodity (NST 1) as an example (Table 1.6) and own elasticities for all commodities (Table 1.7).

The time elasticities are (in absolute value) smaller than the price elasticities as the costs also include non-time dependent costs (e.g. fuel) which are larger than the 10/20 % increase of the costs for the time elasticities. Averaged over all commodities the elasticities are for road transport −0.13 for time and −0.21 for costs, for rail −0.47 and −0.91 and for inland waterways −1.01 and −1.44 respectively.

Table 1.6 Time and price elasticities including all cross elasticities for NST 1 per ton and ton kilometer

NST	Type		IWW		Rail		Road	
			Price	Time	Price	Time	Price	Time
1	WE	ton	0.04	0.02	0.00	0.00	−0.02	−0.01
1	SP	ton	0.05	0.04	−0.18	−0.08	0.39	0.25
1	BV	ton	−0.61	−0.41	0.00	0.00	0.22	0.13
1	WE	ton * km	0.05	0.04	0.01	0.00	−0.05	−0.03
1	SP	ton * km	0.06	0.04	−0.30	−0.15	0.76	0.50
1	BV	ton * km	−0.77	−0.58	0.00	0.00	0.42	0.27

Table 1.7 Time and price elasticities for all NST classes per ton and ton kilometer

NST	Type	IWW		Rail		Road	
		Price	Time	Price	Time	Price	Time
1	ton	−0.77	−0.51	−0.39	−0.18	−0.03	−0.02
1	ton * km	−0.99	−0.75	−0.61	−0.32	−0.08	−0.05
2	ton	−0.82	−0.44	−0.81	−0.34	−0.18	−0.10
2	ton * km	−0.92	−0.58	−1.07	−0.53	−0.52	−0.34
3	ton	−0.64	−0.37	−0.53	−0.22	−0.15	−0.08
3	ton * km	−0.77	−0.53	−0.69	−0.35	−0.40	−0.26
4	ton	−1.12	−0.65	−0.41	−0.18	−0.02	−0.01
4	ton * km	−1.67	−1.20	−0.63	−0.33	−0.05	−0.03
5	ton			−0.57	−0.27	−0.02	−0.01
5	ton * km			−0.76	−0.40	−0.05	−0.03
6	ton	−2.18	−1.30	−0.96	−0.44	−0.16	−0.10
6	ton * km	−3.11	−2.33	−1.47	−0.76	−0.41	−0.26
7	ton	−0.65	−0.35	−0.69	−0.30	−0.18	−0.11
7	ton * km	−0.86	−0.57	−0.95	−0.48	−0.49	−0.32
8	ton	−1.00	−0.58	−0.47	−0.21	−0.09	−0.05
8	ton * km	−1.59	−1.20	−0.73	−0.38	−0.23	−0.15
9	ton	−1.23	−0.68	−0.55	−0.25	−0.07	−0.04
9	ton * km	−1.81	−1.32	−0.83	−0.43	−0.36	−0.23
10	ton	−1.24	−0.83	−0.48	−0.22	−0.27	−0.17
10	ton * km	−1.73	−1.33	−0.70	−0.36	−0.66	−0.43
11	ton	−0.53	−0.30	−0.99	−0.45	−0.20	−0.12
11	ton * km	−0.79	−0.61	−1.50	−0.78	−0.47	−0.30
12	ton	−1.55	−0.83	−0.64	−0.29	−0.12	−0.07
12	ton * km	−2.06	−1.26	−0.99	−0.51	−0.25	−0.16
13	ton			−0.95	−0.42	−0.16	−0.09
13	ton * km			−1.35	−0.70	−0.30	−0.19
14	ton	−1.13	−0.67	−0.49	−0.22	−0.11	−0.06
14	ton * km	−1.48	−1.07	−0.73	−0.38	−0.30	−0.19
16	ton	−1.46	−0.77	−0.72	−0.32	−0.13	−0.08
16	ton * km	−2.08	−1.32	−1.10	−0.57	−0.25	−0.16
17	ton			−1.00	−0.45	−0.18	−0.11
17	ton * km			−1.47	−0.76	−0.36	−0.23
19	ton	−1.75	−1.08	−1.01	−0.45	−0.18	−0.10
19	ton * km	−2.43	−1.87	−1.50	−0.78	−0.37	−0.24

1.4 Time Period Choice

The time period choice is modelled in a special module within the strategic Flemish freight transport model. It determines how many road freight vehicles adjust their departure due to congestion or increased travel costs (e.g. road charge depending on the period of the day). To determine the size of these effects a stated preference (SP) experiment has been designed and carried out by interviewing the receivers of goods (consignees). They were asked to describe a recent shipment that was at least partly transported during the morning or the afternoon peak. The presented alternatives varied in transport time, transport costs, the midpoint and the width of the delivery window. The data is used to estimate discrete choice models. The best fitting model was a model with a Box-Cox formulation for costs and a logarithmic description of times up to 1 hr and a time coefficient of zero for longer times.

The results are used to build a time-of-day-model with seven periods (including the morning and the afternoon peak). The model is calibrated with data of the base year and forecasts changes in the future. The model is described in detail in (de Jong et al. 2014).

To show the sensitivity of the model to policy changes two simulations have been carried out on the population-reweighted sample of receivers. In the first all transport times during morning and afternoon peak are increased by 10 % and in the second all costs during these periods become 10 % higher. The effects of the policies are shown in Fig. 1.4.

In the basis case 21.7 % of all transports are during the morning peak (07.00–09.00 a.m.). An increase of the transport time decreases this share to 21.66 %. The corresponding elasticity is thus −0.02. For the afternoon peak (04.00–07.00 p.m.) the elasticity has a value of −0.08.

Increasing the costs by 10 % has a much larger effect on the time choice. The share during the morning peak decreases to 15.09 % corresponding to an elasticity of −3.05 (−2.34 for the afternoon peak).

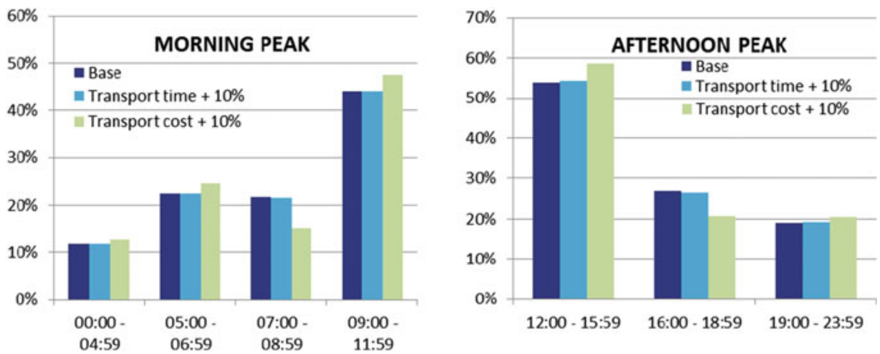

Fig. 1.4 Modelled impact of changes in transport cost and time during the morning peak (*left*) and during the afternoon peak (*right*) (de Jong et al. 2014, colors adapted)

1.5 Conclusion

The Flemish strategic freight model version 4.1.1 is more than an update of the strategic freight model version 1.6. The new version includes a nested logit model of mode and vehicle-type choice as well as a model for time-period choice (on top of also containing a logistics module, which was adopted from the previous version).

For the modal estimation a calibrated deterministic model for road transport has been developed. The mode and vehicle-type choice is estimated with nested logit models for 20 commodities. The coefficients have reasonable values and can be used to forecast the traffic demands for freight transport in Belgium.

By comparing the elasticities with results from literature (see Table 1.8) we find good agreement for the road and rail elasticities (price and time). For IWW the observed elasticities are higher than in the NODUS model and in the Dutch BASGOED.

The time period choice is almost not sensitive to increases in transport time but very sensitive to cost changes.

Table 1.8 Comparison of the average elasticities determined in this study and other studies from literature

	Price elasticities			Time elasticities		
	IWW	Rail	Road	IWW	Rail	Road
NODUS model (RAND Europe 2002)	−0.76					
(Significance en CE Delft 2010)		(−0.8 to −1.6)				
(Significance en VTI 2010)			−0.40			
(Significance, NEA en DEMIS 2010)	−0.28	−0.87	−0.50	−0.30	−0.23	−0.18
This study	−1.44	−0.91	−0.21	−1.01	−0.47	−0.13

For this study the average is determined by weighting the elasticities of each commodity with the amount of ton kilometers

Appendix

Table 1.9 Overview of the 20 commodities used in the Flemish freight model

NST	Description
1	Products of agriculture, hunting, and forestry; fish and other fishing products
2	Coal and lignite; crude petroleum and natural gas
3	Metal ores and other mining and quarrying products; peat; uranium and thorium
4	Food products, beverages and tobacco

(continued)

Table 1.9 (continued)

NST	Description
5	Textiles and textile products; leather and leather products
6	Wood and products of wood and cork (except furniture); articles of straw and plaiting materials; pulp, paper and paper products; printed matter and recorded media
7	Coke and refined petroleum products
8	Chemicals, chemical products, and man-made fibers; rubber and plastic products; nuclear fuel
9	Other non-metallic mineral products
10	Basic metals; fabricated metal products, except machinery and equipment
11	Machinery and equipment n.e.c.; office machinery and computers; electrical machinery and apparatus n.e.c.; radio, television and communication equipment and apparatus; medical, precision and optical instruments; watches and clocks
12	Transport equipment
13	Furniture; other manufactured goods n.e.c.
14	Secondary raw materials; municipal wastes and other wastes
15	Mail, parcels
16	Equipment and material utilized in the transport of goods
17	Goods moved in the course of household and office removals; baggage and articles accompanying travelers; motor vehicles being moved for repair; other non-market goods n.e.c.
18	Grouped goods
19	Unidentifiable goods
20	Other goods n.e.c

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Chapter 2
Building a Model of Freight Generation with a Commodity Flow Survey

Duy-Hung Ha and François Combes

2.1 Introduction

In freight transport models, freight generation is the stage which estimates the amount of cargo generated or attracted by establishments or by geographic zones. The literature distinguishes two classes of models: on the one hand Freight Generation (FG) and Freight Attraction (FA) models, which are the production and attraction of cargo measured in tonnage (or volume), on the other hand Freight Trip Production (FTP) and Attraction (FTA) models, which regard the number of vehicle movements (Holguin-Veras et al. 2014).

Generation models can be estimated with aggregate or disaggregate data. Disaggregate data is interesting because it avoids aggregation biases. It also allows, in some cases, to investigate the influence of variables which only make sense at the disaggregate level, or the presence of non-linear effects. Finally, disaggregate models can be a good basis to disaggregate aggregate data (for example, regional freight data could be disaggregated to the city level with the appropriate establishment dataset and a reliable disaggregate generation model).

The estimation of disaggregate generation models requires disaggregate data at the establishment level. This data is obtained through surveys targeted at business establishments, such as commodity flow surveys. Establishments are typically described by the economic activity sector, economic size (workforce or turnover), location, and type (offices, plant, warehouse, etc.). Variables about production,

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logistics, relationships of the establishments with their business partners (providers, clients, carriers) are generally not described. With adequate data, it is possible to estimate both Freight Generation (FG) and Freight Trip generation (FTG) volumes, as in Holguin-Veras et al. (2012a), who show that FG and FTG do not obey to the same logic.

The French shipper survey ECHO was realized in 2004–2005. This survey was designed to investigate the relationship between freight transport, production and supply chains, among other objectives. As a consequence, a limited number of establishments were surveyed, but a large number of variables were observed for each of them. In particular, this survey provides information on the economic characteristics of shippers (economic sector, turnover, workforce, etc.), production (number of product ranges, number of SKUs (stock keeping unit), etc.), logistics (share of transport costs in the product value, etc.) and economic relationships (number of clients, carriers, type of contract with carriers, etc.), as well as the total number of tons carried out or received per year, and the number of shipments sent per year. As such, this dataset offers the opportunity to statistically analyze the relationship between freight generation and many variables which are usually not observed. Shipment frequency is probably strongly correlated to FTG, but not identical: it is very likely that a unique vehicle can leave an establishment carrying many shipments sent to distinct destinations when the vehicle's destination is a break-bulk platform.

The objective of this study is to build a disaggregate generation model with the ECHO dataset. Generation was studied in the ECHO database by Rizet and Hémery (2008), who examined the relationships between generation, attraction, and some of the variables in the database, but did not investigate the interactions effects, and did not estimate models. In Sect. 2.2, the ECHO dataset is described, as well as the variables of interest for the paper. Section 2.3 describes a sequential analysis of the influence of the explanatory variables on generation using ANOVA and ANCOVA. Then, Sect. 2.4 presents generation and attraction models estimated by ordinary-least-squares, with a number of different specifications. Section 2.5 concludes the paper.

2.2 Presentation of the Data

The ECHO dataset provides information on 10,462 shipments sent by 2,935 French shippers, obtained by face-to-face and phone interviews, and based on closed questionnaires. It is similar to a commodity flow survey or CFS; its main particularity is that it provides very detailed information on the shipper-receiver relationship, and on the way the shipments were transported (Guilbault and Soppe 2009).

In the ECHO survey, a shipper is an establishment. Each shipper is described by a large number of variables, some typical (economic activity, workforce, turnover) and others not. In this study, the dependent variables are: the freight volume generated by the establishments in tons per year E_i, the freight volume attracted by the establishments in tons per year A_i, and the number of shipments sent by the establishment per year S_i. In the following, these variables are transformed into logarithms.

The explanatory variables are categorized into four groups:

- Economic activity: shippers are described by their economic activity group *G*, and by their turnover *T* (turnover is not available directly in the ECHO database, it was discretized into nine classes).
- Relationship with the economic environment: shippers are described by the type of contract *TC* they most often have with carriers (three levels: long period contracts, occasional contracts, or both); the number of clients *Ncl* which constitute 80 % of their activity; and the number of carriers or freight forwarders *CR* with which they worked during the year.
- Organization of the production: the number of distinct product ranges *Npr*, the number of references or SKU *Nr*, and the share of transport cost in the product value *CT*.
- Employment: shippers are described by the number of employees *N* and by their main qualification level *L* (four levels: unskilled, without certification, skilled, highly skilled).

Many of these variables are completely absent from classic freight transport databases: freight transport databases, targeted at carriers, typically do not observe shippers; while commodity flow surveys, targeted at shippers, do not cover the same range of information (see Table 2.1).

The objective of the paper is to analyze the relationship between these explanatory variables and the dependent variables, and then to estimate freight generation models.

2.3 Analysis of the Explanatory Variables

2.3.1 Methodology

The main tools used in this section are the analysis of variance (ANOVA) and the analysis of covariance (ANCOVA); their principles are briefly summarized below.

Table 2.1 Explanatory variables for shipper *i*

Category	Qualitative variables	Quantitative variables
Economic activity	Shipper activity group *G* Slices of turnover *T*	
Relations with economic agents	Type of contract with carriers or freight forwarders *TC*	Number of clients log(*Ncl*) Number of carriers *CR*
Production and logistics characteristics		Number of references log(*Nr*)
		Share of transport cost in product value log(*CT*)
Employment	Labour qualification level *L*	Number of employees log(*N*)

Analysis of variance

Many of the explanatory variables in the ECHO database are categorical ones; the first step to determine whether they have an influence on the dependent variable is the analysis of variance, or ANOVA (Tenenhaus 1996). The ANOVA methodology requires that the dependent variables are normally distributed, which is why E_i, A_i and S_i are transformed into logarithms. It also requires that for each sub-group defined by the categorical explanatory variables, the distribution of the dependent variable is normal, and that the variance is the same among the sub-groups (homoscedasticity).

The one-way ANOVA models is generally used and formulated as follows:

$$Y_{ik} = \mu + \alpha_i + \epsilon_{ik} \tag{2.1}$$

where Y_{ik} is the continuous dependent variable of the kth value in the sub-population i of independent variable μ is the average level value of; α_i is the effect of the sub-population i of X on Y; and ϵ_{ik} is the error term.

The ANOVA procedure also allows examining the effect of interaction between categorical variables on the dependent variable Y. In particular, the two-way ANOVA model is written as follows:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \epsilon_{ijk} \tag{2.2}$$

where Y_{ijk} is the kth value in the sub-group corresponding mutually to the sub-population j of the second independent variable X_2 and the sub-population i of the first independent variable X_1; μ is the average level value of Y; α_i is the effect of the sub-population i of X_1 on Y; β_j is the effect of the sub-population j of X_2 on Y;$(\alpha\beta)_{ij}$ is the effect of the interaction between the ith sub-population of X_1 and the jth sub-population of X_2 on Y; and ϵ_{ijk} is the error term.

In practice, the F-test is applied to verify the null hypothesis of the equality of means among the distinct sub-populations. However, this test is only valid under the hypothesis of homoscedasticity. This null hypothesis can be tested using Levene's statistic. If the test fails, i.e. if there is heteroscedasticity, then other tests can be applied, such as Welch's test to test the equality of means (Welch 1951).

Analysis of covariance

The analysis of covariance is a technique treating both continuous and categorical explanatory variables in relationship with a continuous dependent variable. The categorical explanatory variables in ANCOVA models are called independent *factors* while the continuous explanatory variables are called *covariates*. The ANCOVA is in fact a combination between the ANOVA analysis and the linear regression.

ANCOVA analysis allows increasing the statistic explicative power of the model, because the effects of the factors are adjusted after considering the variability of the covariates. The interaction between the factors and the covariates are also analysed and estimated in ANCOVA.

In general, the ANCOVA models are formulated as follows:

$$Y_{ij} = \mu + \tau_i + \beta X_{ij} + \phi_i X_{ij} + \epsilon_{ij} \tag{2.3}$$

where Y_{ijk} is the jth observed response value of Y in the ith sub-population of the independent variable X; μ is the average level value of Y; τ_i is the effect of the sub-population i of X on Y; β is the overall slope of the model; ϕ_i is the effect of the ith sub-population of X on the slope of Y; and ϵ_{ij} is the error term.

For both the ANOVA and ANCOVA, a series of statistical tests exist, testing against the null hypothesis of the absence of effect of a given explanatory variable on the mean values of the dependent variable. One of the main advantages of ANOVA and ANCOVA methodologies is that they allow to quickly test not only whether the explanatory variables have a significant effect, but also to analyze the pairwise comparisons between subgroups of that variable.

2.3.2 *Results*

In this section, the influence of explanatory variables on shippers' emissions, attractions and shipments is analyzed. Beforehand, the dependent variables are described with a bit more detail.

Table 2.2 shows that the distributions of the generation and attraction volumes and the shipment frequency span very wide ranges, and are extremely skewed. The generation and attraction distributions are relatively similar. By contrast, the logarithm distributions are symmetric, and, incidentally, the distribution of the logarithm of the shipment frequency is similar to the other two (although the standard deviation is substantially smaller). Finally, the normal qq-plots show that the distributions of the three variables are reasonably close to normal (as confirmed by the histograms in Fig. 2.1).

Table 2.2 Dependent variables descriptive statistics

Variable	N	Min	Median	Mean	Max	Std
Generation volume (in natural logarithm)	2935	1	4,600	52,773	6,414,000	235,716
		0	8.434	8.299	15.654	2.641
Attraction volume (in natural logarithm)	2935	1	4,614	38,588	7,500 000	187,421
		0	8.437	8.179	15.830	2.628
Shipment frequency (in natural logarithm)	2935	3	3,900	21,350	3,000,000	90,737
		1.099	8.269	8.260	14.910	1.838

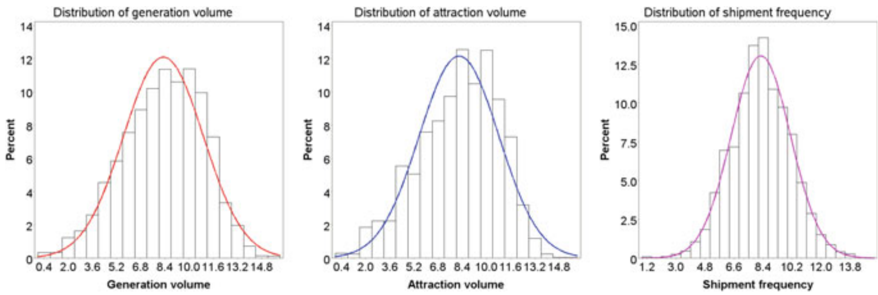


Fig. 2.1 The normality of distribution of the dependent continuous variables

Economic activity

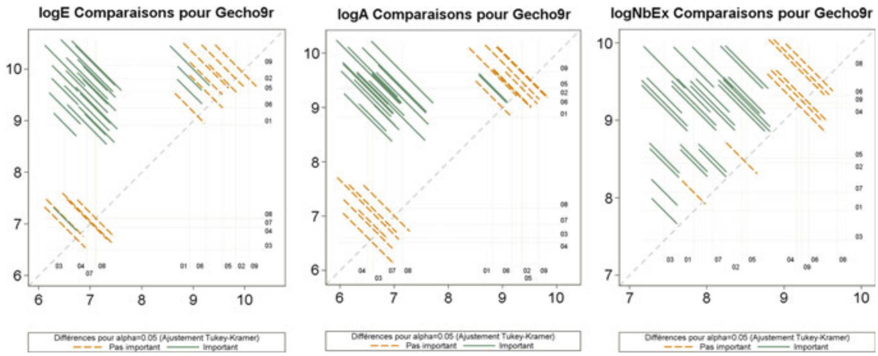
In France, the economic activity of an establishment is described on the basis of the NAP classification of the French Statistics Institute INSEE. This classification, which distinguishes 700 classes, was used to design the sampling pattern of the ECHO survey. In the ECHO database, these classes have been grouped in nine broad categories, to ensure significance:

1. Intermediate goods industry
2. Intermediate goods wholesale
3. Productive assets industry
4. Productive assets wholesale
5. Agri-food industry
6. Agri-food wholesale
7. Consumer goods industry
8. Consumer goods wholesale
9. Warehouses

One-way ANOVA shows that this classification has a significant effect on generation, attraction, and shipment frequency. Levene's test rejects the null hypothesis of homoscedasticity *it* with a p-value lower than 0.001. The Welch test is then applied, and rejects the hypothesis of equality of means.

In addition to this global conclusion, pairwise comparisons can be made. Figure 2.2 presents a diffogram of Tukey's multiple comparison adjustment, which allows to examine quickly and efficiently which groups differ and which do not. In a diffogram, each line corresponds to a pairwise comparison between two subgroups, indexed by the projection of the line's midpoint to the vertical and horizontal axes. Furthermore, the projection of each line on each axis allows us to obtain the corresponding confidence interval of the subgroups. Hence, if the line crosses the diagonal line, the difference is not significant. In that case, the line is orange and dotted. In the contrary case, the line is green and solid, and the difference between the two sub-groups is significant.

Figure 2.2 shows that generation and attraction volumes share similarities. Two groups can be distinguished: the group including (03, 04, 07, 08) from the group



Generation volume *Attraction volume* *Shipment frequency*

Fig. 2.2 Pairwise comparison of the groups of shipper activities

including (01, 02, 05, 06, 09). Broadly speaking, shippers of the agri-food, intermediate goods or warehousing sectors behave similarly with respect to freight generation and attraction, and differently from shippers of the productive assets or consumer goods sectors. In both cases, industry and wholesale are grouped together.

In the case of the shipment frequency variable, the sub-populations are more segmented. There are similarities between activity groups 04, 06, 08, 09, i.e. wholesale and warehousing, except for intermediate goods wholesale.

The other economic variable in the ECHO dataset is the turnover. The exact turnover is not available: the ECHO dataset provides a categorical variable with nine levels. The ANOVA concludes that the four lower tiers of turnover are similar in terms of generation and attraction, while all the others are distinct from this first group and from one another.

Relations with economic agents

As explained above, the three variables examined here are the main type of contract between the shipper and its carriers (three values: long period contracts, occasional contracts, or both); the number of clients *Ncl* which constitute 80 % of their activity; and the number of carriers or freight forwarders *CR* with which they worked during the year. For the first one, an ANOVA analysis is made. For the two others, correlations between them and the explanatory variables are calculated. The results are summarized in Table 2.3.

Again, freight generation and attraction are similar, but shipment frequency is different. In all three cases, the relationship between the type of contract and all the dependent variables is significant. This is the same for the number of carriers.

However, the number of clients making up to 80 % of the shipper's turnover has no visible influence on freight generation and attraction. On the contrary, this variable is clearly correlated with shipment frequency. As a matter of fact, shipment frequency is much more closely related to the structure and constraints of the

Table 2.3 Correlation (Pearson's coefficient) of the business relationships of the shipper and generation

Variable name	Variable signification	Generation volume	Attraction volume	Shipment frequency
TC	Type of contract with carrier	Significant influence	Significant influence	Significant influence
Ncl	Number of clients	Not correlated	Not correlated	9.7 %
Log(*Ncl*)	Number of clients (logarithmic scale)	Not correlated	Not correlated	30.5 %
CR	Number of carriers	29.40 %	29.70 %	16.60 %
log ($CR + 1$)	Number of carriers (logarithmic scale)	27.54 %	27.67 %	14.94 %

logistic chains than commodity flows measured in tons per year. For a given establishment, more clients means a more dispersed supply chain, with more destinations, and the need to send smaller and thus more frequent shipments. There is no such relationship between number of clients and commodity flows.

Production and logistics characteristics

The variables examined here are the number of distinct references *Nr*, and the share of transport cost in the product value *CT*.

Table 2.4 shows, again the similarity between generation and attraction volumes: there is no clear relationship between them and the number of SKUs or the number of product ranges. However, there is a clear relationship between them and the share of transport costs in the product's value. Shipment frequency works very differently: more SKUs or product ranges clearly means more frequent shipments. From a logistic perspective, this is understandable: each SKU is distinct from the perspective of clients; and they are most often not easily substitutable. Therefore, each SKU needs its own supply chain, which means more frequent shipments than

Table 2.4 Correlation (Pearson's coefficient) between production and logistic characteristics and the explanatory variables

Variable name	Variable signification	Generation volume	Attraction volume	Shipment frequency (%)
Nr	Number of SKUs	Not correlated	Not correlated	19.60
log(*Nr*)		Not correlated	Not correlated	33.93
Npr	Number of product ranges	Weak correlation (<5 %)	Weak correlation (<5 %)	9.4
log(*NPr*)		Weak correlation (<5 %)	Weak correlation (<5 %)	12.8
CT	Transport cost share in total sale price	14.53 %	13.42 %	7.04
log(*CT*)		16.03 %	13.76 %	8.30

for a supply chain of homogenous products. Note shipments may be carried together; more frequent shipments do not necessarily mean more frequent vehicle movements (or at least not proportionally).

Employment

Two variables regard employment in the ECHO dataset: the number of employees, and a qualitative appreciation of their overall skill. The number of employees is strongly correlated to the generation and attraction volumes, as well as to the shipment frequency. An ANOVA analysis also concludes that the overall skill level has a significant influence on freight generation and attraction volumes. More precisely, a pairwise comparison of the different levels shows that there are two groups: all the shippers where the employees are less than ‘highly skilled’, and the others. For the shipment frequency, the relationship is significant, but it is less easy to interpret the pairwise comparison.

As a conclusion to this section, the ECHO dataset contains a large amount of information about shippers, their economic activities, production, workforce, logistic characteristics, and relationships with other establishments and carriers. The analyses presented in this section help to draw first conclusions about the relationships between all these variables and the dependent variables of freight generation. Besides, the literature has shown that freight generation and freight trip generation work very differently (Holguin-Veras et al. 2014); this study shows that freight generation and shipment frequency also work very differently. This is not that surprising, given the fact that shipment frequency and freight trip generation are probably closely correlated.

2.4 Generation Models

The second objective of the paper is the estimation of generation models. Two types of models are estimated: exploratory models, making the most of the information available in the ECHO dataset, and pragmatic models, using only variables which are expected to be reasonably easily available to a freight transport modeler. In each case, generation, attraction and shipment frequency are analyzed and compared.

In practice, three groups of models are examined: first, only quantitative exploratory variables are introduced. Second, quantitative and qualitative variables are both taken into account: in this category, the most complete specifications are examined. In the third category, simpler models are presented and discussed.

2.4.1 Models with Quantitative Explanatory Variables

Regarding generation and the characteristics of establishments, the continuous variables in the ECHO database are the number of employees ($\log(N)$), the number

Table 2.5 Generation models, quantitative explanatory variables

Estimated model	R^2
$log(E_i) = 4.63 + 0.86log(N_i)$	0.156
$log(E_i) = 3.95 + 0.77log(N_i) + 0.49log(CT_i) + 0.046CR_i$	0.223
$log(A_i) = 4.19 + 0.93log(N_i)$	0.183
$log(A_i) = 3.58 + 0.85log(N_i) + 0.45log(CT_i) + 0.044CR_i$	0.239
$log(S_i) = 5.98 + 0.53log(N_i)$	0.124
$log(S_i) = 4.20 + 0.52log(N_i) + 0.22log(Ncl_i) + 0.15log(Nr_i)$	0.281

of SKUs (log(*Nr*)), and the number of clients (log(*Ncl*), number of carriers (*CR*), and share of transport costs in the commodity sale price (log(*CT*)).

Table 2.5 presents models for generation, attraction and shipment frequency. In each case, there are two models: one with the number of employees as an explanatory variable, and one with all the significant continuous variables.

The generation and the attraction models are similar: the same variables are significant, the coefficients share similar orders of magnitudes, and the R^2 are equivalent. In both cases, the commodity flows are a bit less than proportional to the number employees. Furthermore, generation and attraction increase with the share of transport costs in the products' sales price: intuitively, larger commodity flows imply higher transport costs, and this cost increase is not necessarily compensated by an increase of the market price of these commodities. There is also a significant correlation between the number of carriers and the commodity flows, although the explanation is less clear. In both cases, the R^2 coefficient is rather low, just below 0.25.

The shipment frequency model differs strongly from the two other models. While it seems to be proportional to the number of employees according to the first model, this does not hold with the second, more complete specification. This is consistent with the theory and empirics about the relationship (or lack thereof) between commodity flow and shipment frequency, as theorized in Baumol and Vinod (1970) and explained in Holguin-Veras et al. (2014). In addition, in the second model, the other explanatory variables are the number of SKUs and the number of clients, two variables which, as explained above, are intimately related to the structure of the supply chain of the shipper. Both variables have a positive impact on shipment frequency. They also have a substantial explanatory power, bringing the R^2 up to 0.281 from 0.124.

2.4.2 Models with Quantitative and Qualitative Explanatory Variables

This section takes more complete models from the previous section and introduces the following qualitative variables: the economic activity sector *G*, the turnover category *T*, the labor qualification *L*, and finally the main type of contract between the shipper and its carriers *TC*.

Table 2.6 Generation models, quantitative and qualitative explanatory variables

	Linear regression (LR)	(LR) and G	(LR) and G*T	(LR) and G*T*L	(LR) and G*T*L*TC
Coefficient of $log(N_i)$	0.7735	0.9745	0.4970	0.4755	0.4418
Contribution Type 1 SS of $log(N_i)$ (%)		31.48	17.79	15.91	13.64
Contribution Type 1 SS of interactions (%)		53.75	66.38	70.05	74.34
R^2	0.223	0.484	0.511	0.576	0.672

Table 2.7 Attraction models, quantitative and qualitative explanatory variables

	Linear regression (LR)	(LR) and G	(LR) and G*T	(LR) and G*T*L	(LR) and G*T*L*TC
Coefficient of $log(N)$	0.8507	1.0362	0.5803	0.5328	0.4940
Contribution Type 1 SS of $log(N)$ (%)		37.49	24.10	20.68	17.70
Contribution Type 1 SS of interactions (%)		48.93	62.00	67.41	72.12
R^2	0.239	0.471	0.495	0.577	0.675

Table 2.8 Shipment frequency models, quantitative and qualitative explanatory variables

	Linear regression (LR)	(LR) and G	(LR) and G*T	(LR) and G*T*L	(LR) and G*T*L*TC
Coefficient of $log(N)$	0.5160	0.5918	0.3920	0.4042	0.3896
Contribution Type 1 SS of $log(N)$(%)		33.58	22.43	18.68	14.70
Contribution Type 1 SS of interactions (%)		23.62	33.74	44.77	56.55
R^2	0.281	0.369	0.373	0.445	0.566

These variables are introduced using the ANCOVA methodology, which means they modify the models' intercepts and the coefficient of explicative variable log (N). For all three models (generation, attraction and shipment frequency), the variables are introduced sequentially. The starting points are the models estimated in Sect. 2.3.1. Tables 2.6, 2.7 and 2.8 report the models' R^2, the coefficient of the number of employees (on a logarithmic scale) and its share in the model variability, the contribution of the interactions between the qualitative variables to the model variability, and the number of non-significant subgroups, for generation, attraction and shipment frequency respectively.

The introduction of the qualitative variables and their interactions increases significantly the model's explanatory power. The best generation model without these variables has a R^2 of 0.223; the R^2 jumps to 0.672 with all the qualitative variables. The most important improvement is due to the introduction of G, i.e. the economic sector (in the log specification, this is akin to modifying the model's slope with respect to G). With the introduction of turnover, the R^2 does not increase much, but the coefficient of log(*N*) decreases substantially: this is to be expected; both variables are correlated, and correlated with the economic activity of shippers, and thus to the amount of commodity they generate. Labor qualification is also very significant: establishments with unskilled workers have very different generation patterns than those with highly skilled workers. Finally, the type of contract bound with carriers CT also brings information about freight generation; although in this case the opportunity of using this variable in a simulation model is questionable: there is a real risk of endogenous bias (cf. Table 2.7).

Once again, the attraction and the generation models behave in remarkably similar ways. The log(*N*) coefficients are consistently but marginally larger; the R^2 coefficients are very similar. The introduction of additional variables and interactions increases the models' explanatory power at the same pace.

The introduction of the qualitative variables does not increase the shipment frequency models' explanatory power as much as the generation and attraction ones, with a maximum R^2 at 0.57 instead of 0.67. However, the improvements brought by each new variable to the shipment frequency models are comparable, in relative terms, to those of the other two groups of models.

In all these models, the explanatory power comes at the cost of the introduction of a very large number of subgroups. G introduces 9 subdivisions; with the three other variables, there are 571–641 subgroups, depending on the model (a half to two thirds of these models are not significant). This raises the question of the model's robustness, and of its usefulness. The main conclusion of this part is that regularities can be found between freight generation and shipment frequency and variables regarding such different fields as economic activity, labor's level of skill, carriers contracts, and so on. Another conclusion is that employment and the type of activity are solid explanatory variables, fortunately often available, and are a good basis to build a pragmatic freight generation model.

2.4.3 Simple Models

In this section, a third group of models is introduced. In order to develop models which can be used with limited data, the explanatory variables are limited to the sector of activity, and to the number of employees. In these models, the interaction between the number of employees and the sector of activity is examined. The estimations are reported in Table 2.9.

From Table 2.9, a number of conclusions appear: first, generation and attraction can be considered as proportional to the number of employees, except for a few

Table 2.9 Simple models (number of employees and sector of activity)

Variable	Generation	Attraction	Shipment frequency
Intercept	4.20***	3.68***	5.65***
1 (Intermediate good industry)	0.0033	0.20	−0.54*
2 (Intermediate good wholesale)	2.88***	2.47***	−0.027
3 (Productive asset industry)	−2.01***	−1.90***	−1.46***
4 (Productive asset wholesale)	−1.79*	−0.95	−1.45*
5 (Agri-food industry)	1.44***	2.19***	0.50
6 (Agri-food wholesale)	0.50	0.92	0.67
7 (Consumer good industry)	−2.48***	−2.61***	0.048
8 (Consumer good wholesale)	−0.25	−1.19	0.98°
Intercept	4.20***	3.68***	5.65***
log(N)	0.99***	1.08***	0.72***
1 × log(N)[a]	0.070	0.031	−0.11°
2 × log(N)	−0.26*	−0.23·	0.035
3 × log(N)	−0.016	0.019	0.016***
4 × log(N)	0.14	−0.13	0.52*
5 × log(N)	−0.080	−0.26**	−0.17
6 × log(N)	0.15	0.079	0.032***
7 × log(N)	0.19**	0.20**	−0.20
8 × log(N)	−0.20	0.11	0.045
# Observations	2935	2935	2935
R^2	0.454	0.449	0.291
Adjusted R^2	0.451	0.445	0.287

Significance levels *** p-value < 0.001; ** p-value < 0.01; * p-value < 0.05; ° p-value < 0.1
[a](and below) interaction between economic sector and number of employees: for example, the coefficient of log(N) in the generation model of the first economic sector is not significantly different from 0.99; the coefficient of the second economic sector is significantly lower

cases (generation increases more slowly in intermediate good wholesale, attraction in the agri-food industry; both increase faster in the consumer good industry).

Second, this is not the case for shipment frequency. Shipment frequency increases less than proportionately to the number of employees. There are significant differences in the productive asset industry and in the agri-food wholesale sector, but the orders of magnitude of the coefficients are similar. Third, generation and attraction are, once more, similar, and the R^2 coefficient is acceptable, at 0.45. The situation is far less satisfying in the shipment frequency model. The last model loses a lot of information compared with the models in Sect. 2.4.2; however those models rely on measures which are usually not available.

2.5 Conclusion

This study took the opportunity offered by the French shipper survey to estimate a disaggregate freight generation model, with a distinction of generation, attraction and shipment frequency. It confirmed that while generation and attraction work in similar ways, this is not the case of shipment frequency, which is not driven by the same economic and logistic mechanisms. Three categories of models were presented, illustrating the potential of using rich datasets to model statistically the behavior of shippers, but also the limitations of models relying on less variables.

The ECHO dataset contains variables that are usually unavailable. This study examined how they impacted statistically the dependent variables. Consistently with the literature, the number of employees and the economic sector were identified as very important explanatory variables. However, other variables also have a substantial explanatory power, such as the share of transport prices in products' sales price on generation and attraction, or the number of product ranges and product references (SKUs) on shipment frequency.

This study is part of an ongoing work, of which the next step is to increase the accuracy of the economic segmentation, and to also introduce a distinction of the types of generated and attracted products (the models developed in this paper only consider the tons sent and received without distinguishing commodity types). In the long term, the objective is to use these results to disaggregate French aggregate freight generation and attraction data at fine spatial levels.

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Chapter 3
Freight Transport Demand Modelling

Typology for Characterizing Freight Transport Demand Models

Carina Thaller, Benjamin Dahmen, Gernot Liedtke and Hanno Friedrich

3.1 Introduction

Freight transport volumes and performances have continuously grown during the past decades. This trend has resulted in a greater susceptibility and risk of congestion of traffic systems and in increasing environmental and ecological costs of freight transport.

In this way, the requirements concerning quantity and quality of transport forecasts and the resulting assessments of transport impacts have increased.

Manifold political measures generate both positive and negative effects (costs and benefits). Consequently, future freight transport demand models shall not only calculate the effects of investment projects and basic infrastructural measures but also contribute to impact assessments of complex behaviour changing measures like City-Logistics concepts.

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Due to the structural heterogeneity of freight transport and its long-term subordinate consideration, there have been low research activities in this field as well as low motivations to integrate this segment into transport demand models for decades. There is also no generally valid framework[1] for freight transport modelling in comparison to passenger transport modelling. Without a common framework, it is difficult to exchange ideas between scientists and to enable an efficient communication and solid agreements between a client and a contractor of a transport modelling service.

For this reason, the German Research Association for Roads and Traffic (Forschungsgesellschaft für Straßen- und Verkehrswesen, FGSV[2]) has initiated in 2011 the working group 1.8.4 *Design and Operation of Freight Transport Demand Models* who should discuss current and future issues regarding freight transport and the possibilities to illustrate freight transport by models.

In this contribution, the authors present an excerpt from this recommendation paper—a typological order of characteristics of freight transport demand models. Based on this typology, a systematic overview of selected international freight transport demand models is carried out and shown. The recommendation paper is still in progress and will be published in 2016.

First, the methodological approach of this contribution is presented. Thereby, a classification and typology or typological order are defined and differentiated. Afterwards, it will be explained why a typology is used to describe freight transport models and their characteristics in this case. In the next step, the development procedure of the typology and characteristics of freight transport models are described in detail. On the basis of the typology, a comprehensive description of selected freight transport models and a cross comparison by the defined characteristics is conducted. The paper closes with a short conclusion as well as an outlook on further research and action in the field of freight transport demand modelling.

3.2 Methodology

In this chapter, the selected methodology is presented and the methodological procedure for developing a typological order to characterize freight transport demand models is described.

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[1]e.g. validated modelling methods, generally accepted requirements for the quality of model data, results and assured knowledge about the behaviour-homogeneous groups of freight transport (c.f. Leerkamp et al. 2013).

[2]The FGSV is a non-profit association with a technical and scientific focus. The primary objective of the FGSV is the further development of knowledge on road traffic. It consists of several professional committees and working groups conducted by honorary members from research and practice.

3.2.1 Classification Versus Typology

For systemizing complex objects two system-building methods—classification and typology—are applicable (c.f. Ahlert and Evanschitzky 2003; Algermissen 1975):

A "classification" carries out a categorization of objects according to specific characteristics. In the multi-level classification the division or grouping of individual characteristics may be carried out successively and is not interconnected, with other words: the generated classes are mutually exclusive. In general, a classification is used for the systematic order of given sets by objects. These objects are grouped into more than one subset, which results in a subordinate relation.

In a "typology" the objects of investigation are summarized to types due to several characteristics with related key values. That means any type represents no less than two attributes. Problems, like one object integrates in more than one class or generated classes are without any object, can be avoided with the system-building method "typology". Types are distinguished by a subdivided form. The attributes within types are given equal importance in typological methods. In contrast to the method of classification, the typology has the higher information content. The reason for this is that at least two attributes are considered, and this method works without the static requirement for the clear assignment of objects to classes. This approach for systemizing freight transport demand models is more suitable than a classification.

The approach for developing a typological order and the subsequent process of type formation thereby includes several methodical measures which are assigned to a two component procedure. First, the focus is on a selection of characteristics and the characteristic values, subsequently the combination of key values to types is carried out. A typological order enables an extensive description of freight transport demand models with their specific characteristics and structures. The individual characteristics are considered equivalent.

The typological procedure for systemizing freight transport demand models is outlined and discussed in detail in the following.

3.2.2 Development of the Typological Order and Selection of State of the Art Models

First, the experts of the FGSV working group discussed and defined characteristics for describing and explaining freight transport demand models. In the next step, a typological order was derived which enables the characterization of freight transport demand models, their structures and functionalities. A further step was an extensive literature analysis of the state of the art in this field. On the basis of the typological order, selected models with their different characteristics and structures were analysed in detail. Each member of the working group had either experience in the development, application or examination of freight transport models. Therefore, knowledge about a variety of internationally known models could be connected. Existing reviews of freight transport models were taken into consideration as well (c.f. BMVBW 2001; Ben-Akiva et al. 2013; de Jong et al. 2004, 2012; Chow et al. 2010; Gentile and Vigo 2007; Leerkamp et al. 2013).

3.3 Typology of Characteristics of Freight Transport Demand Models

In this chapter the typology for characterizing freight transport demand models is presented.

In the first step of the typology development freight transport models are distinguished by following characteristics: level of aggregation, scale of analysis, reference values and spatial resolution. Based on these characteristics freight transport demand models can be analysed more precisely. The typology is shown in Fig. 3.1. This first part of the typology already allows drawing conclusions as to required data, areas of application, system boundaries and the modelling approach. In the second step, which is also presented, the typology can be extended by means of modelling steps. The characteristic reflects which logistics decisions are reflected in the models.

Level of Aggregation

The first characteristic of a freight transport model is its *level of aggregation*. Models can either be aggregated or disaggregated (Mest 2011). Aggregated models require that the area of observation is segmented in traffic analysis zones (TAZ). Subsequently, the demand is generated per TAZ. For the calculation of demand structural data at the level of the TAZ as well as data on traffic behaviour are needed. For the disaggregated freight transport models the focus lies on the individuals within the area of observation. The behaviour of companies or behaviour-homogenous groups of companies has to be considered. The calculation of the transport demand is

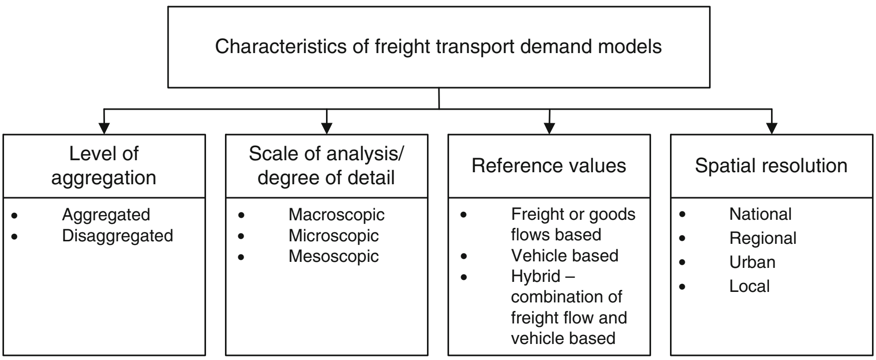

Fig. 3.1 Characteristics of freight transport demand models (*Source* Own diagram)

based on these groups. Agent-based models form a subgroup of disaggregated models. In agent-based models an individual derivation of activities of agents takes place, so that the whole system is characterized by the activities of the individual actors (Thaller 2013). The data basis consists of disaggregated data (Mest 2011).

Scale of Analysis

Another analysis criterion is the *scale of analysis*. Here a distinction is made between macroscopic, microscopic and mesoscopic models (Mest 2011). In macroscopic models behaviour-homogeneous groups are formed and aggregated data is used, e.g. via good types or economic sectors (Tavasszy and Bliemer 2013; Thaller 2013). These models cannot depict the behaviour of single actors (Thaller 2013). Microscopic models calculate the transport demand from the actions of individual actors, whose behaviour is the object of observation. For questions concerning the impact of behaviour of single actors or of interactions between actors microscopic modelling approaches are preferred (Liedtke 2006). The third modelling method covers mesoscopic models. Mesoscopic models combine the macroscopic and the microscopic approach. To sum up, in macroscopic models vehicle or goods flows are illustrated, in microscopic models single agents or firms are in the focus of interest and in the mesoscopic models groups are analysed.[3]

Reference Values and Spatial Resolution

The *reference value*, hence the first occurring value of a model (for the trip generation), can be goods volumes, trips or vehicles or of a hybrid form. The data basis of flow models are statistical relationships between transport volumes and structural indicators of economic sectors. The reference value is a characteristic of the internal architecture or structure of a model. The flows of goods between two TAZ are converted into a flow of vehicles based on mathematical operations. The goods-related modelling approach implies a modelling of the modal choice. For the trip- and vehicle-related modelling the trips of vehicles are the primary objects of modelling. By means of structural data of the TAZ the traffic volume is generated. Since trip and vehicle-related models already generate transport demand differentiated by transport mode or vehicle type, they do not need to explicitly model the modal split (Leerkamp et al. 2013; Thaller 2013; Mest 2011). For hybrid models the characteristics of the good flow related as well as of the trip and vehicle-related approach are combined (Beagan 2007).

The *spatial resolution* of models is chosen according to their area of observation or area of examination. In this paper only freight transport demand models with a national, regional and urban scope are analysed.

[3]There is an analogy to macro- and microeconomics approaches. Macroeconomics examines the total system and the behaviour of and the interactions between decision-makers in this system (e.g. households, economics) at an aggregated level. Microeconomics study the economic behaviour of single economic actors (households or firms). They need disaggregated data.

Internal Architecture or Structure of the Models
Hereafter further characteristics of freight transport demand models are presented that extend the typology—the characteristics of the *internal architecture or structure of the models*. This involves modelling steps and the respective logistics decisions that are taken into consideration. This part of the typological order specifically deals with the structure of freight transport demand models and their calculation steps to generate the transport demand. The 9-step-algorithm based on Liedtke (2013) is an advancement of the 4-step-approach used for passenger traffic. Figure 3.2 shows on the left side the 9 modelling steps in freight transport modelling with a short explanation of each step, and on the right side the respective logistics decisions of stakeholders along the supply chain. It has to be noted that not every freight transport demand model depicts all of these modelling steps and logistics decisions.

Modelling Methods
For each step of the considered model the modelling methods, the mathematical formalisation and the required data are determined. On the basis of mathematical formalisations it is derived which concrete variables are taken into account and which data are necessary for the calculations. During this process the mathematical formula is looked at more closely and split into its components (see Fig. 3.3).

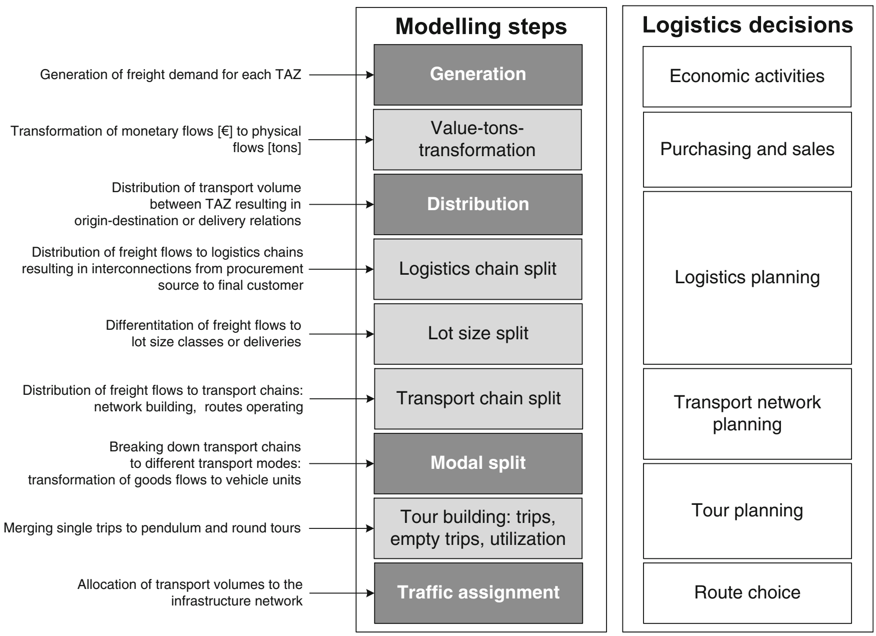

Fig. 3.2 Freight transport modelling steps and logistics decisions (*Source* Liedtke 2013; Tavasszy and Bliemer 2013; Mest 2011; Liedtke 2006; de Jong 2004; Falkner 2004)

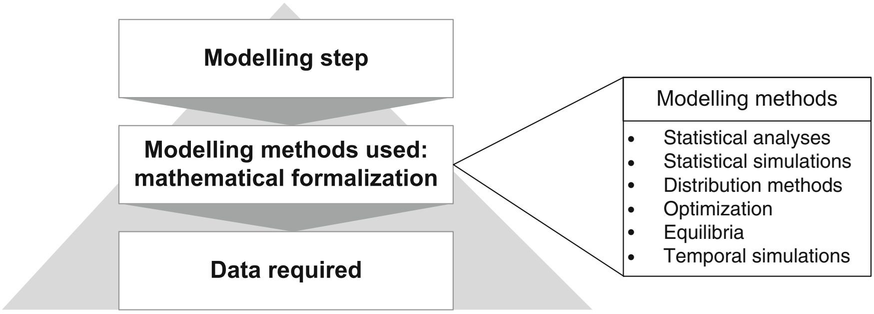

Fig. 3.3 Deriving data required from methods used for each modelling step (*Source* Own diagram)

In freight transport demand modelling specific formal methods and concepts are used and combined. The modelling methods can be differentiated in statistical analyses, statistical simulations, distribution methods, optimization, equilibria and temporal simulations.

In the following Table 3.1 modelling methods are defined, divided into sub-categories, and examples for specific applications given.

In this section a typological order as a means to characterize freight transport demand models was presented. To describe the used modelling methods in a more detailed way the modelling methods, the mathematical formalisation and the required data can be examined for each modelling step of a model.

3.4 Overview and Characterization of Selected Freight Transport Demand Models

In this chapter selected freight transport demand models will be analysed in the framework of the developed typological order. Using this typology the internal structure and their characteristics can be shown in detail.

An overview of the examined freight transport demand models is given below. In the process their functionality and their characteristics are discussed.

The examined models are CALGARY model, CMAP, FAME, Freight Transport Lab, Freturb, InterLog, KWM, LAMTA, SAMGODS/NEMO, SMILE, SWIM2, SYNTRADE, TCI-GV, VISEVA-W and WIVER. The following selection is therefore arbitrary to a certain extend. Still, the attempt was made to present a large cross-section of modelling approaches. Since some of these models can be commercially obtained, ratings of the models were avoided.

First, a characterization of the selected freight transport demand models is given by their level of aggregation, scale of analysis, reference values and spatial resolution (see Table 3.2).

Table 3.1 Modelling methods for freight transport demand modelling

Modelling methods	Definition	Subcategories	Examples for application
Statistical analytical methods	Evaluation of empirical collected data with statistical methods	Univariate procedures: fact acquisition, generation of key values	Arithmetic mean: e.g. trip generation rates per employee
		Multivariate procedures: relations between variables	Distribution: e.g. empirical distribution of distances
			Aggregated and disaggregated multi-variate regression
			Discrete choice models
			Cluster analysis
			Classification trees
			Variance analysis
			Data mining
			Factor analysis
Statistical simulation	Creation of an artificial population considering assumptions, knowing that the detailed structured may not be verifiable	Monte Carlo simulation	Creation of artificial company populations
			Creation of tours using a random generator
Distribution methods	Column and row totals of a matrix are split or a total is split in subsets (generally this problem is under defined)	Entropy maximization, disaggregation	Derivation of a matrix of flows based on row/column totals
			Derivation of detailed intersectoral relations based on aggregated IO-flows
Optimization	Formulating a mathematical optimization problem to describe the choices of individual actors	Convex/linear/integer/non-linear optimization	Route search in diverse models
		Exact and heuristic optimization	Route planning
			Lot size models based on Total Logistics Cost Minimization

(continued)

Table 3.1 (continued)

Modelling methods	Definition	Subcategories	Examples for application
Equilibria	Search for equilibria in markets and transport networks for a comparative analysis	Perfect competition	Traffic flow equilibria in diverse models
		Nash equilibrium	SCGE models (monopolistic competition)
		Monopolistic competition models	
Temporal simulation	Imitation of a system over time	Microscopic or macroscopic simulation	Simulation of traffic flows
	Objectives: finding equilibria or study of the course of time		Multi-agent simulation
			System dynamics

Source Own research

The next Table 3.3 shows the models analysed with their modelling steps and their respective methods used.

3.5 Conclusion and Outlook

In this contribution a typology for characterizing freight transport demand models is presented. The typology developed serves as a valid framework for freight transport modelling. By this instrument, the modelers and users from research and practice get an overview of different characteristics of such models, their internal model architecture and structure as well as existing modelling methods used. On this basis, an extensive description and explanation of freight transport demand models can be carried out, which is exemplary shown on 15 selected freight transport demand models.

The trend for freight transport demand models is towards a very detailed analysis. The modellers have recognised that there is the necessity to include logistics decision-making processes. These processes have been considered for the development of new freight transport demand models. Thereby the increased emergence of agent-based models in the recent past can be explained. Furthermore, a growing implementation of logistics strategies can be observed. Focussing on a microscopic scale of analysis has the consequence that, due to the heterogeneity of the decision-makers, the level of complexity for the modelling rises. This fact is accompanied by an increased need for disaggregated data which is limited. Therefore, in the near future, the objective is to obtain new enterprise and establishment-related data sources as input for the freight transport demand modelling (Leerkamp et al. 2013).

Table 3.2 Characterizing selected freight transport demand models by their level of aggregation, scale of analysis, reference values and spatial resolution

Model	Level of aggregation	Scale of analysis	Reference values	Spatial resolution
CALGARY model (CA) Hunt and Stefan (2007)	Disaggregated	Microscopic	Vehicle based	Urban
CMAP (US) Urban and Beagan (2011)	Disaggregated	Mesoscopic	Hybrid	Urban
FAME (US) Samimi et al. (2010)	Disaggregated	Microscopic	Goods flows	National
Freight Transport Lab (G) Schröder et al. (2012)	Disaggregated	Microscopic	Hybrid	Urban
Freturb (F) Routhier et al. (2007)	Disaggregated	Macroscopic	Vehicle based	Urban
InterLog (G) Liedtke (2006)	Disaggregated	Microscopic	Hybrid	Regional
KWM (G) Janßen et al. 2005	Disaggregated	Macroscopic	Vehicle based	Urban
LAMTA (US) Fischer et al. (2005)	Disaggregated	Microscopic	Goods flows	Regional
SAMGODS (SE)/NEMO (S, N) Östlund et al. (2002), de Jong et al. (2002)	Aggregated	Macroscopic	Goods flows	National
SMILE (NL) Tavasszy et al. (1999)	Aggregated	Macroscopic	Goods flows	National
SWIM2 (US) Hunt et al. (2007)	Aggregated	Macroscopic	Goods flows	Regional
SYNTRADE (G) Friedrich (2010)	Aggregated/disaggregated	Macro-/micro-/macroscopic	Goods flows	National
TCI-GV (G) Röhling (2015)	Aggregated/disaggregated	Mesoscopic	Hybrid	National/regional/urban
VISEVA-W (G) Lohse (2013)	Disaggregated	Macroscopic	Vehicle based	Urban
WIVER (G) Sonntag and Meimbresse (1999)	Disaggregated	Macroscopic	Vehicle based	Urban

Source Own research

Table 3.3 Characterizing selected freight transport demand models by modelling steps and the respective modelling methods used

Model	Modelling steps	Modelling methods
CALGARY model (CA) Hunt and Stefan (2007)	Trip generation	Statistical analysis methods (characteristic values)
	Trip distribution, modal split	Statistical simulation (Monte Carlo simulation) and statistical analysis (Discrete Choice models)
	Tour building	Statistical simulation (Monte Carlo simulation) and optimization (savings heuristics)
	Traffic assignment	Equilibria
CMAP (US) Urban and Beagan (2011)	Trip generation	Statistical simulation (Monte Carlo simulation [synthetic economical population]), statistical analysis methods (characteristic values of I/O-Matrices)
	Trip distribution	Distribution procedures (disaggregation based on I/O-Matrices and further data sources), statistical simulation (Monte Carlo simulation)
	Logistics chain split	Statistical analysis methods (Discrete Choice models), temporal simulation (Multi agent simulation)
	Lot size split	Statistical analysis methods (discrete choice models)
	Transport chain split	
	Modal split	
FAME (US) Samimi et al. (2010)	Trip generation	Distribution procedures (Disaggregation based on I/O-matrices and further data sources)
	Value-tons-transformation	
	Trip distribution	
	Logistics chain split	Statistical analysis methods (Discrete choice models)
	Lot size split	
	Transport chain split	
	Modal split	
	Traffic assignment	Equilibria
Freight Transport Lab (G) Schröder et al. (2012)	Trip generation and trip distribution	Distribution procedures (based on characteristic values)
		Statistical simulation (diverse options)
	Transport chain split	Optimization (choice of the most cost-effective transport chain)

(continued)

Table 3.3 (continued)

Model	Modelling steps	Modelling methods
	Tour building	Optimization (heuristics)
	Traffic assignment	Temporal simulation (of a typical day, of the traffic flow, agent-based simulation)
		Equilibrium (whole system)
Freturb (F) Routhier et al. (2007)	Trip generation, lot size split (to some extend), logistics chain split (to some extend)	Statistical analysis methods (characteristic values)
	Trip distribution	Distribution procedures (maximisation of entropy)
InterLog (G) Liedtke (2006)	Trip generation	Distribution procedures (based on characteristic values)
	Trip distribution: distribution procedures (sectoral distribution), statistical simulation (forming a Firm2Firm matrix)	Distribution procedures (sectoral distribution), statistical simulation (Monte Carlo simulation, forming a Firm2Firm-matrix)
	Lot size split	Optimization (lot size model: minimisation of the logistics costs)
	Logistics chain split	Optimization (choice model)
	Tour building	Optimization (of single transport companies), equilibria (market equilibria of transport markets)
KWM Janßen et al. 2005	Trip generation	Statistical analysis methods (characteristic values)
	Trip distribution	Distribution procedures (gravity model)
	Tour building	Optimization (savings heuristics)
	Traffic assignment	Equilibria
LAMTA (US) Fischer et al. (2005)	Trip generation	Statistical analysis methods (characteristic values), distribution procedures (disaggregation based on I/O-matrices and further data sources)
	Trip distribution	Distribution procedures (gravity model approach)
	Modal split, logistics chain split	Statistical analysis methods (discrete choice models)
	Value-tons-transformation	Statistical analysis methods (characteristic values)

(continued)

Table 3.3 (continued)

Model	Modelling steps	Modelling methods
	Tour building	Optimization (not specified tour generation algorithm)
SAMGODS (SE)/NEMO (S, N) Östlund et al. (2002), de Jong et al. (2002)	Trip generation, value-tons-transformation, logistics chain split	Distribution procedures (disaggregation based on I/O-Matrices and further data sources)
	Trip distribution	Distribution procedures (gravity model approach)
	Lot size split, transport chain split, modal split, tour building	Statistical analysis methods (discrete choice models)
SMILE (NL) Tavasszy et al. (1999)	Trip generation, value-tons-transformation, logistics chain split	Distribution procedures (disaggregation based on I/O-matrices and further data sources)
	Trip distribution	Equilibria (SCGE-model)
	Lot size split, transport chain split, modal split, tour building	Statistical analysis methods (discrete choice models)
SWIM2 (US) Hunt et al. (2007)	Trip generation and trip distribution	Statistical analysis methods (characteristic values), distribution procedures (disaggregation based on I/O-matrices and further data sources), statistical simulation (Monte Carlo simulation [synthetic economical population]
	Trip generation and trip distribution (update/forecast)	Temporal simulation (system dynamics)
	Value-tons-transformation, Tour building	Statistical analysis methods (discrete choice models)
	Traffic assignment	equilibria
SYNTRADE (G) Friedrich (2010)	Trip generation	Statistical simulation (Monte Carlo method) and statistical analysis methods (production rates, disaggregation of trading turnovers)
	Trip distribution	Distribution procedures (I/O-matrices), distribution procedures (gravity model)
	Lot size split, logistics chain split, decisions on warehousing structure, tour building (much simplified)	"Temporal" simulation (simulation of logistics decisions until achieving a stable state)
TCI-GV (G) Röhling (2015)	Trip generation, value-tons-transformation	Statistical analysis methods (time series model based on characteristic values

(continued)

Table 3.3 (continued)

Model	Modelling steps	Modelling methods
	Trip distribution	Distribution procedures via gravity model and rate of attractiveness of TAZ
	Modal split, logistics chain split, transport chain split	Statistical analysis methods (logit model)
	Tour building	Use of a vehicle model for trucks and ships, train composition for rail freight transport
	Traffic assignment	Temporal simulation in consideration of logistics processes
VISEVA-W (G) Lohse (2013)	Trip generation	Statistical analysis methods (characteristic values)
	Trip distribution, modal split	Distribution procedures (maximisation of entropy)
	Traffic assignment	Equilibria
WIVER (G) Sonntag and Meimbresse (1999)	Trip generation	Statistical analysis methods (characteristic values)
	Trip distribution	Distribution procedures (gravity model)
	Tour building	Optimization (savings heuristics)
	Traffic assignment	Equilibria

Source Own research
Remark
For the derivation of the necessary model input data/behavioural data for the single modelling steps (traffic volume rates, distribution of transport distance, trip parameter, etc.) normally statistical analysis methods are used. To ensure a certain degree of transparency in the above table these methods are not listed for each single modelling step

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Chapter 4
System Dynamics Based, Microscopic Freight Transport Simulation for Urban Areas

A Methodological Approach

Carina Thaller, Uwe Clausen and Raymond Kampmann

4.1 Motivation

Concentration tendencies of population and economic activities are observable in cities worldwide. Besides, e-commerce demands in particular of private households as well as offered e-commerce activities within most sectors are increasing. Retail and industry endeavour to reduce their inventory costs as a result of increasing land prices. All these influences create an augmenting demand for freight transport, especially in agglomerations, provoking a higher transport volume and increased pressure on traffic infrastructure. This significant growth of freight transport demand is further marked by high-frequency small-scaled deliveries and by a growing share of trips of light-duty commercial vehicles. Resulting from the frequent stops of these freight vehicles the consequences are negative effects on transport flows and subsequently on the environment.

In this way, the conflict of interests between relevant stakeholders (society, public authorities, economics, logistics and environment) is obvious. Therefore, a strategic planning, which provides a targeted cooperation of the relevant stakeholders involved is necessary. This strategic procedure should achieve a compensation of the discrepancies between ecological objectives and economic acceptability to enhance and protect the urban quality of life and climate (Flämig 2007; Beckmann et al. 2010). But the system *urban freight transport* with its interdependencies, interrelations and feedbacks to other systems is very complex at an urban level. For this reason, a basic understanding of interdependencies between these systems as well as of decisions and behaviour of these systems at urban level is fundamental to develop efficient solutions for the relevant stakeholders.

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4.2 Methodological Objectives and Research Questions

To evaluate the impacts of decisions and behaviour on urban freight transport, an ex-ante assessment of their effects has to be carried out. For this purpose, transport models are used as an essential contribution for decision making processes in transport planning as well as for simulation and assessment of measures. In freight transport modelling, it has not yet succeeded to develop an instrument, which integrates and illustrates functional behaviour patterns and interdependencies of subsystems. Furthermore, there is no model, which provides a transparent and detailed structure identifying these interdependencies or impacts (Tavasszy et al. 2012).

On the one hand, the freight transport demand of traditional freight transport models cannot be investigated dynamically. On the other hand, System Dynamics models (SD), which enable an investigation at infrastructural level or a traffic assignment, have so far not been developed.

To sum up, it is necessary to design a SD model and to link it to an infrastructural based freight transport model (De Jong et al. 2004; Kuchenbecker 1999; Weidmann et al. 2012).

For this reason, the overarching objective of the present work is to develop a linking approach which mutually uses the forecast capability of SD and the detailed resolution of microscopic transport simulation. By this methodological approach the degree of explanation and the accuracy of forecasting as well as the quality and informative value of the impact analysis can be improved and enhanced by conducting point-in-time and long-term forecasts.

By this methodological approach changes in behaviour of the relevant stakeholders can be observed and analysed over time, and in detail at infrastructural level. Additionally, impacts of the stakeholders' behaviour on urban freight and individual transport can be assessed. Long-term forecasts or trend analyses carried out by SD can show structural changes in behaviour over time. Furthermore, activity plans of individual end consumers or transport users are generated in Multi-Agent Transport Simulation (MATSim) based on the results of SD.

This linked approach should enable to investigate the above mentioned developing drivers of relevant stakeholders in urban areas. In this project, behavioural changes of the following stakeholders are in the focus of interest:

- private households as end consumers and transport users
- courier-, express- and package service providers (CEP services)
- the retail sector
- the urban administration

Not only the behavioural changes in the course of time are interesting in this research study, but also the impacts of these changes on urban freight transport and shopping traffic.

The overarching research questions in this project are:

- Are CEP services ecologically and economically preferable to private shopping traffic?
- How does e-commerce demand of private households influence the total consumption of private households, the private shopping traffic and the freight transport in urban areas?
- How does the location-bound retail service sector respond to the changes in behaviour of private households and how will the retail sector develop with these changes?
- Which logistics and transport planning measures are suitable to optimize the urban freight transport?

This contribution presents a linked approach between SD and MATSim.

In the following, the state of the art in System Dynamics as well as freight transport demand modelling at urban level are presented. By assessing the two different modelling fields the research gap and the need for a linked approach between SD and a microscopic freight transport simulation are derived. Afterwards, the methodological procedure of the overarching project is shown. In the next chapter, the specific methodological approach to assess changes in consumer and transport behaviour of private households and impacts on urban freight transport and shopping traffic is described in-depth. Finally, a short conclusion and outlook of further steps within the project are given.

4.3 State of the Art

In the following chapter the state of the art in System Dynamics and freight transport modelling is presented to derive the research gap for this approach.

4.3.1 System Dynamics Modelling

System Dynamics is a methodology which is based on the General System Theory and Control Theory. Jay W. Forrester is the pioneer of the methodology System Dynamics. He develops his Industrial Dynamics 1961, which is used to investigate economics, business and organization systems. His model World Dynamics is designed by order of Club of Rome 1973 to explore the global interdependencies between population, consumption, raw materials and environment.

System Dynamics is used to examine complex, dynamic systems, in which time functions are relevant. In fact, strictly speaking there are no systems, which are not dynamic, since they would not be detectable otherwise. In practice, systems are, however, defined as dynamic systems, if observable changes of internal system parameters are caused by the external system environment.

External interactions or feedbacks are not only considered, but also the internal structure, state or behaviour of a system has to be analysed (Rosenberg et al. 2012; Bossel 2004a; Weidmann et al. 2012).

The objective of System Dynamics is to illustrate the consequences of decisions in dynamically complex systems. System Dynamics enables to illustrate and simulate non-linear feedback structures and functions. This works by identifying and sketching relations between system components in iterative modelling steps and by linking with mathematical methods. Additionally, different boundary conditions can be predefined in the simulation process (Weidmann et al. 2012).

So far, System Dynamics models have only been considered in freight transport modelling in a rudimentary form. The methodologies and procedures for System Dynamics modelling will be presented and discussed in the following chapter.

After sharp criticism of the methodology System Dynamics in the beginnings, the System Dynamics approach has acquired new relevance and is increasingly used to illustrate economic, spatial and transport processes in land use and transportation research in the last decades (see Bossel 2004a, b, c; Sterman 2001).

Lee (1995) and Heimgartner (2001) develop System Dynamics models, which give integrated consideration to transport and land use for improving transport quality. Heimgartner (2001) evaluates measures, which promote sustainability. Within a linked approach of a System Dynamics and an econometric approach, Raux et al. (2003) analyze medium and long term effects of urban transport policy instruments on the sustainable passenger transport. First, Emberger (1999) develops the CARINT model (**CA**usal loop **R**esearch on **IN**tegrated **T**ransport) to analyse socioeconomic systems by causal loops—a qualitative SD approach. Pfaffenbichler (2003) extends Emberger's approach and works out a quantitative SD model on the basis of the causal loops. They build up the aggregated, integrated and dynamic land use and transport model MARS (Metropolitan Activity Relocation Simulation) to investigate transport policy interventions, especially sustainable measures for public and private transport. They link a SD with a land use model to study interdependencies between transport and land use at urban level. Wang et al. (2008) study interdependencies between population, economic development, number of vehicles, environmental influence, travel demand, transport supply, and traffic congestion based on the cause-and-effect analysis and feedback loop structures with data from Dalian, China. Zhan et al. (2012) examine interrelations between population, economy, passenger transport, traffic infrastructure and environment at urban level. Ruutu et al. (2013) models a SD which depicts transport user choice in urban areas among different types of private cars and public transport. The model shows the effects of different policies to aid reduction of greenhouse gas emissions.

Although, these approaches presented focus on urban systems and their interactions between transport, economics and spatial development taking into account sustainable aspects. They also elaborate transport policy measures and their effects in analytical manner. However, the freight transport with its stakeholders (with their logistics and business-related strategies and interests) as part of the holistic system city and transport is not considered.

At the Institute for Economic Policy and Economic Research at the University of Karlsruhe (IWW) a number of System Dynamics models are developed, which are able to demonstrate large-scale effects of political measures for transport regarding sustainable development: These models are structured in four submodules (macroeconomic, regional economic, transport and environment module) in each case. Kuchenbecker (1999) extends this approach of ASTRA (Assessment of Transport Strategies; IWW et al. 2000; Schade 2004) and ESCOT (Economic Assessment of Sustainability poliCies of Transport; Schade et al. 2000) and links the System Dynamics with a macroscopic aggregated transport model. By his System Dynamics Transport Master Model he aims to preserve the existing level of detail of traditional transport modelling and to use the feedbacks and long-term analyses of System Dynamics methodology. He considers freight transport as a share in submodule transport. Hong et al. (2011) evaluate sustainability performance of highway infrastructure projects during the construction and operating stage by their SD approach. Han and Hayashi (2008) examine the inter-city passenger transport in China and develop a SD model for policy assessment and CO_2 mitigation potential analysis. These approaches are designed for national and regional spatial level. In addition, freight transport is not in the focus of interest in these studies.

Salini and Karsky (2002) develop a System Dynamics based model SimTrans to investigate the freight transport market in France. Thereby, they consider the rail and road transport as well as inland shipping and reproduce the interactions between the transportation modes, the productivity and the enterprise capacity. Weidmann et al. (2012) focus on sustainable last-mile distribution in a System Dynamics approach on the case study Switzerland. Their System Dynamics model allows detailed analyses of freight transport systems regarding its stakeholders (shipper, logistics service provider, state), their interests and their interdependencies. Gacogne (2003) presents a System Dynamics model, which analyses the interdependencies between logistics organizations and the freight transport. Aschauer (2013) models the interdependencies between logistics strategies and freight transportation movements for the whole supply chain. He shows that freight transport is influenced by different parameters determined within a logistics strategy. Another approach focuses on growing demand of light duty vehicles (LDV) due to behavioural changes towards online shopping and the resulting need for high delivery flexibility. Based on a given transport demand, a dynamic connection between transport demand and vehicle fleet size of the LDV fleet is shown by this SD approach (Publication without an author 2013). Meyer Sanches et al. (2013) investigate the long term effects of freight vehicle circulation restriction policies in the Sao Paulo metropolitan area. Their analysis encompasses the impacts of this policy in the congestion level as well as the transportation costs. These approaches investigate freight transport and the interactions between the relevant stakeholders, but either along the whole supply chain or at national and regional level.

Villa et al. (2013) analyse retailer order decisions in dependency of supplier capacity acquisition delays by a SD approach. They investigate the interrelations among supplier, retails and customer as well as the supply chain management behind. Bockermann et al. (2005) simulate sustainability strategies for the EU 15 economy. Their SD model includes the measuring of energy and material consumption and indicates the linkage of economic development and environmental impact. Furthermore, they calculate the employment effects of a given policy, thus, permitting the inclusion of a key social concern in the evaluation of sustainability policies as well. Both approaches concentrate on the economic sector.

Concerning the dynamic development of population and private household structures Engel (2010) illustrates the population in cohorts by size of household and age. The relationship between size of household and transport volume are explained in detail. Jin and Xu (2009) concentrate on the relation between number of population and consumer behaviour in their SD approach.

To sum up, it can be stated that few System Dynamics approaches in the transport planning, spatial development and economics as well as in social sciences have been developed. However, most of them have focused on passenger transport. Additionally, some SD models are developed for other political systems, so that the internal structures of and interdependencies between economics, society, transport, land use and policy are not comparable with European cities. So far, the system freight transport has only been analysed either its interdependencies in a theoretical way or in specific subareas. Furthermore, System Dynamics models have been investigated freight transport with its interdependencies at a broad regional level, mostly at national level, but not permeated in detail at urban level.

Nevertheless, existing submodules from state of the art presented will be used and extended for the SD model, which will be developed in this study. The selected submodules representing stakeholders will be adapted to the needs of this research approach and will be related to each other in the framework of a holistic system. This system should illustrate the system urban freight transport and its interdependencies to relevant stakeholders.

4.3.2 Freight Transport Demand Modelling

Now, a short overview is given of how research in freight transport modelling has developed in the last decades and which issues and lacks are currently needed to solve by innovative approaches in this area.

The current "expert systems" in transport are the classical transport models, which are successfully used for designing and evaluating transport measures. However, these approaches are especially referred to passenger transport. In freight transport, there are currently still no comparable developments. Particularly, the models are less sensitive regarding behavioural oriented and logistics measures. Due to the insufficient behavioural basis, the usage and costs of measures can finally not be shown in an adequate way.

Transport models have principally a descriptive character—important here is to illustrate the transport demand and the traffic and not to work out assessments for private economic authorities. Its results provide, however, decision basics for the transport policy by calculating impacts due to the measurement options.

These types of models are based on the so called four-step approach. Originally, this was a sequence of arithmetic operations to generate transport flows on infrastructure networks based on regional structural data. The steps of calculation used aggregated regression models as well as integrated and empirically determined parameters by generating trips or average distances. Over time, transport models are built up as equilibrium models—now there are feedbacks between the individual operations on the different steps. Due to the aggregated regression and parameters as well as the focus on transport flows, the transport models are called aggregated and macroscopic in this context. Moreover, the individual steps of calculation were replaced by estimated econometrically behaviour models, e.g. by discrete choice models. By the feedbacks, the models have become more measure sensitive. Furthermore, the behaviour models can be considered as models of rational deciders or micro econometric optimization models. A modern freight transport model can therefore be assessed by further criteria: It could reconstruct behaviour and show changes regarding the implementation of measures (behaviour sensitivity, measure sensitivity). Dependent on the investigating period the model should also show the changes of the variable costs and usages. A consequent development in the direction of measure and behaviour sensitivity models for urban freight transport is only proceeding slowly. Here, three hurdles are to identify: Firstly, essential individual decision problems are not clustered, for example such as for passenger transport in passengers and households. Secondly, logistics decisions and planning problems represent clearly more complex tasks, e.g. fleet disposition. Thirdly, there is a great heterogeneity of deciders and decision objects.

So-called microscopic models and micro simulation models are based on the principles of Monte Carlo Simulation; they address the problem of heterogeneity and provide a microscopic initially database to apply optimization methods (e.g. generating synthetic business and shipping structures). An agent based model architecture provides a suitable framework to model individual optimization of individual deciders but also interactions between the different agents. Multi Agent Systems are defined as object oriented software architecture, which illustrates individual classes of economic actors. These actors can pursue their own goals, interact with other agents and learn from their own experiences. These complex problems can be solved by decision engines.

This historical overview shows that freight transport models refrain more and more from the four step approach regarding their structures and methodological procedures.

Depending on reference values a distinction can be drawn between goods flow based models, hybrid models and tour based models (Miller-Hooks 2012).

Flow based models are mainly used in the interregional transport planning (e.g. BVU 2001; SAMGODS/de Jong and Ben-Akiva 2007; Schmidt 1977). They focus on choice of lot size and transport means with regard to interregional goods flows. Boerkamps and van Binsbergen (Boerkamps and van Binsbergen 1999) develop an urban, goods flow based transport simulation model and integrate behaviour of decision makers in the supply chain (e.g. shipper, transport service provider, receiver and policy).

Hybrid models use diverse methods to generate tours from the goods flows. The first subgroup of the hybrids resembles the original approach of the 4-step model in their structure. They concentrate on the sequence of not feed-back operations to generate transport flows on the basis of key ratios and structural data (e.g. Freturb/Routhier and Toilier 2007; KWM/Janßen et al. 2005; WIVER/Sonntag and Meimbresse 1999; Schwerdtfeger 1976). The second subgroup consists of disaggregated, microscopic models which reconstruct diverse decisions of individual, heterogeneous actors (e.g. WivSim/Spahn and Lenz 2007; Wisetjindawat et al. 2007) Roorda et al. (2010), Liedtke (2006) and Davidsson et al. (2008) develop hybrid agent based models in long-distance freight transport to enable the illustration of the heterogeneity and the different objectives of the decision makers. Schröder et al. (2012) integrate logistics stakeholders (shipper and carrier) in Multi-Agent Transport Simulation (MATSim) and observe the behaviour of the food retailing industry at urban level.

Tour based models reconstruct tour or route chains to map spatial-temporal vehicle movements. Machledt-Michael (1999/Trip chain model) und Lohse (2004/VISEVA-W) derive single vehicle related trip and route chains by diverse descriptive and inductive analyses. Hunt and Stefan (2007) reconstruct tours by random utility models. Thereby, they determine first the starting time and the primary tour purpose for every single tour. On this basis, the tour stops, the length of stops, stop purpose and stop location are thereupon 'diced'. Joubert et al. (2010) develop a tour based approach to simulate freight transport. Their model is calibrated on data of Gauteng (South Africa). They determine a tour as a consequence of economic activities and simulate these tours using probabilities due to tour characteristics (e.g. starting time, length of stop). These probabilities are calculated based on recorded truck movements. Then, their modelled tours are executed in addition to the passenger transport activities in the simulation platform MATSim.

4.3.3 Assessing the State of the Art

In this chapter, a comparison of System Dynamics approaches and urban freight transport models is carried out to show their respective strengths and weaknesses.

System Dynamics models have the advantage to visualize interdependencies between submodules in a very transparent way. Furthermore, it's possible to illustrate non-linear cause-effect-relations. By SD models, medium- and long-term forecasts, trend analyses or impact assessments of measures can be carried out. With these models changes in behaviour in the course of time can be examined. These models belong to the glass box modelling approaches. They have low data requirements for their high aggregated level. Economic and transport modelling algorithms can also be integrated in the SD models. But there is no possibility for traffic assignment and point-in-time forecasts.

Urban freight transport models are established in the classical transport and infrastructure planning. In contrast to SD approaches, they enable infrastructure based analyses of the effects of selected measures. Exact point-in-time forecasts can be conducted, but no long-term forecasts. A detailed resolution is achieved by these approaches. These models are less sensitive regarding behavioural oriented and logistics measures or perspectives. Usage and costs can finally not be shown in an adequate way. They are mostly black box modelling approaches. For disaggregated models there are high data requirements.

Target is to close the research gap between System Dynamics and urban freight transport models. By using the strengths of respective modelling procedure the weaknesses can be compensated or cancelled out.

Outcome is that it is necessary to enable a combination of both. Hence, the forecast capability of System Dynamics and the detailed resolution of transport simulation can be used mutually.

For this reason, an approach which links a System Dynamics with a microscopic transport simulation is presented in the following chapters.

4.4 Methodological Procedure

In the following chapter, the overarching methodological procedure for developing the linked approach of SD with MATSim will be shown.

System Dynamics modelling procedure

First, it is necessary to explain the SD modelling procedure. Figure 4.1 presents the 10-step procedure for SD modelling.

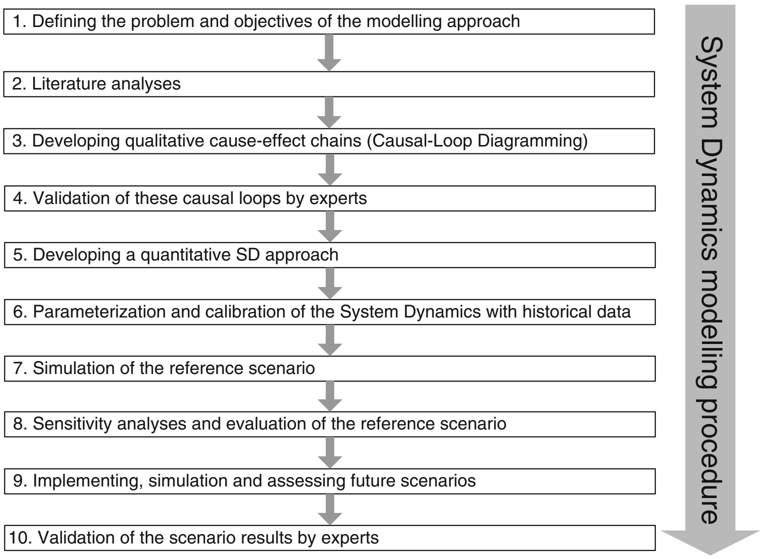

Fig. 4.1 System dynamics modelling procedure (*Source* Own research)

The first step is to define the research problem and the specific objectives (see Sect. 4.1). Based on a comprehensive literature analysis (step 2) qualitative causal loops are developed to describe the internal functionality and structure of urban freight transport and its subsystems (e.g. shipper, carrier, retailer, private households). By causal loop diagramming their interdependencies to each other are also considered. (step 3) In a fourth step, the qualitative causal loops are validated by experts from the field of transport planning and transport logistics.

These validated causal loops are the foundation for the mathematical formalization of the quantitative SD approach. This model consists of differential equation systems and their internal elements stocks, flows and auxiliaries. Then, the quantified SD approach is parametrized with historical data of a selected investigation area (a German major city). The next step is to carry out first simulations with the reference scenario (Business-As-Usual). The model accuracy of the reference scenario is examined by sensitivity analyses. After the optimization of the reference scenario, developing drivers, transport policy and urban logistics measures are thereby implemented in the future scenarios developed. Based on the scenarios simulations are carried out and their outcome is compared with the results of the reference scenario and correspondingly assessed. In the last step the results are validated by further expert interviews.

MATSim simulation procedure

Linking a SD model with a microscopic transport simulation, the Multi Agent Transport Simulation Tool (MATSim) developed by Balmer et al. (2009) is used. This tool provides a simulation environment for vehicle movements at infrastructural level. MATSim has clear interfaces between information transfers from physical to individual decision level. It is an explanatory model, which reproduces the dynamic of the systems (daily planning) and tries to recreate these dynamics in detail. By this approach a full cost-benefit analysis can be carried out to assess the efficiency and effectiveness of transport policy measures. The changes of transport costs, times and distances as well as the impacts on environment caused by measures can be quantified and evaluated. MATSim is an open source project with available simulations and analysis modules and can complemented by own implementations. Figure 4.2 shows the simulation procedure in the framework of MATSim.

First, in the framework of the *Initialization of the World* the investigation area with its traffic supply has to be built up. Thereby, the infrastructural network is developed. Additionally, facilities of the transport participants are integrated (e.g. private households, retailers, companies, distribution centres). In this step, the transport policy measures are also defined and implemented in scenarios.

MATSim runs in six simulation steps. In the first simulation step *Initial Demand* the beginning plans for the agents (tour plans) are generated. Within *Execution* the mobility simulation is carried out and the plans are executed by the agents. In *Utility Function* the individual plan are assessed by cost-benefit functions and, if necessary, are substituted by improved plans in the next step *Scoring*. Thereon, the *Re-planning* is carried out as often as necessary until the optimal daily plans are achieved. Output is an equilibrium of transport demand and traffic supply, the *relaxed Demand.* Finally, the results can be analysed in detail (Balmer et al. 2009).

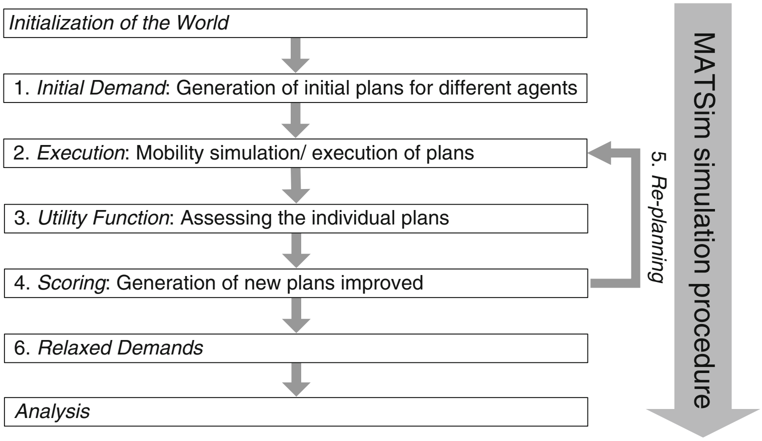

Fig. 4.2 MATSim simulation procedure (*Source* Own diagram based on Balmer et al. 2009)

Methodological procedure for the linked approach

The following step was to link the SD with MATSim. For this reason, an adapter is developed which enables the transfer of key values between SD and MATSim. In Fig. 4.3 the procedure of the final version of the adapter for the linked approach is presented.

In the beginning, an SD model is developed and the time intervals for each trend analysis are determined. In this case, the time intervals are respectively 1 year before stopping the system.

Then, the SD at time t_0 starts with a first simulation run to t_1. Outcome of the simulation is a long-term forecast, which shows a trend graph with a course of development of investigated parameters (stocks). The stocks from time t_1 are transferred to MATSim by an adapter. On the one hand, structural data (e.g. number of population, private households, retailers and customers) which are generated by SD are used in MATSim for the *Initialization of the World*. On the other hand, further SD parameters which represent behavioural data serves as a basis for the generation of the activity plans of the agents (private households, retailers, CEP services) in MATSim. Behavioural parameters are for example used to illustrate and define the decisions of the private households concerning consumer behaviour

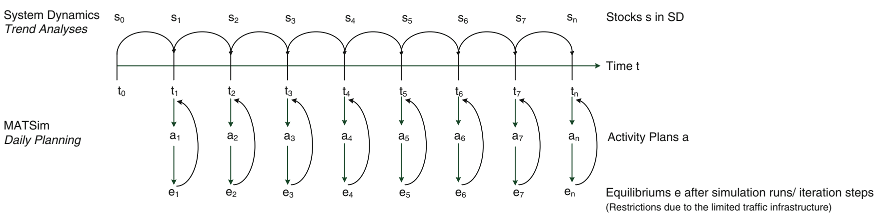

Fig. 4.3 Final procedure of the adapter for the linked approach (*Source* Own research)

(e.g. consumption in location-bound retail or e-commerce) or mobility behaviour (e.g. choice of transport modes). Regarding the retailer's behaviour the ordering decisions are in the focus of interest to derive and characterize the freight transport demand of this stakeholder. For illustrating and describing the behaviour of CEP-services, input data, e.g. volume of goods transported, number of vehicles used, economic and ecological characteristics of the vehicles, operating times, delivery time windows and unloading times, are required to generate the initial daily tour plans for the truck drivers. A tour plan contains the delivery quantity per customer to generate traffic. Delivery relations are determined to distribute the freight transport. Pick-up and delivery activities are specified to describe the transport chain distribution. In addition, the characteristics of transport mode choice and tour building are also determined within this modelling step. Then, iterations of simulations are carried out by the modeler in MATSim. The modeler determines thereby the number of iterations and conducts the simulations runs as many as necessary to achieve a highly promising equilibrium between transport demand and traffic service. The equilibrium, in this case the relaxed demand, is again transferred as an output of MATSim back to SD at time t_1 by the adapter to start a further long-term forecast to $t_{2.}$ This procedure is iterated until the holistic system is stable.

The first version of the SD model is instable and undamped, which shows a specific behaviour. By the agent based simulation in MATSim a learning effect of the individuals could be achieved. The adjusted learning effect aims at optimizing the SD model per time interval. On this basis, a damped system could be derived in SD. This procedure enables the modeler to learn and understand the behaviour of the system during the simulations. The question addressed here is how the holistic system can be stabilized without being collapsed. This issue requires a derivation of specific measures to optimize the system.

To sum up, MATSim dynamically simulates the consumer and transport behaviour of individual agents within a day. Moreover, an environmental impact analysis and benefit-cost-analysis are possible. The System Dynamics model describes the submodules in a transparent form (stock-flow chart) and works with high aggregated data. SD enables long-term forecasts. Thus, the two instruments enhance and complement each other. By the linkage between these two methodological instruments stable systems could be generated at aggregated and disaggregated level.

4.5 The Methodological Approach

In the following the current version of the adapter which links SD with MATSim is described in detail.

General

The Adapter is divided into multiple subprojects which allow for a lot of flexibility and high customizability. These subprojects are the following:

- ITL MATSim Freight Extension:
  This is an extension for MATSim which implements freight stakeholders like CEP service provider. It also implements private households that are able to switch between e-commerce and traditional shopping. This project cannot run on its own, but needs another project to implement its interfaces. These interfaces are:
  - DataSource:
    An interface with getters for data like the number of private households, number of CEP service providers and other parameters for the initialization of the population.
- ITL MATSim SD Adapter:
  This is the actual adapter that connects MATSim with System Dynamics. Like the Freight Extension, this project cannot run on its own, but needs another project to implement its interfaces. These interfaces are:
  - SDInterface:
    This interface is responsible for running the System Dynamics program.
  - VarInterface:
    An interface responsible for holding shared values that can be retrieved and changed by both SD and MATSim.
  - MATSimInterface:
    This interface is responsible for preparing MATSim and providing getters for the MATSim data structures like the network.
- ITL MATSim Freight SD Adapter:
  This project is the actual implementation of the two projects explained above. It implements the interfaces of both projects.

Other subprojects are briefly described in the following which are not planned to be implemented in the context of this research project but may prove useful to be implemented in the future:

- MATSim SD Adapter (without Freight Extension)
  A project that solely implements the ITL MATSim SD Adapter and not the ITL MATSim Freight Extension. This may be useful for simulations that focus on private transport instead of freight transport.
- MATSim Freight File Reader
  A project that only implements the ITL MATSim Freight Extension. It reads the required input from an xml file instead of getting them from System Dynamics/the adapter. Useful for freight simulations without System Dynamics.

Settings

Version 0.1.1 of the Adapter has no settings and can therefore not be adjusted properly. However, the following settings are planned for a future version:

- sdModel: The file which the adapter is supposed to use for the System Dynamics model. This file needs to exist for the adapter to be able to run.

- sdOutput: The file which the adapter is supposed to write the System Dynamics output to. This file will constantly be overwritten.
- sdIntervals: The number of intervals SD is supposed to run in every adapter iteration. Defaults to 10 intervals.
- sdTimeout: The maximum time SD is allowed to take for the simulation. If SD needs longer, the program will be forcibly shut down and the simulation interrupted. If this value is 0, no timeout check will occur, meaning SD can run as long as it needs. Defaults to 0.
- config: The file which the adapter is supposed to use for the MATSim config. This file needs to exist for the adapter to be able to run.
- connectionsFile: The file where the adapter is supposed to look for the connections which define which variables are linked to which SD model stocks (see details below). This file needs to exist for the adapter to be able to run.
- adapterIntervals: The amount of iterations the adapter is supposed to run. Defaults to 10.

Required Input

The adapter requires these input files to work properly:

- SD Model: An xml file that defines the SD model.
- MATSim Config: The config file MATSim uses to configurate itself.
- Network: The network MATSim is supposed to run on. The config needs to define this file as the MATSim network.
- Connections: A properties file that defines the shared variables and the SD stocks they are modified by. After each SD run, the variables' values are set to their corresponding stocks' values.

Now, the functionality of the adapter is discussed.

Functionality

1. Create the SDConnector (implements SDInterface), MATSimInitializer (implements MATSimInterface and DataSource) and VarHolder (implements VarInterface) (see above for the interfaces' functionalities).
2. Create the Adapter with the previously created instances.
3. Run the Adapter:
   a. Initialize MATSim and System Dynamics.
   b. Run System Dynamics.
   c. Grab the values from the System Dynamics model and save them in the VarHolder.
   d. Prepare MATSim for the next run using the previously grabbed variables.
   e. Run MATSim.
   f. Adjust the values of the System Dynamics stocks to the values MATSim has set their corresponding variables to.
   g. Repeat steps b.–f. as often as defined by the adapterIntervals input (10 times by default).

Figure 4.4 presents the functionality of the adapter and its procedure.

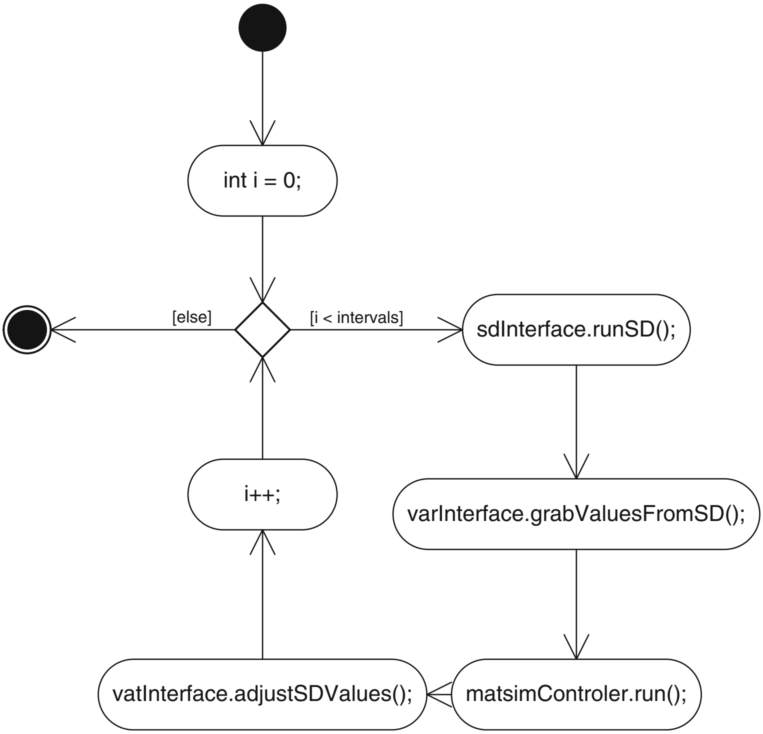

Fig. 4.4 Functionality of the adapter (*Source* Own research)

4.6 Conclusions and Outlook

This contribution presents a SD based microscopic freight transport simulation. First, the state of the art in SD and urban freight transport demand modelling was discussed to identify the strength and weaknesses of the respective approaches. On this basis, the research gap could be derived that it is necessary to link a SD with a microscopic transport simulation. Afterwards, the overarching methodological procedure of the study was described. First, the SD modelling procedure was presented. Then the modelling basics for MATSim simulation were explained. Third, the fundamental conception of the final adapter which links SD with MATSim in a feedback loop was shown. Finally, the current version of the adapter was presented in detail.

