Consideration of logistics for policy analysis with freight transport models

Authors:
Hanno Friedrich
Dr. Gernot Liedtke

Institute for Economic Policy Research (IWW),
Universität Karlsruhe (TH)
Kollegium am Schloss Bau IV
76128 Karlsruhe
Germany

e-mail: friedrich@iww.uni-karlsruhe.de, liedtke@iww.uni-karlsruhe.de,
phone: +49 (0)721 608 4415

Abstract

In recent years a rising attention for logistics in politics and transport analysis can be observed. Therefore, freight transport models increasingly put more attention on logistics. However, logistics is mostly modeled in a very simplified way and different parts of logistics are considered. Modelers have limited options to build more mature logistics models: A detailed representation of logistics requires the description of a heterogeneous economic landscape leading to very high data demand and it requires to model combinatorial logistic problems exceeding the processing capability available. Therefore a balance has to be found between mapping logistic behavior in a “reality-like” way and the need to keep the model as simple as possible. Based on conceptual frameworks on logistic choice levels and logistic structures the paper shortly reviews a selection of existing modeling approaches. This and a detailed discussion of two modeling experiences show future strategies in freight transport modeling towards finding this balance.

1. Introduction

In recent years a rising attention for logistics in politics could be observed. This can be seen in the high number of so-called logistic master plans that are developed on national and international level, for instance, the “Masterplan Logistik” in Germany or the Logistics Action Plan of the European Commission. In addition, there is a trend that logistic aspects are discussed in studies that aim to forecast freight transportation demand.

Indeed logistics or logistic systems can be considered as a link between economic activity and transportation systems (Mannheim (1979), see Friedrich (2009) for details). From this point of view the "new" perception of logistics in transport and general economic policy is not surprising. In transportation modeling, however, the main focus was traditionally on passenger transport causing the main part of traffic. But today freight transportation also significantly causes congestion and the pressure for infrastructure extension. Therefore transport economists and transport modelers are increasingly forced to put their attention on logistics as the link between economy and transport.

In all recently developed large-scale transport modeling systems logistics is somehow represented. However, logistics is mostly modeled in a very simplified way; often this is done by adding an additional logistic module. Thereby the models do not reflect the full range of logistic choices and thus have limited behavior sensitiveness. Modelers from the academic or consulting field have limited options to build more mature logistic models: A detailed representation of logistics requires the description of a heterogeneous economic landscape leading to very high data demand and it requires to model combinatorial logistic problems exceeding the processing capability available. Therefore a balance has to be found between mapping logistic behavior in a “reality-like” way and the need to keep the model as simple as possible.

Based on a short review of a selection of existing modeling approaches and a discussion of two modeling experiences the paper aims to identify future strategies in freight transport modeling towards finding this balance.

The paper is organized as follows: in the chapter following the introduction the link between economic activity system and transportation system and the scope of logistics is lined out. In the next chapter the representation of logistics for a selection of models is discussed. Based on this discussion it is tried in the last chapter to formulate three potential strategies for future modeling of logistics in transportation system analysis.

2. Logistics as link between economic activity and transportation system

A significant number of microeconomic decisions lead from economic activity to vehicle flows on transportation infrastructures. The idea of listing choices and introducing a kind of hierarchy originates from Manheim (Manheim (1979), p. 62). He indicates levels of choices in the economic activity system leading to passenger and freight transportation demand. This list was extended by Friedrich (Friedrich (2009)) by logistic decisions (see Figure 1), a similar list was already established in Liedtke et al (2009).

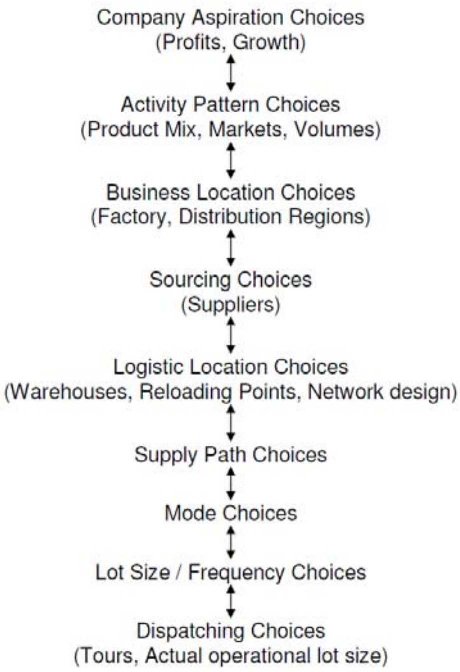

Figure 1: Choice levels connecting economic activity and transportation

Source: Friedrich (2009)

The first three levels are purely related to economic and non-logistic activity: At first there is the choice of the overall aspirations for the companies, for instance describing if the company is profit-oriented. Then there is the choice of the activity, i.e. which products should be produced and for which markets they should be produced. Finally, the locations for the activity are chosen. It can be differentiated between the choices of business locations, logistic locations and sourcing. On the first three levels considerations on logistic systems have only a limited influence, because of the dominance of other factors on the decisions. But nevertheless, especially for the third level, factors like accessibility and availability of compatible transport services determine the spatial environment and can therefore play a major role in transport-intensive sectors. .

On the fourth level (sourcing) logistic considerations have already considerable influence, since the costs for transport will be an influencing factor for sourcing.

The bottom five levels represent pure logistic choices. It was tried to order them in a hierarchical way: On the fifth level there are the choices of locations for warehouses and reloading points. Taking these as given, there are different supply paths that can be chosen for the commodity flows, including for example which warehouse to use. Having assigned commodity flows to paths one can think of the choices that can be taken for bundles of commodity flows on parts of the paths like choices of mode and delivery frequency or lot size. Finally, there are choices that have a more operational character on the actual dispatching level, as the choice of tours and order size.

This list is an idealized hierarchy of choices. In practice decisions often integrate several choice levels. The choice of a logistic location for example depends highly on the business locations as well as on the future supply paths chosen in case the alternative is implemented. And a decision on warehouse location can also include the decision on supply paths. The planning of a logistic system integrates many levels (logistic location, supply paths, frequencies and modes). It should also be noted that the responsibility for the decisions changes between different institutions like shippers or transport service providers.

In transport modeling the logistic levels usually are not fully reflected. But it is well recognized among transport modelers that there is a gap between micro level models of logistics and aggregate transport modeling systems (Liedtke, 2006). The gap exists in two directions: Firstly, although it can be assumed that logistics actors behave (cost) rational it is not possible to model the behavior of the macro logistics system based on individual decisions (aggregation is impossible). Secondly, it is difficult to decompose aggregate freight flows unambiguously into a set of meaningful micro economic homogeneous groups of decision making problems and decision makers (decomposition impossible). This gap is visualized in figure 2.