This methodological approach will be used to investigate trends in urban freight demand and urban freight transport demand in the course of time on the one hand and to analyse the impacts of changes in behaviour of urban freight demand at infrastructural level on the other hand.

This model approach enables to analyse changes in behaviour in the course of time and to investigate point-in-time forecasts. Within the SD modelling procedure the relevant submodules of the system urban freight transport can be developed. The linked approach enhances the sensitivity to control measures on the one hand and improves the transport simulation on the other hand. It serves as a communication and explanation basis as well as decision support for transport policy and logistics.

Further steps will foresee to apply this approach to a suitable examination area, to parametrize and calibrate the model with secondary data collection and to verify the hypothesis.

Further SD submodules representing stakeholders (e.g. shipper, CEP-service provider) will be developed considering their specific behaviour and linked to MATSim to generate individual agents of them. Thus, a realistic urban freight transport landscape will be generated.

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Chapter 5
Analysing the Connection Between Gross Value Added of Industries and Freight Transport Demand—The Merit of Supply and Use Tables in the Identification of Relevant Economic Activities for Freight Transport Demand

Stephan Müller, Axel Wolfermann and Sandra Burgschweiger

5.1 Introduction

It is a basic axiom that economic activity entails freight transport. However, the major question remains: how much freight is generated by which economic activities? And can this question be answered on a macroscopic level? One research area is the analysis of the relationship between GDP and vehicle kilometres or transport intensity (e.g. Pastowski 1997; Kveiborg 2007; Meersman and Van de Voorde 2013). Views differ, though, on whether these variables are coupled or not.

A closer look at the gross value added of distinct industries supports this coupling for the amount of freight transported on national level, if also distinct groups of commodities are regarded (Müller et al. 2015). A regression analysis between an economic indicator based on the weighted GVA of 59 economic activities (divisions according to the Statistical Classification of Economic Activities in the European Community/Nomenclature Statistique des activités économiques dans la Communauté européenne, NACE rev. 1) and the tonnage of 24 kinds of goods (according to the European classification for transport statistics/Nomenclature Uniforme pour les Statistiques de Transport, NST/R-EU-24) using publicly available data for Germany from 1999 to 2007 serves as proof. The weights of economic activities are derived from supply or use tables, which are part of national accounting.

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The mentioned indicator correlates with about two thirds of all commodity groups which represent more than 90 % of the freight transported in Germany.

In this contribution we provide an empirical analysis of the mentioned economic indicator and its correlation with freight transport demand (transported tons). We will follow four contentions:

1. Gross value added (GVA) is a suitable variable to derive the amount of freight transported in a country.
2. Supply and use tables help in identifying the economic activities with relevance for the transport demand of specific commodities.
3. The consideration of dynamics in GVA development is paramount for freight generation, more than the dynamics of the economic structure (i.e. the change in relevant industries for specific commodities).
4. Economic activities on the consumer side of commodities (receiving industry) explain best the freight generation for the vast majority of commodities.

A short outline of the methodology is followed by the results of a regression analysis between the economic indicator and freight transport as proof of the first contention. The following section deals with supply and use tables in national accounting and their merits for the identification of relevant industries for freight generation (second contention). The third contention is related to dynamics in industry importance for freight and dynamics of GVA, the topic of the fourth section. In the fifth section, indicators based on either use tables, supply tables or one core industry only are compared to each other in order to support the fourth contention. We finally provide a test on the robustness of the correlation regarding the mapping of commodities in transport statistics to products in economic statistics, which has to be based to a certain extent on assumptions.

In the conclusions the relevance of the four findings for freight modelling and forecasting, but also their contribution to the discussion of coupling and decoupling of transport from economic growth is discussed.

5.2 An Indicator for Freight Generation Based on Weighted GVA

5.2.1 Outline of the Methodology

The methodology discussed in this paper has been described in detail before (Müller et al. 2015). Here we provide only an overview on the steps to construct an economic indicator which is correlated to the amount of freight transported.

The economic indicator is based on two major processing steps:

1. weighting of industries according to their supply or use of a specific product
2. multiplying the GVA of industries with their respective weight and totalling over all industries per commodity (which constitutes the economic indicator).

Because in Europe until 2007 the classification of products in economic terms (Classification of Products by Activity, CPA) differed from the classification of commodities in transport statistics (NST) a device is needed to relate commodities to products (a third step, which is dispensable for aligned transport and product classifications).

For the first step supply and use tables are deployed to derive weighting factors for each industry's contribution to supply or use of a product. The economic indicators are defined by multiplying for each product i the respective weights α per economic activity j with the gross value added (GVA) of this activity (see Eq. 5.1). Summing up the weighted GVAs leads to indicators per product (classified according to CPA). To convert the product indicators into commodity indicators (classified according to NST/R) a bridge matrix is used (Müller et al. 2015). It assigns each product division to the 24 NST/R classified commodities (see Eq. 5.2). Commodities can consist of more than one product. β expresses to which extent (percentage in economic terms) a product belongs to a specific commodity. The bridge matrix is a many to many assignment. The robustness of this assignment is discussed in a later section of this contribution.

After this step the economic indicator is correlated with the transported tonnage. The transport tonnage is the total of all modes including import, export and intra-zonal traffic of Germany. Data for the years 1999–2007 are used because this period is covered by the transportation and economic statistics in the desired level of detail. For this period the economic activities in the supply and use tables are classified in NACE rev. 1 (59 divisions) and the products are classified in CPA 1996 (59 divisions) (see Appendix).

$$\widehat{EI}_i = \sum_j \left(\alpha_{i,j} \cdot GVA_j\right) \tag{5.1}$$

$\widehat{EI}$ CPA classified economic indicator (€)
α Weight of economic activities j (NACE) for product i (CPA)
i: j Index for products (CPA division) index for economic activities (NACE division)

$$EI_k = \sum_i \left(\beta_{i,k} \cdot \widehat{EI}_i\right) \tag{5.2}$$

EI NST classified economic indicator (€)
β Weight of product i (CPA) for commodity k (NST)
k Index for commodities (NST/R-24 division)

5.2.2 *Correlation with Freight Generation*

Contention 1: Gross value added (GVA) is a suitable variable to derive the amount of freight transported in a country.

In order to proof that GVA is a suitable variable to derive the amount of freight transported for distinct commodities, we conducted a linear regression analysis with the coefficient of determination (R^2) and the statistical significance of the correlation (t-test of independence) as the performance indicators.

Considering always the best correlation result of both options (supply or used based indicator), in result we observe that 16 of 24 kinds of goods have a strong correlation to the economic indicator meaning a significance level of more than 90 % (see Table 5.1). These 16 kinds of goods comprise on average more than 90 % of the transported tons in Germany in the observed time period. We can derive that

Table 5.1 Correlation results of use based indicator (share: mean of transported tons 1999–2007)

NST/R-EU-24 group	R^2	Significance (t-test) (%)	Share of total tons (%)
1	0.31	88	1
2	0.01	21	1
3	0.34	90	1
4	0.25	83	2
5	0.15	70	1
6	0.91	100	10
7	0.65	99	1
8	0.10	58	3
9	0.11	61	0
10	0.57	98	5
11	0.05	43	3
12	0.13	67	0
13	0.83	100	4
14	0.89	100	6
15	0.98	100	37
16	0.45	95	1
17	0.53	97	0
18	0.36	91	7
19	0.15	70	1
20	0.87	100	4
21	0.83	100	1
22	0.67	99	1
23	0.38	92	4
24	0.83	100	8

—presuming suitable weights for distinct industries—the GVA is suited to explain the generation of freight transport. How the weights of industries can be derived from supply and use tables will be described in the next section.

5.3 The Merits of Supply and Use Tables for Freight Generation Modelling

Contention 2: Supply and use tables help in identifying the economic activities with relevance for the transport demand of specific commodities.

5.3.1 Supply and Use Tables in National Accounts

In order to understand the reasoning behind the described methodology and the role of supply and use tables it is useful to start with a short digression to national accounting and supply and use tables as part thereof. A more in depth explanation of national accounting in the European Union is described by the Statistical Office of the EU (Eurostat 2008).

National accounts are concerned with the structure and evolution of economies and describe all economic interactions within an economy. The methodology is based on the idea of Wassily Leontief from the early 20th century to describe an economy as a closed system. To reach international comparability und usability, the United Nations developed a System of National Accounts (SNA) on which also the European standard established in 1995 and the national accounts within the European Union are based. Within the national accounting input-output tables are widely known. These tables are symmetric either on industries (industry x industry) or on products (product x product). The input-output tables are derived from asymmetric tables called supply tables and use tables. Supply and use tables are constructed as product times industry and also based on differing price concepts. The total margins of both tables are equal.

Supply tables report the value of the domestically produced goods and services complemented by imports and, thus, reveal the production structure of the economy distinct by product and industry. Supply tables are assessed at basic prices.

Use tables reveal products and services used domestically, i.e. the intermediate consumption complemented by exports. The good flows are assessed at purchaser's prices. The most interesting difference between the basic price and the purchaser's price with relevance to our transport oriented analysis can be understood as the transport margin and the trade margin which are included in use tables but not in supply tables.

Supply and use tables, thus, relate products to the industries supplying and using them. It appears consequent to conjecture a relationship between freight transport of specific commodities and economic activities derived from this economic connection as we will analyse in the following.

5.3.2 Deriving Relevant Industries for Freight Transport from Supply and Use Tables

The crucial challenge in deriving freight transport demand from economic indicators (like gross value added, GVA) is the determination of relevant industries for specific commodities. The approach suggested here integrates the information from supply and use tables to this end. The approach assumes that the driving industries for the supply and use of products are also the main drivers behind the transport of these products and that their gross value added correlates with the amount of goods transported.

Thus, the supply and use tables from national accounts (Eurostat 2013) are used to determine which industries have to be considered for an economic indicator for freight transport. Therefore, both options (supply and use tables) are tested to get information on significant industries. For now we will focus on the use side. The different industries are weighted by their respective intermediate demand divided by the total demand in the national economy (here: Germany) of the product as provided in the use tables (Eq. 5.3). This weight is multiplied with the gross value added (GVA) of the respective industry in the given year. The economic indicator consists of the sum over all industries for a given product (Eq. 5.1).

$$\alpha^u_{i,j} = \frac{ID_{i,j}}{\sum_j ID_{i,j'}} \tag{5.3}$$

α Relevance of economic activity j for transport of product i $\sum_j \alpha_{i,j} = 1$ for each product i

ID Intermediate demand from use table (€)

i Index for products (CPA divisions)

j Index for economic activities (NACE division)

To illustrate the procedure we will look at metal products (NST/R-EU 24 group 13), a group of intermediate products such as crude steel or semi-finished rolled steel. Metal products (in transport statistics) comprise two product groups (in national accounting): basic and fabricated metals (CPA 27 and 28). Figure 5.1 shows the weight of all relevant industries (weight greater than ten percent) for both products.

The merit of employing use tables (our second contention) can easily be seen: metals are used by a multitude of different industries. The most important ones are

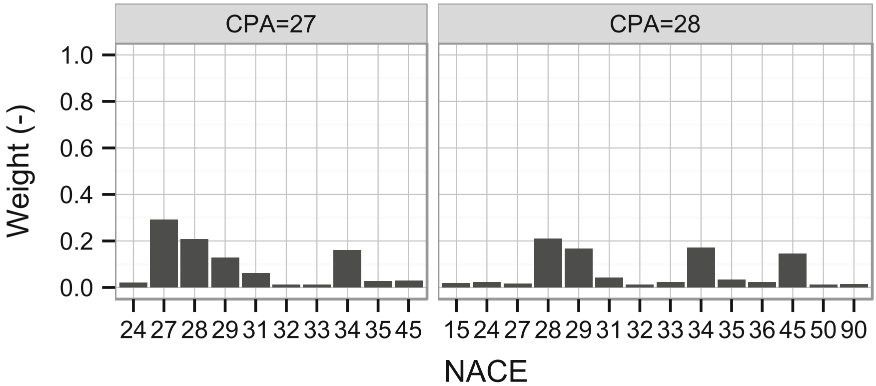


Fig. 5.1 Weights of relevant industries for related economic products of metal products (NST/R 13)

the industries producing metal products (NACE 27 and 28), but also the vehicle industry (NACE 34), machinery production (NACE 29) and construction businesses (NACE 45). If the demand of either of these industries increases, it will have repercussions on the transport of metals. Taking the gross value added as a proxy for demand changes of industries proves to be a useful approach as has been shown above. This use table based indicator explains well the transport of metal products (R^2 = 0.83 at 100 % significance level, cf. Table 5.1).

5.4 Dynamics in Industry Weights and GVA

Contention 3: The consideration of dynamics in GVA development is paramount for freight generation, more than the dynamics of the economic structure (i.e. the change in relevant industries for specific commodities).

The basic idea of deriving transport demand from economic indicators is that the economy remains the underlying cause of freight transport and the dynamics of the economy are an important part of forecasts or scenarios also in other contexts, thus freight transport can rely on such predictions. The dynamics of the economy are reflected in changes of the gross domestic product (GDP) and in more detail by the GVA of different industries.

If, as has been shown before, different industries have to be taken into account for deriving freight demand, the question arises, whether these industries can be assumed as having constant importance for the specific commodities or whether the driving economic activities for the transport of goods change over time. In the given context this is translated into the more specific question whether it is safe to leave the weights of industries α constant over time without introducing significant error into forecasts of freight demand.

On that account the weights and their influence on the economic indicator are analysed. Figure 5.2 shows the contribution of weights for metal products over time. It can be seen that the weights of the manufacturing industries remain more or less constant during the observed 9 years, the sole exception being the manufacture of basic metals (NACE 27), which gains importance. On the other hand, construction slightly loses importance for metal products. Overall the weights remain fairly stable.

In contrast, Fig. 5.3 shows the development of the GVA of the relevant industries. Trends in the machinery (NACE 29) and vehicle industries (NACE 34) as well as in the construction business (NACE 45) can clearly be recognised. In relative comparison with the dynamics of weights (Fig. 5.2) these trends are more pronounced and partly coincide with the trends in the weights.

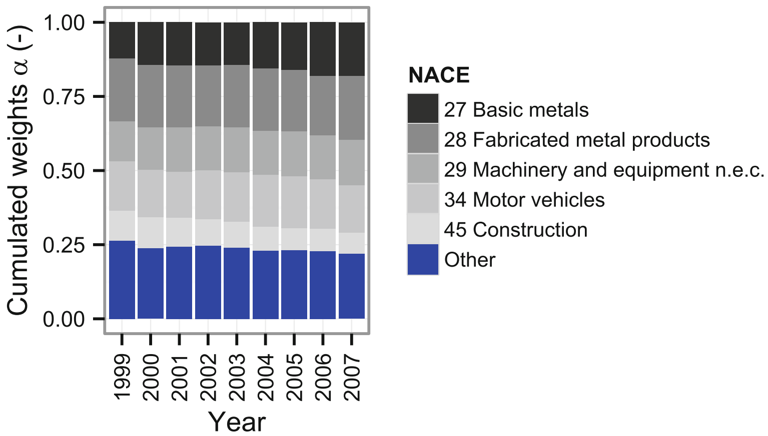


Fig. 5.2 Relative importance α of industries for metal products (NST/R 13)

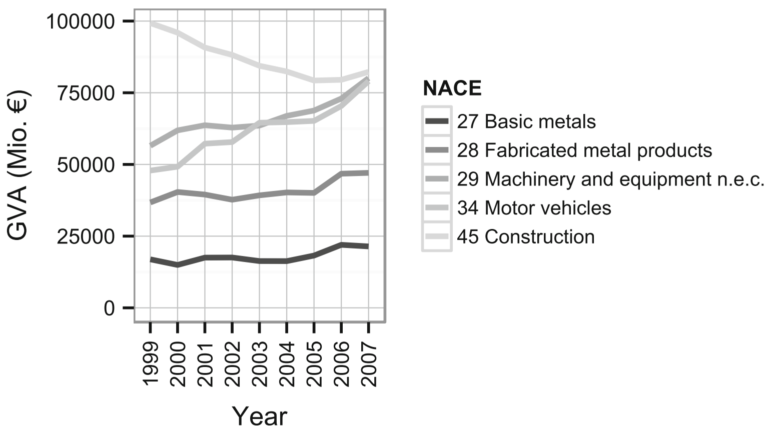


Fig. 5.3 GVA Putting both trends together, those of the weights and those of the GVA

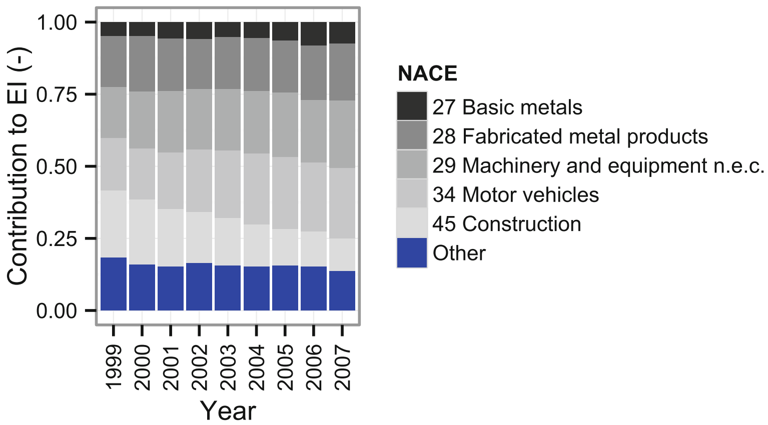


Fig. 5.4 Contribution of industries to EI of metal products

Figure 5.4 shows the contribution of the most relevant industries to the economic indicator for metal products, i.e. the weighted GVA of the respective industries relative to the economic indicator (total of weighted GVA of all industries). It can be seen that the relative contribution of some industries changes significantly, most conspicuous is the reduced importance of construction business and the increased importance of the vehicle industry. The illustration of α and GVA over time as components of the created economic indicator point out, that this significant change in importance of construction is driven by both of the components, but mainly by tendencies of the gross value added. The significant increase in importance of the car industry is only driven by the GVA.

To extend this observation to all commodities, we computed an indicator based on average weights derived from use tables from 1999 to 2007 ("static indicator"). The regression results of this indicator with the transported tons in comparison to the indicator using dynamic weights are shown in Table 5.2 on the following page. It can be seen that for different commodities either static or dynamic weights provide a better regression result. The total share of transported tons that can be explained by such an indicator, however, does not change much if switching from dynamic to static weights for the considered period (taking the coefficient of determination as the performance indicator; by taking the level of significance into account it slightly drops from 90 % to about 80 % for the static indicator).

With few exceptions the explanatory power of static and dynamic indicators for mid-term observations (<10 years) is fairly equal. Changes between both indicators can be observed best in the following Fig. 5.5.

A major reduction of explanatory power with static weights can be seen in the commodity groups wood and cork (4), textiles (5) and mineral oil (10), of which only the latter correlates significantly with the dynamic indicator (Fig. 5.5 and Table 5.2).

Table 5.2 Comparison of dynamic and static weights

NST/R- EU-24 group	R^2		Higher correlation	Significance (t-test)		Share of total tons (%)
	Dynamic	Static		Dynamic (%)	Static (%)	
1	0.31	0.21	Dynamic	88	78	1
2	0.01	0.03	Static	21	37	1
3	0.34	0.36	Static	90	91	1
4	0.25	0.00	Dynamic	83	4	2
5	0.15	0.02	Dynamic	70	31	1
6	0.91	0.94	Static	100	100	10
7	0.65	0.49	Dynamic	99	96	1
8	0.10	0.15	Static	58	69	3
9	0.11	0.45	Static	61	95	0
10	0.57	0.06	Dynamic	98	46	5
11	0.05	0.04	Dynamic	43	40	3
12	0.13	0.17	Static	67	73	0
13	0.83	0.78	Dynamic	100	100	4
14	0.89	0.79	Dynamic	100	100	6
15	0.98	0.87	Dynamic	100	100	37
16	0.45	0.38	Dynamic	95	93	1
17	0.53	0.46	Dynamic	97	95	0
18	0.36	0.26	Dynamic	91	84	7
19	0.15	0.67	Static	70	99	1
20	0.87	0.95	Static	100	100	4
21	0.83	0.87	Static	100	100	1
22	0.67	0.60	Dynamic	99	99	1
23	0.38	0.89	Static	92	100	4
24	0.83	0.96	Static	100	100	8
Share of tons explained (%)	76	76		89	78	100

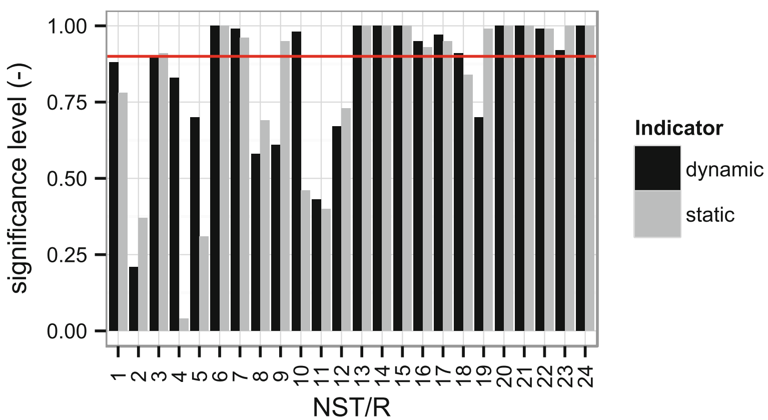


Fig. 5.5 Comparison of dynamic and static weights

To understand the relevance of dynamics in weights and GVA a closer look at weights, GVA and transported tons for the respective commodities (cf. Appendix) elucidates some interesting connections. In case of textiles (NST/R 5) a better correlation results from the role of manufacturing motor vehicles (NACE 34) and health and social work (NACE 85), the weights of which increase in 2003 and decrease in 2004, a peak which is also reflected in the transported tons. In case of using average of weights, only the dynamics in GVA influence the tendency of the economic indicator. Due to the fact that all relevant industries rise constantly, the peak cannot be reproduced by an indicator with static weights.

Wood and cork (NST/R 4) and mineral oil (NST/R 10) are both influenced by a number of different industries, whose weights rise or decline in small amounts and match in sum the trend of the transported tons.

On the other side the correlation between the indicator and transported tons improves by 30 % for paper pulp and waste paper (NST 19) if static weights are used. The reason can be found mainly in the role of public administration (NACE 75), the weight of which drops in 2000 by 7 % which is reflected in the dynamic indicator, but not the static indicator, and which in this case has no repercussions on the transport of paper products. But it should be underlined that this sudden and significant change in the behaviour of one industry (here the public administration) is an exceptional disruption that is difficult to capture in any indicator.

The conclusion is that though the relevance of industries for the use of products change over time, the dynamics of GVA development is paramount for freight generation. If only historic use tables are available, static weights in the construction of the economic indicator can be assumed and work well for the majority of products (contention 3).

5.5 Comparison of Use, Supply and Core Industry Based Indicators

> Contention 4: Economic activities on the consumer side of commodities (receiving industry) explain best the freight generation for the vast majority of commodities.

As we showed above, supply and use tables from national accounts offer a useful tool to identify industries which are relevant for the transport of freight. So far we focused on use tables. Here we will compare this approach to indicators based on supply tables and on one core industry only.

Freight is transported from a shipper (supplier) to a recipient (user). The gross value added of both the supplier and the user, hence, can be expected to be correlated somehow to the amount of goods transported. To take the example of metal products from above: steel products are transported from the metal industry to, for instance, the car manufacturers. If more cars are demanded, the car manufacturers (users of metal products) order more steel from the metal industry (supplier of metal products). Hence, increased car demand will result in more transport of metal products and also in greater turnover (expressed in GVA) in both the metal and car industries. Thus, the supply side and the use side of a product are related to freight transport.

A further simplification is to take only one core industry for every product into account, i.e. to take the economic activity related to the manufacture of the respective product (CPA group equals NACE group). In case of basic metals (CPA 26) this would be the industry "manufacture of basic metals" (NACE 26).

Following this reasoning we analysed the correlation of an indicator derived from weights obtained from supply tables (replacing the intermediate demand by the domestic supply in Eq. 5.3) and based on one core industry per product. Figure 5.6 shows the development of the transported tons and the contribution of the respective economic activities to the indicator for metal products, the latter for the use table based, the supply table based and the core industry indicator.

It can be seen that the supply based indicator in this case equals more or less the core industry indicator (only NACE 27 and 28 are relevant, which represents the two underlying economic product groups, CPA 27 and 28). It can also be seen that all indicators show the same trends. As a result they all show a significant

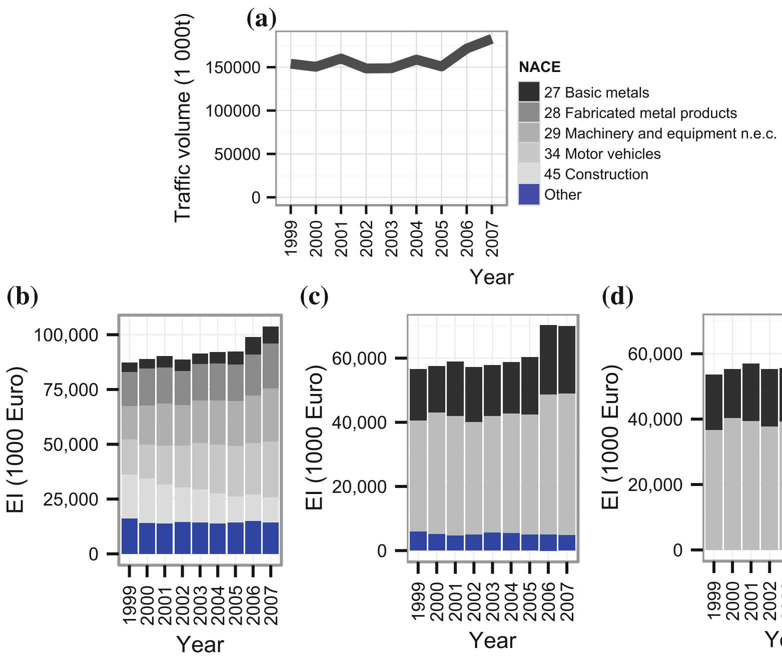


Fig. 5.6 Transported tons and different indicators for metal products **a** transported tons **b** use table based indicator **c** supply table based indicator **d** core industry indicator

correlation with the transported tons (R^2 = 0.81/0.82/0.83 respectively for core/supply/use indicator; all significant at more than 99 %).

While for metal products the supply based indicator is more or less a core industry indicator (only NACE 27 and 28 respectively for CPA 27 and 28 are relevant), for other products different industries might manufacture the product. Examples are given in Fig. 5.7 for office machinery and computers (CPA 30), which are to large extent also provided by the wholesale sector (NACE 51). Another example is radio, television and communication equipment (CPA 32), which is also produced by the electrical machinery industry (NACE 31) and provided by the wholesale sector (NACE 51) (Fig. 5.7).

Comparing the regression between an indicator based on only one core industry and an indicator based on the industries which supply a product with the indicator based on the industries using a product reveals that in the large majority of commodities the use table based indicator is superior to or at least as good as the core industry and supply table based indicators (Table 5.3).

The exceptions are textiles (NST/R 5) and solid mineral fuels (NST/R 8), where the indicator considering only for the core industries performs best, while the use table based indicator does not produce significant results. For leather and clothing (NST/R 23), though the supply table based indicator correlates better, the use table based indicator still shows statistically significant results.

Concluding we can confirm the contention that economic activities on the consumer side (intermediate and finished products) explain best the freight generation. Freight generation approaches looking at only a few core industries are, for most commodities, not able to reflect the complex economic interactions of industries and are prone to miss important activities driving transport demand.

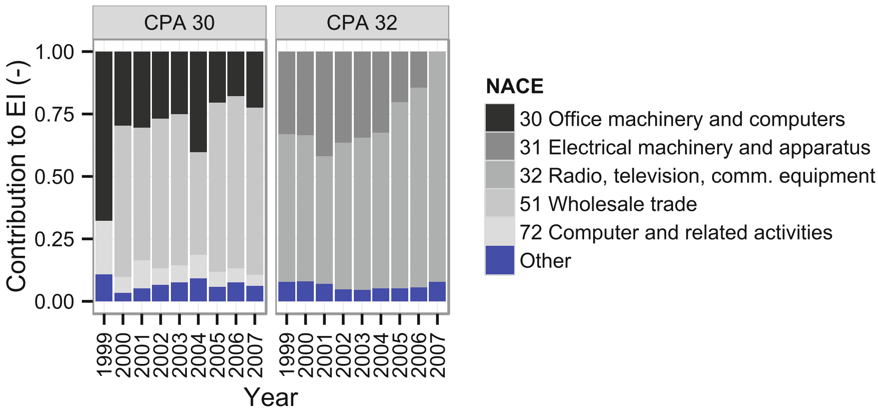


Fig. 5.7 Contribution of industries to CPA 30, 32 and 33 based on supply tables

Table 5.3 Comparison of core industry, supply table, and use table based indicators (significant results highlighted)

NST/R-EU-24 group	R^2			Best correlation	Significance (t-test)			Share of total tons (%)
	Core	Supply	Use		Core (%)	Supply (%)	Use (%)	
1	0.001	0.000	0.310	(use)	5	2	88	1
2	0.044	0.067	0.011	(supply)	41	50	21	1
3	0.220	0.231	0.344	**use**	80	81	90	1
4	0.011	0.072	0.252	(use)	21	51	83	2
5	0.534	0.152	0.152	**core**	97	70	70	1
6	0.132	0.142	0.911	**use**	66	68	100	10
7	0.699	0.700	0.651	**supply**	100	100	99	1
8	0.431	0.369	0.096	**core**	95	92	58	3
9	0.169	0.311	0.106	(supply)	73	88	61	0
10	0.088	0.106	0.568	**use**	56	61	98	5
11	0.114	0.002	0.049	(core)	63	8	43	3
12	0.050	0.028	0.134	(use)	44	33	67	0
13	0.809	0.817	0.828	**use**	100	100	100	4
14	0.785	0.843	0.890	**use**	100	100	100	6
15		0.463	0.981	**use**		96	100	37
16	0.273	0.282	0.447	**use**	85	86	95	1
17	0.457	0.462	0.529	**use**	95	96	97	0
18	0.183	0.184	0.355	**use**	75	75	91	7
19	0.046	0.022	0.153	(use)	42	30	70	1
20	0.969	0.967	0.871	**core**	100	100	100	4
21	0.809	0.784	0.831	**use**	100	100	100	1
22	0.493	0.563	0.670	**use**	97	98	99	1
23	0.117	0.762	0.378	**supply**	63	100	92	4
24	0.912	0.917	0.829	**supply**	100	100	100	8
Share of tons explained (%)	24	29	76		28	68	89	100

5.6 Robustness of the Indicator Regarding the Assignment of Products (CPA) to Commodities (NST/R)

As we mentioned before, the indicator as introduced before relies on a device to relate the classification for commodities used in European transport statistics before 2007 to products in economic statistics. Such a conversion becomes dispensable for classifications in transport and economic statistics aligned to each other (as, for instance, in the USA with SCTG and in the European Union since the update of NST in 2007). The matrix we used to bridge this gap for data before 2008 has to be based on certain assumptions. A unique assignment of products to commodities is possible only on very detailed level, which is not publicly available. Also such a matrix is strictly speaking not static, but might change from year to year. An important question is therefore, how robust the described methodology is to changes in this matrix.

A Monte Carlo Simulation with 1000 runs was conducted, where the elements in the bridge matrix differing from zero and one (unique assignment or no connection) have been randomly varied around their original value. For each model run the correlation between the updated indicator and transported tons was analysed.

Figure 5.8 shows the significance of this correlation for all commodities. Black bars represent the indicator based on the original matrix. The grey boxes show the mean of all simulation runs plus and minus the standard deviation, to give an impression on the variation.

With only two exceptions (foodstuff and leather/textile/clothing, NST/R 6 and 23 which represent together 14 % of transported tons) the indicator still shows a significant correlation on average. Major variations can also be seen for textiles (NST/R 5), a commodity where the indicator does not correlate significantly with transported tons anyway.

The uncertainty in NST/R 6 is related to its composition of food and tobacco products. The GVA of the industries related to the former is more than 20 times the one of the industries related to the latter, which means that slight variations in the composition of the commodity (more food or more tobacco) will result in big differences of the indicator. Also the trends in the GVA of the related industries varies.

The same applies to leather/textile/clothing, which is related to a range of different products from furniture to leather and secondary raw materials, which in turn are used by various industries with different trends and magnitude of GVA.

The Monte Carlo Simulation shows that the indicator is robust to uncertainties in the assignment of CPA classified products to NST/R classified commodities with few exceptions.

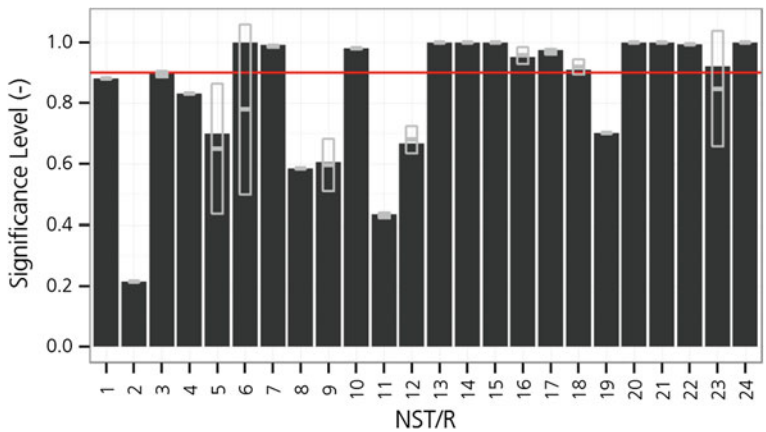


Fig. 5.8 Robustness of significance level towards changes in the bridge matrix (mean of Monte Carlo Simulation with boxes representing ± standard deviation)

5.7 Conclusions

We introduced an economic indicator based on the gross value added of distinct industries and showed its correlation with the transport of 24 specific commodities. The weight of industries in this indicator is derived from supply and use tables in national accounts. With this indicator we could support four contentions:

Firstly, while GDP as an aggregate measure is known not to be suitable to derive freight transport of specific commodities on national level, the gross value added for specific industries is. The art lies in identifying the industries driving freight transport of specific commodities.

This can, secondly, be achieved by supply and use tables. These tables provide the information in economic terms which industries supply and use specific products to which extent. The relevance of industries for transport can be derived from this economic importance.

Thirdly, though the industries identified in this way as being relevant for the transport of specific commodities change over time, the dynamics of GVA development is paramount for freight generation. For most commodities the shift between different industries is of minor relevance as compared to the changes in the GVA of these industries. Hence, for most commodities an average importance of industries derived from historic data is a good approximation for future years.

Fourthly, economic activities on the consumer side (intermediate and finished products) explain best the freight generation. The GVA of these industries (i.e. the industries identified by use tables) correlates better with freight transport.

Lastly, we tested the robustness of the results by varying the assignment of economic products to transport commodities (β). For most commodities the correlation is fairly stable and the methodology can, thus, be considered as robust to changes in the bridge matrix.

These findings will be valuable for several kinds of research. An obvious application is freight generation modeling, i.e. the derivation of freight transport demand from forecasts of GVA (or ideally, but not necessarily also supply and use tables). Models which currently do not have an explicit generation stage but rely on matrix extrapolation will, thus, become sensitive to changes in the economy. A further advantage consists of the fact, that the described methodology requires forecasts of GVA by industries only, which many economic models are able to provide.

Because the methodology as described is able to derive freight *transport* demand, it might also be useful for the provision of estimates for plausibility checks of more sophisticated freight models. Models that separate freight demand and freight transport demand commonly incorporate a number of assumptions which sometimes cannot be directly validated (e.g. due to the lack of data on logistic activities).

We have shortly introduced the discussion on coupling/decoupling of freight transport from economic development. Our findings support a coupling of transport demand with the economic performance of specific industries. Our results encourage the further investigation of market factors behind this correlation.

Finally, the methodology can help to bridge gaps in freight data, where economic data is available for shorter intervals than transport data. For example in the United States transport data are collected every 5 years while economic data are provided on a yearly basis.

Glossary

CPA	Classification of Products by Activity (EU)
EI	Economic indicator
Eurostat	Statistical Office of the European Union
GDP	Gross domestic product
GVA	Gross value added
NACE	Nomenclature Statistique des Activités Économiques dans la Communauté Européenne (Statistical Classification of Economic Activities in the European Community)
NST	Nomenclature Uniforme pour les Statistiques de Transport (European classification for transport statistics)
SNA	System of National Accounts (UN)

Annex

List of NACE rev. 1 divisions and related products classified in CPA 1996

Economic activity (NACE rev. 1)		Products (CPA 1996)	
Code	Description	Code	Description
01	Agriculture, hunting and related service activities	01	Products of agriculture, hunting and related services
02	Forestry, logging and related service activities	02	Products of forestry, logging and related services
05	Fishing, operating of fish hatcheries and fish farms; service activities incidental to fishing	05	Fish and other fishing products; services incidental of fishing
10	Mining of coal and lignite; extraction of peat	10	Coal and lignite; peat
11	Extraction of crude petroleum and natural gas; service activities incidental to oil and gas extraction excluding surveying	11	Crude petroleum and natural gas; services incidental to oil and gas extraction excluding surveying

(continued)

(continued)

Economic activity (NACE rev. 1)		Products (CPA 1996)	
Code	Description	Code	Description
12	Mining of uranium and thorium ores	12	Uranium and thorium ores
13	Mining of metal ores	13	Metal ores
14	Other mining and quarrying	14	Other mining and quarrying products
15	Manufacture of food products and beverages	15	Food products and beverages
16	Manufacture of tobacco products	16	Tobacco products
17	Manufacture of textiles	17	Textiles
18	Manufacture of wearing apparel; dressing and dyeing of fur	18	Wearing apparel; furs
19	Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear	19	Leather and leather products
20	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	20	Wood and products of wood and cork (except furniture); articles of straw and plaiting materials
21	Manufacture of pulp, paper and paper products	21	Pulp, paper and paper products
22	Publishing, printing and reproduction of recorded media	22	Printed matter and recorded media
23	Manufacture of coke, refined petroleum products and nuclear fuels	23	Coke, refined petroleum products and nuclear fuels
24	Manufacture of chemicals and chemical products	24	Chemicals, chemical products and man-made fibres
25	Manufacture of rubber and plastic products	25	Rubber and plastic products
26	Manufacture of other non-metallic mineral products	26	Other non-metallic mineral products
27	Manufacture of basic metals	27	Basic metals
28	Manufacture of fabricated metal products, except machinery and equipment	28	Fabricated metal products, except machinery and equipment
29	Manufacture of machinery and equipment n.e.c	29	Machinery and equipment n.e.c
30	Manufacture of office machinery and computers	30	Office machinery and computers
31	Manufacture of electrical machinery and apparatus n.e.c	31	Electrical machinery and apparatus n.e.c
32	Manufacture of radio, television and communication equipment and apparatus	32	Radio, television and communication equipment and apparatus

(continued)

(continued)

Economic activity (NACE rev. 1)		Products (CPA 1996)	
Code	Description	Code	Description
33	Manufacture of medical, precision and optical instruments, watches and clocks	33	Medical, precision and optical instruments, watches and clocks
34	Manufacture of motor vehicles, trailers and semi-trailers	34	Motor vehicles, trailers and semi-trailers
35	Manufacture of other transport equipment	35	Other transport equipment
36	Manufacture of furniture; manufacturing n.e.c	36	Furniture; other manufactured goods n.e.c
37	Recycling	37	Secondary raw materials
40	Electricity, gas, steam and hot water supply		
41	Collection, purification and distribution of water		
45	Construction		
50	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale services of automotive fuel		
51	Wholesale trade and commission trade, except of motor vehicles and motorcycles		
52	Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods		
55	Hotels and restaurants		
60	Land transport; transport via pipelines		
61	Water transport		
62	Air transport		
63	Supporting and auxiliary transport activities; activities of travel agencies		
64	Post and telecommunications		
65	Financial intermediation, except insurance and pension funding		
66	Insurance and pension funding, except compulsory social security		
67	Activities auxiliary to financial intermediat.		
70	Real estate activities		
71	Renting of machinery and equipment without operator and of personal and household goods		

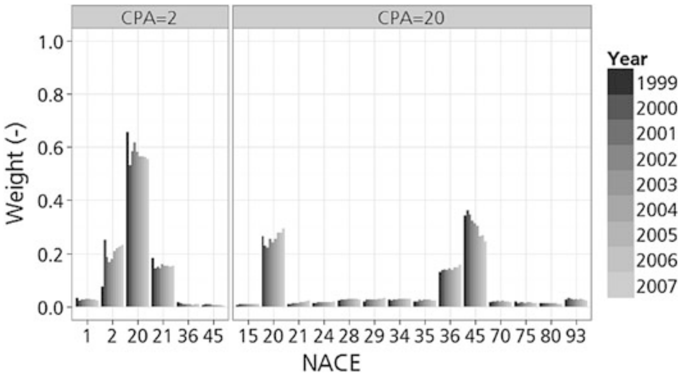
(continued)

(continued)

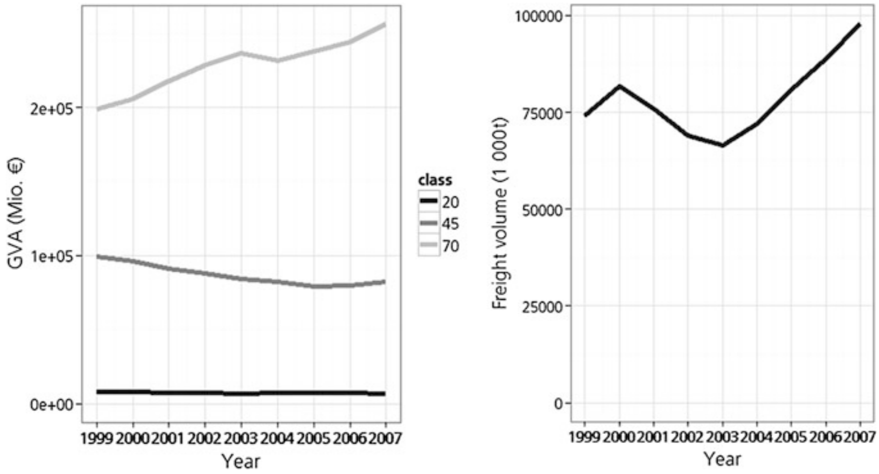
Economic activity (NACE rev. 1)		Products (CPA 1996)	
Code	Description	Code	Description
72	Computer and related activities		
73	Research and development		
74	Other business activities		
75	Public administration and defence; compulsory social security		
80	Education		
85	Health and social work		
90	Sewage and refuse disposal, sanitation and similar activities		
91	Activities of membership organisation n.e.c		
92	Recreational, cultural and sporting activities		
93	Other service activities		
95	Private households with employed persons		

Diagrams for wood and cork (NST/R 4)

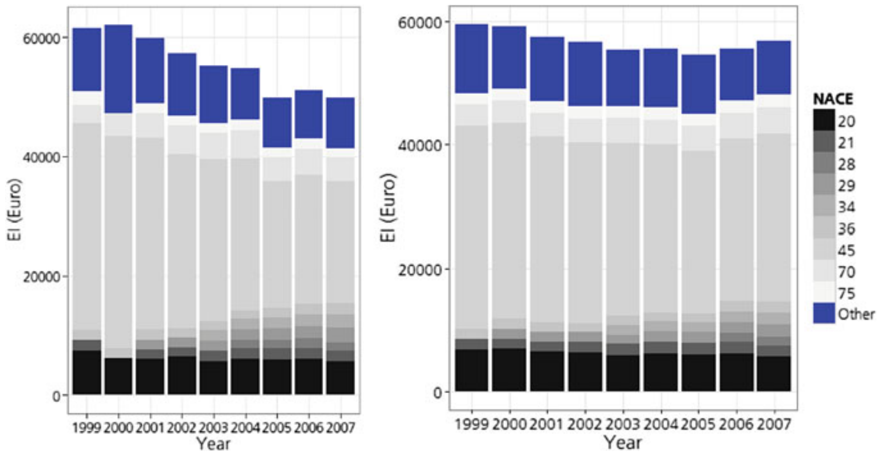
Weights α of economic activities



GVA and transported tons

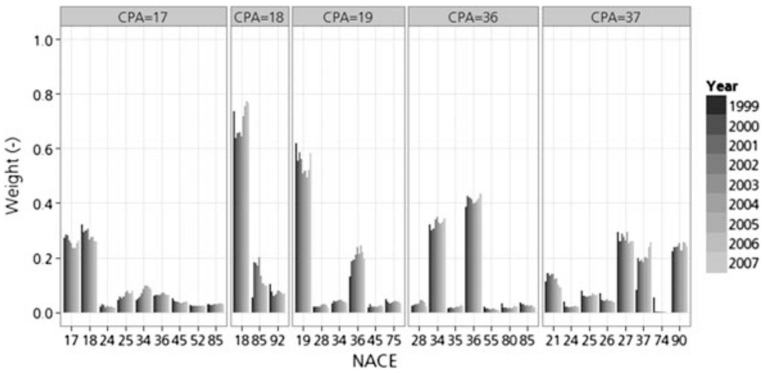


Economic indicator with dynamic and static weights α

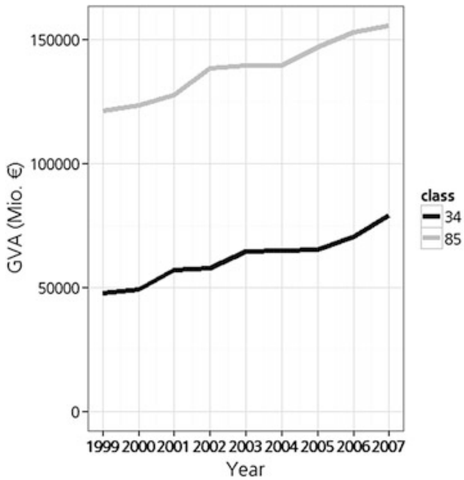


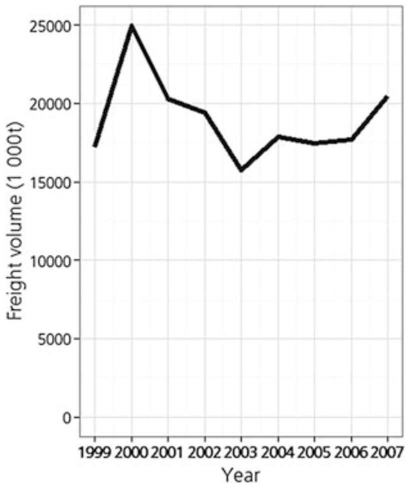
Diagrams for textiles (NST/R 5)

Weights α of economic activities

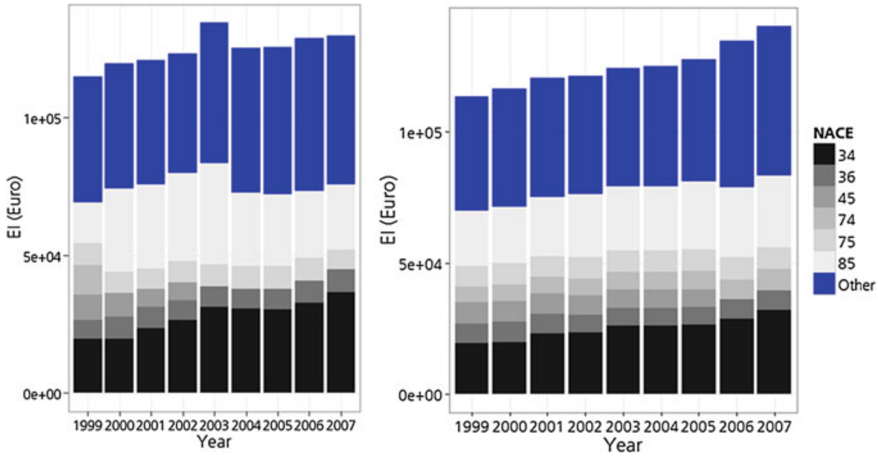


GVA and transported tons



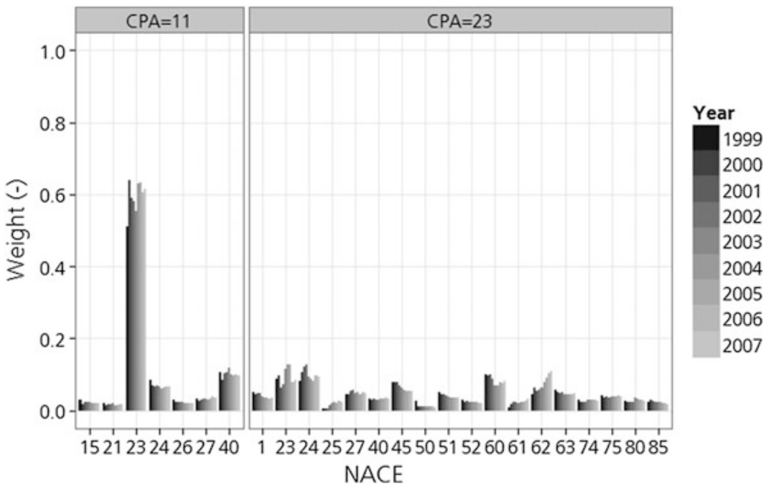


Economic indicator with dynamic and static weights α

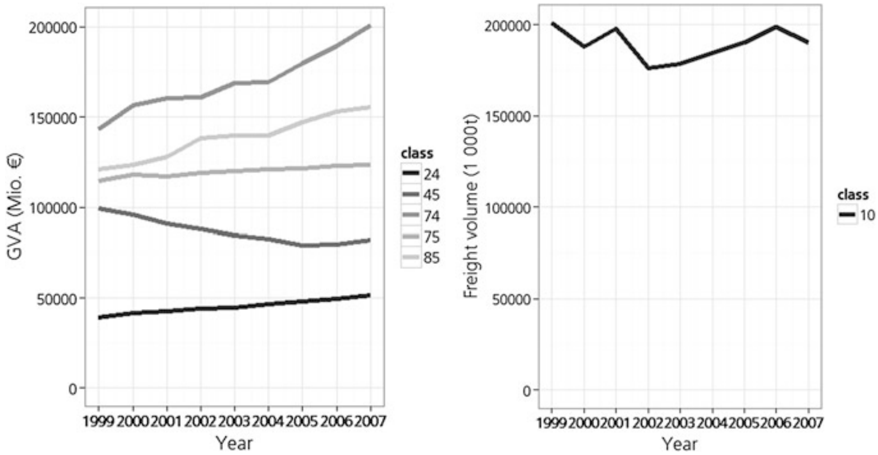


Diagrams for mineral oil (NST/R 10)

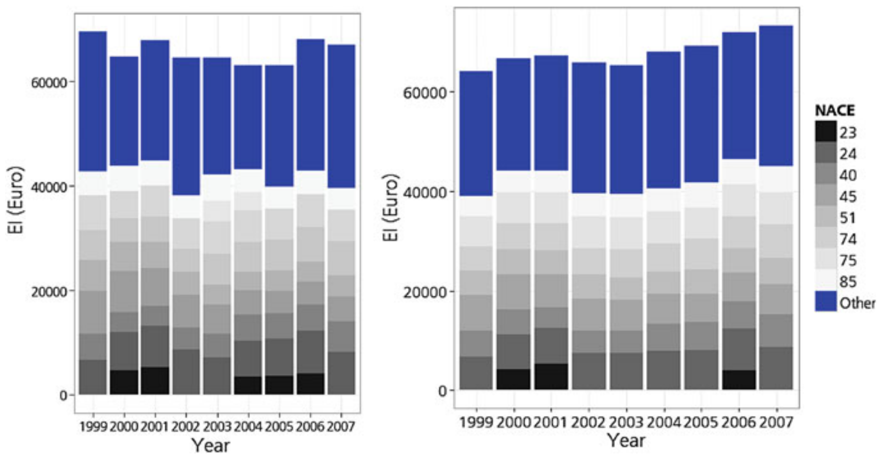
Weights α of economic activities



GVA and transported tons

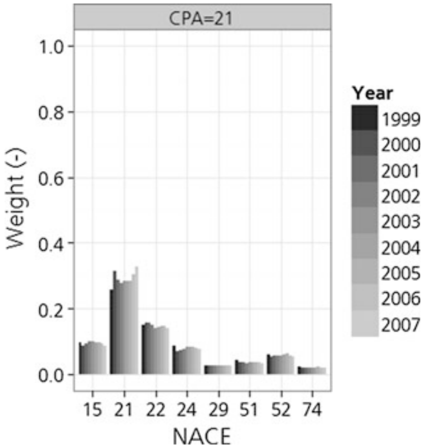


Economic indicator with dynamic and static weights α



Diagrams for paper pulp and waste paper (NST/R 19)

Weights α of economic activities



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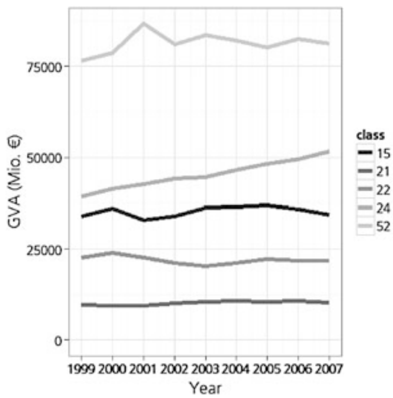
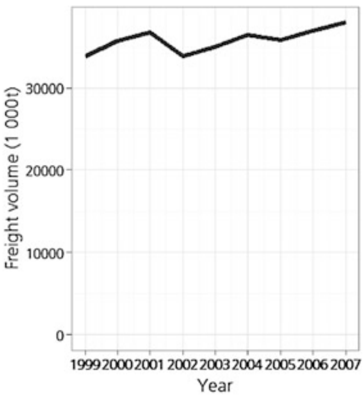
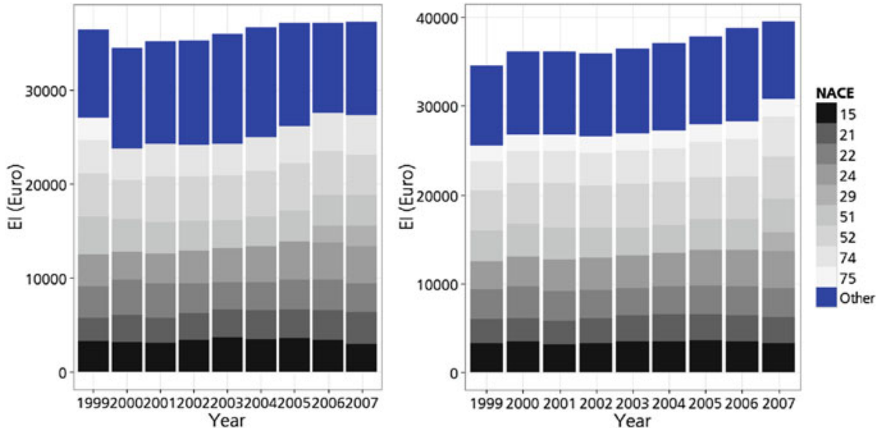




Economic indicator with dynamic and static weights α



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Chapter 6
Requirements for Traffic and Transport Models

Wulf Hahn and Werner Frey

6.1 Introduction and Motivation

6.1.1 Initial Situation and Problem

Lately, the application of traffic models changed more and more: In the past models had been focused on the illustration of private transport to determine the effects of infrastructural measures. Today models are increasingly asked to calculate the effects of regulatory, monetary or information specific (so-called "soft") measures, to reproduce combined transport-modes' usage on the same way, to support environmentally-sensitive tactical traffic management efforts or to test operational optimization measures.

So it is not surprising that the earlier examples of ideas for requirements deal with private transport models because in its origins the traffic models were set up to reproduce the private traffic by cars. In the 80s issues on commercial transport and its traffic only came up occasionally. These issues mainly focused the adaptation of traffic models to local structures dealing with logistical priorities.

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6.1.2 Commercial Transport and Its Modelling

With the increasingly higher requirements of the European Union (EU) for environmental and surroundings-specific sustainability and compatibility of the transport sector (e.g. limitations on the number of allowed overrun days of pollutant emissions, requirements for particulate emissions, guidelines for environmental noise) the economic transport sector gets more into focus because it causes a majority of the pollution. As a result modern traffic models need to reproduce the economic and commercial interactions, for example, to analyze the following measures or to evaluate and plan their implementation:

- regulatory measures: e.g. shipping times for downtown areas, low emission zones or transit traffic restrictions,
- monetary measures: e.g. truck tolls, awarding of start-time slots or port laydays,
- information specific measures: e.g. display of free truck parking spaces on motorway car parks,
- combined transport-mode usage: e.g. combined transport on road and rail,
- environmental sensitive tactical measures: e.g. truck route control and traffic lights programs adapted to limit violations to the 39th and 16th German Federal Emission Protection Directive (Bundes-Immissionsschutzverordnung—BImSchV),
- operational improvements: e.g. slot management or route optimization in delivery traffic to minimize the ramp waiting time or the amount of ramps.

Unfortunately, the usual traffic models cannot deal with the named challenges in an appropriate way. The reason is the lack of approaches and standards for the implementation or traffic model-based reproduction of these issues (Brannolte et al. 1998; Hahn 2010).

To include economic and commercial interactions in traffic and transport models additional objects and aspects have to be included:

- logistical cause-effect relationships
- additional stakeholders, such as freight forwarders and goods transhipment centers
- additional markets, such as distribution logistics or CEP-services (courier, express and parcel)
- additional instruments to control economic and commercial traffic, such as restrictions of access, delivery time slots, congestion charges, environmental zones

For modelling these objects and aspects of economic and commercial interactions standardized approaches are missing in Germany and abroad—there is a gap in the “toolbox of traffic modelling”. There are several model ideas, but both the contracting authorities as well as the modellers in practice usually do not have

- an overview of the existing approaches,
- a recommendation of the aspects to be considered and

- named requirements, which economic transport models should achieve.

Even after the decision for one of the possible methodological approaches the contracting authority is faced with the difficulty to evaluate the results delivered by the modellers in practice.

6.1.3 Works of the Group 1.8.4 of the German Road and Transportation Research Association (FGSV e.V.)

With the draft “Recommendations on commercial transport modeling” elaborated in FGSV Working Group 1.8.4, the authors wish to attempt, at least to close some of these gaps. In the discussions the working-group quickly became aware that there is no standard approach for modelling economic and commercial interactions. So the working-group members first decided to present the typical questions and tasks, model objects and modelling methods, before describing some current commercial transport models and pilot projects as well as the required data bases.

In addition, the requirements on transport models in general and the additional specific requirements for modelling commercial interactions are collected and documented. As shown above these requirements are essential foundations both for modelling private transport as well as economic interactions. They are therefore formulated in general to satisfy both—private transport and commercial interactions.

The members of the FGSV working group hope that the requirements will become a yardstick for future transport model projects, so that both the contracting authority and the modellers in practice can use these criteria.

The work on the“recommendations on commercial transport modelling” is still in progress. The paper will probably be published in 2016. The following contribution contains the main topics of these requirements statements.

In the following the requirements will be described and explained with reference to examples. The examples are taken from existing and hypothetical models for private and commercial transport.

6.2 Requirements for Traffic Models

As well as for models of other sciences the basic problem for traffic and transport models is that their correctness which is an actual precondition for its application can never be conclusively proven formally. A verification is not possible, but a falsification is. The "correctness" can be concluded indirectly when a model meets a number of requirements and creates no conflict with them.

First, in Sect. 6.2.1 the basic requirements for traffic and transport models are described. These requirements have to be achieved always in order to benchmark a model to be set up with correct functionality (ASFINAG /BMVIT 2010; Axhausen 2010; Beckmann 2000; FGSV 2001; Friedrich 2004; Friedrich 2010; Hahn 2010; Heidl 2010; Janßen 2010; Köhler und Wermuth 2001; Rümenapp 2007; Wermuth 1994; Zumkeller 1988). These requirements are shown in the following.

- degree of realism
- consistency and plausibility
- transparency
- usability for forecastings
- reliability

In Sect. 6.2.2 application-specific requirements are named, which have to be achieved in order to solve a specific model task. To solve this data availability, sensitivity of the measures and validity of the model plays a crucial role, which specifies the consistency and predictive power of the model.

6.2.1 General Requirements

Degree of realism

A model has to represent reality and their cause-effect relationships in a suitable manner. The precision and resolution has to be appropriate to the application. This assumes that the relevant parameters and their correlations were detected and sufficiently analyzed prior to the development of a model. So only the influencing factors and their relationships have to be included which are relevant to answer the model-questions (see Sect. 6.2.2 validity). Therefore, the complexity of the individual decision-making structures in private and commercial transport has to be abstracted for modelling (Stachowiak 1973).

For the documentation of the degree of realism of a model an adequate representation of the initial situation, input variables and model relationships are necessary. In addition, the degree of realism is checked by comparing model results with observed values of reality. To achieve this task a status quo-model situation is defined which is based on empirical data. The model has to reproduce this as a basic scenario. For this the modeled parameters (such as transport volume, modal split or vehicle size choice, distance and travel time distributions, traffic service volume, air pollutant emissions) are compared with empirical data. It is essential that the model will be checked not only for the transport volume in the end but also for the modeled steps of traffic generation, spatial traffic distribution and modal split or modal choice. Only if the degree of realism for the analysis or basic scenario is proven the model is ready to be applied for forecasting.

Consistency and plausibility

Consistency is proven if the model is free of contradictions. Plausibility is the traceability of the results due to general knowledge or proper logical expectations. On the interaction of consistency and plausibility the consistency is the stronger criteria.

A model should be checked for consistency and plausibility of the results in two ways:

1. The results of a model should be internally consistent and plausible. So for consistency no situations with incompatible facts go together (e.g. elementary school students looking for work or small-scale distribution traffic in the CEP segment using extended trucks). For plausibility the modeled behavior has to be within reasonable limits (e.g. the day for each person and each actor has a maximum of 24 h, the majority of personal-actions and tours end at the starting point in the evening, travel-speeds are running in a realistic framework).
2. The differences between the modeled results for different initial situations or forecast horizons have to be consistent and plausible (e.g. an increase of prices or travel times for a given mode will not increase its usage or the realization of additional truck parking spaces will have an increase of truck transport demand as a result). If there is a result that is not expected like this, the causal relationships that have led to this counterintuitive result of the model, have to be documented very well.

For example the two requirements of the consistency and plausibility can be checked by the determination and documentation of the model elasticity for the relevant input data. This elasticity values illustrate the changes of the calculation results based on the relative change of the considered input data. Typical elasticity values which are documented in various publications can be used as a benchmark (Bastians 2009; Hauzinger et al. 2004; Intraplan Consult GmbH und et al. 2006; Prognos 2000; Vrtic et al. 1998; Wermuth 1987).

Transparency

Transparency describes traceability of the results at any time, so that these results are repeatable and controllable. Calculation procedures and results shall be designed in a way that politicians and the participating or concerned public can get a clear idea about the relationship between arithmetic results and reality (Zumkeller 1988). All assumptions, the procedures and the model structure have to be transparent, so that the results can be tracked. This includes the disclosure of the basics, input data, assumptions, model structure and methodology, forecasting methodology and calculation algorithms.

So for example the documentation of the origin-destination matrices is an important aspect to support the checking of forecasts and the tracking of calculated results. However, it is not sufficient to set up a documentation of the origin-destination matrices without adding the specific input parameters and the calculation processes. The same applies to the review of the growth assumptions for economic developments and structural changes. To achieve transparency it is important that all plausibility checks of interim and final results as origin-destination matrices and volume values of the network need to be done and documented on the base of empirical data.

Predictive capability
A model forecasts correctly if it is able to estimate the impact of changes in conditions on the traffic and transport demand in a realistic way. This requirement combines the degree of realism, consistency and plausibility because the predictive capability is given if the relevant inputs are linked in correct cause-effect relations and the changes of results between the different model runs are correct on the purpose of their direction of action as well as in their scale. To satisfy these needs a traffic model requires correct input data, a matching effect model and sufficient internal degrees of freedom in order to adapt to the changing preconditions. So it is essential that the predictive capability covers the model application framework according to the model task and the structural data, the traffic network and the behavioral data.

For example, a traffic model with link capacities that are limited to the measured transport volumes and that uses very steep resistance functions can reproduce a status quo transport volume situation perfectly. Concerning the transport volumes of the status quo it is so far considered realistic. However, the model has no real freedom in the resistances calculation for different volume situations it can be assumed that it will not provide correct results for changes on the network or the transport demand. Such a model would not be usable for predictions.

Reliability
The purpose of models is to make effects of measures or changed preconditions quantifiable. For this purpose it is necessary to differentiate random differences from systematic differences. In order to certify the reliability of a model sensitivity analysis or repeated documented model runs must be carried out. The latter is particularly necessary if Monte Carlo simulation techniques are used to reproduce spatial patterns or behavior.

6.2.2 Case-Specific Requirements

Validity
On one hand validity of a model describes its resilience, so that it actually determines what it is expected to do. On the other hand validity describes that the statements based on the models calculation results are stressable. So validity is

always connected with the specific modelling task. The validity thus combines the degree of realism, consistency and plausibility in the context of the specific problem.

Validity decisively influences the model properties of its applicability and its ability to convince:

Model calculations are used to support planning and political decisions. Therefore model results have to be communicated not only to professionals, but especially to decision makers and to the public. So the model results have to be straight forward and easy to communicate to raise their necessary weight in the decision-making practice. This brings up the requirement of models to be comprehensible, transparent and valid.

The ability to convince is accompanied by the applicability of the results. A model has to deliver a result that is usable for the decision-finding. Usually models have to provide this in form of quantitative result values that can be used for an assessment of the different options. From this applicability results the requirements of validity because consistency plausible effects for different variations of the input parameters can be achieved only with a given model (see also sensitivity for measurements).

Sensitivity for measurements

A model is sensitive for measurements, if it is able to reproduce realistic effects for transport planning measures. It is important to build the model in such a differentiation, that intermediate steps between the initial situation and the measurement-including model situation are identifiable (Zumkeller 1988). The sensitivity for measurements is dependent on the particular issue as well as considered measurements and instruments. The sensitivity for measurements has to be properly implemented. So the model's accuracy has to be more precise than the differences between different scenarios in order to determine the effects correctly.

To achieve the already mentioned transparency requirements in combination with the sensitivity of measurements the modellers has to document how input variables change due to the implementation of measurements (e.g. travel times in commercial transport due to an expansion of a motorway) in a comprehensive way.

Operability

A model is operably and can be used for a specific application, if a calibration and validation has been carried out comprehensible for the intended use (Zumkeller 1988). This means in particular that it was built with sufficient effort for the calibration and validation to solve the application task:

Calibration

Before applying a model for a situation assessment or evaluation measures each traffic and transport model has to be calibrated first. Calibration is defined as the optimization of parameters used to weight the behavioral and structural data in comparison with empirical information derived from comparative data (e.g. setting the distribution parameters with the help of purpose and transport mode specific distributions of the trip lengths).

Validation
A calibrated traffic model has to verify its validity in a further step. In the validation process the input data is checked for the right setup, for example by comparing counted with the modeled transport volumes. Like in the instructions for the construction of microscopic transport flow simulations (FGSV 2006) the data used in the validation process must not be used in the calibration process already.

Transport models are often "calibrated" by comparing the assignments results with traffic counts. By comparing the modeled and the observed values the validity is attested directly. However, a consistent status quo reproduction state still gives no proof whether the model reproduces the effects of changes in the resistance correctly. For this it is necessary to perform additional validations in the form of plausibility tests and sensitivity analyzes. Transport flows of individual cells or links can be analyzed (visually) to verify the route choice and trip lengths. In addition, a review of the journey times in the model could be done with real-time data.

Beside the calibration and validation additional requirements for operability arise with regard for usability and economic aspects:

Usability
An important criterion for operability is that the computation time is in a useful context. In addition, an already built model should be set up so that it can be used without major adaptation efforts for various planned applications. So the already named requirements of predictive capability and sensitivity for measures should not have a too limited usage range. Different possible applications should be kept in mind in the design process of the model instead.

This desire for possible fields of application stands in conflict with the complexity of the model, so that the contracting authority and modellers have to discuss the importance of the models complexity and its usability for future fields of application.

An additional need for models is the ability to get updated with limited costs if possible processor independent continuously or periodically to be adapted to current changes in the environment. For this requirement a full and comprehensive documentation is essential.

Economic aspects
In general, growing complexity and resolution increases the accuracy of the model results. This also applies to the quality of the data supplied by accompanying surveys. At the same time this increases the workload for the modellers and in the end the costs. The economic effort of a model has to be balanced with the model task.

Availability, preparation and transparency of data
The basic data for private and commercial transport models can be distinguished in:

- structural data, mainly in the form of regionalized statistics for economic activites (employees, turnover of enterprises, population, foreign trade),
- specific values for traffic generation and attraction and
- data on the spatial movement patterns and structures.

Additional data for the formulation of behavioral models and cause-effect relationships is needed. In the end, the data availability determines the models dimensions such as its separations in different groups of people, industries and transport purposes. Only with sufficient detailed data available, reliable and valid consistent disaggregate models can be developed.

Examples for basic data are revealed-preference- and stated-preference-surveys or parameters for estimating the longitudinal and cross-sectional models for prognostic purposes. Requirements for the data documentation can be taken from EVE (Recommendations for traffic surveys) (FGSV 2011) and the research project of Wermuth et al. (2010). Significant basic information are target and basic population of the survey, spatial and temporal coverage of the survey, survey units, selected survey method, degree of accuracy, measurement methods, selection method, preparation and analysis of the observed data and error discussion.

Unfortunately, the required data base is often not available in the desired details separation. So the use of different secondary statistics necessary. The different data has to be merged as part of a data consolidation and matched to each other. The research, the treatment and the comparison of the different data topics requires statistical knowledge by the modellers in practice and takes up to 50 % of the effort to create a model.

Basically, surveys and the derived parameters (indicators, behavioral parameters and elasticity) should get documented and disclosed. In this way, it is possible to check the suitability of the data and parameters for the calibration. The same applies to the parameters used in the calibration process which are used by the modellers to adapt the model to reality.

Surveys should be disclosed, so that a judgment is possible if the questionnaires satisfy the methodological requirements the traffic surveys are faced with. It is important that the requirements vary in correspondence with each survey and the requirements depend on the importance of the survey for the model. In the research project of the German Federal Highway Research Institute (Bundesanstalt für Straßenwesen—BASt) for determining standards for demand specific quality in traffic surveys the Eurostat concept for quality assurance of data is advised (Wermuth et al. 2010). In this concept, accuracy (mean square error of an estimator for the unknown population ratio), precision (variance) and correctness (correspondence between expected value of the estimator and the true value of the key figure to be estimated) are presented as essential parameters (Wermuth et al. 2010). Other frequently used quality indicators are relative mean error and Geoffrey E. Havers-value (GEH statistics used in transport modelling to compare two sets of transport volumes).

6.3 Positive and Negative Examples of Models

6.3.1 Bypass for the Federal Highway B519n Flörsheim—Wicker—Weilbach (IVV 2010)

In the first example, the bypass of Flörsheim, Germany, was examined by means of a model of individual transport based on the VDRM (Transport Data Base of the Rhine-Main-Area). First, the planning area and its surroundings were described. The structural analysis (e.g. inhabitants, employees, school places) were updated. The cell structure, the street structure and road network were examined in detail.

The modelling of transport was described for private transport as well as for commercial transport on road. The capacity restraints were examined in detail and reproduced in an equilibrium assignment method whereas commercial transport was carried out by the successive assignment method.

Some surveys of the flowing transport were done for calibrating the model. Besides, the transport was counted at 16 junctions and 12 other cross-sections. The already existing public transport network was implemented in the model. For the computational process the measurements without the project are defined that will be realized. The validation was done with support of the so called GEH-mark

$\mathrm{GEH} = \sqrt{((2 \times (\mathrm{M} - \mathrm{C})^2)/((\mathrm{M} + \mathrm{C})))}$ with M = modelled value and C = counted value.

The model is sufficiently valid because the sum of the counting points the GEH is between 10 and 20 and the GEH does not exceed at 85 % of the examined points.

At last it was proved that the demand changes by changed resistances as well.

6.3.2 Bypass B469n—B26n (Aschaffenburg—Markt Stockstadt) (PTV 2011)

The expansion of the federal highways B469 and B26 between Markt Stockstadt and Aschaffenburg, Germany, was also analyzed with an intermodal model based on the VDRM (Transport Data Base for the Rhine-Main Area). The planning area and its surroundings were described regarding the 95 % of the originating and terminating traffic. There were made enquiries about structural analysis (inhabitants, employees, school places). The cell structure (148 traffic districts) was examined in detail as well as the street structure and road network (attributes and typisation from the VDRM).

The modelling of transport was described for private transport as well as commercial transport on road (Software: *Verkehr in Städten und Regionen Erzeugung Verteilung Aufteilung zum Wirtschaftsverkehr*—VISEVA-W with the touring concept: 5 types of car categories and 3 types of economic branches). The modelling was based on 36 transport behavior-homogenous groups, structural analysis and characteristics of offer.

External transport interaction data such as commuters, school and kindergarden trips were used. In addition, data of mobility behaviour was analysed (rates of mobility, route distribution, intrazonal trips) (Lohse 2004).

The capacity restraint concerning private transport was reproduced by VISEVA-P, the commercial transport was analyzed by VISEVA-W with an equilibrium of the matrix. The matrix control was carried out by comparing the old and the new one. External matrices were used; several characteristics were verified and changed within VISEVA (Lohse 2004). The network model was checked for validity as well. The calibration was done with traffic counts from the SVZ 2005 (Traffic Census in 2005). The differences of marks values were verified and there was applied a fine calibration by the matrix correction method.

Besides, some traffic counts (24 h marks) from the road construction authority were used as well. The public transport network was implemented in the model (rail transport, public transport on roads, lines and timetabels). For the computational process the measurements without the project are defined that will be realized. The validation was done with the GEH-mark:

$\mathrm{GEH} = \sqrt{((2 \times (\mathrm{M} - \mathrm{C})^2)/((\mathrm{M} + \mathrm{C})))}$ with M = modelled value and C = counted value.

The model is sufficiently valid because the sum of the counting points the GEH is between 10 and 20 and the GEH does not exceed at 85 % of the examined points. The study demanded that the divergences between counted and modelled marks should not exceed 10 %. In this case the coefficient of correlation was 0.98.

6.3.3 Insufficient Sensitivity for Measurements

An example of the lack of sensitivity for measurements can be illustrated with a traffic model of a Bavarian metropolis:

When adding express bus services in an already set up multimodal integrated transport model it was expected that this would promote public transport to increase its passenger volumes and result in a modal-shift from motorized individual transport to public transport. However, the calculation result surprised the modellers because the express bus increased the passenger volumes and the private transport volumes as well.

The reason for this is the fixed weighting of the (decreasing) travel time of public transport with the travel times by car and bicycle and the walking time to provide an average resistance for the distribution calculation. In the gravity model of the spatial distribution of traffic the average resistance causes an increase in the number of trips to the areas affected by the express bus because of the lower resistance.

In the following modal split calculation this higher amount of trips will be processed in a logit model to the various modes of transport. Since the weighting of the travel times for public transport in comparison to other factors has not the same or a higher weight as in the calculation of travel times for the initial average resistance matrix the public transport gets only a small proportion of the overall higher trip amount.

The motorized individual transport-mode benefits from the lower weighting of public transport travel times in the modal split and can attract a higher number of trips compared to the initial situation.

Since up to date many traffic models include the method of weighting the travel times to provide an average resistance matrix for the spatial traffic distribution this determined nonexistent sensitivity of measurements certainly is part of other models as well. To fix this problem the modellers is faced with quite a few challenges.

6.3.4 *Problem of Data Availability*

An example of the questionable relationship between data availability and segmentation of the traffic model is typical in Germany because many cities use the more or less standardized household-surveys of the Technical University of Dresden for their modeling: A traffic model in a high state of disaggregation includes up to 20 behavioral homogeneous groups with more than 15 different transport purposes and 5 transport-modes. The data base of this household surveys on mobility behavior uses net sample sizes of about 4.000 or even only 1.000 inhabitants.

In the calibration process for the spatial traffic distribution purpose-specific distance or travel time distributions are needed for each group of people. This leads to $20 \times 15 = 300$ different groups of people-purpose distributions, which have to be analyzed and calibrated. With an equal distribution of the survey data on the purpose and people there are 4.000/300 = 13,3 or even only 1.000/300 = 3,33 given individual values for calibration. If the 300 people groups-purpose differentiations even are split for the modal split calculations in the 5 available transport-modes for each calibration task there are only 13,3/5 = 2,7 or even 3,3/5 = 0,7 individual items available.

This example shows that a very detailed usage in modeling requires very large net samples that are often not financed in lack of purpose.

6.4 Summary and Outline

The requirements on transport models apply both to the private and commercial transport models. The authors describe the different requirements and defined uniform standards.

In this way, the quality of the modeling should be increased. In addition the contracting authorities as well as the modellers in practice will get hints for the different requirements and quality criteria.

This contribution should be the basis for a greater understanding of the data needs in order to obtain a higher overall quality in modelling. In addition, this should ensure the planning in jurisdictional context.

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Part II
Potentials for Usage of e-Mobility in Commercial Transport

Chapter 7
Who Are the Early Adopters of Electric Vehicles in Commercial Transport—A Description of Their Trip Patterns

Ina Frenzel

7.1 Introduction

Several German literatures focused on identifying the potential of EVs on the German market or try to characterize the potential early adopters (see e.g. Plötz et al. 2014).

Previous studies focusing on the use of electric vehicles try to describe users primarily on the basis of socio-demographic characteristics and to analyze the factors that have influenced the decision to purchase. In the German-speaking countries most studies based on stated-preference surveys of potential users or on surveys of test users within scientific pilot projects or derive the potential out of large traffic and transport data sets (see e.g. Globisch and Dütschke 2013; Trommer et al. 2013; Wietschel et al. 2012; Götz et al. 2011). In Germany, only few studies focusing buyers of EVs were conducted. But these studies include relatively small sample sizes with less than 100 participants (see e.g. Peters et al. 2011). Their results are limited generalizable. Especially studies focusing the commercial users of EVs in Germany are relatively rare. Nevertheless, there are nearly 20,000 registered EVs in Germany already and thus a notable number of private and commercial users integrating EVs in everyday life (KBA 2015). This target group and their experiences need to be analyzed. Regarding the usage of EV technologies, the influence on the current organization of commercial transport and traffic is one important topic. The paper is therefore focusing on the usage of EV technologies

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and the influence on the current organization of commercial transport and traffic. The main questions within this topic are addressed:

- How is the target group characterized?
- How are EVs implemented in (present) fleet?
- Is the logistical organization of companies restructured by using electric vehicles in comparison to conventional vehicles, and how is thus done?

To answer these questions the paper presents extracts from a conducted study of current electric vehicle users in Germany. Focusing on commercial early adopters the paper will first give an overview of their profile and second describe their trip patterns like distances and trip planning behavior. Finally the paper will give insights into replacements of ICEVs and its effects.

7.2 Data and Methodology

7.2.1 Methodology of the Survey

To describe the status quo of the usage of electric vehicle, and to get an impression of the early adopter and their user behavior for the first time, the Institute of Transport Research of the DLR e.V. (German Aerospace Centre) conducted a survey across all owners (private and commercial) of electric vehicles in Germany. The survey took place between December 2013 and February 2014. Over 9,200 persons were addressed (gross-sample). One third (n = 3,111) of them answered, while the commercial electric vehicle user constitute 37 % (n = 1,165). This proportion corresponds to the one in the gross-sample.

The target group of respondents included owners of all kinds of electric vehicles with an external charging option registered in Germany. These include BEVs, which are equipped purely with a battery electric drive, and so-called plug-in hybrids (PHEVs), which are equipped with an internal combustion engine (ICEV) in addition to the electric motor. No further distinction between PHEVs and so-called range extended vehicles (REEV) was made. On account of the comparatively widespread use of electric light vehicles (e.g. the Renault Twizy), these were also included in the sample, provided that they satisfied the requirement of being a three- to four-wheeled vehicle with at least 300 kg gross vehicle weight. Two-wheeled vehicles were excluded because part of this vehicle group contains of electrically driven wheelchair. Those were not originally targeted. Another limitation regarding the sample refers to the branches. Registered vehicle owners of branches like car manufacturing, wholesale or trade or repair of motor vehicles or car rental as well as car sharing were also excluded. The survey aimed at analyzing the usage of EVs and therefore addressed the users. It was assumed that companies of the mentioned branches do not use electric vehicles themselves in most cases. As a result the actual users of the electric vehicles cannot be determined. Due to these exclusion criteria the finally addressed persons are described as gross-sample and the respondents[1] as net-sample.

The survey was conducted using standardized online questionnaires. These asked not only multiple-choice questions, but also quite deliberately open ones. In co-operation with the Federal Motor Transport Authority (KBA), the target group was contacted by mail and was thus made aware of the online survey. Due to data-protection provisions no personal data were recorded and therefore a non-response-analysis had to be renounced.

The survey contained questions on the following subjects:

- characteristics of the electric vehicle
- motivation for vehicle purchase
- use of vehicle
- charging pattern
- general information about companies using electric vehicles

Generally, the aim of the study was to analyze the actual utilization of electric vehicles in everyday life. Thus, to control the goal been achieved the commercial questionnaire first asked whether the respondents have taken the decision to buy an electric vehicle themselves; and whether they are the vehicle user. If they are not one and the same person, the actual vehicle user should answer the subsequent questions. A solid majority of the respondents (72 %) identified themselves as being both decision-maker and user or the person planning the disposition of the electric vehicle. One reason for this coincidence is the large proportion of small-sized companies among the commercial users of electric vehicles (see next sector). Further 19 % are just user or planning persons and only a minority (9 %) just decided the EVs purchase.[2]

7.2.2 *External Data for Comparison*

To figure out whether and to what extent the commercial EV users perform differently from general commercial traffic behavior, the survey results are compared to information given by a major data source of commercial road transport in Germany called Motor Traffic in Germany (KiD) (WVI 2010). The KiD was conducted in 2010 and collected a large number of driving profiles in commercial traffic. The observation period of these survey covers one day. The data set of KiD 2010 therefore consists of vehicles with and also without movements on the survey day.

[1]This paper concentrates on the description of commercial EV users. Net-sample therefore means commercial respondents. Unless there is no other indicated amount the net-sample constitutes of 1,165 commercial respondents.

[2]At this point no filtering will be executed. It cannot be assumed that the decision-maker are unable to give statements regarding EVs usage.

All references to ICEVs in the following text are own calculations based on the KiD 2010 data set and refer to car-sized and light-duty vehicle up to 3.5 tons gross vehicle weight powered by internal combustion engines. The analyses regarding ICEVs are restricted to these vehicle sizes in order to improve a certain comparability to the EVs data. An inclusion of vehicle sizes of 3.5 tons gross vehicle weight and more would lead to distortions because there are no comparable sizes of EVs available and recorded in the survey. Furthermore analyses of the KiD 2010 data set in this paper exclusively involve vehicles which were used during the observation period.

Both studies differ regarding their survey styles. Meanwhile the KiD collects trip profiles through protocols for the survey day, the survey of electric vehicle users asked of experienced averages. A comparison of groups from both studies therefore can be seen as a first approach only, since "before and after" data are not yet existing to this extent and context.

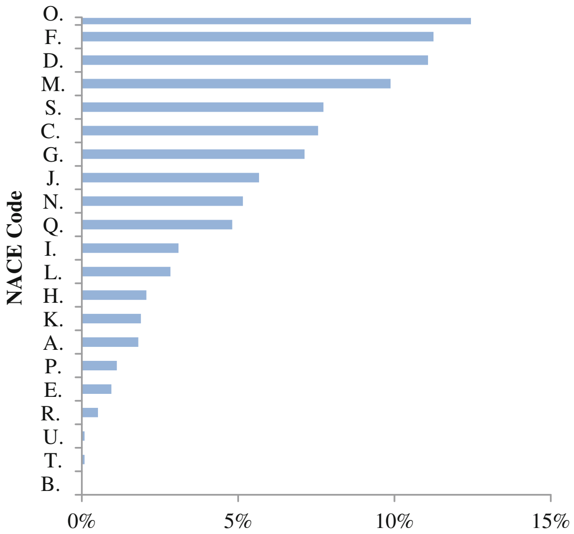
7.3 Profile of the Commercial Users of Electric Vehicles in Germany

First, a short description of the current commercial users of electric mobility will give an impression of their characteristics. Such users primarily (two-thirds) work in small companies[3] with one establishment employing 49 persons and operating a fleet of up to nine vehicles, including one electric vehicle. The main sectors practicing electric mobility are public administration (13 % of commercial users), construction industry (12 %) and energy supply (electricity, gas, steam etc.) (11 %) (see Fig. 7.1). No branch distinguishes itself as having a special affinity for electric mobility. But by combining all its defined branches,[4] the service sector constitutes the largest number of commercial electric vehicle users, at 25 %.

Commercial electric mobility must not only be seen as a phenomenon of major cities (with at least 100,000 inhabitants). In fact it is almost equally present in small-sized towns with at least 5,000 up to 20,000 inhabitants (32 %) and major cities (34 %) (see Fig. 7.2). Due to similar distributions regarding spatial patterns, it can be assumed that the net-sample is approximately equivalent to the gross-sample. A comparison of gross- and net-samples regarding branches shows different distributions. While, as described, the main branches in the net-sample are public administration, construction industry and energy supply, the main part of the gross-sample are other services activities (37 %).

[3]The categorization of companies is along the lines of the NACE classification 2008 from the European Commission (Eurostat 2008).

[4]That includes the NACE Codes K, M, N, S.



Legend

O. Public administration and defense; compulsory social security

F. Construction

D. Electricity, gas, steam and air conditioning supply

M. Professional, scientific and technical activities

S. Other services activities

C. Manufacturing

G. Wholesale and retail trade; repair of motor vehicles and motorcycles

J. Information and communication

N. Administrative and support service activities

Q. Human health and social work activities

I. Accommodation and food service activities

L. Real estate activities

H. Transporting and storage

K. Financial and insurance activities

A. Agriculture, forestry and fishing

P. Education

E. Water supply; sewerage; waste management and remediation activities

R. Arts, entertainment and recreation

T. Activities of households as employers; undifferentiated goods - and services - producing activities of households for own use

U. Activities of extraterritorial organizations and bodies

B. Mining and quarrying

Fig. 7.1 EV users differentiated by branches (n = 1,131)

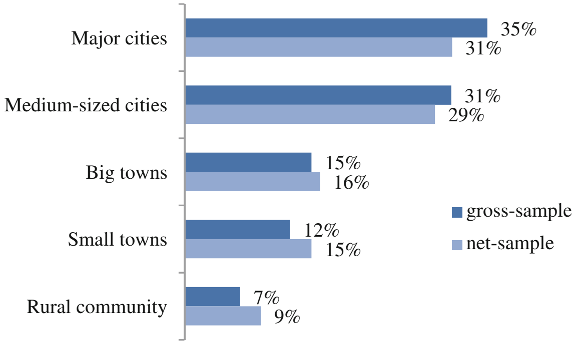


Fig. 7.2 Distribution of EV users' sites within the gross-sample (n = 3,710) and net-sample (n = 1,085). The spatial levels are taken from the Federal Institute for Research on Building; Urban Affairs and Spatial Development (BBSR). Major cities are defined as municipalities with at least 100,000 inhabitants. Medium-sized towns are municipalities with at least 20,000 up to 100,000 inhabitants. Small-sized towns are defined as municipalities with at least 5,000 up to 20,000 inhabitants. Smaller units are defined as rural communities (BBSR 2003)

7.4 Descriptive Analysis of Trip Patterns

7.4.1 Usage Restrictions

Regarding usability, the commercial users were asked which purpose their electric vehicles should serve but are restricted by technical properties. One third answered that they are able to use the electric vehicle without feeling any restrictions to their purpose. The underlying causes of restrictions—if perceived as such—are the low range (41 %) and the long charging duration (28 %).[5]

In the following, the paper will go into more detail regarding aspects like daily driven distances, EV trip planning and whether the EVs replaced an ICEV and the resulting impacts.

7.4.2 Distances

Half of the respondents (52 %) report daily tours[6] of up to 30 km per trip on average across the entire fleet. A further 31 % state the tours of the company fleet differ between longer and shorter distances and longer and shorter stops. The remaining 17 % are driving more than 30 km per trip on average. The daily distance covered by the electric motor of plug-in hybrids is 47 km, and of BEVs (battery electric

[5]Within the question concerning usage restrictions multiple answers were possible.

[6]A tour is understood as a sequence (linkage) of several trips. A tour has the same start and end point (Clausen 2009, p. 155).

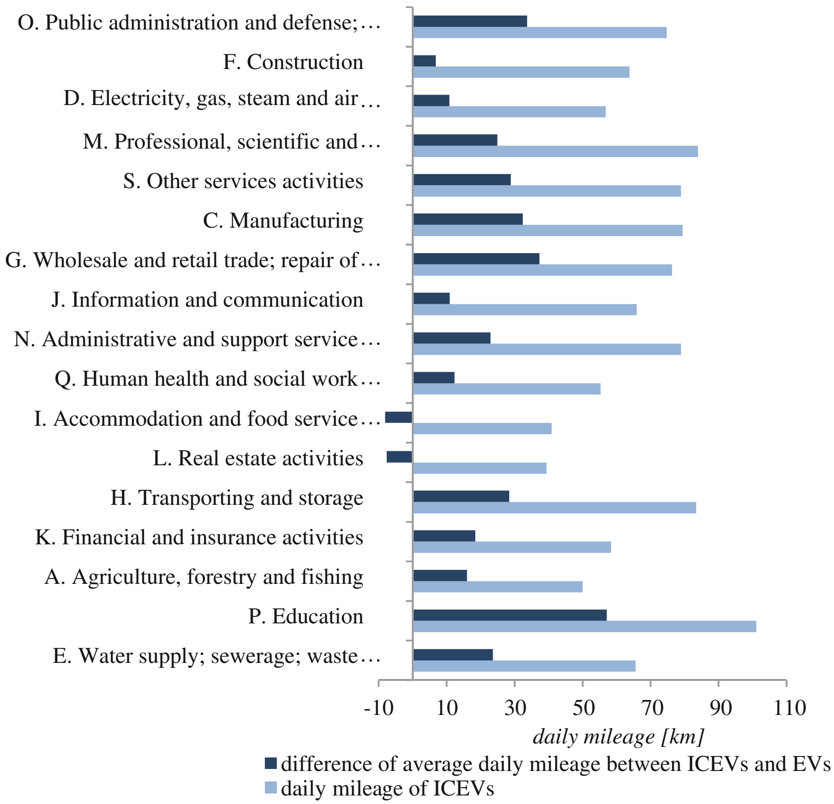


Fig. 7.3 Average daily mileages of ICEVs and the differences between average daily mileages of ICEVs (n = 26,199) and EVs (n = 1,131) in kilometers sorted by branches frequency. The information regarding the daily driven distances of ICEVs are the author's own calculations based on the KiD 2010 data set and refer to mileage for the purpose of commercial transport (WVI et al. 2010). As mentioned, the group of ICEVs considered consists of car-sized and light-duty vehicle with up to 3.5 tons gross vehicle weight. Information about the daily mileages of EVs is calculated based on the survey data. The respondents were requested to specify their average daily electric-driven kilometers for commercial purposes. Sectors which were mentioned by less than 10 respondents are unconsidered in this figure

vehicles) is 49 km. Every fourth commercial user drives even shorter electrical distances per day of up to 25 km. To get an impression whether EV usage differs from ICEV usage a comparison with trip data out of the KiD 2010 will be given in the following.

When considering the commercial daily mileage separated by type of vehicle propulsion and branches, it is recognizable that the majority of electric daily driven distances are between 40 and 60 km, whereas in more than half of the branches (13 out of 21) ICEVs' daily mileages are over 60 km in average (see Fig. 7.3). But only three sectors (P. Education, M. Professional, scientific and technical activities and H. Transporting and storage) drive on average more than 80 km per day.

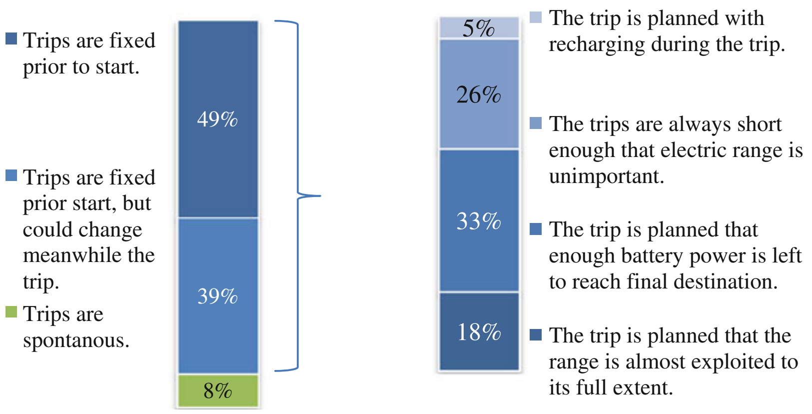


Fig. 7.4 Trip planning profiles. The remaining percent to 100 % are accounted for the answers "do not know" and "not specified". And the importance of electric range within trip planning

Further information is gained by an analogy of the daily mileages of electric powered vehicles and those powered by internal combustion engines, demonstrated by their differences per branch.[7] The majority of commercial EV users drive fewer kilometers per day on average compared to their ICEV counterparts. Deviations are varying from 11 up to 56 % of the ICEVs average daily mileage per branch. Focusing on the top three most common represented sectors within the EVs (see also Fig. 7.1), differences vary between 7 km (F. Construction) which means a deviation of 11 % and 34 km (O. Public administration and defense; compulsory social security) which means a deviation of 45 %.

7.4.3 *Trip Planning*

Currently, the majority (88 %) of commercial electric vehicle users plan their trips in advance (see Fig. 7.4). Almost half of them (45 %) use manual trip planning.[8] Only a minority of 9 % of plans are software-based. Note that an additional 19 % of those planning their trips are not integrating their EVs in these processes. The proportion of trip planning by users of EVs is, however, higher compared with car-sized and light duty vehicles powered by internal combustion engines in Germany (WVI 2010). Trips are manually planned in 24 % of ICEVs. The amount of non-planned trips is 40 % within ICEVs. Unexpectedly, considering the fact of

[7]The calculation of the differences based on the ICEVs' average daily mileages subtracted with those of the EVs.

[8]Within the question concerning the usage of trip planning technologies multiple answers were possible.

limited range and long charging duration, it seems unnecessary to strictly regulate EV usage for every fifth user. But those who are planning their trips with an EV are aware of its limited range. One third of planned trips are prepared in a way that enough battery power is left when finished. Even 18 % almost exploit the electric range. This applies to PHEVs (27 %) and BEVs (17 %) as well.

Distinguishing between users who plan their trips and those who do not shows only small differences in electric daily driven distances. Planned trips cover 46 electric driven kilometers on average per day. Meanwhile, spontaneous trips reach 44 km daily. It is interesting that users, who have planned trips which may change during the trip, drive electrical on average 54 km. That is on average 8 km more than exclusively planned trips and 10 km more than spontaneous trips.

EV usage in branches with less differences, such as the construction industry, is more planned and thus there is a greater awareness of the length and duration of their trips. However, such assumptions cannot be confirmed by the data. The construction industry plans its EV usage less compared to the average of EV users. Only 35 % of users of this branch plan their EV trips in advance, whereas a branch recording large deviations between the daily mileages of ICEVs and EVs, such as in sector O (Public administration and defense; compulsory social security) plan their EV trips more often (59 %).[9]

Even if the differences are quite large when looking at the average daily mileages of ICEVs, it seems unnecessary to be aware of restrictions in electric range, which would be sufficient to cover the daily mileage directly even without recharging. A further look at Fig. 7.4 shows that, only a minority (5 %) is integrating recharging into their trip planning. That means few commercial users are taking f.e. the usage of public charging infrastructure into account while preparing their EV trips. That en route recharging is rare, is also evident in the question of charging places and times. The majority (77 %) start charging in the afternoon and evening hours between 15:00 and 22:00. The preferred place for charging is the own premise. 62 % uses this charging place (almost) daily.

7.4.4 Replacement of ICEVs by EVs and the Impact on Transportation Processes

Due to the reduction of transport-related CO_2 emissions, it is relevant whether the electric vehicle was purchased by the company in addition to the already existing vehicles powered by internal combustion engines or if vehicles were replaced. Forty percent of the commercial respondents indicated that they have replaced another vehicle since the purchase of an electric vehicle. Another 9 % plans to replace it within the next 12 months. This shows that almost half of the respondents (plans to) exchange an existing ICEV for an EV. The question of whether such abolition has a

[9]For the average of trip planning behavior see Fig. 7.4.

causal relationship to the purchase of the EV was confirmed by 89 % of the commercial respondents.

The EV mostly replaced the other vehicle directly. Only a relatively small proportion (9 %) of commercial electric vehicle users used the vehicle temporarily in parallel with the subsequently replaced vehicle, and decommissioned the latter only within the first 12 months after the purchase of the EV. There were a variety of reasons: the users wanted to test the reliability of the EV, gain confidence, and in case of malfunctions, be able to replace the electric vehicle with a conventional vehicle, or they just generally wanted to experiment with using the electric vehicle.

In distinguishing between BEVs and PHEVs, it can be seen that since the EV's purchase already more than half of the PHEVs (57 %), though only 41 % of BEV users, replaced an ICEV. This suggests that using a BEV is perceived as more restrictive and therefore in the event of a default hold a replacement ICEV.

The analysis shows that almost every fourth commercially used EV is a small car (e.g. VW Polo). Another 20 % are EVs with 3.5 tons gross vehicle weight. In 32 % of all cases, the electric vehicle replaces another vehicle (50 % diesel, 42 %

Vehicle segment of the substituted vehicle

Vehicle segment of the EV	Light vehicle	Very small cars	Small cars	Compact cars	Medium-ranged cars	Luxury cars, Sportswagon	Light-duty vehicles
Light vehicle	4	4	13	5	7	5	0
Very small cars	0	18	18	9	5	5	3
Small cars	0	5	36	25	10	8	14
Compact cars	1	0	7	31	34	18	11
Medium-ranged cars	0	0	0	2	4	5	0
Luxury cars, Sportswagon	0	0	1	1	5	16	2
Light-duty vehicles	0	1	7	6	4	2	62

Legend

0 respondents
1-10 respondents
11-20 respondents
21-30 respondents
31-40 respondents
over 40 respondents

Fig. 7.5 Comparison of vehicle segments of the EV and the substituted vehicle (n = 414)

gasoline). A closer look at cases where the EV replaces a car refutes the thesis: a trend towards smaller sizes is recognizable (see Fig. 7.5). Almost every second (49 %) user who replaced another vehicle chose a smaller sized EV. This fact indicates that commercial users partly have to choose smaller EVs because of the limited number of models available at the moment. This is at least confirmed by analyzing the usage restrictions of commercial EV users. The data show that low possible payload is a central reason for non-usage especially regarding the transportation of goods. In other words, the limited options of EVs with larger payload limit the amount of users.

To answer the question whether a replacement of an ICEV and the usage of an EV influences transport organizations, the survey asked if the yearly driving performance of the fleet changed after the introduction of the EVs.[10] Nevertheless the majority (70 %) of these users who replaced a vehicle by an electric one quotes no change, neither increasing nor decreasing, in the annual driving performance of the company's fleet. A separate analysis—of cases in which the EV replaced another and those who do not—shows no differences in the response towards annual mileage.

Further, the users were asked whether the payload has changed through the use of the EV instead of the substituted Diesel or gasoline engine. The results given by Fig. 7.5 are confirmed within the question asking about a possible change regarding their payload. One third of users who replaced a combustion engine vehicle by an electric vehicle report a diminished payload capacity. The majority (59 %) feels no changes in point of payload.

7.5 Conclusions

The analysis first shows that a majority of smaller companies are the early adopters of electric mobility. They are driving electrical distances of 49 km on average per day. The commercial early adopters in Germany are mainly to be found in branches realizing mainly business passenger transport (f.e. public administration, energy supply or service sector) in small-sized towns as well as in major cities.

It is conceivable that EVs cannot operate all kind of trips, due to their limited range. The restrictions and possibilities associated with the electric vehicle technologies (e.g. range, charging time and emission-free usage) and the type of implementation in fleets could affect the organization of commercial transport and traffic and the demand of adjustments. Therefore, it seems reasonable to assume that trips are recreated while implementing EVs in present fleets. This could have an impact on the driving performances of fleets. However, the results are giving no indications to confirm this thesis. Only 40 % of the commercial EV users substitute another Diesel or gasoline engine within the purchase. That means the majority

[10]At this point only companies owning two and more vehicles are considered.

integrate EVs as additional vehicles in their fleets. Half of the substitutions were connected with a reduction in vehicle sizes. That influenced partly the impact on the payload. Every third user remarks a diminished payload. In addition, constraints mentioned by the commercial users are rather seen in the transportation of goods and materials due to insufficient payload. It could be assumed that the down-scaling while substituting an ICEV can be explained by a limited variety in electric vehicle models. Particularly when it comes to transport loads larger vehicle sizes of EVs are required.

One major result is that the commercial early adopters have trip structures matching the range and charging characteristics of EVs. So they have therefore trip-profiles which allow usage without any adjustments or adaptations regarding technical conditions. The analysis regarding distances further shows that the EV usage varies thereby from sector to sector partially immense from those of the ICEVs used in Germany. Few branches seem to use their EVs similar to their ICEVs with respect to daily mileages, while others are rather cautiously and drive less kilometers electric than with combustion engines. The results indicate that the commercial early adopters are not restructuring It therefore seems that the commercial early adopters of EVs are not representative for their branch in this point.

In addition regarding the topic of logistical organization it is noticeable that compared to the German average EV using companies are planning more frequently their trips in advance. One could be forgiven for thinking that trip planning behavior has an impact on the willingness to integrate EVs in the company fleet. But a test of correlation between these two aspects cannot be given by the study. Furthermore whether these variations in daily mileages and downscaling (within replacements) are leading to logistical conflicts is a matter of speculations. To gain insights into this topic it is necessary to examine the whole heterogeneous fleet and ideally to select before/after data.

A further interesting result of the analysis of trip planning behavior is that recharging during trips is rarely planed by the commercial early adopter and the majority charges on their own remises. An expansion of public charging infrastructure seems not necessarily to be a solution to increase the attractiveness of electric vehicle for potential commercial user.

The paper describes results of a study of commercial early adopters of electric vehicle with a special focus on their trip patterns. As mentioned due to data-protection provisions a non-response-analysis had to be renounced. A representative status of the study therefore had to be verified by sample characteristics. A closer view on electric users company locations described by postal codes first shows an almost similar distribution within the gross- and the net-sample. Meanwhile a second comparison of branch distributions shows variations. But because of different survey methods, however, industry classification cannot provide guidance towards representative status. In the gross-sample, employees of the Federal Motor Transport Authority (KBA) categorized the vehicle-owning companies into branches. The respondents, in contrast, were requested to specify the branch of their company themselves. In terms of categorizing their company with respect to the branches of NACE classification, respondents often deviate from the categorization given by official authorities (WVI 2012, p. 288ff.). The self-specification on the level of sections (A to U) may lead to inaccurate information. Further characteristics for testing representativeness are unavailable due to a lack of information within the gross-sample.

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Chapter 8
Potentials of e-Mobility for Companies in Urban Areas

Wolfgang Trummer and Norbert Hafner

8.1 Introduction

8.1.1 Survey on e-Mobility for SME Companies in Graz

In 2013, a 22 month research project on urban logistics called “Urbane E-Lieferservices” (Modellregion für Elektromobilität Graz, Austria) was started. The project included a survey on requirements for e-based logistics in urban areas. Within the survey, two subjects were defined: firstly, the current situation of transport and delivery logistics at urban companies had to be determined; secondly, the companies’ technical, logistical and operational requirements and needs for comprehensive electric city logistics were investigated. The survey consisted of 50 individual questions and was implemented by using an online platform. The Styrian Chamber of Commerce supported the project.

Twenty-one companies from Graz participated in the survey during the period from November 2013 to February 2014. When selecting the participating companies, a balanced mixture was considered, company size and commercial sector being decisive criteria in determining the test partners. Only small and medium-sized companies doing their main business in and round Graz were invited to participate in the survey. Additional criteria included the companies’ general interest in alternative concepts in the field of urban logistics. These companies were contacted personally via phone or email.

The twenty-one participating companies can be assigned to four different commercial segments:

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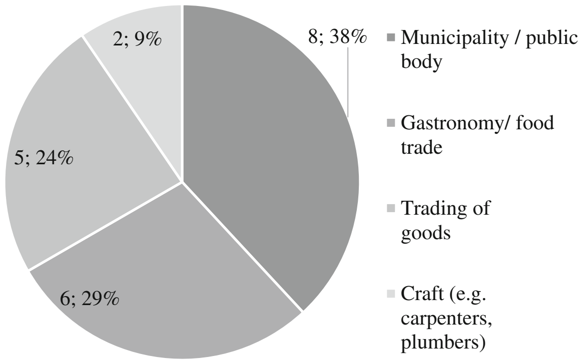


Fig. 8.1 21 participating companies (=100 %) within the survey, classified according to commercial segments

1. Municipalities/public body: 8 participating companies (=38 %)
2. Gastronomy/food trade: 6 participating companies (=29 %)
3. Trade of goods: 5 participating companies (=24 %)
4. Craft (e.g. carpenters, plumbers): 2 participating companies (=9 %)

The "municipalities/public body" segment was the group with the highest company participation, followed by the "gastronomy/food trade" group (Fig. 8.1).

The companies' logistic terminals are located in and around the City of Graz. While 16 companies have their registered location directly in the City of Graz (equivalent to approximately 76 % of participants), five companies are based in the area surrounding Graz (equivalent to approximately 24 % of participants).

8.1.2 Testing Campaign for SME Companies in Graz

During the testing campaign, nine participating companies were invited to test their logistic performance on electro-mobility ability. The testing was carried out with an e-mobility tracking app in which the driving performance was recorded and analyzed afterwards with respect to different best-case and worst-case scenarios. A resulting report informed the participants under which conditions the operation of electric vehicles in their company seemed reasonable from a technical and economic point of view.

8.2 Survey—Main Results

8.2.1 Current Situation of Freight Logistics in Urban Areas

The first part of the survey dealt with the current situation of freight logistics in urban areas from companies' perspectives. Within the survey, the following results were determined:

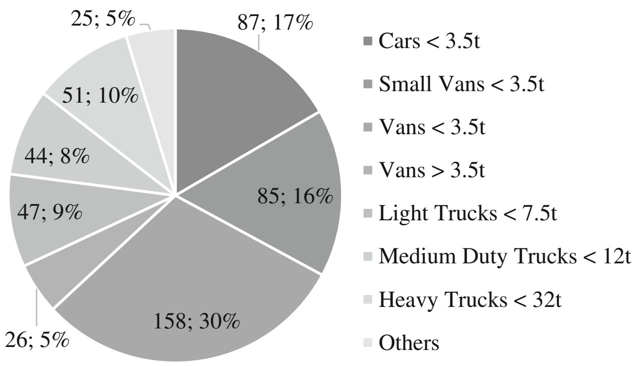


Fig. 8.2 Number of vehicles in use at the companies, classified according to vehicle types

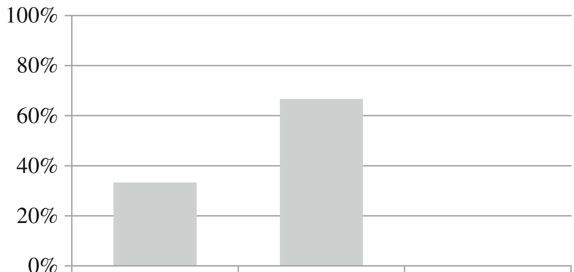
Current truck fleet at the companies

Depending on their scope and responsibilities for business goods logistics, the companies' truck fleet has a specific structure. In total, 523 vehicles used at the companies were counted. This corresponds to an average of about 25 vehicles per company. These vehicles were mainly light trucks under 3.5 tons, amounting to about 30 % of the vehicles, followed by about 17 % passenger cars under 3.5 tons and vans under 3.5 tons, amounting to about 16 % of the vehicles listed.

The number of vehicles under 3.5 tons gross vehicle weight thus comprise about 63 % of vehicles listed (Fig. 8.2). Specifically, this segment of electric commercial vehicles is covered well by the market.

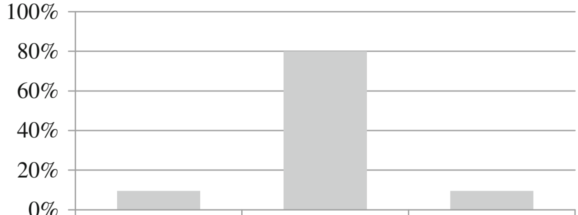
Current usage of electric vehicles in urban areas

Approximately 33 % of participating companies within the survey (=7 companies) already use electric commercial vehicles (Fig. 8.3). As already mentioned, especially companies that showed interest in electric mobility were addressed in the survey. A company with its own electric vehicles tends to show a higher affinity for these topics than other companies. This partly explains the high proportion of companies with electric vehicles within the survey.



	YES	NO	not specified
counts	7	14	0
percent	33%	67%	0%

Fig. 8.3 Number of companies with electric commercial vehicles in use



	maximum permissible weight	cargo volume	not specified
counts	2	17	2
percent	10%	80%	10%

Fig. 8.4 Criteria for vehicle selection

In total, 81 electric vehicles were named. However, the distribution of active vehicles in each company has a high spreading: minimum is one electric vehicle; maximum is equal to 67 electric vehicles for one participating company (company from the segment of public body). Overall, this result emphasizes the trend towards electric mobility for enterprises in urban areas (Projekt CycleLogistics 2014).

Shipping volume of vehicles

Available cargo space or maximum permissible weight are important criteria for selecting commercial vehicles. Loading capacity and maximum permissible weight are often reduced in electric vehicles (due to the large volume or weight of battery systems), compared to conventional vehicles. The total vehicle weight in turn has a significant impact on energy consumption and range of electric vehicles.

Approximately 81 % of the participants see transport volume as a decisive factor for choosing the vehicle. Therefore, only 10 % of respondents see maximum permissible weight as a limiting factor when choosing commercial vehicles (Fig. 8.4). Further investigations show that the use of maximum cargo space volume is taken for about 58 % of logistic trips. In comparison, the use of maximum allowable transport weight is needed only for 33 % of trips.

The result shows that maximum permissible transport weight is not claimed in the majority of the performed transportation and delivery operations. This allows a higher operating distance of electric commercial vehicles in daily use (BVL Österreich 2014).

Mileage per day

The studies of commercial vehicle mileage in Graz show:

- 82 % of mileage is covered within the inner City of Graz
- 18 % of mileage is covered within surrounding local areas

Further detailed results show the distribution of mileage in Graz (inner city and surroundings). The average mean distance traveled by single commercial vehicles per day is about 80 km (AM), whereby 75 % of all vehicles do more than 30 km/day (IQR_Min) and 75 % do less than 100 km/day (IQR_Max). However,

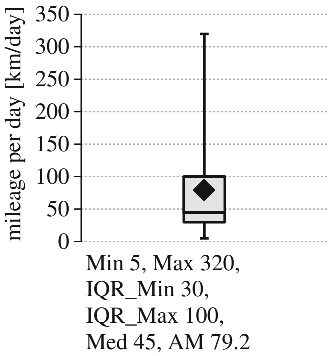


Fig. 8.5 Distribution of companies' mileage per day

the distribution of the length of the route has a high spreading: minimum (Min) is 1 km a day; maximum (Max) is equal to 320 km a day and the median is 45 km a day (Med) (Fig. 8.5).

Commercial electric vehicles up to 3.5 tons gross vehicle weight that are currently available on the market have an average range of about 100 km with one single battery charge (according to the manufacturer specifications). Comparing these values with the survey results, it appears that a majority of daily delivery trips can be easily handled by electric vehicles. Advantages for usage of electric vehicles in the field of last mile logistics can be seen (small transport volumes, short distances, high stop-and-go content working on energy recovery, etc.), especially in urban areas (Leonardi et al. 2010).

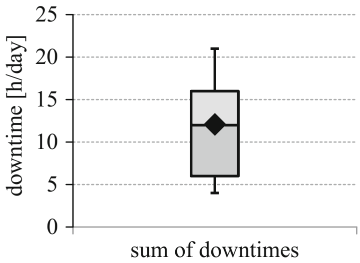
Available charging time

Vehicle downtimes within the daily use of electric commercial vehicles may be used for battery charging. According to the survey, the total vehicle downtime is about 12.1 h/day on average mean (AM). 75 % of responses give a total downtime of vehicles longer than 6 h/day (IQR_Min), 50 % giving a total stop time longer than 12 h/day (Med) and 75 % with a total downtime shorter than 16 h/day (IQR_Max). Minimum (Min) is 4 h a day and maximum (Max) is equal to 21 h of total downtime a day (Fig. 8.6). Currently available commercial vehicles up to 3.5 tons gross vehicle weight require an average battery charging time of about 5 to 10 h (according to the manufacturer specifications). Comparing these values with the survey results, most of the daily transport routines provide sufficient load time for vehicle battery loading.

Current problems in central urban areas

Specific traffic and loading time regulations provide municipalities opportunities to control and support sustainable city logistics (Emission-free last mile delivery service 2014). From the companies' perspective, main problems within actual transport and delivery services in urban areas are:

- Insufficient loading zone areas
- Difficulties traveling from bypass roads to city centers



Min 4, Max 21,
IQR_Min 6, IQR_Max 16,
Med 12, AM 12.1

Fig. 8.6 Vehicle downtime per day

- Restricted access times and duration
- Parking taxes.

8.2.2 Requirements for Successful Future e-Based City Logistics

Further results within the survey illustrate current and/or future requirements for e-based logistics in urban areas, from the companies' point of view:

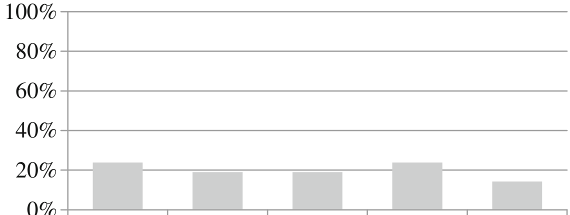
Restrictions of electric vehicles
Companies have specific requirements in electric vehicles for future developments (descending ranking according to the number of mentions):

- Short battery loading times
- Sufficient maximum load (cargo space)
- Low additional costs incurred
- Sufficient typical range

Therefore, demand for vehicle performance is of minor importance. The result thus makes clear that companies are currently worrying about challenges in fields of battery technology and occurring costs by switching to e-based logistics. Further developments in these fields are expected.

43 % of companies need a maximum distance up to 100 km per battery charge (Fig. 8.7). Nowadays, most electric commercial vehicles under 3.5 tons are available with a range of 100 km (according to manufacturers' specifications). Therefore, the use of electric commercial vehicles for many companies seems possible.

Subsidies for successful implementations of electric mobility
52 % of companies expressed their interest in funding opportunities for electric vehicles. This result shows the importance of electric mobility for future logistic solutions. Looking at the results in relation to companies already using electric vehicles (about 33 % of the respondents), companies still seem to be reluctant about the topic. When it comes to funding, the majority of the companies (about 67 % of



	less than 50 km	less than 100 km	less then 150 km	more then 150 km	not specified
counts	5	4	4	5	3
percent	24%	19%	19%	24%	14%

Fig. 8.7 Required vehicle range for electric commercial vehicles

the respondents) would prefer a direct subsidy for the purchase of electric vehicles and related infrastructure.

Necessary infrastructure for urban e-based logistics
The following requirements of urban infrastructure for electric city logistics have been defined. The list is ranked according to the number of mentions:

- Demand for standardized battery change systems (expiry of battery durability)
- Establishment of specialist workshops on electric mobility
- Establishment of public e-charging stations
- Easy access to loading/unloading zones for electric commercial vehicles (costs, duration, space)

The results show that companies currently see challenges in the field of technology standardization, creation of infrastructure for battery charging and repair of vehicle fleets. Further developments are expected in these fields. It is possible to operate electric logistic solutions in urban areas by creating appropriate conditions.

8.3 Testing Campaign

8.3.1 Overview

During the campaign, nine participating companies tested their logistic performance on electro-mobility ability.

We recorded the logistic transport routines of the companies using a GPS-tracking app with extension for electric mobility within the testing campaign, as performed by one of the project partners. The participants received an "electric vehicle simulator" within a smart phone application, which they carried during their daily logistic operations in their vans. This application also calculated relevant electric vehicle parameters such as current battery status, remaining range, etc. So, results could be obtained regarding practically relevant statements for the usage of electric commercial vehicles.

The test campaign ran from May to July 2014. Each participant had the opportunity to test up to five working days. We worked out a detailed test report for every participant.

8.3.2 Results and Reports of the Testing Campaign

The results of the testing campaign were processed according to the following criteria:

- Qualified data base that gives clear statements about potential benefits, strengths and risks in the implementation of e-logistic concepts for companies
- Usability of electric vehicles within the company based on individual logistic tours (regarding vehicle range, battery charging time, cost savings)

In particular, the following results could be achieved:

Daily tour behavior (Figs. 8.8 and 8.9)

From the resulting GPS-tracking data, we specified the routine on daily tours (including mileage, transport times, vehicle downtimes, etc.).

Investigation scenarios for electric mobility (Fig. 8.10)

Within a specific analysis, we determined the energy consumption for e-based vehicles. In further studies, several worst-case scenarios, supposed different battery loading times and additional energy consumption through heating/air condition were evaluated.

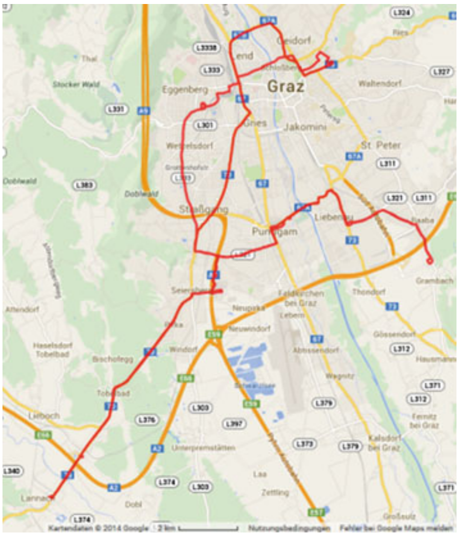


Fig. 8.8 Evaluation of GPS-tour tracking for one specific day

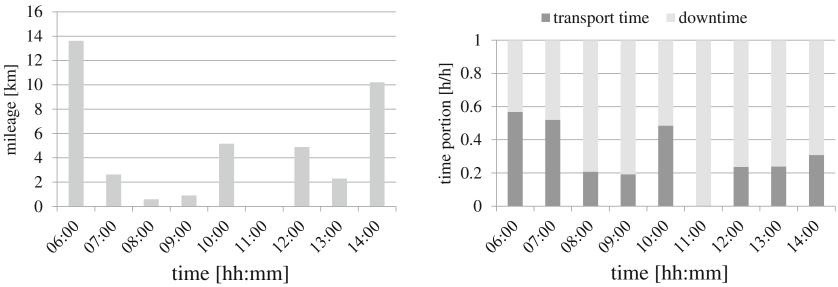


Fig. 8.9 Evaluation of tour distances per hour for one specific day; evaluation of time portions per hour for one specific day

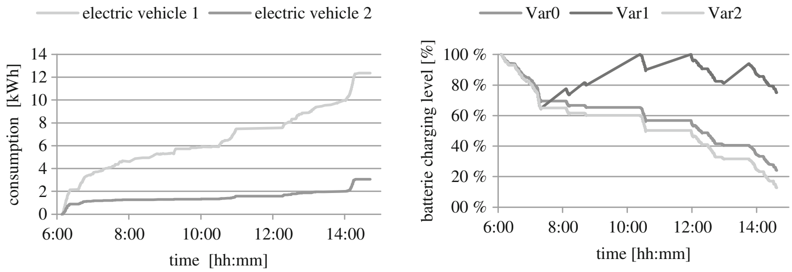


Fig. 8.10 Investigation of energy consumption per day for different reference vehicle scenarios; investigation of battery level per day for different worst-case scenarios

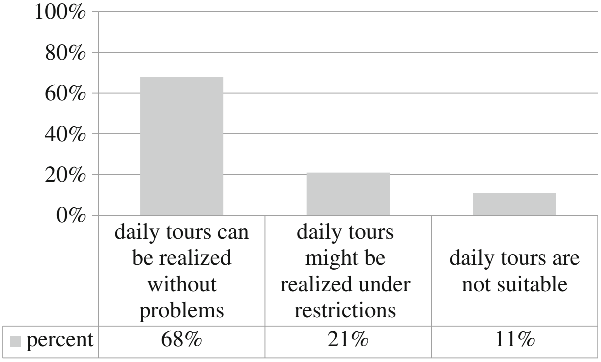


Fig. 8.11 Potential for realization of daily delivery tours by e-based vehicles

Within the test campaign, over 60 records of daily tours from nine companies were evaluated with a total of 4200 driven kilometers. Focusing on specified worst-case scenarios, the analyses yielded the following results. We can see the potential for successful realization of daily tours by e-based vehicles (Fig. 8.11):

- 68 % of daily tours can be realized without problems
- 21 % of daily tours might be realized under restrictions
- 11 % of daily tours are not suitable

8.4 Summary and Outlook

The survey and the following testing campaign within the project "Urbane E-Lieferservices" carried out a detailed overview of companies' logistics tour profiles, transport routines, technical restrictions for vehicles, etc. Furthermore, the requirements to be met for the use of electric vehicles by companies in urban areas were worked out (C-LIEGE 2014).

For many companies, currently available electric commercial vehicles possess adequate technical functions (vehicle range, payload, etc.). For primarily demanded vehicles (especially vans under 3.5 tons gross vehicle weight), numerous electrified vehicle models are available. Battery charging times (especially overnight) are mostly sufficient to fully recharge empty vehicle batteries. Therefore, electric mobility is suitable for usage in sustainable urban logistics (Bretzke 2012).

The executed testing campaign gave companies the possibility to make their own experiences with electric logistic solutions. The results assure benefits of electric mobility for companies (SUGAR 2014). Some companies still show uncertainty about changing to electro mobility. Therefore, the need for better access to specific information is apparent (BESTUFS 2014).

The implementation of an e-based urban logistics solution will be realized within a future project. The project results thus yield essential conclusions for further projects on sustainable electric based logistics for the region of Graz and beyond.

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Part III
Balancing and Reducing the Environmental Impacts

Chapter 9
Global Standardisation of the Calculation of CO_2 Emissions Along Transport Chains—Gaps, Approaches, Perspectives of the Global Alignment Process

Verena Ehrler, Aad van den Engel, Igor Davydenko, Daniel Diekmann, Jan Kiel, Alan Lewis and Saskia Seidel

9.1 Background and Motivation

The transport industry, consumers, shippers and political bodies are all pressing for a global standard for the calculation of emissions along supply chains. Comparability of the chains' efficiency, reduction of energy consumption,

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transparency of the carbon footprint of products and identification of best practice are at the core of the need for such a standard. It has several important pre-conditions though: it needs to be globally applicable, cover all modes of transport and all supply chain elements, it needs to be easy to use and transparent in its mechanisms. Furthermore, it must be clear and concise, particularly in its requirements towards quality of data used for emission calculations, whether it is measured, standard or default values. In order to meet these requirements and to ensure the standard's acceptance, its development needs to be industry-led. Additionally, the standard needs to balance the aspects of ease of use, transparency and flexibility. Several steps into that direction have been taken, such as: EN 16258, GHG Protocol, ISO 14064, ISO/TS 14067, standards developed by IATA, Smart Way and Green Freight Europe or tools and approaches such as EcoTransIT or GreenEfforts and many more. So far there is no standard in place though that aims at the specific transport chain requirements, is globally applicable and covers all supply chain elements as well as all modes. It is the aim of this paper to show in more detail, based on the findings of real-life test cases, which existing gaps need to be addressed in a next step of standardisation efforts. Furthermore, the paper describes which approaches and perspectives offer themselves from a combined industry-research perspective for the development of a standard for emissions along transport chains.

9.2 Methodology

Following a state-of-the-art-overview on existing standardisation efforts, a case-based assessment of application practices and feedback from the transport industry are described. These findings are complemented with outcome of and insights gained during an industry preference survey through stakeholder workshops held. During these workshops, industry and other stakeholders discussed on a neutral, open platform experiences with calculation tools as well as requirements towards next development steps towards harmonised methods for a coherent quantification of CO_2e emissions of freight transport. The outcome of these discussions is the basis for the recommendations toward the developments of a global emission calculation framework for transport chains. Both methodological as well as content related aspects are considered in the recommended next steps towards a globally accepted standard. The paper closes with an outlook on possible perspectives for such a standardisation and framework (see Fig. 9.1).

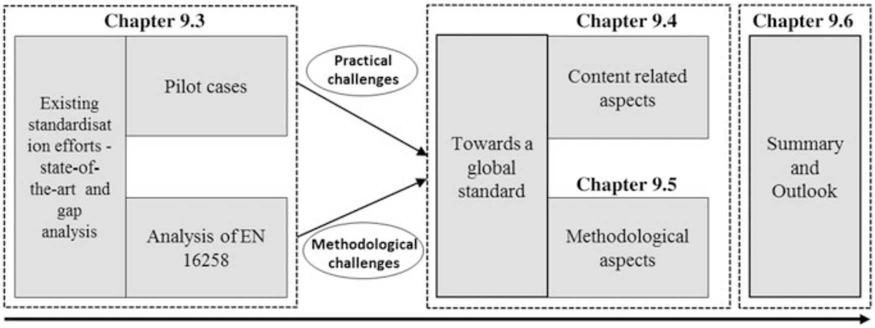

Fig. 9.1 Structure of research

9.3 Currently Existing Standardisation Efforts and Remaining Gaps

During the past decade many efforts have been made to develop a standard for emission calculation. Today there are over 140 calculation tools in place, including data basis, calculation methods, software tools, standards, etc. These tools are not imbedded in one globally applicable framework though and many of them are based on the initiative of individual organisations, of industry organisations, or of groups of corporates, NGOs, etc. They were developed to accommodate the needs of specific transport modes, or they reflect the needs and status of transport technology of a specific area. As a consequence, these existing calculation approaches are neither combinable nor compatible and their results are not comparable. Some of these tools are standards. Still though, they do not reply to the need for a global standard for emission calculation of transport chains: GHG Protocol Scope 3, ISO 14064, ISO/TS 14067 are global standards for the calculation of emissions of corporate value chains, organisations and products, not specifically covering transport chain related issues. Given the fact that these are global standards related to emission calculation they are an important basis for further developments in this sector. Specific transportation chain related issues, e.g. the question of how to ensure comparability between various transport modes, remain untouched within these standards though. Other tools, for example EcoTransIT, Smart Way and Green Freight Europe, are designed specifically for the calculation of emissions along transport chains. They are not issued by a globally established norm-giving organisation though. The IATA RP 1678 is considered a standard, focuses on aviation though. EN 16258 is an international transport chain related standard and comes closest to a globally applicable emission calculation tool. It is a European standard though, therefore regionally limited in its acceptance. Also, elements such as the calculation of emissions of logistics hubs need to be included in a next version of the standard. To shed some lights on the requirements towards a global emission standard and their complexity, in the following, first findings of a pilot-case based analysis of emission calculation in general are summarised, followed by an in-depth analysis of EN 16258. Whereas the first analysis, the pilot case study, reveals the practical and pragmatic challenges related to emission calculation, the second analysis focuses on the European standard and therefore more on the methodological side of the challenges of emission calculations.

9.3.1 Pilot Cases—Practical Challenges of Calculating Transport Chain Emissions

Industry repeatedly has emphasised the importance of balancing *practicality and completeness* with any further proposed CO_2e calculation method(s). This meant that in addition to the more theoretical approach of allocating CO_2, a profound insight had to be gained from the use of existing calculation methods in daily operations of the industry. Therefore detailed pilots were developed and run with industry partners to gain valuable information in regards to the practicality of the available methods and norms. These pilots were run in the period September–December 2013 with partners of the from the following industries: aluminium car parts, coffee, cotton, mineral water, parcels, apple juice, cement and paper reels. During the course of the pilots and their evaluation, not only did the practicality of the emission calculation tools become apparent, but also the gaps between daily practice and theoretical methods was rendered very visible.

In the test cases the transport chain approach was followed, i.e. entire transport chain was analysed, rather than individual transport services. This approach also implies that the allocation of CO_2 emissions at nodes, i.e. terminals, warehouses, etc., needs to be included in the calculations as they form an integral part of a transport chain. Most important findings and observations are summarised in the following:

- *Confidentiality of data is at stake.*
  The emissions of CO_2, the Carbon Footprint, should be calculated on base of the energy consumption of the actual activities that take place in a certain transport chain. This means that for a correct calculation, deeper knowledge of the company's activities is needed. This conflicts with the participant's policy concerning the confidentiality of certain company data.
- *Activity Based Carbon Allocation could be an option.*
  For the allocation of the costs of business activities the method of Activity Based Costing (ABC) is often used in business economics. ABC is an approach to the cost calculation of products and services based on the monitoring of activities. Resources used (direct and indirect) are assigned to activities and activities to cost objects based on consumption estimates. As a result, ABC allows to attach activity costs to outputs. Although this method is time and resource intense, when properly applied, it results in a reliable allocation of the costs to output. The principles of activity based costing were used for fair

allocation of carbon emissions in the pilots. It proved to be difficult to make an 'activity based energy use' model for the allocation of energy consumption. Different assumptions needed to be made to get things working. Although EN 16258 provides a method in allocate carbon emissions, in practice information and data on the allocation of emissions is not easy to obtain (mostly entirely missing). Especially data on the relation between certain (sub) activity and its energy consumption is hard to get. Therefore a more practical approach, such as a manual giving examples, is most desirable and a proper method forward.

- *Overview of the Transport Chain is essential.*
  The test cases showed that in no case there was comprehensive, all aspects covering information for the entire transport chain available. Instead, in every transport chain and its individual chain elements, assumptions had to be made regarding data needed for emission calculation. For ensuring transparency of calculations, a clear documentation of the transport chain and any made assumption is therefore important when discussing emission calculation results. This description should include as minimum requirements:

  - An introduction to the commodity for which the CO_2e calculation was made in terms of physical aspects like shipment unit, volume and weight;
  - An overview of the entire chain i.e. in text and maps;
  - An indication of the overall accuracy level of the data and the final calculation results;
  - The standards, data sources and calculating methodology that were applied;
  - A listing of the providence of the data that was used.

- *There is a need for verified default data.*
  In the ten test cases run, none of the involved companies had a full ownership of the entire transport chain. This meant that part of the data that was needed for the determination of the CO_2e emissions originated from other companies. Although some of these companies were willing to present these figures, this was not generally the case.

In order to be able to perform CO_2e calculations, a generally accepted source of default data would be practical. However, it would be recommendable to improve the quality of such data sources so that a mentioning of the source already provides the requested minimum level of data reliability.

9.3.2 Analysis EN 16258—Methodological Challenges of Calculating Transport Chain Emissions

The aspects where EN 16258 requires further specification comprise the data accessibility and availability, the inclusion of nodes, the definition of vehicle operation system and the 'fairness' of the standard. This is acknowledged in the introduction to EN 16258 itself. When drafting the EN 16258 use was made of earlier work such as ISO 14064, ISO 14067, GHG protocol and EcoTransIT World (see references in the EN 16258). In general the EN 16258 is compliant with these publications. However, closer analysis leads to the following conclusions:

- The calculation of GHG emission from *nodes* is not included in the EN 16258 (which is mentioned in the standard itself). The quantification boundaries are limited in that sense. If users would like to include the nodes, then they should describe transparently how they include nodes in the calculations. This issue can potentially lead to different outcomes as different methods can be applied, e.g. by use of average values or detailed input. The challenges related to the emissions calculation of nodes resemble to those of the emissions calculation of transport: difficulty of getting measured data for all aspects, transport operator, transport operator fleets versus the use of averages or industry standard values).
- Concerning the *vehicle operation system (VOS)*, the EN 16358 intentionally leaves a large degree of freedom to the user to define the boundaries of the VOS. Both a detailed and aggregate level for a VOS have different pros and cons. Almost by definition, within a transport chain different VOSs are used at different levels. This makes the calculation of consistent results almost impossible. The only way to overcome this problem is to use for every leg the same level. But in the end this leads to using less accurate input data, probably based on averages.
- The *fairness of allocation of GHG emissions* concerns the prescription to use weight and tonne-kilometres. The standard allows different units if they are described well. For the allocation of emissions -the use of weight or tonne-kilometres is not always easy and may lead to less optimal allocation of emissions to entities.
- *Data availability and data accessibility are critical points* in using the methods in EN 16258. The standard leaves room for the use of different values at different levels of detail. As a consequence, some parts of a transport chain might be based on accurate data, while other parts are less detailed. The standard leaves the user a great degree of freedom. It emphasises a pragmatic solution, which does not promote the process of standardisation.

Currently existing efforts for the development of a standard for emission calculation of transport chains have achieved to prepare the grounds for a global standard and with EN 16258 a first transport chain specific, international standard is developed and implemented. Given the practical challenges related to the use of any calculation method and the specific gaps of the EN 16258 as well as other existing approaches, further development and cooperation is needed to achieve a global standard. In the next paragraph possible steps on such a development path are mapped out, both on the methodological side regarding the question of how such a development path could be approached, as well as on the content side of the next steps, regarding the question of which gaps should be addressed and how they could be closed. The suggestions are based on extensive empirical research and workshops carried out by research and industry jointly.

9.4 Towards a Global Standard—Content Related Aspects and Considerations

As seen during various workshops held with industry and other stakeholders of a global standard for emission calculation of transport chains, any standard needs to specify the framework for a calculation on three different levels:

- on the level of cargo—for understanding the emissions related to the individual cargo
- on the level of network—for the optimisation of efficiency and reduction of emissions of transport organisations over their entire network
- on the level of operation of transport chain elements—for optimisation of the efficiency of individual operations within the transport chain.

These three levels acknowledge the different requirements of shippers, logistics service providers, carriers and other stakeholders, in regards to decision making and reporting of emissions, as the overall goal of the emission calculation is to support an improvement in the effectiveness within the global logistics sector:

- shippers require harmonised methodologies for calculating and reporting emissions that considers fuel and the carbon footprint to be able to compare modes or carriers before making a freight purchase decision.
- carriers must have confidence in the performance of technologies before deciding to invest in them, and technology verification can contribute to that.
- logistics providers are seeking transparency on the efficiencies of their routings and networks
- governments want to be able to steer transport towards lower emissions

By addressing these needs we help the freight sector to accelerate the adoption of emission reduction measures as individual companies but more importantly, as collaboration efforts between carriers and shippers and customers.

Both the first (cargo level) as well as the third level (operation of transport chain element) include the concept of the Transport Chain Element TCE. This concept is based on the understanding that a transport leg and terminal or warehousing/distribution operation should be considered as an atomic part of the chain. For instance, if a shipment is loaded into a vehicle departing from the shipment origin and arriving to the consolidation centre, this operation cannot be split into further sub-operations, or such a split up would not contribute towards CO_2 computations. Ehrler et al. (2013) and Davydenko et al. (2014) provide ideas on how the concept of TCE can be realised. A standardised methodology therefore should provide a set of unambiguous instructions on how to split a supply chain into TCEs.

In the following, more detailed consideration for the calculation of emissions on the individual levels is given.

9.4.1 Calculation on Cargo Level

Conceptually, a standardised CO_2 calculation methodology capable of determining emissions at the cargo level along a complex transport chain should provide the following four basic functionalities:

1. Split up of the complex supply chains into Transport Chain Elements (TCE)
2. Determination of the physical CO_2 emissions attributed to each TCE
3. Determination of the share of CO_2 emissions within the TCE related to the cargo under consideration
4. Information exchange and default data for the summation of the relevant TCE-level emissions to determine the total cargo origin-destination emissions.

Once the TCEs are determined, the second functionality of the methodology should provide instructions on how to determine physical CO_2 emissions within a TCE. For instance, the European standard EN 16258 introduces the notion of Vehicle Operating System (VOS), which is a consistent set of the vehicle movements taking into account empty and return running. Determination of physical emissions within a TCE could become a sophisticated matter due to the following reasons: First, up to now the VOS notion is not specified precisely, as the EN 16258 standard leaves flexibility regarding VOS specifications. The VOS could be of a single vehicle movement, through to all vehicle movements within a fleet over a complete year. The second difficulty is determination of physical amount of CO_2 emitted within the TCE: the fuel or electricity usage should be monitored and noted. For instance, refuelling of a road vehicle may not coincide with the boundaries of the TCE, thus making it difficult to determine fuel use, and hence, emissions. The third difficulty is of conversion of fuel use into CO_2 emissions. For fossil fuels it is relatively straightforward: the type of conversion should be agreed upon (well-to-wheel, tank-to-wheel) together with the known fuel type and the share of renewable fuels in the total mix. In case of electricity it is more difficult, as there are many production methods for electricity and the total electricity mix may not be known. The IWA workshop results suggest that determination of TCE-related physical emissions should be further fragmented on a per-mode basis, as transport operations are dependent upon mode-specific practices.

When the physical emissions on TCE-level have been determined, these have to be split between a number of shipments travelling at the same time in a vehicle. Therefore, the third functionality of the CO_2 calculation methodology should specify the method on how the TCE-level emissions are divided among and assigned to the possibly multiple shipments travelling simultaneously. The most common method, also suggested by the EN 16258 standard, is to allocate emissions proportionally to the tonne-kilometres travelled. This method may not be most appropriate for all situations, especially if the fairness of emission allocation is taken into account (see Davydenko et al. (2014) for more details). In case of logistics facilities, there is no standard or universally established allocation method in place yet; however, the European Green Efforts project and the World Ports

Climate Initiative focused with their work on this topic and have developed a basis for further standardisation efforts.

Once the shipment TCE-level emissions have been determined, the methodology should provide instructions on how to sum up supply chain level emissions. Therefore, the fourth functionality should describe information exchange requirements to determine chain-level emissions and, in case of missing information, a way to close this gap, balancing accuracy with the feasibility of computations. The issue of information exchange becomes important in hierarchical systems, for instance, if emissions are computed for a pallet, which is loaded into a container. A transport service provider, such as shipping line, cannot determine pallet-level emissions, as it deals with the whole container. Such complexity of the transport system requires a (hierarchical) method on emissions-related information exchange. Furthermore, missing information on, for instance, a single link or TCE, would make computation of the shipment emissions at the chain level impossible if the methodology does not provide for instructions on how to deal with these situations. Therefore, there should be instructions and commonly agreed default data on how to gap the missing link information.

9.4.2 Calculation on Network Level

On a network level the most important challenge is to develop a practical approach for the definition of the network itself and how outsourced processes, subcontractors etc. are to be included. Related to this challenge is the issue of data collection of subcontractors: Many transport chains include subcontractors and even sub-subcontractors. Tracking and measuring energy consumption is, as seen in the pilot cases, often challenging. A clear guidance on how to report data within transport chains, including the question of data quality requirements and data reporting requirements therefore need to be specified.

9.4.3 Calculation on Operation Level

The definition of vehicle operation systems is the most important and pressing specification need on the operation level. It is partly addressed in EN 16258. A further specification is needed; no specific approach has been made yet though.

9.4.4 General Aspects and Considerations

Beyond these level-related requirements for further specifications, there are several aspects regarding the calculation of emissions of transport chains in general: An important factor that needs to be approached when further developing towards a global emission calculation standard is, as identified in the gap analysis, the unambiguous definition of data and data quality, especially in regards to energy consumption. Currently, the base methodologies align around the basic principle of identifying the actual amount of fuel needed to carry out a certain amount of work when transporting the goods, i.e. are primarily fuel-based in nature whilst acknowledging the relevant transport activity. This must include the fuel used by vehicles when they are being repositioned between individual trips and on a round trip basis.

This ‘consumption factor’ is used as the basis of transferring data between the different players in the supply chain. The consumption factor = total fuel (energy) consumption divided by the total work done, expressed as distance × mass, or in scientific notation:

$$Transport\,consumption\,factor = \left(\frac{\Sigma\,fuel}{\Sigma\,tonne\ kilometres}\right)$$

The emissions resulting from combustion of the fuel are then calculated using a fuel-based emission conversion factor. This may be done on the basis of including emissions that result from fuel production (a well-to-wheel) factor and can be formulated to include the impact of only CO_2 or to include other greenhouse gases (the CO_2 equivalent).

The trips that are included within the calculation of the consumption factor must clearly be representative of the service that is being provided. EN 16258 acknowledges this by referencing a vehicle operating system (VOS), but then leaves the definition open, except that empty trips are always to be included. A possible approach to addressing this challenge is the concept of transport service clusters. Transport service clusters are groups of round trip journeys averaged over 12 months that represent the way that freight transport services are procured. This approach has been taken because it is in line with:

- the needs of stakeholders of the freight transport,
- the more general description of vehicle operating systems in EN 16258,
- taking an element by element approach to a more complex transport chain
- the principles of practicality and reliability of results.

For consistency of comparison, the transport service clusters should be defined in a manner that is as homogenous as possible. The preference is to use transport clusters that are directly relevant to the mutual needs of the providers and users of the transport service. This will likely result in data with medium granularity that is sensitive enough to make system changes visible within the consumption factors, but not over-sensitive to volatilities that are outside the influence sphere of industry or require unreasonable amount of data to fulfil them (attempting to respect the principle of simplicity and practicality). The detailed basis upon which transport service clusters should be defined will vary depending on the nature and structure of the transport service provided and the mode used.

EN 16258 includes four incomparable levels of accuracy in relation to data. The level of "transport operator specific values" is considered the best way to proceed: transport operators (carrier) are the organisations who have access to the real fuel used and work done information. Transport operator specific values are therefore considered to provide for best possible transparency and ease of use.

An important aspect to take into consideration when defining data quality requirements for emission calculations is the organisation's position in the chain—specifically if it is a transport service buyer or transport service provider. The main distinction between the two roles is that the transport service buyer does not have access to data on fuel consumption, exact routings, filling rate, empty trips etc., nor is the transport service provider likely to share this because that would disclose sensitive cost structure information of the carrier. For this reason the transport service buyer will need to make use of consumption factors for the transport service clusters purchased. The carrier on the other hand should have fuel consumption data available, or at least average fuel use data for its fleet, and it makes more sense to use this data when the need is to calculate the company or product carbon footprint.

9.5 Towards a Global Standard—Methodological Aspects and Considerations

Recent work on a harmonised framework has progressed through two interlinked mechanisms:

1. On an organisational level: the Global Logistics Emissions Council (GLEC), initiated by the nucleus of a group of logistics companies and industry led initiatives, which formed the Advisory Board of the FP7 project COFRET, together with the Smart Freight Centre (SFC).
2. On a formal level: the International Workshop Agreement IWA No 16 "International harmonised method(s) for a coherent quantification of CO_2e emissions of freight transport".

Since it foundation in 2014, the GLEC has been expanded to a global level with additional companies and experts, SmartWay, Green Freight Asia and global industry associations. GLEC aims to achieve:

- A common industry vision statement regarding methodologies and broader green freight
- Globally harmonised methodologies (Global Framework for Freight Methodologies) for measurement and reporting of emissions from freight movement covering all modes, transfers and regions
- Alignment of industry led/backed initiatives across modes and global regions
- Active engagement and communication with the entire global freight sector and other key stakeholders, e.g. government, scientific/research institutes, NGOs, development agencies

Smart Freight Centre has been given the mandate and resources to lead and coordinate the work of GLEC. SFC's role is to:

- Lead the development and implementation of a strategy in support of the group's objectives
- Organise and facilitate meetings of the group and cooperation between its members
- Engage with the global freight sector and other key stakeholders relevant to this group, which includes positioning the work of the GLEC within a wider portfolio of programs aimed at increasing freight sector efficiency

The overall purpose of this approach has been to obtain consensus through wide stakeholder agreement on the scope of a future methodology framework backed up by an action plan for harmonisation towards a practical framework applicable across sectors and regions.

The centrepiece of the GLEC is the development of a Global Framework for Logistics Methodologies as well as ensuring wide acceptance and taking its application to scale. An initial version of this framework, referred to as the Base GLEC framework, was published in January 2015 and opened to public consultation as part of ongoing work towards a revised version due in late 2015/early 2016.

The IWA "International harmonised method(s) for a coherent quantification of CO_2e emissions of freight transport" was published as ISO IWA No. 16 in January 2015 and states: "A continued close cooperation between the GLEC and global standard issuing organisations, e.g. GHG Protocol and ISO is recommended to further work on this emission calculation standardisation, thus enabling a swift and effective next step towards the optimisation of transport chains' efficiency and related reduced transport emissions on a global scale".

The Base GLEC framework as well as the IWA structure is based on the concept of using as far as possible existing methods and tools as a starting point for further standard developments. Furthermore, both approaches recommend a mode specific approach: air, sea, road, rail, inland waterways and transhipment centres, with Base GLEC further distinguishing between sea, container, and sea, other (bulk, tanker, ferry, etc.). The following existing methodologies are recommended as the starting point for the aligned methodology framework (see Table 9.1).

Because the framework is based primarily on existing practices and calculation tools, the base methodologies have been developed independently and are at different levels of maturity. An alignment of the maturity levels is therefore an important next step in the development of a global emission calculation standard.

The here described approaches towards a next step in the standardisation of emission calculation of transport chains are the outcome of close cooperation between industry and research. This approach has proved to be very successful, as it encourages the open discussion and reflected discussion in a heavily politically loaded topic, where striking the right balance between transparency, easy-of-use and adaptability is most important. A continuation of this process therefore is recommended for further developments of emission calculation standards.

Table 9.1 Methodologies recommended for the aligned methodology framework

Mode	Base GLEC—Suggested base methodology per mode	IWA 16—Suggested base methodologies per mode
Air	International Air Transport Association (IATA) Recommended Practice 1678 others considered: EN 16528, US SmartWay air module, EU ETS, French Info CO_2	EN 16258, IATA RP1678
Sea, container	Clean Cargo Working Group others considered: EN 16258, Clean Shipping Index Protocols, IMO EEOI	EN 16258, Clean Cargo Working Group, IMO MEPC.1, circ.684
Sea, other (bulk, tanker, ferry…)	IMO Energy Efficiency Operating Index (EEOI) others considered: EN 16258, Clean Shipping Index Protocols, IMO Energy Efficiency Design Index (EEDI)	
Road	SmartWay road module EN 16258, at level of transport operator specific values others considered: French Info CO_2, EcoTransIT, NTM, Defra, HBEFA	SmartWay road module, EN 16258
Rail	EcoTransIT others considered: EN16258, SmartWay rail module, NTM, French Info CO_2	EcoTransIT, EN 16258, SmartWay rail module
Inland waterways	IMO EEOI others considered: SmartWay steaming module, STREAM, EN 16258	EN16258, SmartWay streaming module, IMO MEPC.1/circ. 684, STREAM international
Transhipment centres	Green efforts others considered: Green Logistics, ITEC	GreenEfforts, Green Logistics, ITEC

9.6 Summary and Outlook

The EN 16258 is a first general standard for the calculation of emissions of transport chains, encompassing all modes. The standard is intended for use by freight and passenger transport, different organisations and different transport operations. In that sense the standard is a 'one-size fits all' product. The freedom that EN 16258 allows for values and allocation principles is understandable. It balances between the desire for precision and scientific rigour. Nevertheless, the standard itself also has room for future updates and expresses this ambition. The EN 16258 as it is now is a good starting point for the calculation of GHG emissions in transport. For future updates of the EN 16258 one might look at the work already done in EcoTransIT, Green Efforts and GFE. These two made some further steps on nodes and data accuracy.

One of the most important issues that needs to be addressed in any next step towards a global standard is the issue of data sources and data accessibility, as it poses a challenge to the user groups. On one hand the level of detail can vary, thus leading to potentially different results for similar transport operations. On the other hand, data for parts of the transport chain are not available or accessible. This will cause further inaccuracies in the results.

With IWA 16 being published, the GLEC is a valid frame for continuing the work towards a global emission calculation standard. Currently it is developing approaches towards the following issues:

- emission conversion factors appropriate for the various transport fuels, possibly by global region, at well-to-wheel and CO_2 equivalent levels
- default factors for different modes and transport service clusters for use in circumstances where carriers are, for whatever reason, unable to provide their own operational figures
- targeted research on issues such as evaporative and fugitive emissions, energy use of different types of temperature controlled containers, the impact of black carbon emissions
- practical validation of the approach, particularly in respect of data availability at source, the ability to share among all stakeholders in the supply chain and the ability to support environmental decision making.

An open discussion on a neutral platform is needed for future standardisation developments. This platform should continue to bring standardisation organisations, stakeholders and researchers together and it should be industry led. It is also important to bear in mind, that any further development should be applicable on a global level, based on easily accessible and usable tools.

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Chapter 10
Role of Cargo Weight and Volume: Minimizing Costs and CO_2 Emissions in Container Transport

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10.1 Introduction

Use of containers enables complementarity of freight transportation modes by offering a higher fluidity to movements and standardization of loads. The container has substantially contributed to the adoption and diffusion of intermodal transportation, which has led to profound changes in the transport sector. By means of reducing handling time, labor costs and packing costs, container transportation allows considerable improvement in efficiency of transportation. In other words, the containerization represents a revolution in the freight transport industry and, for many decades, the containerized trade has been the fastest growing market segment.

The global containerized trade grew by 5.8 % in 2014, with the total volumes reaching 169.3 million TEUs, in comparison to 160 million TEUs in 2013. In terms of total transported tons, the containerized trade participated with 16 %, or, 1,524 billion tons. The intraregional (led by intra-Asian trade) and South-South trades jointly accounted for 40.1 % of the global containerized trade shipments in 2014, followed in descending order by North-South trade (17.0 %), Transpacific (13.4 %),

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Far East-Europe (13.1 %), secondary East-West (12.6 %) and Transatlantic trade (3.8 %). Three routes on the major East-West trade lane—the Trans-Pacific, the Asia-Europe and the Trans-Atlantic route, connect three main economic regions, namely Asia (China, in particular)—the manufacturing centre of the world, Europe and North America, traditionally the major consumption markets. Asia, Europe and North America jointly accounted for nearly 80 % of the world GDP in 2012 (at constant 2005 prices). In 2013, the total containerized volumes carried across this major East-West trade lane increased by 4.3 % in 2013, reaching the total volume of 48.3 million TEUs, or 30.2 % of the global containerized trade (Review of Maritime Transport 2014).

Transportation costs and transit time are two most common considerations in addressing transport planning problems. For some customers the main objectives by supply chain planning are the costs and for others the main objectives are the transit times. However, rising concerns about carbon dioxide (CO_2) emissions can no longer be ignored when planning supply chains. On the one hand, companies have a moral obligation to operate in a sustainable manner and, on the other hand, customers are becoming increasingly aware of the profound effect that a supply chain design has on CO_2 emissions. The reduction of CO_2 emissions—an important cause of global warming, has become a priority, and, consequently, there is an increasing pressure on governments and industries to come forward with initiatives to reduce CO_2 emissions. This is highly relevant for the transport sector, as the transportation's share in CO_2 emission is still increasing, while other sectors are reducing their CO_2 footprint.

This paper analyzes container flows with primary focus on import of containers of different number and type, depending on different weight and volume of shipment transported from one point to another. The container flows are considered to use two legs. The first leg represents deep-sea shipping (ocean freight) from the loading port to the ports of discharge. Different operators with different types of service are closely related to the first leg. The second leg of the chain represents the inland distribution component, in which containers are routed from gateways to the final destination by road, rail or barge.

The developed mathematical model, programmed in MATLAB, offers a possibility of determining optimal solutions in terms of concurrent minimization of the observed criteria (transport costs and CO_2 emissions). The model provides a possibility of selection of cargo volume and weight, based on which a number of required containers, transported from the port of consignor to the consignee, is determined. Determination of cargo weight and volume is one of the crucial information when selecting the type of container and whose information the buyer of the goods must always specify to the appropriate forwarding agency how they organize transport making booking for appropriate type of container. By means of subjective determination of weighting coefficients, each user is given the opportunity to define the importance of each of the observed criteria. In addition, the mathematical model leaves a possibility of analyzing all possible routes, as well as of ranking the obtained solutions.

The remaining part of the paper is organized as follows: Sect. 10.2 presents the literature review; Sect. 10.3 describes the bi-objective problem approach which is suggested in this work; Sect. 10.4 explains the mathematical model and Sect. 10.5 reports and analyzes the results of the mathematical model and illustrate how the model could be used. Finally, Sect. 10.6 is focused on conclusions and future developments.

10.2 Literature Review

The optimization aims at making the best choice from a number of variants of possible alternatives, or between a number of alternatives, which in mathematical sense means searching for functions' extrema. The optimization is performed by using different methods, depending on a type of relation in the mathematical model, the criterion function and constraints, which determine the "best" solution to a particular mathematically defined problem. The selected "best" solution has a high probability of being truly the best, representing a satisfactory compromise between the conflicting interests of different stakeholders (Opricovic 1998).

In real-life situations, decision makers often have to deal with conflicting objectives. Furthermore, the inclusion of additional objectives into the model enables obtaining more accurate information of the observed objects. When studying literature data, it can be noted that most researchers address only one of the problems of minimization, either transportation cost or CO_2 emission.

A multimodal transportation problem addressed by Kim et al. (2008), was the problem of determining the transportation flow, i.e. volume of container cargoes, and the transportation mode in each trade route, with the aim of minimizing the sum of shipping and inland transportation costs. The problem takes into account two restrictions: maximum cargo volumes capacitated at each seaport and maximum number of vehicles available at each transportation mode. With a view to providing an optimal solution to the problem, a mixed integer programming (an operations research technique), is employed. A case study performed on the container cargo data in Korea produced several conclusions that enabled attaining an increased efficiency in the transportation of international trade cargoes in Korea.

A similar investigation was conducted by Infante et al. (2009). It was focused on the intermodal freight transport service in which containers represent the moved loading units. More precisely, the investigation deals with the advantages of combining the sea and road transportation: the sea transportation was used for transporting large quantities over long distances, whereas the road transportation was used for collecting and distributing goods over short and medium distances. With a view to minimizing the total service costs, a ship-truck intermodal transportation problem was formulated as a Travelling Purchaser Problem (TPP), in this way broadening the real-world applications field of the TPP.

Han et al. (2011), addressed the problem of determining transportation quantity and mode in international cargo transport between Myanmar and its trading countries, focusing especially on countries in the South East Asia, with a view to examining the extent of short-sea shipping usage and inland transportation. The objective of their research is to minimize transportation costs, depending on form of transportation, between cargo origin and destination, subject to maximum cargo volumes being handled at each seaport. With a view to optimizing the short-sea shipping and inland transportation in Myanmar, their paper proposes application of a linear programming model.

Payman and Robert (2011), introduced analytical models for predicting the allocation to ports and transportation channels for containerized goods imported from Asia to the USA. The first model—the Long-Run Model, is a large mixed integer non-linear programming model, solved with a set of heuristics. The model objective was to minimize the total costs of transportation and handling, pipelining inventory, and safety-stock inventories. The Short-Run Model uses the Long-Run model as a component and integrates it with a set of analytical queuing models that estimate the import container flow times through port terminals, rail intermodal terminals and rail line-haul channels as a function of traffic volumes, infrastructure and staffing hours.

Francesetti (2005), presented an analysis of the costs of shipping containers from four Chinese ports to representative central European destinations. It demonstrated that the sum of sea and land transport costs, using both truck and rail transport, clearly favors the Italian ports, Genoa and Trieste in particular.

Schneider (2011), still focuses on one objective—CO_2 emissions of cargo flows from Bangkok to Frankfurt and vice versa, a specific and measurable aspect of sustainability that helps professionals in their practical decision-making.

Mostert and Limbourg (2014), focus on the intermodal transport network design, analyzing the total carbon dioxide emissions. The study proposed a bi-objective location-transportation model that deals with the assignment of flows on the intermodal network, aimed at minimizing the total transportation costs and the carbon dioxide emissions.

Xue and Irohara (2010), presented a study aimed at minimizing both the transportation costs and CO_2 emissions. This model addressed a transportation scheduling problem in which loads are transported from an overseas production base to three domestic demand centers.

Similar research in terms of testing the bi-objective optimization, (cost and transit time minimization), was conducted by Lam and Gu (2013). This research analyzed the import and export container flow to and from inland China. The results and analysis provide managerial insights into the impact of trade-offs between cost and transit time, and the effect of different carbon footprint requirements on transport planning.

Kim et al. (2009), examined the relationship between the freight transportation costs and the carbon dioxide (CO_2) emissions in given intermodal and truck only freight networks. When the trade-off, represented as the relationship, is changed, the freight mode share and the route choice are also modified. The tool that was developed is applied to a simplified freight transportation network connecting two large European ports: the Port of Rotterdam (the Netherlands) and the Port of Gdansk (Poland).

Studying literature data, this paper observed intermodal transport where is conceived bi-object model based not only on the units of containers, but also on the impact of weight and volume as one of the so far not considered problem, solving the given problem with a priori methods, assessing each of the criteria the respective odds.

10.3 Problem Description

This paper examines transportation of goods from one part of the world to another. All cargo of different volume and weight is transported in containers by ship, assumed to originate from a major loading point far away. Depending on different dimensions and weight of shipments, the type of container in which goods are loaded is selected. This paper considers three different types of container: 20′ container, 40′ container, 40′ high-cube container (Table 10.1).

The considered network includes three categories of nodes: origin port (port of loading), gateway ports (ports of discharge) and destination (place of delivery), and two categories of links, maritime and inland. The first one represents maritime transfers from origin port to gateway ports and the second the inland component of the distribution, in which containers are routed from gateways to final destination by road, rail and barge (Fig. 10.1).

Within the group of analyzed loading ports, the Asian ports maintain the leading position among the top 50 world container ports. The Asian ports hold nine of ten top port rankings and fill 26 of the 50 slots in the 2013 rankings. The Middle East's largest container port, Jebel Ali in Dubai, is ranked ninth, handling 13.6 million TEUs in 2013. Jebel Ali is the flagship facility of the parent DP World, a global terminal operator, handling 55 million TEUs in 2013 and 29.4 million TEUs in the first half of this year. The Europe's largest container port Rotterdam is ranked 11th with 11.6 million TEUs in 2013. When combined, the top two U.S. ports—the Southern California's Los Angeles and Long Beach, rank ninth globally, with 14.6 million TEUs. Figure 10.2 presents the list of 10 ports with the largest container throughput in 2013 (Review of Maritime Transport 2014).

Gateway ports are connected with the origin port, but only by incoming links. It is possible to reach a gateway port from an origin port, but the opposite direction is not envisaged by the model, since it addresses only the incoming flows. A destination is connected to the gateway ports by a direct link, representing the shortest path to be reached from that gateway by road, rail and barge.

Table 10.1 Weights and dimensions of some common types of containers

	20′ container	40′ container	40′ high-cube container
Internal volume (cbm)	33.1	67.5	75.3
Maximum gross weight (kg)	30.400	30.400	30.848
Empty weight (kg)	2.200	3.800	3.900
Net load (kg)	28.200	26.600	26.580

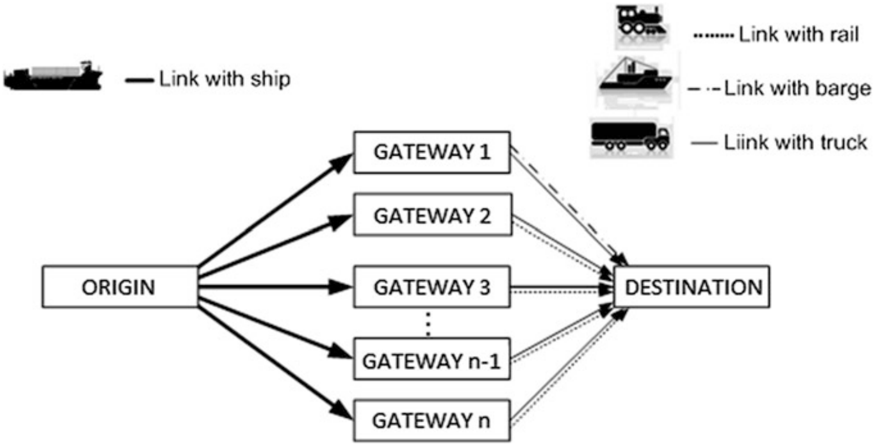

Fig. 10.1 Intermodal container transport network

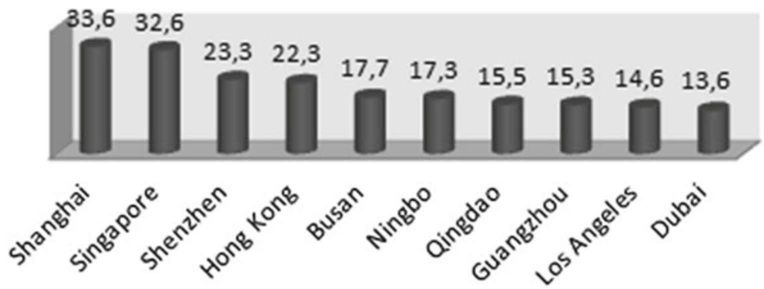

Fig. 10.2 Container throughput in 2013. *Source* The JOC Top 50 World Container Ports

Maritime links are those between an origin port and gateway ports. As for intercontinental links, there may be more than one link connecting the origin port to the gateway port, and each such link belongs to a different service, with given travel time and frequency depending on different operators. The top 10 container shipping companies are presented in Table 10.2.

Inland links are those between gateway ports and place of delivery of containers. There are three available inland transportation modes to be selected, including truck, railway and barge. When rail or barge linkages are available, line-haul may be done by rail or barge before last mile delivery by truck. Without such facilities, containers may be transported all the way from gateway ports to end-customers by truck.

Table 10.2 Top 10 container shipping companies in 2014

Rank	Operator	Vesseles	TEU	% 0–4999 TEU	% 5000–9999 TEU	% ≥10,000 TEU
1	Mediterranean Shiping Company	461	2,609,181	27.14	40.42	32.45
2	Maersk Line	456	2,505,935	27.35	47.88	24.77
3	CMA CGM	348	1,508,007	30.83	34.09	35.08
4	Evergreen Line	229	1,102,245	27.64	53.49	18.87
5	COSCO Container Lines	163	879,696	24.03	42.90	33.07
6	Hapag-Lioyd	159	762,613	49.34	33.35	17.31
7	China Shipping Container Lines	134	750,644	30.40	31.73	37.87
8	Hanjin Shipping Company	115	671,210	30.54	36.95	32.50
9	APL Limited	121	629,479	30.14	44.42	25.45
10	United Arab Shipping Company	73	610,294	19.01	15.60	65.39

Source Alphaliner

10.4 Materials and Methods

The presented mathematical model analyzed the bi-objective optimization, aiming at minimization of transportation costs and CO_2 emission.

The transportation costs were analyzed for each of the most-commonly used types of containers (Fig. 10.1) in the container transport, based on a 'free on board' (FOB) term. In addition to the cost of transport from a loading port to a destination, (taking into consideration different operators), the total costs include local costs in the port of discharge, which may vary subject to a type of operator and container, customs clearance and handling costs.

Different modes of transportation were used for inland transport. Different modes of transportation were used for inland transport, with a view to making more adequate comparison of 'door to door' container transportation costs. Given that solely transportation by truck enables direct connection, the final truck delivery to end-user is included in the rail and inland waterway transportation costs.

The total CO_2 emissions include ocean transport emissions from container ships per each container and land emissions produced by truck, rail and barge. This paper excluded CO_2 emissions in ports of discharge due to their negligible share in total emissions.

CO_2 emissions = Transport volume by transport mode × average transport distance by transport mode × average CO_2 emission factor per tone-km by transport

Table 10.3 Emission factors

Transport mode	gCO_2/tone-km
Road transport	62
Rail transport	22
Barge transport	31
Deep sea container	8

Source Alan McKinnon

mode (Table 10.3) [Tones CO_2 emissions = tones × km × g CO_2 per tone-km/1,000,000], (McKinnon 2010).

The model formulation and corresponding explanations are given as follows (Table 10.4)

$$(i,j) \in FL, 1 \leq i \leq n_i, 1 \leq j \leq n_j$$

$$(j,k) \in SL, 1 \leq j \leq n_j, 1 \leq k \leq n_k$$

The total content per container includes a uniform density, $\rho = \frac{M}{V}$,
Objective Function 1 (Z_1) minimizes the total transportation cost:

$$Z_1 = \min\left[\sum_{(i,j)\in FL}\sum_{t=1}^{n_t}\left(COG_{ij}^t + CGC_{ij}^t\right)cf_{ij}^t + \sum_{(j,k)\in SL}\sum_{t=1}^{n_t} CGP_{jk}^t cs_{jk}^t\right] \tag{10.1}$$

Objective Function 2 (Z_2) minimizes the CO_2 emissions:

$$Z_2 = \min\left[\sum_{(i,j)\in FL}\sum_{t=1}^{n_t}\sum_{l=1}^{n_l^t}\sum_{s=1}^{n_s} DOG_{ijs}EM\left(m_l^t + T^t\right) + \sum_{(j,k)\in SL}\sum_{t=1}^{n_t}\sum_{l=1}^{n_l^t} DGP_{jk}EM_k\left(m_l^t + T^t\right)\right] \tag{10.2}$$

Constraints:

$$\sum_{i=1}^{n_i} cf_{ij}^t = \sum_{k=1}^{n_k} cs_{jk}^t, 1 \leq j \leq n_j, 1 \leq t \leq n_t \tag{10.3}$$

$$\sum_{(i,j)\in FL} cf_{ij}^t = n_l^t, 1 \leq t \leq n_t \tag{10.4}$$

$$\sum_{(j,k)\in SL} cs_{jk}^t = n_l^t, 1 \leq t \leq n_t \tag{10.5}$$

$$\sum_{t=1}^{n_t}\sum_{l=1}^{n_l^t} m_l^t = M \tag{10.6}$$

Table 10.4 Model formulation and corresponding explanations

Set	Description
N	Set of nodes, let N = O ∪ G ∪ P, while O stands for origin port, G stands for gateway ports and P stands for place of delivery
A	Set of routes connecting the origin and destination nodes, let A = FL ∪ SL, while FL presents first leg arcs (ocean leg) and SL presents second leg arcs (land leg)
Decision variable	*Description*
cf_{ij}^{t}	Representing total number of different type of containers "t" on first-leg arc, operator "i" to gateway "j" on each route, $1 \leq i \leq n_i, 1 \leq j \leq n_j, 1 \leq t \leq n_t$
cs_{jk}^{t}	Representing total number of different type of containers "t" on second-leg arc, gateway "j", mode of transport "k", $1 \leq k \leq n_k, 1 \leq j \leq n_j, 1 \leq t \leq n_t$
m_l^t	Represents the mass of all containers of various type, $1 \leq t \leq n_t, 1 \leq l \leq n_l^t$
n_l^t	Represents the total number of containers of various type, $1 \leq t \leq n_t$
Parameter	*Description*
n_i	Number of operators
n_j	Number of gateway ports
n_k	Mode of transport
n_s	Number of possible cargo shipper services to a single target port
n_t	Number of container types
COG_{ij}^{t}	Transportation cost on first-leg arcs (expressed in €)
CGP_{jk}^{t}	Transportation cost on second-leg arcs (expressed in €)
CGC_{ij}^{t}	Port cost (expressed in €)
EM	Emission factor on the ocean leg
EM_k	Emission factor in hinterland
DOGijs	Distance on first-leg arcs (expressed in km)
DPGjk	Distance on second-leg arcs (expressed in €)
T^t	Tare of container (expressed in kg)
V	Volume of cargo (expressed in m^3)
M	Mass of cargo (expressed in kg)
LM^t	Net mass limit
LV^t	Net volume limit

$$\sum_{t=1}^{n_t} \sum_{l=1}^{n_l^t} m_l^t \frac{V}{M} = V \tag{10.7}$$

$$m_l^t \leq LM^t, 1 \leq l \leq n_l^t, 1 \leq t \leq n_t \tag{10.8}$$

$$m_l^t \frac{V}{M} \leq LV^t, 1 \leq l \leq n_l^t, 1 \leq t \leq n_t \tag{10.9}$$

The objective function (1) minimizes total costs of container import flow throughout the entire transportation network. The total costs include transportation cost on the first leg-arc (ocean costs), port cost and transportation costs on the second leg-arc (the hinterland costs, i.e. trucks, rail and barge). The objective function (2) minimizes total CO_2 emissions of container import flow throughout the entire transportation network. The total CO_2 emissions include CO_2 emissions for container ships on the first leg-arc (maritime transport) and CO_2 emissions for inland vehicles on the second leg-arc. Constraint (3) shows that the total number of containers reaching the port of discharge is equal to the number of containers leaving the same port. Constraints (4) and (5) equate the total number of containers of different type with the total number of containers from previously defined set, for each of the defined routes, either sea or land. Constraints (6) and (7) define a sum of the weight and volume for all type of containers. Constraints (8) and (9) show limitations in terms of mass and volume for each type of container.

Finally, the proposed mathematical model offers a broad range of solutions (Z_{fin}) and provides the possibility of their ranking. Through a selection of different cost (α) and CO_2 emission (β) coefficients, conducted by means of weighting, certain groups of optimal solutions are obtained, presenting the adequate minimization of the observed parameters.

Rank list for cost: Rank list for CO_2 emission:

$$Z_1 = min\begin{pmatrix} c_1 \\ c_2 \\ \vdots \\ c_{n-1} \\ c_n \end{pmatrix} Z_2 = min\begin{pmatrix} e_1 \\ e_2 \\ \vdots \\ e_{n-1} \\ e_n \end{pmatrix}$$

Final bi-objective rank list:

$$Z_{fin} = \frac{1}{\alpha + \beta} min\begin{pmatrix} \frac{\alpha c_1}{z_1} + \frac{\beta e_1}{z_2} \\ \frac{\alpha c_2}{z_1} + \frac{\beta e_2}{z_2} \\ \vdots \\ \frac{\alpha c_{n-1}}{z_1} + \frac{\beta e_{n-1}}{z_2} \\ \frac{\alpha c_n}{z_1} + \frac{\beta e_n}{z_2} \end{pmatrix}$$

10.5 Model Application

The case study analyzes the results obtained by the developed optimization model, aiming at minimization of transportation costs and CO_2 emissions in intermodal transport depending on different weight and volume of transported cargo. The supply chain network is analyzed with a primary focus on import of containers from

Far East to Serbia through selected Mediterranean ports (Koper, Rijeka, Bar, Thessaloniki and Constanta), taking into consideration different liner shipping services on the sea and truck-rail-river inland transportation networks from selected ports. By applying a bi-objective model for container flows from Far East through Mediterranean ports, the most optimal route for container import to Serbia was determined. The model was programmed in MATLAB and simulations were performed on the Intel Core i7-3612 QM 2.1 GHz computer. The original input data were used for the period between July and December 2013. The developed mathematical model enables offering a broad range of possible solutions and the possibility of their ranking. Groups of all possible solutions are ranked in an ascending order and the observation period in the mathematical model does not have to be time-limited. The advantage of the model is its applicability to various "point to point" relations, in which containers are transported by a combination of sea and land. By means of implementation of adequate input data, reliable solutions to the analyzed problem can be obtained. In this way, using this model companies and individuals can independently calculate and receive solutions differently weighted problems (Table 10.5).

The presented case study analyzed specific type of containers with certain limitations in terms of weight and volume, considered the basic limitations in the case study (Table 10.6, Fig. 10.1).

The model attains a broad interaction with the user, offering the possibility of assessing the importance of each of the observed criteria, as well as of selection of the total amount of transported goods, based on which a number of transported containers is determined. More precisely, the selected mass is closely related to pollution, whereas the volume is closely related to selection of number and type of containers, which directly affect the structure of transportation costs.

Figure 10.5 illustrates the results of bi-objective optimization using equal value of scalars. The results show top three solutions, ranked in an ascending order. The

Table 10.5 Input arguments

Input arguments	
n_t	3
n_s	3
n_k	3
n_i	6
n_j	5

Table 10.6 Characteristics of specific type of containers with certain limitations in terms of weight and volume

n_l^1	n_l^2	n_l^3
1	0	0
2	0	0
3	0	0
1	1	0
0	1	0
0	0	1

Fig. 10.3 Dragon service. *Source* Mediterranean Shipping Company

optimal (rank:1) transportation costs and CO_2 emissions in intermodal transport between Shanghai and Belgrade are 2922 EUR and 4,1322 CO_2/t-km, using both sea and land legs. The operator Mediterranean Shipping Company-MSC uses Dragon service (Fig. 10.3) from Shanghai to Gioia Tauro, and West Mediterranean service (Fig. 10.4) from Gioia Tauro on the first-leg arc reach to the gateway port—Rijeka, and proceeds by rail on the second-leg arc to the final destination—Belgrade.

10.6 Conclusion and Future Developments

The optimization deals with the type of problems that involve one or more objectives, representing functions of some real or integer variables that should be optimized. By means of a scrupulous observation of the bi-objective optimization and an analysis of applied algorithms, we concluded that development of appropriate mathematical models could be an accurate method for problem-solving and making simultaneous and significant criteria decision.

The developed mathematical model, programmed in MATLAB, offers a possibility of determining optimal solutions in terms of concurrent minimization of the observed criteria (transport costs and CO_2 emissions). The model provides a possibility of selection of cargo volume and weight, based on which a number of required containers, transported from the port of consignor to the consignee, is determined. By means of subjective determination of weighting coefficients, each

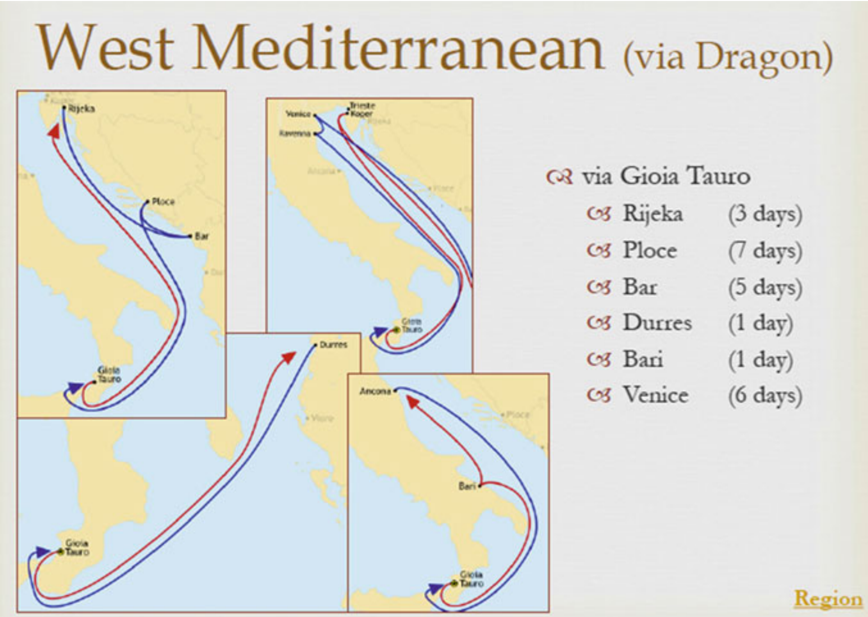

Fig. 10.4 West Mediterranean service. *Source* Mediterranean Shipping Company

user is given an opportunity to define the importance of each of the observed criteria. In addition, the mathematical model leaves a possibility of analyzing all possible routes, as well as ranking of the obtained solutions.

The model's advantage is its applicability to various "point to point" relations, in which containers are transported by combination of sea and land. By means of implementation of adequate input data, reliable solutions to the analyzed problem can be obtained. The findings presented in this paper indicate that the optimization performed by use of an immunized bi-objective evolutionary algorithm is a viable approach that may help managers responsible for a company policy-making to improve their business performance by following constant market changes and making reliable comparisons.

A mathematical model has also a practical use in determining the optimal route. Using this model it can be generate competitive bids in transport organization. Appropriate forwarding agency can provide these bids to its customers and constantly it can inspect the most optimal routes depending on the selected criteria.

This paper examines the case study involving transportation of goods of different weight and volume from Shanghai to Belgrade. By means of analyzing six largest container shippers, using various services (transportation routes) in ocean transport, and inclusion of three types of land transportation, solutions that provide qualitative information in terms of minimization of transport costs and CO_2 emissions, are obtained.

```
Command Window
>> dortmund
Input volume (0-75 m^3):70
Input weight (0-26 t):23
Input scalar for cost: 1
Input scalar for emission: 1
Input number for rank list: 3
Transport between: SHANGHAI - BELGRADE

. . .

Rank: 1

Port of loading: SHANGHAI
Number of containers: 20DV: 0, 40DV: 0, 40HQ: 1
Operator: MSC
Number of transshipments: 1
Service: DRAGON / WEST MEDITERRANEAN
Route: SHANGHAI - Yantian - Hong Kong - Chiwan - Singapore - GIOIA TAURO / GIOIA TAURO - RIJEKA
Port of discharge: RIJEKA
Mode of transport: RAIL
Place of delivery: BELGRADE

Rate: 2922 EUR
Emission: 4.1322 CO2/tkm
```

```
. . .

Rank: 2

Port of loading: SHANGHAI
Number of containers: 20DV: 0, 40DV: 0, 40HQ: 1
Operator: COSCO
Number of transshipments: 1
Service: MD1 / AFS
Route: SHANGHAI - Taipei - Hong Kong - Shekou - Suez - PIREAUS / PIREAUS - Thessaloniki - Pireaus - RIJEKA
Port of discharge: RIJEKA
Mode of transport: RAIL
Place of delivery: BELGRADE

Rate: 2950 EUR
Emission: 4.1012 CO2/tkm


. . .
```

```
Rank: 3

Port of loading: SHANGHAI
Number of containers: 20DV: 0, 40DV: 0, 40HQ: 1
Operator: CMA-CGM
Number of transshipments: 1
Service: BEX / FEMEX1
Route: SHANGHAI - Ningbo - Chiwan - Yantian - Tanjung Pelepas - Izmit - Istanbul Ambarili - CONSTANZA
Port of discharge: CONSTANZA
Mode of transport: RIVER
Place of delivery: BELGRADE

Rate: 2811 EUR
Emission: 4.3230 CO2/tkm
```

Fig. 10.5 Simulation results. *Source* MATLAB Mathematical model by author

Given the principal aspects of future research aimed at determining the most effective and ecologically justified routes, additional objectives may be included, relevant for adequate and quality decision-making. Transportation time, as one of the important transportation task factors, represents one of the possible criteria that may be included in future research. In addition, the presented model may be comparatively analyzed with some of the software packages that perform a reliable optimization of several criteria simultaneously.

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Chapter 11
Determination of GHG-Emissions of Handling Operations in Multimodal Container Terminals

Zoran Miodrag, Jan Kaffka, Uwe Clausen and Lars Munsel

11.1 Motivation

The climate change and its numerous negative influences to the development of weather are ascribed to the emission of greenhouse gases (GHG), especially carbon dioxide (CO_2). Those are identified as climate-damaging. To reduce these emissions and to counteract to the climate change national and international arrangements are made.

Since the global emission is growing continuously, Germany reduced its emissions in total to the target values which were assigned in the Kyoto protocol. Umweltbundesamt states that the transportation sector reduced its emissions by 5.1 %. The overall GHG-emissions of Germany's economy sectors were reduced by 21 %. In contrast to transportations, manufacturing reduced its emissions by 34.9 % in the same time as well as private households by 33.1 % and the energy sector by 14.8 % (UBA 2013). Those numbers show the minor ratio of transportations concerning the reduction of CO_2–emission. If only transportation is considered the emission is even increased by 13 % regarding 1995 to 2010 (Thomas 2012, S. 506).

Transportation is a substantial sector regarding the GHG-emissions and got a ratio of 20 %. Only the energy sector got a higher impact to the total GHG-emission.

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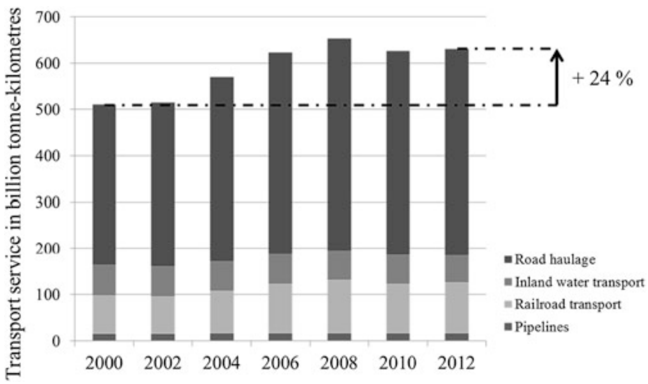


Fig. 11.1 Modal Split (DIW, 2014)

So realization of successful arrangements becomes essential. The increasing GHG-emission caused by transportation is not only obvious in Germany. It is also globally identifiable. Statistics, published by the Organization for Economic Cooperation and Development show that the total amount of GHG-emission declines from 1990 to 2005 by 2 % but on the other hand they increased by 43 % in the transportations sector (OECD 2010). Also the European commission verifies this trend. Even though greenhouse gas emissions from transportation started to decrease in 2008, they still exceeded the target emission from the 2011 Transport white paper target by 67 % in 2012 (European Commission 2015).

A reason for the difficulties to reduce GHG-emissions concerning the transportation sector is the continuing growth of transport volume. Especially the freight traffic via road grew in recent times while simultaneously other modes of transport lowered their volume of ton kilometers (see Fig. 11.1).

This claims an analysis of Bundesverband Güterkraftverkehr Logistik und Entsorgung (BGL) e.V. The analysis shows the distribution of ton kilometers concerning the modal split in freight transportation. Remarkable is that road transportation showed an all over volume share of 70.5 % ton km. This is a plus of 24 % in comparison to the modal split share in 2000. This leads to higher increase of GHG-emission caused by the transportation sector. A chance to counteract that trend is to shift road transportation to other modalities. This is called modal shift. But unnoted which kind of modality is chosen for transportation it will cause GHG-emission.

It is necessary to allocate emissions caused by operations along the transportation chain. This is already possible for individual transportation modes. The emissions of related handling operations are usually estimated on the total consumption data of the whole facility. Information of handling emissions of loading units is insufficient. Regarding these circumstances a detailed calculation of emission data is required to be able to allocate CO_2–emissions for handling operations in multimodal container terminals.

In this paper an approach is presented to evaluate GHG-emissions of container handling procedures in multimodal container terminals precisely.

11.2 Project Boundaries

In addition to the earlier developed method kit which allows the determination of GHG-emissions for different transport modalities the analysis is now focussing the terminal areas. In general hinterland container terminals are considered in this analysis to complement the already existing method kit for transportation modalities. The analysed values for GHG-emissions of handling in container terminals add the module for terminals to that method kit. After the analysis and implementation into that tool it is possible to evaluate the emissions along the entire transportation process.

11.3 Solution Approach

The presented project is based on a former developed method kit to evaluate Greenhouse-Gas emissions for various transportation modalities. In this project research is focused on the emissions of handling operations in multimodal container terminals. Therefore five work packages are defined. To meet a high level of accurateness simulation is used to evaluate emission data for different terminal layouts. The estimated values are the system load for the simulation independent CO_2-method kit which is developed in MS Excel.

The approach contains a current state analysis. In this step the multimodal container terminals of the industry project partners are analysed concerning layout, modal split and handled loading units. Furthermore throughput, utilization and seasonal deviations are calculated individually. Depending on the modes of transport the container terminal can be divided into various functional areas according to the connected modalities. This paper focuses on bimodal and trimodal terminal layouts. Figure 11.2 illustrates all functional areas in a schematic layout.

At second the evaluation of consumption values of various handling equipment of container terminals is concerned. In this case specialist literature is studied and data of manufacturers of handling equipment are collected. Furthermore all data and information need to be validated and complemented. Therefore measurements will be done which record the consumption for an exemplary early shift. Those measurements take place at the multimodal container terminal facilities of project partners.

In the following, consumption affecting factors are determined by deductive analysis. The objective is to higher knowledge about all relevant factors or technical specifications which influence the energy consumption of specific handling equipment. At this point in the project a lot of discussions about the results lead to

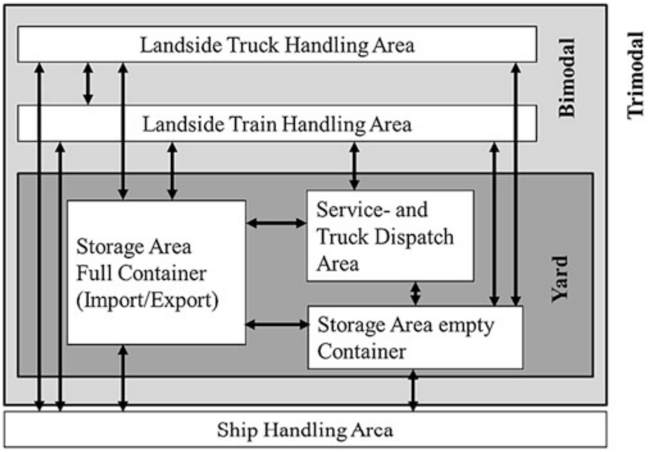


Fig. 11.2 Functional areas of a container terminal

the ability to identify emission causing factors of handling operations in terminal layouts. The evaluated results will be categorized and furthermore presented to all project partners to evaluate relevant influencing factors.

The next milestone in the project contains the simulation for allocating Greenhouse-Gas emissions of logistics operations within multimodal container terminals. In recent times the Institute of Transport Logistics and the company INCONTROL simulation solutions developed a tool to run simulations for handling facilities within combined transportation chains. This tool isfocussed in simulation and will be complemented by a module which allows evaluating GHG-emissions. This is an event-driven and module based simulation which maps multimodal container terminals including all stochastic interdependencies of different functional areas in an experimental model. For that purpose various, appropriate to all evaluated emission causing factors, facility models are analysed by scenario technique. On this way system load for each scenario is generated. Based on those and by help of a key performance indicator catalogue the GHG-emissions are possible to allocate accurately for each loading unit.

The results of all described working steps are then gathered in one module for multimodal logistics hubs. This is an advancement of the already existing determination tool for GHG-emissions among the entire transportation chain of containers. With help of this module it is also possible to evaluate the GHG-emission of a specific terminal layout by filling in all relevant KPI's. The decision to choose Microsoft's application "Excel" to develop that method kit is obvious since the first version of this GHG-emission method kit is based on it and the program "Excel" is the most common program, even in small companies, which don't have to invest a lot to gain benefits from such a method kit.

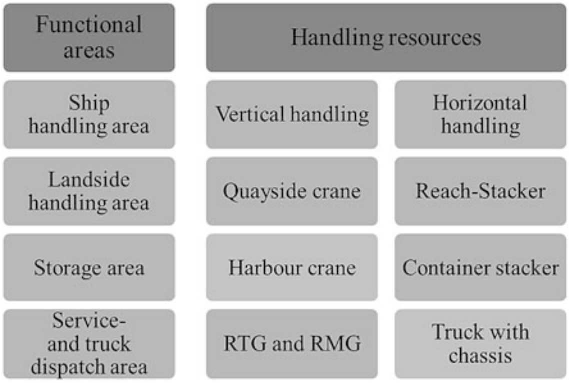


Fig. 11.3 Handling resources

11.3.1 GHG-Emission Causing Factors

This paper concerns the first three work packages of this research project. In the following sections the theoretical approach, as well as validation of consumption values of handling resources and furthermore the estimation of GHG-emission values is examined.

In this phase of the research project for the method kit the analysis of emission values in multimodal container terminals is focussed. To get a valuable system load for the method kit the handling resources which are used in a container terminal need to be identified. Depending on the layout and the connected modalities to the terminal various resources can be operated. They are either categorized to vertical or horizontal handling resources. Figure 11.3 illustrates this differentiation. Furthermore it depends on the location and the layout of the container terminal which type of handling resource is suitable for the handling operations. Concerning the different functional areas from Fig. 11.3 in this paper it is to state that there are different handling resources suitable for the various functional areas.

To identify all factors, the resources need to be analysed regarding their energy consumption per loading unit. As stated in the section before a lot of consumption characteristics are published either by specialist literature or manufacturer data. The focus of this analysis is on the consumption influencing factors which should be identified by measuring numerous operations. The measurements are meant to map exactly all single movements of the handling resource. As a result, the allocation of consumption values to single movements of the resources is feasible. To determine those factors, measurements in different container terminals of the project partners are done to collect real-time data. This is useful to be able to compare different and also similar types of container terminals. Such a comparison is also essential to identify emission causing factors.

Varying models of gantry-cranes are analysed to identify differences in emissions which can be caused by technical specifications or a deviant terminal layout. Also Quayside Cranes and reach stackers are taken into account.

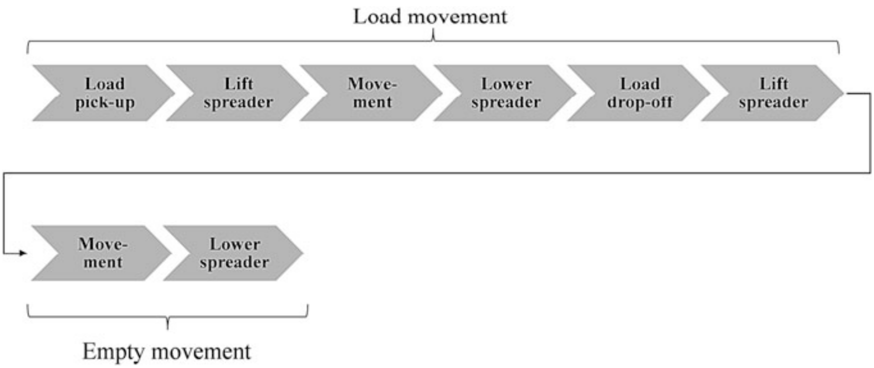


Fig. 11.4 Process chain in container handlings

The measurements are realized directly at the project partner's location. To collect data it is essential to install measurement equipment at the cranes to record the consumption data for following analysis. To map the handling process in container terminals a common morning shift was measured. In this shift each handling process was recorded in detail. Since container terminal operators are focussed on optimizing GHG-emissions of their terminals the objective is to allocate the total consumption to all movements of the equipment to identify.

A typical crane handling process consists of a trip with load and an empty trip to reach the next container which needs to be handled (Fig. 11.4). Such a sequence is defined in the following as a cycle. Although the terminal layouts are different the crane cycles are similar. It starts with the load pick-up and after the spreader is lifted the loading unit is carried to its drop-off position. The cycle continues with the empty tour. In this process the crane is moving to the next loading unit which needs to be handled.

The first approach showed that it is not representative to measure all single movements of the crane. While operating a full cycle the crane works with different motors simultaneously. Basically the consumption of each motor in such a crane is interesting but in this case of analysis not representable since the emission for a typical handling cycle needs to be validated. In this case it is more practicable to record the cycles. To analyse the recorded data a mask is developed which allows to map all the processes while the shift.

To get an idea of the emission causing factors in multimodal container terminals it is essential to seek after all parameters of the cycles in the recorded shifts. Basically it is the aim to get results for energy consumption data per loading unit.

In this context the parameters of all loading units should be classified to identify emissions of loading units with different technical specifications, weights or handling durations.

Type	Name
20 feet	20‘
40 feet	40‘
45 feet	45‘
High-Cube	HC‘

Weight	Name
empty	CT + 1
0 < t <= 10	CT + 2
10 < t <= 20	CT + 3
20 < t	CT + 4

Fig. 11.5 Container classification

11.3.2 Definition of Weight Classes

Therefore all loading units are classified to different weight classes to group them and in case to show allocation of emission for each weight class. To be able to analyse all loading units regarding their weights, classes are defined. On that basis all loading units can be assigned to on weight class. Those weight classes are named by the type of loading unit plus the number for the individual weight class.

Figure 11.5 gives a schematic overview about the definition of classes. Furthermore those classifications also exist for Trailer. In case of trailer handling in terminals the classification of the loading units regarding their weight is similar and the weight classes remain.

- Example: a 20 feet sized container which carries 21 tons is defined in container class 204

11.3.3 Definition of Distance Classes

Furthermore the covered distance for each handled loading unit is focussed to identify possible influence to GHG-emission. Therefore the covered distances of loaded and empty tours are important for the analysis. Similar to the weight classification also those distances are grouped to distance classes which are able to be examined regarding their GHG-emission (see Fig. 11.6).

Relation	Distance class
Distance loaded	EL
Distance empty	EI
Distance Cycle	Eg

Distance	Class
< 20 m	ET +1
20 m < x < 60 m	ET +2
60 m < x < 100 m	ET +3
> 100 m	ET +4

Fig. 11.6 Distance classification

In contrast to the weight classes it is beneficial to specify the distances of each handling cycle more detailed. Basically the total distance of a single handling operation can be separated into a distance covered with load or without load. Within the analysis both components are defined as separate class. Class “EL” represents the covered distance with load and in contrast to that “El” represents the distance which is need to covered empty.

This detailed classification is essential, since both distances can differ a lot in one full cycle. It is possible that a resource has to cover a huge distance loaded and just cover a very small distance unloaded because the next loading unit is waiting right next to the previous drop-off position. Of course the situation can occur vice versa. Since the distance is surely an emission causing factor it is part of this analysis to identify if there is a difference in loaded and unloaded movements.

11.3.4 Analysis of Energy Consumption

Before evaluating the average energy consumption to achieve a statement regarding the GHG-emission of handling operations in multimodal container terminals the key figures which describe the measuring span have to be evaluated. Based on those data the average consumption can be identified.

To get this measuring span every terminal is analysed concerning

- Amount of container classes
- Distance classes per loading unit
- Total consumption and consumption per type of loading unit
- Consumption depending on covered distance and weight.

11.3.5 Amount of Container Classes

For each container terminal where measurements were done statistics state the distribution of the different kinds of unit loads. Those data give a quick overview of the container or trailer mix which is representable for daily operation. In Fig. 11.7 a sample is developed to show how the mix of loading units was mapped.

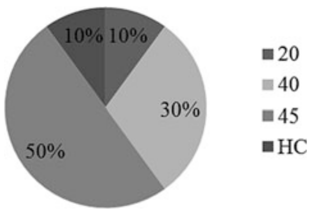
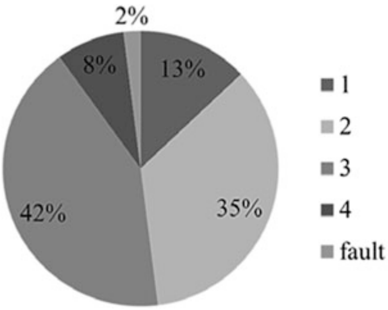


Fig. 11.7 Share of container classes (example)



Weight	Designation
empty	CT + 1
0 < t <= 10	CT + 2
10 < t <= 20	CT + 3
20 < t	CT + 4

Fig. 11.8 Share of container

All those basic parameters about the mix of loading units need to be analyzed in detail. Since a point of concern is the average consumption depending on the weight of a loading unit it is also essential to know the distribution according to the defined weight classes. Those overviews allow evaluating the representativeness of the recorded consumption values. By considering the size of all single samples it is possible to identify outliers or average values. Figure 11.8 shows a sample distribution in a specified container weight class.

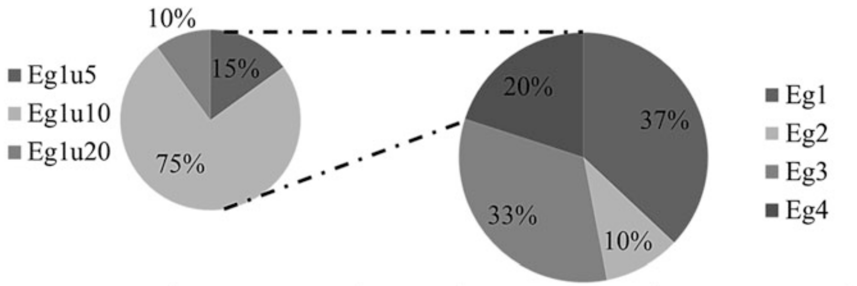
11.3.6 Distance Classification

To evaluate more consumption causing factors a point of concern is furthermore the covered distance while handling operations in multimodal container terminals. After discussions with project partners and operators of container terminals the distance of the handling operations were identified as possible factor. Taking this in account an analysis based on the covered distance is meant to turn assumption to statement.

For that reason each kind of loading unit is also considered according to their individual distance. Similar to the weight classifications also the distances of the cycles are grouped to specific classes. Also in that case useful classes were defined to get a detailed insight to the distance depending energy consumption (see Fig. 11.9).

11.3.7 Total Consumption and Consumption Per Type of Loading Unit

The total consumption of each handling resource is recorded by the measurement devices. Those devices record all consumption data on a secondly basis. The difficulties in that case are that the devices are not able to show the individual movements of the resource after transferring it to “Microsoft-Excel”. Another task is the fact that the devices record the consumption data on a secondly basis. Taking that into



Distance	Designation
0 < M <= 5	Eg1u5
5 < M <= 10	Eg1u10
10 < M <= 20	Eg1u20

Distance	Designation
0 < M <= 20	Eg1
20 < M <= 60	Eg2
60 < M <= 100	Eg3
> 100 M	Eg4

Fig. 11.9 Distance classes

account a manual record is also essential. Analysing both simultaneously by summarizing the data sets each movement of the handling resources is accountable. By measuring the handlings also manually it is easier to record consumption peaks in the distribution of energy of the handling resource. On the x-axe the time is shown and on the y-axe the graph points out the consumption in watt in every second. Figure 11.10 show a partial overview of a random energy consumption of handling resources in container terminals. Remarkable are the repeating peaks of the graph which show a strong increase of energy consumption at this point. With all these data it is now possible to allocate the movements and the full handling cycles to the energy consumption values which were recorded by the devices.

11.3.8 Consumption Depending on Covered Distance and Weight

After validating all necessary consumption values the recorded data are able to sort by either container class or distance class. For both the total or average energy consumption [in KW/h] is taken from the record which is transferred by the measurement devices. To get an expressive analysis the classes are summarized in boxplot statistics to show which consumption values were measured the most in the individual samples. Figure 11.11 shows such an exemplary boxplot statistic and furthermore points out that the weight of loading units is not a relevant emission causing factor regarding GHG-emission. The average consumption values on loading unit basis showed for the container classes no reasonable trend.

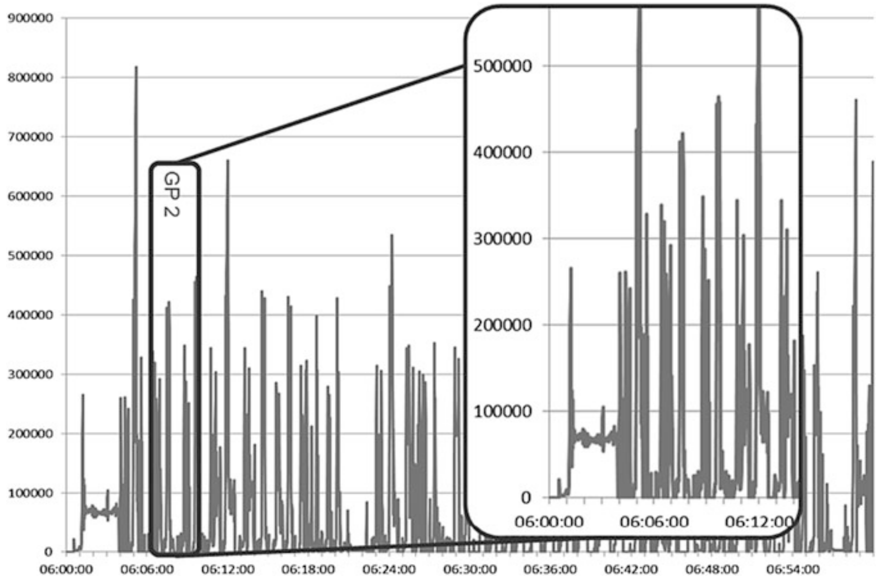


Fig. 11.10 Exemplary energy consumption

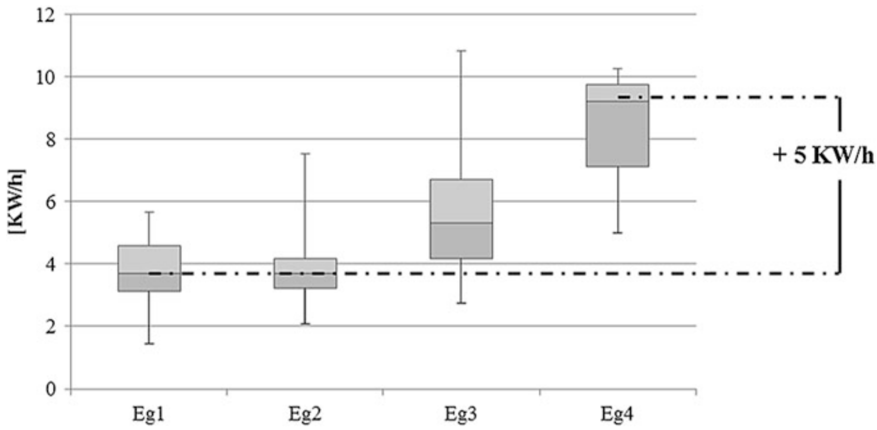


Fig. 11.11 Exemplary consumption analysis

In contrast to that, as already shown in Fig. 11.11, the consumption data of loading units sorted by distance classes show a continuous increase of energy consumption. In the example shown in Fig. 11.11 the average energy consumption increases by 5 KW/h from the first distance class to the fourth. This leads to the statement that the covered distance of a handling operation got a bad influence to energy consumption and according to that also to GHG-emissions of multimodal container terminals.

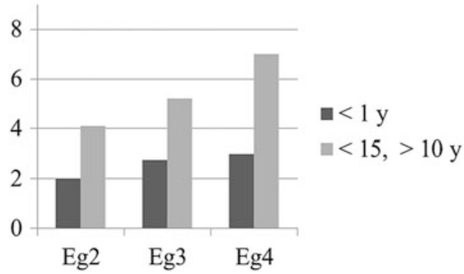


Fig. 11.12 Comparison of younger and older handling resource

By comparing all measured resources differences are identified concerning the energy consumption. As a result the question occurred what specifications are relevant for those differences. Also that case of study was able to solve with the data sets which were recorded at the project partner facilities. Figure 11.12 below shows the comparison of handling resources in different ages. The analysis was feasible for three distance classes due to the fact that there was no value sample for the first distance class. Concluding it is to state the younger resource is much more energy saving than the older one. Basically the reason for that is not to find in the age of the resource. After discussing those results with the project partners an understandable reason is that some resources are able to recover energy. IN that case the total energy consumption is much lower and caused by that the GHG-emission of course not that increasingly.

11.3.9 Exemplary Calculation

In addition to the analysed consumption values costs of GHG-emission in multimodal container handling terminals are calculated. For that calculation an exemplary mix of container is supposed, to calculate the total cost of the consumption caused by each loading unit (Table 11.1). This calculation gives an overview of the

Table 11.1 Expenses caused by GHG-emission

C-type	Iteration	kg/$C0_2$	kW/h	Cycle time (Sec.)	€	kg/$C0_2$	kW/h (Sum)	Cycle time (Sum)	€(Sum)
201	20	1,5	3,5	150	0,4	30	70	3.000	8
203	25	1,6	3,55	175	0,45	35	88,75	4.375	11,25
401	75	1,7	3,6	180	0,4	100	270	13.500	30
403	45	1,8	3,65	380	0,45	75	164,25	17.100	20,25
404	25	3,2	7	290	0,8	65	175	7.250	20
						305	768	45.225	89,5

idea how to implement the calculation of costs caused by emissions. An exemplary calculation for GHG-emission of a crane in an unspecified container handling layout is shown. The mix of the container is randomly chosen. The values in columns 3 to 6 are average values out from the presented analysis which were multiplied by the amount of handling iterations.

A sanity-check will be realized by comparing measured terminal and calculated consumption data. Therefore, the CO_2-Method kit extension will be operated by selected terminals. The sum of the calculated kW/h and l/h for every container movement will be compared with the measured overall energy consumption. The difference between these values will show the deviation of the developed method.

11.4 Results

By data analyses, average energy consumption values can be assigned to container handling operations in terminals, taking into consideration of e.g. terminal layouts, container or weight characteristics. Furthermore, the examinations show that the influence of the covered route on the total energy consumption of a crane cycle is slightly higher than the influence of the container weight. Summarizing it is to state that the validated and calculated emission values meet the experiences of the participating terminal operators. It is approved that covered distances of handling operations influences GHG-emission. The main challenge caused by that is the desire for short and quick handlings for each loading unit. Although there is already intelligent software implemented which supports in allocating loading units to their location in the terminal it is noticeable that there are still potential for optimization regarding the shortening of handling distances and GHG-emissions. Further results and identified dependencies (e.g. influence of the container classes or terminal layout) are shown in this paper.

11.5 Conclusion and Outlook

This paper presents results of the research project "Enhancement of the CO2-method kit for an exact determination of environmental effects in terminals". The aim of the research is to enhance the CO2-method kit with a terminal demonstrator-tool to empower sme logistic service provider to determine GHG-emissions of handling operations in multimodal container Terminals. Therefore, power consumption measurements have been carried out and terminal input data has been analysed.

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Part IV
Logistics Hubs as Interlinkages for Intermodal Commercial Transport

Chapter 12
Developing Dry Ports Through the Use of Value-Added Services

Dan Andersson and Violeta Roso

12.1 Introduction

The growth of containerised sea transport demands improved efficiency and increased capacity in the transit through seaports as well as in the transport to and from seaports in the hinterland. This development can also be related to the competitive situation of seaports, which compete not only in terms of transhipment efficiency and tariffs but also in terms of the quality of the service offered (Mourão et al. 2002; Saeed 2009). Lack of space at seaport terminals and congestion in the access routes serving their terminals may be major problems for seaports (Rahimi et al. 2008). The implementation of dry ports would help solve capacity issues (Roso et al. 2009) and promote economic development and logistics integration (Bergqvist 2005; Rahimi et al. 2008).

Transport policy makers at different levels have for a long time advocated an increased use of rail transport (European Commission 2001) by shifting transport volumes from road to rail. This would result in less environmental stress and a reduction in congestion at seaport terminals, as well as in seaport cities. However, despite these efforts over a very long time period, there is in most cases still a relatively low share of rail in the transport of containers from seaports to the hinterland. Road transport has, with its 73 % share, the largest part of the modal split (European Union Road Federation 2012). If the goal to change the modal split is to be achievable, it is apparent that rail-based transport solutions must be made more attractive, which may be achieved by the inclusion of a number of value-added services (Beresford and Dubey 1990; Roso et al. 2009). Since terminal operators have perceived that shippers and carriers appreciate additional terminal services, such services at and near terminals have been offered (Konings 1996).

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Substantial research has been conducted on dry ports: in general about the concept (Roso 2008; Roso et al. 2009; Ng and Gujar 2009; Rosa and Roscelli 2010; Notteboom and Rodrigue 2010; Roso and Lumsden 2010), on dry port applications and their role in the belonging countries (Ng and Gujar 2008, 2009; Roso 2008; Rosa and Roscelli 2010) and on their environmental impact (Roso 2007). However, research regarding value-added services offered at a dry port and their importance for the actors of the transport system is rather scarce. Bask et al. (2014) discuss which seaport services could be moved to an inland terminal, while Schwartz et al. (2009) evaluate the potential for the movement of postponement activities, such as assembly and packaging, to dry ports. However, no one has conceptually explained the potentially central role value-added services may have for a dry port. The purpose of this conceptual paper is to analyse how value-added services can support the development of a conventional inland terminal into a dry port and how an existing dry port can be further developed through the use of value-added services.

12.2 Method and Case Descriptions

This conceptual paper combines literature from the field of dry ports with literature addressing value-added services, with data obtained through interviews with actors in the transport system. Empirical data have been collected to support the conceptual discussion. Phone interviews were conducted with terminal managers, operators and present and past customers of the terminals. In addition, a review of secondary sources such as documents and archival records from terminals has been performed.

In this study, the port related to the inland terminals is a large container seaport handling more than 900,000 TEUs per year—40 % of which are transported by rail to inland destinations. The port is no railway operator but rather a very important driver for developing a national intermodal system in general and rail-based hinterland services in particular. The seaport is working on increasing its container rail volumes by cooperating with other actors in the transport systems, and there are rail shuttles for different freight terminals. Two of these freight terminals, one well established dry port (referred as Terminal A) and one in the development phase (referred to as Terminal B) are used as cases in this study.

Terminal A, which is situated some distance from its sea ports (which makes it a midrange/distant dry port), was established jointly by a municipality and rail operators, who also initiated the implementation of a combi terminal at the end of the 1990s. There are daily rail connections to several different seaports. This dry port offers the following services that are usually available at seaports: transhipment with two reach stackers, storage and depot, customs clearance, maintenance of containers, cross docking, forwarding and road haulage. In its best year the terminal handled 65,000 TEU. Terminal A offers also a large set of additional value-adding customisation functions, such as labelling, power supplies, manuals etc., are better to perform in proximity to the final markets (Notteboom and Rodrigue 2010), and the customers of Terminal A seem to be of the same opinion.

The initiative to establish an intermodal terminal, Terminal B, came from a municipality in early 2000 at a time when volumes were already being transported to the seaport by truck. However, it was not until the end of 2006, when a large company showed interest in establishing a terminal in the area, that the work on actually building the terminal started. Once the location was chosen and the terminal built, in 2007, a number of problems arose—such as insufficient volumes, competition with other terminals and further development issues. The rail shuttle used to operate four times a week, reaching approximately 10,000 TEU in the beginning, but then there was a major decrease in volumes, and, for a period, the operations were halted.

12.3 Intermodal Terminals—Dry Ports

An intermodal road–rail terminal can be described as a place equipped for the transhipment and storage of intermodal loading units (ILUs) between road and rail. As suggested by Höltgen (1995), intermodal terminals can be classified according to some basic functional criteria such as traffic modes, transhipment techniques, network position and/or geographical location. Nevertheless, the transhipment between traffic modes is the characterising activity. Depending on the role and the services offered, the transport industry operates different kinds of terminals under different names.

An Inland Freight Terminal is, according to UN ECE (1998), "any facility, other than a port or an airport, operated on a common-user basis, at which cargo in international trade is received or dispatched". An Inland Port is located inland, generally far from seaport terminals; they supply regions with an intermodal terminal offering value-added services or a merging point for different traffic modes involved in distributing merchandise that comes from ports (Harrison et al. 2002). According to the European Commission (2001, p. 59), a dry port is simply "an inland terminal, which is directly linked to a maritime port". Since this definition of dry port is rather broad in its meaning, all terminal facilities might adopt the use of the term dry port due to their existing road links to seaports.

Differentiation between "conventional" transhipment terminals and the various types of large-scale intermodal logistics centres, as well as an aim to find a unique definition for the same, has been an issue among researchers as well as practitioners for some time now. A dry port is an inland intermodal terminal that has direct rail connection to a seaport, where customers can leave and/or collect their goods in intermodal loading units, as if directly to the seaport (Roso et al. 2009). As well as transhipment, which a conventional inland intermodal terminal provides, value-added services such as storage, consolidation, depot, track and trace, maintenance of containers and customs clearance are available at dry ports (ibid).

The dry port's performance is very much dependent on the quality of the road–rail interface and the access to the seaport. However, the quality of inland access depends on the behaviour of a large variety of actors and requires coordination between all actors involved (Van Der Horst and De Langen 2008; Almotairi and Lumsden 2009). Scheduled and reliable high-capacity transportation to and from the seaport is essential. The benefits of distant dry ports derive from the modal shift from road to rail, resulting in reduced congestion at the seaport gates and its surroundings (Rahimi et al. 2008) as well as reduced external environmental effects along the route. Besides the general benefits to the environment by shifting flows from road to rail, the dry port concept mainly offers seaports the possibility to increase the throughput without physical expansion at the site (Roso 2007). The distant dry port extends the gates of the seaport inland, with shippers viewing the dry port as an interface to the seaport and shipping lines. However, Ng and Gujar (2008) indicate that the current solution, where shippers often choose dry ports located closest to their production base, is not necessarily the optimal solution in terms of the minimisation of transport cost, mainly due to government policies and dry ports' inability to provide needed value-added services to the shippers.

Port processes along the transport chain should be seamless according to Paixão and Marlow (2003), and the idea behind the dry port concept is to make the flow smooth—in other words, not to stop the flow in the nodes but to make all node activities seamless and by that to make the part of the intermodal transport chain seamless (see Fig. 12.1). The problem of needless long stops in the nodes is also discussed by Woxenius (1997), where the author questions the functionality of intermodal terminals and even sees them as barriers to intermodality. A stop in the node should be justified only on customer request due to some value-adding activities demanded. The implementation of a dry port could create seamless sea-port inland intermodal access—that is, smooth transport flow with one interface in the form of a dry port concept instead of two, one at the seaport and the other one at the inland destination. The same can be compared to the case of an increased level

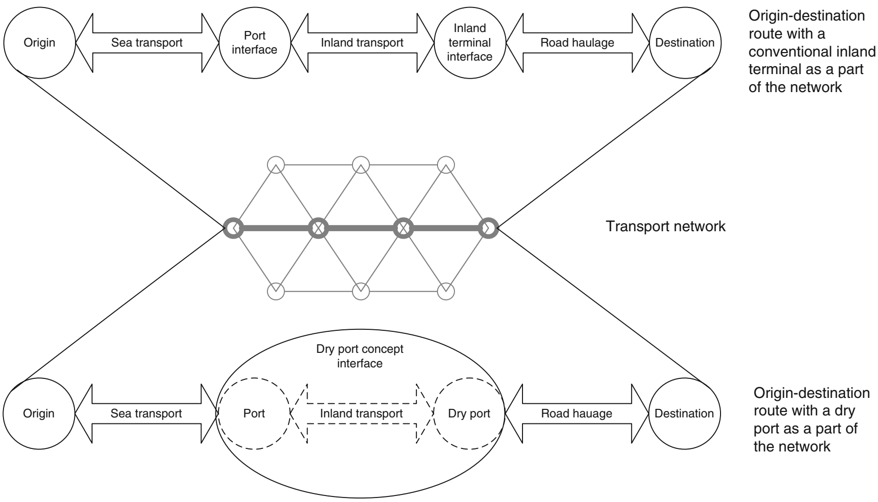

Fig. 12.1 Transport network with and without a dry port (Roso and Rosa 2012)

of functional integration in supply chains (Notteboom 2006), where many intermediate steps in the transport chain have been removed and therefore have enabled so-called one-stop-shop, allowing many shippers to have a single contact point at a regional or even global level.

12.4 Intermodal Terminals and Value-Added Service

According to Chesbrough and Spohrer (2006), services are often the key drivers of growth and profitability. Vargo and Lusch (2004) define services as "the application of special*ize*d competences (knowledge and skills) through deeds, processes, and performances for the benefit of another entity or the entity itself".

Logistics service providers in general have extended their service operations to include those that earlier had been carried out by shippers. The aim is to provide services with the best match to shippers' supply chain strategies (see, e.g., Bask 2001). The meaning of value-added services has changed over time. LaLonde and Cooper (1989) argued that logistics service providers' value-added services included, for example, electronic data interchange, tracking and early warning of late shipments, warehousing, intermodal capabilities, equipment leasing, international shipping services, brokerage and containers. Later on, the concept of value-added services was broadened, and today these services also include such things as packaging, sorting, labelling, assembly operations, sequencing and light manufacturing (Bask 2001; Ng and Gujar 2008; Noteboom and Rodrigue 2010).

A review of the literature about intermodal terminals shows that the transport industry operates different kinds of terminals under different names depending on the role and the services offered. In Table 12.1, some of those definitions are compiled with the emphasis on the mentioning of value-added services. All types of terminals may feature some value-added services that are used to distinguish them from each other. Podevins (2007) notes that inland terminals are growing in importance as consolidation hubs for continental freight but also as providers of value-added services for seaports. Developing inland activities can trigger volumes through sea terminals, particularly if the seaport is in charge of the commercialisation of the intermodal services; thus, the value-added in the "extended gate" approach is higher than that in the "traditional" approach (Franc and Van de Horst 2010).

From a seaport's perspective, the development of container terminals is seen as an important activity that goes beyond the storage of goods; moreover, the introduction of new value-added services is seen as the key to survival for some seaports (Cheung et al. 2003). Paixão and Marlow (2003), in their study on ports' agility, suggest that dry ports should become seaports' new customers, which would enable the seaports to go from a cost minimisation attitude to a value-added maximisation of the entire network.

Table 12.1 Value-added services in the definitions for different terms used in relation to inland terminal facilities (Adapted from Roso and Rosa 2012)

Source	Term	Definition (value-added/accompanying services underlined)
UN ECE (1998)	Inland clearance depot	A common-user inland facility, with public authority status, equipped with fixed installation and offering services for handling and temporary storage of any kind of goods (including containers) carried under customs transit by any applicable mode of inland surface transport, placed under customs control to clear goods for home use, warehousing, temporary admission, re-export, temporary storage for onward transit and outright export
Indian Customs (2007)	Inland container depot	A common-user facility with public authority status equipped with fixed installations and offering services for handling and temporary storage of import/export laden and empty containers carried under customs transit by any applicable mode of transport placed under customs control. All the activities related to the clearance of goods for home use, warehousing, temporary admissions, re-export, temporary storage for onward transit and outright export and transhipment take place from such stations
Cardebring and Warnecke (1995)	Intermodal freight centre	A concentration of economically independent companies working in freight transport and supplementing services in a designated area where a change of transport units between traffic modes can take place
EC (2001)	Logistics centre, freight village	Geographical grouping of independent companies and bodies that are dealing with freight transport (for example, freight forwarders, shippers, transport operators, customs) and with accompanying services (for example, storage, maintenance and repair), including at least a terminal
Harrison et al. (2002)	Inland port	Located inland and generally far from seaport terminals, they supply regions with an intermodal terminal offering value-added services or a merging point for the different traffic modes involved in distributing merchandise that comes from ports
Roso (2007)	Dry port	Dry port is an inland intermodal terminal that has direct rail connection to a seaport, where customers can leave and/or collect their goods in intermodal loading units, as if directly from the seaport. Value-added services such as storage, consolidation, depot, track and trace, maintenance of containers and customs clearance should be available at dry ports

12.5 Provider and Shipper Perspectives on Value-Added Services Related to Dry Ports

Based on information gathered from the two cases, the perspectives of the related service providers and customers on the role of value-added services in dry ports will be discussed in this section.

The strength of Terminal A is its location—distant from the seaport but in the vicinity of numerous shippers in the need of different logistics services. Seaports today compete not only in terms of transhipment efficiency and tariffs but also in terms of quality of the service offered, such as the speed and reliability of shipments to destinations on the continent (Mourão et al. 2002; Saeed 2009). Terminal A does not need to rely on the seaport as a customer for storage capacity but rather on its local shippers, which have realised the opportunities of Terminal A being the seaport's inland interface. It has been argued that the implementation of dry ports could help in solving capacity issues in sea ports (Roso 2008; Roso et al. 2009), as many seaports face problems related to limited land and access capacity (Rahimi et al. 2008). However, in the case of terminal B, where the seaport is not facing a capacity issue, moving, for example, storage to terminal B is interpreted as a loss for the seaport, not a gain. The proximity of terminal B to the seaport makes it very suitable as a depot or stand-by-storage for units/goods that are not time sensitive; however, this function is not in use. A dry port as storage for a seaport that is not facing the capacity issues may be viable if the seaport is the owner of the dry port (Roso and Lumsden 2010). In the case of terminal B, the seaport is a customer of the dry port, not the owner; however, that should not stop the terminal from functioning as storage for local shippers in need of it. And, the need is there, according to one interviewed local customer of terminal B:

> If the terminal could offer storage, it would be more attractive—as well as a depot so that customers do not have to go to the seaport to pick up or leave their empties.

A market offering has two elemental characteristics for the customer: its value and its price. The difference between value and price equals the customer's incentive to purchase or use a market offer (Anderson and Narus 1998, p. 54). It is also important to understand that customers perceive value in different ways—that is, there is a need for some kind of segmentation of the customers and product flows. The value provided by the enlargement of scopes in inland terminals depends on the existing offer: The value is high when the market offer is poor and the provider can improve the supply of such services by stepping into the business (Franc and Van de Horst 2010).

Time-criticality is less a characteristic of peripheral depots/dry ports than of the central seaport terminal, and value-added activities are likely to be less cost intensive in those peripheral locations (Robinson 2006). From the shippers'/customers' perspectives, those time and cost issues are very important if not crucial. Most dry port users establish close relationships with the personnel at their local dry port, which results in smooth transport, customs and documentary clearance processes (Ng and Gujar 2009). These benefits were recognised by interviewees from both terminals. According to one Terminal B customer:

> Customers have demand the service; to be on time is very important.

Different actors in the system might perceive the importance of different services differently, and therefore the communication between the actors is important. According to Mirzabieki et al. (2013), there is a growing trend of using radio-frequency identification (RFID) technology, which improves the confidence of shippers to meet the expectation of their customers. In so doing, the reliability of the service would improve, implying shorter transit times, higher frequencies and better timing as well as the possibility for the customers to track their shipments in terms of their location and condition. However, none of the interviewees expressed interest in or a need for the implementation of RFID technology.

Europe consists of very different customer segments with a variety of tastes, preferences and languages as well as technical standards; thus, there is a significant need for customisation for each specific market. This can be accomplished through the use of different postponement concepts (van Hoek 2001), which could be beneficially performed at the dry ports (Schwartz et al. 2009). Postponement services, such as labelling and adding power supplies, manuals etc., need to be performed in proximity to the final markets, as market fragmentation renders source-based functions prohibitive for many ranges of goods—for example, a change from an ISO-pallet to a Europallet or a change in packaging to meet local tastes and language (Notteboom and Rodrigue 2010).

Traditional transport activities are not providing sufficient returns and opportunities to add value to the supply chain is being sought by many companies (Cheung et al. 2003). However, the number of extra services offered at freight terminals has been growing due to increased interest from carriers and shippers; it started with fairly simple container services such as empty depots and container repairs and has expanded steadily, moving into various forms of physical distribution activities (Konings 1996).

To offer value-added services may be one way to differentiate the service, increase the value of the offering and thereby increase the demand and revenues. But it may also be a possibility to reduce the cost and thereby additionally improve the profitability. By offering a wide range of services, Terminal A is able to take advantage of economies of scope and thereby reduce the cost to produce their services, as explained by Terminal A's manager:

> Our personnel is trained to provide all services that the terminal offers. At the peaks, there is a need for all personnel to be involved in transhipment, but in the mean time they can perform other value-added activities such as, for example, sequencing. Consequently, the cost for sequencing can be low.

12.6 Establishment Versus Development Through Value-Added Services

One of the first models for describing the development of inland terminal facilities —that is, dry ports—was presented by Wilmsmeier et al. (2011). Their focus was on the directional development of a dry port and thus on strategies for co-operation between ports and inland terminals, and this perspective has been supplemented by Bask et al. (2014), who, for instance, included the role of value-added services and type of dry ports.

Terminal A, a well-established dry port, has developed its services according to the steps in Fig. 12.2. It started as a conventional intermodal terminal with basic terminal service, and, gradually added more services such as container maintenance and warehousing, and then introduced more advanced value-added services such as sequencing and kitting (by the request of one of their major customers). The development of the offering of Terminal A continues since new value-added services generate new customers, who eventually need more customer-oriented value-added services. However, the precondition is scheduled rail service to the seaport and availability of road haulage for final delivery, as explained by Terminal A's manager:

> Diversity in value added services is important for the customers when they choose a terminal, but a functioning rail connection to a seaport and road haulage are essential.

At the time when the study was conducted, Terminal B planned to transform the terminal from a conventional one to a dry port, which means offering further services such as the storage of containers, customs clearance, the maintenance of containers and warehousing as well as other services upon customer demand. Table 12.2, with the results of the preliminary study with SWOT (strengths, weaknesses, opportunities and threats) analysis, shows the potential that Terminal B has regarding future development.

There is widespread acceptance that freight terminals cannot compete in pricing and that in order to prosper or to maintain competitive advantage, the introduction of value-added services is a must (Cheung et al. 2003). When it comes to the terminal's development in relation to value-added services and their importance, one can see in Table 12.2 that there are opportunities for Terminal B with new customers and new

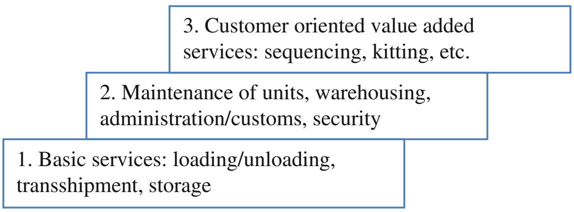

Fig. 12.2 Step-by-step development of value-added services

Table 12.2 Results of terminal B's SWOT analysis

Strengths	**Weaknesses**
Infrastructure is in place	Insufficient marketing
Direct rail link to the port	Lack of awareness about new customers
Fast service	Coordination between the actors
Owners very determined	Dependence on the sole port traffic
Creates new jobs in the area	Short distance to the port
Short distance to the port	
Lower environmental impact	
Opportunities	**Threats**
Higher shuttle frequency	Overall economic crisis
Increasing interest in intermodality	The sea port facing ownership issues
New customers in existing market	Another terminal in the vicinity
New markets	

markets potentially needing new value-added services. Terminal B's operator is aware of the importance of value-added services, but states:

> We are planning to introduce new, more advanced value-added services, but one can realise that there is no use of introducing new value-added services when there is no reliable and scheduled rail connection to the seaport!

The inclusion and expansion of different value-added services may play an important role in the development of intermodal transport. A service provider can include value-added services in the service portfolio in order to be able to offer clients different types of benefits. However, these services will have no value if there are deficiencies in the basic services.

12.7 Results and Conclusions

The development of dry ports and their viability may depend on different value-added services being available at the dry port, once the infrastructure and basic services are in place. The availability of value-added services may increase a dry port's attractiveness. However, these services seem to have no value if there are deficiencies in the basic services (their amount or quality). We have so far not observed how value-added services attract new customers, instead it seems to be a way to increase business volumes and customer satisfaction within established relationships.

A service provider can include value-added services in his service portfolio in order to be able to offer his clients different types of benefits. The value of a service a provider offers its clients can lie in a reduction of costs or an increase in the shipper's revenues (by influencing the service levels). Cost reductions can be achieved both in the provider's operation and on the shipper's side. This requires further investigation to describe the effects and where they occur. However, it is clear that it is not only the shippers that benefits directly from the use of value-added services; the providers may also reduce their costs by economies of scope. Two different generic value-creating mechanisms are in play in the investigated cases: exploitation (efficiency) and exploration (innovation). The value of a logistics service can be enhanced by a combination of exploitation (refining the present) and exploration (new thinking) (see, e.g., March 1991). The value-added services seem to have elements of both these mechanisms; however, this is something that requires further investigation.

Since an issue was how to increase the attractiveness of certain rail-based transport solutions, it is also important to identify and understand how service providers communicate the value of their offerings and through which main value mechanisms the value will be created. In the reviewed cases the value-added services were not used to increase the attractiveness of rail-based services, they were either a result of the existence of them or the need of customers utilising the terminal (regardless of the mode of transport). It seems that the logic has not been to create a service offering (including attractive value-added services) and then market this, but to first secure a certain goods volume and establish a railway connection and then develop this business. This could be a consequence of the division of labour in the service production system.

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Chapter 13
Outlying Location of Logistics Activities: The Example of the Burgundy in France

Cecilia Cruz and Christine Belin-Munier

13.1 Introduction

Logistics activities grew in last decades because there a lot of mutations in production: the supply chain is more fragmented due to the generalization of just-in-time organisations. As Veltz (1996) points out that production is done in more and more establishments. Guilbault and Soppé (2009) observed that the number of companies had increased in France between 1988 and 2004 and leads to the fragmentation of flows. In the same time, the stocks in stores decreased. All these trends lead to the development of warehousing.

Previous papers emphasize the development of warehousing in last decades in France (Wemelbeke Mariotte 2007) but also in other countries of Europe (Strale 2010) or in USA (Cidell 2010; Dablanc and Ross 2012).

However, most of researches focus on large urban areas like Paris Region (Bahoken and Raimbault 2012). Researches about development of logistics activities in France also describe the development at national scale (Masson and Petiot 2012; Guerrero and Proulhac 2015) but the location of logistics in the outlying places isn't studied.

Strale (2010) identified some outlying location in Europe like the Burgundy region. The Burgundy is halfway between Paris (North) and Lyons (South) (Fig. 13.1). This location could give some advantages due to its relative position.

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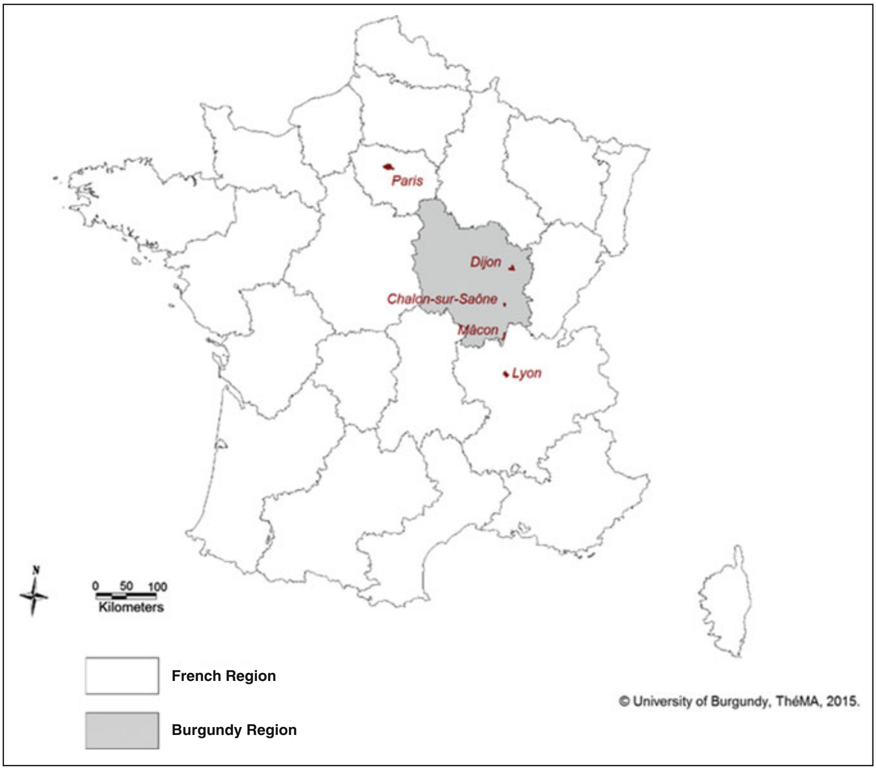

Fig. 13.1 Map of France and location of Burgundy region

Indeed, some logistical providers and companies from e-commerce settled in that region in last years.

The aim of this paper is to understand why and when an outlying location is come within strategies' companies, and how these 'outlying' logistics activities work. To answer to the first objective, we assess the development of logistics using a database from Ministry in charge of Transports that inventories all of building permits since the beginning of 1980s. Warehouses from trucking sector and from others sectors are counted.

However this database gives us only information the number m^2 of built, not the reasons that explain this location choice. So complement this quantitative analysis, face-to-face interviews were done with transport and logistics managers from different sectors of activity: e-commerce, agri-food industry, industry in order to understanding better why Burgundy could be an advantage for that companies. Moreover, these interviews allow us to identify the characteristics of this outlying location choice. Finally, these projects could be built because of the involvement of local authorities; some interviews with public authorities give us some details why they take an interest to attract the logistics activities.

The paper will be divided into three sections.

First, to understand the strategies, it is important to identify where the construction of warehouses are located and to quantify the surface areas built. Secondly, the location is linked to the strategies of companies that it is necessary to identify. Thirdly, how are the advantages of a location in Burgundy for a company and for local authorities and how these organisations are linked to adjacent regions.

13.2 Burgundy: The Development of Logistics Activities

13.2.1 Data

To identify the development of logistics activities, we use data from Ministry in charge of Transports, the database is so-called SIT@DEL. The database inventories all of constructions of buildings in France since 1984. It based on building permits. Warehouses are identified like a category of buildings. Data collected is at municipal level which can give detailed insights especially at urban scale. This database gives an account of the development of logistics activities because all of new buildings are identified. Nevertheless, the data doesn't allow us to assess the situation before 1984. So the analysis focuses on dynamics of logistics activities.

We use data at local level (municipalities) to understand in details where warehouses are located in Burgundy and to identify some changes in location during the studied period. For that purpose, we identify two periods 1984–1998 and 1999–2013 to detect some changes in location.

13.2.2 Logistics Sprawl and Polarization

Warehousing increased in Burgundy very fast: between 1984 and 2013, more than 4.3 million of m^2 were built. In comparison, for industrial buildings, 5.5 million of m^2 were built and only 3.5 million for trade building.

All municipalities don't have the same area, so in our analysis of the spatial distribution of warehousing activities, we use the number of m^2 by km^2 to avoid the impact of the big municipalities that can more built areas than others only because there are extended municipalities.

In the two periods: 1984–1998 (Fig. 13.1) and 1999–2013 (Fig. 13.2), we see that the construction of new warehouses is mainly concentrated next to major routes. We also can identify the main urban areas in Burgundy: Dijon in East, Chalon-sur-Saône in the South, 70 km from Dijon, Mâcon that constitute a North/South route. However, the distribution in the two maps is different.

During the first period 1984–1998 (Fig. 13.1), 2.3 million of m^2 of warehouses were built. The construction of warehouses is concentrated: 50 % of buildings areas of warehouses were done in 3.15 % of areas of municipalities. However, we observe that only 213 municipalities don't have construction of warehouses during this period.

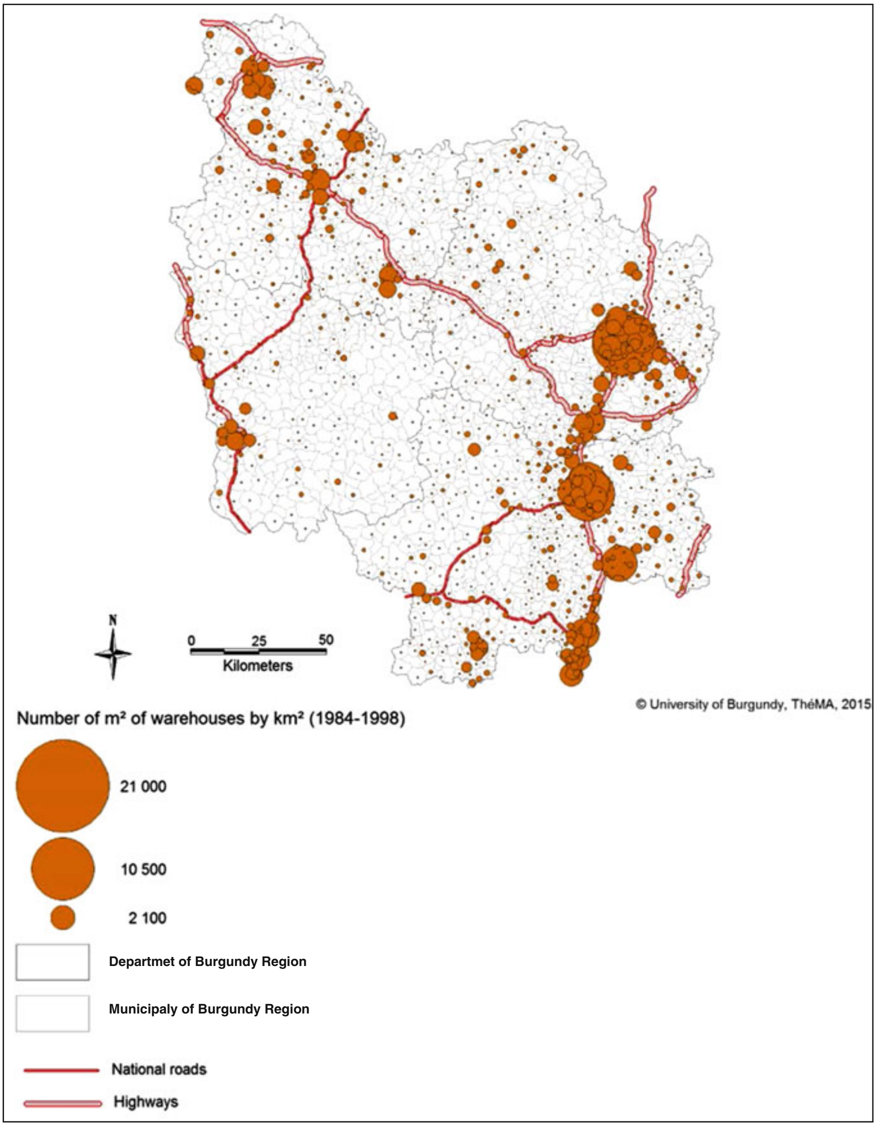

Fig. 13.2 Development of warehousing in Burgundy region (1984–1998)

During the second period 1999–2013 (Fig. 13.2), the rate of construction was less intense: about 1.9 million of m^2 but it is more concentrated because more 50 % of areas of warehouses built were done in only 0.8 % of areas of municipalities. The polarization of logistics activities is stronger during the second period. Indeed, the number of municipalities where there is no building of warehouses increase: 508 municipalities. The density of building of warehousing reach 20,418 m^2/km^2 during

1999–2013, whereas during the first period (1984–1998), the maximum was only of 11,103 m^2/km. In the meanwhile, the maximum density observed for construction of industrial buildings is of 7,338 m^2/km^2 during the first period 1984–1998 and of 5,072 m^2/km^2 during the second period. So, logistics activities tend to be more concentrated than industrial activities.

Between the two periods, as Guerrero and Proulhac (2015) observed in some big French urban areas or Cidell (2010) in USA, we identify a phenomenon of logistics sprawl but in a lesser extent. This could be explained by the size of cities that are smaller cities. So the outlying region follows the trend noticed in bigger urban areas like Paris.

This analysis shows that logistics activities develop very fast in Burgundy (on average 140,000 m^2/year) like in the others French regions. The concentration is very high in comparison with the construction of industrial buildings. (see Figs. 13.2 and 13.3).

13.3 Differentiated Strategies of Companies According Their Activity

The location of warehouses is the result of the strategy of a company and it is only the visible part of a much larger organization. This latter includes customers of service providers, the holdings companies that implement them or independent groups that will build a supply chain on these structures to provide their franchisees a logistics service. To understand the choice of their location, it is useful to identify the strategies of these organizations. That is the purpose of this second section. The strategies could be studied by economic sectors of activity.

13.3.1 Production

If before, logistics was essentially a logistics of domestic production, now, the management of the industrial supply chain is increasingly that of an inter-organizational supply chain highly and geographically fragmented (Belin-Munier 2013a, b, 2012a, b; Dubos-Paillard and Belin-Munier 2011). Sourcing practices have generated purchasing offices which see the world as a single supply area. Each step of the production process will be located in the much appropriate geographical area; the distance seems irrelevant a priori. Logistics is most of the time only a support function and it is only if the operation is truly impossible that the localization model will eventually be reviewed. Certainly, the logistical factors are integrated into decision-making, but not always at the strategic level (Belin-Munier and Moncef 2013). In a strategic context, with a high level of logistics maturity, the distinctive organizational strategic competence of industrial organization becomes a competitive competence. It is designated as Global Supply Chain Management. It is based on intangible resources

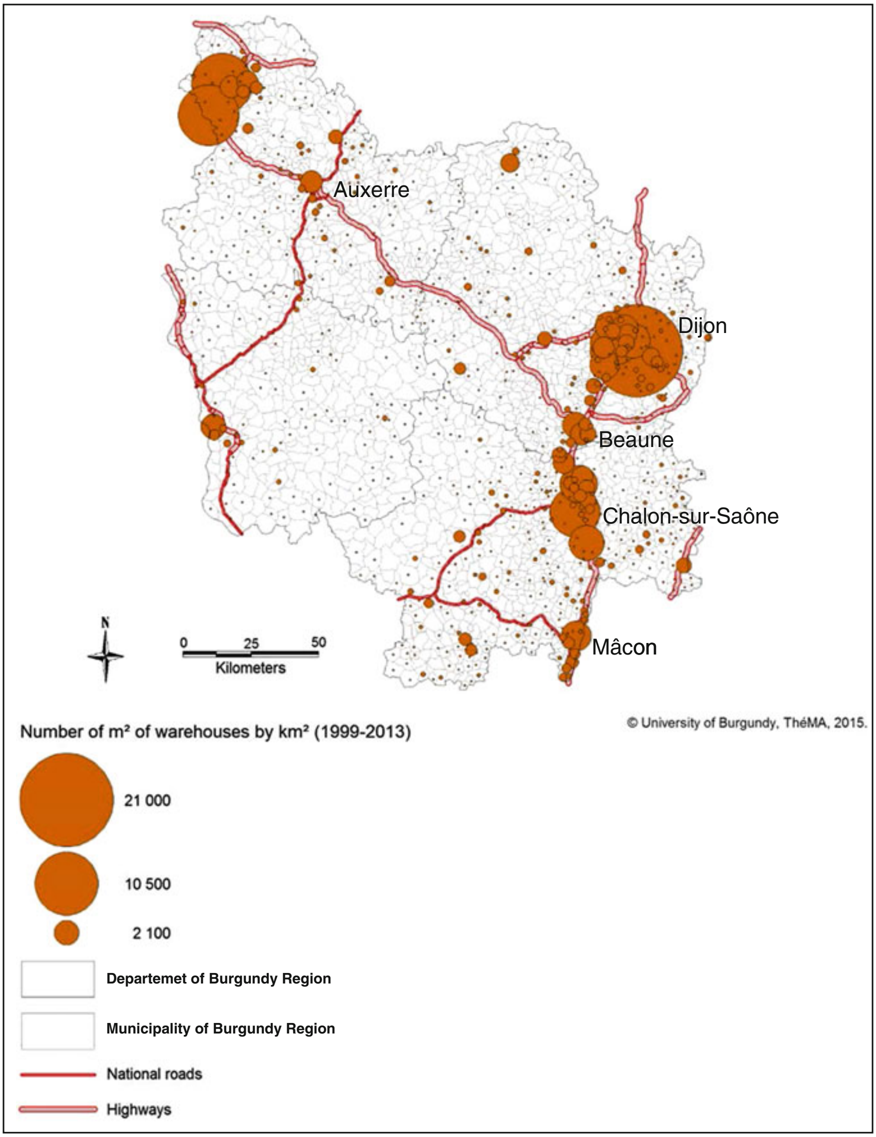

Fig. 13.3 Development of warehousing in Burgundy region (1999–2013)

(management, relational) but also on physical resources such as supply centers (to consolidate geographically diversified flows necessary to the one specific manufacturing process) as well as distribution centers (for the flows to different clients that can also be subsidiaries of the group). In a context of specialization of tasks by geographical areas rather than by products, these logistics bases can be a source of territories conversion. The location of warehouses will be closest to the centroid of the points of consumption/supply, taking into account of course also of local labor, land prices, the presence of transport infrastructure and logistics and of any financial aid from the State and Regions (Dornier and Fender 2007; Munier-Belin 2005). Many industrial companies in Burgundy have a distribution/supply center (Philips Eclairage, Socla, …).

13.3.2 Distribution

Large scale distribution

Logistics has always been disputed in the retail sector. If it was originally supported by suppliers and wholesalers, since trade began to concentrate; the large retail companies saw this as a way to strengthen their control over the supply chain (Dornier and Fender 2007). Logistics platforms controlled by distributors allow a consolidation of orders, reduce inventories by regional consolidation; they open the retail market to smaller suppliers and therefore increase upstream competition; the well-known logistics costs can be useful for negotiating for direct delivery point of sale; the logistics knowledge of the retailers increase the power of the decisions centers on the suppliers via the logistics expertise power and the opaque screen of information between suppliers and end customers. These platforms are usually specialized by product type (fresh, groceries and perfumes, textile …) and geographical area (except for the general import of products such as textiles or brown and white goods that can be centralized on national warehouses). The activity in these platforms has changed dramatically over the past decade. If some of them were used for storage (e.g. groceries and perfumes) and others only for transit with many cross-docking (e.g. fresh goods), the share of storage has declined for just-in-time replenishment, this leads to transfer the responsibility for inventories to the suppliers. In response, these suppliers (sometimes at the initiative of a retailer) had to add intermediate shared storage (Belin-Munier 2010). Finally, the distribution chain also became fragmented and some storage warehouses have to find new uses for their areas.

Franchises

Franchises allow retailers to rely on pre-established business models upstream by the franchise: marketing, central purchasing, logistics services. In the latter case, franchisees have access to centralized supply and replenishment from the central warehouses. The pooling of investments between the franchisees makes possible more investment, on the principle of economies of scale. In textiles, for example, warehouses are often semi-automated or automated sorter systems with increasing the productivity of order picking (Belin-Munier and Moncef 2013). The decision is made in the headquarters of the franchise.

E-commerce

While e-commerce still covers today a small market share, its restructuring power seems very strong (Belin-Munier 2013a, b). Last mile delivery, heterogeneous and not consolidated flows forced the e-retailers to review their logistic models. Warehouses could be automated but flow variability makes setting very difficult setting. Also, the most frequently chosen solution is a semi-automated solution, relatively intense in labor. Traditionally, e-retailers location strategies could be classified in two categories. If priority is given to the consolidation of stocks or to the specialization process by product families, warehouses will instead be nationals (example of Ventes Privées, a pure player of e-commerce and its implementation in Beaune for wine and food), otherwise they will rather diversified and placed warehouses closer to the consumer areas (that is one of the reasons for location of Amazon in Chalon-sur-Saône, although the store is a little more oriented for large volumes). In addition to the proximity of consumer basins, basins, transport infrastructure, for this type of warehouse local incentives can play a greater role (due to very strong pressure on costs in the e-commerce sector) and also the proximity of mail or postal warehouse platforms since the final transport is mostly by parcel (Belin-Munier 2013a, b).

13.3.3 Logistics Service Providers

Once the investment is not too specific and it remains flexible in its equipment, it may be easier and therefore faster especially for industrial or distributor to look for an existing infrastructure, rather than a creation. This is even easier than automated equipment are increasingly modular and transferable today. Furthermore, if the proximity of transport infrastructure is crucial to the choice of warehouse location (and possible multi-modality) the availability of carriers and dedicated training center will also count. The dependence on national decision-making centers should not be also neglected, because of the existence of groups or carriers and logistics providers, and carriers' networks for courier companies.

13.4 The Burgundy, an Intermediary Solution to Have More Efficiency in Supply Chain

As Strale (2010) points out the Rhone Valley between Dijon and Lyon is an intermediary logistics. However, the latter years, there are some important developments of logistics zones in Burgundy. The recent implementations of big companies like Amazon (40,000 m^2) in Chalon-sur-Saône urban area in 2012, or Rhenus Logistics (22,000 m^2) in the same city in 2015 or Dachser (30,000 m^2) in the North-West of the region in 2013 give an evidence of the recent attractiveness of Burgundy. The purpose of this third section to emphasize the reasons for a company to locate a warehouse in Burgundy and why is the part of public authorities in these new settlements.

13.4.1 Road Connections to Short Access Times

As we mentioned, Burgundy is half-way between Paris and Lyons (the second bigger city in France). Burgundy appears very well-connected to these two French cities. Beyond this, the transport managers interviewed underline the good connection with the rest of Europe mainly by road. So, although there is no international airport or port in the region, Burgundy could be attractive.

The highways allow connecting quickly to Paris or Lyons or other. The companies look for cheaper costs of land but it is very important to have a good connection. Indeed, some companies located in the North of Burgundy want to keep not so far away from Paris. It is important to maintain a strategic position in a geographical way to maintain a national coverage and its influence. These companies only follow the trend of Parisian urban sprawl.

In the East of Burgundy, the position of warehouses isn't so clear because the cities are bigger like Dijon, the capital of the region and the distance from Paris is higher (about 300 km from Dijon to Paris). So the warehouses are used for local deliveries or national like Ventes-Privées in Beaune, some of them for international deliveries e.g. Rhenus with its customer Zooplus. It depends more on the sector of activity than the location. Moreover, a location of a warehouse allows covering better the territory. Thus, for a long time Amazon had only one warehouse in France in the municipality of Saran (next to Orléans) and in 2010, the company implemented another warehouse in the South of France 150 km from Lyons (Montélimar) and in 2012, it wants to deploy new warehouse in order to shorten time deliveries. So this company is in a strategy of coverage the French territory and Burgundy appears as a well-connected region.

13.4.2 The Labour: An Industrial Region that Looking for Some Jobs Versus a Region with Skilled Labour

Industry activities are in crisis leaving people without job. For example, Kodak closed in 2007 its establishments in Chalon-sur-Saône leaving about 3,000 people without a job. This situation is an important issue in an urban area of about 100,000 inhabitants.

The unemployment people could be seen as an opportunity for companies that are looking for a new location. Indeed, this people used to work in industry in hard conditions of work, so it could well adapt to conditions in logistics activities that required high levels of productivity in picking activities.

Thus, Amazon in 2012 and more recently Rhenus were welcomed as an opportunity for unemployed people. The labour pool is wide and allows not having problems of recruiting people.

Furthermore, some companies want to locate their warehousing activity in Burgundy because of skilled labour e.g. Ventes. privées, a pure player of e-commerce wanted to develop its food and wine activity and located its warehouse in Beaune, a region specialized in wine activity. The company wants to take advantage of this skilled labour because the product are fragile and requires a knowledge.

13.4.3 The Part of Local Authorities and the Property Developer

Beyond a labor supply, there are conditions that could attract companies. For example, we underline in previous sections that some companies want to be close to Paris Region. One of the reasons to put a warehouse in Burgundy rather in Paris region is the taxes. In Paris, there is a specific tax on offices and warehouses. A low taxation could attract new companies in the region whereas they follow their activities with Paris. Besides, local authorities try to promote that side.

Sometimes some projects could be built but they don't find a buyer. It is the case of Pagny, a municipality that is located 30 km from the Est of Beaune. The project was ambitious because there was a will to develop a logistics zone that could be access by road, rail and waterways. The idea is very interesting to promote other modes than road, but the problem is that there is another inner port close to this one (Chalon-sur-Saône is about 50 km in the South). To develop this port, it is important to find goods matching with local activity.

Very big warehouses were built in Pagny but they are not used because they don't answer to a supply. In projects of this kind, it is important for new companies to have services next to the warehouses. The location isn't also very attractive, because the major highway (A6) is far away from 30 km and moreover, the labour pool is very small. It is very difficult to attract new labour from bigger cities that are not well connected by public transport.

13.5 Conclusion

This paper shows the growth of logistics activities in Burgundy Region is more concentrated in the latter years and follows the trend of logistics sprawl.

The locations of warehousing in the North of Burgundy are the consequences of the Parisian logistics sprawl. The cost of land and favorable terms of taxes attract companies that look to reduce their costs.

In order to attract logistics activities which need a numerous labour, it is important to supply a labour pool with a minimal size. In Burgundy, former industrial spaces offer a numerous labour that don't have job and could adapt very easy to logistical activities. Indeed, this labour uses to work in assembly lines work with high levels of productivity.

Although Burgundy could appear as distant from major centers of activities in France and in Europe, this paper showed that this outlying location could be an advantage because of the infrastructures and because of the presence of labour ready to work in logistics activities.

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Part V
ICT System Integration in Production, Logistics and Traffic

Chapter 14
Networking of Information Flows—Improved Concept for the Inland Waterway Transport on the Danube

Milosav Georgijevic, Sanja Bojic and Miljan Matijevic

14.1 Introduction

The Danube Strategy strongly supports the development of the IWT as the most cost effective and environmentally friendly mode of transport and therewith the development of ports as core nodes of the inland waterway (IWW) network (DD 2010). The ports on the Danube are currently in the transition phase. They are developing from cargo handling transport centres to logistics centres that are offering value added logistics services and besides being dedicated exclusively to the modernization of the cargo handling and storing activities they should focus on the process integration within the SC as well (Notteboom and Rodrigue 2005). The current situation of inland waterway (IWW) ports shows that besides the need for value adding logistics services there is a need for a higher level of internal IT and their further networking along the SC (Giannopoulos 2009).

In the inland navigation on the Danube, RIS is used for this purposes and it comprise services such as electronic navigational charts, vessel tracking and tracing, electronic reporting, etc. Currently, RIS is operational in European waterway corridors in a variety of sophistication levels. However, existing RIS applications focus mainly on the safety of inland navigation while logistic purpose information exchange among the ports, terminal operators, freight brokers and shipper are not taken into consideration by them. At the same time, interoperability of national RIS systems and international data exchange require improvements.

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Since the development of RIS, there were a couple of projects dealing with the development of different applications for logistics purposes that could represent an upgrade of the basic RIS functions. DaHar project was one of them and within the project; the detailed analysis of the SC that included inland waterway transport and the IWW ports as the main SC nodes was conducted. The analysis comprehended SC processes, SC partners and their intern IT as well as the information flows among them. Based on the analysis, the concept and algorithm for the effective networking of the information and document exchange among the SC subjects have been developed. Upon the concept and algorithm, a software called RIS TLS have been developed, implemented and tested.

14.2 State of the Art

The RIS was developed in 2005, but application of its basic functions along the entire Danube was not introduced before 2014 (ECD 2005). The reason for that were the required investments and harmonization of legislation in all Danube countries. Thereat, Germany (Bavaria on the Danube) deploys its own IT system for navigation with similar functions.

Considering that the development of RIS represents a great European Commission initiative, the further development of the system was done exclusively through the EU research projects. The EU research projects that were dealing with the RIS further development are RISING, PLATINA, NEWADA, etc. Most of the projects were facing the challenge of integrating existing services into day-to-day commercial operations and defining new services that would offer value added for the subjects in the SC (NEWADA 2009; PLATINA 2011).

Significant step towards the logistic applications was made with the project RISING through developing the RIS services for transport and logistics divided into several sub systems (RISING 2011):

- RIS Transport and Execution Status Platform (Advanced services supporting, logistics to logistics information exchange)—TES Platform;
- RIS fleet management application (Pilot for RIS fleet management application);
- RIS ETA Calculation Service (RIS web services supporting transport and logistics);
- Identification and positioning of un-propelled vessels;
- RIS ports and berths management platform (Usage of RIS information for ports and berths);
- Lock management services for transport and logistics.

For this research, it was significant to analyse the applications RIS Transport and Execution Status Platform (the TES Platform) and RIS ETA Calculation Service.

The TES platform is a sort of tracking and tracing of the cargo, that makes it possible for the port and terminal operator to know the exact transport status of the incoming vessel. As a result of this, the mainly vessel-related RIS services shall be utilized in ways that a transport-related tracing is supported. This transport status information shall include, amongst others, voyage status information of vessels currently being navigated and in relation to the given transport or other meaningful status information at the port or terminal of destination if applicable.

The RIS ETA is the application that real time calculates estimated time of arrival of vessels, provides also cargo management, which involves planning of cargo loading/unloading, based on available equipment and berth places as well as working hours, billing (harbour dues and cargo rates), taking into account time spent in port, cargo transhipped, the length of berth occupied as well as possible mooring time, statistics data.

The analyses related to the state of the art showed that the RIS:

- Represents a non-commercial service for the control of navigation,
- Is open as an interface for the future upgrades,
- Is a system that offers the minimal logistic support (ETA, Notices to Skippers),
- Represents a basis for RISING (with the pilot applications), which united RIS with several port and logistics services.

Striving to capitalization of RIS and IT resources with a networking of information flows in logistics processes between ports and other partners in the SC, was the motivation for the development of the RIS TLS software and one of the goals of the DaHar project.

The project DaHar—Danube Inland Harbour Development, gave its contribution to this subject and provided some outputs that are used as valuable inputs for the new research projects, such as NEWS—Development of a Next generation European Inland Waterway Ship and logistics system.

Research within the DaHar project has shown that an upgrade of the RIS towards networking of all inland waterway SC subjects and towards paperless flows of information and documents among them could create an added value to the all participants in the SC (DaHar 2014). The main issue thereat are privacy regulations, defined within the EU Directive 2005/44/EC and related to the EU regulations (No 414/2007; No 415/2007; No 416/2007; No 164/2010 and 689/2012), which are basically an obstacle to the use of RIS platform for TLS applications.

Having in mind the regulatory issues for the upgrade of the RIS, within the DaHar project, a RIS TLS software has been developed. The software enables networking of the actors in the SC, transfer of the required data between the actors and generation of standardized documents accompanying the movement of goods through the entire chain, while guaranteeing the privacy rights of all involved partners.

14.3 Methodological Background of the Software Development

Starting from the state of the art analysis, in order to develop the RIS TLS software, the Waterfall methodology has been followed.

The Waterfall methodology is a sequential development approach, in which development is flowing steadily downwards (like a waterfall) through several phases. (Benington 1983) The four development phases which were represented in the development of the RIS TLS software are:

- Definition of the software requirements:
  - Specification of the SC subjects requirements regarding the information and documentation exchange,
  - Specification of the privacy regulation requirements,
- Software design
- Implementation
- Testing.

The first phase comprehended definition of software requirements related to the information and documentation exchange and privacy.

Specification of the requirements was realized based on the mapping of the SC which are including the IW ports and on-site interviews with the SC subjects, such as: production or trading companies (importers/exporters), freight forwarding companies, customs offices, ports, shipping companies, logistics services providers, etc. Considering that the ports, within this research, were observed as the central points of the SC, the companies selected for the interviews were the ones that are closely cooperating with the Danube ports. The interviews were conducted with over 100 SC subjects located in the Danube region between the 850–1450 river km.

Based on the SC maps and interviews, it has been detected 11 different types of potential SC subjects (companies and institutions) and 35 different types of documents that are circulating between them.

In this phase, in order to understand and specify the information and documents flows requirements, the four matrix were constructed defining the following relations:

- SC subject—required (usually exchanged) documents,
- SC subject—required information (data),
- Required information (data)—SC position at which the information (data) are generated,
- Format of the information (data)—affiliation of the information (data) to the required document.

Based on the matrix, the algorithm of information and document flows in the inland waterway SC, with IWW ports as the main SC nodes, has been defined (Fig. 14.4).

At the same time, through the conducted interviews, based on the SC subjects current information and documents exchange privacy level, the privacy requirements for the RIS TLS software have been specified. At that time, the exchange of the information and documents among the SC subjects was realized mostly by phone, fax and e-mail. The interviewed subjects stated to be satisfied with the privacy level that they have through this communication forms. Therefore, the same level of privacy has been specified as the requirement for the RIS TLS software. In order to ensure the defined (required) level of privacy, it was specified that within the RIS TLS software, every SC subject has to determine which of his uploaded information and documents can be visible to which SC partner. Additional requirement was to authorize the subjects that can approach to the software while it is in the testing phase.

The requirements defined within the first phase represented the input for the second phase. The software developed within the second phase has been implemented and tested in the Port of Novi Sad (phases three and four). The phases are, in more details, described below.

14.4 Algorithm of Information Flows in the Inland Waterway SC, with IWW Ports as the Main SC Nodes

Improvement—handling efficiency in logistics processes, where ports are the most significant nodes in the SC, is possible through a networked flow of information between partners in the SC in all segments of the business process, which starts with the announcement of a business arrangement that is later executed and monitored. For this purposes the RIS TLS software has been developed.

For the development of this type of software, an information flow algorithm was used, indicating who generates the first document and who receives it, as a partner in the SC, based on which subsequent documents are generated until the end of the process, with numerous feedbacks.

Figure 14.1 shows a simplified scheme of partners within the SC, starting with the Exporter, who, after the documents have been generated, in cooperation with Port A and other partners prepares and conducts transport of material—goods to the Importer, who, in cooperation with Port B and other partners in the SC generates new documents, thus facilitating the flow of information (and goods) to the Buyer.

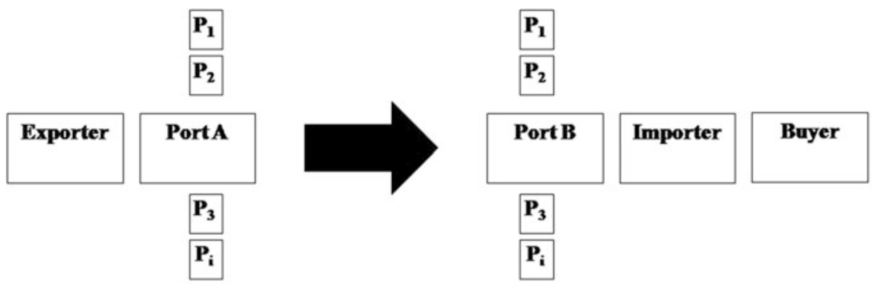

Fig. 14.1 SC with ports as nodes

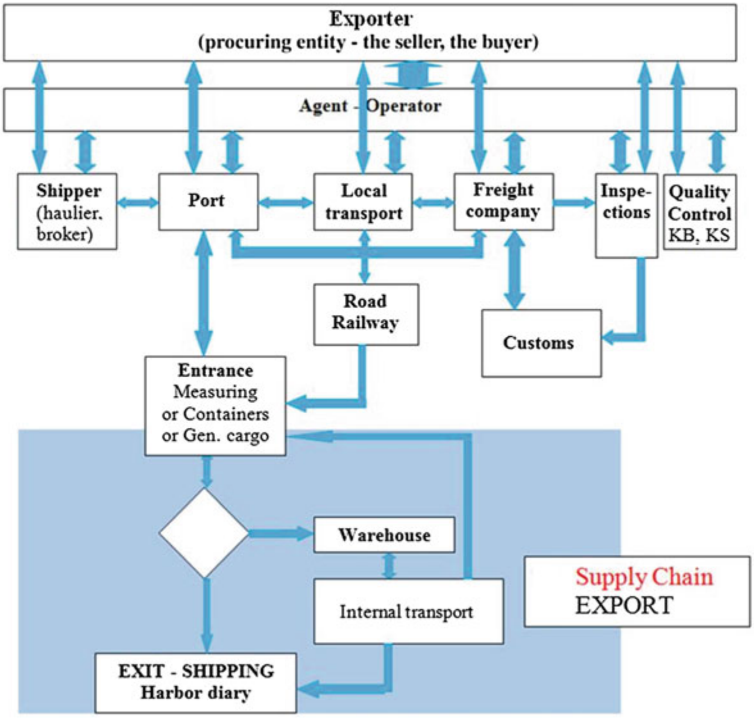

Fig. 14.2 Information flows in the export

The algorithm that shows the flow of information and documents generated by Exporter as the initiator of a new job/SC, is presented in Fig. 14.2. The same rules regarding the information flow apply in the case of the Importer—the recipient of the goods.

The partners in the process are: the agent, the port, the shipping or carrier company (or a broker working for the shipping company), freight forwarding and local transport agencies, in cooperation with control and inspection institutions.

The Exporter first generates a new business activity, gives it a name and then generates first documents that are delivered to the agent, or the agent and the port, the local transport company and the freight forwarding company. The Seller and the Buyer communicate with their respective control institutions and, depending on the agreement, the one designated to be the project leader (Exporter) communicates with a local inspection. The feedback channel runs through the agent (or directly to the Contracting Authority).

For each open document from the database, the user receives an optional question asking who of the partners from the SC is allowed to see the document. For each type of partners a list is created with potential names of the partners in the SC in question.

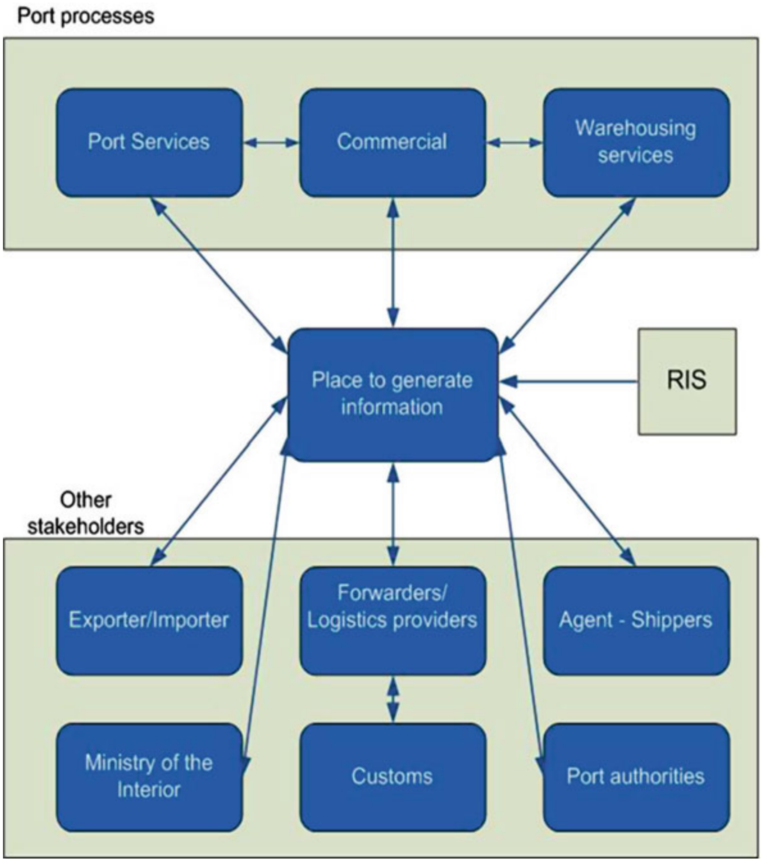

Fig. 14.3 The role of IWW ports as the node points in the SC and interface for the connection of the TLS with the RIS (Stevanov et al. 2014)

The Exporter (or the Agent) organises local transport, informs the Exporter/Agent, who in turn informs the Port and other partners.

The actual flow of goods is generated by the port entry documents (using the scale or the number of containers or specification of general cargo). It is the Port that defines which partners in the SC can see these documents and the current transport status.

The flows of information (and goods) in the Port can go directly to the ship (or any other means of further transport, such as the train), or through a port warehouse, which means that the goods are collected together before further transport (Fig. 14.3).

The freight forwarding agency, in cooperation with the port and inspection institutions, initiates customs procedures.

The harbourmaster's log records loading and exit from the port and provides the information to the information system that continuously monitors current activities, which are available on-line to the partners granted access to the information by the port. During the transport—navigation, RIS provides information and data from its domain, as well as information about the expected time of arrival at the port of the recipient, where begins the import process (see Fig. 14.3).

The flow of goods and information has been set to respond to the real conditions, thus focusing on the participants in the transport flow, while neither the points where certain documents are generated, nor the flow scheme are presented. Figure 14.4 shows the flow and document origin point algorithm. This algorithm, based on the analysis of the processes, includes all crucial documents for efficient functioning of the TLS system.

14.5 RIS TLS Software

Upon the defined algorithm, the RIS TLS software has been developed. The RIS TLS is a web-based software, which uses RIS as the source of the navigation data. The RIS TLS software system encompasses networked data transfer between the subjects in the SC with the ports as the main nodes. The software facilitates generating standardised documents, which follow the flow of goods from the onset of the process, which basically does not occur in the port, but does enter it at a later stage, through the subsequent flow of documents via a web-base, at the same time guaranteeing the privacy rules for the partners in the SC. Internal flows of information at ports do not belong to this system.

The software was set to the web page http://www.dahar.rs and made available (selecting the option DaHar TLS) only to registered partners in the supply chain. The list of potential users of the DaHar TLS includes the following subjects: Importer/Exporter(IE), Shipping agent (SA), Shipping company (SCo), Port (PO), Control house (CH), Customs (CU), Freight forwarding (FF), Local transport (LT), Administrator (AD) and Authorised partners in the DaHar project (DP).

For the registered partners, within the software, three main applications are available:

- Planning of activities in the supply chain (SC)
- Monitoring of activities in the supply chain (SC)
- Monitoring of vessels

Planning of activities in the supply chain is an application that facilitates input and overview of activities planned by sellers and buyers of goods transported on waterways, as well as ports in which the goods will be handled. The application includes managing of the documents in the SC. The Managing of documents option in the SC facilitates access to uploaded documents related to all stages of transport activities. This option enables all partners in the supply chain to use standard documents, to fill them in and use for conducting their business operations. The types, content and layout of the documents are part of the RIS TLS projects, which envisaged adjustments on behalf of the partners and all interested parties in the

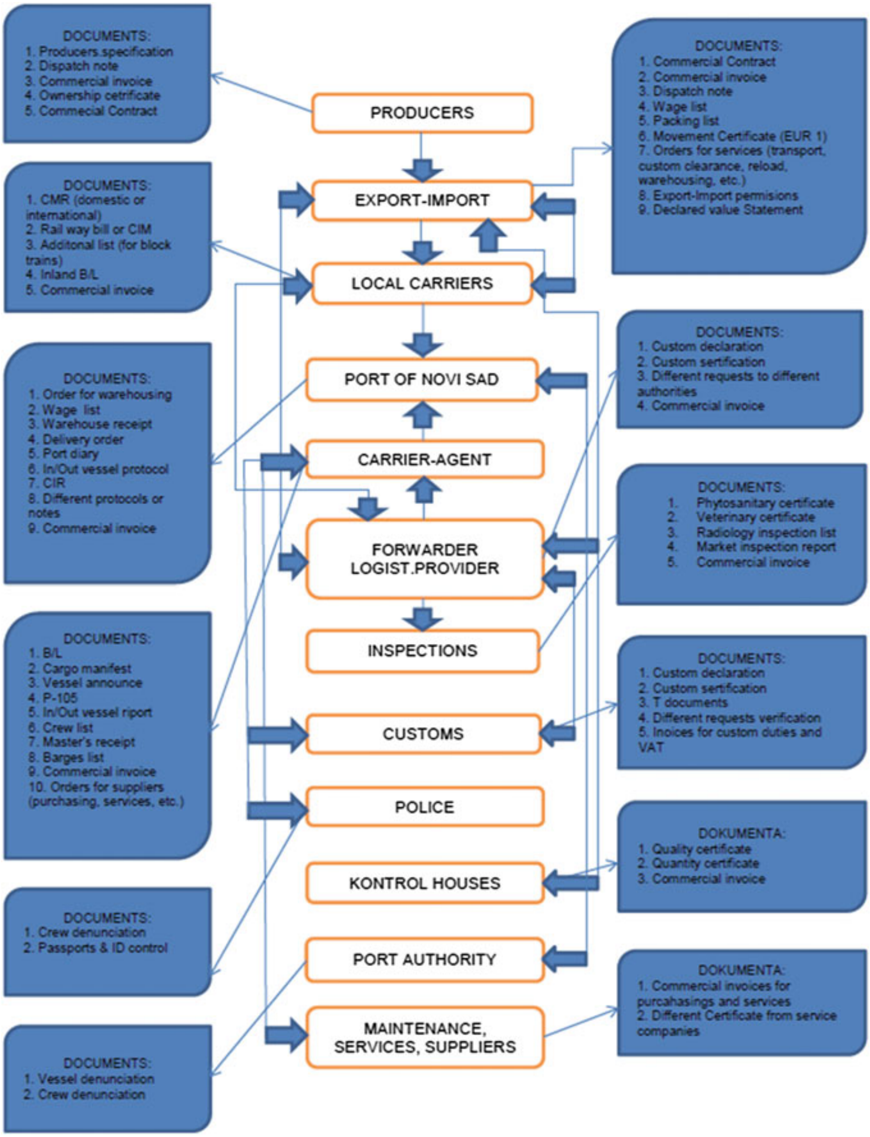

Fig. 14.4 Flow and point of document origin algorithm

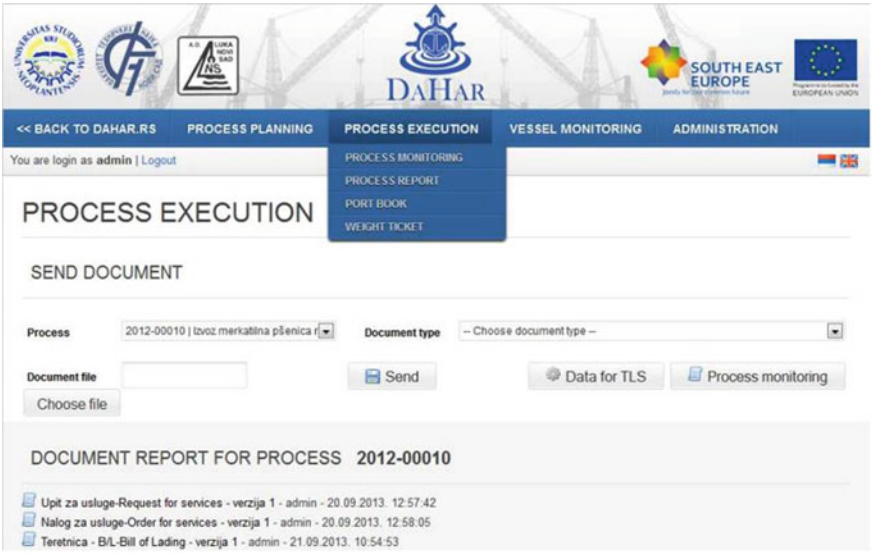

Fig. 14.5 Menu for uploading documents and monitoring business processes

testing stage. The document management option enables all participants to download the documents from DaHar TLS to their own computers. The application enables the user to upload the completed documents to DaHar TLS, so that other partners in the chain could download the completed documents. The application also facilitates sending the completed documents uploaded to DaHar TLS to designated partners in the activity, as defined by the partner who completed the document first or one of the subsequent users.

Monitoring activities in the supply chain is an application that provides an access to the data in the harbour's databases, to all authorized partners in the supply chain. The application provides the precise data about the processes which are carried out in the port, including precise time, duration and status of the process, for every particular cargo and every particular vessel. The main source of information used in the database is the harbourmaster's log, an automated record.

Monitoring of vessels is an application that enables all authorised and registered participants to access information about the positions of vessels along the Danube waterway. This application has been designed because of the current problems with the implementation and functionality of the RIS system on the Danube. The application is highly practical, since it features data updated by the participants in the transport of goods themselves, primarily shipping agents, brokers, control houses and ports.

The menu which is used for uploading documents for a particular activity and monitoring the business process is presented at Fig. 14.5.

14.6 Application—Testing

RIS TLS was tested in the port of Novi Sad,[1] for on-going business processes. The testing results confirmed the all initial assumptions of research and innovation ideas for networking of information flows between the port and all other partners in the SC. During the test applications, minimum improvements of certain functions in accordance with a given algorithm, have been introduced.

The test application showed that RIS TLS:

- Is applicable for different SC processes with a wide range of different partners and the ports as the main cargo handling centres, i.e. nodes in the SC,
- As an innovative software does not require paper, fax or SMS communication between the partners in the SC,
- Allows to the all partners in the SC (according to the given ID number) 24 h on-line communication with the system and information about the status of the processes in the SC (e.g.: loading of the vessel completed at 11 pm or the vessel departure from the port at 1 am) without directly contacting any other SC partner by phone or E mail,
- Allows, for example for the importer—the recipient of the goods, an on-line information on the progress of work during the preparation, loading, movement of the ship and setbacks during navigation (via RIS), as well as all supporting documents related to the goods and transport.

The main obstacles for a mass implementation of the RIS TLS are resistance towards innovation by the SC subjects and the fear of confidential data disclosure. This was concluded during the consultation with experts from the ports in Bavaria and on the Rhine. As it took time to replace paper letters with the fax and further with electronic mail, in the same way it will be required time to get the SC partners used to communication using the TLS software.

The privacy of the information with the RIS TLS is on the same level as with all actual IT and internet communication. Since the flow of goods involves the cooperation with state institutions, such as police and customs, in the future it will be necessary to adapt the procedures for obtaining agreements and documents from these institutions in an online form of IT which are based on paper documents.

14.7 Conclusion

Currently, information technologies for facilitating and supporting the cargo flows in the Inland waterway transport on the Danube are not exploited enough, although their application could significantly improve the logistic parameters of the processes.

[1]The port yearly handles about million tons of cargo.

Therefore, within the DaHar project, an innovative software has been developed and tested. The RIS TLS software enables networking of the information flows and paperless flow of documents that are following the cargo flows in a SC.

It provides support to further affirmation of the RIS system.

The software is developed as a support to the IWT and the ports as the main nodal points in the SC, but can be applied to all and any intermodal transport SC.

Software users, besides the IW ports, can also be logistics services providers (e.g. logistics centres) that are seeking to network their internal IT system with the other SC partners.

The software is implemented in the Port of Novi Sad. Testing of the software gave very good results, but also opened the issue of its ownership and therewith the security related responsibility. Therefore, its future application is expected to take place in the cloud offered by a recognized reliable provider.

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Chapter 15
CargoSwApp—Short-Term Replacement of Cancelled Cargo Transports

Mathias Bös, Patrick Crucq and Bioniko Tauhid

The demand concerning availability and quality of goods is still raising and calls for better and better matching processes. This affects in particular perishable goods. These have to be transported about a complex transport chain up to POS within minimum time. The planning of these highly complex transport chains is affected by insufficient systems with multiple media discontinuities. Because of this reason all involved parties are planning the transports with high safeties resulting in short term cancellations what makes sea transports unviable.

The following article covers a new developed application for maritime transport operation planning. These CargoSwApp called application helps connecting of shippers and carriers, improves the quality of bookings and supports the determination of short term compensation of these transport. Therefore CargoSwApp is focused onto two business challenges. The first are late cancellations concerning some 20–30 % of all bookings for contemplated use case of perishable goods. The second challenge is the operational efficiency because of missing eligible systems.

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15.1 The Ongoing Logistics Challenge

The transport and logistics domain is a highly fragmented and complex domain composed of both in house and logistics service providers. Services provided by these entities include the movement and storage of freight, cross border trading activities, insurance provisioning, management and design of networks, transport planning, last mile delivery, parcel and package shipment, port operations (see Fig. 15.1), and numerous other activities. Freight movements occur over land, on the sea, on inland waterways, on rail roads, in the air, and through pipelines. The fact that all goods that are consumed, either by intermediaries as raw materials or by final customers as finished products, are handled by logistics service providers of one kind or another means that this industry is a critical component of modern society.

The transportation and logistics domain has experienced an unprecedented level of growth over the past 30 years. Prior to 1980 the transportation industry consisted of a highly fragmented set of operators providing trucking, rail, warehousing, barge, and some international freight services. The non-captive logistics service providers in the industry were largely unsophisticated independent operators focused on local, regional or, at best, national services. The large and sophisticated international logistics companies that dominate today's global freight activities did not exist. The rapid growth of the industry is a direct consequence of growth in global trade.

Trade growth has been rapid over the past 30 years primarily because of trade liberalization, infrastructure investments, advances in information technologies and competition in first world countries (World Trade Organization 2008). Trade today accounts for an ever increasing amount of the gross domestic product of all Western countries, exceeding 25 % of GDP for the United States and 50 % of GDP for Western Europe (OECD Trends in the Transport Sector 2012).

Fig. 15.1 Transport of perishable goods by vessels

But the transport and logistics industry is facing a number of challenges that are a direct result of globalization and the rapid development of countries such as Brazil, Russia, India and China. These challenges can be broadly grouped into five areas. These grouping are:

- Costs—transportation and logistics is a highly competitive industry with margins for traditional services rarely exceeding 4 % of turnover;
- Risks—increasing weather, geological, geo-political and supply uncertainties are creating significant problems as supply chains grow longer and more complex;
- Demographics—changing global demographics are driving companies to move into non-traditional markets where supply chain infrastructures are less mature and operating practices less advanced;
- Energy—length, speed and tonnage transported determine the energy consumption of supply operations. As supply chains have grown longer and more complex their demands for scarce energy resources has increased raising risks associated with energy price variations as well as availability;
- Environment—transport and logistics operations have a large impact on the environment because of CO_2 emissions from the combustion of fossil fuels and wastes

These are reasons why the efficient operation of transport and logistics networks requires skilled operators as well as modern information systems. Unfortunately, current ICT systems are difficult to implement, costly to operate and provide limited support for inter-company collaboration. Especially the last aspect causes lots of problems for operating time critical supply chains as those for perishable goods. In the last consequence these supply chains are highly ineffective and cost-intensive.

15.2 The FIspace Program of European Union

The European Union counteracts this aspect with forcing the extension of Future Internet technologies in Europe. With Future Internet Public Private Partnership (FI PPP) program the European Union aims to disseminate the Future Internet technology into common usage. Amongst others the program targets the increase of digitalization of business processes of all industry and retail branches. Especially the business relationship of companies shall be supported by using this new technology to create and operate advanced supply chains.

One part of FI PPP is the project FIspace. The ultimate aim of the FIspace project is to develop, validate, and establish a future business collaboration space (the FIspace) that facilitates radical improvements for information exchange, communication, and co-ordination among business partners and prepares the way for fundamental changes in how collaborative business networks and the involved stakeholders work in the future. The FIspace will utilize Future Internet technologies developed in the FI PPP, and be implemented in an open manner so that other

FI PPP projects, as well as external IT providers and interested users, can easily use, test, and exploit its features and services and contribute to its expansion and establishment.

The foreseen FIspace collaboration service provides users with innovative visibility, event management, contracting and planning services that attempt to overcome the traditional parochial focus of supply chain participants thus leading to a truly collaborative end-to-end approach to supply chain management. The challenges that the transport and logistics industry face demand changes in how shippers and logistics service providers operate and manage the global flow of goods and services. These changes must address the large inefficiencies that exist in global logistics operations so that more streamlined flows of goods and services can yield all participants benefits. The FIspace project aims to displace the current state of inefficient supply chain operations by the application of Future Internet based technologies, a cloud computing approach to collaboration and execution management.

The FIspace will be a value added Collaboration Space in the Cloud that enables actors operating in Collaborative Business Networks (e.g., enterprises of all sizes, authorities, public and private service providers) in various application domains to seamlessly interact, communicate, and coordinate activities with business partners and to easily create and act in open and dynamic networks of connected businesses —similar to modern web-based solutions already existing in the B2C world, but focused on the requirements arising in B2B environments. In addition, the FIspace propagates a future business model for enabling the rapid development of high-quality ICT solutions at minimal costs by enabling the provisioning, consumption, and re-use of on-demand solutions in the Cloud. General business, as well as domain-specific, functionalities are developed by IT solution providers. These 'apps' are provided via the FIspace Store, from which the Apps can be consumed and new Apps can be developed by re-using the features of existing ones.

By FIspace new Future Internet Business Collaboration Networks in Agri-Food, Transport and Logistics shall be established by creating new applications on the basis of advanced ICT und Future Internet, that allow all players, small or large, to collaborate and compete on an equal footing. The idea behind the FIspace is to truly move forward in conceiving of a new paradigm in computing that is based on emerging Future Internet technologies and leverages the full potential of the cloud-based services concept. FIspace will exploit the FI technologies for enabling substantial increases in the efficiency and effectiveness of cross-organizational business processes and pioneer on novel business models that allow for innovation by external stakeholders with high prospects for industrial uptake and market impact.

By defining, setting up, and executing cross-domain use cases for selected real-world business scenarios from the Agri-Food and the Transport and Logistics sectors the FIspace capabilities and benefits in the real-world shall be demonstrated. The conceptual prototypes will be implemented within the FIspace environment using FI PPP Generic Enablers and domain-specific enablers. These implementations will be tested in different use case trials in order to determine whether the underlying technologies being utilized are capable of delivering the functionality, performance, security, privacy and reliability necessary for large scale expansion.

15.3 CargoSwApp for Transport Planning

CargoSwApp is one of these apps to be developed. It is part of theme of intelligent Perishable Goods Logistics which addresses monitoring and environmental management issues of perishable goods as they flow through their supply chains so that waste is minimized and shelf life maximized. It was developed in cooperation of Norwegian Marine Technology Research Institute (Marintek, Norway), North Sea Container Line AS (NCL, Norway) and SDZ GmbH (Germany). The superior use case trail of CargoSwApp is called Fish Distribution and (Re-)Planning Trial. This trial focuses on the planning of logistics and transport activities, including transport order creation, transport demand (re)planning and distribution (re)scheduling.

15.3.1 Range of CargoSwApp Application

CargoSwApp is a transport management web application working as a meeting place for carriers and shippers. It provides access to a worldwide marketplace for open cargo transport demand (see Fig. 15.2). It helps carriers to find cargo that needs to be transported, and shippers to find available transport services. The App is used both for late cancellations in order to try to fulfill a promised service level agreement and improvement of vessel utilizations.

Cancellation of transport bookings is a headache for the entire transport sector. Late cancellations and no-shows are common practice, and affect approximately 30 % of the bookings. To help carriers in handling these late cancellations, the CargoSwApp provides an easy way to match transport offers with transport needs. It helps the carrier to find new cargo to replace cancelled transport bookings by getting easy and quick access to a large pool of transport demands.

Cargo replacement is a very important task in the sector of distribution of perishable goods. CargoSwApp is supposed to find partners and consignments in the case of late cancellations of booked capacities and to assist carriers in raising the utilization level of their transport vehicle resources. It uses functionalities from the "Marketplace Operations App" and input from the backend booking systems.

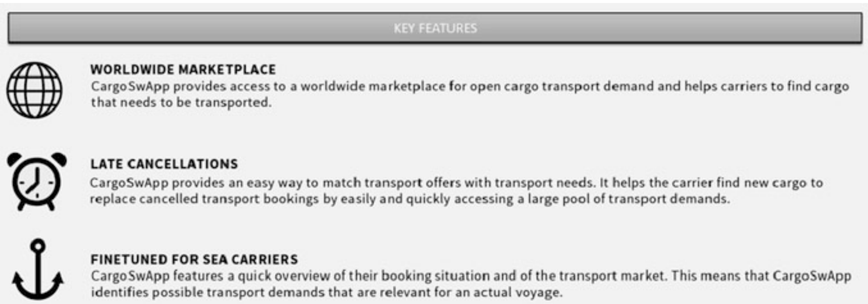

Fig. 15.2 Application of CargoSwApp

15.3.2 Functionality of CargoSwApp

A special feature is the visualization of the replacement task in combination with other cargo orders. Here an appropriate scheduling algorithm was implemented which allows the customer to visualize his decision in a complex environment with a multitude of transportation requests. CargoSwApp offers alternatives where the consequences of each decision can be made aware to the participants of the transportation chain.

The key-factor of the CargoSwApp application is the opportunity to attract new business partners in case of (business) emergency instead of bearing the last-minute loss of formerly reserved capacities. The direct connection to marketplaces or to the planning functions on the FIspace platform allows the user an efficient handling of such emergency situations and preventing huge losses and environmentally disadvantageous transport hauls. CargoSwApp will also make use of applications for providing other transport demands since those demands with the highest likelihood to match the carriers service offer will be ranked on top of the list. The user can then approach the client with the corresponding demand and start negotiations. For the negotiations, CargoSwApp will also be connectible to other applications. Apart from the link to further apps from the FIspace platform, CargoSwApp will also be connected to external data sources and legacy systems, e.g. in order to check the vessel utilization data prior to the search for new cargo. By this the application can be adopted to other transport areas of perishable goods as well as non-perishable goods in the future.

The CargoSwApp functionality is fine-tuned for sea carriers to give them a quick overview of their booking situation (see Fig. 15.3) and of the transport market. This means that CargoSwApp identifies possible transport demands that are relevant for an actual voyage.

CargoSwApp possesses about planning functionality for two different scenarios. One is about the matching of transport capacity with transport demands, and the other shows replacement of booking cancellations received short time before departure.

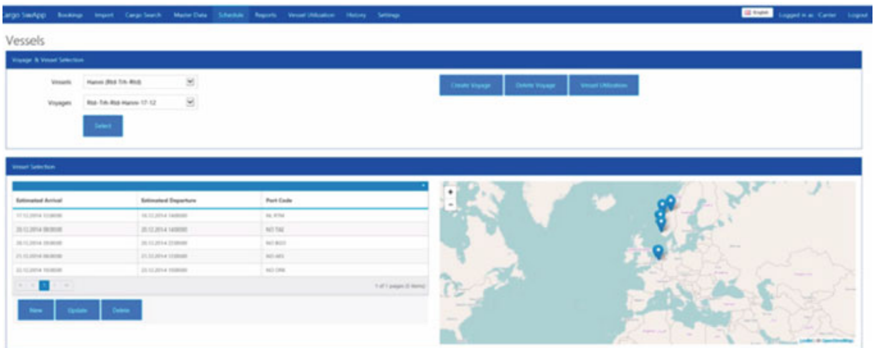

Fig. 15.3 Visualization of one vessel cycle

15.3.3 *Maximizing the Utilization of Vessels*

For the first scenario, the matching of transport capacity with transport demands, the shipper is in the role of a user. He searches for a transport of one to multiple containers of different size. Therefore he will register a transport demand. After submitting, this new transport demand is available in the CargoSwApp transport marketplace ready for bids by carriers.

A carrier uses the CargoSwApp to plan an upcoming vessel voyage. For this, he uses the vessel utilization chart visualizing the current capacity situation of the vessel. It depicts the amount of free space measured in TEUs and reefer plugs still available for each transport leg as well as the used amount of space. If the vessel disposes about free capacity for containers or reefers the carrier will directly head to the cargo search in CargoSwApp, letting CargoSwApp set up an appropriate filter.

The most attractive transport demand is found by looking at the booking probability of matching transport demands (see Fig. 15.4). The booking probability gives the carrier an indication on how reliable a booking is. This probability is computed based on historical data of the shipper's bookings and cancellations, as well as status information about the cargo. This functionality enables the carrier to select the transport demand with the lowest cancellation risk.

After selection of a transport demand the carrier places his bid. The shipper is instantly notified about every new bid. If he receives bids from several carriers, all the bids are shown in one screen on the shipper's side, making it easy for the shipper to compare the various bids. The shipper can check the transmitted transport offers of the carrier and can accept or refuse them. A possible shipper's confirmation is automatically sent to the carrier. When the carrier has allocated the cargo to a specific vessel and voyage, the shipper is notified about this.

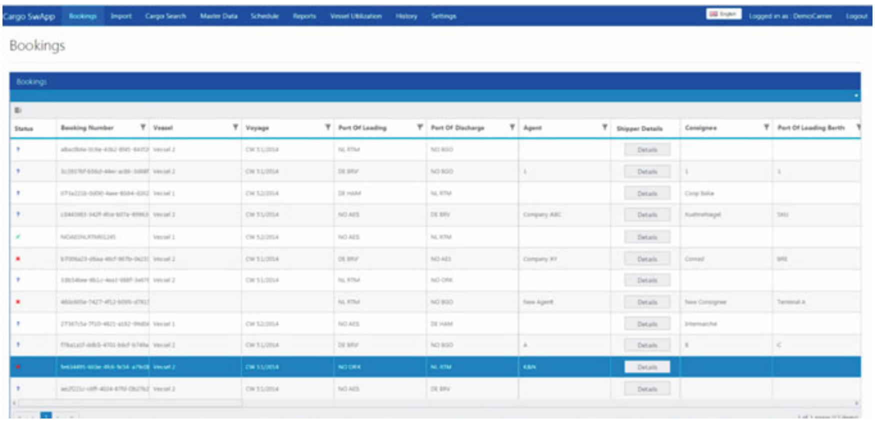

Fig. 15.4 List of bookings

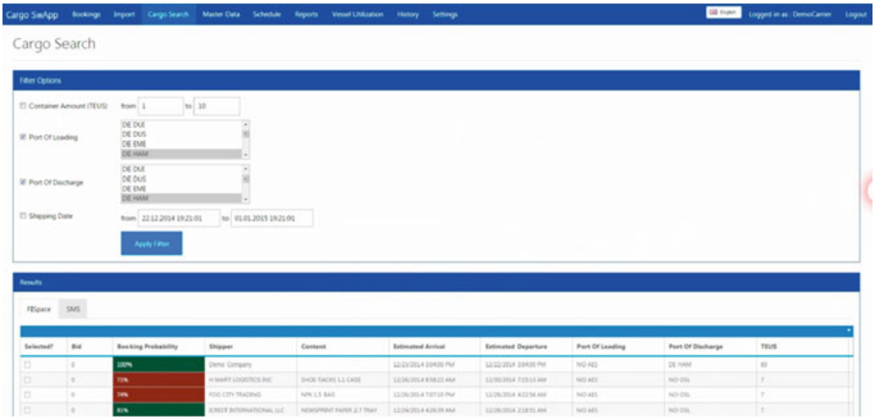

Fig. 15.5 Cargo search for cargo replacement

15.3.4 Cargo Replacement in Case of Late Cancellations

The second functionality of CargoSwApp supports the carrier by filling up the vessel again after receiving a booking cancellation. Shippers cancel their transport bookings for several reasons: cargo not ready, paper work trouble, change in transport plan, or even dummy and multiple bookings. CargoSwApp is well aware of these problems and enables shippers to cancel their demands and carriers to find replacement in time.

If a shipper cancels a transport demand the carrier receives an instant notification about this cancellation. The vessel is no longer fully booked and the carrier needs to find additional cargo on time before departure by the cargo search functionality. For finding a suitable cargo replacement by the carrier CargoSwApp provides a list of transport demands (see Fig. 15.5) that can fill the gap resulting from the recent cancellation. The carrier selects the best transport demand based on the booking probability value and sends a bid to the shipper. And the same process of booking confirmation as in the previous scenario is repeated. When the shipper accepts the offer, the capacity utilization is increased, and the loss due to late cancellations is reduced.

Carriers can also have a pool of existing customers. To increase the chance to find replacement cargo, CargoSwApp can be used to send messages (SMSs and e-mails) to these customers to announce available transport capacity. This functionality will speed up the process of publishing transport capacities. Keep in mind that up to 30 % of the bookings are cancelled on the day of departure or the day before, leaving the carrier with a short time window to fill up their vessel again.

15.4 Conclusion

CargoSwApp supports matchmaking between carriers and shippers. The application provides an easy way to match the transport capacity with the transport demand. Carriers can find new cargo in a hurry, after receiving a booking cancellation.

CargoSwApp is a web-based application, meaning that it can be launched anywhere and anytime with no local software installations needed. CargoSwApp includes the ability to import and export datasets from and to 3rd party applications so that vessel utilization is always synchronized with transport orders on both ends.

Chapter 16
ORFE to AFEX—A Conceptual Look into the Future of Online Freight Exchange

René Föhring and Stephan Zelewski

16.1 An Introduction to Freight Exchanges

Constantly increasing freight rates accompanied by the lasting internationalization of freight traffics lead to research into new ways to organize transports and their mediation more efficiently and sustainably. An idea emerging in this context time and again is the more efficient configuration and coordination of transport chains with the help of freight exchanges.

Freight exchanges are market places where offers for and demands after transport services find one another. Contrary to forwarders, which constitute the classic form of freight mediation, they themselves are no participants of the processing of transport services. They merely mediate transport services, regularly combined with freights or freight space, between shippers and carriers.

Since their origination in the 1970s and 1980s the freight exchanges processed this umpiring primarily via the media telephone, telefax and BTX. The majority of the companies specializes in the mediation of truck freights. By contrast, multimodal transports are being mediated fewest of all (Merkel and Kromer 2002). Reasons for the strong focus on truck freights are the large share of this transport carrier on the total freight traffic as well as the high demand on transparency in this segment. In case of truck freights the focus lies on part and full load transports for trucks, box vehicles and refrigerated vehicles. Special freights like dangerous or bulk goods are less often traded in freight exchanges as the considered freight volume is too small. Because of the same reason the short-distance traffic is not

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relevant in freight exchanges. Furthermore, the portion of the empty trips is lower here than in the long-distance traffic.

With the advent of the internet in the 1990s and 2000s another medium appeared whose advantages towards the “traditional mediation method” became soon apparent: The greater range for customer acquisition as well as the higher comprehensiveness when providing individual information play a part in contributing to the electronic commerce supporting the opening up of new sales channels and markets and providing a more transparent and comprehensive offer for demanders.

Of the participation in virtual freight exchanges the participants expect different advantages: Next to the opening up of new sales channels a more efficient processing of the transport mediation shall especially lead to economic advantages that can be passed on to the customers to increase turnover. A side effect of freight exchanges is a thus indirectly increased transparency in the transport market that leads to a reduction of information asymmetries. From this development forwarders and transport carriers benefit in equal measure: The forwarders reduce their freight charges as the freight capacity can be offered more favorable and the transport carriers reduce their portion of empty trips. Also in case of transaction costs advantages emerge through the increased efficiency when searching for, comparing and selecting transport services.

For reasons of impartiality the operators of freight exchanges are themselves not part of the industries in which they mediate freights and cargo space. For funding their business activity, however, well-known manufacturers, commercial and service enterprises have partially a share in freight exchanges.

Independent of the shareholding structure three business models for generating turnover can be identified from whose implementation the economic success of the online freight exchange is essentially dependent of: application fees, basic fees and transaction charges (Habib and Bruns 2012). While the transaction charge is only due when a transaction takes place via the exchange, business models that are primarily based on basic and application fees ensure the operators of the freight exchange their revenues even if no transactions take place. The freight exchange earns in these cases even though they fail their actual objective to mediate transport services. Another source of revenue of the operators of the freight exchanges can be the so-called “value added services”, i.e. additional services that can be sold as complementary products like, for example, insurances, packaging or personnel services.

16.2 ORFE: Establishment of an Online Freight Exchange

ORFE is the name of a software prototype for an Online Rail Freight Exchange. The following chapter gives a comprehensive overview over the research and outcomes achieved by the project as part of the multinational joint project CODE24 of the European Union (EU). An overview of the project can be found in Brenienek (2014).

The primary goal of the joint project consists in the integration and advancement of the activities on the trans-European transport axis no. 24 which connects the harbors of Rotterdam and Genoa and is the main railroad line through the Swiss Alps.

The conception and implementation of an online freight exchange is a central component of CODE24 (Endemann and Kaspar 2011) because comprehensive and publicly accessible information on how many freight trains will use the corridor is currently missing. Also, it is uncertain how much this capacity can be improved through a higher utilization of the existing infrastructure. Finally, a considerable market non-transparency exists for forwarders that take a transport of their freight by rail into consideration, especially regarding the connection possibilities to freight transports in pre-carriage and on-carriage by means of trucks as well as inland or maritime vessels (Endemann et al. 2012).

Tasked with the conceptualization and implementation of the prototype, the Institute for Production and Industrial Information Management of the University Duisburg-Essen began its research work by systematically engineering the requirements for an online rail freight exchange through the analyses of the relevant literature as well as interviews and workshops with industry experts as the essential logistical actors (Bruns et al. 2010; Habib and Bruns 2012; Klippert et al. 2010). Further analyses of user requirements were contributed by project partners of the institute (Dörr and Endemann 2014; Endemann et al. 2012). One of the most important conclusions was that a freight exchange which is one-sidedly tailored for the rail freight traffic has no realistic market potential. Detailed market analyses show that no such online freight exchange could establish itself on the European transport market in the long term (Klippert et al. 2013). Especially the transport carrier road has to be involved in order to be able to exhaust the potential of multimodal transport chains. The following elaborations provide a brief overview of the subsequently implemented software prototype ORFE ("online rail freight exchange") in its final version. It is elaborated in detail on the concept development in Bruns et al. (2012a, b) and on the software development in Föhring and Zelewski (2013).

One of the first steps in implementing the online freight exchange was an evaluation which data would be required to advertise a transport service within the new system because internal data-structures, information flow as well as input masks would have to be modelled after this process.

Figure 16.1 shows the necessary steps for the creation of an advertisement for a transport offer. Since the adoption of any support software relies critically on the user acceptance of its interface, the process for advertising transport services on the user interface was given a special importance and the workflow was redesigned several times based on extensive feedback by the project partners.

Figure 16.2 shows an exemplary screenshot of the software prototype with an overview in which registered companies can chose from all advertisements of transport offers. Companies can register in several different company categories, like e.g. as "forwarder" or as "railway forwarder". Companies thus receive the possibility to restrict the visibility of their advertisements to specific company categories.

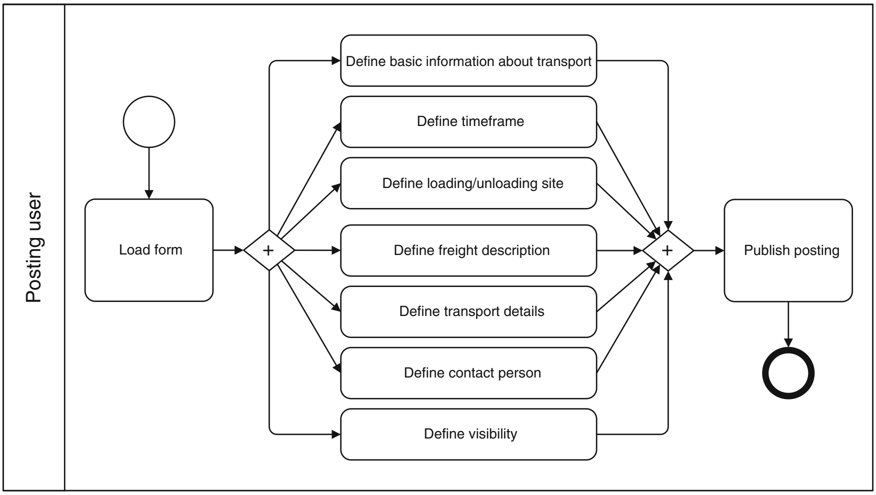

Fig. 16.1 Process of posting a transport service offer

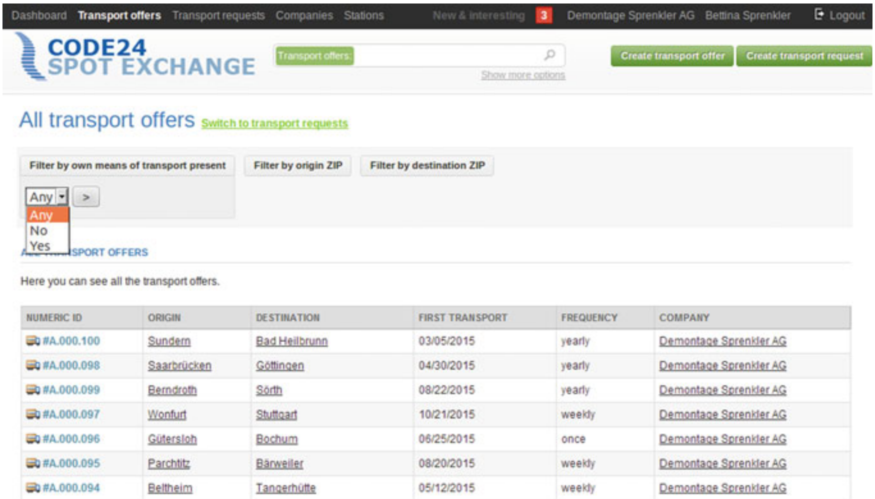

Fig. 16.2 Overview of transport offers in the ORFE prototype

While the prototype was very well received inside the project consortium as an instrument for further requirements engineering, it was agreed upon from the outset that, once completed, the final prototype would have to be refined and re-implemented into a business software product. On the first steps of this it is being commented in Dörr and Endemann (2014).

It was very important for all questioned project partners and also for other interviewed experts that, with regard to the management concept to be developed, the future operator of the online freight exchange ORFE should behave in an economically impartial way towards all exchange users. The authors got the impression from various expert interviews and also from other sector specific research projects that the sector of the rail freight traffic is being characterized by a high intensity of competition and mutual distrust. Numerous market actors doubt that an operator can be found inside the industry that acts “truly” impartially. Industry outsiders, on the other hand, are often denied the competence to run an online freight exchange economically successfully (Dörr and Endemann 2014; Klippert et al. 2013).

16.3 Real Problems in Operating ORFE

Currently two potential operators, who cooperate with the partners of the joint project CODE24 and to whom the previously described ORFE prototype was made available as a working basis, try to establish themselves with their platforms on the market: “Railcargo-Online” (http://www.railcargo-online.com) as well as “Freit-One” (http://www.freit-one.de) (Dörr and Endemann 2014).

The development of the ORFE prototype has shown how complex the endeavor to develop an online freight exchange is. Especially, it proved to be a big challenge already in the early stages of the prototype development to reconcile contradictory opinions of potential users about single functions and processes. An indirect proof for the complexity of the development can be seen in the fact that both previously mentioned commercial platforms announced their start in the year 2013 for the month of June, but missed this self-imposed launching date independently of each other by 4 or 5 months, respectively (Heinrici 2013; Saalbach 2013).

But further problems are obstacles to a successful establishment of an online freight exchange. For if the virtual market place fails to reach the critical mass because of lacking acceptance and provides a mediation rate of less than 5 %, the automatizing of processes becomes irrelevant, since the forwarders and transport carriers will keep settling their transactions the traditional way. But even if this obstacle can be overcome, freight exchanges are primarily suited for the mediation of transport services that are dealt with through spot markets, but many transports carried out within Europe are still bound to contracts. Therefore an online freight exchange has to either control the existing spot market or to strengthen the “spot character” of transport services in general (Merkel and Kromer 2002).

To sum up the results of the requirement analysis it can be said that the establishment of an online freight exchange meets four central real problems:

The first problem is the loss-free operating. For the purpose of covering expenses, an applicable operating model has to be found that specifies a royalty for every user of the online freight exchange (Bruns et al. 2012a, b).

The second problem is the disclosure of competition-sensitive data. All participants of a centrally organized market place are required to submit their data to the central operator in order for him to be able to perform his function as an intermediary. This requires a high confidence in the discretion of the operator.

The third problem is the experience of the potential operator. The role of the operator of an online freight exchange for the auction of transport services requires intimate knowledge of the respective sector. At the same time, the potential market place members questioned on this demand the impartiality of the operator on the market of the rail bound freight traffic. Based on the small market size and fragmentation it is difficult to find an operator that has the necessary expertise, but is not themselves a member of this market in one form or another (Bruns et al. 2012a, b).

The fourth problem is the consideration of multimodal traffics. As the combined traffic is going to play a bigger role in Europe in the future, the demand for considering multimodal traffics can be regularly found in publications on requirements for an online freight exchange (Endemann et al. 2012; Habib and Bruns 2012).

The challenge in solving the first and second problem lies in the minimization of the costs of operation and participation and the believable guarantee of the impartiality and discretion of the operator. Desirable would be the existence of a market place that serves the auction of multimodal transport services, can be operated without loss by an impartial party, keeps the initial cost as low as possible for potential users, promotes the reduction of information asymmetries as well as supports the pre- and on-carriage via other traffic carriers. It becomes apparent that a promising online freight exchange has to be a multimodal freight exchange that is capable of taking several traffic carriers into consideration. Furthermore, it becomes clear that the first three problems can be attributed to the central nature of the market place as in case of a central realization one single operator has to bear the costs for the provision of the infrastructure and would dispose of the data of all members as well as would have to reassure potential users about their expertise for the purpose of customer acquisition. It should be therefore researched if, when realizing an online freight exchange, an automatized and *decentrally* organized approach would be an economically attractive alternative to the thus far pursued *central* approach. This alternative would alleviate the previously mentioned four problems as not one central operator would be needed, all members would have the same data available, from the members' point of view only very low costs would be incurred and the consideration of multimodal traffics would be easier to realize in an automatized freight exchange than in an exchange organized in a central and purely contact mediating way.

16.4 AFEX: A Draft Towards Agent-Based Freight Exchanges

16.4.1 State of Research

In specialized literature it was only faintly taken note of the topic "online freight exchange for transport services in the rail freight traffic". The majority of the publications on this topic were published within the project CODE24 at the Institute for Production and Industrial Information Management of the University Duisburg-Essen (Bruns et al. 2010; Bruns and Zelewski 2011; Bruns et al. 2012a, b; Föhring et al. 2012; Föhring and Zelewski 2013; Habib and Bruns 2012; Klippert et al. 2013). Beyond that, only few publications exist and from these many merely assert the need for such an exchange (Endemann and Kaspar 2011; Scheck and Wilske 2011). The usage of two-sided combinatorial auctions is, on the other hand, discussed elaborately in specialized literature for different markets (Ackermann et al. 2011; Parkes and Ungar 2001) just as the usage of multi-agent systems (Davidsson et al. 2005; Fox et al. 2000; Jennings 2000).

The paper at hand suggests the merging of these findings on the requirements for an online rail freight exchange, on the usage of two-sided combinatorial auctions as well as on the organization of autonomous multi-agent systems in order to enable the conception and prototypical development of an agent-based freight exchange (AFEX for short) for multimodal transports. This market place is an automatized exchange in form of an electronic market place and organized as a decentralized system that is able to function without a central market place operator. The autonomous trade between equal actors is being enabled by the usage of agents that form a multi-agent system and employ two-sided combinatorial auctions in order to auction off multimodal transport services. The subsequent prototypical implementation will have a graphical user interface by which the software agents can be controlled.

In the following chapters it is being elaborated on chosen requirements for a prototypical AFEX-system.

16.4.2 Multi-agent Systems as Decentralized Electronic Market Places

While traditional electronic market places require a central operator, that coordinates the market activity, an AFEX-system has to be able to organize itself decentrally. This means that, while in case of the central solution all market activity is coordinated by the market place operator, the configuration and coordination of the activities in the decentralized version happens by the actors themselves. The market place operator is no longer needed as an intermediary; a disintermediation of the trade chain occurs.

In order to develop a multi-agent system that is capable to coordinate itself without a central nodal point, the first requirement is that agents have to be able to locate trade partners. This is a nontrivial problem, as a central authority for mediating the contact between the agents is missing. This "contact problem" can, however, be solved if the agent software enables the manual entry of agent addresses, which describe the necessary information for making contact with another agent through the internet.

As soon as an agent contacts another agent, they exchange all contact information known to them. Through this approach single agents get to know successively the whole network known to the other agent via only one contact. Before closing the agent software it has to save the contacts found during the runtime in a way that it is able to contact the previously known agents again without renewed user input.

The contact problem can be solved substantially more user-friendly if other software agents can be discovered without the intervention of the user. For this purpose there should be one or several predefined agent instances on the internet whose fixed addresses are embedded in the agent software. These predefined agents have no trading preference but serve as a kind of beacon, i.e. they only answer contact requests. If a list of these "beacon-agents" is going to be embedded in all agents and stands at their disposal after installation, they can be contacted without intervention of the human user.

Figure 16.3 illustrated the process: Agent A does not yet know other agents beside the beacon-agent B. He contacts agent B and gets further agent addresses from him, e.g. those of agent C and agent D. Agent A saves the received contacts and can recall them again with the next start and approach them without being dependent on the beacon-agent as a contact mediator. The advantage of this method is that beacon-agents can be operated, communicated and used independently of each other. They support the decentralized organization of the AFEX market place since they solve the contact problem without requiring a user interaction, but are not necessary for operating the decentralized network (as the human users could always build up their own "contact networks" via the manual entry method).

In the next step the user chooses from two input masks in order to either capture their preferences for an offer of or demand for a transport service. With their help they specify similar transport-related preference data (for loading and unloading location, timeframe, etc.), that has already been captured in the ORFE prototype and is depicted in Fig. 16.1.

The difference between the ORFE prototype and AFEX becomes apparent afterwards: After the entry of their preferences the AFEX system does not need further user interaction. All agents that are in contact with each other exchange their preferences automatically and thus ensure complete market transparency.

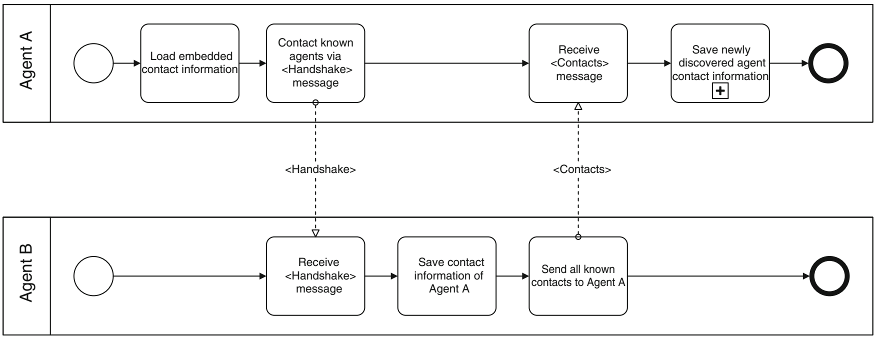

Fig. 16.3 Contact initiation between agents

The preferences are hereby transmitted in a unified data format which all agents understand. Agents then try to buy one of their combinations being in demand from one or more agents offering this combination at an auction.

16.4.3 Choosing Combinatorial Auctions

Another challenge is the pricing between buyer and seller regarding the offered transport services. Three pricing models can be made out (Grieger 2003): The *bulletin board model* that serves primarily the publication of advertisements and as a pure information and contact platform (this variation was implemented in the ORFE prototype). The *fixed price model* in which case the supplier and demander specify the final price for the service being in demand or offered.

Virtual exchanges made possible by the internet that offer its members a dynamic pricing with the help of auctions.

It seems to suggest itself immediately that a concept would be desirable that ensures an efficient auction of the traded transport services. From the three mentioned alternatives, this requirement can be only met by the dynamic pricing through auction. Crucial for the efficiency of an auction is the choice of auction form (Ausubel and Cramton 1998; Krishna and Perry 1998). There are two reasons why the employment of the two-sided auction form, in which case the auction participants can appear as buyer and as seller, is reasonable: Firstly, many auction exchanges and resource markets in the real world are organized as two-sided auctions (Yang 2002). Secondly, in this way the members get no dedicated role assigned, but act according to their respective preferences in the role of supplier or demander of transport services. In order to be able to depict multimodal transport services in an auction, other dimensions next to the price have to be taken into account. Multidimensional auctions promise a high allocative efficiency despite the possibly complex preferences of the participating tenderers concerning the traded dimensions. Combinatorial auctions are very well researched multidimensional auctions that make it possible for participants to make a tender for indivisible combinations of goods and only then win the bid if they receive exactly that combination of demanded goods (Bichler et al. 2005). Resulting from these considerations an AFEX system can employ a two-sided combinatorial auction model in order to meet the previously mentioned requirements.

16.4.4 Ad hoc Auctions

Another organizational problem concerning the draft of an AFEX system is the fact that an autonomously coordinated exchange without a central operator also lacks a central figure as the auctioneer. Because of this, the agents do not only have to find each other, as described earlier, but also have to coordinate among themselves the initiation and implementation of auctions. Based on the exchanged preferences they ascertain among themselves the compatibility of their trading intentions, a step which is necessary for the initiation of negotiations. In case of complementary preferences the agents form a group through which the auction of specific goods (transport services) is made public. Within a group members can be distinguished in those that offer transport services (suppliers) and those that request them (demanders). As soon as a sufficient number of suppliers and demanders have entered a group the auction starts. For this purpose the agents carry out a spontaneous "ad hoc auction".

The difference between ad hoc auctions and "normal" auctions in centrally organized market places is that the auctioneer is dynamically selected from the crowd of suppliers of a group. The role of the auctioneer falls to the supplier that tries to dispose of the highest number of transport services or, if several suppliers make an equal number of offers, that supplier which entered the group first. The auctioneer subsequently carries out a two-sided combinatorial auction according to the auction model and specifies the final freight allocation within the group. After all participants agree to this new distribution the group dissolves.

Figure 16.4 depicts an AFEX system of 24 agents, six of which formed a group that performs an ad hoc auction (dotted circle in the middle).

It also illustrates that not all of the agents are maintaining an active connection to each other all the time, e.g. agents currently participating in an active auction are not maintaining any active connections except the one with the auctioneer.

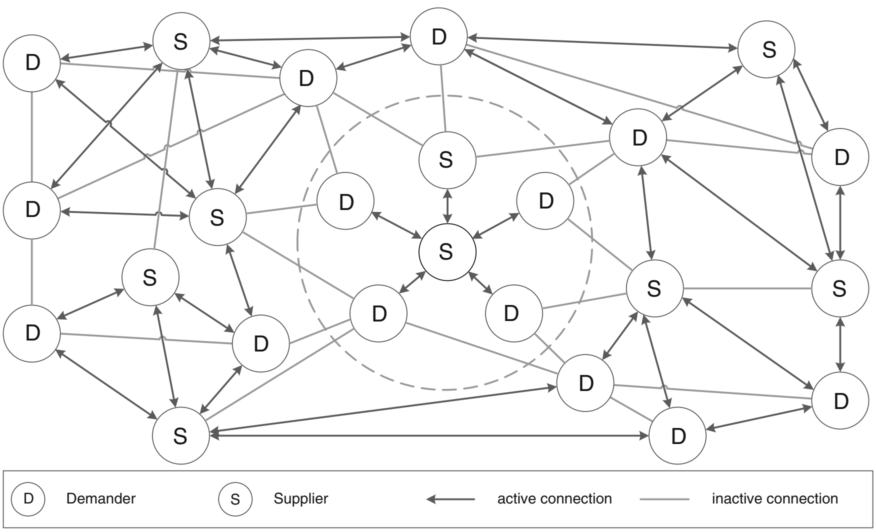

Fig. 16.4 Ad hoc auction inside an AFEX system

16.4.5 Implications

The outlined market place concept AFEX provides three implicit advantages in contrast to conventional approaches:

Fairness—all members of the market are subject to the same rules of action. Although agents are started with individual preferences, they cannot deviate one-sidedly regarding their strategy, which is deposited in the software.

Efficiency—the usage of the two-sided combinatorial auctions allows for optimal solutions for pricing through the deployment of mathematical models. The efficiency criteria can thus be specified in a goal-oriented way in the design phase.

Transparency—the conditions of the market and the market activity are completely transparent from the point of view of the software agents: all agents make contact among themselves and exchange their trading preferences.

In addition, the described approach provides a realistic modeling of the roles perceived by the members of the market place, as the agents do not only act explicitly as supplier or demander, but also (analogously to operators in the real world) play either the role of a supplier or of a demander dependent on the context.

16.5 Summary

In this paper the efforts to establish an online freight exchange for the mediation of multimodal transport services using the example of the European rail freight traffic have been outlined. The research on online freight exchanges and the development of the prototype ORFE have been described as well as the challenges with which a new online freight exchange is being faced. The investigation of these problems resulted in the development of an innovative market place concept: AFEX, an online freight exchange that is based on autonomous agents. The requirements for the development of decentrally organized agents, which would be able to trade autonomously, have been outlined.

The next steps in the development of the presented concepts is the development of a generic adaptive agent behavior that is able to adjust to different market situations as well as the definition of an abstract traffic route notation that is suitable for the description of the transport route being in demand by the agents. Moreover, next to the traffic route notation a description language for the offer of and demand for transport services within auctions has to be defined. Finally, for the research work to be done, stands the selection of a two-sided combinatorial auction model as well as the combination and implementation of all mentioned aspects into a prototypical agent software.

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Chapter 17
Delivery Time Windows for Road Freight Carriers and Forwarders—Influence of Delivery Time Windows on the Costs of Road Transport Services

Ralf Elbert, Dominik Thiel and Daniel Reinhardt

17.1 Introduction

The importance of delivery time windows for road freight carriers and forwarders has been increasing over the last years (Bundesamt für Güterverkehr 2011; Winkler 2011). Manufacturing companies started imposing time window constraints several years ago along with sourcing concepts like just-in-time (JIT) or just-in-sequence (JIS) (Ward and Zhou 2006; Koether 2014). Nowadays, retailers and other industrial companies are increasingly introducing slot management systems to optimize the capacity utilization of warehouse gates (SCI 2011). Hence, road freight carriers and forwarders have to ensure timely and accurate deliveries to reduce waiting times as well as penalties (hwh 2013; Bundesamt für Güterverkehr 2011). Tours with various stops, long distances and a congested road infrastructure make this requirement even more challenging.

Therefore, time window constraints have a growing influence on the production concept and, accordingly, on the costs of road transport services. Despite this importance, only a few research activities cover the perspective of road freight carriers or forwarders and develop measures to manage the arising challenges (Winkler 2011; Bundesamt für Güterverkehr 2011; Cargoclix 2012). Furthermore, warehouse gates act as interfaces between production, logistics and traffic so that a comprehensive perspective is necessary (Krummer et al. 2009). Beyond that, the academic discussion focusses on time windows as constraints in the context of

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mathematical optimization models—e.g. vehicle routing problems (Krummer et al. 2009; Bräysy and Gendreau 2005; Savelsbergh 1992; Solomon 1987). The consequences of violating these constraints for road freight carriers and forwarders are usually not considered comprehensively and close to reality. However, particular cost items (such as fuel costs) are already considered comprehensively (Tas et al. 2013; Suzuki 2012). A consideration of the overall cost structure of road freight forwarders and carriers with realistic assumptions about the various cost components combined with an implementation of traffic load curves to model traffic demand cannot be found in the literature so far. A realistic assumption regarding the additional costs for road freight carriers and forwarders associated with the introduction of time windows is consequently missing and shall be in focus of this research.

17.2 Research Background

With increasing globalization and international production sites, companies are confronted with global value chains (Pfohl et al. 2013). This trend is intensified by a high cost pressure which forces companies to specialize on their core competencies and to implement lean production principles (Reinhart et al. 2011). In this context, all non-value adding activities are either sourced out or reduced to a minimum (Clausen et al. 2007). The associated change from an internal division of labor, within one company, to an external division, throughout various companies, results in an increased transport volume between different companies and sites (Clausen et al. 2007). The specialization of companies on their value adding activities and core competencies leads, due to the larger spatial expansion of business activities, to a growing need for freight transport services and thus to an increased traffic demand (Lenz et al. 2010). Therefore, the existing problems of road infrastructure shortages in Germany will intensify, resulting in traffic jams and greater environmental pollution (Molitor and Boltze 2014).

A decisive role in the evaluation of traffic demand and capacity shortages plays the distribution of traffic throughout the day (Pinkofsky 2006). Time-dependent peaks in traffic load curves increase the danger of traffic jams and delayed delivery (Bushuev and Guiffrida 2012, Brilon 2004). In combination with slot management systems and strict time window constraints traffic disruptions can represent a relevant risk for delayed deliveries. For road freight carriers and forwarders these delays imply additional costs (e.g. extra labor costs for extended waiting times, fuel costs for detours and penalties).

During recent years the extensive introduction of slot management systems determines a predominant influence on the costs of road freight carriers and forwarders (Bundesamt für Güterverkehr 2011). Whereas waiting and handling times as well as inefficiencies and costs in the supply chain could be reduced, the liabilities of road freight carriers and forwarders escalate (Bundesamt für Güterverkehr 2011). This effect can be particularly observed in retail logistics. While the

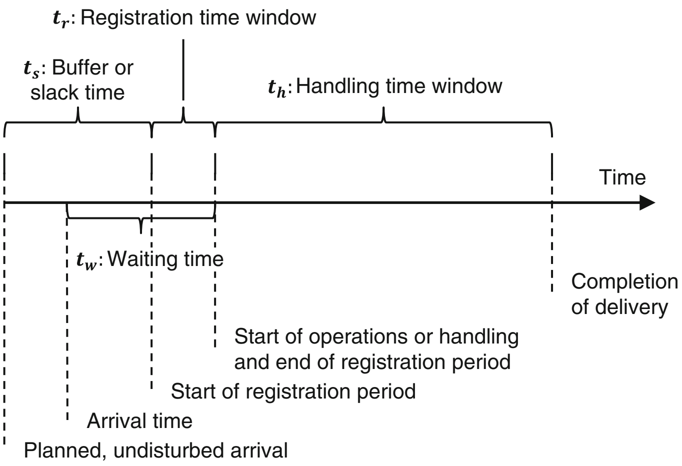

Fig. 17.1 Important times for the delivery process with support of slot management systems

efficiency of warehouse and ramp operations could be increased, road freight carriers and forwarders struggle with the emerging challenges regarding on-time delivery (Berlit 2012; Bundesamt für Güterverkehr 2011).

In this research, the key interface between road freight carriers and consignees is the warehouse gate where the goods are loaded or unloaded. Long waiting and service times occur at this point of a transport chain (hwh 2013; Bundesamt für Güterverkehr 2011). In this context waiting time (t_w—see Fig. 17.1) is understood as the period of time between arrival at the consignee and the beginning of loading or unloading activities (hwh 2013, Bundesamt für Güterverkehr 2011). After the arrival the truck needs to be registered within a given period of time (t_r—registration time window). The handling time (t_h) describes the period of time which is provided for handling operations by the warehouse operator (usually loading or unloading). Waiting and handling times usually differ substantially in various industries (Ward and Zhou 2006; Bundesamt für Güterverkehr 2011). By strengthening the link between production and logistics, manufacturing companies could significantly reduce waiting and handling times. Especially the extensive use of concepts like JIT and JIS led to those shortened process times. Along with these concepts a closer integration of information flows between manufacturers and suppliers can be observed. In order to reduce long waiting and handling times without any extensive cooperation many companies use slot management systems to improve their efficiency.

The handling time slots need to be booked for each transport order. Three common ways of time slot booking exist (hwh 2013; Winkler 2011). First, the consignee or ramp operator defines a fixed time slot and informs the carrier or forwarder. This concept is mainly used for JIT or JIS delivery. Second, the booking of a time slot is performed by bilateral coordination, e.g. via telephone or telefax. The third and most commonly used booking procedure is the ICT-based[1] time slot management system carried out by road freight carriers or forwarders.

With this concept of an ICT-based slot management system, each road freight carrier or forwarder is responsible for the slot booking on its own. According to individual preferences, available time slots can be booked via an electronic platform. There are various providers for time slot management systems. Examples of providers for standardized booking platforms are Cargoclix, Eurolog, Leogistics, Mercareon and Transwide (Winkler 2011; Cargoclix 2012; Mercareon 2015). If the truck arrives before the booked time slot (t_h), it usually has to wait until the beginning of the time slot in case the consignee cannot provide a backup slot. In case of a delayed arrival (time window is not met), more negative consequences for carriers can occur. Road freight carriers must reckon with additional delay due to a subsequent clearance or even with a new delivery. Moreover, the consignee may claim a monetary penalty. These claims are usually held by the consignee against his supplier who passes those claims on to the road freight carrier. Because of these substantial negative consequences of delays, the road freight carrier has to consider buffer or slack time (t_s) during the route planning process to avoid new deliveries as well as penalties. By increasing slack time, additional waiting time before registration and handling is accepted.

With these explanations all relevant periods of time for the observed problem are introduced (see Fig. 17.1). While t_s and t_w can be influenced by the road freight carrier himself, the other values t_r and t_h are explicitly or implicitly specified by the consignee (usually the operator of the warehouse). The time period $t_{tw} = t_s + t_r$ will be considered as the relevant arrival time window for the road freight carrier or forwarder. If the arrival takes place during this time window, no negative consequences in terms of penalties or new deliveries occur. If this time slot is not met, the arrival is later than the end of the last possible registration time resulting in additional costs (penalties). By increasing the buffer time (t_s) this risk can be reduced.

For an assessment of the slack time the expected disruptive events during the driving time are most relevant. Caused by the stochastic character of disruptive events a complex planning task or decision problem emerges. The route distance and the temporal position of the time window represent relevant factors for this planning task (Bushuev and Guiffrida 2012; Guiffrida and Nagi 2006).

In the scientific literature different definitions of time windows can be found (see Table 17.1). Most definitions are roughly consistent with the definition explained above.

Studies in the field of operations research mainly deal with the determination of optimal tours under consideration of time window constraints (Bushuev and Guiffrida 2012; Guiffrida and Nagi 2006; Krummer et al. 2009; Savelsbergh 1992; Solomon 1987). The consideration of temporal constraints for vehicle routing

[1] Information and communication technology (ICT).

Table 17.1 Different understandings of time windows in academic research on logistics

Author	Understanding of time windows
Aydogdu	Basically a time window specifies the period of time, when a shipment is delivered to a recipient or collected from a sender. It consists of two basic elements—the registration window and the stopover time. The registration window is an agreed period for delivery or pickup. Within this period, the logistics service provider must register at the reception or the goods receipt/outgoing goods department for unloading/loading the corresponding goods (Aydogdu 2013, p. 39)
Boomgaarden	A time window is the period of time, within which the delivery of a customer has to be started (Boomgarden 2007, p. 2)
Bushuev/Guiffrida	A delivery window is defined as the difference between the earliest acceptable delivery date and the latest acceptable delivery date (Bushuev and Guiffrida 2012, p. 227)
Gietz	So-called time windows specify allowable time intervals for the start of handling activities (Gietz 2008, p. 145)
van Bonn	Time windows of customers determine the period of time, a customer can be supplied (van Bonn 2013, p. 294)
Wenger	Time windows define a time restriction at the point of loading or unloading which have to be considered and which necessitate a temporal as well as a spatial coordination of orders (Wenger 2010, p. 49)
Jaruphongsa et al.	A time window is basically a grace period during which a demand can be satisfied with no early or late shipment penalty (Jaruphongsa et al. 2004, p. 170)

The explanations of Aydogdu, Boomgarden, Gietz and Wenger are translated from German to English by the authors

planning occurs in various ways. In general, for finding an optimal solution penalty costs and waiting costs have to be weighted (Bushuev and Guiffrida 2012). Furthermore, concerning the modeling of time window problems in operations research ‘hard time windows’ and ‘soft time windows’ can be distinguished. ‘Hard time windows’ describe constraints which have to be adhered to in order to reach a valid solution (Min 1991; Iqbal and Rahman 2012). ‘Soft-time windows’, however, are time windows regarding transport orders which lead to penalties (e.g. time penalties, fines) in case of non-adherence (Min 1991; Iqbal and Rahman 2012). For the present research, this perspective is more appropriate because this particular trade-off between penalties and waiting costs plays a crucial role in the following analysis regarding time window constraints. In contrast to research in the field of operations research, however, no optimal solutions are derived. Only the monetary effects of different time window characteristics are investigated in detail. For this work the (arrival) time window ($t_s + t_r$ in Fig. 17.1) is considered as the relevant time period for on-time arrival.

Furthermore, road traffic-related research represents an important field of interest in this context. In particular the traffic capacity of roads or road networks as well as traffic demand is investigated (Pinkofsky 2006; Brilon 2004; FGSV 2009). Also, congestion phenomena caused by traffic overload (traffic demand greater than capacity) and other disruptive events (e.g. accidents, breakdowns, road works) (Geistefeldt and Lohoff 2011) have a critical effect on travel time (Brilon 2004, Brilon and Estel 2008). As the most important factor for delays on highways, the traffic load can be identified (Geistefeldt and Lohoff 2011). Thus, the following research will focus on the impact of traffic overload on the transport processes of road freight carriers and forwarders.

Considering the examined literature in the various research areas, it can be stated that the situation of road freight carriers and forwarders and the influence of slot management systems on their particular cost structure has been considered little (Bundesamt für Güterverkehr 2011). Therefore, this paper examines the influence of different time window characteristics by regarding an exemplary transport route. Consequently, the research question can be phrased as follows:

> What is the influence of different (arrival) time window lengths and temporal positions on the costs of road freight carriers and forwarders considering traffic overload?

To answer the research question this paper is divided into two parts which build on one another. Initially, the cost structure of road freight carriers and forwarders regarding the individual parts of transport costs is described and relevant cost items for the subsequent simulation study are selected.

In the second part, a prototypical computer simulation model is used to investigate the impact of various temporal positions and lengths of time windows on the relevant cost items identified before. By using a simulation approach, stochastic influences and complex relationships can be modeled and analyzed. In this paper, a time-discrete, stochastic simulation is carried out with the simulation software AnyLogic (version 7.0.3) which is highly flexible regarding various modeling approaches and allows the implementation of custom Java code. In the simulation a single trip of a truck is modeled considering variable driving times. As an approximation for driving times, a traffic flow model based on a deterministic queuing model for congested traffic conditions is used to calculate average speeds on a highway section subject to time-varying traffic demand (modeled by traffic load curves). Hereby, traffic overload as one dominant reason for driving time variations is implemented.

17.3 Cost Structure of Road Transport Services

As costs for the provision of road transport services the following cost items have to be considered: driver costs (C_{dr}), imputed depreciation (C_{dep}) and interest (C_{int}), fuel and lubricant costs (C_{fl}), tire costs (C_{tire}), toll (C_{toll}), costs caused by maintenance and repair (C_{mr}), taxes and insurance (C_{ti}), contractual penalties (C_{pen}) as well as waiting costs (C_{wait}) (Wittenbrink 2014; Commerzbank Research 2013). Overhead costs like administration costs are not considered in the following. With these various cost items, the overall costs (C_{ov}) for road transport services can be expressed as follows:

Table 17.2 Monetary vehicle parameters (Wittenbrink 2014; ETM 2015)

	Truck tractor	Semitrailer (3 axles) (€)
Net price	98,000 €	25,000
Replacement price (3 % increase p.a.)	100,940 €	25,750
Residual value	20,000 €	5,000
Depreciation value	78,420 €	18,530
Capital lockup (fixed assets)	49,000 €	12,500
Interest rate (fixed assets)	4.5 %	
Capital lockup (current assets)	14,000 €	
Interest rate (current assets)	6.5 %	

$$C_{ov} = C_{dr} + C_{dep} + C_{int} + C_{fl} + C_{tire} + C_{toll} + C_{mr} + C_{ti} + C_{pen} + C_{wait}$$

These overall costs can be calculated for particular tours with respect to tour-specific parameters, such as distance, used roads or driving time (Bürli and Friebe 2012). In this paper, a tractor-trailer combination (e.g. Mercedes Actros 1448 LS Euro 6 and a semitrailer) which is typically used for long distance travel is taken as a basis for calculation.

The parameters used for the calculation of the imputed depreciation (C_{dep}) and interest (C_{int}) are listed in Table 17.2. The depreciation (C_{dep}) primarily depends on the replacement price, the residual value and on the usage time of the vehicle (Wittenbrink 2014). In addition, the fixed (tractor-trailer combination) and current assets cause imputed costs through capital lockup (C_{int}). Current assets are sold or consumed in accordance with the business activities of a company (e.g. fuel, tires).

Relevant operating conditions of the tractor-trailer combination are listed in Table 17.3. These parameters are later on used to express the annual costs as costs per kilometer and costs per driving hour, respectively.

The costs for fuel and lubricants (C_{fl}) are calculated according to the fuel consumption of trucks and the fuel price (see Tables 17.4 and 17.5). The level of fuel consumption depends on the distances, vehicle design and operating conditions (Nahmias 1989). In this study we neglect these influences and assume a constant fuel consumption per 100 km. Moreover, the consumption costs of fuel and

Table 17.3 Operating conditions (Wittenbrink 2014; ETM 2015)

	Truck tractor	Semitrailer (3 axles)
Annual mileage	130,000 km	130,000 km
Operating days per year	240 days	240 days
Useful time	5 years	10 years
Lifetime of tires	160,000 km	200,000 km
Daily use time	9 h	9 h

Table 17.4 Technical vehicle parameters (Wittenbrink 2014; ETM 2015)

	Truck tractor	Semitrailer (3 axles)
Number of tires	6	6
Costs per tire	420 €	370 €
Fuel consumption	34.5 l/100 km	
Adblue consumption	5 % of fuel consumption (1.725 l/100 km)	
Costs for lubricants	1 % of fuel costs	

Table 17.5 Price parameters (ETM 2015; BGL 2015; Bundesministerium der Justiz und für Verbraucherschutz 2015)

	Cost value
Adblue	0.25 €/l
Diesel	0.9612 €/l
Toll charges	0.131 €/km

Table 17.6 Driver costs (per year) (Wittenbrink 2014)

	Cost value
Annual gross wage	29,000 €
Drivers required to operate the truck during the year	1.25
Social security contributions paid by the employer (in % of the annual gross wage)	26 %
Out-of-pocket expenses	2,880 €
Other driver costs (e.g. training)	500 €
Total driver costs per year	49,055 €

lubricants are determined by the current prices. The corresponding prices for the following investigation are shown in Table 17.5.

Tire costs (C_{tire}) depend on the price per tire, the number of tires and their lifetime. Tolls and road charges (C_{toll}) are country- and road-specific. Since 2005 trucks with a gross vehicle weight over twelve tons are charged in Germany for the use of highways and other selected roads (Bundesamt für Güterverkehr 2014). Thus, the level of toll charges depends on the distance driven on the respective roads.

Driver costs (C_{dr}) are determined by the driver's annual gross wage and additional costs (see Table 17.6). Costs for maintenance and repairs (C_{mr}) can be approximated by a constant cost rate per kilometer (Wittenbrink 2014).

Motor vehicle taxes and insurance costs (C_{ti}) are fixed costs which have to be paid independent of vehicle usage (see Table 17.7). The insurance covers liability insurance, comprehensive insurance and transport insurance (Wittenbrink 2014).

Penalties (C_{pen}) refer to costs caused by delayed deliveries. The amount of penalties to be paid is usually negotiated between the respective parties. The amount of the agreed penalty can vary highly. A general statement about the

Table 17.7 Cost parameters related to taxes, insurance and repairs/maintenance (Wittenbrink 2014)

	Truck tractor	Semitrailer (3 axles)
Motor vehicle tax	556 € per year	373 per year
Car insurance	4,00 € per year	600 € per year
Transport insurance	600 € per year	300 € per year
Repair/maintenance/washing	0.05 € per km	0.01 € per km

Table 17.8 Yearly cost overview

Cost item	Amount	Dependence (in the simulation model)
Driver costs	49,055 €	Driving time
Imputed depreciation	17,537 €	Distance
Imputed interest	3,678 €	Distance
Costs for fuel and lubricants (incl. Adblue)	44,102 €	Distance
Tire costs	3,491 €	Distance
Toll charges	0.131 €/km	Distance driven on toll roads
Taxes and insurance	6,429 €	Distance
Maintenance and repairs	7,800 €	Distance
Penalty costs	500 €	Arrival after registration time window
Waiting costs	0.70 €/min	Waiting time

amount of penalties is not possible. To provide a suitable value for the simulation model we assume fixed penalty costs of 500 € for a delayed delivery as mentioned in Lauenroth 2013.

In case of early arrival (the truck arrives before the end of the registration time window), the truck has to wait before the handling time window begins. During this time no operational activities take place and thus additional time-dependent costs arise for the road freight carrier or forwarder (C_{wait}) (Semmann 2009; hwh 2013). These costs are mainly caused by time-dependent costs like driver costs. As a realistic assumption for the waiting costs we use 40 € per hour, as proposed by Semmann 2009.

An overview of the yearly costs is shown in Table 17.8. The table also indicates how the various cost items were operationalized in the simulation model. Most cost items were modeled dependent on the distance of the trip. Therefore, the respective total yearly costs were divided by the annual mileage to receive a cost-rate per kilometer. The toll charges per kilometer are given and depend directly on the distance driven on toll roads. Driver costs are modeled time-dependent resulting in a cost rate per hour. A fixed penalty has to be paid in case of late arrival as described before. Waiting costs are approximated by a cost rate per minute. The time difference between the arrival and the end of the registration window multiplied with the mentioned cost rate determines the absolute waiting costs.

17.4 Simulation Study

To analyze the monetary impact of varying (arrival) time window lengths[2] and different temporal positions of time windows we conducted a prototypical simulation study. In the simulation, the one-way trip of the described tractor-trailer combination is evaluated regarding arrival time and resulting monetary consequences. The average speeds used to obtain the driving time for the trip are calculated based on a traffic flow model which relies on a deterministic queueing model to account for congested traffic conditions. The current version of the model only incorporates traffic overload (traffic capacity smaller than traffic demand) to simulate congestion. Other reasons for congestion like accidents, breakdowns or road work are not considered. In reality, these aspects increase driving times leading to a higher monetary impact of penalty costs.

To simulate different temporal positions of time windows, various start times of handling time windows (e.g. 10:00) are analyzed with the simulation model. For every examined start time of a handling time window two kinds of trips are simulated: the 'reference trip' with maximum allowed speed (60 km/h on country roads and 80 km/h on highways) and the 'actual trip' (speed determined by the traffic flow model). Because the driving time of the actual trip is influenced by stochastic factors (traffic demand), this trip is repeatedly simulated.

By definition, the arrival time of the reference trip is equal to the planned, undisturbed arrival (see Fig. 17.1). The calculated driving time of the reference trip is used to determine its starting time. This starting time also applies for the actual trips. However, the arrival times of the actual trips will be later than the planned, undisturbed arrival due to the occurrence of traffic congestion. Thus, the (arrival) time window serves as a buffer for varying driving times.

If the arrival time of an actual trip is later than the end of the arrival time window (equal to the start time of the handling time window), a fixed penalty is imposed on the road freight carrier or forwarder. If the arrival time of an actual trip is before the end of the arrival time window, the driver has to wait until the beginning of the handling time window resulting in waiting costs (proportional to the waiting time).

In accordance with the cost structure explained above, 'overall costs' (C_{ov}) is the relevant dependent variable of the simulation model. Since most of the costs solely depend on the distance of the trip (see Table 17.8), which is constant in the simulation study, the respective costs are subsumed under the cost item 'other costs (const.)'. Only driver costs (time-dependent), penalty costs and waiting costs (depending on the arrival time) are analyzed in detail because they differ for different configurations of the independent variables. Corresponding to the research objective, (arrival) time window length (e.g. 20 min) and temporal position (start time of the handling time window, e.g. 14:00) are the independent variables of the simulation study.

[2]In the simulation model the length of the time window t_{tw} is varied.

17.4.1 Route Characteristics and Modeling of Traffic Demand

As a scenario for the simulation study the following route characteristics were chosen (long distance transport). The route consists of three legs. The first and the third leg are modeled as country roads (60 km/h average speed) of 11 km length. These serve as the routes to and from the highway (second leg), respectively. The highway section has a length of 250 km. The speed on this part of the route is different for the two types of trips as explained above. As a simplification for this prototypical simulation study, the highway is modeled as a single road section without intersections and with constant parameters (traffic demand, slope, speed limit, share of heavy vehicles, position inside/outside urban area) for the whole length. Concerning the used traffic flow model, the highway section represents a single bottleneck. Relevant characteristics of the highway section used to obtain the needed parameter values for the traffic flow model from the German Highway Capacity Manual (HBS) are shown in Table 17.9.

The temporal varying traffic demand for the highway section is modeled using the generalized traffic load curves according to Pinkofsky 2006. The daily traffic load curves distribute the average daily traffic (ADT) across the day.

We used the generalized daily traffic load curve of type B for the time period from Tuesday to Thursday which is one of the common traffic load curves for highway sections (Pinkofsky 2006). The shape of this traffic load curve is depicted in Fig. 17.2. It is characterized by a distinct peak during the morning hours of the day. A smaller peak can be observed in the evening hours. If the daily traffic demand is distributed more evenly across the day, less congestion occurs.

The original version of this daily traffic load curve is based on hourly values (Pinkofsky 2006). For this simulation study we interpolated the demand curve by a piecewise linear function (with segments of 30 min) to gain varying traffic load values for every minute of the day according to a procedure described in Brilon and Zurlinden 2003 (see also Brilon and Estel 2008). Demand values for every full hour are calculated by averaging the values of the two adjoining hours (see also Fig. 17.2). For every half hour, the value of the demand is determined by the condition that the area below the calculated demand value is equal to the area below the respective hourly traffic demand value.

To account for stochastic demand we adopted the approach presented in Ober-Sundermeier 2003. Before the daily traffic load curve is interpolated, the hourly values are varied stochastically for every actual trip. According to the approach in

Table 17.9 Highway section parameters

Parameter	Value
Number of lanes	2
Speed limit	None
Slope	Smaller than 2 %
Inside/outside urban area	Outside

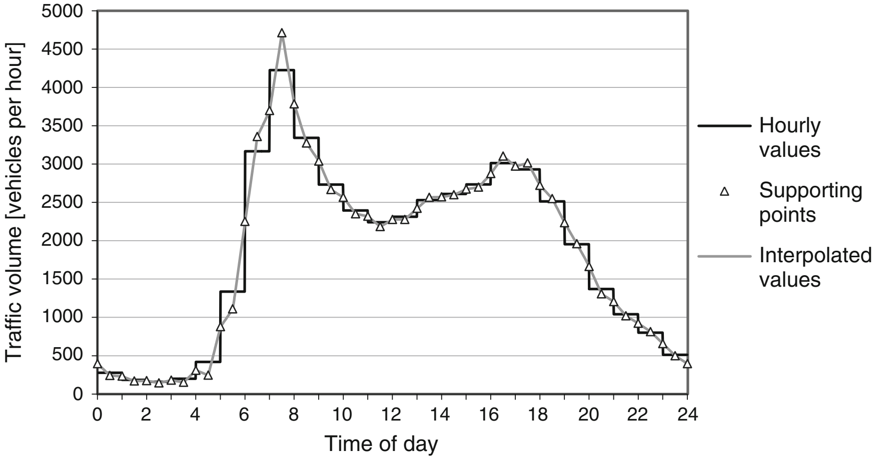

Fig. 17.2 Traffic load curve type B according to Pinkofsky 2006

Ober-Sundermeier 2003 we modeled the hourly traffic demand as a normally distributed random variable. While the mean of this random variable equals the hourly traffic demand, the standard deviation is determined by a coefficient of variation which is set to 0.05 in our simulation study (Ober-Sundermeier 2003). The random variable is bounded by 0.5 (lower bound) and 1.5 (upper bound) times the hourly value of the traffic demand (Ober-Sundermeier 2003).

To account for different capacities of the highway section depending on the share of heavy vehicles, a separate traffic load curve for heavy vehicles is implemented in the simulation model (type A according to Geistefeldt 2003, as cited in Brilon and Estel 2008). Typically, the share of heavy vehicles is higher during the night than during the day. The average share of heavy vehicles was set to 15 % in our simulation study which was the average value on German highways in 2013 (Fitschen and Nordmann 2014).

17.4.2 Calculation of Driving Times

A macroscopic traffic flow model according to Geistefeldt 2005 (see also Brilon and Estel 2008; Geistefeldt and Hohmann 2014; Hohmann 2014) consisting of two components is employed to relate traffic demand to average speed on the highway section. For free traffic flow, a speed-volume-relationship according to the German Highway Capacity Manual (HBS) is used (see also Brilon and Ponzlet 1995). In case of congested traffic conditions, the additional travel time is estimated based on a deterministic queuing model. For every time interval, traffic demand and capacity are compared. In case of a higher traffic demand, congestion occurs due to vehicles queuing up (vertical queueing). This model was chosen since it implicitly accounts for the temporal shift of traffic demand in case of traffic overload (Geistefeldt 2005; Brilon and Estel 2008). Other approaches to model driving times in case of congestion like capacity-restraint functions (e.g. BPR functions from the Traffic Assignment Manual of the United States Bureau of Public Roads) were not considered in the simulation model.

The combined traffic flow model is used to calculate the additional travel times in case of congestion due to traffic overload. These additional travel times are not differentiated by vehicle type. Therefore, the travel time is transformed into an average speed on the highway section for each time interval (1 min). We assume that the speed of the truck equals 80 km/h if the average speed of all vehicles is higher than 80 km/h (Geistefeldt 2005). However, if the average speed is lower than 80 km/h, the speed of the truck is adjusted to this reduced value. In reality, the actual speed of the truck might be even lower. Additionally, we consider a capacity drop in case of congestion on the highway section. The capacity of the highway section in case of congested traffic conditions is set to 95 % of the free flow capacity (Brilon and Estel 2008). Relevant parameters for the highway section (e.g. capacity, free flow speed) were obtained from the German Highway Capacity Manual (HBS) using the parameter values depicted in Table 17.9.

17.4.3 Numerical Results

For the scenario described above we conducted simulation experiments for various values of the independent variables (see Table 17.10). For every possible combination of the independent variables 1000 simulation runs (1000 actual trips) were performed.

The directional average daily traffic was set to a comparatively high value of 45,000 vehicles per day resulting in a highway section of low quality regarding traffic flow. Penalty costs were fixed to 500 € (Lauenroth 2013) and waiting costs were equal to 0.70 € per minute (Semmann 2009). During various parts of the day no congestion could be observed which increased the driving time. According to the used traffic load curve (peak in the morning hours) different travel times of the actual trips compared to the reference trip could only be determined for start times of handling time windows presented in Fig. 17.3.

The histograms depicted in this figure show the corresponding driving time distributions. The upper left histogram demonstrates that less than 100 actual trips exhibited driving times of 210 min (driving time of the reference trip) or less. The

Table 17.10 Experimental setup (independent variables)

Independent variable	Values
(Arrival) time window length	10, 20 min
Start time of the handling time window	4:00–24:00 (every hour)

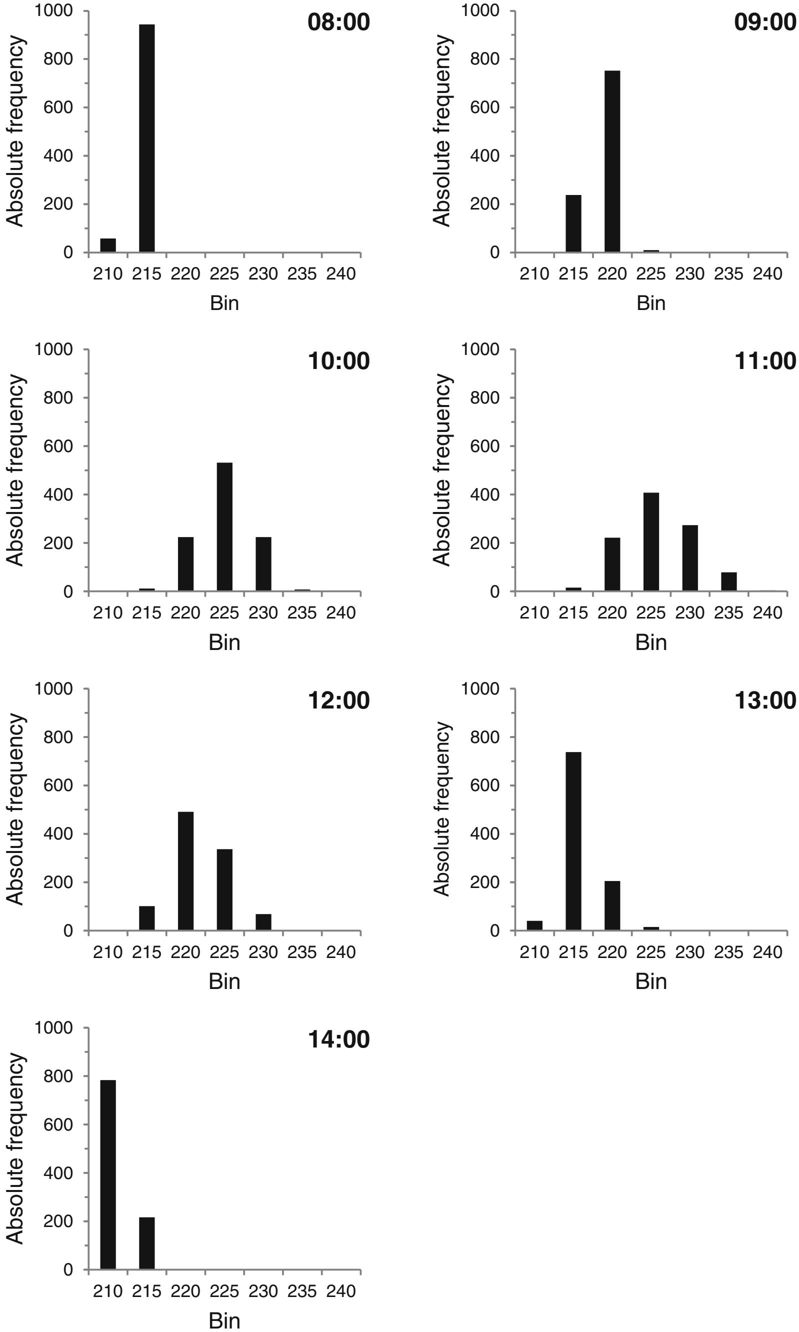

Fig. 17.3 Driving time histograms for selected start times of handling time windows

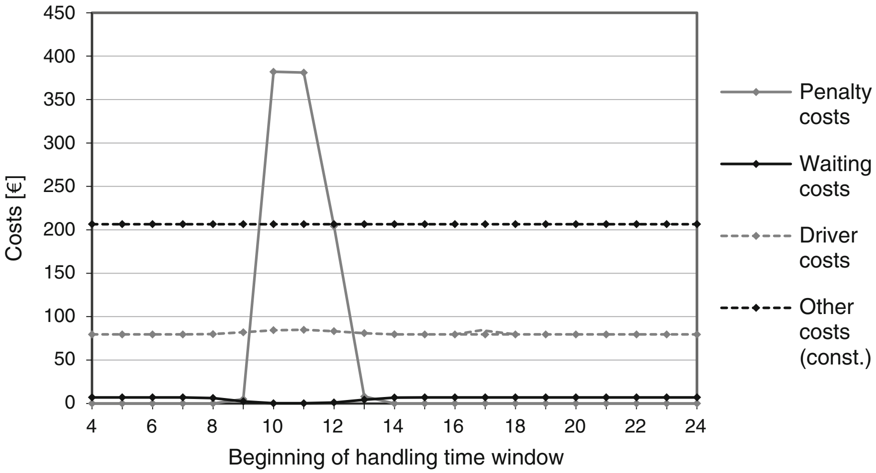

Fig. 17.4 Cost structure for various start times of handling time windows (arrival time window (t_{tw}) 10 min)

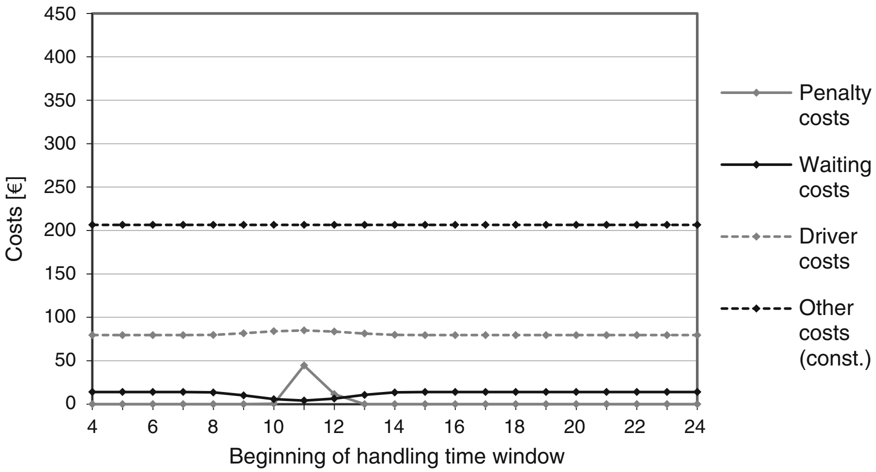

Fig. 17.5 Cost structure for various start times of handling time windows (arrival time window (t_{tw}) 20 min)

driving times of over 800 actual trips were between 210 and 215 min. According to the histograms the highest driving time variability could be observed for a start time of the handling time window at 11:00.

Regarding overall costs, these driving time distributions led to the costs structures depicted in Figs. 17.4 and 17.5 (mean values for 1000 actual trips). Those parts of the cost structure which only rely on distance (see Table 17.8) are summarized as 'other costs (const.)' in the diagrams as described above. In contrast, penalty costs, waiting costs and driver costs (driving time-dependent) vary for different values of the independent variables.

For an arrival time window of 10 min, high penalty costs can be observed due to comparatively high driving times. High penalty costs for start times of handling time windows between 10:00 and 12:00 (arrival time window 10 min) and at 11:00 (arrival time window 20 min) are caused by the peak in the traffic load curve in the morning (see Fig. 17.2). The high traffic demand in the morning is shifted to later hours due to congestion (many vehicles in the queue). Waiting costs were low for both time window lengths (10 and 20 min). Concerning the trade-off between waiting costs and penalties due to late arrival, waiting costs can almost be neglected for the time period between 10:00 and 12:00 (for both arrival time window lengths). For all other time periods waiting costs can also be considered as low compared to other cost items (e.g. driver costs).

However, an arrival time window of 10 min for a trip with a length of over 250 km can be considered as too small. In case of average penalty costs higher than 300 € more than three out of five actual trips arrived too late. 20 min or even longer lengths of the arrival time window seem to be more appropriate. Nevertheless, the influence of longer time windows on costs should be evaluated considering accidents, breakdowns, road work and other factors as possible reasons for traffic congestion.

17.5 Conclusion, Limitations and Further Research

The results of the simulation model highlight the crucial influence of penalties for missing time window constraints for the scenario described above. Even if the exact amount of penalty costs can vary considerably in practice, the payment of penalties can be seen as a relevant factor of the costs for road transport services. Caused by short arrival time windows, these penalties can outbalance the costs for waiting essentially. Therefore, route planning approaches should consider the trade-off between waiting costs and penalties in a detailed manner. While high traffic loads which were implemented in the presented simulation model can be anticipated by road freight carriers and forwarders by evaluating past travel times, traffic disruptions due to accidents or breakdowns are challenging to forecast.

Those uncertainties regarding travel times necessitate an extension of arrival time windows. The analysis of the simulation model results show the reduction of costs by using more extended time windows for route planning. Due to the high penalty costs compared to waiting costs, accepting additional waiting time seems to be reasonable for road freight carriers and forwarders. Additional disruptive events, like accidents and breakdowns, which are currently not included in the presented simulation model, are expected to make this result even more impressive.

Particularly for road transport services this change of cost structure needs to be observed carefully. To ensure the necessary profitability, road freight carriers and forwarders have to adapt their route planning processes to the increasing introduction of time windows accompanied by penalty costs. Reliability must be increased, without losing sight of cost efficiency. As a measure to increase reliability, for example, the use of two or more smaller vehicles for separate parts of the tour can be named. Through the use of complementary smaller vehicles additional flexibility and thus improved planning reliability can be achieved. Additionally, in cooperation with ramp operators the shifting of time windows to favorable times of the day (e.g. night) or extended ramp opening times are possible.

As already mentioned above, the presented work has several limitations. As one relevant limitation, the exclusive focus on traffic overload situations can be noted. Further disruptive events like accidents, breakdowns or bad weather could detail the results. Even if the qualitative results should not be affected, the quantitative values could gain on accuracy. Furthermore, traffic is considered in a simplified manner. The highway is modeled as a single, homogenous section without any intersections. Additionally, the traffic demand on the highway is modeled by a single traffic load curve for the whole length and the capacity of the highway is assumed to be constant. Hourly values for the capacity of the road section are also used for the calculation of the average speed for every minute. Hourly capacity values are typically lower than the corresponding values for smaller time intervals (Hohmann 2014). A more detailed approach including a precise model of the road network and different traffic load curves for different highway sections (with stochastic capacity) would help to transfer the results to real road systems.

The investigated scenario with time windows has not been compared with a scenario without any time windows. In this case uncoordinated truck arrivals may cause additional waiting times which could negatively influence the cost structure of road freight carriers and forwarders as well. Furthermore, a potential compensation of delays due to higher speeds (above 80 km/h on highways) is not considered in this work. In favor of a focused and distinct result, only a single trip is investigated instead of a more common tour with several stops. For tours with several stops there are dependencies between the segments of the tour. An increased driving time for one segment of the tour can also influence the probability on on-time arrival for other segments of the tour (Guiffrida and Nagi 2006).

The consideration of historical tour data (e.g. travel times, number of stops) of road freight carriers and forwarders and the integration of additional traffic data may represent two starting points for further research. As a continuation of the gained results, a closer look at the applied route planning processes of road freight carriers and forwarders could be of interest. Additionally, the overall economic impact of the implementation of slot management systems and the consequent introduction of time window constraints could be considered in future research.

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Part VI
Supply Chains and Networks

Chapter 18
Application of Service Engineering Methods for Developing a Functional Model for a Supply Chain Service Using the Example of the Air Cargo Supply Chain Service "CairGoLution"

Hans-Christian Pfohl and Tamer Kurnaz

18.1 Introduction

Air cargo supply chains are marked by heterogeneous broken structures. The involved actors are sender, consignee, handling agents, airport operator, forwarder and airline (Grandjot 2002). System disruptions between the involved actors are potential weak points in air cargo chains for internal and external attacks. Actors have to deal with a variety of system-external and system-internal risks to ensure a reliable logistics system.

Terrorist attacks are a major risk in air cargo supply chains. Attacks like on the 11th of September, 2001 or the increasing number of explosives findings in air cargo (for example, Cologne in 2010) during the past years makes clear the risen danger potentials in the air cargo chain. This situation led to legal innovations in the USA (for example, Implementing Recommendations of the 9/11 Commission Act, the US model Security programmes, the US all Cargo Internationally Security programmes) and in Europe (for example, EU orders 300/2008 and 185/2010). This regulation minimises single risks but offers no solution for all relevant security risks.

An alternative is to use a hybrid supply chain service, which enables the monitoring of the whole air cargo supply chain from sender to consignee. Hybride Supply Chain Service is a service bundle that consists of the provision of goods and the provision of services (see "CairGoLution"). Through monitoring the whole air cargo supply chain, all unauthorized accesses in cargo can be recognised and

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prevented immediately. Furthermore, unnecessary security checks can be prevented. Besides recognising external risks, it is also possible to monitor process parameters like process cycle time to prevent delays. Therefore, a hybrid supply chain service offers more extensive protection against external and internal risks in air cargo supply chains, like by safety measures established currently. In this paper, we introduce a functional model of a hybrid supply chain service in air cargo supply chains, which enables actors to deal with internal and external risks.

This contribution is embedded in the research activities of the national security research project “CairGoLution”, which is part of the topic “Securing Aviation” of the German security research programme. The project is initiated and financed by the Federal Ministry of Education and Research (BMBF). Goals of the project include an enhancement of security in the air cargo supply chain through use of real time transparency. This is achieved by the concept of hybrid technical solutions, which guarantees the integrity of unit load devices (ULDs) used in the air cargo supply chain. A ULD is a standardised pallet or container for air transportation. Project partners are the Technische Universität Darmstadt, Fraunhofer IIS, Cetec GmbH, DHL Express, DHL Customer Solutions & Innovation, DoKaSch GmbH and Escrypt GmbH. The project started on July 1, 2013 and will end on June 30, 2016.

This paper is structured as follows. In Sect. 18.2, we briefly display the current state of air cargo supply chains. In the connection the external as well as internal risks of the air cargo supply chains are analysed. This will provide an overview of the required features of a hybrid supply chain service for air cargo supply chains. In Sect. 18.3, we describe the service idea. In Sect. 18.4, the functions of the hybrid supply chain are derived by logical deduction directly from the identified risks in the air cargo chain. Finally, we give a conclusion in Sect. 18.5.

18.2 State of the Art of Air Cargo Chains and Risk Analysis

18.2.1 Air Cargo Supply Chains

An air cargo supply chain includes all technical and organizational processes which enable the transport air cargo from sender to consignee (Pfohl 2010; Vahrenkamp 2007). Air cargo is freight which is transported under conditions of transport of IATA (International Air Transport Association) (Vahrenkamp 2007). Mail is not included in this definition.

The air cargo supply chain is a multi-level, multi-modal supply chain that comprises three parts. These parts are pre-carriage, main-carriage and post-carriage. Only the main-carriage is performed using an airplane. The pre- and post-carriage are performed by ground-based vehicles, usually on the road. In the pre-carriage, air cargo is collected from different senders and transported to a consolidation point. The main-carriage may consist of several flights between several airports. In addition, the main-carriage can also be performed by road feeder services (Schieck

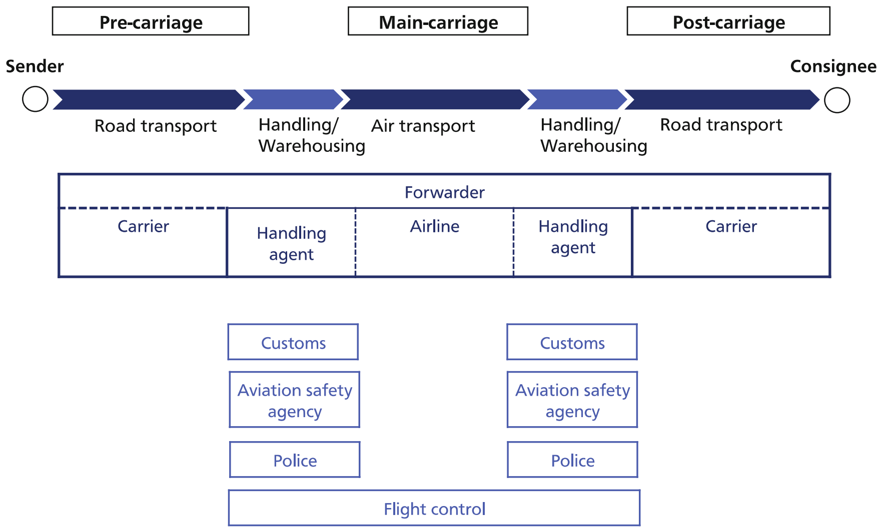

Fig. 18.1 Actors and process of classic air cargo supply chain

2008). The transport process between the destination airport and consignee represents the post-carriage. Between the parts there are handling and warehousing processes. Figure 18.1 illustrates this.

18.2.2 Risks in Air Cargo Supply Chains

There are various definitions of the term "risk". Generally, risk is an unpredictable event that may occur in the future (Waters 2007; Pfohl et al. 2008). Risk is characterized by uncertainty. The event occurs, and this is usually negative. Often, "risk" is used in connection with an adverse event, such as a damage or loss. This understanding of risk should also be used in the context of this paper.

The air cargo supply chain concerning risks can be divided into external and internal risks. The external risks are all risks which have their source outside of the air cargo supply chain. They result from the interaction with the environment (Waters 2007; Wolke 2008). Internal risks are defined as risks, which exist within the system of an air cargo supply chain. To analyse the risks, the method of the process analysis was applied (Solmon 2013; Scheer et al. 2006). On the basis of process maps, processes were analysed and the risks were derived. In following, the external and internal risks are described in detail. Figure 18.2 summarizes all identified risks and the process of their occurrence in the air cargo supply chain.

The external sources of risk can be divided into people-related risks and nature-related risks. A people-related risk is the smuggling of prohibited objects, like explosive objects. This risk exists in pre-carriage and in the handling process

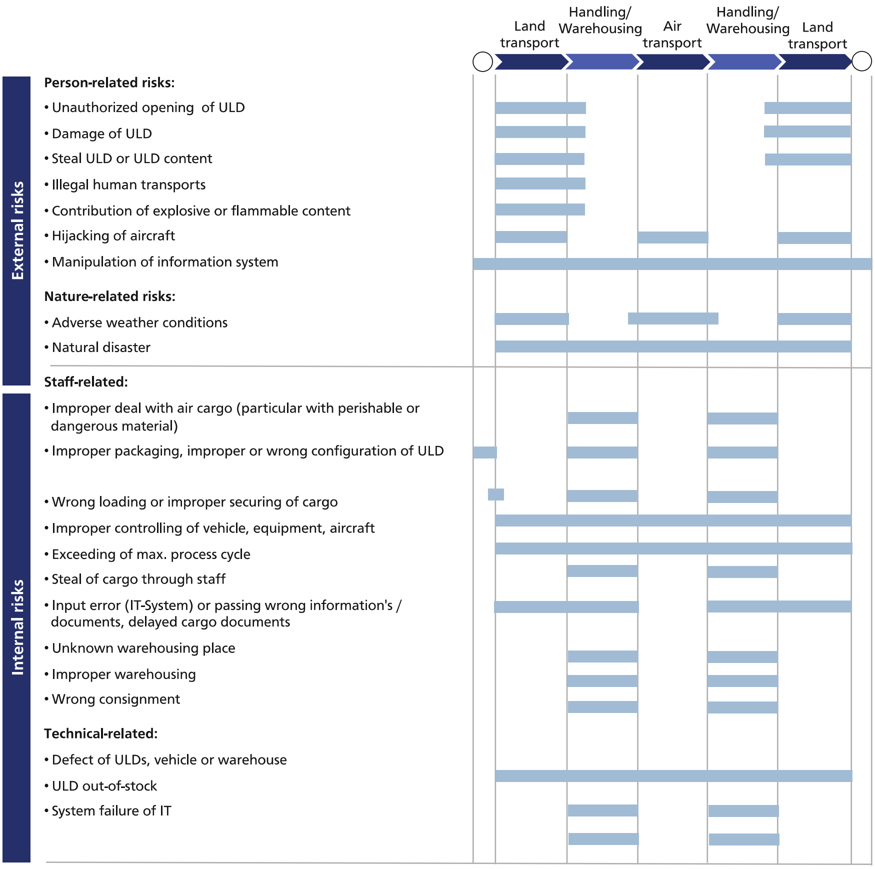

Fig. 18.2 Internal and external risks in air cargo supply chains

until the safety area of the airport is reached. Also listed is smuggle of contraband. Even, this must be done before the ULD reaches the safety area of the airport. Another external people-related risk is theft of goods.

A special form of people-related risk is staff-related risk. This risk exists internally. It is estimated that 85 % of thefts are caused during handling by staff (Solmon 2013). This risk occurs mainly in handling and consolidation processes (Solmon 2013). Thefts take place especially during weekends and at largely unguarded places. In addition to the smuggling of dangerous objects, contraband or theft may cause the opening or breaking of the ULD. This can also lead to cargo damage or loss. If the ULD is open the cargo can fall out or is no longer properly cooled or protected from light. Therefore, the opening of the container must be classified as a risk.

In addition, there are nature-related risks. For example, there are extreme weather events and natural disasters. Adverse weather events can cause damage to the cargo and ULD that lead to process delays or damage. Natural disasters can ultimately have a negative impact on the whole transport chain.

A staff-related risk factor is improper handling of ULDs in the handling process. In addition, air cargo can be damaged by choosing inadequate packaging or an unsuitable transport vessel. This is especially important for temperature-sensitive, fragile or perishable goods and dangerous goods in the handling and transport process.

In the pre-, main- and post-carriage, damage can be caused by the improper operation of vehicle, aircraft and technical equipment. The improper securing of cargo can also contribute to damage, particularly the risk of exceeding the process cycle time concerning perishable cargo. Risks can also occur during the warehousing process. This can lead to a strong capacity limitation of the logistics system and cause material damage and a clearance delay of perishable goods. Thus, the placing of containers in an undisclosed location in the warehouse or on the ramp leads to delays in the transport process if they cannot be found immediately. A further risk is that special cargo is not warehoused in the corresponding special place such as a refrigerated warehouse or a warehouse for valuable cargo. This can lead to damage to the cargo or to unauthorized access. In the handling process, the risk of wrong picking can lead to air cargo being transported to the wrong destination. In addition, the error rate of the processes may increase. A risk of damage during transportation and processing delays also arises if special ULDs are missing or damaged. Additional risks are caused by missing or incorrect information in the logistics process.

Besides flows of goods, there are also flows of information in logistics processes. Interruptions of information flows may occur, for example, because of typing errors in the IT system, incorrect information in the air way bill or delayed air cargo documents. An extreme case ultimately represents the failure of the IT-system. If air cargo documents are missing, e.g. at the customs control, process delays or hand searches of ULDs can occur.

18.3 Supply Chain Service Idea "CairGoLution"

In Chap. 2, the actors, processes and risks of the air cargo supply chain were discussed. In the processes of the air cargo supply chain, there are a variety of internal and external risks that lead to cost increases, damage of transported goods and process delays. External risks with high criticality are counteracted by EU Regulation 300/2008. The lack of monitoring is in the pre-carriage. This leads to security controls for suspected cases and leads to a significant cost increase. In addition, numerous external risks such as the theft in the wake of this are not counteracted. The logistics processes themselves contain risks such as improper handling of cargo. Since air cargo often consists of very high quality, perishable or fragile goods, there is a high risk of damage at this point. The hybrid supply chain service is an information service that collects extensive ULD- and cargo-related

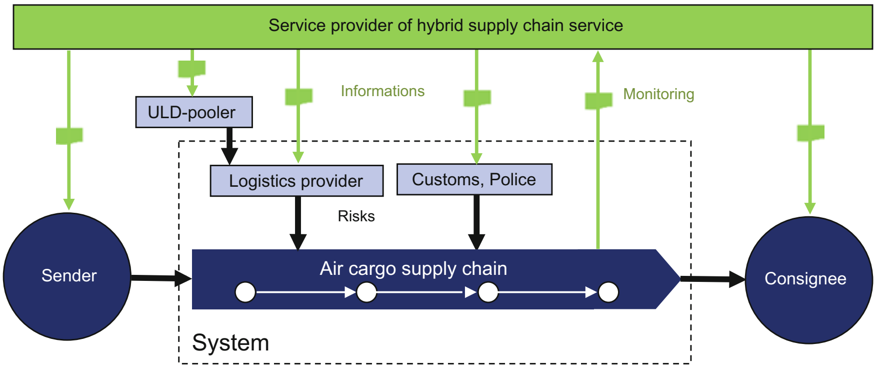

Fig. 18.3 Service idea—functions of hybrid supply chain service in the air cargo supply chain

data from the logistics processes and actors. The actors will be given the opportunity to use this information to identify risks and consequences of risks to avoid (see Fig. 18.3). The functions of service will be guided by the identified risks in Sect. 18.4.2.

18.4 Functional Model of CairGoLution

18.4.1 Methodology

The systematic development of services is a concern of the scientific field of service engineering. Service engineering is a relatively young discipline of Business Administration, which has developed since the mid-nineties. The aim of service engineering is to provide appropriate process models, methods and tools that enable the systematic development of services similar to the development of products or software (Scheer et al. 2006). Service engineering provides various process models for the development of services. Process models for services can be divided into linear, iterative and prototyping models (Bullinger and Meiren 2001; Preiß 2014). In linear models, services are developed in successive phases. In iterative models, it is possible to go back to earlier stages of development or go through the development process several times. Prototyping models are based on several development runs, in which preliminary versions of the product are developed and tested (Bullinger and Meiren 2001). Common characteristics of all process models are the identification of requirements and the derivation of functions (Bullinger and Meiren 2001). The identification of requirements leads to the same result with all phase models. Therefore, there is no need to decide on a process model. The results can be used in all three process models.

The basis for the development of a hybrid supply chain service is the identification of service requirements (Jung 2006). In the first step, it raises the question of

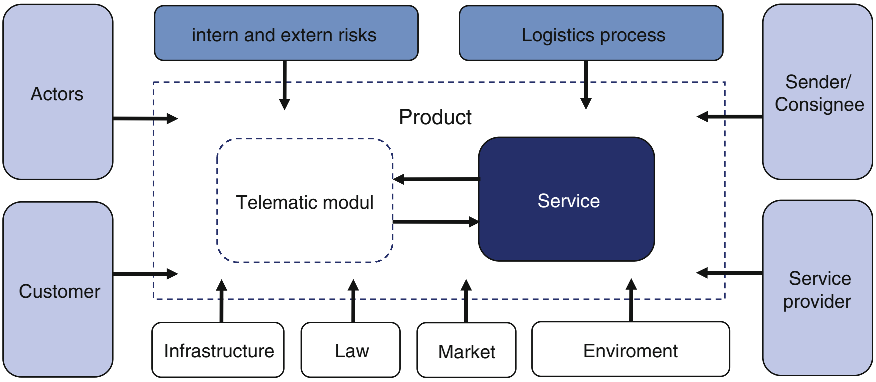

Fig. 18.4 Sources to identify requirements of hybrid supply chain service in the air cargo supply chain

how related requirements can be identified. The requirements of hybrid services take into account that the product is related to other elements of its environment (Jung 2006). Service and service environment cases can be considered as systems which have interfaces with each other. For the identification of relevant requirements, therefore, it is first necessary to consider the system of the service and its environment and to identify existing relations (Hua-An and Chien-Yi 2011).

The main interface consists primarily between technical system and service. Thus service performance must be tailored to the mandatory functions of the technical system. This is achieved by analysing the technical requirements list and documentation for the technical system. Other important requirements are defined by the actors. Furthermore, the benefit of this particular service consists of avoiding risks that affect the air cargo chain. Therefore, the air cargo supply chain risks form a core requirements source. Another request source is the operating company itself, which provides the service under certain economic interests. The service is addicted to the existing infrastructure, legal regulations, market conditions, and environmental and social aspects. Figure 18.4 shows all factors that must be included in the requirements analysis as an overview.

18.4.2 Functional Model

The main objective of the hybrid supply chain service is to reduce external and internal risks. The functions of the core service, therefore, are derived from the identified risks (Sect. 18.2.2). Figure 18.5 provides a comprehensive overview of the risks and which risk leads to which function.

Function 1 consists of the detection and reporting of integrity failures in ULDs. This information is reported to a control center and to the responsible actors. It enables the detection of external risk factors on the ULD, avoidance of risk consequences, and

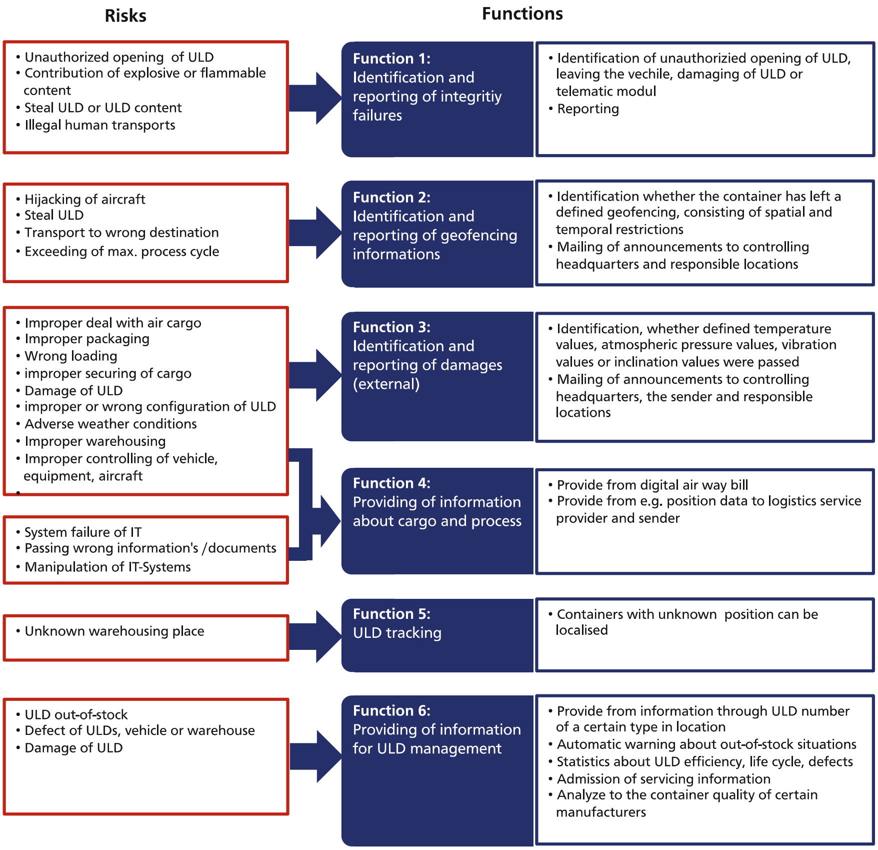

Fig. 18.5 Overview of functions of hybrid supply chain services based on identified air cargo supply chain risks

offers the possibility of claims investigation. A major benefit of this function is also to maintain the "secure supply chain" by unequivocally ruling that "safe" cargo is unsafe according to Regulation (EC) 300/2008 and Regulation (EU) 185/2010 through unauthorised access. The hybrid supply chain service provides security data for handling service providers, customs and federal police. On this basis, these actors can decide, whether cargo security controls shall be carried out.

Function 2 offers to the customer the option to set geofencing and to be informed if cargo leaves this geofencing during transport, storage or handling. The aim of this function is to prevent theft or provide information to clarify thefts.

Function 3 protects the cargo from damage. Factors which lead to damages are results of improper handling in logistics processes, technical failures or meteorological conditions. The goal is to be able to identify deviations of temperature, air pressure, vibration or inclination. This function is particularly important for temperature-sensitive, shock-sensitive, light- sensitive or moisture-sensitive goods.

Function 4 provides information about the supply chain process. Actors can use this information to reduce risks. Digital air freight documents provide a quick overview of the freight and logistics processes. In addition to the air freight documents, customs and federal police can check information about ULD parameters (temperature, moisture, etc.), occurred incidents, access to the ULD and the current position of the ULD.

Function 5 is to support the actors in the handling process to tracking the ULD. This is achieved by tracking and tracing with the telematics module, for example by entering the consignment number or ULD in the front end.

Function 6 supports the logistics service provider by inventory planning and maintenance of the ULD fleet by providing ULD-specific information. The ULD inventory planning has two main planning issues: first, the container deployment must be planned so that the required ULD is always available (Hua-An and Chien-Yi 2011). Second, existing ULDs must be replaced with new containers periodically. Both planning problems should be solved by the hybrid supply chain solution. To manage the ULD inventory, the hybrid supply chain solution provides information about available inventory and detailed information about certain types of ULD for selected locations. This information allows the creation of statistics on the use of ULDs and warns about out-of-stock situations. These functions allow the reduction of shortage, and on the other hand the reduction of safety stock. The reduction of safety stock is advantageous because large ULD fleets bind warehouse capacity and require maintenance. It also supports the maintenance and procurement processes. Providing information about damage and maintenance measures makes it possible to recognize the typical sources of damage and to carry out damage prevention. The data can also be used to derive statements about the quality of different ULDs for the manufacturer and this information can be used to determine the procurement strategy.

18.5 Conclusion

This paper had the goal of developing a functional model for a hybrid supply chain service for risk reduction in air cargo supply chains. After analyses of the air cargo supply chain and its risks, finally, a functional model was created which describes all risk-relevant functions of hybrid supply chain service. The described functions allow the logistics service provider for identify unauthorized access to the cargo, as well as damaging influences in logistics processes and this as soon as possible. With these functions, the product helps actors across the whole air cargo supply chain to deal with external and internal risks. In addition, the functions enable the actors to identify integrity failures in pre-carriage and to avoid unnecessary and time-intensive security checks. Furthermore, the functions offer the ability of process optimization through additional information.

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Chapter 19
A Holistic Approach to Measure Quality of Service in Freight Transport Networks

Albert Mancera, Dirk Bruckmann and Ulrich Weidmann

19.1 Introduction

This paper presents a holistic approach to measure quality of service in freight transport chains from shippers' point of view. The goal is to evaluate holistically intermodal and intramodal freight transport in order to get a harmonized performance of the quality, and to compare different elements of the transport chain with different characteristics. Moreover it aims to be used as a support for decision making in investment allocations and transport policy. The method is developed based on four requirements:

1. It must be applicable to all parts of the transport chain (logistic facilities and transport means).
2. It must answer major customer requirements.
3. Data to run the method should be available or measurable.
4. It must set standards so different activities of the transport chain can be compared in terms of quality.

In this paper these four requirements are expanded. In Sect. 19.2 "Standardization of the elements of the transport chain", concept 1 is developed. All transport chain parts are identified and delimited. In Sect. 19.3, "Quality of Service for freight transport" the known concept of QoS is applied to freight transport and shipper's requirements are identified and delimited. In Sect. 19.4, "Quality attributes" a selection of freight quality attributes is presented, based on literature review of research projects and scientific publications that use measurable indica-

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tors (concept 3). In Sect. 19.5, "Level-of-Service for freight transport" a standardized quality scale is presented which has been previously used to rank quality of heterogenic systems. In Sect. 19.6 "Conclusions", a summary of the paper and further work description are presented.

19.2 Standardization of the Elements of the Transport Chain

Freight transportation is the physical process of transporting goods from an origin to an intended destination. The process is divided in two different partial processes: transportation processes and logistic processes (Rodrigue et al. 2009). By combining transportation processes and logistic processes the freight transport operators transport goods. The combination of these processes is called transport chain (Fig. 19.1).

The United Nations (Terminology on combined transport 2009) define Intermodal Transport as:

> The movement of goods in one and the same loading unit or road vehicle, which uses successively two or more modes of transport without handling the goods themselves in changing modes.

It is important to distinguish it from Multimodal Transport, which consists in conveying one commodity with at least two different transport modes in an integrated manner. In this paper four transport modes, and their transshipment points, will be considered: road, rail, waterways and short sea shipping, main transport modes in the European network, and intermodal terminals as transshipment points.

19.2.1 Logistic Processes and Logistic Facilities

Logistic processes depend on the type of transport product (e.g., single wagon load, intermodal transport, full trains, etc.) and take place in a logistic facility. They can be simplified as: loading, unloading, transshipping, storing and shunting.

- *Loading* and *unloading* processes are those logistic processes responsible of moving the goods in and out the transport vehicle. These activities might be done manually or using mechanical devices such as cranes, forklifts, pipes (for liquids or bulk), etc., depending on the type of good and the equipment available. Operational standards must be followed to ensure safety and security requirements for goods and operators (see Fig. 19.2).

Fig. 19.1 Schema of a transport chain

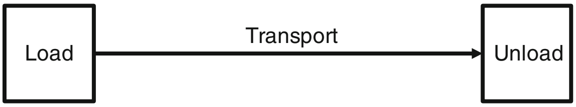

Fig. 19.2 Shipment schema with only loading and unloading processes

- *Transshipping processes* are those intended to transfer goods from one vehicle to another so the shipment can proceed. This activity can also be done either manually or by mechanical devices such as cranes, forklifts, pipes (for liquids or bulk), etc., depending on the type of good and the equipment available. Again, there are operational standards to be followed in order to ensure safety and security requirements for the goods and the operators. One special case of transshipment is Cross-docking. While transshipment processes often include temporal storage of the cargo in some warehouse, cross-docking consists in transshipping cargo directly from vehicle to vehicle (see Fig. 19.3).
- *Storing* is a logistic process that consists in placing goods in a dedicated location where they can be safely kept away from any type of weather or criminal actions. This location needs to be properly equipped so goods are saved according to their specific requirements. Storing can also be done either manually or by mechanical devices such as cranes, forklifts, pipes (for liquids or bulk), etc., depending on the type of good and the available equipment (see Fig. 19.4).
- *Shunting* is a vehicle sorting operation, which consists in exchanging positions of non-motorized vehicles within the same transport formation connected to a tractor vehicle or, switching a non-motorized vehicle from one transport formation connected to a tractor vehicle to a different one. This operation is mostly used in hub-and-spoke networks, either in rail, road or waterway systems (see Fig. 19.5).

Fig. 19.3 Shipment schema with transshipment process between loading and unloading point

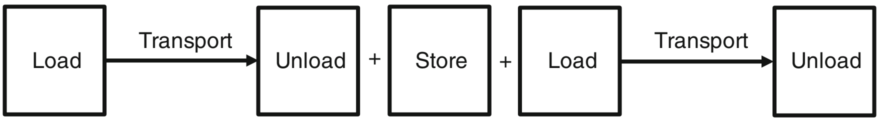

Fig. 19.4 Shipment schema with storing process between loading and unloading point

Fig. 19.5 Shipment schema with shunting process between loading and unloading point

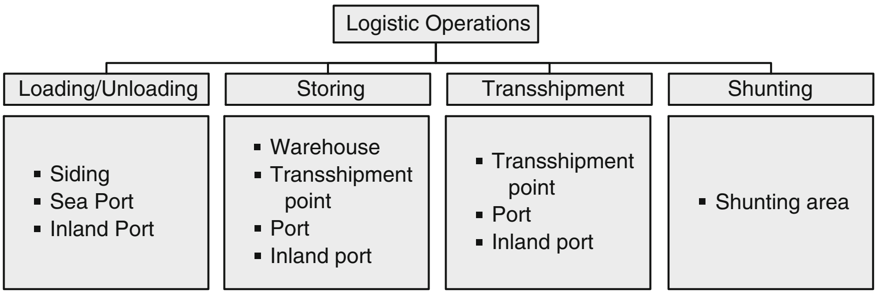

Fig. 19.6 Logistic operations, logistic areas and facilities

– In road transport, shunting is used to group, ungroup or sort combinations of tractor-trailer-semitrailer, tractor-trailer, tractor-semitrailer and tractor-semitrailer-semitrailer.
– In rail transport, shunting is mostly used in Single Wagonload networks to sort wagons in shunting yards either by gravity procedures or by using shunting locomotives.
– In inland waterway transport (IWT), shunting is used as well to sort combinations of push boat and barge(s) by the same principle. Some authors (Konings et al. 2013) name this operation horizontal handling process.

These logistic processes are carried out in logistic facilities that can be classified as: warehouse, siding, transshipment point, shunting area, seaport, inland port, etc. Figure 19.6 shows the existing logistic processes and indicates the logistic facilities where they usually take place.

Transshipment facilities are nodes of the freight network where cargo is assembled and/or dispersed. There is equipment for loading and unloading goods and areas dedicated to allocate the transport means. Usually these facilities are classified according to the type of cargo they handle (bulk, general or containers) and the type of transport mode allowed (only rail, only road, only IWT, only short sea shipping (SSS) and intermodal) (Rodrigue et al. 2009). Intermodal terminals are strategic areas where the different freight transport modes gather. The intermodal material (i.e., containers or swap bodies) are stored or transshipped from one mode to another. They are equipped with mobile or fixed equipment to load and unload the cargo and realize different logistic operations. Storing area for the cargo might be required (Younossi 2009).

Table 19.1 Factors influencing quality to evaluate in transshipment facilities

		Road	Rail	IWT	SSS
Road	Resources	E, P, C			
	Processes	L, S, T, Sh			
Rail	Resources	E, P, C	E, P, C		
	Processes	L, S, T	L, S, T, Sh		
IWT	Resources	E, P, C	E, P, C	E, P, C	
	Processes	L, S, T	L, S, T	L, S, T, Sh	
SSS	Resources	E, P, C	E, P, C	E, P, C	E, P, C
	Processes	L, S, T	L, S, T	L, S, T	L, S, T, Sh

E = Equipment; P = Personnel; C = Capacity; L = Loading/unloading; S = Storing; T = Transshipment and Sh = Shunting

Table 19.1 shows the relevant factors for the evaluation of the performance of the transshipment facilities. It sorts the transport modes available in the terminal by pairs. The case of Road—Road terminal describes a transshipment terminal only for road transport. A Road—Rail terminal is an intermodal transshipment terminal for road and rail transport. Trimodal terminals are not explicitly included in the table but the factors that need to be taken into account are stated for each type of transshipment. For instance a trimodal terminal Road—Rail—SSS like at Basel Port in Switzerland, can be evaluated by the factors of each individual transshipment (e.g., Road—Rail transshipment, plus Road –SSS transshipment, plus Rail—SSS transshipment).

19.2.2 Transport Processes and Transport Modes

Transport processes are carried out, in a continental context, along continental transport networks of different transport modes, e.g., road, rail, IWT and SSS. On the European level the requirements for transport infrastructure are defined in the TEN-T Guidelines.

Road

According to the TEN-T Guidelines, the TEN-T roads is composed of motorways and high-quality roads—existing, new, to be built or to be adapted. Road freight transport's strengths are more dominant in the short and medium distance transport, mainly in door-to-door transport. It also covers last mile shipments in intermodal long distance shipments. Its weaknesses are mainly the elevated costs per unit transported, smaller capacity and need for more personnel (compared to other modes). It also produces a higher pollution per unit than other modes.

Usually road freight transport is structured in Full-Truck-Load shipments (FTL), Less-Than-Truck-Load shipments (LTL) and intermodal containers. Using these load configurations several schemes of delivery can be organized. Each of them serves different client interests and commercial strategies, depending on the type of business they provide the service to. The main system types are:

- Door to door shipment: A FTL or container shipment goes from origin to destination on the same road transport vehicle without transshipping or getting stored anywhere.
- Feeder shipment: LTL shipments with different origins and same destination get shipped by different trucks until an specific location on their routes. The cargo gets reorganized in a bigger truck that can carry the full load of the resulting FTL shipment and it is shipped to the destination point.
- Liner shipment: LTL trucks that ship under regular schedules and load and unload cargo in commercial stops along their commercial route.
- Hub-and-Spoke: a set of road shipments containing cargo with different origins and destinations are organized by intermediate stops in hubs, where the cargo is redistributed by shunting procedures in case of FTL, or loading and unloading procedures in case of LTL or intermodal containers. Thus, the trucks that exit the hub ship the goods with identic destination point.

Rail

Rail is the strategic sector that offers the broadest possibility for the integration of transport in sustainable development. The guidelines define the TEN-T for railways of the 27 Member States as comprising high-speed lines and conventional lines. Rail freight strengths are in long distance transport, costs per unit transported, capacity, risk of accidents and pollution (compared to other modes). Its weaknesses are mainly in short distances, door-to-door and last mile shipments.

Rail freight transport uses freight wagons, and flat wagons carrying intermodal containers, swap bodies, and roll-on/roll-off (RORO) road vehicles. Within these possibilities different rail freight strategies can be offered:

- Block train: trains that ship goods between two terminals. The number of wagons may depend on the demand (block trains), or it can be a fixed formation (shuttle trains).
- Feeder train: Also called group trains, they are a combination of small trains of the same region that travel as a unique train for a long distance, although in a previous step they moved as independent trains from different origins.
- Liner train: regular service trains that can incorporate small terminal operations of intermodal transport such as loading and unloading intermodal containers on a fixed composition of wagons or coupling and uncoupling some wagons to and from the liner train.
- Single Wagon Load (or Hub-and-Spoke system): rail freight system than collects costumer sidings, collection fields, shunting areas, and distributions fields. Small groups of wagons are taken from private sidings to collection fields where they are coupled to other wagons from the same area. Then they are shipped to shunting areas where they are sorted according to their destination and coupled to a locomotive that will ship them to another shunting area where the train will be divided in smaller trains and they will be shipped to distribution fields.

Finally from these distribution fields the wagons will be driven to their destination sidings. This process usually involves different types of locomotives and power engines.

Inland Waterways

Consists of rivers, canals and its various branches as well as links which connect them. The TEN-T inland waterway projects aim to help connect industrial regions and urban areas and link them to ports. Its strengths are a high level of safety, less harmful to the environment than road and rail transport, fuel efficiency, reliability and cost, if distances are significantly long. The weaknesses are low speed, lack of flexibility, lack of accessibility, high investments in new barges and waterways, natural constrains and limited lock operating hours (Wiergmans 2007).

- Direct ship: traditionally barges and push boats containing bulk material that sail from one terminal to another directly.
- Liner ships: periodic IWT shipments that have a fixed route and that allow transshipment of containers in their commercial stops and also allow shunting of the barges attached to the push boat.
- Hub-and-Spoke: Although this system is not applied yet to IWT, there is some recent research done in this field that points out its potential. According to (Konings et al. 2013) potential benefits in economies of scale, reducing costs, reducing operations, and an effective way to enhance the hinterland of seaports.

Short Sea Shipping

Maritime transport is the backbone of international trade, yet its capacity has not been fully exploited in Europe. SSS strengths are lower freight rates due to inherent economies of scale and distance, unlimited capacity, safety of navigation, and lack of necessity for additional investment and superstructure except the harbors. Additionally, it can contribute to reduce the energy consumption levels. The weaknesses are the impossibility of a door-to-door transport service (the exception being for liquid and dry bulk cargoes), and the use of dedicated terminals and a network of well-located inland terminals (Paixão 2002).

Table 19.2 summarizes the aforementioned delivery strategies. Although there exist operational differences within modes, the delivery concepts are similar. Therefore these similarities will be used in this study to standardize the elements of the transport chain to obtain a systematic approach to freight operations so the evaluation tool can be robust. The performance of the processes is in both cases,

Table 19.2 Summary of shipment types per mode

	Road	Rail	IWT	SSS
Direct shipment	FTL	Block train Shuttle train	Direct ship	Direct ship
Feeder shipment	LTL + FTL	Feeder train		
Liner shipment	LTL + FTL	Liner train	Liner ship	Liner ship
Hub-and-Spoke	Hub-and-Spoke	SWL	Hub-and-Spoke	

transport processes and logistic processes, dependent of the infrastructure and the operations. Therefore, the quality resulting from each process needs to be calculated counting on those parameters.

19.3 Quality of Service for Freight Transport

In the early research projects the focus was centered on the econometrics of freight transport (Roberts and Wang 1979). Later on some researchers realized the relevance of commodity groups roles. Studies on willingness to pay of shippers showed that relevance of different aspects of the transport services vary depending on the type of good transported (Rapp Trans and Zurich 2008; Rapp Trans 2005; Bolis and Maggi 1999; Patterson et al. 2008; Bouffioux et al. 2006; Rapp Trans 2005; Vellay and de Jong 2003. Shipper needs depend on the type of commodity they ship therefore a segmentation of the freight transport market to specific commodity groups is required. The segmentation criteria for achieving consolidated groups with similar transportation needs falls to two conditions (Fries 2009):

- Modal-split values of the commodities within each group should be as similar as possible to avoid one mode dominated products in the group;
- Demand characteristics of shippers should be as similar as possible to augment statistical significance of the relevant criteria in the resulting model.

This market segmentation is suggested applying this criteria to the NST classification (see Table 19.3).

As mentioned, the transport chain can be described as a set of transportation and logistic processes that are combined to transport goods from an origin to a destination. The same logic is also intended to be used to quantify the quality of transport chains, i.e., to quantify the quality of the processes that when combined describe a transport chain, to calculate its overall quality. Several authors researched on the concept of freight transport quality.

Quality of service (QoS) can be perceived under different perspectives. Depending on the focus, one might define and quantify quality by different factors. The European Standard EN 13816 for Public passenger transport (European Committee for standardization 2002) explains different types of QoS and the relationships between them. It aims to provide guidance for defining, targeting and measuring quality of service. (see Fig. 19.7) The EN13816 norm defines four types of QoS:

- QoS sought, it is the one costumers would like to have.
- QoS perceived, it is the one costumers think they receive.
- QoS targeted, it is the one service providers would like to offer.
- QoS delivered, it is the one service providers really offer.

The first two QoS reflect the costumer's view, and the other two the service provider's one. The difference between QoS sought and QoS perceived is the

Table 19.3 Market segmentation according to (Fries 2009)

Group	Commodity groups	NST 2007
01	Agricultural raw material	Any type of agricultural and forestall material as well as textiles and waste paper. This group is characterized by low value products which NST classifies in groups 1, 6 and 14
02	Food and animal feed products	All kind of food products and fodder. Typically shippers of these commodities value on-time reliability and transit times due to perishable goods. NST group 4 as well as part of group 1 belongs to this group
03	Chemical and mineral products	NST groups 2, part of 3, 7, 8, and 9, which belong to the chemical industry and usually have similarities in their logistics and travel needs
04	Iron and metal products	Metal ores and other mining and quarrying products, basic metals and fabricated metal products. Most of the products have low specific value and are non-finished products, directly sold to end-costumers. It contains parts of group 3 and parts of 10 of NST classification
05	Building products	Parts of group 9 and 10 of the NST classification and that has specific logistic needs
06	Manufactured goods	Manufactured goods including general machinery and vehicles. The group is characterized by high value goods which shippers mostly worry about damage/loss and on-time reliability aspects of the shipment. The NST groups 5, 11, 12, 13 and 16. are part of this commodity group
07	Other products and containers	All products that don't fit in any of the previous categories, which in NST classification are groups 15, 17, 18, 19 and 20. General not specific cargo falls into this category

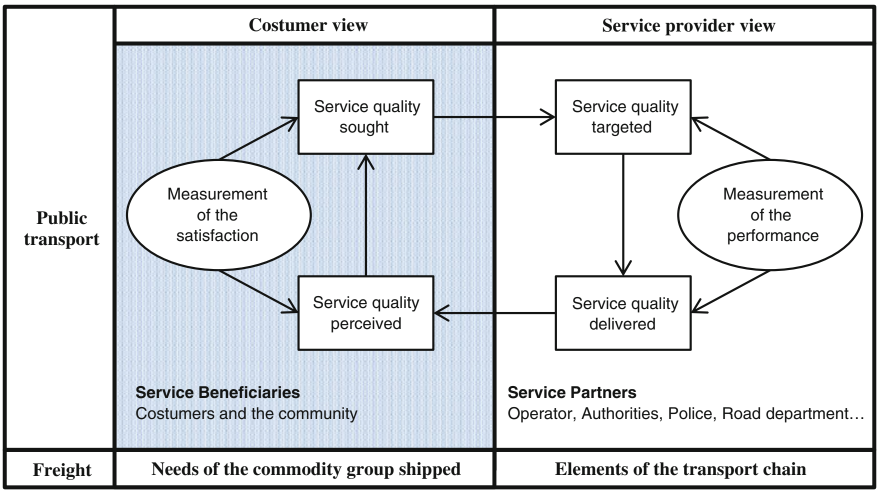

Fig. 19.7 Modification of the QoS loop (European Committee for standardization 2002)

degree of customer satisfaction. The difference between QoS targeted and QoS delivered is a measure for the service provider's efficiency. The difference between QoS sought and QoS targeted is a measure for the capability of the service provider to direct their efforts towards the costumer quality needs. The difference between the QoS perceived and the QoS delivered is a measure of the knowledge of the costumers about the real function of the service delivered.

Adapting this concept to freight transport, the four QoS can be divided to "shipper's view" and "transportation and logistics provider's view". Therefore the QoS sought is the quality the shippers expect to have, or in other words, a high QoS. The QoS perceived is the quality received, under shipper's opinion, during a transport service. The difference between QoS sought and QoS perceived is the relation that indicates the Level-of-Service (LoS) perceived by the shipper. Detailed information about LoS are mentioned in Sect. 19.5.

19.4 Quality Attributes

Research in freight transport has been considering freight attributes since the very first attempts to describe freight behavior. Attributes represent certain characteristics of a system or an object: In this particular case, freight transport quality. They define specific aspects of transport or logistic processes quantified by the indicators. Table 19.4 indicates which freight quality attributes are used in reviewed research work.

According to Table 19.4, the most used attributes are transport or transit time, reliability, safety, frequency, flexibility and accessibility (this last one is mostly used for evaluating freight terminals). A LoS for freight transport can be build up on a subset of relevant attributes. Indicators need to be selected to quantify each attribute. For a given attribute, different indicators might apply depending on the process type (logistic or transport wise) or transport mode. In Sect. 19.5, an example of two indicators linked to two attributes is presented.

Next, interrelationships between attributes need to be quantified. To do this, a first step is to run a SP and RP shippers survey where the important attributes for each market segment can be identified. Furthermore, the results should enable the construction of a frame that weighs attributes according to their relevance for each market segment (see Fig. 19.8). The intended steps to achieve this are as follow:

- Develop a hierarchic list of attributes, measured by indicators, per commodity group, $\{I_1, I_2, \ldots, I_N|_{Commodity\_Group\ j}\}$, that state which indicators are more relevant in terms of transport quality for each commodity group.
- Establish the quality levels for each indicator per commodity group, $\{V_1, V_2, \ldots, V_N|_{Indicator\ i}\}$.
- Develop an algorithm to combine these items to calculate an overall LoS, e.g. given the values for each indicator $\{I_1, I_2, \ldots, I_N\}$ for a process and a commodity

Table 19.4 Freight quality attributes used in different studies

Attributes	Document/Paper/Study							
	(Beuthe and Bouffioux 2006)	(Ruesch et al. 2005)	(Arvis et al. 2014)	(Ballis 2004)	(Wang et al. 2014)	(Danielis and Marcucci 2007)	(Feo-Valero et al. 2014)	(Cargo et al. 2015)
Frequency	X		X			X	X	
Reliability	X			X		X	X	X
Safety	X	X		X	X	X		
Travel time or transit time	X	X		X	X	X	X	
Flexibility	X			X		X		X
Accessibility		X	X	X				X
Efficiency		X	X		X			
Rapidness							X	X
Information			X					X
Adaptability								X

group j, QoS = $f(I_1, I_2, \ldots, I_N)|_{Commodity\_Group\ j}$. This QoS corresponds to a LoS depending on:

- $LoS(x_i) = A \Leftrightarrow QoS(x_i) \geq V_{iB}$, and V_{iB} is the minimum value of the LoS A.
- $LoS(x_i) = B \Leftrightarrow V_{iB} \geq QoS(x_i) \geq V_{iC}$, and V_{iC} is the minimum value of the LoS B.
- $LoS(x_i) = F \Leftrightarrow V_{iF} \geq QoS(x_i)$, and V_{iF} is the minimum value of the LoS E.

19.5 Level-of-Service for Freight Transport

Indicators allow to quantify freight transport performance, by evaluating certain attributes of freight service. Standards need to be set so different activities of the transport chain can be compared in terms of quality. Many researchers agree on using the LoS concept to set quality standards in similar systems, such as road transportation (Highway Capacity Manual 2000; Forschungsgesellschaft für Strassen- und Verkehrswesen 2002), public transportation (Orth et al. 2012; Orth et al. 2013), pedestrian and cycling transportation (Scherer et al. 2010), or even freight terminals (Ballis 2004). It is aimed to use the LoS classification due to its great acceptation on the sector and its clearness.

The LoS follows a six level structure, from A to F, being A the highest quality and F the lowest. The levels depend on the selected attributes to calculate quality. Given a value of an indicator that quantifies an attribute, this attribute may fall into one level or another (see Fig. 19.8). The combination of the levels of each attribute used to determine the quality of a segment of the transport chain provide the LoS.

For instance, we can take a look at the road LoS diagram (see Fig. 19.9). On the vertical axis there are the speeds that a driver can reach on the lane, and on the

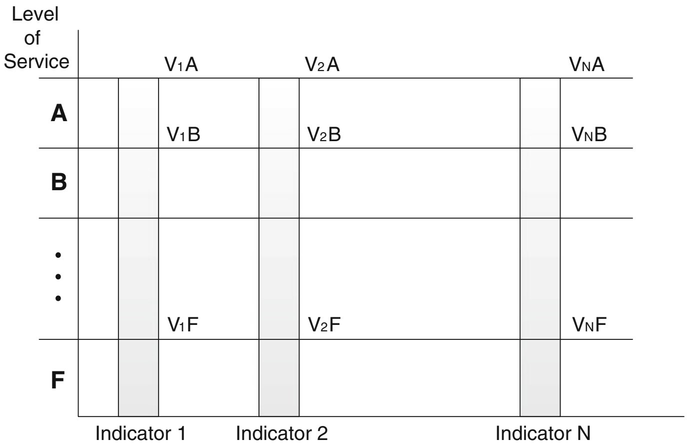

Fig. 19.8 Intended structure of QoS for a given commodity group

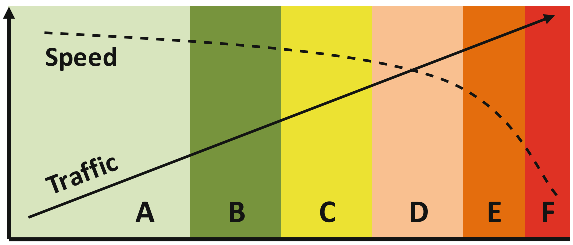

Fig. 19.9 Levels of Service (Highway Capacity Manual 2000)

horizontal numbers there are the levels (A–F). In diagonal there is the density of cars on the lane. It can be observed that when de density of the lane increases, the speed decreases (red discontinuous line), and the LoS decreases as well. In that case, the LoS is represented by 2 indicators, speed and density.

Usually, for any A–F LoS classification, values from A to D are acceptable values of performance and E and F are not acceptable. Therefore if an infrastructure or service rank E or F means that they are not suitable for the service they have been designed to. In this paper, levels of the LoS are described as follows:

- A—This level describes the best quality of service. The indicators used to evaluate the relevant attributes for the process rank in the best 10 % performance possible.
- B—This level is slightly below the best quality of service. The indicators used to evaluate the relevant attributes for the process rank just between the best 10 % performance possible and the best 20 %.
- C—This level implies some minor disruptions on the quality of service. Some of the indicators used to evaluate the relevant attributes for the process rank poorly but still manage to be between the best 20 % and the best 35 %.
- D—This level offers the last acceptable quality of service. Some of the indicators used to evaluate the relevant attributes for the process rank poorly (below the best 35 %) but still manage to be above the average.
- E—This quality of service not acceptable. The indicators used to evaluate the relevant attributes for the process rank below the average performance.
- F—The service is not offered anymore. Total disruption of the service.

We take for instance a part of a rail freight shipment. The attribute travel time, measured by the indicator “commercial speed”, and the attribute terminal accessibility, measured by the indicator “working hours per day” (see Table 19.5).

Assuming this is a good sample of European rail freight commercial speeds, the LoS for travel time derived from this data sample correspond to the following values (Table 19.6). Values for evaluating freight terminal LoS (Ballis 2004) are also included.

From this example it can be derived that, in terms of transport process, full trains for bulk freight offer a LoS D concerning average speed, SWL services offer a LoS between D and B concerning average speed and express trains for postal services

Table 19.5 Rail freight commercial speed (Frank 2013)

Commercial speed (km/h)	Full train for bulk freight	SWL	Express train postal service
Minimum	51	64	59
Average	56	71	81
Maximum	59	86	105

Table 19.6 Example of LoS for travel time and terminal accessibility

LoS	Commercial speed (km/h)	Working hours per day (Ballis 2004)
A	>90	24
B	80 > 89	16
C	65 > 79	16
D	50 > 64	16
E	35 > 49	8
F	<34	System breakdown

offer a LoS between D and A concerning average speed. Depending on the accessibility to the rail freight terminal, the LoS of the system (transport + logistic operations) will be better or worse. In other words, if travel time rates A but the accessibility rates F, it is not possible that the system rates A. Additional work needs to be done to determine which are the exact mechanisms to calculate the overall LoS of a system using the LoS of its elements.

19.6 Conclusions

The requirements to build a holistic method to measure QoS in freight transport chains from shippers' point of view have been presented: A standardization of the transport chain elements, a description of QoS from four possible points of view (shippers' point of view among them), an appropriate market segmentation, a selection of freight quality attributes and a metric for a freight quality LoS.

This paper shows that it is plausible to develop such a method. It presents consistent information about how to analyze a freight transport chain quality-wise. Some concepts are already used and accepted by the research community, such as market segmentation, QoS, freight quality attributes, indicators and the LoS concept. Linking these existing concepts to design a new evaluation method is an accomplished task.

Therefore, this paper could be considered as a first stone towards the construction of a LoS for freight transport. The authors suggest to carry on a SP and RP experiment to collect shipper's preferences on freight attributes. Results should be classified by market segment, and analyzed to calculate relative importance of attributes and derive their weighing. Furthermore, a literature review on freight indicators should be conducted. It will allow the selection of indicators for each attribute, process and mode.

Finally the method needs to be tested with real data and used to evaluate some freight shipments, freight corridors and freight networks. Synergies to combine LoS from transport chain elements to calculate an overall LoS of a transport chain need to be developed.

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Chapter 20
Supply Chain Collaboration or Conflict? Information Sharing and Supply Chain Performance in the Automotive Industry

Liyuan Wang, Hans-Christian Pfohl, Ulrich Berbner and Anna Katharina Keck

20.1 Introduction

Most supply chains are composed of independent companies with individual preferences (Fiala 2005). To coordinate supply chain activities and overcome supply chain dynamics, information sharing is widely employed as an essential tool to enable timely and accurate decision-making and supply chain collaboration (Sahin and Robinson 2002; Moberg et al. 2002; Chana and Chana 2009; Yigitbasioglu 2010).

Many studies have investigated different factors affecting information sharing and collaborative behaviour in supply chain management, such as trust and power (Yeug et al. 2008; Shou et al. 2013), trust and commitment (Kwon and Suh 2005), trust, commitment, reciprocity, and power (Wu et al. 2013), and conflicts (Simatupang and Sridharan 2002). However, few studies have investigated how the decision-making antecedents including organizational goals, inter-organizational

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conflict of goals, power, and trust (GCPT) interact with information sharing behaviour and how information sharing affects supply chain performance.

Although there has been a growing stream of studies on information sharing in supply chain management, the predominant approach of such studies is to simplify the industrial context so that the basic underlying trade-offs can be explained analytically using quantitative modelling. However, simplifying the industrial context compromises the external validity of the results by eschewing the realistic environments such as multi-echelon supply chains with multiple products (Sahin and Robinson 2002) and thus hinders cumulative theoretical development and further illumination of the underlying decision-making mechanism. Also, existing quantitative studies which mainly focus on hypothesis testing are limited in facilitating a better understanding of decision-making antecedents and therefore are not able to give better insights into the "black box" of supply chain decision-making process.

Based on the above we apply an exploratory multiple case study approach aiming to answer two research questions:

1. How do the decision-making antecedents and supply chain information sharing/retaining in the multi-tier supply chain of the automotive industry interact?
2. What is the relationship between information sharing/retaining and supply chain performance?

Due to the inherent complexities of the decision-making context, the case study examines four essential aspects of the decision-making context: organizational goals, inter-organizational conflicts, power, and trust (Handfield and Bechtel 2002; Johnston et al. 2004). It should be noted that the following are results of a case study considering a limited range of the decision-making context of information sharing/retaining. Other factors, such as incentives (Eisenhardt 1989) and relational norms (Heide and John 1992) may also have an impact on the information sharing/retaining behaviour but are beyond the study's research scope. The study focuses on the multi-tier supply chain relationship, as it best reflects the supply chain configuration in the automotive industry and avoids drawbacks of studying the dyadic relationship in a supply chain (Wu et al. 2010). Inter-organizational information sharing is treated as a multidimensional concept.

Drawing on supply chain management theory, this study aims to identify the relationship between decision-making context and information sharing/retaining behaviour as well as the impact of information sharing/retaining on supply chain performance. To achieve this objective, the remainder of the study is structured as follows: First, a review of the pertinent literature is conducted to set our theoretical background and thereby develop a preliminary research model. Second, the methodology of the case study is explained. Next, the findings and the resulting propositions are elaborated. Conclusions, limitations, and avenues for future research are presented in the final section.

20.2 Theoretical Background

This section starts with reviewing the literature pertaining to the course of investigation and then provides definitions of GCPT in the research model, as illustrated in Fig. 20.1.

A company's success depends on the interaction between five interlocking flow systems, namely the flow of information, materials, money, manpower, and capital equipment (Forrester 1958, 1961). The flow of information is often considered as a generic remedy for supply chain ailments (Forrester 1958; Lee et al. 1997) and its advantages have been intensively discussed (Cachon and Fisher 2000). Though important, some researchers have argued that information sharing, per se, is insufficient to enable significant supply chain performance improvements (Hong-Minh et al. 2000; Baihaqia and Sohalb 2013). Supporters of this argument claim that the significance of its impact on supply chain performance largely depends on which information is shared, when and how it is shared, with whom (Holmberg 2000) and how it is used. Companies may opportunistically use information without considering total supply chain goals and objectives. Other researchers adopt a different angle to view information retaining and claim that companies seem to have a built-in reluctance to share more than minimal information with their trading partners (Berry et al. 1994). Information transparency thus becomes the weakest link of the supply chain (Coleman et al. 2004). It is suggested that conflicting goals, divergent interests, local perspective, opportunistic behaviour of maximizing individual profit, and different ways of interpreting customer information may become obstacles for the efficient information sharing among supply chain partners (Simatupang and Sridharan 2002; Feldmann and Müller 2003).

To foster information sharing among supply chain partners, some researchers emphasize the importance of building trust, commitment, and system coordination (Christopher 2011; Sahin and Robinson 2005; Wu et al. 2013). Other researchers consider trust, commitment, reciprocity, and power the antecedents of supply chain information sharing and collaboration (Wu et al. 2013). We focus on four key

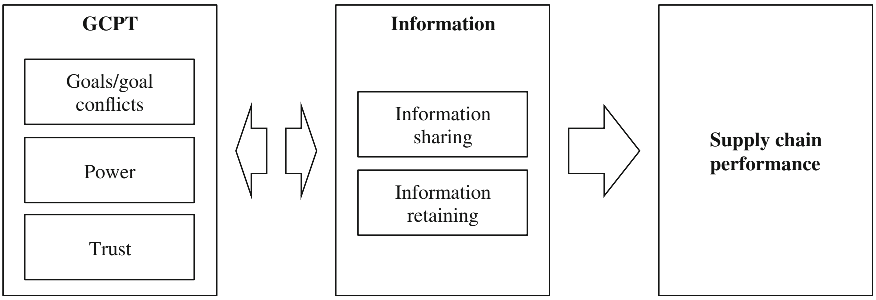

Fig. 20.1 Research model

aspects of the decision-making antecedents in this study—organizational goals, inter-organizational conflicts, power, and trust.

Based on the dimensions suggested in the sand cone model (Ferdows and De Meyer 1990), organizational goals in this study are examined based on quality, time, flexibility, robustness (Wagner and Bode 2006), and cost. It should be noted that the purpose of this paper does not correspond with the idea to study whether the manufacturing performances are related in a cumulative manner as the sand cone model implies, a trade off model (Skinner 1969; Slack 1991), or an integrative model (Clark 1996). As every company aims to achieve its own goals and gains the best position in the system, it does not always take into account any ethical principles or altruistic behaviour for instance (Crane and Matten 2010). Thus, inter-organizational relationships are established and maintained for causes of self-interests (Shook et al. 2009). The often conflicting goals of the supply chain members may pose many challenges for effective supply chain integration and information sharing (Sahin and Robinson 2002).

Conflict is defined as the circumstance in which a supply chain member's organizational goal is impeded by another and the supply chain performance is adversely affected (Gaski 1984). Although sources of conflicts on the supply chain level such as the incompatibility of the decision makers' underlying objectives, dysfunctional role definitions, and varying perceptions of the reality can hardly be directly observed or foreseen, they can be reflected by the decision outcomes (Blackhurst et al. 2008). Although a certain degree of conflict is inevitably inherent in all kinds of exchange relationships, not all conflicts are counterproductive (Anderson and Narus 1990).

As one of the main determinants of coordination and conflict among supply chain members, power refers to a company's ability to control the decision variables of other exchange members as a result of relative dependence between exchange members (Stern and El-Ansary 1992; Gaski 1984). As power results from asymmetricly distributed resources (Pfeffer and Salancik 1978), organizations with control over the demanded resource such as critical information consequently have more power (Hallen et al. 1991; Wu et al. 2013). Information disclosure can thus be considered as a potential loss of power. Companies fear that information may either leak to potential rivals or weaken their negotiation advantages (Li and Lin 2006). Examining the relationship between power and conflict, Gaski (1984) argued that conflict can be either a cause or a consequence of power, in other words, a non-recursive relationship. Because a company's potential power is less traceable and less measurable than the exercised power (Gaski 1984; Stern and El-Ansary 1992), we focus on the exercised power in this study.

Trust is a company's subjective state of positive expectations that its partner will perform an action to benefit the company's interests irrespective of the control on the partner (Mayer et al. 1995; Das and Teng 2001). There are two dimensions of trust: competence trust meaning a partner's ability to perform according to agreements, and goodwill trust meaning a partner's intentions to do so (Nooteboom 1996; Das and Teng 2001). Trust is a key element in cooperative relationships at the inter-organizational level (Ring and Van de Ven 1992). A high level of trust would motivate partner firms to openly communicate and jointly take/share risks (Corsten and Kumar 2005; Kwon and Suh 2005).

Supply chain performance is largely determined by the achievement of the supply chain objectives, which are to provide value to the end consumer and for each supply chain exchange member to garner a profit (Sahin and Robinson 2002). To evaluate the impact of information sharing on supply chain performance, we focus on the type, accuracy, frequency, and timeliness of information sharing (Carr and Kaynak 2007).

20.3 Method

Due to the holistic nature of the investigated phenomenon and the exploratory nature of the research questions, an exploratory multiple case study approach (Eisenhardt 1989) is favoured, which allows a holistic study and comparative setting in seeking to answer "how" and "why" questions (Yin 2003).

The case study's main objectives are to examine the information sharing/retaining practice in the supply chain of the automotive industry, to learn about its underlying decision-making context and to investigate the relationship between information sharing/retaining and supply chain performance. Data was collected in semi-structured interviews, which were protocolled and, if permitted by the interviewees, also recorded, transcribed, and analysed by applying methods such as qualitative content analysis (Gläser and Laudel 2009) and data triangulation. The research framework follows a four-step logic path, as shown in Fig. 20.2.

An integral step before conducting qualitative research is the development of the interview guideline. To avoid biased data and to maintain data integrity, independent experts revised the interview guideline several times. In addition, the triangulation

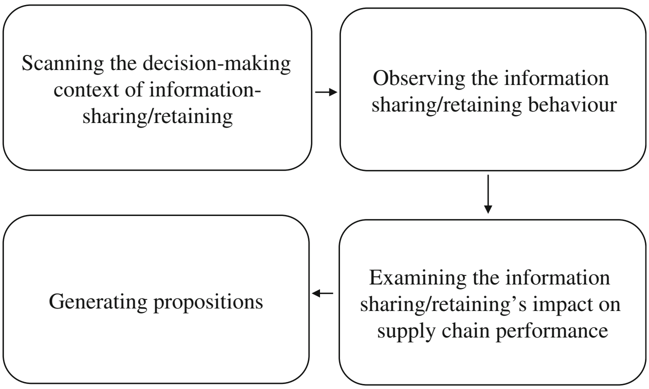

Fig. 20.2 Research framework

Table 20.1 General characteristics of the selected cases

Company (code)	Country of origin	Annual turnover	Job function of interviewees
OEM (T0–1)	Germany	>50 bn. €	Manager of spare parts logistics
1st tier supplier (T1–1)	Germany	>10 bn. €	Manager of strategic supplier management
1st tier supplier (T1–2)	Germany	>10 bn. €	Project manager of sourcing
1st tier supplier (T1–3)	Germany	>1 bn. €	Project manager of logistics
1st tier supplier (T1–4)	Germany	>10 bn. €	Manager of technical sourcing
2nd tier supplier (T2–1)	Germany	>1 bn. €	Manager of customer logistics
3rd tier supplier (T3–1)	Germany	>250 mi. €	Supply chain manager
3rd tier supplier (T3–2)	China	Not disclosed	Manager of customer support
Logistics service provider (LSP-1)	Germany	Not disclosed	Managing directors

approach (Webb et al. 1966) was adapted. Up to three facilitators interviewed a total of ten interviewees from nine different companies. These companies were selected based on their buying-supplying relationships in the supply chain, which consisted of a buyer, suppliers, suppliers' suppliers, and the logistics service provider of the buyer. The general characteristics of the selected cases are summarized in Table 20.1. In addition, data from secondary sources such as company archives, scholarly books, and articles were displayed. The two primary facilitators who guided all interviews in the field transcribed the recordings, coded the transcriptions and later performed a comparison of the coding results. We applied the software MAXQDA for qualitative data coding and analysis according to scientific qualitative data analysis techniques (Strauss and Corbin 1989; Gläser and Laudel 2009). The approach of methodological and multi-investigator triangulation ensures that the course of our investigation is not explored through one lens, but rather a variety of lenses. This allows for multiple facets of the phenomenon to be revealed and thus enhances confidence in our findings (Denzin 1970).

20.4 Findings

20.4.1 Observation of Inter-organizational Goal Conflicts

During our case study, we were able to observe manifold goal conflicts on the inter-organizational level. Goal conflicts where observable based on past decision processes where not all involved parties were content with the decisions' outcome. Intuitively, we could observe classical conflicts of goals among quality, flexibility, and cost between supply chain members. However, it seems that there is not always a trade-off between those highly interrelated goals, according to the interviewees.

> Interviewee from LSP-1: Quality and flexibility do not exclude each other; instead they belong to each other. If you are not able to keep up with quality concerning flexible action, you have lost already.

In the supply chain context, which includes multiple decision makers, it is not easy to foresee goal conflicts, since they are not easily identifiable on the goal level, but often only become apparent when a decision is made. This is complicated due to the fact that goal conflicts might change dynamically over time.

> Interviewee from T0–1: The potential for conflict outside the company is already very high.
> Interviewee from T1–4: But this is what I mean with conflict: The supplier has other goals than we have. Then it is all about recognizing this.
> Interviewee from T1–4: It is indeed the case that goal conflicts and the essence of conflicts shift dynamically over time, because the general business conditions are changing.

Thus, for effective mitigation, goal conflicts have to be identified early. Understanding how those antecedents are related to goal conflicts will facilitate the further development of conflict-mitigating measures.

> Interviewee from T2–1: And therefore, the conflicts should be mitigated beforehand, by securing some level of possibilities for reaction.

20.4.2 *Impact of GCPT on Information Sharing/Retaining*

While information exchange can facilitate the mitigation of goal conflicts, it might be the subject of goal conflicts themselves, since often, companies are not willing to pass on information in order to secure information asymmetries and to gain advantages from not sharing information like cost data and inventory data.

The information sharing/retaining behaviour among LSP, tier-2, tier-1 and OEM observed in our study confirmed the interaction effect of GCPT. Power effect can be reflected by information control (Shou et al. 2013). Similar observations have been found in our interviews. OEMs increasingly try to shift supply chain complexity and risk to their suppliers using coercive power. They trust in highly automated information exchange on the operational level and thus require their tier-1 suppliers to adopt the same operational standards (e.g. delivery concepts) and enforce them to implement robustness and flexibility-related strategies to absorb emerging volatility. The coercive power of OEM is found to fuel the information sharing of tier-1 suppliers with the OEM (Yeung et al. 2008). Nonetheless, provision of the right information at the right time to the right person cannot be enforced, as this behaviour largely depends on the trust between OEM and its tier-1 suppliers.

> Interviewee from T1–4: We wrote it as a requirement in the contract, that we need clear communication in this case (…). Even if he [the supply chain partner] signs this, there is of course still the question whether he does comply with it.

Proposition 1 The more a firm's decision-making is influenced by the power of a supply chain member, the more likely the firm will share information with its supply chain member.

While we did find a high level of competence trust on the level of OEM-tier-1 relationships, the observed goodwill trust is somehow limited. Tier-1 suppliers show reduced willingness to share information if the information could potentially weaken its competitiveness. In this case, tier-1 suppliers hold back information if they engage a strong position in the supply chain.

> Interviewee from T1–1: There has been an OEM initiative in order to gain knowledge which parts were sourced from which supplier. In this case, we have been really reserved. Our position permitted us to do so. So we could say: Our information, no way, our business.

For example, critical information on raw material prices and its sub-tier supplier network is rarely shared, even in a highly integrated and trustful cooperation. Several reasons why such information is considered sensitive could be identified: Suppliers fear being bypassed by their customer, which might in the future source directly from its' sub-suppliers. Suppliers also fear the erosion of margins due to sales price decrease and also, that with the provision of information on their sub-suppliers and underlying sourcing strategies, they might disclose potential supply chain risks to their partners.

Tier-1 suppliers in our study show limited competence trust in their suppliers, the majority of which are medium- or small sized companies. Therefore, tier-1 suppliers have to react on volatility by tightly integrating their suppliers on the informational level, making goodwill trust a key issue of those partnerships. Information provision is enabled through the high buying power towards the smaller tier-2 suppliers. Problematic in this area usually is the lack of advanced standards, capabilities and communication technologies of tier-2 companies that are required to share the right information.

Proposition 2 The more a firm's decision-making is influenced by the power of a supply chain member, the more likely the firm will share information with its supply chain member.

Proposition 3 The more a firm's decision-making is influenced by its trust in a supply chain member, the more likely the firm will share information with its supply chain member.

20.4.3 Impact of Information Sharing/Retaining on GCPT

We have seen that company-internal goal conflicts lead to ill-designed goals on the supply chain level impeding supply chain integration and leading to conflicts between supply chain partners. We could also observe suppliers knowing their customers' processes better than themselves due to lacks of internal information exchange. Improved company-internal information exchange between departments like logistics, purchasing and production can therefore lead to better overall goal alignments and fewer conflicts. In practice, setting up internal documentation standards and guidelines, which e.g. define processes and responsibilities have led to reduced conflicts on the supply chain level.

> Interviewee from T1–4: Learning from a former conflict, we developed a logistics guideline. This is pretty important to us.
> Interviewee from T1–4: I don't want to rain on the OEM's parade, but the OEM probably has not the expertise. He just says "Well, this is what I demand".

Intercompany transparency can help decision makers to understand how their goals are conflicting with those of others leading to suboptimal supply chain solutions and in the end falling back on the initial decision maker. While shaping an understanding of goals and conflicts might be sufficient, transparency additionally enables companies to develop more integration-focused incentive systems focusing on overall supply chain performance.

Information sharing is not only seen as positive, because revealing too much information will reduce relational rents by giving more power to customers and allowing them to reduce the suppliers' margins or to exclude some of their suppliers from the supply chain altogether.

> Interviewee from T1–2: And there is always danger that the margin is affected [when sharing critical information].
> Interviewee from T1–1: Suppliers are often not happy to reveal information [about their suppliers] since they are afraid to be bypassed [by their customer] who then may directly approach the sub-suppliers.

Vice versa, information exchange can also be used by suppliers to gain more power over their customers in order to achieve an advanced position in the supply chain. One example in this case is a key tier-2 supplier, who uses its strategic importance in the supply chain to directly exchange information with the OEM, not including the tier-1.

> Interviewee from T2–1: And therefore it is important for us to directly exchange information with the OEM. It is helpful to directly talk to the OEM since the supply chain visibility is sometimes very poor.

Nonetheless, information-sharing on the personal level is one of the most important antecedents of goal congruence and trust observed during the case study.

> Interviewee from T2–1: I find information exchange at the personal level vitally important. I need to talk to my business partner face to face and get the feeling of his confidence level. This helps me to interpret his message.

But the relationship between trust and information exchange also has a reciprocal component. In a business relationship built on trust, when inaccurate/delayed information is shared, trust will be negatively affected which will also affect future information exchange. On the other hand, intense and regular sharing of information will also be an antecedent of trust in the relationship.

> Interviewee from T0–1: In case of the distorted/delayed information provided, the contact will not be terminated. But you will be more cautious, for sure.

Proposition 4 The more efficient the information sharing is, the more likely the firm's decision antecedents will be positively influenced.

20.4.4 Impact of Information Sharing/Retaining on Supply Chain Performance

Previous research on information sharing in the automotive supply chains focuses predominantly on the function and impact of the information sharing content (Lee et al. 1997; Niranjan et al. 2011). Only few studies have identified the relevance of particular information items (Lee and Whang 2000; Lumsden and Mirzabeiki 2008). In the following, we first identify information items suitable for mitigating goal conflicts when shared among supply chain members. We will therefore build on the typology introduced by (Lee and Whang 2000) and differentiate information items into inventory, sales and demand forecast, order status, production schedule and capacity as well as supply chain network design related information. The following Table 20.2 summarizes information items shared among supply chain members and their relevance for mitigating goal conflicts and to increase the overall supply chain performance.

Supply chain members who exchange information efficiently can better understand the customer needs and hence respond faster to market volatility. The known effects, "bullwhip effect" and "double marginal effect" will be mitigated. Bullwhip effect refers to the amplification of demand order variations in supply chains moving upstream towards the original source. Double marginal effect means that the total profit of the supply chain under decentralized decision is less than that under centralized decision (Zhang and Chen 2013). Provision of information may enable better control of the supply chain. It supports a rapid response to deviations or changes and is the basis for aligning product and capacity availability.

The provision of inventory data supports both, suppliers and customers. During the case study, we could observe suppliers not willing to share inventory data since low inventory might suggest to customers a low level of robustness while excess inventory might be interpreted as a signal for low efficiency or low overall demand. Customers in some cases are also not willing to reveal inventory data, for example if they are willing to stockpile goods.

> Interviewee from T1–4: I was realizing that one of our customers was making false statements concerning his actual demand, his buffer inventory. He built up pressure and told us, that they could not serve their customer because of us. (…) (this was) just safety thinking. He wanted to get enough on the side for himself.

Table 20.2 Different information types and their relevance concerning supply chain performance

Information type	Information items	Relevance
Inventory	• Finished goods • In process inventory • Raw materials	Reduction of bullwhip effect by aligned inventory decisions
Sales and demand forecast	• Current sales • Future aggregated demand	Integrated master planning by alignment on inventory build-up and production scheduling
Order status/event management	• Status of current orders in production process • Early escalation of production errors and delays	Early adjustment of production capacities and readiness concerning business continuity measures
Production schedule and capacity	• Future availability • Current spare capacity/flexibility • Future spare capacity/flexibility • Production cost	Integrated master planning by alignment of production schedules and optimized network planning due to the use of capable suppliers
Production/process capabilities	• Production quantity capabilities • Production quality capabilities • Process capabilities • Quality/Quantity demands	Gaining transparency and aligning actual requirements with actual demand is the key for efficient supply chain management to avoid negative surprises
Supply chain network	• Supply chain configuration • Sourcing concepts • Upstream suppliers	Developing an optimum supply chain

But sharing individual inventory data can help to set the inventory goals right in the overall supply chain (e.g. by reducing the bullwhip effect) and therefore lead to overall cost savings and also to increased flexibility/timeliness (by optimized allocation, faster reaction) and increased service quality/robustness (by enabling secure supply).

Sharing sales and demand forecasts helps in a similar way, especially by supporting all supply chain members in allocating production capacity. Goal conflicts are becoming apparent through customers not forwarding (actual) demand data or by purposeful underestimation of demand in order to shift risk to the supplier. This induces additional volatility in the supply chain, especially affecting supply chain robustness.

> Interviewee from T2–1: (…) they only want to commit themselves to as few as possible buying quantities; they want as much flexibility from the supplier as possible. (…) We require highly precise demand forecasts from our customers.

Concerning the order status, the data supports customers especially on the level of early warning mechanisms so they are informed early in case of a disruption contributing to overall flexibility and service quality. Customers are willing to get status data deep from the production process while suppliers are in some cases not willing to share this data, referring to the low benefit of such data and to the high effort of preparation.

> Interviewee from T2–1: I don’t want to give him such information. This has to be prepared manually and there are no resources to do this.

Concerning (future) production capacity, offering this information to supply chain partners would be a prerequisite for truly integrated and perhaps centralized supply chain planning and goal alignment. But parallel to inventory information, suppliers are often not willing to share that information since it e.g. might negatively affect negotiations with customers.

Information concerning a supplier’s production capability concerns the supplier’s ability to deliver the demanded product in the required quality and quantity in a given timeframe. While the lack of intra-organisational information flow might lead to contradicting requirements (see above) in order to fulfil conflicting goals of cost and quality, a supplier might issue wrong statements concerning its capability, in the end leading to higher overall supply chain cost.

> Interviewee from T1–4: I asked how the results from the first (reference) implementation were. And their answer was that that they postponed it for two years.

One of the most important and probably neglected information type is the network structure. Events like the tsunami at Fukushima have proven, that demands in supply chain risk management are increasing and that network transparency is a risk management prerequisite in order to safeguard against supply shortages. Information on network structure can therefore be used to optimize networks for supply chain robustness and flexibility and contribute to supply chain performance.

However, excessive information shared among members may decrease the visibility of the supply chain due to increased complexity and impede supply chain performance. For example, the overwhelming and sometimes conflicting data may overload or confuse managers, as the processing of the data may be very time-consuming. In addition, managers often feel challenged communicating with a vast number of inter- and intra-organizational stakeholders due to the growing complexity of the communication network.

> Interviewee from T0–1: The number of E-Mails is a catastrophe. The diversity and sometimes contradiction of the numbers strike you in a lot of cases. (…) This is impossible. What do you do? You don’t read it at all!
> Interviewee from T1–4: It is an inflation of criteria. And today, focussing on the important ones, I like to say the vital ones, is missing a little bit.

Thus, the interviewed managers continuously work to improve existing information sharing systems, which should be fine-tuned according to the development of business requirements. In order to enable information sharing to increase supply chain performance, concepts of information logistics have to be implemented ensuring the availability of the right information at the right time in the right format and at the right place (Sandkuhl 2008).

Interviewee from T0–1: Transparency does mean to exchange the right information.

Identifying the right information is not quite easy due to the unequal distribution of information on the company and supply chain level. Therefore specific processes and standards need to be defined, describing who is in charge of which process and who is holding which information. Those processes and standards need to be made available broadly in the form of shared documents and company- or supply chain-wide guidelines.

Also, in some cases, the facilitation of horizontally integrated workgroups among OEM, tier-1 and vital tier-2 suppliers can enable the exchange of relevant information. In order to ensure the information availability at the right time in the right format in times of ever-growing amounts of data, new processing technologies are required.

Based on those observations, it's becoming clear that while information sharing holds huge benefits for all supply chain partners, it also bears additional costs, especially for setting up new information systems and building standards/process documentations. But also, increased efforts on the personal level as well as potential risks like exploitation that come with increased cooperation have to be considered.

Proposition 5 The more efficient (higher quality and lower cost) the information sharing is, the more likely the supply chain performance will be positively influenced.

20.5 Discussion and Conclusion

In this paper, we explored the interdependent relationship between information sharing and its decision-making antecedents and the impact of information sharing on the supply chain performance based on a multiple case study approach.

Our research contributes to a better understanding of information sharing in supply chain management and yields practical insights for practitioners to better understand the "black-box" of decision-making Our findings show that GCPT and information sharing are highly interdependent and interactive. On the one hand, goal congruence and trust significantly influence both the behaviour and quality of information sharing positively. While power might be an enabler of information sharing in some cases, exercising power does not guarantee the quality of information shared. Goal conflicts often lead to information-retaining behaviour. On the other hand, efficient information sharing behaviour indicates a positive impact on building trust, reconciling goal conflicts, and rebalancing power. However, supply chain members seem to treat information sharing/retaining very cautiously, although it is widely agreed by companies that in order to deliver the right product to the right place at the right cost (Zhang and Chen 2013), they must coordinate decisions and probably share sensitive information. The role of goal conflicts on the organizational level and its impact on the supply chain is also widely ignored in research and practice. Especially with growing complexity and a growing disintegration of supply chain related functions, comprehensive standards, documents and guidelines can facilitate goal alignment and reduce confusion on the supply chain level.

Concerning the possible impacts on supply chain performance, managers should not take the impact of information sharing for granted. Information sharing does not guarantee better supply chain performance per se. Informal, frequent, and bi-directional information sharing on the personal level seems to be a more effective enhancer of supply chain performance compared to IT systems and technology-based approaches, at least concerning decisions on the mid-term and long-term level. Only effective information sharing can strengthen cooperation and also alleviate goal conflicts. In terms of selecting suppliers, buying firms should not only consider cost, quality, and time of delivery, but also make an effort to understand the corporate goals and trustworthiness of the supplier, as dysfunctional goal conflicts and opportunistic behaviour decrease the willingness to share information and compromise the longevity of relationships. If there is a lack of goal congruence or trust, the buying firm should cautiously exercise its power. To improve the quality of information sharing, buying firms should invest on building long-term relationship and trust.

The study also has several limitations, which open up avenues for further research concerning future research directions as well as further methods to be implemented. The provided understanding of relationships between the surveyed antecedents can build the foundation for further exploration and development of explicit measures and tools to mitigate goal conflicts. E.g. the suitability and applicability of measures like incentive systems, intercompany workgroups, information standards, guidelines, and information systems, has to be further investigated. Also, the case study was limited in only providing a first understanding of underlying mechanisms. Structural modelling in combination with the collection of broad empirical data can be used for further hypothesis testing, to support and extend our study's results. Finally, since there was only one Chinese company in the sample, we did not examine the cultural dimension in our study. Future study can deepen our understanding of information sharing by taking the influence of culture into account.

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Part VII
Empirical Studies and Data Mining for Analysing Commercial Transport

Chapter 21
Empirical Analysis of Freight Transport Prices Using the French Shipper Survey ECHO

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21.1 Introduction

Freight transport is a complex system: it plays a pivotal role in supply chains of firms, which are very heterogeneous in their geography, characteristics, requirements, etc. It also causes heavy environmental and congestion impacts, particularly in cities. As a consequence, freight is a center of attention for public deciders willing to promote sustainable transportations.

In the decisions of shippers, prices paid to carriers for transport operations play a central role. For example, changes in fuel prices, vehicle taxes or tolls will have an influence on shippers through the prices they have to pay. The analysis of prices can also reveal the willingness of shippers to pay for other characteristics of freight transport, such as speed and logistics operations. Given the fact that road freight transport is essentially a multiproduct industry, multivariate econometric analyses seem to be an adequate tool to assess the structure of its prices and to disentangle the relative importance of the multiple services embedded within transport operations. Having a good understanding of the road freight prices' structure is of prime interest for policy makers since their interventions may impact differently the various components of transport operations.

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This paper explores empirically road freight prices thanks to the French survey ECHO. ECHO is a commodity flow survey with a very large range of information about shippers, shipments, and transport operations. Prices are studied with the objective to identify the respective roles of the cost structure of carriers, the preference of shippers, market structure and transaction costs in the formation of road freight transport prices.

The paper proceeds as follows. Section 21.2 reviews the literature on the structure of road freight costs and prices. Section 21.3 presents the ECHO database and analyses the variables used for the empirical tests. Section 21.4 presents the econometric methodology and outcomes. Section 21.5 concludes the paper.

21.2 Costs and Prices in Freight Transport

Road freight transport is a complex transport system, and also a complex market, or more precisely a large set of partially substitutable markets. Road freight operations are characterized by a number of attributes: origin, destination, departure and arrival time, shipment size, reliability, flexibility, conditioning, number of transshipments, etc. Some are important to the shippers, others are important to the carriers. Both have a direct influence on costs and prices.

21.2.1 From the Carriers' Perspective

An important driver of the price of a given transport operation is the marginal production cost: in theory, a given carrier will produce operations so that his marginal benefit is, at least, equal to its marginal production cost.[1] Marginal costs mirror the structure of the production function, which depends itself on the type of transport operation. As a matter of fact, the following properties of freight transport marginal costs can be intuited, all other things equal. Some logically increase marginal production costs; others are more ambiguous with that respect:

- Commodity type and conditioning: transport costs depend on the nature of the commodity. For example, transporting fragile commodities, hazardous materials, or refrigerated products requires specific assets and expenses;
- Mileage driven: longer distances are more expensive due to the additional needs of fuel, vehicle immobilization and wear and tear, tolls, drivers' wages, and other consumables;
- Transport speed: faster transport is expected to be more expensive, due to more recent vehicles, the additional fuel expenses, the fares paid to use faster

[1]In practice, it appears that some carriers, particularly one-man businesses, are structurally unprofitable.

infrastructures (highways), as well as the fewer opportunities to transport distinct shipments together. However, faster transport also means less vehicle immobilization costs and driver costs (Strandenes 2013);

- Shipment size: larger shipments are more expensive to carry because they use more of the vehicles' capacities, and they sometimes need bigger vehicles. However, bigger vehicles are less expensive on a per ton basis (Strandenes 2013);
- Route structure: transport operations with transshipments are more costly because they involve detours and transshipment operations, although they can be less costly on a per shipment basis, because they offer an opportunity for consolidation that direct transport does not (Combes and Tavasszy 2013);
- Spatial coverage: urban transport is more expensive than interurban transport due to congestion, but consolidation—through vehicle rounds for example—is easier: transporting smaller shipments inside cities is easier than outside cities, the contrary is expected for larger shipments;
- Reliability: the probability that the shipment is delivered at the time initially announced can be increased by increasing buffer times, applying more demanding procedures, etc., at an increased cost for carriers;
- Flexibility: the possibility to send shipments with short (or no) notice and/or toward a wide range of destinations is expected to be more expensive because it limits the ability of carriers to share their resources and to decrease costs (Strandenes 2013);
- Safety: the probability that the shipment is delivered at all, and intact, is also expected to be more expensive, due to the additional constraints and more expensive resources it involved;
- Additional services: if logistic services (picking, handling, packaging, etc.) are realized together with the transport operation, they incur an additional cost.

Furthermore, the freight transport industry is essentially a multi-product industry. For example, freight transport from A to B and from B to A are essentially joint products, made by vehicles commuting between the two locations. Thus, it is impossible to isolate the marginal cost of transport in one direction from that of the other direction, and the prices will depend as much on the demand schedules as on the costs (Felton 1981; Demirel et al. 2010). Joint production also plays a complex role in the relationship between shipment size and freight rates (Combes 2013).

21.2.2 From the Shippers' Perspective

From the perspective of shippers, freight transport is part of a logistic chain. The logistic chain's objective is to provide goods or services to customers at the right places and times, but also to a limited cost. The preferences of shippers regarding freight transport derive from their own logistic requirements. It is now customary, in the freight modeling literature, to model the preferences of shippers by a total logistic cost function (see e.g. Ben Akiva and de Jong 2013) which takes into account transport prices, travel time, travel time reliability, but also inventory and warehousing costs. More generally, shippers are willing to pay to improve transport speed and reliability (de Jong 2014), or to send smaller, more frequent shipments to their receivers, because it limits the capital opportunity cost associated to owning the commodities, and it offers a better flexibility and reliability of the supply chain (Baumol and Vinod 1970). As a consequence, we easily understand that the various factors detailed previously for the freight producer also matter for the shippers.

Somehow symmetrically to the decision of carriers, shippers will not agree to bear one road freight price that exceeds their marginal willingness to pay for a given transport operation. Since that operation is made of various characteristics (speed, safety, logistics operations, etc.), the prices paid to carriers should be consistent with the marginal benefits linked to each dimension of the transport service, from the shipper's perspective. As highlighted by the "hedonic price" methodology (Rosen 1974; Haab and McConnel 2003) in the case of multidimensional products (e.g. housing notably), equilibrium prices on the road freight market should consequently equalize, for each characteristic, the marginal production cost of carriers to the marginal willingness to pay of shippers, making so-called "shadow prices" for various attributes.

21.2.3 Other Determinants

Importantly, we believe that road freight prices do not only depend on costs and benefits: two other dimensions also play a crucial role: transaction costs, and market structure.

Transaction costs refer to the efforts or resources associated with finding the most relevant contracting party, deciding the terms of the contract and monitoring the transaction. Given the attributes involved with a road freight transport operation, these costs are probably substantial; although the existence of online marketplaces would let think otherwise. Transaction costs may depend on the technology with which the shipper, receiver and carrier communicate together. They may also depend on the economic size of the agents; a bigger shipper (i.e. sending more shipments per year) may benefit from reduced transaction costs due to "relational" agreements. Thus the transaction frequency is often thought to decrease the need for contractual "completeness" (thus reducing "ink costs").

Market structure regards the existence of "market powers", either on the supply or on the demand side. Road freight transport is often considered a very competitive market. Although there has been some academic debates on this topic at the time it was deregulated, the low requirements in terms of fixed capital insures "free-entry" onto the market. Empirical analyses of the structure of road freight transport costs mostly concluded to constant returns to scale (Xu et al. 1994), consistent with strong competition. As a consequence, prices should not divert significantly from marginal costs since no “mark-up” should be applied. Nevertheless, some sub-markets of road freight transport are clearly, at best, monopolistic; this is the case of express transport (flat freight rates commonly found in this market can theoretically be considered as consistent with third type price discrimination, exercised by a monopoly—Tirole 1988), for example, or for some “niche” markets which are characterized both by their relatively small size and by the specific transport techniques they involve (oversized transportation, cash transport). Also, some empirical studies concluded that road freight transport exhibited *ad valorem* pricing, which is not consistent with perfect competition (Szpiro et al. 1996; Reme-Harnay 2012).

Road freight transport should be considered as a large number of closely related markets, characterized by multiple attributes, with a non-trivial market structure. Prices mirror both the cost structure of carriers, the preferences of shippers, and may be strongly influenced by their relative market powers. In this context, multivariate econometric analyses are expected to yield particularly instructive conclusions. They should allow computing the willingness of shippers to pay for variations of the attributes of road freight transport operation. Our empirical work relies on a rich dataset (ECHO) whose latest version has never been used for this purpose.[2] This dataset has two specific properties: first, the transport operations are described in detail, including the number of transshipments. Second, the database also provides information on the shipper, the receiver, and their relationship. As explained in the next section, it makes it possible to test the influence of many variables which are generally absent from freight transport databases.

21.3 Data

21.3.1 The ECHO Survey

ECHO is a French shipper survey, carried out in 2004–2005. The dataset provides information on 10,462 shipments sent by 3,000 French shippers, obtained by face-to-face and phone interviews, based on closed questionnaires. It is similar to a commodity flow survey or CFS; its main particularity is that it provides very detailed information on the shipper-receiver relationship, and on the way the shipments were transported (Guilbault 2008; Guilbault and Gouvernal 2010).

In the ECHO survey, shippers are described by their location, activity type, number of employees, turnover, but also by the total number of tons of commodities and the total number of shipments they send or receive per year, the number of customers which account for 80 % of their demand, etc. Similar information is available about the receivers. The shipments are described by their

[2]Szpiro et al. (1996) and Massiani (2008) have crossed previous waves of the ECHO survey with the hedonic price methodology in order to assess the values put on various freight characteristics and freight time savings respectively.

commodity type, weight, value, conditioning, etc.; the shipper-receiver relationship is also described (yearly commodity flow rate, means of communication, etc.), as well as the transport operation (mode, sequence of elementary transport operations, transport price and duration, etc.)

In the ECHO database, shipments are carried by road (own account and for hire), railway, combined transport, inland waterway, air and sea. In order to work on a sufficiently homogenous sample, we selected the shipments carried by road, by commercial haulage companies, with their destination in the EU 15. This represents 4,561 shipments over the 10,462 shipments of the full dataset (44 %).

21.3.2 Variables of Interest

This section describes the variables used in the econometric analysis. The dependent variable is the price paid by the shipper or the receiver for the transport of the shipment. The ECHO dataset distinguished three cases: either the price was fully paid by the shipper, or it was fully paid by the receiver, or neither. Besides the dataset does not say what the prices cover exactly (FOB, CIF, etc.). This is an inherent source of inaccuracy of the data. In the following, we kept shipments either in the first or the second case, not the third (because we were not certain that the totality of the price was accounted for in the latter case).

The empirical analysis presented in the following section involves a number of explanatory variables. The ECHO dataset contains a lot of variables; those for which the definition was unclear or with too-many missing values were not kept. Based on our discussion in Sect. 21.2, the variables kept for the econometric analysis may be categorized into four groups:

- Supply variables: those variables are expected to have a direct influence on transport costs, because they constitute constraints for carriers. This influence is expected to have an impact on prices. For example, the number of transshipments has a direct influence on costs.
- Demand variables: they characterize the shippers in ways which concretely influence the transport operation (e.g. the shipper-receiver distance, the commodity type), or have preferences regarding (e.g. travel time duration); they are willing to pay for an improvement in these variables;
- Transaction variables: those variables are related to the ease (or lack thereof) for a shipper to contract with a carrier or freight forwarder (e.g. bigger shippers would experience lower transaction costs per shipment); they should influence prices accordingly.
- Market structure variables: those variables are related to the market power of shippers, or carriers. For example, a bigger shipper may benefit from more competitive prices due to its size and ability to organize a fiercer competition; shippers in dense urban areas may not experience the same level of competition than shippers located in other places.

Table 21.1 Variable list and categorization

Name	Definition	Categories[a]
Price	Price (paid by the carrier or the receiver) of the transport operation (€)	
Distance	Shortest road distance (km)	S, D
Duration	Time between the start of the first transport operation and the end of the last transport operation (h)	S, D
Nb_traj_i	Number of transport operations is equal to *i* (1, 2 or 3 +)[b]	S, M
Weight	Shipment weight (kg)	S, D
Condi_i	Conditioning of the commodity is of type *i* (bulk, palletized, containers, all kinds)	S, D
Constraint_i	Commodity requires handling precautions of type *i* (hazardous material, fragile, controlled temperature)[b]	S, D
Val_dens	Value density of the shipment (€/kg)	S, D, M
NSTi[c]	Commodity belongs to commodity type *i*	S, D
Production_prog[d]	The shipment's production was planned (make-to-stock).	D
Total_shipper	Total number of shipments sent by the shipper per year (shipment/y)	S, T, M
Shipper_workforce	Number of employees of the shipper	T, M
Shipper_receiver_flow	Total amount of commodities sent by the shipper to the receiver per year (t/y)	S, T, M
Shipper_pop	Population of the urban unit to which the shipper belongs	S, M
Same_firm[d]	The shipper and the receiver belong to the same firm	T
Same_group[d]	The shipper and the receiver belong to the same group	T
E_mail_contact[d]	Contact between the shipper and the carrier was by e-mail	T

[a] The categories are *S* Supply, *D* Demand, *T* Transaction costs, *M* Market structure
[b] More detail are available in the ECHO database, it was dropped either because the definitions were unclear or to keep the results legible
c The NST are the categories of commodities in French freight transport databases before 2007. In the ECHO dataset, the following categories are met: NST 0 (agri-food sector), NST1 (food products), NST 3 (petroleum products), NST4 (ores for the metal industry), NST 5 (metals), NST 6 (minerals and building materials), NST 7–8 (fertilizers and chemical products—the two NSTs are merged in ECHO), NST 9 (manufactured products). NST 2 (solid fuels) is absent from ECHO
[d] Is equal to 1 if true, 0 else

Table 21.1 lists the variables and Table 21.3 in Appendix provides descriptive statistics of these variables. Table 21.1 indicates whether they are related to the supply or demand side, if they may be related to transaction costs, or to market structure.

Unavoidably, this classification is most often ambiguous. Few variables belong to only one category. The number of transport operations is one of them: clearly relevant to carriers, because the technologies involved by direct and break-bulk transport are entirely different, it should be transparent for shippers. Besides, it may also have an influence in terms of market structure: the level of competition may not be the same between direct transport and break-bulk transport.

Most of the other shipment related variables are relevant for both shippers and carriers. Value density plays a specific role. In theory, it should not be important to carriers; in practice, it may be associated with specific constraints increasing significantly the transport costs, such as safety, flexibility, or reliability, which are either not or incorrectly measured in the ECHO database. It may also be associated with *ad valorem* pricing, theoretically not possible under perfect competition, thus providing information about the road freight transport market structure.

The variables describing the shippers should provide information related to the market structure, or to transactions costs: an influence of shipper size (measured in number of employees or in the amount of commodities sent per year, total or towards a given receiver) on prices would indicate a stronger market power, or decreased transaction costs. Transaction costs may also be analyzed through the relationship between the shipper and the receiver (do they belong to the same firm?) and through the communication technology between the shipper and the carrier (did they communicate by e-mail?); in both cases, a positive answer would be associated to lower transaction costs.

21.4 Empirical Study

21.4.1 Model Specification

Empirical studies looking at the price structure of multidimensional products generally allow the greatest flexibility in model specifications (Halvorsen and Pollakowski 1981; Cassel and Mendelsohn 1985). For that purpose, the Box-Cox transformation is often used (Haab and McConnel 2003; Massiani 2008):

$$P^{(\theta)} = \alpha_0 + \sum_{i=1} \alpha_i X_i^{(\delta)} + \varepsilon_i \tag{21.1}$$

Where $P^{(\theta)}$ denotes the dependent variable (the price paid for the transport service) and $X_i^{(\delta)}$ a vector of explanatory variables (characteristics of the transport service). Parameters α_i have to be estimated in order to estimate the shadow prices of characteristics X_i. ε_i represents the error term (unobserved determinants of the price) assumed iid. Importantly, $P^{(\theta)}$ and $X_i^{(\delta)}$ are Box-Cox transformations of the data. If we focus only on $P^{(\theta)}$, we get:

$$P^{(\theta)} = \frac{\left(P^{\theta} - 1\right)}{\theta} \quad if\ \theta \neq 0\ \ and\ \ P^{(\theta)} = \ln P\ \ if\ \ \theta = 0 \tag{21.2}$$

Given the trade-off to be made between flexibility and tractability, we choose here to restrict the empirical analysis to only four specifications: lin-lin (θ and δ = 1), log-log (θ and δ = 0), lin-log (1; 0) and log-lin (0; 1). For each of these specifications, the model is estimated using the ordinary least squares methodology.

Four models are estimated in this paper:

- The complete log-log model: the logarithm transformation is applied to all continuous variables (dependent and explanatory). All the variables of Table 21.1 are introduced. Importantly, the log-log model allows us to interpret estimated parameters as elasticities. Note also that interaction terms between number of transport operations and the weight of the shipment as well as between value density and transport duration were introduced;
- The complete log-lin model: same as above, except for the continuous explanatory variables, which are not transformed;
- The consolidated log-log model: based on the complete log-log, but all non-significant explanatory variables were removed (a variable was removed when its p-value was higher than 0.1)
- A simplified log-log model: the objective here was to keep the minimum number of variables, while keeping the most important features of the model: shipment size is kept, as well as the number of transshipments; other variables are the distance and commodity type.

A Box-Cox transformation was also tested on the dependent variable: the conclusion was that taking the logarithm of the price variable is an adequate choice.

21.4.2 Results

The models were estimated using the ordinary least square methodology. Table 21.2 presents the results. For each parameter, the table gives an estimation of its value, its *t*-stat and significance.

The log-log specification performs best, with a R^2 close to 0.75. It performs significantly better than the log-lin model, which is not surprising given the very large and asymmetric dispersion of many of the explanatory variables.

The supply variables, in the sense of Sect. 21.3, have a strong influence on prices. Prices depend on shipment size, shipper-receiver distance, commodity type and conditioning. The coefficients are significant, and stable, whatever the model tested. The log-log models also show the strong non-linearity of freight prices: the elasticity to distance is only 0.2, the elasticity to shipment weight is 0.4. This non linearity was already identified in the literature; with the ECHO dataset, it is

Table 21.2 Model results

Name	Complete model (log-log)	Complete model (log-lin)	Consolidated model (log-log)	Simplified model (log-log)
Constant	1.102 (3.89)***	4.527 (38.51)***	0.8392 (4.65)***	1.2975 (13.36)***
Distance	0.2014 (8.38)***	$1.342*10^{-4}$ (11.66)***	0.1931 (9.87)***	0.2371 (18.69)***
Nb_traj_2	−0.5962 (−3.39)***	−1.058 (−11.29)***	−0.6192 (−4.29)***	−0.6695 (−6.17)***
Nb_traj_3	−0.9748 (−6.25)***	−1.513 (−17.30)***	−0.8275 (−6.62)***	−0.7068 (−7.85)***
Weight	0.4010 (17.01a)***	$2.77*10^{-5}$ (9.19)***	0.4364 (27.61)***	0.3793 (38.62)***
Nb_traj_2 * weight	0.0415 (1.46)	$1.772*10^{-5}$ (2.51)**	0.0521 (2.30)**	0.0692 (4.18)***
Nb_traj_3 * weight	0.1069 (4.05)***	$1.595*10^{-4}$ (6.77)***	0.0834 (4.03)***	0.068 (4.59)***
Condi_freight_all_kind	−0.1790 (−2.02)**	−0.7658 (−7.13)***	−0.1369 (−2.67)***	
Condi_palletized	−0.0418 (−0.53)	0.2512 (2.50)**		
Constraint_hazmat	0.3526 (2.19)**	0.6262 (3.01)***	0.3164 (2.22)**	
Constraint_controlled_T	0.0760 (0.58)	0.095 (0.426)		
Constraint_fragile	0.1641 (2.08)**	0.1207 (1.21)		
Duration	0.0749 (2.61)***	$-9.969*10^{-6}$ (−0.08)	0.0792 (3.54)***	
Value_dens	0.2542 (7.68)***	$-3.468*10^{-4}$ (−1.33)	0.2790 (10.88)***	
Duration*val_dens	−0.0353 (−3.74)***	$-1.824*10^{-6}$ (−0.36)	−0.0320 (−4.21)***	
NST_0	−0.3736 (2.46)**	−0.271 (−1.46)	−0.2125 (−2.13)**	−0.3464 (−4.22)***
NST_1	−0.1346 (−1.24)	0.150 (1.21)		−0.1593 (−3.44)***
NST_3	0.9574 (3.29)***	1.08 (2.97)***	0.7588 (2.92)***	
NST_4	0.6049 (1.82)*	0.719 (1.74)*	0.5057 (2.01)**	
NST_5	−0.2302 (−1.77)*	0.034 (0.208)		
NST_6	−0.1814 (−1.18)	−0.160 (−0.85)		−0.3886 (−3.95)***

(continued)

Table 21.2 (continued)

Name	Complete model (log-log)	Complete model (log-lin)	Consolidated model (log-log)	Simplified model (log-log)
NST_78	−0.1050 (−1.28)	−0.117 (−1.14)		−0.1707 (−3.39)***
Production_prog_true	−0.1633 (−3.07)***	0.0727 (1.10)		
Total_shipper	−0.0607 (−3.67)***	$-2.02*10^{-6}$ (−3.79)***	−0.0504 (−3.98)***	
Shipper_workforce	0.0526 (1.93)**	$2.56*10^{-4}$ (2.01)**	0.0424 (2.05)**	
Shipper_receiver_flow	0.0202 (0.77)	$-1.22*10^{-7}$ (−0.019)		
Shipper_pop	0.0089 (0.76)	$4.62*10^{-9}$ (0.33)		
Same_firm	0.3253 (2.75)***	0.3887 (2.58)**	0.2834 (3.15)***	
Same_group	0.2143 (1.95)*	0.3207 (2.32)**	0.2120 (2.39)**	
E_mail_contact	0.1050 (1.64)	0.1423 (1.77)*		
Number of observations	*1142*	*1142*	*1910*	*4351*
Model degrees of freedom	*29*	*29*	*19*	*14*
R^2	*0.7494*	*0.5963*	*0.7307*	*0.6515*
Adjusted R^2	*0.7430*	*0.5860*	*0.7281*	*0.6504*

Significance levels ***means p-value <0.01; **means p-value <0.05; *means p-value <0.1

confirmed in the European context for a large and heterogeneous population of shippers and shipments.

Prices also depend strongly on the number of transshipments: Road freight operations with transshipments are cheap for small shipments, while direct transport is more competitive for large shipments. The road freight transport system is in fact a combination of interrelated systems, each adapted to a specific demand, deriving from distinct supply chains.

In regards with demand variables, the results are less clear, and more difficult to interpret. Consider the case of transport duration: as discussed in Sect. 21.2, shippers would be ready to pay for lower durations, particularly so for commodities with a higher density value. The coefficient of interaction between transport duration and value density has the right sign, but not the coefficient of transport duration alone. In practice, an increase in transport duration decreases transport price only if the value density is larger than 8 €/kg. This is only the case of half the shipments in the dataset used in this study (Massiani (2008) reached similar conclusions). Several causes may explain that result. Travel time may differ between two origin-destinations which are at the same road distance from one another. In that case, the longer travel time is more expensive for carriers, thus the price increase. Finally, transport duration does not seem to be reliably measured in the ECHO dataset: a lot of values are missing, and many of them seem inconsistent. It should be noted that the log-lin model does not yield significant coefficients for travel duration and its interactions.

The value density parameter is positive and significant. As discussed in Sect. 21.2, this can be interpreted in a number of ways: it may mirror indirectly the additional cost for carriers to transport expensive commodities, or the preference of shippers for speed, imperfectly captured by the travel duration coefficients; it may also be interpreted as evidence of *ad valorem* pricing and thus of imperfect competition.

The influence on prices of the existence of a production planning is unclear: according to the log-log model, it is significant, and negative. This makes sense: if a shipper can give its carrier(s) visibility on shipments, they can anticipate and therefore be more cost-efficient. However, the variable is not significant anymore in the log-lin model.

Shipper size variables are also significant: the total number of shipments sent by a shipper per year has a significant negative influence on prices; this may result from transport economies of scale but also from reduced transaction costs. This effect is not observed at all with respect to the shipper-receiver commodity flow. Besides, it is to a certain extent cancelled out by the positive effect of the number of employees of the shipper on prices. Finally, it is not possible to identify an effect of the population of the urban unit on prices.

Regarding transaction costs, three parameters are relevant: the presence of communication by e-mail between shippers and carriers has no visible influence on prices. However, the fact that a shipper and a receiver belong to the same firm, or group, has a significant, positive influence on prices. This is not an intuitive results; one would have thought that this would have helped the coordination of transport, and therefore better prices. The fact that the contrary is observed is not easy to interpret. It may mirror the fact that intra-firm transport is very specific, less prone to mutualization with other clients, or maybe more demanding in terms of level of service, thus causing larger transport costs, and prices.

Thanks to the depth of the ECHO dataset, it was possible to analyze many dimensions of the structure of road freight prices. However, such information is never available in practice. For this reason, a simple model has been developed, where the only explanatory variables are the distance, shipment weight, number of transshipments, and commodity type. This model shows that the parameters of these variables are quite stable, and also that commodity type seems to be able to capture, at least partly, the variables pertaining to the nature of the shipments (value density, conditioning, constraints). It can be considered as a reasonable starting point to introduce these variables in a freight transport simulation model.

21.5 Conclusions

This article does not claim to be the last word on the assessment of the prices' structure in the road freight industry. By using the extensive ECHO survey and multivariate regressions, several conclusions nevertheless emerge in the French case.

First, road freight prices are not a simple linear function of shipments' attributes. As a consequence, we cannot extrapolate shippers and/or carriers characteristics to predict the price charged for a given transport service. This has potentially important implications in the field of freight transport modeling. Second, this price depends on various "technical" attributes that influence the production costs of transport operators, such as load weight, travel duration or distance. But the characteristics of the shipped goods matter too. Expensive shipments and commodities with specific constraints (fragile goods or hazardous materials) tend to be charged at higher prices. Third, the analysis of the prices' structure made it possible to distinguish two specific freight markets. Light shipments are more likely to accommodate multiple transshipments, as opposed to heavy shipments. Since the price paid for former operations is lower, this provides additional rationales for public policies based on investments in logistics platforms. Lastly, we have highlighted the influence of non-traditional factors: A continuous relationship between the transport operators and the shippers decreases the price charged; the bigger the shipper, the fewer he pays; intra-group exchanges tend to be over-priced.

Future research should try to understand more accurately later results, either by analyzing in depth the forces at stake or by finding new variables that describe more precisely the influences of transaction costs and market structures on freight prices. Also, a proper analysis should target the assessment of freight values of the time. Such extension would be of major interest for policy and business analyses.

Acknowledgments This research is part of a study on freight transport modeling realized by the Cerema for the French Ministry of the Environment and Sustainable Development. The authors gratefully thank an anonymous referee for their useful comments.

Appendix

Table 21.3 summarizes descriptive statistics of variables used for computations. We present data for both complete and simplified models. We refer to Table 21.1 for the definition of variables.

Table 21.3 Descriptive statistics

Models	Complete			Simplified		
	Mean	Stand. Dev.	Obs.	Mean	Stand. Dev.	Obs.
Price (€)	387	2,163	1,177	450	2,694	4,351
Distance (km)	347	292	1,177	365	292	4,351
Weight (kg)	5,067	13,145	1,177	4,194	9,251	4,351
1 transport operation	44 %	–	1,177	42 %	–	4,351
2 transport operations	20 %	–	1,177	19 %	–	4,351
3 + transport operations	36 %	–	1,177	39 %	–	4,351
Transport duration (h)	47	260	1,177	44	229	2789
Value density (€/kg)	53	166	1,177	48	160	3,066
Constraint_hazmat	3 %	–	1,177	2 %	–	4,351
Constraint_controlled_T	7 %	–	1,177	6 %	–	4,351
Constraint_fragile	12 %	–	1,177	12 %	–	4,351
Production_prog	46 %	–	1,177	45 %	–	4,351
Total_shipper (t/year)	19,348	61,596	1,177	25,300	133,987	4,351
Shipper_workforce	134	260	1,177	145	356	4,351
Shipper_receiver_flow (ship./year)	149	440	1,177	172	643	3,749
Same_firm	5 %	–	1,177	6 %	–	4,351
Same_group	7 %	–	1,177	7 %	–	4,351
E_mail_contact	24 %	–	1,177	24 %	–	4,351

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Chapter 22
An Inventory-Focused Analysis of German Food Supply Chains: The Case of Dairy Products

Ole Hansen and Hanno Friedrich

22.1 Introduction

This work was created as part of the research project SEAK, which looks into possible causes and consequences of food shortfalls in Germany and is moreover also aimed at developing and evaluating possible mitigation strategies for these shortfalls. For the management of shortfalls in food supply it would be, as a first step, crucial to have information on existing inventories. Making for example decisions on the reallocation of food products into regions affected by disasters is only possible if knowledge about the (regional) availability of food quantities is present in the first place. This could be considered as a necessary transparency.

However, in the German food sector, it is hard to get data about the inventories kept by companies like producers, logistic service providers (LSP's), wholesalers or retailers. This is due to the fact that usually companies are not obliged to publish this information. Moreover, this information is also considered confidential in most companies, since it would give competitors insight into their business model and processes, which are oftentimes the basis for their success. Since information concerning food inventories is not publicly available, it has to be derived in another manner. This work is aimed at providing a scientific basis for the modelling of inventories along food supply chains. More specifically, it does so for the food commodity group of dairy products. We gathered information on all available food products, but limit this particular analysis to dairy products as a showcase of our approach. First, we introduce the data set used for the analysis and the methodology applied to it. In a next step, characteristics of typical German dairy supply

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chains are described using practical evidence as well as literature findings. The description follows the supply chain's structure from start to finish, downstream. In the end, concluding remarks are made and possible further research ventures are suggested.

22.2 Data Set and Methodology

A broad literature analysis concerning food inventory management case studies was performed and 20 first-hand interviews with practitioners from production companies, LSP's, wholesalers and retailers involved in food supply chains were evaluated. The literature scanned ranges from scientific papers to empirical studies and topic wise from operational research over logistics management to food retail management in general. The interviews were non-standardized. However, they were guided interviews and every interview's questionnaire was prepared according to the participant's role in the supply chain and the company itself. Some information, like inventory management parameters every company features, was nonetheless collected from all the interview partners, examples being lead times of suppliers or stock ranges. We applied the method of qualitative content analysis to extract information from the raw data, as it is described in Mayring (2011). For preparation, conduction and analysis, we turned in addition to renowned works on qualitative research like f.i. that of Gläser and Laudel (2010) or Flick et al. (2013) and followed their guidelines.

The literature and interviews were hence scanned for data concerning the inventory management of specific food commodity groups. The commodity groups were constructed by taking into account properties like temperature requirements, perishability and standardized assortments frequently used in retailing. Based on the findings, typical food supply chains for each commodity group, from an inventory point of view, were identified. The commodity group under scrutiny in this work, dairy products, has high requirements in terms of temperature and hygiene. It is also a commodity group that is often categorized and handled as a collective by food retailers and wholesalers and therefore qualifies to be treated as a bundle of products. The ultimate goal of this research is to enable approximations of total inventory on a regional scale. As part of the research project that serves as cause for this research, a database on food supply chain companies is being established. This database can in a next step be combined with the information on inventory management in different food supply chains and, on an even more detailed level, their actors. Accounting for the logics and dynamics between these actors, which are also surveyed in this research step, a model of the German food supply network could be set up. Using this model, an approximation of the total inventory of a commodity group in a region, held by all actors combined, could be derived.

22.3 Profiles of Different Dairy Supply-Chains

Figure 22.1 shows an empty framework for food supply chains that can store the information that characterizes different supply chains of a commodity group. It can represent many possible ways for dairy products through the dairy supply chain.

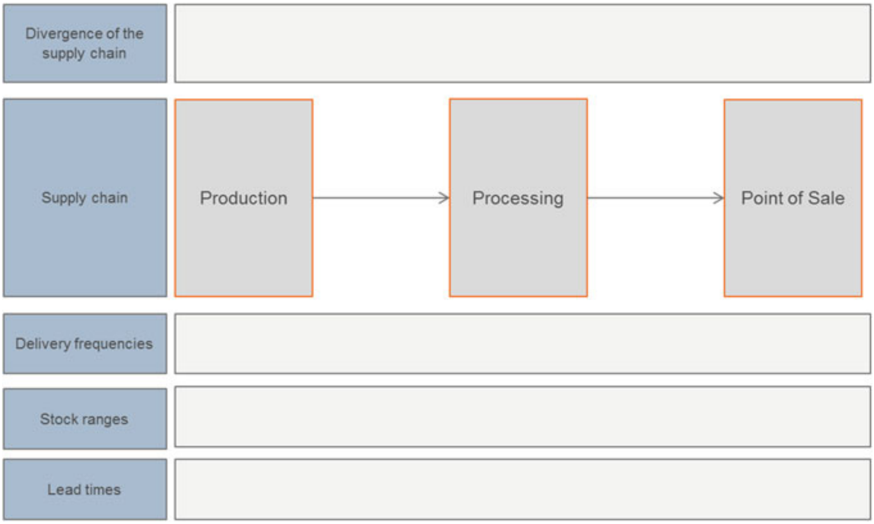


Fig. 22.1 Framework for the profile of a dairy supply-chain indicating the Divergence of the supply chain, Delivery frequencies, Stock ranges and Lead times

The goal of the next chapter will be to set the information extracted from literature and interviews into context and supply data to identify and describe common dairy supply chains.

In the filled profiles, information about the divergence of the supply chain is given, indicating whether the number of different actors increases or decreases when products are transferred from one stage of the supply chain to the following. Furthermore, a value or a range of delivery frequencies between the different stages of the supply-chain profile in question are shown. Stock ranges are indicated according to actors that are able to hold stock. Moreover, values or ranges of Lead times between actors can be extracted.

22.4 A Study of Supply Chains for Dairy Products and Their Inventories

22.4.1 General Description of the Supply Chain for Dairy Products

Food Production

The main ingredient for dairy products, raw milk, is yielded by livestock that is in the possession of many individual farmers. In the next step of the supply chain, the raw milk is then either aggregated in collectives, who forward it to the dairy, or delivered directly from the farmers to the dairy. Here, the flow of goods is split up into several streams. Raw milk is processed into several different products that can be further assigned to subcategories according to their handling, production and product characteristics.

Subcategories

Within the dairy industry, most companies distinguish between two or more assortments. While Kotzab and Teller (2005) quote the white, the colored, the yellow and the yellow fat pallet, we also encountered definitions that were either more precise or more general in our enquiries with the different dairy-supply-chain actors. The most commonly used distinction was that of the "white line" and the "yellow line". An overview of the relation between these two extreme distinctions and some of their products as well as their shelf-life can be found in Table 22.1.

Fresh milk can be supplied by the dairy to the next stage of the supply chain (e.g. wholesalers or retailers) in a relatively short amount of time. Other products like hard cheese which have to ripen for a certain period of time before they reach their desired state or quality and can be forwarded to the next stage. In between these two examples are a range of products that need processing more complicated than that of fresh milk, but are also shorter in their processing time than hard cheese—like yoghurt, cream or cream cheese, for example.

Food Trade

According to our observations, once the final dairy products leave the processing site, they can take one of several routes through the supply chain on their way to the customer. If the processing company supplies a wholesaler, the products are

Table 22.1 General distinction and shelf-life (according to interviews and literature), advanced distinction and examplatory products (according to Kotzab and Teller)

General distinction	Advanced distinction	Products (e.g.)	Shelf-life
White line	White pallet	• Fresh milk • Whole milk • Curd cheese • Yogurt • Cream • …	Short-medium
	Colored pallet	• Fruit yogurt • Curdled milk with fruit • Milk mix drinks • Fresh desserts • …	Short-medium
Yellow line	Yellow pallet	• Hard cheese • Cut cheese • Soft cheese • Cream cheese • …	Medium-long
	Yellow fat pallet	• Butter • Margarine • Butter oil • …	Long

transported directly towards the respective warehouse. From here, the wholesalers' customers are supplied either directly or via cross-docks. When supplying a retailer, the products leaving the processing company's site can be stored at the warehouse of a logistics service provider (or LSP). The LSP stores the products and in a next step also distributes them among the desired points-of-sale of the retailer. If, however, the retailer prefers to use its own channels, the dairy products can be either cross-docked before forwarding them to points-of-sale or stored in a warehouse. Direct deliveries from producers to retailer's points-of-sale are also inside a dairy FSC's scope.

22.4.2 Product Characteristics Influencing Inventories and the Path Along the Supply Chain

Perishability

The path the dairy products take along the supply chain and the possibility to store them at certain points along the chain, are influenced by characteristics of the products. Firstly, the biological characteristics of raw milk make it highly perishable and thus demand swift processing after being delivered to the processing site. Hence, there is no intentional inventory of raw milk kept at the processing sites. Deliveries of the raw product from collectives and farmers are processed as soon as technically possible.

Remaining Shelf-Life and Best-Before-Date

When packaging and labeling the dairy products, the processing company assigns a best-before-date to each produced batch. There are no legal restrictions concerning the maximum or minimum best-before-date of dairy products other than that the producers have to assign one after production. This means that the dairy is theoretically free in its choice of the remaining shelf-life it assigns to a batch.

In the market of groceries however, wholesalers and retailers alike have come to agreements (in terms of frame contracts) with producers. These agreements concern the minimum remaining shelf-life, measured in days, which the dairy products have to exhibit when arriving at the goods receipt of the wholesalers or retailers. This derives, among other things, from supermarket's observations: Most consumers visit stores once a week (Kahn and Schmittlein 1989). Hence the supermarkets try to maintain a minimum remaining shelf-life norm of 7 days at their stores (van Donselaar et al. 2006). If these values are not met, the buyers (wholesalers/retailers) have the legal right to refuse the goods. This creates an additional constraint on the link between producers of perishable goods and their customers since it shortens the time frame the producer can plan its inventory of processed products ahead. This restriction is the result of negotiations between buyer and vendor, in this case the wholesaler/retailer and the processing company. The implications of such agreements are positive for wholesalers and retailers. In terms of planning reliability for instance, they can plan the flow of products through their own supply chain starting at a certain guaranteed remaining shelf-life.

Hygiene and Temperature Regulations

The degree of perishability, expressed as the remaining shelf-life, quality regulations and the need for cooling of dairy products along the supply chain, have a great influence on the supply chains network structure. As animal products, they have to undergo strict hygiene and temperature regulations and controls every time they are handed from one actor to another or from transport to storage and vice versa. They are also subject to microbiological decay and have therefore a short- to medium-term shelf-life. While products with unrestricted or a very long shelf-life can pass through multiple warehouse stages on their way to points-of-sale, time is of the essence when handling dairy products. Therefore, dairy supply chains are shorter than for instance supply chains for dry goods and are highly eligible for measures that decrease throughput time, like cross-docking.

Different Processing Times

Furthermore some products, like cheese, have to undergo a period of ripening before they reach the quality and state that is fit for customers at points-of-sale. As an example: One of the dairies reported ripening periods of 6 weeks to 6 months for their assortment of cheese. While the processing takes considerable more time, the production rate is not necessarily affected by this. However, the degree to which the producer can react to unexpected shifts in demand is lower. In logistical terms, this can be expressed through longer lead times. These lead times can then in turn affect for instance safety stocks.

22.4.3 Evidence from Literature and Expert Interviews

General

According to our interviews with the dairies, raw milk is multi-sourced from a high number of farms, an example being 110 farms supplying one processing site. Concerning product characteristics, van Donselaar et al. (2006) state in their case study “that all products which require a conditioned environment (e.g. as stated on the packaging by the manufacturer) have a shelf life that is equal to or less than 30 days”. Accordingly, they assumed shelf-life to be at a maximum of 30 days for perishables in their work. They furthermore introduce another group of perishables that features a shelf-life of less than or equal to 9 days. While 30 days of shelf-life may correspond to products like cream, cheese or curd, 9 days or less is a characteristic that one would suggest when dealing with products such as fresh milk. The latter assumption is in line with information from one of the dairies, who specified the remaining shelf-life of milk leaving their site to range between 10 and 12 days. It has to be noted though, that the former generalization has its weaknesses, since hard cheese for instance can have a significantly greater remaining shelf-life at the point of sale than the mentioned 30 days. As a result, supply chains for these types of cheese might look different.

Food Production

Storage

Concerning input products, which consist in case of a dairy first and foremost of raw milk, it was stated by the dairies that the ingoing raw milk has to be processed within 24–36 h. Since raw milk is delivered to the dairy on a daily basis and due to its characteristics, there is no intentional storage of input products. Regarding stock ranges of finished products, the interviews with three dairies yielded the following insights: The smallest of the three dairies, in terms of throughput, indicated that their storage could only carry 2 days production. Therefore this acts as a structural upper threshold to their stock range of finished products. The medium-sized dairy works in close cooperation with a LSP when it comes to storing its finished products and hence possesses very little storage space itself. The larger dairy stated in an interview that they normally carry a stock range of 4–5 days, but that this is partly due to quarantine restrictions (for testing) laid upon them by public administration. Even though the values for average stock ranges differ, this does not necessarily point towards different stocking strategies for finished products. The cooling of finished products is costly and the restrictions concerning the remaining shelf-life also suggest that the finished products are delivered as soon as possible. Hence, the assumption can be made that inventory of finished products at the processing stage is limited to a few days stock range, at maximum. (see Table 22.2).

Cooperation with LSP

There is another factor that may explain extremely low stock ranges at the production stage. The dairy that cooperates with the LSP described a different business model in terms of storage: around 80 % of their production sites did not have their own storage, but finished products were instead collected on a daily basis by a LSP and stored in its facilities. Here, the LSP takes on the role of an intermediate stage that stores finished products before passing them on to the dairy's customers. An interview with this LSP, who specializes in storing and handling services for dairy products (and fresh products in general), indicated that the stock range at their facilities lies between 3 and 5 days. While the other dairies do not follow the same storing strategy, they had their finished products transported to the next stage in the supply chain by LSP's as well.

Table 22.2 Name, Revenue and Storage of finished products of the interviewed dairies

Name	Revenue (million €)	Storage of finished products
Dairy #1	<100	0–1 days stock range
Dairy #2	>1.000	Cooperation with LSP
Dairy #3	>1.500	4–5 days stock range

Volatility in Demand

The indicated small stock ranges could supplementary be promoted by a high stability of demand, since the more stable the demand rates, the less safety stock is needed in order to be able to react to unpredictable fluctuations. This consideration is supported by evidence from the dairies. Demand was described as rather stable, especially that of processed milk, excluding seasonality in form of holidays and seasons as well as during retailers' advertising and pricing campaigns. Fluctuations caused by campaigns can be predicted if they are communicated early enough. Therefore they can also be included in the production planning process and accordingly do not necessarily lead to higher safety stocks or the need for higher stock ranges of finished products.

However, the seasonal fluctuations in demand for finished products do not extend to the same magnitude to the dairies' demand for raw milk. Here it was stated that, for instance, a higher demand for butter in winter is opposed by increased demand for certain cheese types, like mozzarella, in the summer season, resulting in little to no difference in the amount of raw milk required for production. Minor fluctuations in demand from retailers and wholesalers can under normal circumstances be compensated via night-shifts and weekend work. One dairy stated that, with the exception export activities and companies that further process their products, they do not produce on orders. Rather, for the national retailers and wholesalers, future demand is estimated on the basis of past sales and the general setups of production adjusted accordingly. Short-term adjustments by customers can only be made up to 2 days before delivery occurs.

Food Trade

Distribution Structure

Once the finished products are ready for delivery, a one-stage distribution concept seems to be the network structure favored by most retailers for the transportation to their points-of-sale. This was amongst others, found by Peilnsteiner and Truszkiewitz (2002) and more recently as part of an empirical study of the logistics of the D-A-CH food industry, by Kuhn and Sternbeck (2011). Thus, from either the production companies' or the LSP's storage sites, the dairy products are distributed via a central or a regional warehouse to the points-of-sale. This was confirmed by the interviewed producers, who indicated delivery to central warehouses of their customers (the retail and wholesale companies).

When dealing with dairy products, the warehouse of this one-stage architecture can also take the form of a cross-dock, as was found for instance in the case study of a large Dutch retailing company by van Donselaar et al. (2006), where the majority of dairy products with a shelf life of less or equal to 9 days were cross-docked. The authors suggested that this might be caused by the low remaining shelf-life values of most dairy products. These in turn allow for little to no tolerance for delays at storage sites when matched with required minimum remaining shelf-life norms of the points-of-sale. In this case, cross-docking or direct deliveries are efficient options to meet these requirements, even though they can be more costly.

Delivery Frequencies and Lead Times
The large German discounters possess great market power due to the oligopoly-market-structure and their hence high market shares. It was stated by one large producer, that these discounters demand the option of daily delivery in their framework agreements with the producers. This was confirmed by another producer that stated a delivery frequency to retailers and wholesalers warehouses of 5–6 times per week. The delivery lead time and hence the time frame within which the customers can still change the amount delivered, was quoted to be 2 days. Table 22.3 summarizes information we gathered on delivery lead times and delivery frequencies. They apply for relations between retailers' warehouses and their stores or wholesalers and their customers.

One of the interviewed retailers moreover described the time flow that goes along with the ordering of dairy products by a retail store: When ordered before 8:30, the stores would get their delivery on the same day. This can be used to explain the lower values of lead times like 12 h.

Storage at Points-of-Sale
A wholesaler stated that their inventory of dairy products would last only 1–2 days without replenishment. One of the large German discounters indicated that most retailers equip their stores with a small storage space for dairy products. Serving as another point of data, in their case study, Thron et al. (2007) assume a maximum stock range of 1 week for dairy products and base this on their vast experience in the sector. These values refer to the total stock at points-of-sale, which consists of front-store and back-store inventory. This overall inventory could also be separated

Table 22.3 Delivery lead times and frequencies from warehouses to PoS for dairy products

Delivery lead time	Delivery frequency	Source
3 days	4–5 times per week	Discounter #1
	Daily	Discounter #2
	3 times per week	Discounter #3
	Daily	Discounter #4
1–3 days		Supermarket #1
	5–6 times per week	Supermarket #2
1 day		Warehouse #1 Supermarket #3
	Daily	Warehouse #2 Supermarket #3
12 h	Daily	Wholesaler #1
1–2 days	3–4 times per week	Wholesaler #2
	1–3 times per week	Peilnsteiner and Truszkiewitz (2002)
	Daily	Kotzab and Teller (2005)
1 day		Broekmeulen and van Donselaar (2009)
12–30 h		Smaros et al. (2004)
12 h	3–6 times per week	Kuhn and Sternbeck (2011)

into safety and cycle stock. Smaros et al. (2004) found in their study safety stocks of food products in general to lie between 0 and 10 days with a median of 2 days. This value increased when looking at the larger types of supermarkets (e.g. hypermarkets). When it comes to back-store capacities, one discounter reported the storage space for cooled goods such as dairy products at their points-of-sale to amount to 4 euro-pallets. At a wholesaler, the space for all fresh goods was stated to lie at around 4 cooling-chambers, though without naming their size. One of the dairies interviewed also stated that there is an ongoing trend towards the (further) reduction of inventories when it comes to storing dairy products at retailers' stores. An increasing number of retailers and hence their stores would now order more often, but in smaller batches to achieve lower average inventories at points-of-sale. Confirmed by one of the wholesalers we talked to, it was pointed out, that lower average inventory levels at points-of-sale have to be compensated for by producers by either adding storage space or increasing flexibility.

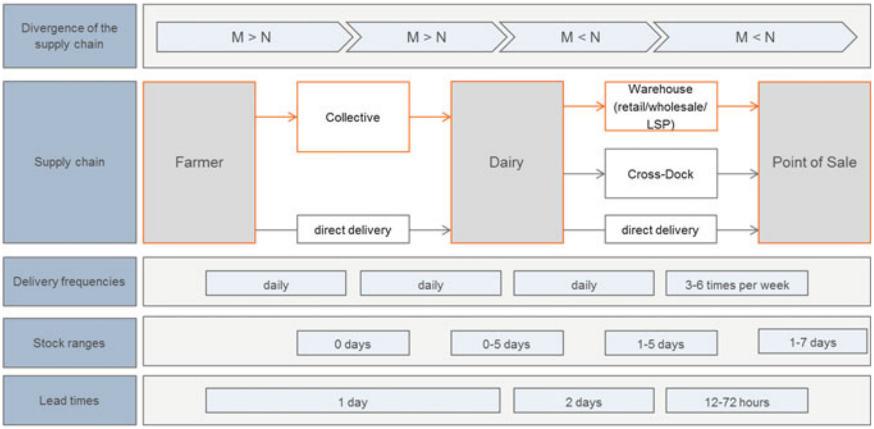
22.5 Results

The fundamentals for deriving modelling assumptions that have to be considered in the process of reproducing dairy supply chains have been extracted from practice. Additionally, structures and parameters that are necessary for modelling inventory courses along dairy supply chains have been described.

The descriptions are based on a database for all commodity groups, containing more than 250 data points that were collected from 20 first-hand interviews and over 30 literature sources. Future food inventory modelling ventures can use this research as a basis for their work and thus now be more precise and consistent.

As an example of how the gathered information can be used, an exemplary dairy supply chain profile has been filled with data derived in this work. It can be found in the Appendix and showcases the inventory movements of dairy products that move from farmers over collectives to the dairy and in terms of food trade, through the warehouse of a retailer or wholesaler, before being delivered to their point of sale. This filled profile can be used in combination with data on the size and amount of production, processing, retailing and wholesaling companies in a region to first derive inventories on the level of actors. In a next step, these inventory levels of a commodity group can be aggregated to approximate the total inventory of this commodity group present in the considered region.

Appendix



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Part VIII
Urban Commercial Transport

Chapter 23
Factors Influencing the Performance of Urban Consolidation Schemes

Sönke Behrends

23.1 Introduction

Urban logistics is essential to the functioning of modern urban economies. Cities are places of consumption relying on frequent deliveries of groceries and retail goods, express deliveries to businesses, and a fast-growing home delivery market. For people, urban logistics ensures the supply of goods in stores and for firms it forms a vital link with suppliers and customers (Crainic et al. 2004). Urban logistics is therefore an important component for economic vitality of cities (Anderson et al. 2005). However, the urban environment characterised by scarcity of access, e.g., congested roads, space constraints and limitations of infrastructure restricts the efficiency and quality of urban logistics operations (Hesse and Rodrigue 2004). Freight vehicles are delayed by congestion and are constrained to carry out loading and unloading because of insufficient parking spaces. The time spent for loading/unloading the cargo tend to occupy the majority of the vehicle time and therefore make up most of the freight operator's costs, particularly as they have to allow additional time in scheduling for delays due to congestion (MDS Transmodal 2012).

Reversing the perspective, urban logistics is increasingly perceived as disturbing activity for passenger transport and the citizens' quality of life. Freight traffic in urban areas has several negative impacts, including environmental impacts (e.g., atmospheric emissions, use of non-renewable fuels, waste and loss of ecosystems), on society (e.g. public health, accidents, noise and reduction of quality of life) and on the economy (e.g. waste of resources and congestion resulting in decreasing journey reliability and city accessibility) (Quak 2007). Though freight transport operations in cities represent only 20–30 % of road traffic, they account for up to 50 % of the emission of air pollutants (depending on the pollutant considered) by

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transport activities in a city (Dablanc 2007). In London, freight traffic stands for 23 % of all CO_2 emissions emitted by all forms of transport and half of all cyclist fatalities are due to accidents involving freight vehicles (MDS Transmodal 2012).

As the population has increasingly come to live in urban areas and the demands on an attractive urban environment increase (European Commission 2007), the development of growing urban logistics problems was followed by an increased awareness for urban logistics. Cities around the world have engaged in extensive experimentation to manage urban logistics in order to improve logistics performance while at the same time reducing the negative environmental and socio-economic impacts. Various urban consolidation centres (UCC) have been implemented, however, many UCCs have struggled to operate on a commercial basis and are either terminated or depend on government subsidies (Macharis and Melo 2011). Literature has identified many factors influencing the environmental performance as well as the economic feasibility of urban consolidation schemes, including range and type of products handled, location and spatial coverage of the UCC (Browne et al. 2005). A prerequisite for implementing economically viable UCCs is a better understanding of these factors. The purpose of the paper is to analyse the relevance and significance of the key factors on the environmental and economic performance.

The paper is based on a case study, analysing a pilot project of consolidated last mile deliveries in the city centre of Gothenburg. The paper is organised as follows: The second section introduces the CUTS Model, which is used for the calculation. The third section introduces the case study and presents the calculation results. The fourth section presents a sensitivity analysis on the key factors influencing the UCC performance. The paper concludes with a discussion of research implications and with an outline of directions for further research.

23.2 The CUTS Model

Full sustainability requires that all stakeholder goals are met at the same time. It is therefore important that urban freight transport actions aiming to improve the situation for one actor group do not lead to negative consequences for another actor group. The purpose of the CUTS Model is therefore to evaluate the appropriateness of urban freight transport measures by taking all relevant stakeholders into account. The Model aims to help local authorities to get a holistic understanding of the implications of the different measures. Furthermore, it helps authorities to assess whether successful measures from elsewhere can be successfully implemented in the local context. By indicating the implications of possible urban logistics initiatives for all stakeholders, local authorities can identify promising measures taking transport chain characteristics and the spatial constraints of the respective city area into account (Behrends 2013).

The CUTS-Model decomposes the “total amount of goods consumed” in the area of analysis into a series of key parameters, affecting the goals of the different stakeholders. These key-parameters are determined by factors characterising the

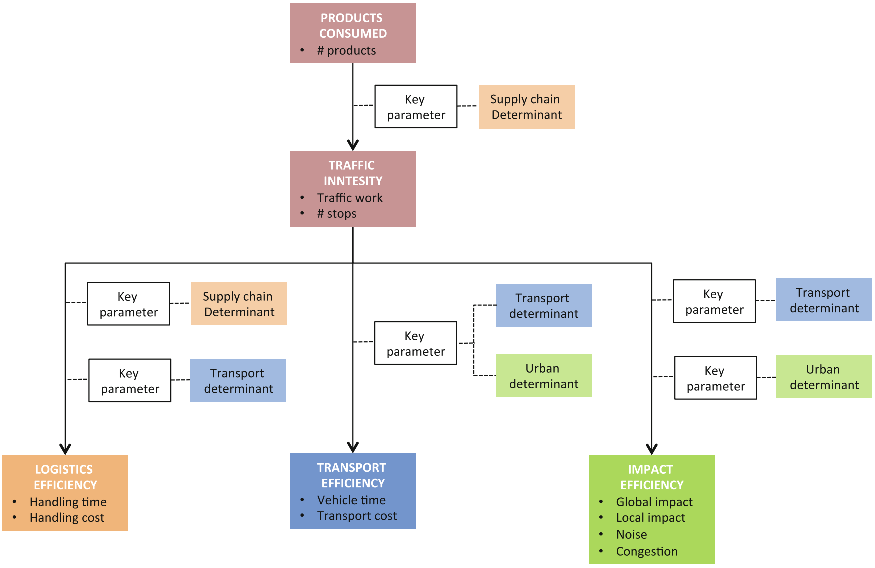


Fig. 23.1 CUTS model Structure

supply chain, the transport system, and land-use system. The structure of the model is shown in Fig. 23.1.

In the first step, the CUTS-Model determines the *traffic intensity* of the solution, by decomposing the "total amount of goods consumed" in the area of analysis into traffic indicators, including both moving traffic (the total distance travelled) and stationary traffic (the amount of vehicle stops), which drive the cost and emissions of the movement of goods. In the following steps, the traffic indicators are then decomposed into a series of key parameters determining the *logistics efficiency* representing the goals of shippers and receivers (e.g. minimising handling time and cost), the *transport resource efficiency* representing the goals of transport operators (e.g. minimising vehicle time and cost) and the *impact intensity* representing the goals of local authorities (e.g. minimising global climate change, local public health impacts, noise and congestion). The formulas for each of these steps are presented below (see Fig. 23.1).

23.2.1 Traffic Intensity

In the first step the model converts the amount of goods in the area of analysis into traffic indicators, including both moving traffic (the total distance travelled) and stationary traffic (the amount of vehicle stops), which drive the cost and emissions of the movement of goods. The stationary traffic is determined by the amount of goods and the number of stops per vehicle trip:

$$S_{tot} = G_{tot} \times \frac{1}{G_C} \times \frac{1}{C_S} \tag{23.1}$$

Where S_{tot} is the total number of stops in the area, G_{tot} the total amount of goods transported into the area, G_C the average amount of goods per consignment (shipment size), and C_S the average number of consignments per stop (consolidation rate).

The distance travelled is the product of number of stops and the distance between the stops:

$$D_{tot} = S_{tot} \times D_{stop} \tag{23.2}$$

where D_{tot} is the total distance travelled in the area, and D_{stop} the average distance between the stops of all vehicle trips in the area.

23.2.2 Logistics Efficiency

The goals of the receivers are maximising the efficiency of logistics operations including the receiving of the goods. They aim for minimising the amount of deliveries, which are disturbing activities since they occupy receiver staff while focussing on selling and the vehicles block the display windows. The total number of deliveries can be calculated by:

$$DL_{tot} = G_{tot} \times \frac{DL_R}{G_R} \tag{23.3}$$

where DL_{tot} is the total number of deliveries, DL_R the average delivery rate per receiver, and G_R the average amount of goods per receiver.

The number of deliveries can be translated into real costs for the receiver:

$$CH_{tot} = DL_{tot} \times TH_R \times CS_R \tag{23.4}$$

where CH_{tot} is the total handling cost for receiver, TH_R the average handling time for receiver and CS_R the average costs for receiver staff.

23.2.3 Transport Resource Efficiency

The goal of the transport operators is an efficient use of their resources. The traffic intensity indicators developed in the previous step are now converted into resource efficiency indicators. These are distance-related and time-related costs. The distance-related costs include the distance-related vehicle costs and energy costs:

$$CD_{tot} = D_{tot} \times (EU_V \times CE_V + CD_V) \tag{23.5}$$

where CD_{tot} are the total transport distance costs, (EU_V) the average energy use of the vehicle per distance unit, CE_V the average cost per energy unit and CD_V the average distance-related vehicle cost.

The time-related costs are determined by the total vehicle time multiplied with the sum of the time-related vehicle costs and the costs for the driver:

$$CT_{tot} = TV_{tot} \times (CT_V + CS_T) \tag{23.6}$$

where CT_{tot} are the total time costs, TV_{tot} the total vehicle time, CT_V the average time-related vehicle costs, and CS_T the average costs for driver. TV_{tot} is the sum of driving and handling time:

$$TV_{tot} = D_{tot} \times v_V + DL_{tot} \times TD_V \tag{23.7}$$

where v_V is the average vehicle speed, DL_{tot} is the total number of deliveries, and TD_V the average dwell time consisting of parking time and handling time at the receiver.

23.2.4 Impact Intensity

The unsustainable impacts of the urban distribution activities includes local emission impacts on human health and ecosystems, noise impacts on human health, climate impacts of GHG emissions and contribution to congestion:

$$I_{tot} = IG_{tot} + IL_{tot} + IC_{tot} + IN_{tot} \tag{23.8}$$

where I_{tot} are the total impacts unsustainable impacts of the distribution activities, IG_{tot} the total climate impacts, IL_{tot} the total local emission impacts, IC_{tot} the total congestion impacts, and IE_{tot} the total noise impacts. These different impact types are calculated in the following way:

The total climate impacts are the product of the total distance travelled, the GHG-emission-performance of the vehicle and the external cost value of GHG emissions:

$$IG_{tot} = D_{tot} \times EG_V \times CE_G \tag{23.9}$$

where EG_V is the average emissions of GHG emissions per distance unit, and CE_G external costs per unit of GHG emission.

The local emission impacts is the product of the emissions taking place in emission sensitive areas multiplied with the external cost value of the different emission parameters causing local health problems:

$$IL_{tot} = D_{es} \times \sum_{n} (EL_V^n \times CE_L^n) \quad (23.10)$$

where D_{es} is the distance travelled through emission sensitive areas, EL_V the average emissions of local emission n per distance unit, and CE_L the external costs per unit of local emission.

The congestion impact is the product of distance travelled through congested traffic and the external cost value of the vehicle in this traffic:

$$IC_{tot} = D_{con} \times CE_{con} \quad (23.11)$$

Where D_{con} is the distance travelled through congested traffic, and CE_{con} the external costs for congestion per vehicle-km.

The noise impact is the product of the distance travelled through noise sensitive areas, the vehicle's noise intensity and the external cost value of traffic noise.

$$IN_{tot} = D_{ns} \times N_V \times CE_N \quad (23.12)$$

where D_{ns} distance travelled through noise sensitive traffic, N_V average vehicle noise intensity, and the CE_N external costs for noise.

23.3 The Case Study

23.3.1 Case Description

The case studied in this paper is a pilot project of consolidated last mile deliveries in the city centre of Gothenburg. The project aims at reducing delivery traffic in the central business district (CBD), which today is characterised by many vehicles delivering part loads with a low level of utilisation. The project provides a UCC ('micro-terminal') close to the city center where shipments to small and medium sized shops are consolidated for subsequent delivery into the retail area in small zero-emission vehicles with a high level of load utilisation. In the micro-terminal the incoming parcels are sorted and prepared for the delivery to the receivers.

The project started with a pilot phase in January 2013. During this phase the micro-terminal did not serve the whole CBD but only a small area (Fig. 23.2). In July 2013 the traffic data at the Micro-terminal on 5 days (1 week) was collected, including the incoming traffic flows into the micro-terminal (number of incoming vehicles to the micro-terminal), goods handled at the micro-terminal (number of parcels, deliveries and receivers) and the outbound flows (last mile deliveries). In total, 25 vehicles from 5 distinct transport operators delivered 129 parcels to the Micro-terminal destined to 55 distinct receivers. These parcels were delivered from the terminal to the shops are performed by two last-mile distribution trips per day, one with a cargo bike and one with small electric truck.

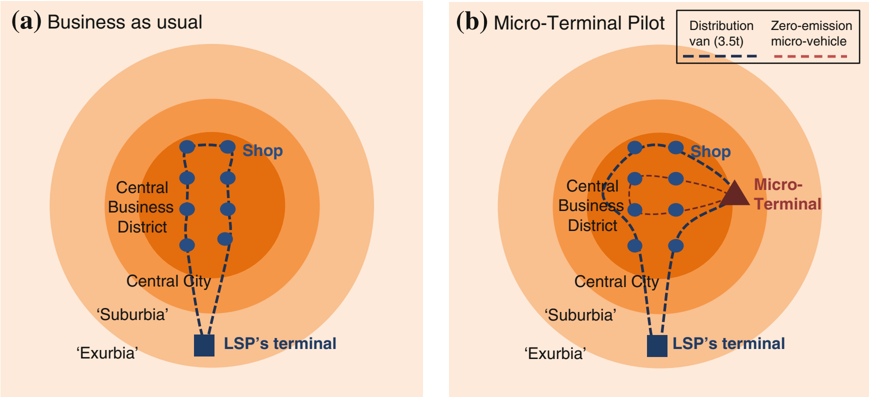
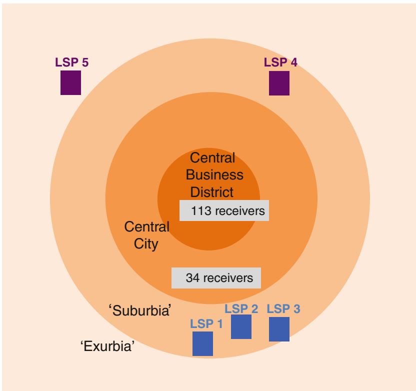


Fig. 23.2 Design of UCC project Stadsleveransen. **a** Business as usual (no consolidation), **b** Micro-Terminal in pilot phase

While the service of the micro-terminal in the initial phase is provided free of charge for both transport operators and receivers, the goal is that the service operates on commercial terms without subsidies. The users are therefore expected to contribute to funding of the service. A prerequisite for an economically viable business model is that the combined benefits of the services outweigh the costs. The goal of the evaluation is therefore to quantify the potential benefits of the micro-terminal for the different stakeholders. Since the project was of very limited scale during the pilot phase when the data was collected, a case is constructed assuming that the micro-terminal serves the whole CBD of Gothenburg. The collected data during the pilot phase was extrapolated to create a case describing full scale-operation of the micro-terminal (Fig. 23.3).

The case is based on the following data: There are 5 distinct logistics service providers (LSP) with one distribution tour each in the city center (including CBD and central city) using a LDV (3.5 tons, Diesel EURO 4). LSP 1, LSP 2 and LSP 3

Fig. 23.3 Case definition



are large-scale operators. Their final deliveries are geographically focused so that they have dedicated tours to the CDB with a high vehicle utilisation. LSP 4 and LSP 5, on the other hand, are small-scale operators. Their final deliveries are geographically spread over the whole central area serving both the CBD and the central city with the same tour.

The terminals of LSP 1, LSP 2 and LSP 3 are located in close proximity to one another in the same suburban area approximately 10 km from the CBD. The terminal of LSP 4 is located in another suburban area approximately 10 km away on the opposite side of the city centre, while the terminal of LSP 5 is located in a rural area approximately 15 km away from the city centre. These 5 LSP combined serve 113 receivers in the CBD and 34 receivers in the Central City. The handling time is 4 min per delivery. The traffic conditions on the access roads from the LSP's terminals to the city centre are 'near capacity' (i.e. the traffic volume to capacity ratio is between 0,75 and 1). The traffic conditions on the local streets in the city centre are 'free flow' (i.e. a ratio less than 0.25) as defined by Gibson et al. (2014).

The CUTS Model was used to calculate the performance indicators for the different stakeholders. In the present stage the model does not include any cost indicators, i.e. the model is limited to the following indicators: The *logistics efficiency* is measured in terms of the receivers' handling time. The *transport resource efficiency* is measured in terms of the operators' traffic work including vehicle-time and vehicle-km. The *impact intensity* is measured in terms of external cost for climate impact, impact on public health and ecosystems, impact of noise, safety risks and congestion. The input values to the CUTS model on vehicle emissions are calculated according to NTM (2007) and the external costs values used are based on Gibson et al. (2014).

23.3.2 Definition of Scenarios

Three scenarios representing different levels of implementation are analysed and compared (Fig. 23.4). The first scenario ('Business as usual') represents the operations without any micro-terminal, i.e. it includes 5 distribution tours from the LSPs' terminal directly to the receivers in the central city. The second scenario ('Collective last mile') represents the case of a micro-terminal serving the whole CBD. It includes 5 distribution tours from the LSP's terminals to the micro-terminal in the city centre, where the goods destined to receivers in the CBD are unloaded. Zero-emission micro vehicles, i.e. a cargo bike and electric micro truck, perform the last-mile distribution from the micro-terminal to the receivers in the CBD. The vehicles from LSP 1, LSP 2 and LSP 3 return empty to their terminal, while the vehicles of LSP 4 and 5 continue their distribution tour in the Central City.

The third scenario ('collective feedering') separates the trunk movements from local deliveries, making the use of a larger vehicle for the feedering into the CBD feasible. To achieve this the consolidation of the goods of LSP 1, LSP 2 and LSP 3 takes place in a micro-terminal in the suburban area in close proximity to their

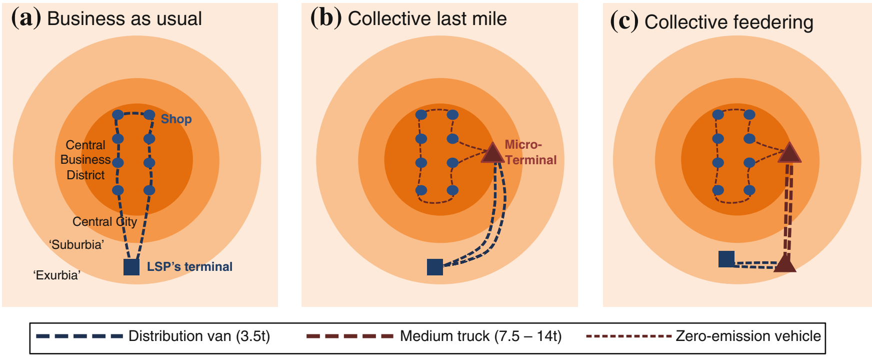


Fig. 23.4 Scenarios analysed in the case study

terminals. From there, a medium-duty-vehicle (7.5–14t, Euro 5) transports the goods collectively to the micro-terminal in the city center, from where last-mile deliveries are executed as in scenario 2. LSP 4 and LSP 5 operate as in scenario 2, since their terminals are too far away from the suburban micro-terminal area.

23.3.3 Results

This section presents and analyses the results of the calculations of the scenarios. First, the distribution of the externalities are analysed by type of impact and by location. Then the improvement potential of the scenarios from the different actors' perspectives are presented.

Analysis of externalities

Figure 23.5 shows the externalities in the Business-as-usual scenario. In total, the distribution operations of the 5 LSP cause externalities in about 70€. Congestion is by far the biggest externality accounting for approximately 80 % of the total

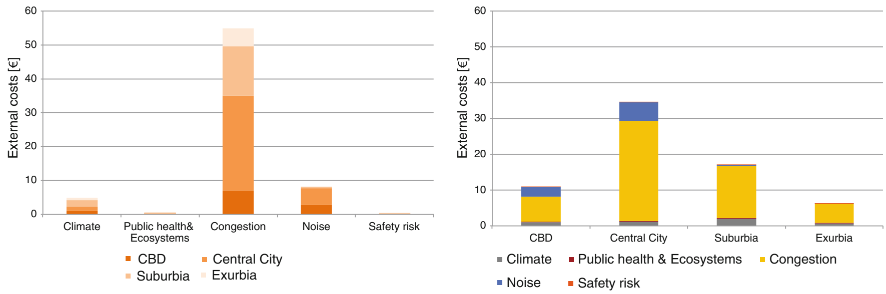


Fig. 23.5 External costs in scenario 'Business-as-usual' by type of externality (*left*) and by urban area (*right*)

externalities. Additional impacts with some significance are noise (12 %) and climate impact (7 %), while safety risks (<1 %) and impacts on public health and ecosystems (<1 %) are negligible. The urban area exposed to the highest externalities is the central city (50 %), followed by suburban areas (25 %), the CBD (16 %) and exurban areas (9 %).

Comparison of scenarios

The results of the calculations show that 'collective last-mile' slightly reduces the externalities (−9 %), while 'collective feedering' reduces the externalities significantly (−38 %). Figure 23.6 shows that these saving in 'collective last mile' mainly occur in the CBD, i.e. the target area of the UCC implementation. 'Collective feedering' leads to significant network effects, as it in addition to the savings in the CBD also involves significant savings in suburban areas.

Figure 23.7 displays the changes in the indicators from the CUTS Model representing the goals of the different stakeholders in the two scenarios in comparison of the business-as-usual scenario. For the receivers, collective last mile' reduces the number of handlings by 18 %, which also reduces the time spent for handlings by the same amount. Since 'collective last-mile' and 'collective feedering' do not differ in the way the last mile deliveries are operated, there is no difference for the receivers between these scenarios. For the operators, the results show that the traffic work in terms of veh.km is only slightly reduced in 'collective last-mile' (−3 %), while the reductions in 'collective feedering' are significant (−36 %). The traffic work in terms of veh.time, on the other hand, increases in both scenarios, although the veh.time of the LSP decreases considerably in both scenarios (−53 % in

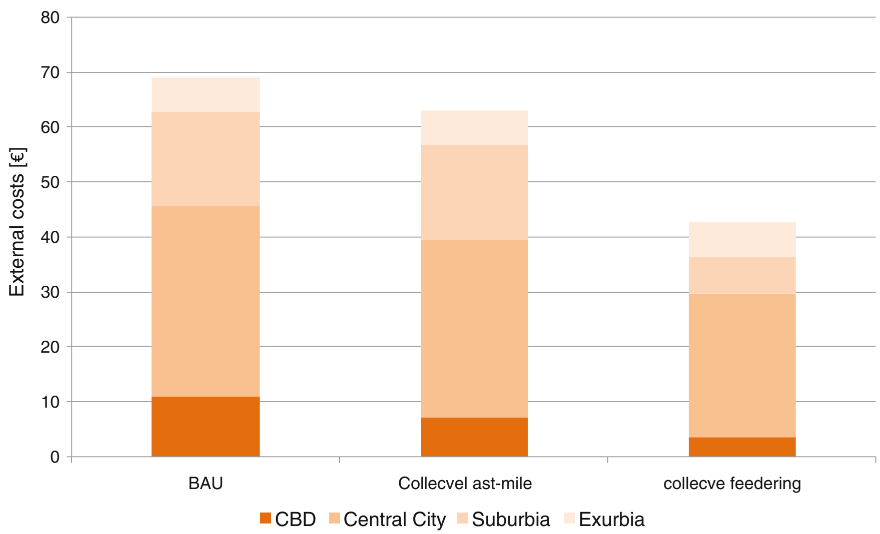


Fig. 23.6 Comparison of scenarios by urban area

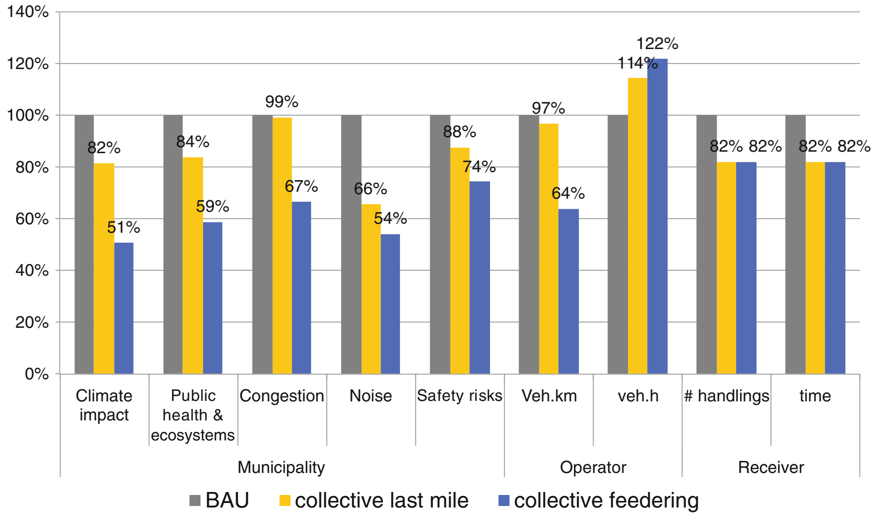


Fig. 23.7 Comparison of scenarios

'collective last-mile' and −57 % in 'collective feedering'). However, these savings are overcompensated by the additional handling time in the terminals and collective vehicle operations. As a result, the total vehicle time including both the LSP and UCC operator increases by 14 % in 'collective last-mile' and by 22 % in the 'collective feedering'. The municipalities mainly aim for a reduction of the externalities caused by urban distribution operations. The calculations show that 'collective last-mile' has no impact on congestion costs, which are by far the biggest externality of urban distribution. This is due to the fact that the LSP still have to drive on the congested urban main roads to access the micro-terminal in the city centre; hence there is no change in the amount of traffic on congested roads in comparison to the BAU scenario. In 'collective feedering', on the other hand, congestion costs are reduced by approximately one third, due to the fact that the consolidation takes place already in suburban areas and hence three distribution vans are replaced by one medium-duty vehicle, which reduces driving on congested roads significantly. The climate impact, which is the second biggest impact in BAU is reduced by 18 % in 'collective last mile' and by almost 50 % in 'collective feedering'. Finally, noise costs are reduced significantly in both scenarios (−34 % in 'collective last-mile' and −46 % in 'collective feedering').

In total, the analysis shows that 'collective last-mile' leads to some improvements in terms of externalities; however, it does not contribute to reducing congestion, which is the most significant type of externality. 'Collective feedering', on the other hand has the potential to significantly reduce congestion and other externalities. This scenario leads also to significant time-savings for the LSP; however, these savings are over-compensated by the collective UCC-operations, including terminal handling, feedering and last-mile deliveries.

23.4 Sensitivity Analysis

23.4.1 Factors Influencing the Environmental Performance of UCC

This section presents a sensitivity analysis of two factors on the environmental performance of UCCs. The first factor analysed is the vehicle technology used. Innovative technology, such as electric vehicles, offers a significant reduction of emissions. The choice of vehicle technology has therefore a significant effect on the externalities of urban distribution. In practice, many existing UCCs involve last-mile distribution with electric vehicles as they promise sustainable transport operations.

The second factor used in the sensitivity analysis is the type of urban area. Since congestion is the dominating impact category, the traffic conditions on the urban road network and the distance travelled in congested traffic have probably a high impact on the results. It can therefore be assumed that urban distribution activities have significantly higher marginal congestion externalities in large urban areas where traffic is congested and distances between the LSP's terminals and suburban areas and CBD are great, compared to small cities with uncongested traffic and short distances to the CBD.

23.4.2 Case Definition

To test the sensitivity of the factors defined above, the externalities of one of the large LSP from the case study presented in the previous section are calculated for two different cases using different input values for the factors to be tested. The factors tested are first, the vehicle technology used; and second, the type of the urban area.

The cases compared are 'business as usual', and 'collective feedering'. 'Business as usual' represents direct deliveries from the LSP's terminal in a suburban area to the shops in the CBD. 'Collective feedering' includes three trips: the first-mile (LSP-Terminal to Micro-Terminal in surburban area), the feedering (Micro-Terminal in suburbia to Micro-Terminal in CBD), and the last-mile (Micro-Terminal in CBD to shops).

Three different vehicle technology combinations for the 'collective feedering' case are tested (Table 23.1). The first combination ('conventional/conventional') uses only conventional technologies, i.e. Diesel internal combustion engines, on the feedering trip and the last-mile trip. The second combination ('conventional/electric') uses an electric vehicle on the last-mile trip, and the third combination ('electric/electric') uses electric vehicles on both the feedering and the last mile trip. In 'business as usual' a conventional van is used, and this is not altered in one of the scenarios.

Table 23.1 Vehicle technologies in the sensitivity analysis

Case	Trip	Vehicle technology	
		Conventional	Electric
Business as usual	Whole trip	LDV <3.5t—Diesel Euro 4	
Collective feedering	First mile	LDV <3.5t—Diese Euro 4	LDV <3.5t—Electric
	Feedering	MDV 7.5–14t—Diesel Euro 5	MDV 7.5–14t—Electric
	Last mile	LDV <3.5t—Diesei Euro 4	LDV <3.5t—Electric

The different vehicle combinations are tested in three different urban areas (Table 23.2), representing different traffic conditions and distances between suburbia where the LSP's terminal is located and the CBD (feedering distance). In the first urban area ('small city') the feedering distance is short (5 km) and there is no traffic congestion (100 % free flow). In the second urban area ('medium city') the feedering distance is medium (10 km) and traffic volumes reaches capacity on parts of the network (50 % free flow, 50 % near capacity). In the third urban area ('large city') the feedering distance is big (20 km) and traffic is very congested (50 % near capacity, 50 % over capacity).

23.4.3 Analysis

In the fist step, the effect of the city type in the 'business as usual' case is tested. Figure 23.8 shows the externalities per parcel delivered in the different scenarios. The total externalities are 1.57 €-cent per parcel delivered in the scenario representing a small city (5 km feedering distance, and free flow traffic). The total externalities in 'medium city' (10 km and 50 % near capacity traffic) are about 4 times higher, and even about 15 times higher in 'large city' (20 km, 50 % near capacity and 50 % over capacity). The differences in externalities are therefore much higher than the differences in distance, suggesting a high relevance of the level of congestion. Compared to 'small city', the externalities of climate impact, public health and ecosystems, noise and safety are all about 1.5 times bigger in 'medium city' and about 2.5 times bigger in 'large city'. The difference in congestion cost on the other hand, are about 27 times higher in medium city and 124 times higher in 'large city'.

Table 23.2 City characteristics in the sensitivity analysis

City	Feederingt distance	Traffic condition		
		Free flow (%)	Near capacity (%)	Over capacity (%)
Small city	5	100	0	0
Medium city	10	50	50	0
Large city	20	0	50	50

Figure 23.9 shows the results of the scenarios in the case ‘collective feedering’ with different vehicle combinations. The results show that ‘collective feedering’ with conventional vehicles approximately halves the externalities in all scenarios (in ‘small city’ by 45 %, in ‘medium city’ by 47 % and in ‘large city’ by 43 %). Replacing the conventional vehicle with an electric vehicle in the last-mile trip (scenario ‘conv./el.’) leads to significant improvements in ‘small city’ (additional −22 % reductions) and to small improvements in ‘medium city’ (additional −5 %), while in ‘large city’ there is almost no change (−1 %). A similar effect can be observed when using an electric truck on the feedering trip (scenario ‘el./el.’), as this leads to significant reductions in ‘small city’ (additional −23 %), but only to some reductions in ‘medium city’ (−8 %) and in ‘large city’ (−4 %). In total the scenario using innovative technology on both the feedering and the last-mile trip reduces the total externalities compared ‘business as usual’ by 90 % in ‘small city’, by 60 % in ‘medium city’ and by 48 % in ‘large city’.

Analysing the relative contribution of the different factors, i.e. (1) organisational change from BAU to collective feedering, (2) electric last-mile and (3) electric feedering reveals the following. The organizational change leads to significant improvements in all city types without using any innovative vehicle technology. Innovative vehicle technology has a significant impact in small cities where air pollution and climate impacts dominate the externalities. In cities where traffic problems dominate the relative contribution of innovative vehicle technology to the reduction of externalities is marginal (see Fig. 23.9).

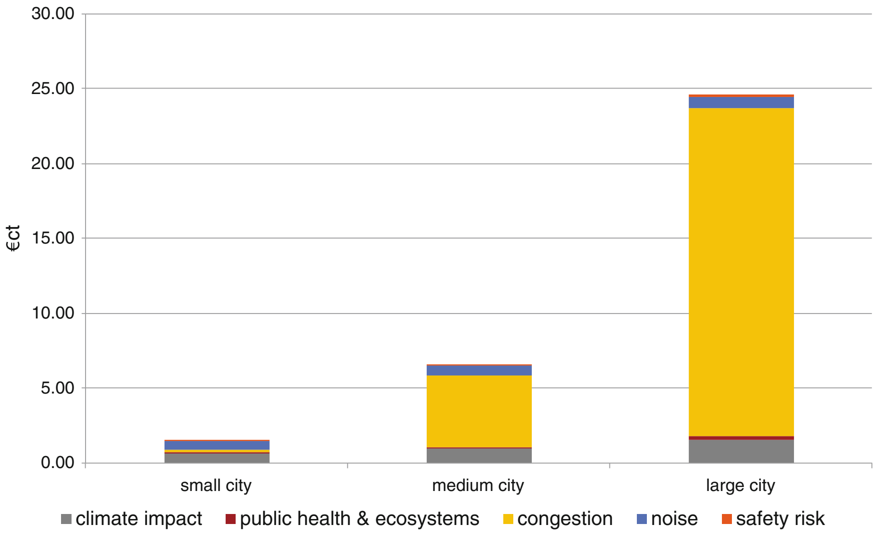


Fig. 23.8 Externalities per parcel delivered in BAU-scenario in a small, medium and large city

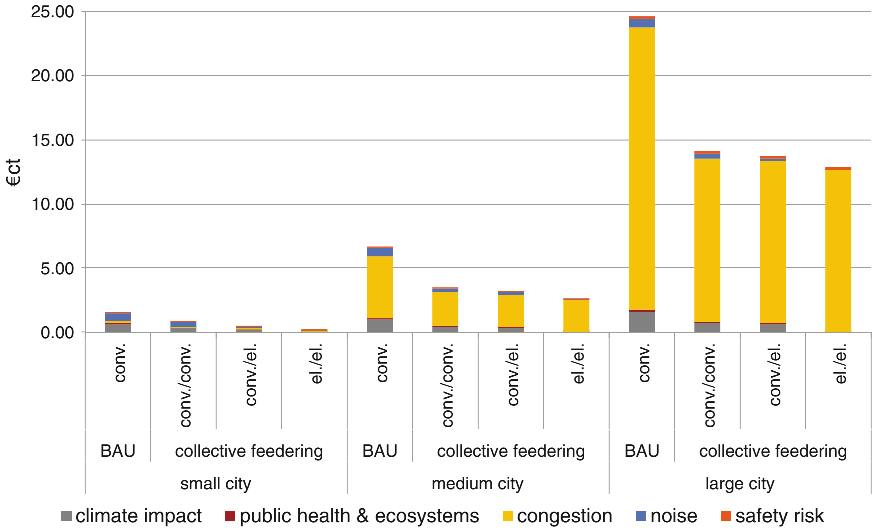


Fig. 23.9 Comparison of externalities per parcel delivered between BAU and 'collective feedering' in different cities and for different vehicle technologies

23.5 Discussion and Conclusion

This paper analyses the relevance and significance of some key factors on the environmental and economic performance of UCC schemes. The paper studies the effects of the implementation of an UCC in the city of Gothenburg. The results are therefore context-specific and based on many assumptions. The absolute values presented in the paper are therefore not generally transferable to other contexts. However, the results provide some general evidence on the type and scale of relations and relative effects identified in the case. This section summarises these findings and discusses their practical implications and theoretical contributions.

Many existing UCCs aim for improving the street environment in a city's CBD or historic centres, which are suffering from congestion, noise, visual intrusion and perceived safety risks. The results of the case study confirm that UCCs can potentially reduce these impacts and by this contribute to an attractive city environment in the target area of a UCC. However, the case study also indicates some limitations of UCCs schemes with consolidation points in close proximity to the target areas. First, the contribution to reducing local air pollutants and is very limited, which is due to the fact that current conventional vehicles (Diesel Euro 4 and newer) have very low emission levels and as a consequence there are only minor saving potentials if zero-emission vehicles are used. Second, the contribution to a reduction of greenhouse gas emissions is also limited, since a close consolidation point reduces traffic work only marginally. Third, the impacts in the target area are relatively small in comparison of the citywide impacts of urban distribution. In cities with congested access roads, the by far biggest externality of urban distribution is contribution to congestion. These impacts cannot be reduced by UCC schemes with consolidation points in close proximity to the target areas, since they do not reduce traffic on the access roads. UCC schemes with consolidation points in suburban areas allowing for a separation of feedering and last-mile delivery, on the other hand, can clearly reduce congestion on the access roads, implying that these schemes also generate citywide benefits. The case results indicate that these benefits in terms of congestion reduction are much bigger than the benefits in the target area in terms of a more attractive urban space.

These findings suggest that the improvement potential of innovative technology enabling zero-emission last-mile distribution is only marginal. Organisational changes enabling a separation of feedering trip and last-mile trip have a much bigger improvement potential, even in case conventional technology is used for last-mile deliveries. The relative importance of organisational changes in comparison to innovative technology increases with city size and level of congestion on the citywide road network.

From an economic perspective, the results indicate that UCCs can generate benefits for receivers in terms of a reduced number of handlings resulting in a reduction of time spent for handlings. The results also indicate that UCCs can lead to time savings for the LSP, since they have to spend less time in making individual deliveries. However, there is also evidence that these time savings of the LSPs can be overcompensated by additional handling and distribution of the UCC operator, indicating that a viable UCC requires a critical mass of users and volume proportionate to its size.

These findings have also some practical implications. The first implication is that the externalities of urban distribution activities by large-scale LSP with geographically focused deliveries in smaller urban areas with limited congestion levels are relatively low. The potential benefits generated by UCC schemes in these cities focusing on the large-scale LSP only are therefore too small to offset the additional cost generated by the consolidation activities. However, the findings also disprove the arguments suggesting that the concept "will never work" as it identifies the preconditions under which UCCs can provide significant benefits.

The second implication is that innovative vehicle technology, which is likely to increase the cost of UCC schemes, is not required to achieve substantial benefits. Organisational changes enabling the use of larger vehicles for the collective feedering into the city centre offer much higher benefits, especially in cities with congested access roads. UCCs should therefore not only be considered as a measure for improving the attractiveness of city centres, but also as a measure for reducing congestion on the citywide road network.

From a theoretical perspective, the paper contributes to clarifying the relevance of the city's context and vehicle technology for the improvement potential of UCC. Given that UCC projects have been based on intuition of urban planners rather than hard facts (Browne et al. 2005), a better understanding of the influencing factors is essential for further developing the interactions of urban form and logistics as an interdisciplinary phenomenon.

There is a range of questions arising from the findings presented in this paper, which offer possibilities for further research. To begin with, the paper did only look at a limited number of factors. Important factors such as goods volumes, load factors, and type of receivers were beyond the scope of the research presented in the paper. However, these factors have a significant impact on both environmental and economic performance of UCCs. A study focusing on analysing the significance of these factors is therefore an interesting issue for further research. Furthermore, the case study results suggest that the benefits of consolidation for the actors involved are over-compensated by the additional cost of the UCC operator. An interesting question for further research is therefore what the critical size and volume is for a viable UCC. There is a need to better understand the factors influencing the size of the critical mass in order to develop economically sustainable business models for UCC.

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Chapter 24
Ho.Re.Ca. Logistics and Medieval Structured Cities: A Market Analysis and Typology

Thomas Verlinden, Eddy Van de Voorde and Wouter Dewulf

24.1 Introduction

A city without freight transport is no liveable city, while a city with freight transport could bother citizens, shop owners and policy makers. Finding a delicate balance between these two extremes is the challenge of many regulations and innovations. Originating from the literature and the 'real world', we can conclude that some of these new innovations and policies generate positive effects on some sectors and adverse effects on other sectors (Allen et al. 2012; Browne et al. 2012; Gatta and Marcucci 2014). One of the economic sectors new policies and innovations are often directed to, is the Hotel-Restaurant-Café/Catering (Ho.Re.Ca.) sector. Within the Flanders region of Belgium, the Ho.Re.Ca sector is seen as a vulnerable sector with strong competition and low profit margins (Guidea 2014).

On the other side, problems such as congestion, noise, traffic violations and pollution in peak hours within cities are attributed to the Ho.Re.Ca sector. There are different reasons for this evolution. To explain and link these causes to specific delivery characteristics, the final aim of this chapter is to build a market typology.

A glance at the market shows that different companies are involved in the supply chain of Ho.Re.Ca. locations. A first problem which appears, is that there is no clear definition of what is included when using the word 'Ho.Re.Ca.'. A second problem is that the sector is historically divided into three (hotel-restaurant-café) plus one (catering) segments. Besides the fact that there are many different parties involved,

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Table 24.1 Diversity between and within the Ho.Re.Ca. sector (*Source* Own composition)

Segment	Main activity	Additional services	High—low class
Hotel	Offering overnight accommodation and lodging	Cafe + restaurant	5*^{s} hotel—hostel
Restaurant	Selling meals and accompanying drinks	Cafe	3*restaurant—fast food
Café	Selling drinks	/	Cocktail bar—pub
Catering	Organisation of concepts	On demand	Reception—festival

there are big differences between and within the segments. Catering is seen as a separate, no common segment because it is a service which is performed on demand. Due to this stochastic profile and big diversity in demand, it is more difficult to measure and link these activities with one specific segment (Guidea 2014). Table 24.1 illustrates two significant differences.

As Table 24.1 illustrates the Ho.Re.Ca. sector is not only different in terms of end product but also in terms of the used business model. A hotel can be part of a franchise company, while a café can also be managed as a one-man business. To structure and link these differences with the way deliveries towards these different types of organisations are performed, the chapter is looking for key factors to structure the Ho.Re.Ca. sector in an efficient and transparent way. Therefore, the chapter selects a parameter which can distinguish, define and structure the different activities which are performed in the sector. In a next step, the chapter examines whether this structure aligns with the current demand and supply chains of the Ho. Re.Ca. sector in general and with the separate segments.

24.2 Research Strategy

The research starts with an extensive problem description, compromising the definition problem and regularly applied variables in the literature. This problem description is the initial starter towards definitions and a global framework for the Ho.Re.Ca. sector and its specific logistics and deliveries. These findings are extended with the vision of some business experts[1]. These experts are as well receivers as suppliers as governing bodies and several sector organisations. For the second part of this research an observation was done in the city of Antwerp, on different times in a specific quarter. This observation illustrates the impact of the habits, which are very specific for the Ho.Re.Ca. sector, on cities. Furthermore,

[1]Ho.Re.Ca. Flanders, FeBeD, HOTREC, Guidea, Stad Antwerpen, Flemish department of mobility and public works, Bubblepost, Bpost, Dockx and 4 Ho.Re.Ca. goods suppliers and 7 Ho. Re.Ca locations.

different delivery patterns could be distinguished. In a next step, these findings were once more presented to the same business experts. By consequence, the underlying reasons for some results are explained more in depth.

The choice for this methodology found its origin in the fact that the data and the literature around this topic are rather limited and the sector is rather conservative. During the data collection some difficulties arose. The Ho.Re.Ca. sector is a conservative sector in which expertise is bundled with a small group of persons. As a consequence, they critically consider new initiatives. Besides, policy makers never thought about how the sector is organised. Hence, the available consistent data is rather limited. Given these difficulties and the mix of qualitative data with observations, this chapter is written from a visionary point of view.

To come to the final aim, the chapter will follow the following structure. After the extensive problem description, the chapter starts with the further demarcation of the sector: definitions of Ho.Re.Ca., Ho.Re.Ca. logistics and Ho.Re.Ca. deliveries are stated and the evolution of the sector is investigated more in depth. A second part links current stakeholders' preferences, decisive delivery variables and market trends to different observed types of deliveries. This chapter concludes with four different market typologies from which recommendations can be stated. The recommendations include some fields of opportunities in which all stakeholders accept adaptations. While inventing and implementing new innovations and policies, these recommendations can be valuable guidelines. To conclude, a number of further research opportunities are defined.

24.3 Problem Description

Originating from the introduction, the need to define and structure some key words emerges.

24.3.1 The Ho.Re.Ca. Sector

As already stated in the introduction and illustrated in Table 24.1, the Hotel-Restaurant-Café/Catering sector is a heterogeneous sector in its organisation, end product, specific needs and specific expectations. Besides, the literature around this topic is rather limited. For this evolution several reasons can be added. In the state we are now, this specific goods flow cannot longer be ignored and major stakeholders show their interests in the topic.

The literature can be divided into two main streams. On the one hand, the academic literature targeting this particular topic is rather limited. On the other hand, much non-academically written literature with a local focus by governing bodies or sectorial organisations is available. Another stumbling block is the diversity of the terms used. In the literature several terms appear to bundle hotels, restaurants and cafes: Ho.Re.Ca., HOTREC, food and drinking places, food and beverages. These terms target sometimes just a part or a segment of the total sector.

As already stated in the introduction, research strategy and above, there is no clear definition available of the Ho.Re.Ca. sector. Besides, the link with logistics is not highlighted by many authors. A definition of the Ho.Re.Ca. sector, which compromise as well academic as non-academic literature and the definitions given by the business experts, is the following:

> The Hotel-Restaurant-Café (/Catering) sector is creating value to consumers by combining different ingredients to one experience. Key words in this experience are lodging, eating and drinking or a combination of these three.

For the sequel of this chapter, this definition is the starting point to narrow down towards the logistics and deliveries behind this sector. Finding a bridge between this definition and the logistics and deliveries of the Ho.Re.Ca. supply chain, is subject to some constraints and specific characteristics.

A main characteristic which influence the way logistics and deliveries are performed towards Ho.Re.Ca. locations in cities, is the difference in business models. The two extremes are: being a part of a franchise agreement and on the other side being a one-man company. This difference will affect the freedom of choice owners have in the number and type of goods they want to use. Franchise operators are characterised by a strong focus on economies of scale and scope by the headquarters of the franchisor. Whereas a one-man business has the freedom of choice of its different suppliers. But also one has to be aware of the information and the logistic costs of the diversity of deliveries it requires (Blauwens et al. 2012). This main characteristic is often one of the main starting points and has a significant influence on the organisation of the logistics and the deliveries.

A second main characteristic, and which is in close relation with the business model, is the complexity of the end product. Table 24.1 already illustrated that, within the segments of the Ho.Re.Ca. sector, there are large differences between but also within the segments. A hotel is performing more services towards clients but the multitude of services is also depending on the targeted end product. For example, a hostel is less complex in its organisation than a five-stars-hotel.

These two constraints have a given influence on the way Ho.Re.Ca. logistics and deliveries are performed in cities.

24.3.2 The Ho.Re.Ca. Sector and Urban Logistics

Originating from the different opinions of the business experts and the first part of the problem description, it is clear that a good description of Ho.Re.Ca. related transport is necessary to build further conclusions and recommendations. Therefore two terms are defined: Ho.Re.Ca. logistics and Ho.Re.Ca. deliveries. The playing field of Ho.Re.Ca. deliveries is more focussed on the delivery of goods towards the last business-to-business owner, just before it is prepared for the final consumers.

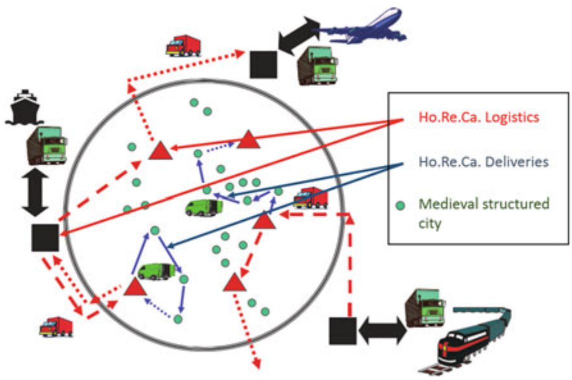

Fig. 24.1 Keywords (*Source* Crainic et al. (2012), p. 49 with own adjustments)

Whereas Ho.Re.Ca. logistics tries to formulate recommendations on a more operational and organisational level.

As an extra dimension, this chapter focusses on the deliveries towards cities, and in particular, medieval structured cities. Figure 24.1 gives a first simplified impression about the content of these key words.

24.3.2.1 Ho.Re.Ca. logistics

Originating from the literature (Gevaers 2013), some main trends of new innovations can be distinguished. On the one hand, there are innovations which target the city as an entity. By consequence the Ho.Re.Ca. sector is also targeted. On this level, new policies and innovations are pushed towards the Ho.Re.Ca. sector. Examples are road restrictions and infrastructure adaptations. On the other hand, innovations and policies which target more operational activities can be distinguished. These initiatives are more sector related and have a high degree of transferability to other sectors or specific activities. An example is the use of an urban distribution centre. In Fig. 24.1, Ho.Re.Ca. logistics are illustrated by the red arrows.

Ho.Re.Ca. logistics innovations are situated into this category. It involves the organisation and the structure of the logistics behind the final product. Whereas Ho.Re.Ca. deliveries focus only on the last part of the supply chain and the transport to the last business-to-business partner in the Ho.Re.Ca. supply chain.

24.3.2.2 Ho.Re.Ca. deliveries

As already stated above, Ho.Re.Ca. deliveries only take the last mile into account. The origin of the goods towards the last business-to-business partner determines the way the last mile is to be organised. This depends on several factors like demanded frequency, volume and constraints like the accessibility of the final destination.

Transport will be organised in another way. Besides these factors and constraints, the behaviour of the suppliers, receivers and policy makers influences the efficiency of the last mile transport. Originating from the literature (Gevaers 2013), some new trends and innovations can be ascribed to Ho.Re.Ca. deliveries. Examples are pick-up and drop-off boxes and the use of alternative vehicles. A more specific example is the 'beer boat[2]' for Ho.Re.Ca. deliveries in the inner city of Utrecht, The Netherlands. In Fig. 24.1, Ho.Re.Ca. deliveries are illustrated by the blue arrows.

These two terms cannot be investigated separately. Innovations and policies will always interfere in certain levels, but this division will make it easier to assign new innovations and policies to a given category and structure.

24.3.2.3 Medieval structured city

An extra dimension to this chapter is found by focussing on Ho.Re.Ca. logistics and deliveries towards medieval structured cities. Figure 24.2 shows the evolution of the urban form through several years. The figure illustrates that medieval structured cities are differently structured from other types of cities. History learns that European cities were found in the medieval period and that American cities tend to organise their cities more structured from the beginning of the 20th century (Marshall and Garrick 2010).

These differences tend to have an effect on the decision making process of several stakeholders within the specific structured cities. Sometimes this will imply that given initiatives are more viable in another environment than in this specific configuration. Previous research shows this trend in, for example, road safety (Marshall and Garrick 2010). Examples of logistic measurements can be found in dedicated parking spots for loading and unloading (Allen et al. 2012; Quak and de Koster 2009).

European medieval structured cities are characterised because of their sporadic growth pattern around important buildings or squares and sometimes within old city walls. This city layout generates not only constraints but also opportunities for several stakeholders. In the inner medieval structured city of Antwerp, the hotels,

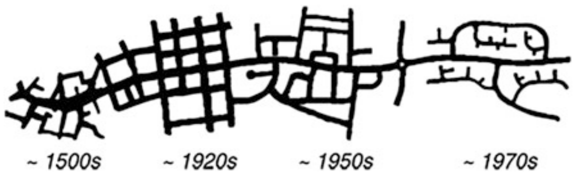

Fig. 24.2 The evolution of city patterns (*Source* Marshall and Garrick 2010)

[2]The "Bierboot" (Beer boat) is a boat which sails on the inner city open channels in the Dutch city Utrecht. In this specific case, the boat is delivering drinks to Ho.Re.Ca locations near the channels. More information: http://www.civitas.eu/content/city-distribution-boat.

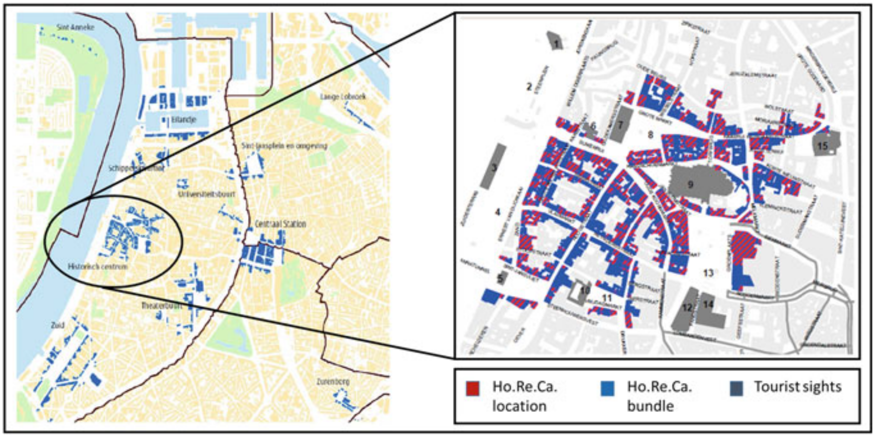

Fig. 24.3 Cluster pattern of Ho.Re.Ca. location and city lay out (*Source* Own illustration based on Stad Antwerpen (2008), p. 25 & 64)

restaurants and cafés are clustered around these, often tourist, sights (Quak and de Koster 2009; Stad Antwerpen 2008). This evolution implies that innovations and policies for shop owners can be better targeted on specific parts of the city and that potential higher drop rates can be achieved. Figure 24.3 illustrates the cluster pattern and the specific city layout of Antwerp. Remarkable is the high number of dead ends and narrow, often one way, streets.

Like many other European cities, there is also a time window regulation in the inner city of Antwerp. From a logistic perspective, this can be seen as an extra constraint. This example makes it clear that besides the receivers and the suppliers, there is also a significant responsibility for local and national governing bodies.

24.3.3 Decisive Variables from the Literature

Originating from the limited literature, some main variables can be distinguished. To counter the limited available literature, other literature around decisive variables but from other sectors is also listed, reviewed and discussed.

In their several off-peak deliveries studies, (Holguin-Veras and Polimeni 2006), took the special characteristics of restaurants and drinking places in Manhattan into account. Besides the conclusion that these types of companies do not have to make many additional operational costs for the acceptance of off-peak deliveries, some major sector specific characteristics were defined. The authors suggest that frequency, volume, sort of goods, storage capacity, geographic location and opening hours are major variables. The linkage between these variables is not examined in detail. Nonetheless, the study area of his research is an American structured city.

Table 24.2 Decisive variables of urban deliveries (*Source* Own composition)

Variable	Source	Variable	Source
Frequency	Blauwens et al. (2012)	Lead time	Blauwens et al. (2012)
Volume	Blauwens et al. (2012)	Time windows	Quak and de Koster (2009)
Returns	Gevaers (2013)	Modal choice	Dablanc and Rakotonarivo (2010)
Location	Macario (2013), Alho and de e Silva (2015)	Bundling	(Stathopoulos et al. (2012), Gatta and Marcucci (2014)
Perishability	Morganti and Gonzalez-Feliu (2014)	Environmental impact	Arvidsson (2013)

Macário (2013) investigated the influence of the role of the location of food and beverages and the impact of these activities on cities. In her paper, a geographic perspective is linked to an economic perspective. The main conclusion is that location is one of the main variables which is common between mobility and logistics. By consequence, the deliveries of Ho.Re.Ca. cannot be uncoupled from mobility measurements of cities.

Ponce-Cueto and Carrasco-Gallego (2009) already listed some delivery pattern but the authors do not make the link with product specific characteristics and new trends in urban logistics. The authors also formulate some variables similar to the once of (Holguin-Veras and Polimeni 2006). In this chapter, we expand this list and investigate the organisation and decisive variables from a market demand perspective.

Other literature in which hotels, restaurants or cafés are examined, is rather limited. As already suggested before, the available data on this sector is, by consequence, also limited. To tackle this problem, variables from comparable sectors and other urban logistics studies are selected and taken into consideration. Table 24.2 gives an overview of the different variables.

24.4 Ho.Re.Ca. Logistics and Delivery Specific Characteristics

In the second part of the chapter, the aim is to structure the Ho.Re.Ca. sector in a different way with special attention for specific variables. In line with the heterogeneity of the sector itself and from the in-depth interviews and observations, we can conclude that the logistics and deliveries of the Ho.Re.Ca. sector are as heterogeneous as the sector itself. A frequently used method to structure the market from a business approach, is the use of standard parameters like the number of employees or the NACE[3]-code but these parameters are more applicable for financial and organisational questions and not for logistic issues.

[3]The NACE code list is a list of the European Union to structure different economic activities within the member states.

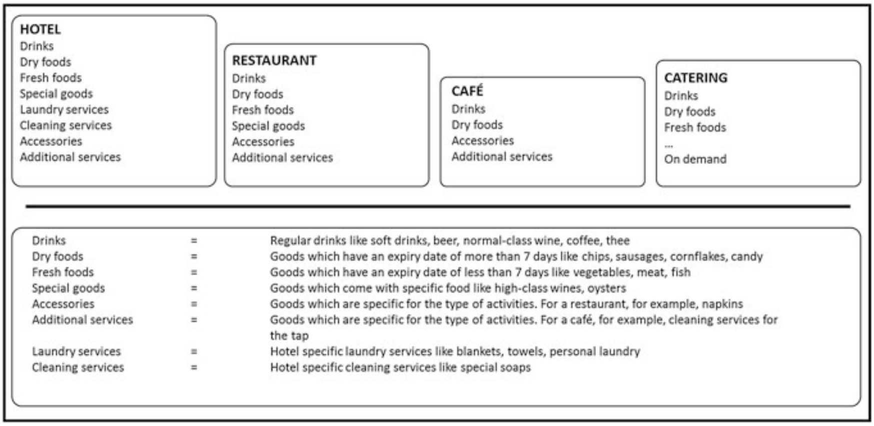

Fig. 24.4 Ho.Re.Ca. segments with specific product categories (*Source* Own composition)

In this part of the chapter, the division based on the goods Ho.Re.Ca. locations require for their daily service is presented and explained. From a logistic point of view, this approach gives insights in as well the way receivers look at the physical characteristics of goods as the way suppliers deal with these specific characteristics. Figure 24.4 illustrates the groups of goods which are taken into consideration. This figure (Fig. 24.4) confirms the division and the diversity recognised in the previous sections.

As shown in Fig. 24.4, diverse goods are needed and the diversity is increasing related to the services which are performed within a market segment. A good example are superior wines; the attention for special wines often appears when it can accompany food. This implements that with the complexity of the end product the number of goods needed also increases. This is due to the diversity of specific goods which are needed. A similar trend is noticed for a hotel; the more specific and special goods used, the more different suppliers involved throughout the whole supply chain (Alho and de e Silva 2015). However, if the numbers of deliveries they receive are investigated, one can conclude that the market is not organised based on this intuitive statement that the number of deliveries is increasing whether the end product is more complex or the segment is different.

As already stated, the activities performed and goods needed in the Ho.Re.Ca. sector depends on the type of company and the complexity of the end product. Besides the fact that the impact on cities depends on the physical characteristics of the goods, it also depends on the behaviour of receivers and suppliers and on policy constraints.

24.4.1 Characteristics of the Goods

Table 24.3 illustrates the impact of Ho.Re.Ca. deliveries on the selected area of the city of Antwerp of Fig. 24.3. The table is based on observations and interviews with 22 suppliers and 7 receivers. Besides the number of deliveries, the frequency and the time needed for the delivery were observed. These observations were linked with the product categories defined in Fig. 24.4. Originating from these results, the choice to divide and define Ho.Re.Ca. logistics and deliveries based on goods they require is more clear. These results give an indication of the normal state of organisation of the Ho.Re.Ca. sector. Depending on other exogenous factors, these values can increase or decrease proportionally. An unanimously frequently stated factor is the ratio sun and temperature; when the weather is fine, demand is rising.

Table 24.3 Impact on cities per goods category (*Source* Own composition based on observations)

Goods stream	Frequency per week		Volume per delivery		Delivery time		Observation
	Average	Variation	Average	Variation	Average	Variation	
Drinks	1.8	0.2	2 pallets	0.1	15′	6′	Opening truck, unloading, stacking, loading reverse, securing goods
Dry foods	1.2	0.5	1 pallet	0.5	5′	2′	Quick drop-off
Fresh foods	5.7	0.2	0.25 pallet[a]	0	5′	3′	Quick but conditioned drop-off with special treatment by receiver
Special goods	3.1	0.8	0.25 pallet[a]	0	5’′	2′	Quick drop-off with special after delivery treatment by receiver
Accessories	0.8	0.3	0.25 pallet[a]	0	7’	2’	Quick drop-off
Additional services	1.1	0.3	/	/	5′–45′	/	Depending on activity
Hotel specific deliveries (Laundry, cleaning and others)	5.7	0.7	/	/	5′–45′	/	Depending on activity

[a]0.25 pallet = small package which can be carried by ore person

!Observation based on small sample of deliveries towards 7 Ho.Re.Ca. places situated in the targeted zone of Fig. 3

!During observation spoken with *22* suppliers and 7 Ho.Re.Ca. owners

Originating from the table above and from the in-depth interviews, some Ho.Re. Ca. specific types of goods can be distinguished:

- **Drinks** are delivered from a minimum volume onwards. The lead time of the delivery illustrates that the additional services receivers do expect from suppliers, are more complex than for a standard delivery. By consequence, the impact on the city is higher because the truck has to be parked somewhere. Besides, two specific drink suppliers highlight not only the unloading, stacking and loading of the reverse goods as an extra service but they also put the attention on load theft which happens frequently with that specific type of goods.
- **Dry foods** require less specific treatment. Besides, the goods are easily manageable. Hereby, the frequency is often related with the capacity of the storage space.
- **Fresh food** requires a different supply chain. The frequency of deliveries is significantly higher because the products are fast moving consumer goods. In addition, the goods are conditioned and should be transported with very specific material. The impact on the city results in a high number and almost daily frequency of deliveries. Additionally, the treatment of the goods during and after the transport needs special attention of the different parties involved.
- **Special goods** are characterised by the same elements as fresh foods, al-though the delivery number is lower. Often the prices of these goods are higher, therefore the shop owner tries to minimize the stock level to avoid that too much of his cash flow is blocked in high value stocks. Special goods occasionally need special treatment or cautiousness while treating, similar to the treatment of fresh food.
- **Accessories and additional services** can be categorised in the same category as dry foods which have the same characteristics as a standard delivery.
- **Hotel specific deliveries** contains elements of catering. The demand for these types of goods are on request, depending on the choice and the number of consumers. However, these are proportional to the number of customers. The conditions for deliveries and logistics are similar to dry foods and accessories deliveries, the only difference is that the volume is often proportionally higher.

Each group requires its own treatment and way of delivery, but this division has also implications on the logistics. In general, we can conclude that the physical elements of goods are one of the decisive variables. Extra services are sometimes historically grown with product segments. As long as the extra costs are covered by a large volume, this is reasonable and economically viable.

In the next Sect. 24.4.2, the consequences of these provisional conclusions are linked with the way Ho.Re.Ca. logistics and deliveries are structured and organized at this moment from the suppliers’ perspective.

24.4.2 Observed Delivery Schemes and Supply Chains

In this next step, the chapter examines whether the different needs according to the type of good and the special attention for the perishability and price of the goods, is optimised in the supply chains of these types of goods. While observing and interviewing suppliers, four different distribution patterns could be distinguished in the Ho.Re.Ca. delivery sector:

1. **Franchise**
   A delivery to a Ho.Re.Ca. location which operates under franchise is often served by a truck of the franchisor or a logistics service provider which provides the deliveries for the franchisor. These deliveries are part of the franchise contract between those two parties. The truck is following an optimised routing between all the franchise locations.
2. **Local/goods specialists**
   A local/goods specialist is really a specialist for a specific type of product, for example cheese or beer. Additionally, their location is always nearby the final consumer due to the product characteristics (Blauwens et al. 2012). Besides, these specialists are characterised by a high service level performed to their consumers. But they are also characterised by sometimes not optimised routing tours. The deliveries are often provided by small trucks or vans which are only equipped for the delivery of a specific good.
3. **Ho.Re.Ca. supermarkets (with deliveries)**
   Another delivery to Ho.Re.Ca. locations in cities is the one-stop solution which Ho.Re.Ca. supermarkets with deliveries perform. These deliveries are characterised by a large number of different products. The deliveries are performed by a van or truck of the supermarkets which optimise their routing before entering the cities. Therefore, the supermarkets work with an ordering system.
4. **Cash and carry supermarkets**
   Another delivery pattern appears if the Ho.Re.Ca. owner is getting some of the products himself. This implements that another kind of transport is performed and that that type of transport also has another—more difficult to measure—impact on the city. For this sort of delivery, the owner often uses his private car or van.

The traditional auto-sales model which (Ponce-Cueto and Carrasco-Gallego 2009) examined in their paper is not observed anymore in the city of Antwerp. Remarkable is that each business model is following its own strategy of delivering and receiving towards and in cities. Some business models excel in the degree of optimisation, other business models are characterised by demand driven, non-optimal behaviour based on confidence and a high level of product information. Figure 24.5 gives a good illustration of this behaviour and the four different types of deliveries observed.

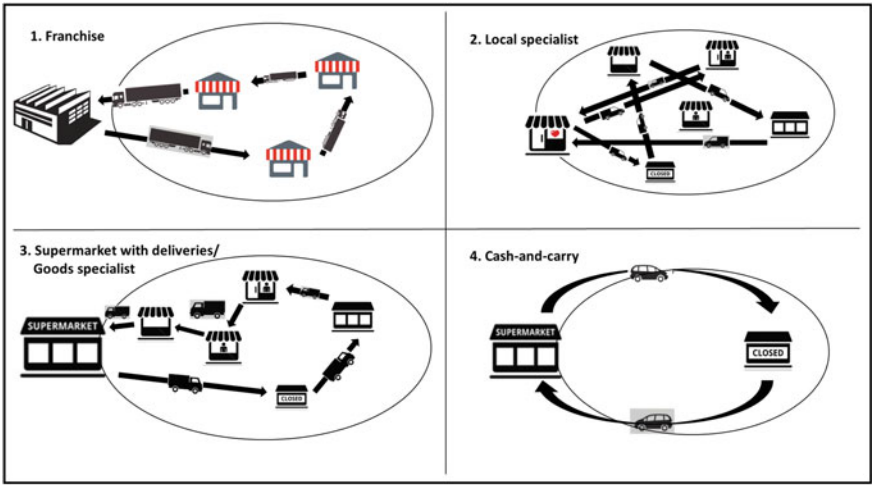

Fig. 24.5 Observed Ho.Re.Ca. deliveries (*Source* Own composition)

24.5 Market Typology

The following market typologies link the separate product groups and the observed delivery patterns with each other. Some delivery schemes are more applicable for specific types of Ho.Re.Ca. goods while other product types are even so specific that these are only provided through a given delivery scheme at this moment. Besides, some major trends towards vertical and horizontal integration can be distinguished in the market. Figure 24.6 illustrates the linkage and the flows between different parties. Additionally, the distinguished types of goods are linked with this scheme.

Four different market typologies are observed and examined:

A. (Small) Local specialist and cash-and-carry

A local/goods specialist is really a specialist for a specific type of product, for example cheese or superior wines. Additionally, their location is always nearby the final consumer. Besides, these specialists are characterised by the high service they perform to their consumers. But are also characterised by sometimes not optimised routing tours and as well the supplier as the receiver often follow a subjective decision making process. At the one hand these suppliers have higher costs but at the other hand they excel in the specific goods and quality they deliver. This behaviour frames in a trend towards smaller choice of different services of Ho.Re. Ca. locations. This trend is countered with a highly authentic and local character of the limited services performed.

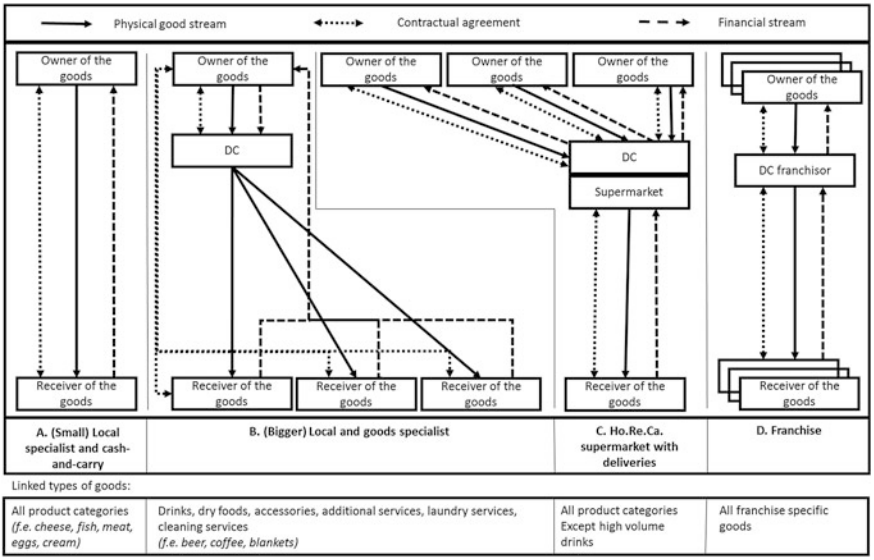

Fig. 24.6 Market typologies of the Ho.Re.Ca. sector (*Source* Own composition)

B. (Bigger) local and goods specialist

The path, this market typology is following, is more complex than the one above. The main difference is that the service of the delivery is outsourced to another party. This step implements that an extra step is added to the global supply chain.

On the one hand, this method works for specific types of goods. On the other hand, this method is not applied for fresh food because the lead time is too high. Additionally, the service quality and also the responsibility over the goods differs from actor to actor. Remarkable is that this typology is frequently used to deliver drinks. An explanation for this trend can be found in the additional services which are performed at the Ho.Re.Ca. location. Besides, perishability is not an issue and the reverse flows also bring other challenges.

C. Ho.Re.Ca. supermarkets with deliveries

The Ho.Re.Ca. supermarkets are growing because of their large range of products and rather fast one-stop deliveries. The main reason why the sector is evolving towards this pattern is based on economies of scale and scope. This business model saves trips for suppliers and, by consequence, costs from which they are able to offer more competitive prices. On the other side, the Ho.Re.Ca. owner receives his goods in one-stop. The main disadvantage is that product specific information is lost. Looking at the goods which are delivered, we can conclude that almost every good type is delivered, except high volume drinks like bottles and beer barrels. An explanation for this trend can be found in the specific characteristics of these goods: high volume, high weight, extra services and reverse flows.

D. Franchise

Franchise is one of the business models in which there is an extra—non logistic—relation between the shipper and the receiver. By consequence, those two parties optimise their processes based on logistic but also other factors. If the franchisor is managing the transport of goods to the city itself, the logistic and delivery process is optimised within the franchisors' network. If the franchisor has outsourced its logistics and deliveries, these activities are handed over to a logistic service provider and follows the path of a (bigger) local and goods specialist (market typology B).

24.6 Conclusions

The Ho.Re.Ca. sector is characterised by special needs and expectations of different stakeholders. As a consequence, the sector has its own specific impact on cities. The main goal of this chapter was to structure the market in a transparent and consistent way. The chapter suggests that structuring the market based on the goods Ho.Re.Ca. locations require for their daily services, is a good way to link the heterogeneous character of the sector to the logistics and deliveries.

From this research, five main Ho.Re.Ca. types of goods could be distinguished which require each a special treatment. In a second phase, these categories were linked to observed delivery patterns. We can conclude that due to specific Ho.Re.Ca. sector characteristics the market is sometimes not organised in an optimal way. Besides, some goods can be combined more easily with other types of goods and are more applicable in given distribution patterns. The final market typologies provide a good overview of the way the sector is organised and which parties are involved. This insight gives a framework and highlights the weak points of the current supply chains. Innovations and new policies should focus on these specific parts. By using the market typology, the influences of these new initiatives can already be monitored from the start.

Decisive variables which determine the choice for a given market typology are the volume/weight ratio, the prices of the goods, attention for personal product advice and extra services, and the most important variable the perishability of the goods. This factor will also have a decisive influence on other variables like the frequency and the modal choice.

The role of the medieval structured city lay out generates opportunities to increase the drop density due to their clustered geographical location. However, this configuration also results in some additional constraints in the suppliers' decision making process. Originating from these results, we can cautiously conclude that this pattern triggers other variables than in American cities.

To extend the knowledge of this specific sector and to measure the impact on the long term, further research is required.

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Chapter 25
Capacity for Freight in Urban Railway Networks—An Analytical Model for Capacity Consumption of Freight Trains in Urban Networks

Tobias Fumasoli, Dirk Bruckmann and Ulrich Weidmann

25.1 Introduction

With growing urbanization, increasing mobility and changing consumer behaviour, urban regions are subject not only to increasing passenger (i.e. commuter) transport but also changing goods flows. Congestion, noise, accidents or air pollution are increasingly addressed by urban planners, regulators and transport companies. One of the approaches suggested for mitigating the negative externalities and inefficiencies in freight transport in urban regions is the (re-)integration of "heavy" railways in urban logistics (Alessandrini et al. 2012; Browne et al. 2014; Dinwoodie 2006; Maes and Vanelslander 2010; Motraghi and Marinov 2012).

As with other transport means, the planning of freight railways involves a range of topics which need to be addressed in the urban context. In terms of logistics, rail freight services need to be integrated into urban supply chains. Due to the deindustrialization of many cities, the major stakeholders in urban transportation are currently construction, retail (especially food) and waste.

In terms of transport systems, two fields can be distinguished: (i) the "landside" of urban freight transport, i.e. the distribution of goods to points of sales (POS), end consumers (in the case of home delivery) and other destinations (or origins) of freight movements. Planning tasks mainly focus on the planning of delivery tours. This generally involves road transport, since other transport systems (rail, water, pipelines) do not have comparable network densities. (ii) the "railside" of urban freight transport, i.e. the transport from hubs (e.g. central warehouses, intermodal

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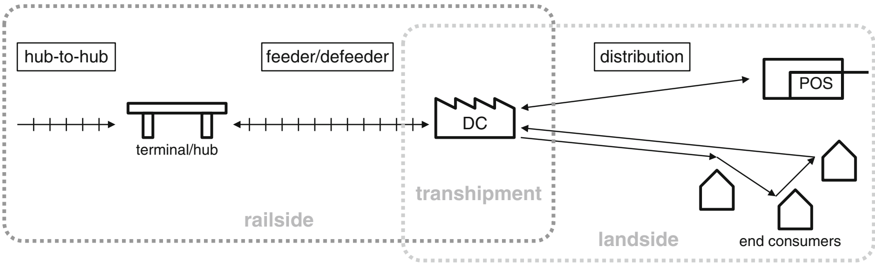

Fig. 25.1 Transport stages in urban rail freight

terminals) to distribution centres, sometimes referred to as defeeder transports (Hesse and Clausen 2012). A major issue for freight railways in the urban context is the availability of railway network capacity, respectively the lack of suitable train paths due to diverging train dynamics between passenger and freight trains (Frank 2013). The two fields of railside and landside of urban freight transport are connected by the transhipment process. (see Fig. 25.1).

25.2 Conceptual Framework

25.2.1 Urban Railway Networks and Freight Operations

From an operational point of view, railway networks can be divided into three main categories: (i) interurban main lines, (ii) regional secondary railway lines and (iii) urban railway lines. "Heavy" railway lines in urban areas urban need to be distinguished from other urban rail based transport systems, e.g. rapid transit (underground) or light rail, which are not considered in this study. In contrast to designated systems, urban railways are fully interoperable to main line and secondary line operations.

Mixed traffic networks exist for economic and/or historical reasons, when designated infrastructure is not available. In Zurich (Switzerland) for instance, commuter and regional trains share infrastructure with other users on approximately 70 % of the network (Frank 2013).

As a result, mixed traffic networks need to suit a range of users (Table 25.1). Discrepancies in train characteristics lead to longer buffer times and increase lost capacity. Depending on infrastructure (signalling systems, block sections) and train operation—speed, variety and order of trains–, maximum utilisation (i.e. capacity) is approximately 8–12 trains per hour and track in mixed traffic sections, compared to a maximum of 24 for a homogeneous usage pattern (Frank 2013).

Usage patterns in densely used urban networks increasingly shift to the disadvantage of freight trains. To keep braking distances short, freight trains currently need to run significantly slower than passenger trains. Therefore harmonising traffic is expected to reduce buffer times and increase usable capacity. This means

Table 25.1 Characteristic train parameters in Switzerland (adapted from Frank (2013))

	Main haul freight trains	Express freight trains	Commuter/ regional trains	Medium/long range passenger trains
Max. train length	750 m	500 m	100–300 m	300–400 m
Average speed	51–86 km/h	59–105 km/h	37–63 km/h	68–102 km/h
Acceleration	0.1–0.2 m/s^2	0.2 m/s^2	0.7–1.0 m/s^2	0.6 m/s^2
Deceleration	0.4–0.5 m/s^2	0.6 m/s^2	0.8–1.0 m/s^2	0.8 m/s^2

narrowing the range of train characteristics—such as acceleration, deceleration or train length. Speed seems to be less of an issue, since line speed is generally lower in urban networks. However, with passenger services being the predominant network user in metropolitan areas, the operation of freight trains needs to be adapted.

25.2.2 Modelling Capacity Consumption of Freight Trains

An analytical model is developed to identify the most efficient measures to adapt freight trains to urban networks (Fumasoli et al. in press). The impact analysis uses line capacity consumption as indicator (Tables 25.2 and 25.3). Capacity consumption is calculated, using the factors speed, acceleration, deceleration and train length. These factors can be attributed to the specifics of rolling stock, such as traction, vehicle and bogie construction, coupler construction, brake technology, train weight or axle load.

The expected value of infrastructure occupation is determined by a calculation of train runs. The infrastructure occupation time (t_{occ}) is composed of

Table 25.2 Factors of the impact analysis and the related vehicle parameters

Indicator	Factors	Parameters
Line capacity consumption	Speed	Motive power (traction)
		Vehicle construction
		Bogie construction
		Brake technology
	Acceleration	Motive power (traction)
		Coupler and drawgear construction
		Train weight
	Deceleration	Brake technology
		Train weight
		Axle load
	Train length	

Table 25.3 Elements of capacity according to UIC leaflet 406 (UIC 2004)

I	Capacity consumption	(a)	Infrastructure occupation
		(b)	Buffer time
		(c)	Crossing time
		(d)	Supplements for maintenance
II	Unused capacity	(e)	Usable capacity
		(f)	Lost capacity

- time for route formation (t_{form}),
- time for visual approach distance (t_{vis}),
- time for approaching the block section (t_{appr}),
- journey time in the block section (t_{jrn}),
- clearing time (t_{clr}) covering the overlap distance and the length of train, and
- time for route release (t_{rel}).

The train run is calculated in a straightforward approach. Approach, journey and clearing times are functions of speed, acceleration, train length, presignal distance, block length and overlap. Linear acceleration and deceleration is used for starting and braking trains. This approximation is considered to be sufficient for planning purposes and is common in commercial train scheduling tools.

Route formation and route release are constants, as is visual approach—the time for the driver to register the signal aspect. Pachl (2008) suggest a signal setting duration of 5 s and 12 s for the visual perception of signals.

In practice, infrastructure occupation is subject to a range of inaccuracies (e.g. through differing weather conditions), expressed through a constant factor for the variation (C_{var}). UIC (2004) suggests a time supplement of 5 %. The occupation time is therefore expressed as in Eq. 25.1.

$$t_{occ} = t_{form} + t_{vis} + \left(t_{appr} + t_{jrn} + t_{clr}\right) \cdot C_{var} + t_{rel} \qquad (25.1)$$

The recommended buffer time is allocated proportionally to the occupation time, thereby avoiding complex calculations requiring knowledge of the exact train sequence and the distribution of expected delays (e.g. Schwanhäusser 1974). As a guideline for the ratio between infrastructure occupation and buffer serve the "recommended values" according to UIC (Table 25.4). The proportional allocation of buffer times also reflects actual planning and operations.

The crossing buffer is neglected in the calculations, assuming availability of double track lines. Additionally the maintenance supplement is not taken into consideration in the impact analysis. In the impact model the capacity consumption time therefore is approximated by the sum of the (direct) infrastructure occupation time and the recommended buffer time (Eq. 25.2).

$$t_{cons} = t_{occ} + t_{buffer} \qquad (25.2)$$

Table 25.4 Recommended values of added infrastructure occupation (UIC 2004)

Type of line	Peak hour (%)	Daily period (%)	Comment
Dedicated suburban passenger traffic	85	70	The possibility to cancel some services allows for high levels of capacity utilisation.
Dedicated high-speed line	75	60	
Mixed-traffic lines	75	60	Can be higher when number of trains is low (smaller than 5 per hour) with strong heterogeneity.

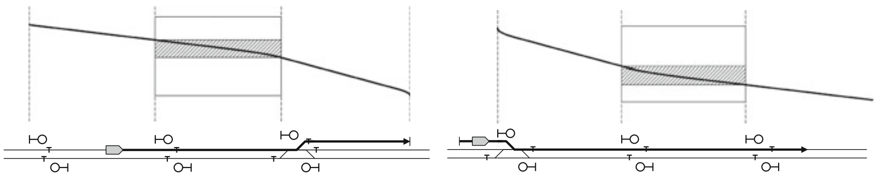

Fig. 25.2 Case (i) train arriving at siding. Case (ii) train departing from siding

25.2.3 Operational Setting

The impact of improved rolling stock is modelled for two exemplary cases. Assuming uniform block lengths, the most time-sensitive situations are (i) a freight train entering from a siding, accelerating on the main line, and (ii) an approaching freight train, decelerating on the main line and then pulling out to the siding with switch speed before coming to a halt (Fig. 25.2).

When entering the main line, accelerating consumes more (direct) occupation time, than a through-running train would. A decelerating train consumes more track clearing time due to lower speed when pulling out of the main line. Long train lengths also add to the clearing time.

The model is run with a generic set of infrastructural inputs, i.e. block length, presignal distance, overlap distance and maximum line speed. For this study, input factors are based on Swiss regulations and conditions (VoeV 2014; BAV 2014).

25.3 Results

25.3.1 Variation of Capacity Consumption

Exemplary results of the model show, that in case of an accelerating freight train, the capacity consumption can be reduced by increasing acceleration and

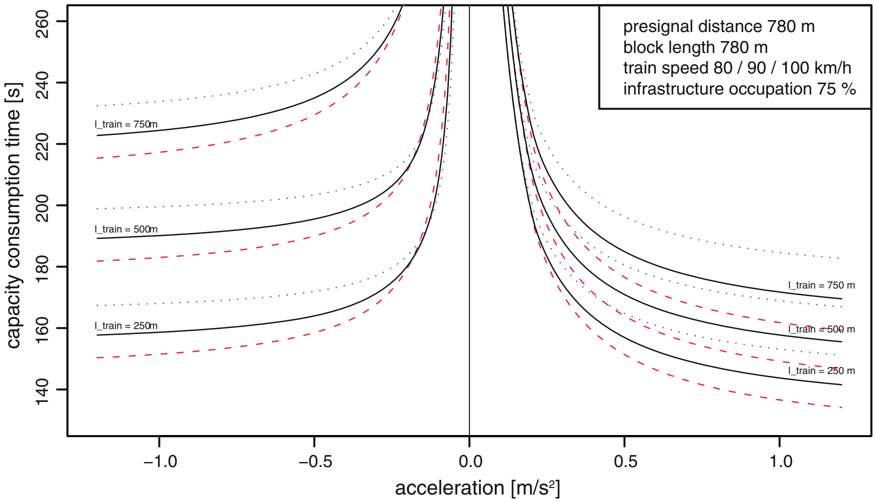

Fig. 25.3 Capacity consumption time in relation to the starting and braking acceleration for different speeds (*dotted*: 100 km/h; *dashed*: 80 km/h)

deceleration respectively (Fig. 25.3). Capacity consumption is generally higher for trains approaching a turnout (negative acceleration values), but also less sensitive to changing acceleration rates. However, train length has a higher impact on the capacity consumption time of approaching trains.

Bringing the acceleration of freight trains closer to commuter trains, e.g. from 0.2 to 0.6 m/s^2, reduces the capacity consumption by approximately 39–49 s per train (Table 25.4). However, changing the deceleration from –0.4 to –0.8 m/s^2 only leads to reductions between 9 and 12 s per train.

For an approaching train, deceleration during the clearing of the overlap dominates block section occupation. By contrast, acceleration during the approach of the first signal is dominating the occupation time of starting trains.

As Fig. 25.3 shows, the reduction of *train length* can also reduce capacity consumption. However at current acceleration (0.2 m/s^2) and deceleration (–0.4– –0.6 m/s^2) levels, shortening trains from 750 to 500 m for instance, reduces capacity consumption by approximately 12 and 24 s respectively. (see Table 25.5).

25.3.2 Comparison with Real Networks and Timetables

The modelled results are compared to timetables planned with *FBS*, an off-the-shelf timetable planning tool, applied to an exemplary part of the Swiss railway network. The railways in the region of St. Gallen in eastern Switzerland include commuter rail ("S-Bahn St. Gallen"), national and international intercity connection but

Table 25.5 Exemplary (direct) infrastructure occupation times for main-main-signalling in intervals of 780 m for the peak hour

Train length (m)	Initial/target speed (km/h)	Deceleration (s)			Acceleration (s)		
		−0.4 m/s^2	−0.6 m/s^2	−0.8 m/s^2	0.2 m/s^2	0.4 m/s^2	0.6 m/s^2
250	80	130 s	128 s	127 s	156 s	133 s	126 s
	90	125 s	122 s	120 s	153 s	128 s	119 s
	100	122 s	117 s	115 s	153 s	124 s	115 s
500	80	154 s	152 s	150 s	179 s	157 s	149 s
	90	149 s	145 s	144 s	176 s	151 s	143 s
	100	145 s	141 s	139 s	175 s	148 s	139 s
750	80	186 s	180 s	177 s	202 s	180 s	173 s
	90	180 s	174 s	170 s	200 s	175 s	167 s
	100	–	169 s	165 s	199 s	171 s	162 s

virtually no freight traffic. Utilisation of the short two-track section between St. Gallen main station and “St. Gallen, St. Fiden” is 8 trains per hour (one direction). The maximum number of possible freight train paths is manually inserted to the prospective timetable, using the method suggested by Pachl (2008): paths for freight trains are bundled without buffer times, leaving some paths unused (so called “buffer paths”) in order to maintain timetable stability (Fig. 25.4).

Train paths are inserted for express freight trains with a length of 250 m and a gross weight of 520 t. Traction is provided by one standard Swiss locomotive (Swiss class Re 420). In this example traction is doubled by adding another

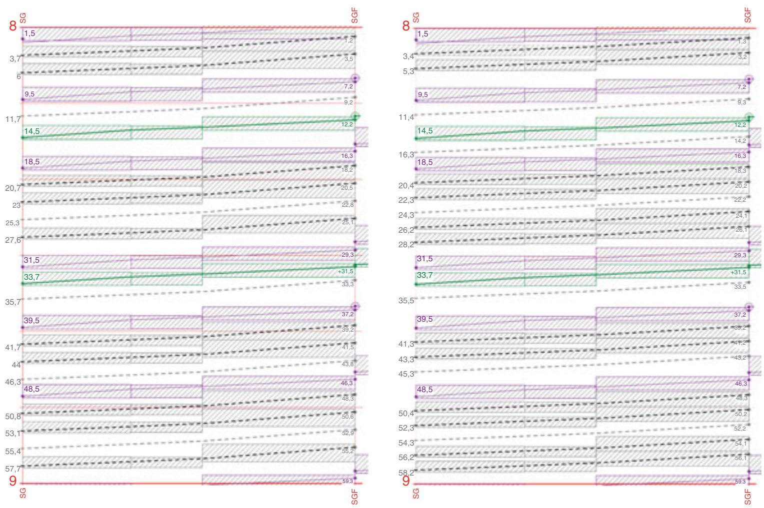

Fig. 25.4 Comparison of graphic timetables for single (*left*) and double traction (*right*) for express freight trains (*dotted*), designed using FBS

Table 25.6 Train data and results for the case study

	Length (incl. loco)	Load	Acceleration	Train paths		Calculated capacity consumption per train
				Inserted	Usable	
I	250 m	520 t	0.2 m/s^2	15	10	199 s
II	266 m	520 t	0.5 m/s^2	18	12	161 s
	change		+150 %		+20 %	−19 %

locomotive of the same type. This increases possible acceleration from 0.2 to 0.5 m/s^2.

The timetables show that by increasing acceleration—all other parameters unchanged—the number of usable freight train paths can be increased from 10 to 13 trains per hour (Fig. 25.4). The corresponding modelled capacity consumption is reduced from 229 to 191 s (Table 25.6).

25.4 Conclusions and Discussion

In this study the capacity consumption is analytically modelled in order to determine the effects of rail freight on urban railway networks under different operational assumptions. The proposed model provides decision support for strategies in urban rail freight. It does not replace proper scheduling in order to reduce unused capacity. Additionally, the study applies to mixed-use networks only. It does not determine whether or not to separate freight from passenger lines completely (which would undoubtedly simplify operations significantly).

The results from running the model with exemplary inputs shows that, if a reduction of capacity consumption of freight trains is to be achieved, a combination of measures will be needed. With the current specifications, increasing acceleration shows the biggest potential for reduced capacity consumption. Acceleration can be improved by increasing tractive power and/or reducing train weight. Corresponding measures include limiting payload, consequent lightweight vehicle construction or shorter trains. However, additional limitations of acceleration such as drawbar forces or adhesion weight are not regarded in the model. This involves almost inevitably distributed traction and central couplers, which are still uncommon among European rail freight operators.

On the other hand, increasing deceleration, i.e. introducing better brakes, does not show much potential. Shorter braking distances contribute only to operations in networks with limited presignal distances, allowing freight trains to run at higher line speeds. In networks with overlapping blocks (main-main-signalling) there is little or no effect. However, the abovementioned measures to reduce train weight would also contribute to better braking properties.

In consideration of the operational costs, i.e. the significant investments involved in improving traction and brakes, the value of reduced capacity consumption also needs to be analysed. Not all reduction measures lead to an increased number of available train paths, rather to an increase of buffer time. The stabilising effect of increased buffer times is of major interest to railway infrastructure managers (IM), which also have the possibility to create incentives for improving rolling stock for freight.

The findings on the capacity consumption of freight trains also need to be integrated into the wider context of rail freight transport, especially at the interface to the "landside" of urban freight transport. Urban planners need to know about the specifications for freight trains in order to determine which types of areas to hold available for freight transport. Furthermore, shipping size and frequency is crucial for dimensioning last mile fleets.

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Part IX
Innovative Approaches for Production, Logistics and Transport Systems

Chapter 26
Automatic Robot-Based Unloading of Goods Out of Dynamic AGVs Within Logistic Environments

Adrian Böckenkamp, Frank Weichert, Yan Rudall and Christian Prasse

26.1 Introduction

Most of today's companies are faced with the increasing need to operate effectively and efficiently. Since many business parameters are less predictable and the global markets became more dynamic, traditional ways of designing and operating logistic systems are not able to handle these new challenges. They are mainly driven by the globalization of supply chains, shorter product life cycles, mass customization, and the rising speed of delivery, (cf. Wahab et al. 2008; Wiendahl et al. 2007). All these changes are obviously affecting the logistics of companies.

Decreasing sizes but an increasing number of shipments emerge, e.g., from a continuously growing share of e-commerce. This faces the retail, distribution and production logistics with a difficult task—constant quality of delivery. One approach to increase efficiency in sorting, distributing, and order picking processes, is the automatization of today's mainly manually performed operations. Especially in terms of flexibility, human workers with a huge bandwidth of cognitive skills are hardly to substitute by machines. A dynamic approach of automation of storage and order picking processes is the so called Multishuttle Move system (Kamagaew et al. 2011) at the Fraunhofer Institute for Material Flow and Logistics. In this application, Automated Guided Vehicles (AGVs) provide storage areas for bins.

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Lecture Notes in Logistics, DOI 10.1007/978-3-319-21266-1_26

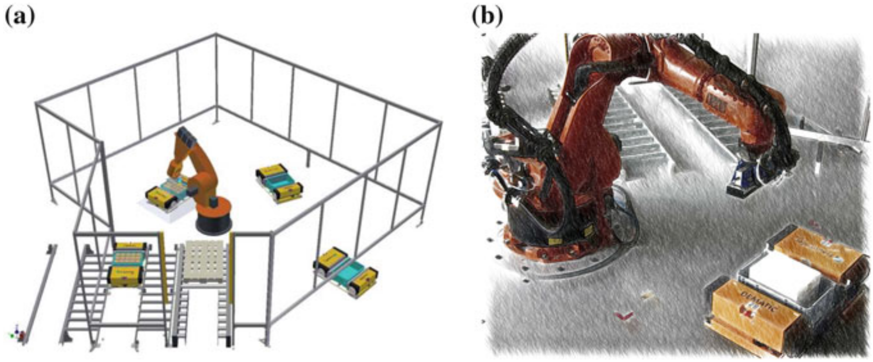

Fig. 26.1 System overview of the environment employed in this work. **a** Overview of the transfer station showing the actuators of our setup. **b** Detailed view of the setup where the robot currently unloads an AGV

Additionally to the manually operated picking stations, the system exhibits an industrial robot which is able to pick or place cuboid shaped goods from or to moving AGVs.

The robot–equipped with a vacuum gripper and a tool-mounted 3D camera–is located in the center of a transfer station bordered by a safety fence (cf. Fig. 26.1a). AGVs are carrying bins, entering, and leaving the transfer station area on freely programmable routes. Additionally, the robot cell contains a stationary 2D camera and a (de-) palletizing area. Within this setting, the robot is picking a packet from a moving AGV (cf. Fig. 26.1b). Hence, two major problems have to be approached: First, the moving AGV and its loading needs to be detected and localized. Second, the detected loading needs to be grasped on-the-fly. The latter includes following the AGV with the robot arm by predicting its position in the near future, grasping the packet at a reasonable point in time during the tracking, and depositing the packet at the unloading area (see Fig. 26.1a).

The process of unloading is related to the bin-picking problem albeit with moving charge carriers. Bin-picking in static scenarios is a well-known problem in research—several approaches and solutions came up in the late 80s and early 90s (cf. Al-Hujazi and Sood 1990; Bolles and Horaud 1986). In the meantime, many mobile robot platforms have been developed. Equipped with manipulators and camera systems, they are able to grasp objects out of non-moving boxes (Nieuwenhuisen et al. 2013). Thus, the moving part here is the robot, not the bin. In logistic applications, dynamic bin-picking systems for box-shaped objects can be found in the industry but these systems work with belt or roller conveyors only (Robo Pick 2015) and, hence, the picking goods are having simple predictable trajectories. In contrast, the robot in our setup is fixed and the AGV moves through the transfer station during unloading.

In this paper, we present a novel approach for automated unloading of AGVs, which operate in a dynamically changing environment. The removal of goods from the moving AGVs is done using an industrial robot. For reasons of energy efficiency and overall performance, passing vehicles will not reduce their speed. For the detection, localization, and classification of vehicles and their loadings, different types of vision technologies are applied. The detection of vehicles and especially the prediction of its motion is done using stochastic tracking algorithms based on 2D information from a CCD camera, see Sect. 26.2. The detection of the AGV's load for planning collision-free paths including grasping the load is done using a 3D camera, see Sect. 26.3. With this information, a dynamic motion path is calculated to control the robot's movement by means of a closed control loop using a PI controller with the KUKA Robot Sensor Interface (RobotSensorInterface 2009). Experimental results are provided in Sect. 26.4 and a conclusion is given in Sect. 26.5.

26.2 Locating the AGV in the Transfer Station

This section details the coarse-grained localization of the AGV within the transfer station using the images provided by the stationary (wide view) 2D CCD camera. The latter is located in one of the top corners of the station and therefore being able to overlook the whole scene, see Fig. 26.3a. Given the 2D position of the AGV within the camera's coordinate system (cf. Sect. 26.2.1), it is Kalman-filtered and finally transformed to the robot's world coordinate system (cf. Sect. 26.2.2). The transformed position is then used to move the robot's tool-mounted 3D depth sensor above the vehicle. When the 3D camera is positioned, fine-grained localization of the AGV's loading can be performed. The approach enhances flexibility of where the AGV is allowed to enter the transfer station by eliminating the disadvantage of the 3D sensor (i.e., a restricted field-of-view, FoV) and focusing on the resulting advantage (retrieving point cloud data containing just the region of interest).

Figure 26.2 depicts the processing flow for the 2D camera data. First, acquired images are being masked given a static image mask to discard irrelevant areas. Second, general motion detection is employed followed by edge and line detection. Third, the extreme coordinates of the detected lines are used to compute the center of the AGV. To reduce the impact of measurement errors, a Kalman filtering and prediction step is added.

The camera delivers a series $\mathcal{M} = \langle \mathbf{G}^0, \ldots, \mathbf{G}^{t-1}, \mathbf{G}^t, \ldots \rangle$ of images $\mathbf{G}^t = \mathbf{g}^t_{i,j}$ where $i \in \{0, \ldots, I-1\} = \mathcal{I}$ denotes the row and $j \in \{0, \ldots, J-1\} = \mathcal{J}$ the column indices. The pixels $\mathbf{g}^t_{i,j} \in \{0, \ldots, 255\}^3$ store color information in the RGB color

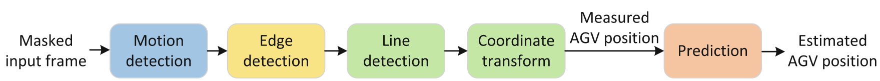

Fig. 26.2 Processing pipeline for 2D image data, acquired from the stationary CCD camera

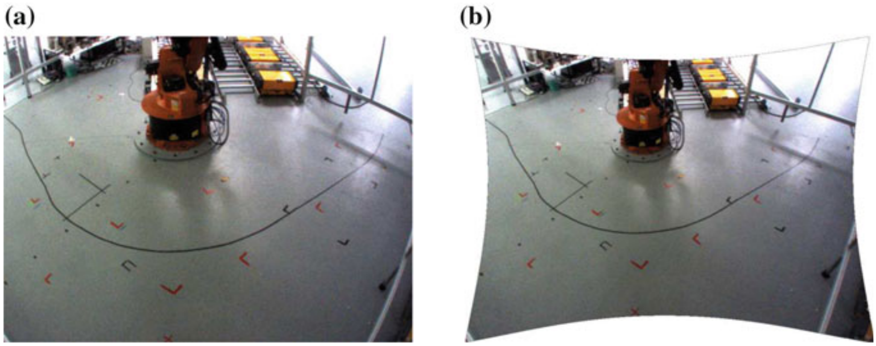

Fig. 26.3 Exemplary input frame **a** of the employed CCD camera, and **b** the result of camera calibration (Zhang 2000) (distortions have been reduced considerably)

space. Cameras are always affected by variations in quality during the lens production process, effectively causing distortions in the FoV. To overcome this issue, a camera calibration (see Fig. 26.3) has been carried out firstly to get intrinsic $\mathbf{K} \in \mathbb{R}^{3\times3}$ (and extrinsic) camera parameters using a chessboard pattern (Tsai and Lenz 1989; Zhang 2000). The extrinsic parameters are not needed to reduce distortions; instead, they will be used for the coordinate transformation described in Sect. 26.2.1.

26.2.1 Coarse-Grained AGV Detection by Means of 2D Camera Data

An input image $\mathbf{G}^t$ is first statically masked (Kapsalas et al. 2008) to remove regions where the AGV will never be (reduces false positives and processing time). Figure 26.4a shows an example of the masked input. Next, general motion is detected in the current image by applying frame differencing, i.e., $\mathbf{g}^t_{i,j} = \mathbf{g}^t_{i,j} - \mathbf{g}^{t-1}_{i,j}, \forall i \in \mathcal{I}, j \in \mathcal{J}$. This classifies regions of the image as static (motionless) and dynamic, cf. Fig. 26.4b. On the downside, motion of the robot's end effector is detected as well (if its inside the mask) and, additionally, if the AGV stops shortly (e.g., in a turning manoeuvre), no motion is detected meaning that all subsequent AGV detection steps fail (more details in Sect. 26.2.2).

Given the classified image, edge and line detection by means of the well-known Canny operator and the Hough line transform are applied (Canny 1986; Hough 1962). The center $\mathbf{c} \in \mathcal{I} \times \mathcal{J}$ of the AGV is then computed using the minimum and maximum coordinates of the Hough lines. Figure 26.4c shows the resulting Hough lines (red) and the computed center of the AGV (green) for an exemplary input image.

In order to allow the robot to move to the estimated center, $\mathbf{c}$ needs to be transformed from the (2D) camera coordinate system to the (3D) world coordinate system of the robot. This problem is displayed by Fig. 26.5a where the red arrow indicates the required transformation given the two coordinate systems. The

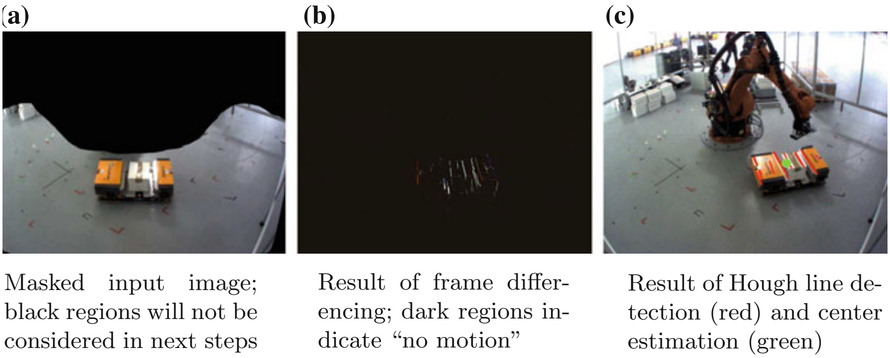

Fig. 26.4 2D processing flow (interim results): **a** masked image, **b** substracted successive frames, **c** detected lines and AGV’s center point

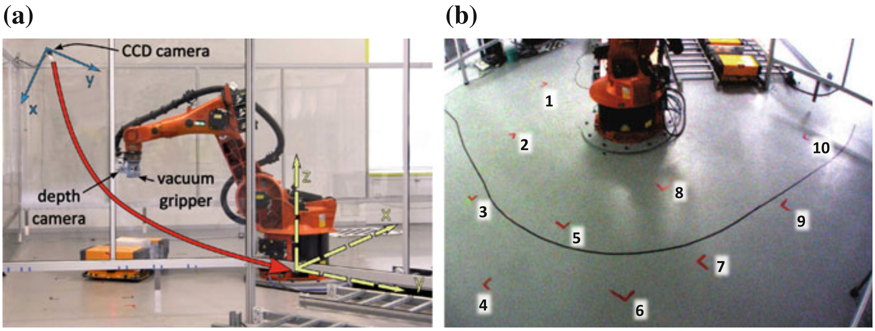

Fig. 26.5 Determination of the coordinate transformation from the 2D camera- to the robot’s world coordinate system to use the detected (and transformed) AGV position as input for the robot positioning. **a** CCD camera (*upper left*) and the required transformation (*red*) from camera- to robot’s world coordinate system. **b** Custom marker pattern on the ground of the transfer station to find correspondences for the transformation

intrinsic and extrinsic camera parameters are required for the transformation. The extrinsic matrix $\mathbf{D} = (\mathbf{R}, \mathbf{t}) \in \mathbb{R}^{3\times4}$ is composed of a rotation matrix $\mathbf{R} \in \mathbb{R}^{3\times3}$ describing the rotation of the camera’s origin related to the world coordinate’s origin and a translation vector $\mathbf{t} = \left(t_x, t_y, t_z\right)^{\mathrm{T}} \in \mathbb{R}^3$ representing the offset between the two origins. Using Rodrigues’ rotation formula, the extrinsic parameters $\mathbf{D}(\mathbf{a})$ may be expressed as a function of the vector $\mathbf{a} = (\mathbf{t}, \mathbf{a}_R)^{\mathrm{T}} \in \mathbb{R}^6$ which condenses the translation and rotation respectively (Zhang 2000). The rotation axis is $\mathbf{a}_R = (x, y, z)^{\mathrm{T}}$ and the angle of rotation is given by $\theta = |\mathbf{a}_R|$. Thus, $\mathbf{a}$ encapsulates the unknown parameters required for the transformation. They are determined by finding point correspondences $k : (\mathbf{x}, \mathbf{x}')$ between a world coordinate $\mathbf{x}'$ and an image coordinate $\mathbf{x}$. Since $\mathbf{a}$ consists of 6 elements, at least 6 correspondences are needed (Hu and Wu 2002). Figure 26.5b visualizes the employed custom markers (enumerated from 1 to 10) on the ground in the transfer station which have been used to find such correspondences. More specifically, the robot was positioned on all these markers and the resulting position both in the robot's and camera's coordinate system were conceived as the correspondences $k_j : \left(\mathbf{x}_j, \mathbf{x}'_j\right), j = 1, \ldots, n$ (with $n = 10$). This yields the optimization problem

$$\min_{\mathbf{a}} \sum_{j=1}^{n} \left(\mathbf{x}'_j - \mathbf{KD}(\mathbf{a})\mathbf{x}_j\right)^2 \tag{26.1}$$

where $\mathbf{KD}(\mathbf{a})\mathbf{x}_j$ maps the image coordinate $\mathbf{x}_j$ to the world coordinate $\mathbf{x}'_j$. Equation 26.1 was solved using the Levenberg–Marquardt algorithm (Zhang 2000).

Now assume, we are given the (homogenous) AGV position $\mathbf{c}^\star = (\mathbf{c}, 1)^{\mathrm{T}}$ in an image and want to get the corresponding world coordinate $\mathbf{c}'$ which is obtained by inverting $\mathbf{D}$ and $\mathbf{K}$. Thus,

$$\mathbf{q}^\star = \left(q_x^\star, q_y^\star, q_z^\star, q_w^\star\right)^{\mathrm{T}} = \mathbf{D}^{-1}\mathbf{K}^{-1}\mathbf{c}^\star \in \mathbb{R}^4 \tag{26.2}$$

gives a possible homogenous world coordinate which can be normalized by $\mathbf{q} = \left(q_x^\star/q_w^\star, q_y^\star/q_w^\star, q_z^\star/q_w^\star\right)^{\mathrm{T}} \in \mathbb{R}^3$. Since an image $\mathbf{G}^t$ does not contain any depth information, all points on a line through $\mathbf{q}$ and the camera's origin $\mathbf{o} = \left(o_x, o_y, o_z\right)^{\mathrm{T}} = \mathbf{R}^{-1}\mathbf{t}$ are possible. Finally, solving

$$\mathbf{c}' = \begin{pmatrix} c'_x \\ c'_y \\ h_{\text{fix}} \end{pmatrix} = \begin{pmatrix} q_x \\ q_y \\ q_z \end{pmatrix} - \lambda \begin{pmatrix} q_x - o_x \\ q_y - o_y \\ q_z - o_z \end{pmatrix} \quad \text{with} \quad \lambda = \frac{q_z - h_{\text{fix}}}{q_z - c_z}, \tag{26.3}$$

taking the known height h_{fix} of the AGV into account, yields the desired world coordinate $\mathbf{c}'$.

26.2.2 Prediction of Future Positions and Smoothing

The previous section already stated issues related to the underlying motion detection by means of frame differencing. Additionally, due to varying results of the edge and line detection, the detected center position of the AGV changes erratically. To overcome these problems, probabilistic filtering in terms of the Kalman filter (Kalman 1960) is applied; experimental results are shown in Fig. 26.6 to demonstrate the effects. Figure 26.6 summarizes the experimental results of the Kalman filter (green, orange), Condensation algorithm (light green, magenta) and raw measurements (red, blue). Two observations can be derived from the plot: First, at around 23 and 40 s the detection failed so that there is no position data available.

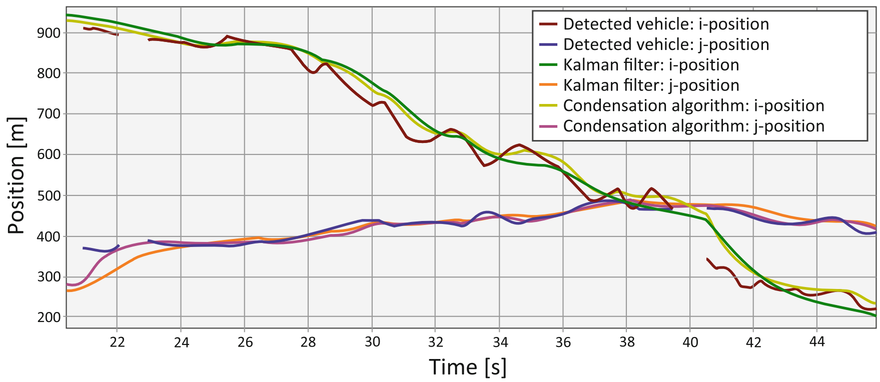

Fig. 26.6 AGV positions in the robot's world coordinate system (*i*: *red*, *j*: *blue*), filtered/predicted results using Kalman filter (*i*: *green*, *j*: *orange*) and Condensation algorithm (*i*: *light green*, *j*: *magenta*)

However, both filtering algorithms compensated this issue. Second, especially the *i*-values (red) are highly interfered with noise. Both algorithms filter the raw values appropriately (while Kalman performs slightly better). It can be summarized that the combination of 2D detection (see Sect. 26.2.1) with a probabilistic filtering exhibits stable positions of the AGV which can be used to command the robot's tool to that position.

26.3 Detecting the Position and Orientation of the Load

Based on the coarse-grained position retrieved by the algorithms described in the previous section, this section focuses on the fine-grained detection of the AGV and its loading. By analyzing the point clouds of the 3D sensor attached to the robot's vacuum gripper, a precise localization is possible. An important requirement is that the robot is re-positioned to keep track of the AGV's topside; otherwise, the 3D sensor data would get lost (in such cases, we switch back to the 2D detection). We assume that the AGV carries a cuboid shaped boxboard having a color not equal to the color of the AGV which seems reasonable since most packagings have this sort of appearance.

Figure 26.7 visualizes the processing steps of a point cloud $\mathcal{P} \subset \mathbb{R}^6$ retrieved by the 3D camera. It captures point clouds (see Fig. 26.8a) from the topside of the AGV which get preprocessed by dynamic distance filtering to remove the ground points $\mathbf{p}_i = (x_i, y_i, z_i, r_i, g_i, b_i)^{\mathrm{T}} \in \mathcal{P}$, voxelgrid downsampling to reduce the size of the input while still preserving the geometric structure of the AGV, color filtering to remove the salient colored body elements of the AGV (orange in Fig. 26.1), and statistical outlier removal to suppress scattered points in the residual point set. By detecting planes in the point cloud, we obtain an approximation of the packet

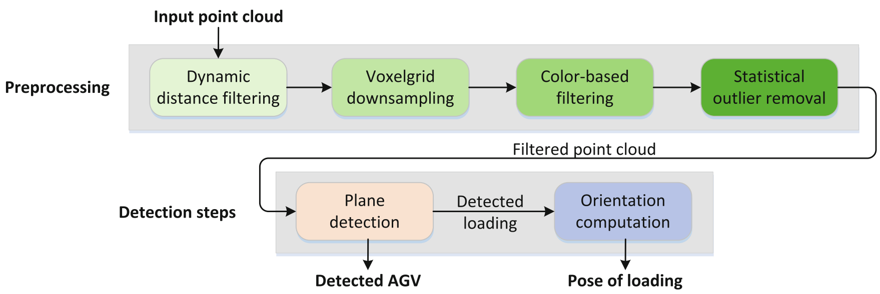

Fig. 26.7 Processing pipeline for 6D point cloud data, acquired from the mobile structured-light-sensor mounted on the robot's gripper

transported by the AGV (cf. Sect. 26.3.1). Finally, the orientation of the packet is determined to properly align the vacuum gripper (see Sect. 26.3.2) for grasping. Again, like in Sect. 26.2, positions need to be predicted in the absence of point cloud data which occurs when the robot actually grabs the loading. Details are explained in Sect. 26.3.3. Consecutive processing steps discard elements of $\mathcal{P}$ which will finally yield the point cloud(s) describing the vehicle (cf. Fig. 26.8c) and its loading respectively.

26.3.1 Fine-Grained Load Detection Using 3D Camera Data

For each captured input point cloud $\mathcal{P}$, a few preprocessing steps are required to discard non-needed points for the subsequent detection (Kobbelt and Botsch 2004); notably, these steps preserve the geometric structure of the AGV and its loading. First, a dynamic distance filter is employed to remove the points belonging to the ground plane around the vehicle. The resulting point set is given by

$$\mathcal{P} = \left\{ \mathbf{p}_i = (x_i, y_i, z_i, r_i, g_i, b_i)^{\mathrm{T}} \in \mathcal{P} \,|\, \alpha \geq z_i \geq \beta \right\} \tag{26.4}$$

where α is the current z-coordinate of robot's Tool Center Point (TCP) and $\beta = 0.05$ has been determined experimentally. It accounts for noise in the point cloud making up the ground plane. Figure 26.8b shows an example of applying this filter. The red points (ground) will be removed by the filtering while green points (vehicle) remain in the set. Second, voxelgrid downsampling based on a regular grid of size s is used to reduce the cardinality of the point cloud $\mathcal{P}$ by

$$\mathcal{P} = \left\{ \hat{\mathbf{p}}_i = \frac{\sum_{\mathbf{p} \in \mathcal{V}_i} \mathbf{p}}{|\mathcal{V}_i|} \,|\, \mathcal{P} \stackrel{s}{=} \bigcup \mathcal{V}_i \right\} \tag{26.5}$$

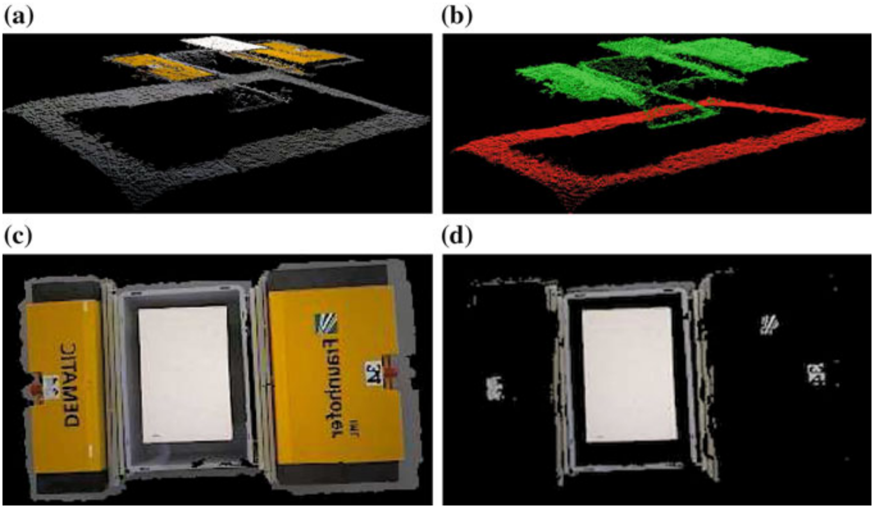

Fig. 26.8 Interim results of the point cloud processing. **a** Input point cloud $\mathcal{P}$ in *lateral view* with 76,800 points. **b** Result of the distance filter (removed points are *red*). **c** *Top view* on the AGV prior to applying the color filter. **d** Result of applying the color filter given (**c**) as input

which speeds up the processing. This step reduces the point cloud to 14.66 % of its original size (76,800 to 11,256 points). Third, a color filter removes points belonging to parts of the salient orange-colored body of the AGV, see Fig. 26.8c. The result is depicted in Fig. 26.8d; the RGB color thresholds have been derived from a set of real point clouds by computing the RGB histograms. Finally, statistical outlier removal (Rusu et al. 2008) suppresses residual scattered artifacts. Therefore, assume $\mu(d_i)$ is the averaged Euclidean distance d_i to all k neighbors of a point $\mathbf{p}_i \in \mathcal{P}$, μ is the mean of all $\mu(d_i)$, and σ is its standard deviation. The filtered set is then given by

$$\mathcal{P} = \{\mathbf{p}_i \in \mathcal{P} \,|\, d_i \geq \mu + \gamma \cdot \sigma\} \tag{26.6}$$

where γ is an empirically determined multiplier of the standard deviation.

Recap that we are interested in determining the loading which is assumed to be a packet with a planar top surface. The RANSAC algorithm (Fischler and Bolles 1981) is utilized to detect this top plane. It subdivides the input set $\mathcal{P}$ to a distinct set of clusters whereby the largest cluster $\mathcal{C} \subset \mathcal{P}$ approximates the packet's topside. To compute the 3D center point of the packet, we average the extreme coordinates $x_{\min}, y_{\min}, x_{\max}, y_{\max}$ of the largest cluster's convex hull, i.e.,

$$\mathbf{q} := (0.5 \cdot (x_{\min} + x_{\max}), 0.5 \cdot (y_{\min} + y_{\max}))^{\mathrm{T}}. \tag{26.7}$$

Experiments have shown that the sensor data is highly interfered with noise, causing the z-values to vary within ± 5 mm. With regard to precisely position the vacuum gripper onto the packet, a median filter is applied to the series of z-values to reduce the impact of noise over time. Taken all together, the previous processing steps result in the remaining point cloud $\mathcal{C}$ and the top center point $\mathbf{q}$ of the loading. Note that since the packet's height is determined from the sensor data, the algorithm works with different packet heights, too. For the sake of robustness, additional checks are performed by testing whether

(a) the ratios of the detected geometry equal the AGV's geometry ratios,
(b) the AGV actually has a loading (if not, the robot aborts its motion), and
(c) the detected loading is entirely contained in the vehicle's loading area.

All checks are done using geometric constraints by taking the predefined dimensions of the AGV into account.

26.3.2 Orientation of the Loading and Coordinate Transformation

The previous section explained the methods required to obtain a 3D position of the loading in the (3D) camera coordinate system. Clearly, to maximize the probability of successfully grasping the packet, its orientation should be considered. This allows adjusting the yaw angle of the robot's end effector to increase the covered area of the vacuum gripper matching the packet's top surface. We use Principle Component Analysis (PCA) on the point set $\mathcal{C}$ (cf. Sect. 26.3.1) to compute the rotation around the (robot's) z-axis (see Fig. 26.5a). The first eigenvector regarding the largest eigenvalue specifies the major orientation of $\mathcal{C}$ which is used to compute the required angle ϕ.

The pose $(\mathbf{q}, \phi)$ of the packet is still only given in the coordinate system of the 3D camera. It is therefore necessary to transform the pose to the coordinate system of the robot which is done by a Hand-Eye calibration (Tsai and Lenz 1989). Refer to Prasse et al. (2015) for more details. Given the transformed result, we can continuously reposition the robot's vacuum gripper above the loading.

26.3.3 Predicting Positions in the Absence of 3D Sensor Data

When the robot grasps the packet, it moves towards the object of interest (AGV and packet) so that the 3D sensor data gets lost due to the range limitations of the camera (for a camera-to-object distance of < 0.8 m). Since the AGV continues its drive through the transfer station, ongoing detections are needed. Our solution again involves predicting the future positions based on recent observations. More precisely, we assume a constant velocity $\mathbf{v} \in \mathbb{R}^2$ of the AGV for the short period of time (e.g., for about 0.5 s at 0.15 m/s) where the sensor stops delivering data. A position $\mathbf{x}^{\star}$ is predicted at time $t = t_{\text{grasp}} - t_{\text{lost}}$ by

$$\mathbf{x}^{\star}(t) := \mathbf{q}_0 + t \cdot \mathbf{v} \quad \text{with} \quad \mathbf{v} = \frac{\mathbf{q}_j - \mathbf{q}_i}{\Delta t} \tag{26.8}$$

whereby $\mathbf{q}_0 \in \mathbb{R}^2$ is the last known (2D) position (at t_{lost}) of the AGV and t_{grasp} is the time of grasping the packet. Thus, the velocity $\mathbf{v}$ is estimated based on the last available positions $\mathbf{q}_i, \mathbf{q}_j \in \mathbb{R}^2, j > i$ with a time gap of $\Delta t = t_j - t_i$. The predicted position $\mathbf{x}^{\star}(t)$ is used to grasp the packet.

26.4 Results and Discussion

This section deals with the experimental results of the presented concepts. First, the system setup is presented in detail. Second, the accuracy of the 2D AGV detection is elaborated (see Sect. 26.4.1). Third, the accuracy of the 3D load detection is analyzed (see Sect. 26.4.2). Finally, the overall system performance is presented involving all algorithms described in this paper (see Sect. 26.4.3).

As already introduced in Sect. 26.1, the transfer station (cf. Fig. 26.1) is essentially composed of two types of actuators: an industrial robot of type KUKA KR 125/3 equipped with a vacuum gripper tool (SCHMALZ FX-400/12C-SV) and the AGVs of the Multishuttle Move system (Kamagaew et al. 2011). They store and transport a single boxboard with a cuboid shape and a solid color. The sensors in this setup are the (stationary) 2D CCD camera DFK 31BU03. H produced by The Imaging Source GmbH with a resolution of 1024 × 768 px at 30 fps and the ASUS Xtion Pro Live. The latter provides a resolution of 640 × 480 px at 30 fps and a working range of 0.8–3.5 m.

26.4.1 Accuracy of the 2D AGV Detection

For the purpose of evaluating the 2D detection accuracy of the algorithms explained in Sect. 26.2, a test video has been recorded. It shows the moving AGV with a velocity of 0.2 m/s driving past the robot and finally leaving the transfer station. Meanwhile, the robot is moving as well to create a realistic test case. Every second frame has been annotated with the ground truth center point of the AGV.

The outcomes are depicted in Fig. 26.9 for x and y respectively; the plots also contain the Kalman results (green). The manually specified ground truth data is displayed in light green and the detected x and y coordinates are visualized in red. Note that the data has been transformed to the robot's world coordinate system, see Sect. 26.2.1. Both Fig. 26.9a, b allow three important observations: First, the

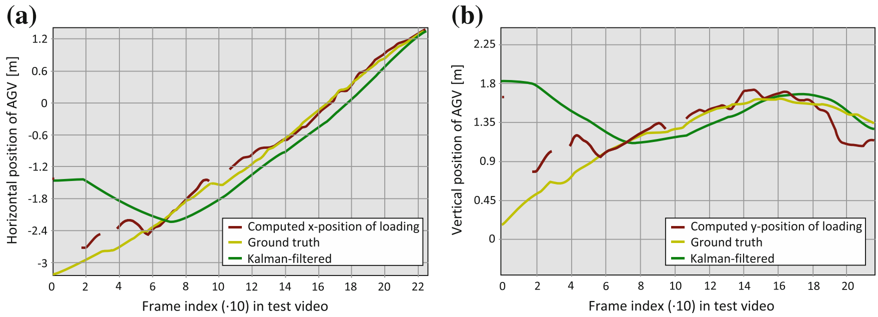

Fig. 26.9 Accuracy of the 2D detection of the AGV (*red*) using the processing described in Sect. 26.2 (including the Kalman filter, *green*). **a** x-dimension. **b** y-dimension

Kalman filter converged after approx. 70 frames and removed a few outliers as intended. However, the filtered results have a systematical drift of about 0.2 m for Fig. 26.9a (x-dimension) and 0.15 m for Fig. 26.9b (y-dimension) w. r. t. to the detected positions. Second, with an exception between frames 20–60, the data for both x and y approximates the ground truth results. Third, in the frames 190–220 in Fig. 26.9b, there is a higher deviation of about 0.4 m which was successfully compensated by the Kalman filter. Recall that the z-coordinate is not checked since is it set to a fixed value so that the 3D camera's field of view includes the entire vehicle.

26.4.2 Accuracy of the 3D Load Detection

The 3D-based detection has been exemplary tested by using the position information reported by the robot controller as ground truth data. Given the non-moving AGV located next to the robot, its tool was moved to the topside center of the load which resulted in $(x, y) = (1570\,\text{mm}, -815\,\text{mm})$. Afterwards, the robot was moved to the predefined height to allow a detection using the 3D data. The detection returned $(x', y') = (1585\,\text{mm}, -0835\,\text{mm})$ as the center position of the loading. In terms of accuracy for the positioning of the vacuum gripper, a variation of 15 in x- and 20 in y-direction can be considered as sufficient. With the use of the median filter (see Sect. 26.3.1), a z-related accuracy of 1 mm was achieved; this is very important since invalid heights may cause damage to the robot, vehicle, and/or loading.

In this setting, the width and length of the packet have been computed using the point cloud data as well because this is used to verify whether the detected load is actually located within the loading area of the AGV, see Sect. 26.3.1. Given the true dimensions of 400 mm (longitude) and 250 mm (latitude), 10 measurements have been averaged to obtain the resulting values of 421 mm (longitude) and 276 mm (latitude). These results indicate the need for thresholds when comparing the

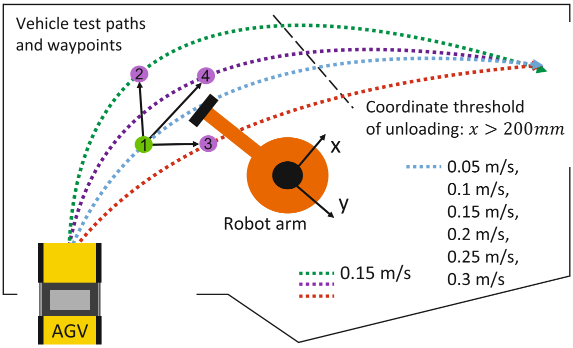

Fig. 26.10 Varied parameters during the tests of the overall system performance: velocity and waypoints of the AGV within the transfer station; the resulting paths are depicted as the *dotted lines* (*green*, *purple*, *light blue*, and *red*)

detected with the actual dimensions to account for the herein revealed inaccuracies which can be traced back to the fact of sensor noise.

26.4.3 Performance of the Overall System

This section finally describes the analysis of the overall system performance including all software and hardware components. It yields the number of successful unloadings whereby the latter is defined by successfully grasping a packet and moving it out of the AGV to the unloading area. In all subsequent tests, unloading has always been triggered statically, i.e., when the x-position of the detected loading exceeds 200 mm as indicated in Fig. 26.10. It shows the AGV (lower left), the robot, the different velocities and paths using 4 different waypoints. Other triggering methods have been tested as well but the aforementioned technique performed best.

The AGV was instructed to follow a previously defined path 1 (sketched as a light blue dotted line in Fig. 26.10) using 6 different velocities, namely 0.05, 0.1, 0.15, 0.2, 0.25, and 0.3 m/s. Each drive was repeated 10 times; the results are summarized in Fig. 26.11a. As indicated, higher velocities reduce the number of successful unloadings considerably. For example, with a velocity of 0.3 m/s, none of the attempts succeeded. This is caused by the PI controller which demands too much time to reach the target position. However, the results are promising up to a velocity of 0.2 $\frac{\mathrm{m}}{\mathrm{s}}$.

The previous results have been used to deduce the "optimal" velocity (= 0.15 $\frac{\mathrm{m}}{\mathrm{s}}$) which fits the trade-off of a high AGV velocity vs. a high resulting accuracy best. This speed was used to vary the waypoints of the AGV through the transfer station to test the flexibility, cf. Fig. 26.11b. As it can be seen in Figs. 26.11b and 26.10, paths 2 and 3 located close to the border of the robot's workspace performed worse (60 %) compared to paths 1 and 4 (90 and 100 % respectively) passing through the middle.

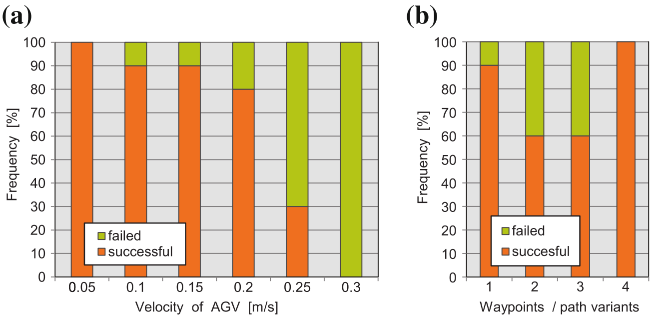

Fig. 26.11 Frequency of successful and failed automated unloadings with varying parameters to verify the performance of the system in case of **a** different velocities, and **b** varying paths/waypoints (cf. Fig. 26.10)

Additionally, the performance was evaluated using another packet, effectively changing the height that needs to be approached by the robot. This way, the approachable height was decreased from 43 to 40 cm (already critical w. r. t. a successful attempt). The results are promising: 8 out of 10 cases resulted in successful unloadings. Failed cases may be due to inaccurate predictions (cf. Sect. 26.3.3) of the AGV position while 3D data got lost.

26.5 Conclusion

In this paper, a novel approach has been presented to allow automatic unloading of moving AGVs by using an industrial robot arm as well as 2D and 3D cameras to observe the environment in which the unloading takes place. The solution of this paper involves 2D image processing to detect where an AGV enters the transfer station in order to position the robot's tool above the incoming AGV. Afterwards, the tool-mounted Structured-Light-Sensor provides detailed 6D data (position and color) of the vehicle and its loading which allows to precisely detect the actual position of the loading (see Sect. 26.3). By tracking the moving AGV and fusing the sensor data, the robot is able to grasp the loading without having to stop the AGV. This increases throughput and energy efficiency. The solution demands the robot controller to cancel the current motion at any time and immediately change over to the next position (realized by a PI controller). The results show that the system is capable of autonomously unloading the passing AGVs at lower speeds of around 0.15 $\frac{\text{m}}{\text{s}}$. For velocities $> 0.2\,\frac{\text{m}}{\text{s}}$, both the closed control loop and the processing algorithms need to be improved in order to handle the specific real-time requirements of the process.

More specifically, the presented approach made some assumptions and has some other shortcomings. First, the loading of the AGV must not have the same color as the AGV's body since this would break down the color filtering in the point cloud processing (see Sect. 26.3). In general, color-based segmentation (both in 2D and 3D) is sensitive to environmental illumination changes and, thus, error prone. Second, with respect to the dimensioning of the PI controller, AGVs faster than 0.3 $\frac{\text{m}}{\text{s}}$ are difficult to handle because the robot is not able to chase them.

These shortcomings will be addressed in future research. Additionally, the end-consumer-level 3D sensor, an ASUS Xtion, may be exchanged by an industrial ToF camera to get enhanced point clouds (Foix et al. 2011). Nevertheless, the working range of depth sensors is still a (general) problem to consider. Moreover, position information from the AGVs may be incorporated to improve the localization. Finally, more sophisticated approaches to decide when to grasp the packet are currently being developed and tested.

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Chapter 27
PROduction Plan Based Recovery of VEhicle Routing Plans Within Integrated Transport Networks

Michael Schygulla and Andreas Stadler

27.1 Overview

Industry and commerce now depend more than ever on reliable logistics. In practice, however, supply chains face numerous challenges from disruptions such as traffic jams, technical issues, missing goods, and any number of other unforeseeable circumstances. This then calls for manual correction. In the ProveIT project (PROduction plan based Recovery of VEhicle Routing Plans within Integrated Transport Networks), researchers are now developing an IT platform that will give dispatchers the tools they need to make objectively assessed and dependable interventions in connected logistics systems. The aim is to build up reliable, cost-effective supply chains that are not disrupted due to misguided reactions and interventions.

Nowadays complex and geographically wide-spanning supply chains depend to a high degree on reliable logistics processes. An overall seamless production and logistics planning and execution procedure throughout the entire supply chain is not given in the reality. Substantial breaches in the different interfaces between stakeholders and transportation chains are common situation in the supply chain. Moreover, the assessment of measures, robustness of plans and optimization potential in the supply chain at different stages is complicated. Local optimization approaches might lead to an overall decrease of efficiency or an unbalanced advantage in one part of the chain.

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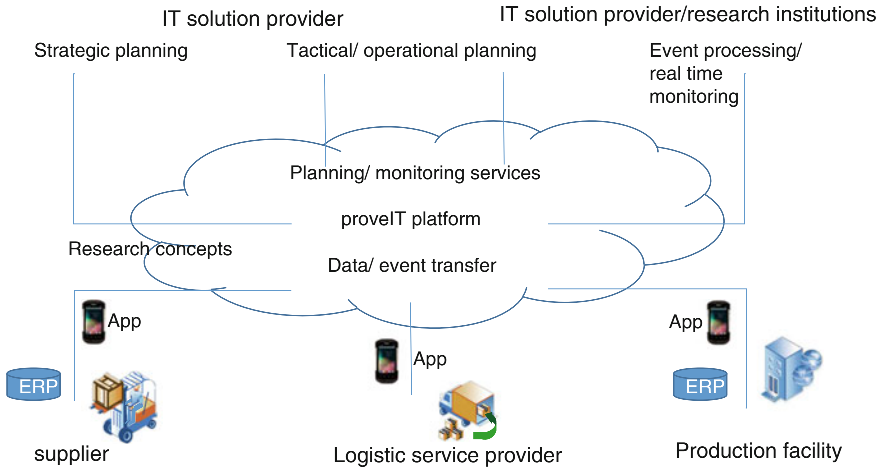

Fig. 27.1 ProveIT general architecture—involved partners and roles

ProveIT is aiming at solving some of these inefficiencies by integrating production plan and transportation network as well as operational logistics planning and execution.

Within the project, all relevant stakeholders of the supply chain are involved. IT solution providers are developing the system supported by research institutions, which are responsible for the overall approach and research concepts. Industry partners and Logistic service provider (LSP) are making sure that the requirements for the developments and pilot phases for testing the systems are being defined with practical relevance and on the basis of their underlying processes (see Fig. 27.1).

27.2 Project Goals

The concrete project goals can be referred to the levels

- Planning process from production planning to delivery
- Event handling within transport execution
- Micro and macro economical goals and foreseen effects.

Enhancement of planning process

The decision making process within the logistic network and transport execution process will be enhanced by providing alternatives for reactions. In connection with the ProveIT technical systems, only appropriate measures for the different steps should be proposed instead of instant reactions without knowledge of other process steps. Uncritical disturbances in the overall context of production planning can be neglected. Only relevant deviations should be detected, filtered and handled with minimum necessary plan changes.

Reduction of technical and organizational disturbances
At first, the process of data gathering over the entire logistical process should enable a better visibility of the entire logistic process with all the different and possible events. Root cause analyses about the reasons for technical and organizational deviations can be conducted. Hence, it will be possible to consider reasons for disturbances on all nodes and segments of the underlying network and to cope with these deviations.

Economic benefits
The provision of a tool-based decision making support for a logistic network should enable better and more stable planning processes and results. The necessity of interventions is being detected on a network level, critical deviations are being identified, analysed and appropriate reactions are calculated. The efforts for troubleshooting and situative "overreactions" should be minimized. The planner will be able to work more on quality management and the enhancement of the overall planning and distribution rather than on getting the relevant information about transport status via phone calls. Focus is to stabilize the entire system with tailored measures for the different planning and execution levels (strategically, tactical, operational planning, execution).

Not only technical developments and automated processes should be developed but more the enhancements and improvements are being scientifically evaluated within the different process steps. Together with the partners, KPIs will be defined such as tour durations, disturbances, deviations and the efforts to clear them.

Logistic benefits
Another benefit could be modal split changes to more intermodal transportation due to better tactical planning capacity and processes. A more long-term planning of transport processes should be facilitated. The transportation process should become stable and not as sensitive for disturbances as it is in certain cases of very short-term plan changes.

27.3 Approach and Methods

The project developments are being performed in four phases: conceptual phase, technical developments and IT solutions, pilot phase and evaluation phase. Conceptual analyses of the current situation, requirements of stakeholders, and optimization potentials of the entire supply chain between the involved practice partners are the basis for technical developments and IT solutions.

Currently systems and applications are being developed regarding tactical and operational network planning, operational transportation planning and real time event management. The concept foresees a system architecture to enable appropriate reactions of the different stakeholders on possible deviations from the planned tour.

In parallel to the concept phase and the development of the technical system, an assessment procedure is being created for gathering the effects of the measures realized in the ProveIT system.

As a precondition, process data from different parts of the supply chain has to be collected for the time before the realization of the ProveIT system (baseline) as well as for the pilot and the evaluation phase. This data is the input for the computation of KPIs (key performance indicators), which form the indicators of the above mentioned assessment procedure.

Overall, the project is divided into 7 work packages. The work packages include:

- WP1: Fundamentals and design concept
- WP2: Platform development: strategic and tactical planning and operational planning
- WP3: Operational transport and tour planning and control
- WP4: Deviation management services
- WP5: Operational pilot
- WP6: Economic evaluation
- WP7: Exploitation, transfer and implementation

Figure 27.2 shows how the exchange of messages and data between the different components will take place and which functions among the participants of the supply chain (shippers, suppliers, logistics service provider) must be used. Instead of a monolithic, centralized platform the ProveIT project is realized by distributed services: this intended architecture is the integration of the entire system through

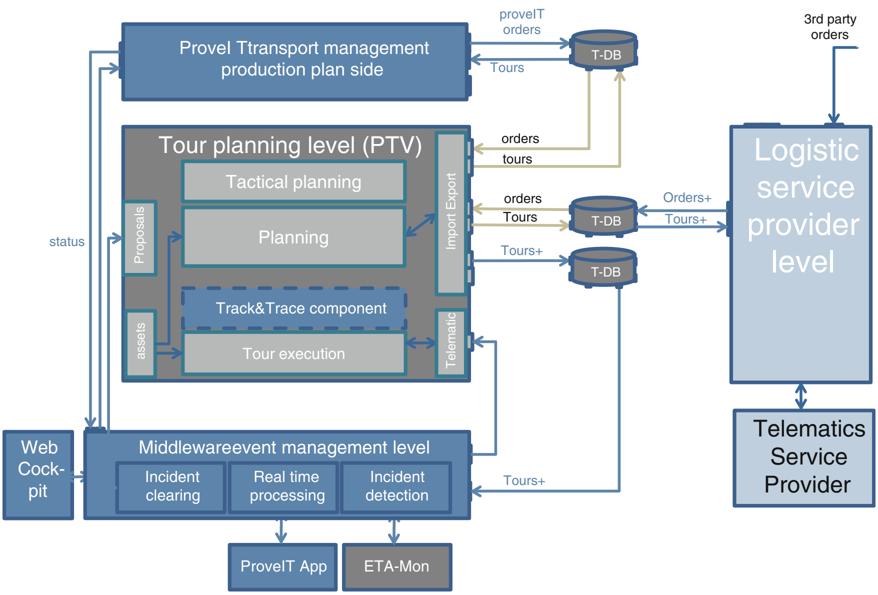

Fig. 27.2 System architecture ProveIT with interfaces and components

standardized web service interfaces and exchange formats, for example for plan or event messages.

The advantage of such a federated architecture is that the users of the ProveIT system will not be dependent on individual providers or individual implementations. Hence, businesses can more easily combine services and implement business processes faster, more dynamic and more flexible. Within the project duration greater dynamism in the development itself will be possible, because parts of the system can be developed independently from each other.

The overall system from a process related point of view is consisting of the following parts:

1. Production plan and demand related part
   Planning services are offered to the shipper for its transport planning. The shipper is being enabled to plan for its network strategically and tactically. The result of network planning will be deposited as a target for further planning steps. The following shippers can pass material requirements via an interface. The components to optimize orders check the material requirements against previously stored assets and determine a purchase proposal, which will be returned to the shipper. If no shipments are being available to the system another component is provided for the delivery planning.
   The shipper has then the possibility to pass a shipment either according to the generated purchase order proposal or a different shipment for transport planning to the corresponding component. This component determines the appropriate transport channel and the appropriate transport provider. The corresponding transport request is generated and passed to the shippers. The transfer order that is confirmed by the shipper is passed to the further planning of the components of the logistics service provider.
2. Logistic service provider part
   The logistic service provider has the flexibility to plan and adjust its network and to set it up for further steps of planning. Orders for the logistic service provider will be combined and planned from different sources. This will be done with the planning component of ProveIT. Here the tour with the assets, orders, restrictions, routes and time is being optimized and then transferred to the assets/drivers. Then the tour execution starts and the monitoring of the real time transportation chain begins.
3. Event processing part
   During monitoring of the transport process track and trace information from the on board unit/telematics application in the vehicle are being retrieved and stored for further processing. Via the component of event management deviations can be detected and according to the level of occurrence appropriately handled. At first clearing possibilities (change of routing or asset, tour replanning) on the level of the logistic service provider will be checked and proposed to the dispatcher. If the plan cannot be met within the given restrictions, the mechanism of above located event processing level will be requested. On this level, planning on production side and logistic service provider is being checked and

evaluated regarding the possibilities for incident clearing on the different process levels. Options for different reactions will then be given to the different users. Moreover, tactical plans are being monitored and from time to time changed if beneficial effects can be achieved.

27.4 System Architecture and Components

For the realization of the ProveIT system and the required planning and control applications, the technical system architecture has been defined together with the involved technical partners. Since the beginning of the second project year, the system architecture is available for all partners. Interfaces have been defined, agreed and realized between the participating technical components for planning, order management, tactical planning, operational tour planning and event management.

In the following picture, the system architecture is being described. Specific focus here in this context is on the logistic service provider part respectively planning and monitoring applications. The above located transport management production plan side is being developed by the project partner LOCOM, whereas partner FZI is mainly responsible for the Middleware event management level.

Core elements of PTV are the planning environment with the base components tour planning and execution of the tour with the track & trace module. As a separate component, the so-called ETA xTour monitor is used to support event management level. Corresponding interfaces are defined for phase 1 and realized to the systems of the technical partners. There is no direct access to the systems/processes of the logistic service provider, however, interfaces are being created. As main data-exchange instance the so-called Transfer-Database (T-DB) is being implemented either at the platform/tour planning level or at the LSP-level. T-DB is being used for appropriate data/order and tour exchange between different system levels. According to Fig. 27.2 the following functions or generations of planning results are being developed and implemented:

- Retrieval of orders of the logistic service provider into the planning environments
- Tour planning with generation of valid tours for the use cases including third party orders
- Transfer of the tours to transport management system of the logistic service provider and to the middleware event management component
- Retrieval of events from the ProveIT App/telematics on board unit via telematics interface into the planning system
- Processing of the events in the track & trace component
- Provision of updated calculations to the event processing engine
- On the basis of events recalculations of Estimated time of arrival will be conducted and transferred to the event management level

The system will support the whole transport process from origin to destination by generating plans and iteratively updating the relevant information for the users at the different stakeholders.

27.5 Data Integration and Web Based Interfaces

The project team is drawing on a range of familiar technologies, including vehicle tracking using GPS and software for transport planning. What is new is that production information is also incorporated into the decision making process. Production plan and material demand forecasts depending on the time windows and urgency of deliveries will influence the transportation planning and execution level.

Big data relating to unit sales of products and the traffic situation can also be incorporated into the platform, which will pool all this information and provide users—both companies and logistics service providers—with a range of services for planning and managing logistical processes. For instance, if the actual process begin to depart from target data, the platform will warn users and display appropriate responses. The responses offered will take into account the implications for the whole transport network, considering actions holistically rather than in isolation. To enable the platform to factor in real-time data such as vehicle position or delivery status, the project partners are also developing an application that truck drivers can use on their mobile devices.

The distributed architecture enables the whole system to collect various data both historical and real time on different levels. On a strategic level regional and transport network data for different transport channels can be integrated into the planning system.

Furthermore, demand data for manufacturing items and related shipping information will be used for pre-planning purposes on the different transport channels. For the transport itself various data sets on transport capacities, assets, opening hours, frequencies and more will be considered in the further planning steps. During transport execution data on process status are being collected through tailor made solutions both on the mobile unit and on the backend event management components. The process of data gathering on this level will be partially automated to make sure that the driver will not be overloaded by additional tasks beside his regular job of truck driving, loading/unloading and administrative handling. Moreover the driver should be guided through the system and only be responsible for certain confirmations on the senslets to retrieve the correct status of the deliveries at the different stop points of the tour.

Data and information transfer will be realized by using standardized interfaces, especially web services, remote calls, database queries.

27.6 Evaluation

27.6.1 Basic Approach

The main task of work package 6 “Economic Evaluation” consists in the verification of the effectiveness and efficiency of the optimisation measures realised in the ProveIT project. For this purpose, the situations in the different phases of ProveIT are compared with the situation before or without ProveIT (zero case).

The evaluation is carried out in two steps. The first step aims at the measurement of isolated effects of certain measures, e.g. the effect of order optimisation on the number of orders. This evaluation is realized by the computation of key performance indicators (KPIs). Only in the second step, the effects of measures on the whole process (supply chain) and the coaction of different measures are analysed. A critical part of the overall assessment plays the use of a process cost model, which allows to express effects in monetary terms.

27.6.2 Problems and Challenges

Data

As a necessary precondition for the assessment there must be sufficient data describing the situation before (or without) ProveIT (baseline) as well as after the implementation of measures in the different phases of the project.

As a result of the analysis of the availability of data for the baseline, among others, the following information was or could be made available by the project partners:

- Material requirements, goods received, and available stock.
  This data is available on a daily base. It is particularly relevant for the order and the transport optimisation by the shipper.
- Transport orders, structure of the logistics network, and information on the consolidation of orders (tour planning).
  This data is necessary for understanding and assessing the transport optimisation by the logistic service provider.
- Number of extra tours and statistics on delivery reliability of different suppliers.
  This information is used to compute the baseline for the assessment of the event (incident) management system, from the perspective of the shipper.
- Ranked list of frequently occurring incidents from the LSP.

As it is common case in many real circumstances some other information was incomplete or qualitatively insufficient. Therefore, the following data had to be replaced by assumptions, models or detailed studies:

- Mapping of material requirements to received goods (goods intake)
- Actually driven tours resulting from transport orders (executed tours at LSP)

- Reasons for extra tours initiated by the shipper
- Direct cost and other consequences resulting from incidents concerning the LSP.

Here, a special challenge was the reconstruction of actually driven tours from transport orders and other information concerning transport planning by the use of a tour planning software.

Use Cases and organisational restrictions
Generally, it would be preferable to directly measure the effects of optimisation measures (e.g. order optimisation) on the different process steps. However, this approach is restricted by organisational reasons, as for example the geographical regions for transport optimisation by the shipper and the LSP were in the begining of the project not identical. Other barriers are caused by the necessity of substantial organisational changes, e.g. concerning cooperation and communication between shipper, LSP and suppliers. During the project life span, some of the desirable changes may only be realised in a limited way or for special testing periods only.

Planning levels and time horizons
The evaluation also has to take into account the different planning levels and time horizons of the optimisation measures. So, the transport optimisation at the shipper and the LSP, as well as the event management are realised on the operational level, whereas the order management and the tour optimisation based on the evaluation of past event data are addressing the tactical, and the optimisation of the LSP's network structure even the strategic level.

First of all, this means that it is not possible to combine costs, benefits and other KPIs in a simple way, e.g. by adding them together. Furthermore, dependencies between measures on different levels have to be taken into account. For example, the re-planning of tours based on the analysis of past events (tactical planning) should result in a reduction of incidents, so that the reactive real time event management on the operational level would be activated less often.

Restrictions concerning implementation and testing
Even more difficulties for the evaluation task result from the fact that certain changes may only be realized for certain test regions or tours. So the resulting amount of data may not allow for statistically sound conclusions. This especially is the case for the assessment of optimisations on the tactical or strategic level, as the project life span may be too short to evaluate their mid-term and long-term effects.

27.6.3 Process Cost Model

The process cost model forms the basis for the overall assessment procedure.

As an important precondition for the appraisal of relevant effects, the main process steps were identified (see Fig. 27.3). Then for each step, useful KPIs were defined. Finally, to allow for the computation of costs and benefits in monetary terms, the project partners contributed costs rates for different indicators and process steps.

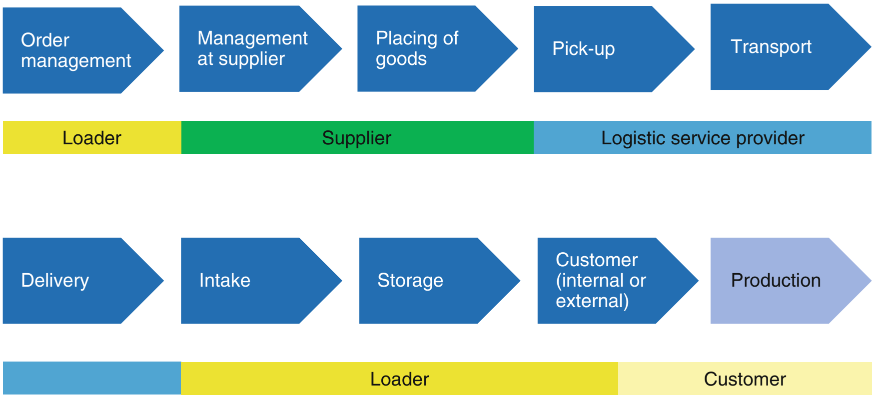

Fig. 27.3 Process steps

27.6.4 Assessment of Isolated Effects

As a prerequisite of the overall assessment of the whole ProveIT system, isolated effects of measures on single steps of the process chain are evaluated by the use of KPIs. For example, for the appraisal of effects on the transport by the LSP the following KPIs are used:

- number of orders
- order volume [t]
- transport performance regarding orders (origin—destination) [t km]
- transport performance regarding transports (tours) [t km]
- transport performance regarding vehicles [km]
- utilized capacity of vehicles [%]
- transport cost [EUR].

Within the KPIs concerning transport performance, it will be further distinguished between direct tours, collection tours between suppliers and hub, and shuttle tours between hub and goods recipient (shipper). All these KPIs were computed for the duration of two representative weeks (baseline), and they will be compared with values from different realisation phases of the ProveIT project.

In a similar way, KPIs for the other process steps were computed for the baseline.

27.6.5 Overall Assessment

First of all, in the overall assessment the isolated effects of measures (measured by KPIs) are combined and expressed in monetary terms.

The last especially allows for the assessment of measures with opposing effects. For example, it is expected for the order optimisation by the shipper to reduce the total number of orders resulting in reduced costs for order management and goods intake. On the other hand, the temporal consolidation of orders may lead to higher total stock, meaning an increase in costs for storage and capital commitment.

Secondly, measures should also be assessed in the combination with other measures, e.g. to ensure that the combination of the transport optimisations by the shipper and the LSP not only results in advantages for one of the partners, but in a globally optimised process.

In this context, a very important aspect is to complement the neutral, global assessment with evaluations from the perspectives of the different project partners. Such evaluations form the basis to avoid disadvantages in certain fields for single partners or to provide compensational advantages for them in other fields. This is especially important for assuring the acceptance of the overall system as well as of single measures.

27.7 Results so Far

The project has a duration of 3 years. In the sense of a proof-of-concept, a pilot system was set up within the first year of the project. Hence, the planning and control components that are provided as services can be developed in an iterative process, tested, and evaluated directly with practice partners. From the beginning, it is ensured that research and development partners are entering an intensive exchange with practice partners about the concepts and developments.

As interim results after the conceptual analysis, basically four main success factors for improving complex supply chains could be identified:

- Integration and provision of relevant status information of the production and logistic network,
- Appropriate and dynamic assessment of deviations between plan and actual state,
- Nearly full automatic deduction of corrective actions to bring the network back to planned state,
- Mid- and long-term stabilization of processes through stronger tactical and strategic planning instances.

The main components and applications on the different planning levels will finally support the users to find appropriate measures for stabilizing the system.

After the first project year, the initial pilot phase has started which means that the technical system infrastructure has been successfully set up. Exemplary data set from the industrial users have been transferred via web-based interfaces to the planning and event management systems. Demo sessions with the involved technical systems have been successfully performed. User interfaces and devices for

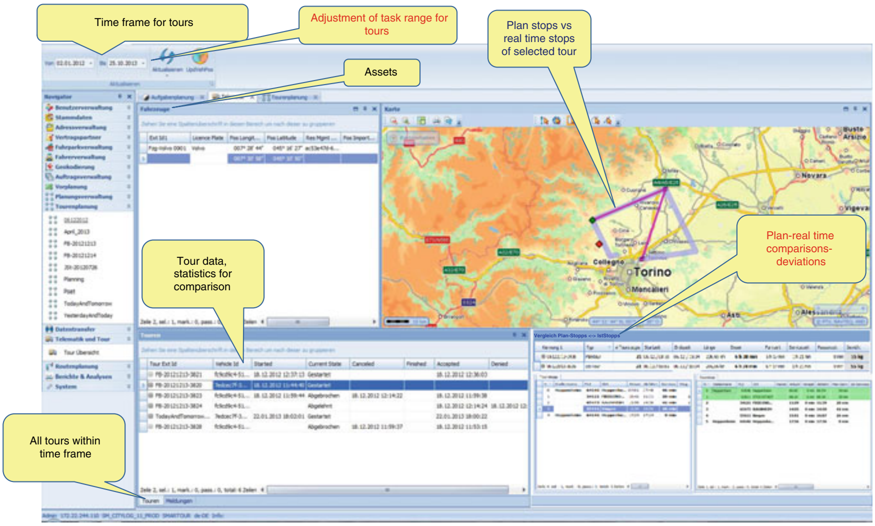

Fig. 27.4 PTV Smartour user interface for tour planning with foreseen extensions

pilot phases are ready to use. The different pilot phases and project related use cases are being currently sharpened and prepared for operational tests.

User interface for planning is being implemented and accessible via web interface (see Fig. 27.4). Further extensions of functionalities are being planned for the next project phase.

Regarding evaluation, the KPIs on the different economic levels have been defined. In addition, other factors (e.g. emissions) are being considered. First results of baseline evaluation (tours, driven km, regional distribution) have been produced.

27.8 Conclusions and Outlook

Next steps in the project are the extended evaluation phase with different use cases and real usability tests.

Furthermore the applications with advanced planning procedures for the different planning levels strategically, tactical and operational will be developed and step by step implemented in the components for the use cases and pilot tests. A dynamic development process has been set up in order to consider different requirements from the use cases in a flexible way.

First system demonstrations and successful implementations already proved the technical feasibility and the exemplary data transfer between the different system components. System architecture is running solid and is accessible for the project partners.

Within the pilot phases, the test system should run with sufficient performance and will be checked on usability and functionalities.

Further steps in the evaluation work package will be the macroeconomic assessment of the ProveIT methodology and the appraisal of its potential concerning the German transport sector.

The presentation will put emphasis on first evaluation results, the features and usability of the realized system components.

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The project consortium consists of industry partners (Robert Bosch GmbH, ZF Friedrichshafen AG, Geis Transport und Logistik GmbH), IT solution providers (LOCOM Software GmbH, PTV Planung Transport Verkehr AG) and research institutions (Institut für Fördertechnik und Logistiksysteme (IFL), Forschungszentrum Informatik (FZI).

Chapter 28
Monte-Carlo Tree Search for Logistics

Stefan Edelkamp, Max Gath, Christoph Greulich, Malte Humann, Otthein Herzog and Michael Lawo

In this paper we review recent advances of randomized AI search in solving industrially relevant optimization problems. The method we focus on is a sampling-based solution mechanism called *Monte-Carlo Tree Search* (MCTS), which is extended by the concepts of nestedness and policy adaptation to establish a better trade-off between exploitation and exploration. This method, originating in game playing research, is a general heuristic search technique, for which often less problem-specific knowledge has to be added than in comparable approaches.

The production and logistics problems we consider include vehicle routing, container packing and robot motion planning tasks, which are usually considered to be connected to *Operations Research*, often referring to decades of research. Despite the long history of the problems addressed, we are able to state that NRPA, a recent variant of MCTS with nestedness and policy adaptation, computes promising results, sometimes even of a quality that is difficult to match with other global/local optimization strategies.

The breadth of the three different application domains illustrates that a strong search paradigm is entering the arena, which might eventually lead to a paradigm shift.

28.1 Overview

Combinatorial search in the area of Artificial Intelligence has a long history encompassing heuristic, constraint and local search. Around 2005, a new generation of Monte-Carlo search based algorithms emerged. These caused a revolution in many domains in which AI methods had performed sub-optimally. The most famous example is the game of Go where any AI approach (e.g., neural networks, minimax, theorem provers, pattern matching techniques) had failed to even beat a human amateur player.

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Monte-Carlo search significantly changed that, and nowadays engines play at the grandmaster level. The basic idea is to guide the search by results of the Monte-Carlo simulations (aka. random playouts). Monte-Carlo search is attractive for many application domains, since it promises to overcome the "knowledge acquisition bottleneck" and make intelligent applications easier to engineer in many fields. This family of search algorithms is not only restricted to classic artificial environments that are just deterministic, fully observable, discrete, static, and only involve at most two agents. They have also been successfully extended to stochastic, partially observable, dynamic, continuous, and multi-agent environments.

There are more general applications of the original game-tree search techniques that can be employed outside the field of strategy games (see Browne et al. (2012) for a survey). Monte-Carlo search based algorithms developed in this field can be used in general optimization and long-range planning problems. For example, one Monte-Carlo search variant has been applied to optimize C++ libraries for different platforms. Monte-Carlo Tree Search (MCTS) was successfully applied for Production Management Problems, which are found in manufacturing and airline scheduling. For the medical field, MCTS has been used for scheduling patients for elective cardiac surgery by optimizing the assignment of several hospital resources. Nested Monte-Carlo search was utilized to minimize the number of stops for bus passengers. These are only some of the many fields benefitting from applying Monte-Carlo search based algorithms.

In this paper we review the recent progress in MCTS in further application domains and conduct experiments to illustrate further research progress. We look at the interplay of randomized exploration of paths and a policy learning mechanism, which is reflected in biasing the selection of child nodes. The logistics problems covered are *vehicle routing*, *container packing* and *robot motion planning* tasks that are often considered to be typical candidates for being solved by other Operations Research methods.

28.2 Method

In order to solve challenging optimization problems efficiently, we introduce sophisticated novel randomized exploration approaches based on *Nested Monte-Carlo Search with Policy Adaptation*, also called *Nested Rollout Policy Adaptation*, NRPA for short.

Traditional Approaches

The NRPA algorithm was one of the first ones which applies the MCTS paradigm to solve large and highly constrained *traveling salesman problems* (Cazenave and Teytaud 2012; Edelkamp et al. 2013a, b), especially problems which contain *pickup and deliveries* (Edelkamp and Gath 2014), a domain which is generally dominated by methods from Operations Research (see Pillac et al. 2013, or Nalepa et al. 2014), including optimal approaches using Mixed-Integer (Linear) Programming, Branch-and-Bound, Branch-and-Cut, and suboptimal approaches using Large Neighborhood Search, Particle Swarm Optimization, Genetic or Ant Algorithms, Simulated Annealing, etc. (Lawler et al. 1985).

Monte-Carlo Tree Search

Monte Carlo Tree Search (MCTS) is a method for making optimal decisions in artificial intelligence (AI) problems, typically move planning in combinatorial games. It combines the generality of random simulation with the precision of tree search. Research interest in MCTS has risen sharply due to its spectacular success with computer Go and potential application to a number of other difficult problems. Its application extends beyond games, and MCTS can theoretically be applied to any domain that can be described in terms of {*state*, *action*} pairs and simulation used to forecast outcomes. MCTS is a statistical search algorithm that iteratively performs random walks in the search space. It applies *myriads* of so-called *rollouts* (a random path usually to the end of the solution generation, also called *playout*), until the algorithm finds a valid solution, a maximum amount of time is elapsed, or a maximum number of rollouts is performed.

Upper Confidence Bounds Applied to Trees

The MCTS method originated in the area of two-player (board) game playing, where UCT is the variant that is most often referred to. Around 2006 Rémi Coulomb and other researchers provided a new approach to move planning in computer Go now known as MCTS. Kocsis and Szepesvári (2006) formalized this approach into the UCT algorithm. Actually their publication contributed a machine learning algorithm, which was looking at more general probabilistic MDP (Markov Decision Process) problems. Essentially, UCT grows a tree and performs rollouts at the leaves. A formula that trades exploration versus exploitation guides in which direction the tree should grow (in form of a new leaf).

Each round of UCT consists of four steps. *Selection*: starting from root r, select successive child nodes down to a leaf node l. The section below says more about a way of choosing child nodes that lets the game tree expand towards most promising moves, which is the essence of MCTS. *Expansion*: unless l ends the game, create one or more child nodes of it and choose from them node c. *Simulation*: play a random rollout from node c. *Backpropagation*: using the result of the rollout, update information in the nodes on the path from c to r.

While generally applicable to MDPs, in single-player variants that we consider for solving optimization problems in logistics, the algorithmic idea of Monte-Carlo search with UCT underwent different simplifications and refinements.

Nested Rollouts and Policy Adaptation

Nested rollouts perform an additional heuristic that determines next moves within the rollouts to guide the search in promising directions. Nested Monte-Carlo Search (NMCS) by Cazenave (2009) extends this approach by the concept of levels. NMCS makes the decision in level l on basis of the result of recursively exploring the successors of a node. NMCS takes as an argument and decrements the value in every recursive call. If the value is decreased to 1 (or to 0 depending on the implementation), a rollout is initiated. At each choice point of a rollout the algorithm chooses the successor that gives the best score when followed by a single random rollout. Similarly, for a rollout of level l it chooses the successor that gives the best score when followed by a rollout of level l—1. (see Fig. 28.1)

Inspired by the success of Nested Monte-Carlo Search in single-player challenges with large branching factors, *policy adaptation* leads to considerable improvements. Rather than navigating the tree directly, Nested Rollout with Policy Adaptation (NRPA) by Rosin (2011) instead uses gradient ascent on the (Boltzmann softmax) rollout policy at each level of the search. NRPA extends NMCS by adapting a *policy* (a strategy mapping from states to successor states) during the search and by introducing branching iterations (see Fig. 28.1 for an example with *iterations* = 4 and level $l = 2$).

Besides the joint concept of nestedness the two algorithms NMCS and NRPA are considerably different. In NRPA we prefer the rollouts to start at the root node, while NMCS commits moves in the search tree, so that rollouts start at depth l. The pseudo-code of the recursive main search routine NRPA is as follows

```
NRPA(level,iterations)
  best->score = MAX;
  if (level == 0)
   best->score =  rollout();  // sets solutions
   best->solution = solution;
  else
   backup[level] = global;
   for (i=0; i<iterations; i++)
      current = NRPA(level – 1);
      if (current->score < best->score)
       best = current
       adapt(best->tour, level)
   global = backup[level];
  return best;
```

It takes the current recursion level as a parameter and initializes the best-known solution in this level, and updates it according to ones suggested from higher recursion depth. At the end of the recursion (level 0) *rollouts* perform random searches according to the policy global and return the evaluation *score* (the solutions is maintained globally). In a rollout, a randomized roulette wheel selection mechanism (similar to the one known from genetic algorithms) chooses the successors according to an exponential function.

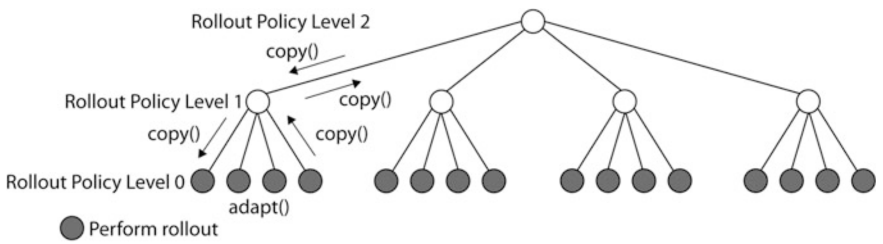

Fig. 28.1 Nested rollout with policy adaptation

Learning takes place in the form of *policy adaptation*, where the current policy-kept separated in each level of the search- is improved based on the better solutions found deeper in the search. Values for the improved solutions are increased in the policy, while the other entries are simultaneously reduces by a small margin. In other words, the planner learns a policy in form of a likelihood mapping from going from one state to another one. The policy is initialized to zero and is adapted each time an improvement to a given plan has been found. Moreover, by the virtue of the nestedness of the search the policy tables are refreshed (one table acts in each level of the search), yielding a compromise between exploration and exploitation.

This approach has been applied to efficiently solve the Traveling Salesman Problem with Time Windows (TSPTW) optimally or very close to the optimum. For solving single-vehicle pickup and delivery problems (with up to 400 stops), the NRPA algorithm for TSPs with time windows has been extended and extensively evaluated on two benchmark sets. The results reveal that the approach is competitive to other heuristics and meta-heuristics. The developed algorithm computes state-of-the-art solutions and has a high rate of success for finding feasible and best-known solutions. It handles these problems also in an adequate computation time.

28.3 Application Domains

Vehicle Routing

We look at improving individual logistics systems. Our first example is *vehicle routing* (Fig. 28.2), minimizing the travel time for a fleet of vehicles to pick up and deliver objects from customers.

Applications are interesting to companies that offer groupage traffic and reliable, safe and timely delivery from retail to local customers. We optimize the planning and scheduling of industrial processes by using the example of courier and express services. In order to handle the rising demands and to capitalize on the increasing optimization potential in transport logistics, which results from the consequent integration of the *Internet of Things and Services* into the real world, we must

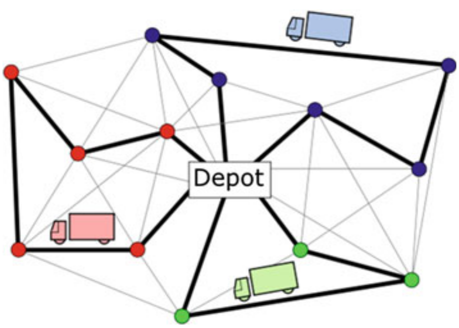

Fig. 28.2 Vehicle routing problem

ensure a flexible, adaptive, and proactive system behavior. Intelligent selfishly acting agents represent logistic entities, which negotiate and communicate with each other to optimize the allocation of orders to transport facilities.

The system has been designed in cooperation with experts on courier and express services and is able to include deliveries from one customer to the other. Such *pickup and delivery* problem setting is illustrated in Fig. 28.3.

In the pseudo-code we extend the solver to general vehicle routing problems (with service times, time windows and capacity constraints) using V vehicles and N stops. Stop 0 is the depot, which is visited V times. Further global variables are the policy *global* and the solution *tour. In* classical VRPs, function *check* tests if a a node has been visited. In pickup and delivery problem it also checks that a delivery is preceded by a pickup.

```
Rollout-VRP()
  for (j=1;j<N;j++)  visits[j] = 1;
  visits[0] = V-1; tour[0] = 0; tourSize = 1; // start node already visited
  node = prev = makespan = capacity = violations = cost = 0;
  while (tourSize < N+V-1)
   sum = 0.0; successors = 0;
   for(i = 0; i < N; i++)
      if (check(i))
        moves[successors++] = i;
        for (j = 0;j < N;j++)
           if (i != j && check(j))
              if (l[i] > r[j] || makespan + d[node][i] > r[j]) successors--; break;
   if (successors == 0)
      for (int i = 0; i < N; i++) if (check(i)) moves[successors++] = i;
   for (i=0; i<successors; i++)
        value[i] = exp(global[node][moves[i]]); sum += value[i];
   mrand=random(sum); i=0; sum = value[0];
   while (sum<mrand) sum += value[++i];
   prev = node; node = moves[i];
   tour[tourSize++] = node;
   visits[node]--;
   cost += d[prev][node];
   makespan = max(makespan + d[prev][node],l[node]);
   capacity += w[node];
   if (node == 0) prev = makespan = capacity = 0;
   violations += (capacity > max_capacity) + (makespan > r[node]);
  tour[tourSize++] = 0; // Finish at the depot;
  cost += d[node][0];  // Add cost to depot
  makespan = max(makespan + d[node][0], l[0]);
  violations += (makespan > r[0]);
  return (VIOLATION * violations) + cost;
```

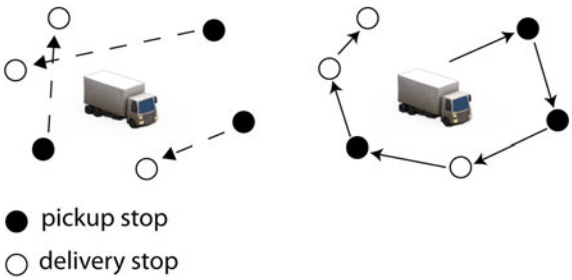

Fig. 28.3 Pickup and deliveries

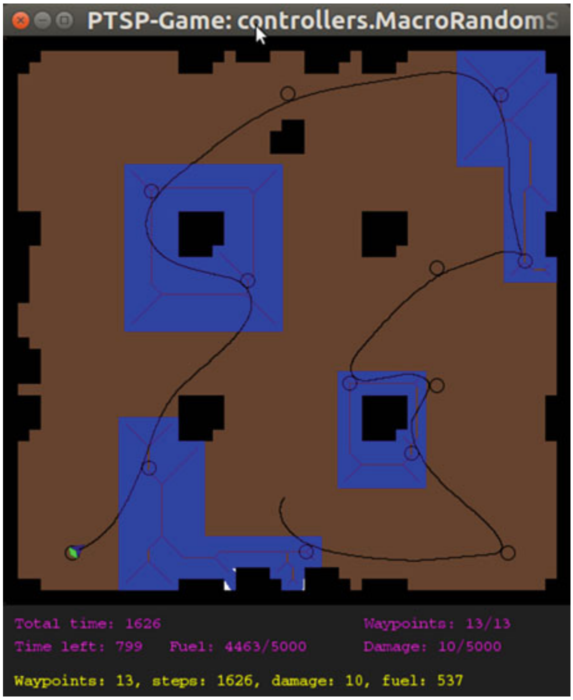

Fig. 28.4 A physical inspection problem

Motion Planning

Our third example stems from in-door production, the steering a moving robot in a 2D/3D environment with obstacles. In contrast to production systems that support vehicle movements on monorails or on coarse grids, here we are aiming at minimizing the simulation time of movements in free space for visiting a number of waypoints in the best possible order.

There are two settings: the one is the navigation on a detailed image (see Fig. 28.4), the other is a polygonal world, where the workspace has been partitioned into geometric objects. This so-called *physical multi-goal path planning problem* calls for an intelligent interplay of search in the continuous and discrete space. The solution space is further restricted by the coloring of the available for the vehicle(s).

Another application of multi-goal motion planning is surveillance planning, for which waypoints are pre-defined in a way that the complete environment becomes visible for the robot. There is a need for efficient and high-quality solutions to the robot inspection problem (a variant of the watchman route or art gallery problem), especially for computing underwater pipeline inspection.

Container Packing

Our second example is finding a tight packaging of objects into one or several containers (see Fig. 28.5). We are interested in finding the location and orientation of objects of various sizes. This *packing problem* is already computationally hard in 2D. First solutions to the problem with one container have been presented by Edelkamp and Greulich (2014). Here, we present solutions by using NRPA to the packing of a minimal number of containers.

Due to the ever-increasing globalization of trade, the amount of cargo shipped in containers is on the rise and the efficient utilization of transportation capacity will be a competitive advantage for companies. Using less containers for shipping a specific number of goods will reduce the costs, not only because the lower number of containers required, but also because potential breakage is reduced through the dense packing. If the available storage is limited, deciding which items to defer to a later shipment is also an important issue regarding profit and customer satisfaction, e.g., by not violating deadlines. But the problem of packing small items into large objects is not necessarily limited to loading containers and trucks. The large objects can range from pallets to ships and planes or even warehouses. Depending on the large receiving object, the set of small items may also include said pallets and

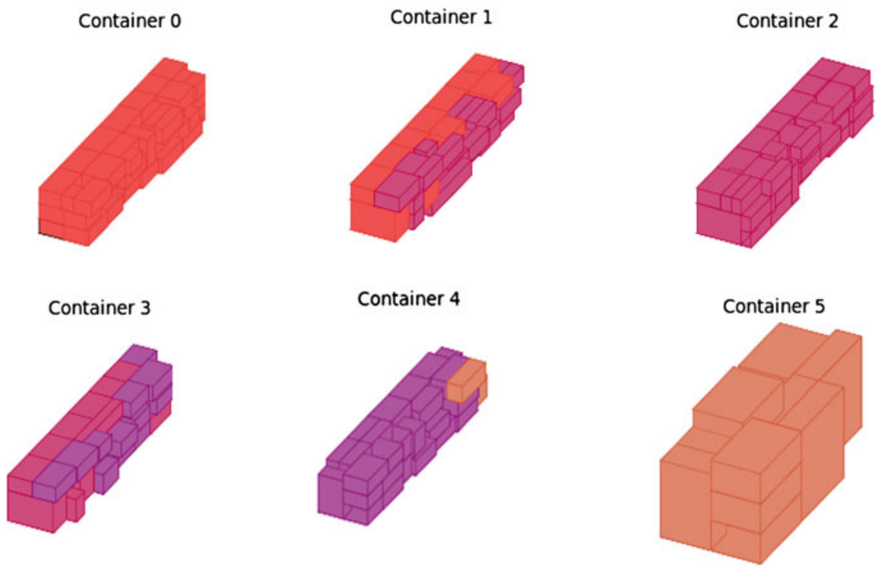

Fig. 28.5 Solution to the multi-container packing problem

containers, irregularly-shaped items like furniture, or just small rectangular boxes. The general problem can be considered a cutting and packaging problem and, therefore, also covers material utilization when cutting glass or wood for example. It is even possible to use this concept for scheduling problems by redefining the axis appropriately. Assuming a limited number of workers and machines that require an uninterrupted processing time for a specific order, cutting and packing methods can be used to schedule workers and machines to reduce the downtime when either not enough workers nor machines are available. We are working together with an optimization company that aims at packaging solutions for car manufacturing companies that assemble vehicles overseas.

28.4 Results

We briefly recall results of previous work on MCTS search in the three different scenarios vehicle routing, 3D packing, and motion planning, and, then, add experiments in extended settings (multiple vehicles, multiple containers, inspection areas). Detailed results on all three domains are found in the respective papers in the bibliography. All implementations have been realized in GNU c++ (compiled with gcc -O3) and ran on a Laptop computer using one core of an i7 Intel CPU.

Vehicle Routing

In the first scenario we achieved results that are state-of-the-art for traveling salesman problems with time windows (TSPTW), see, e.g., Edelkamp and Gath (2013), Edelkamp et al. (2014a, b), Gath et al. (2013a,b,c), Gath et al. (2014) showed that NRPA could solve pick-up-and-delivery problems with time windows and capacity for one vehicle (1PDPTW) optimally with about 200 orders, pointing to some inconsistencies of precursor results in the literature.

For vehicle routing problems (VRPs) we have found some first tours, which are at least very promising. The most established and often applied benchmarks for Vehicle Routing Problems (VRP) are the artificial Solomon benchmark (1987) and the benchmark of Homberger and Gehring (2005). There are six versions:

- The sets R1 and R2 include problems with randomized customer locations.
- The sets C1 and C2 include problems in which customers are grouped in clusters.
- The sets RC1 and RC2 include problems with both clustered and randomized customer locations.

The time-windows of the sets R1, C1, and R1 are shorter and more restricted than these of the sets R2, C2, and RC2. Thus, more vehicles are required to transport all orders in the problems in the restricted problems. In all problems, vehicles have limited capacities. There is no underlying transport infrastructure. Distances are computed by Pythagoras' theorem. It is assumed that driving a distance of 1 consumes 1 time unit. Solomon provides 56 problem smaller instances with 100 customers. Homberger and Gehring (2005) extend Solomon's problem set for larger size problems and provide 300 larger instances having 200, 400, 600, 800, and 1000 customers. They provide 10 instances for each problem set and size.

The artificial benchmark sets are much more restricted than real-world problems. For the computation of correct best-known solutions it is necessary to compute the Euclidian distances with double precision arithmetic. Using any lower precision arithmetic will determine incorrect solutions. Thus, even rounding the distances after a fixed position after the decimal point can avoid that a vehicle reaches the next stop within the orders defined time window. It is very likely that the problems are constructed around one existing solution. Obviously, in real-world processes such small delays of less than a nanosecond are absolutely insignificant. In some instances, however, it appears that rounding is essential to obtain the optima reported. For example, in RC101.50 (50 vehicles) the optimum value 944 can be found only with rounding to the first digit. NRPA ran on instance R101 (with 100 vehicles) finds, without any clustering, the following optimal solution after 10 min:

Level: 5,3, score: 1650.7823, runs: 3240000
[0,59],[59,99],[99,94],[94,96],[96,0], [0,92],[92,42],[42,15],[15,87],[87,57],[57,97],
[97,0],[0,27],[27,69],[69,76],[76,79],[79,3],[3,54],[54,24],[24,80],[80,0],[0,28],
[28,12],[12,40],[40,53],[53,26],[26,0],[0,95],[95,98],[98,16],[16,86],[86,91],
[91,100],[100,0],[0,14],[14,44],[44,38],[38,43],[43,13],[13,0],[0,72],[72,75],[75,22],
[22,74],[74,58],[58,0],[0,63],[63,64],[64,49],[49,48],[48,0],[0,45],[45,82],[82,18],
[18,84],[84,60],[60,89],[89,0],[0,33],[33,29],[29,78],[78,34],[34,35],[35,77],[77,0],
[0,39],[39,23],[23,67],[67,55],[55,25],[25,0],[0,36],[36,47],[47,19],[19,8],[8,46],
[46,17],[17,0],[0,5],[5,83],[83,61],[61,85],[85,37],[37,93],[93,0],[0,62],[62,11],
[11,90],[90,20],[20,32],[32,70],[70,0],[0,31],[31,88],[88,7],[7,10],[10,0], [0,2],[2,21],
[21,73],[73,41],[41,56],[56,4],[4,0],[0,52],[52,6],[6,0],[0,65],[65,71],[71,81],[81,50],
[50,68],[68,0],[0,30],[30,51],[51,9],[9,66],[66,1],[1,0],

(www.sintef.no/projectweb/top/vrptw/solomon-benchmark/100-customers/).

Motion Planning

For robot navigation we showed a competitive performance of our system in the Physical Traveling Salesman Problem with up to 50 waypoints, and for non-linear motions and colored goals, we could find optimized solutions with up to 100 goals (Edelkamp and Plaku 2014; Rashidian et al. 2014). For the latter scenario, precursor systems could not expand to more than 20 goals. Most importantly, the single-source shortest path graph traversal algorithm has to be fast (Greulich et al. 2013).Real-time recordings of simulations of a snake-like robot, a complex bumping car and a blimp show the apparent working of the approach in 2D and 3D environments (see videos at https://www.youtube.com/watch?v=hc-xKbCZqHw https://www.youtube.com/watch?v=K2aV-RFMQok).

In solving the discrete optimization problems, Edelkamp and Greulich (2014) took several measures for the improved integration of physical motion into account like minimizing the angle and the area crossed.

Dijkstra's algorithm for all waypoints finished and copied. Time was 1966 ms.

Level: 5, score: 2336.4385986378893, eval.: 50625

Level: 5, score: 2326.512287419163, eval.: 607500
Level: 5, score: 2271.5866602251385, eval.: 658125

Order: 0, 2, 5, 1, 3, 4, 7, 12, 10, 8, 6, 9, 11, cost 2271.5866602251385. Time was 257 ms.

Container Packing
In 3D container packaging of axis-aligned boxes we managed to solve an industrial benchmark of 124 rectangular iso-oriented items (in two possible orientations) in 5 × 40″ high-cube and 1 × 20″ standard containers, while respecting further constraints like frees-pace for the door region.

We do not yet have input on the weight distribution, so that other constraints such as overlap are not yet looked at. We also have some initial results (derived in the context of 3D printing, but with obvious applications to container packaging) with optimizing irregular shaped, and arbitrary rotated (initially triangulated) objects based on realizing a very fast intersection test, where we generate so-called sphere trees. There are recent competitions to variants on the container packaging problem.One result of the packing with NRPA obtained in <1 h is as follows (Container No:(Size) + [Position], […] information omitted).

Level: 4,22, score: 158090, runs: 621000
0:(215,162,154) + [0,0,0],0:(119,191,75) + [0,0,154],0:(119,191,75) + [0,191,154],0:(109,191,75) + [0,382,154],0(109,143,75) + [0,573,154],[…],5:(100,120,110) + [59,75,0],5:(100,120,110) + [59,195,0],5:(50,76,192) + [0,498,0],5:(119,75,191) + [59,315,0],5:(59,198,225) + [59,390,0],5:(119,191,75) + [118,390,0],5:(59,225,198) + [159,75,0],5:(119,191,75) + [118,390,75],5:(119,191,75) + [118,390,150]

28.5 Conclusion and Discussion

The paper contributes to the fact that the industrial interest in improved problem solutions for logistic problems is continuously rising. With Monte-Carlo Tree Search, an interesting search paradigm is entering the Operations Research arena. Reading the success story in Interactive and Combinatorial Games (http://mcts.ai/), MCTS is predicted to show many further advances in a widespread set of industrial relevant applications. With our research we show that this randomized optimization method is indeed promising and, in some cases, can produce state-of-the-art solutions to challenging problems.

In this paper, we looked at three different application areas in logistics: free-space robot motion planning (e.g., for production floor planning), groupage traffic (including courier and express services for large distributors), and container packaging (with 3D boxes and orientation). All these problems can be interpreted as being of central importance for warehouse and distribution companies (we are aware of many other optimization problems that arise in such infrastructures.)

In all the above examples, MCTS plays a significant role in the optimization process. While Monte-Carlo simulations are often used to improve controllers for non-player characters in interactive games, here we look closer to complex optimization processes that occur in industrial practice.

Additionally to the set of published results new insights to multi-vehicle vehicle routing, 3D container packing, and inspection tours with MCTS have been added. Here, we also discuss general trends, as (by the virtue of the No-Free-Lunch Theorem) we do not expect MCTS to be the best choice for each every optimization problem. The number of constraints and the problem size are crucial parameters for the choice for optimization procedure. Thus, we would not recommend to solve ordinary TSPs with MCTS, as there are very good lower bound heuristics for this problems. For smaller problem instances, it turned out that the exploration speed in terms of running time per node becomes the critical issue, so that (depth-first) *branch-and-bound* with no or fast incremental heuristics perform better than MCTS. Some of our research is also looking at how to exploit the depth-first nature of the search to spend only a constant amount of time at a node.

In a constraint environment, the global optimization with MCTS often scales better than traditional Operations Research methods. The real problem to be attacked are dynamics in all of the above optimization approaches: new orders (e.g., packages, containers, goals, or obstacles) continuously come in, others are canceled, and the optimizing process has to be adapt to the new setting. Besides computing a new global solution off-line, it is often preferable to recompute only parts of the solution on demand. As one approach one can continue the MCTS optimization process given the new objective, or partition the solution into agents, which all support decision-making components based on MCTS. In our multi-agent (simulation) system (http://plasma.informatik.uni-bremen.de/) vehicle routing, package and vehicle agents negotiate for an adapted assignment, or, for container packing, boxes and container agents fight for resources. For multi-goal planning new tours may have to be computed on-the-fly in an incremental computation process., due to the overhead of negotiations it is not the only aspect to look at to solve challenging optimization problems. In benchmarks we frequently found that for the static problem global MCTS optimization was consistently better in run-time performance compared to a multiagent solution of local solvers. Even in a distributed solution setting, one always has to look for sufficient solution quality produced by the individual components at any given amount of time.

We found that the policy, which is learned and continuously improved, is of crucial importance to the success of the search. It has to be compact enough to be sufficiently touched by successful rollouts, but expressive enough to differ between good and bad successor choices. *Algorithm engineering* of the MCTS algorithm as well as infrastructure components (shortest-path search, priority queue operations, hashing, efficient node representation etc.) is very important for the overall effectiveness of the system. A trade-off between pre-computation and on-line computation has to be found and the right level of abstraction will make a difference.

Similar to other randomized optimization approaches like Simulated Annealing and others, there is no guarantee on the solution quality. Even approximate solutions not being worse by more than some percentage or more than some absolute difference off the optimum are often not available (unless a strong lower bound is given). The virtue of this method might be cast in finding the needle in the haystack with an experimentally shown performance using less implemented expert knowledge compared to other optimization schemes.

Further work will include other optimization problems like the multiple sequence alignment problem (MSA). There are relations of MSA to the TSP including resources that we consider and direct implementation of the MCTS approach that we have implemented. First results are promising and available using only limited computer memory, but are not yet state-of-the-art. As the search heavily relies on a mass execution random rollouts, a parallelization of MCTS is recommended and often not difficult to obtain. As most of the results were achieved on an ordinary PC or laptop computer, we expect better results on stronger computing infrastructures.

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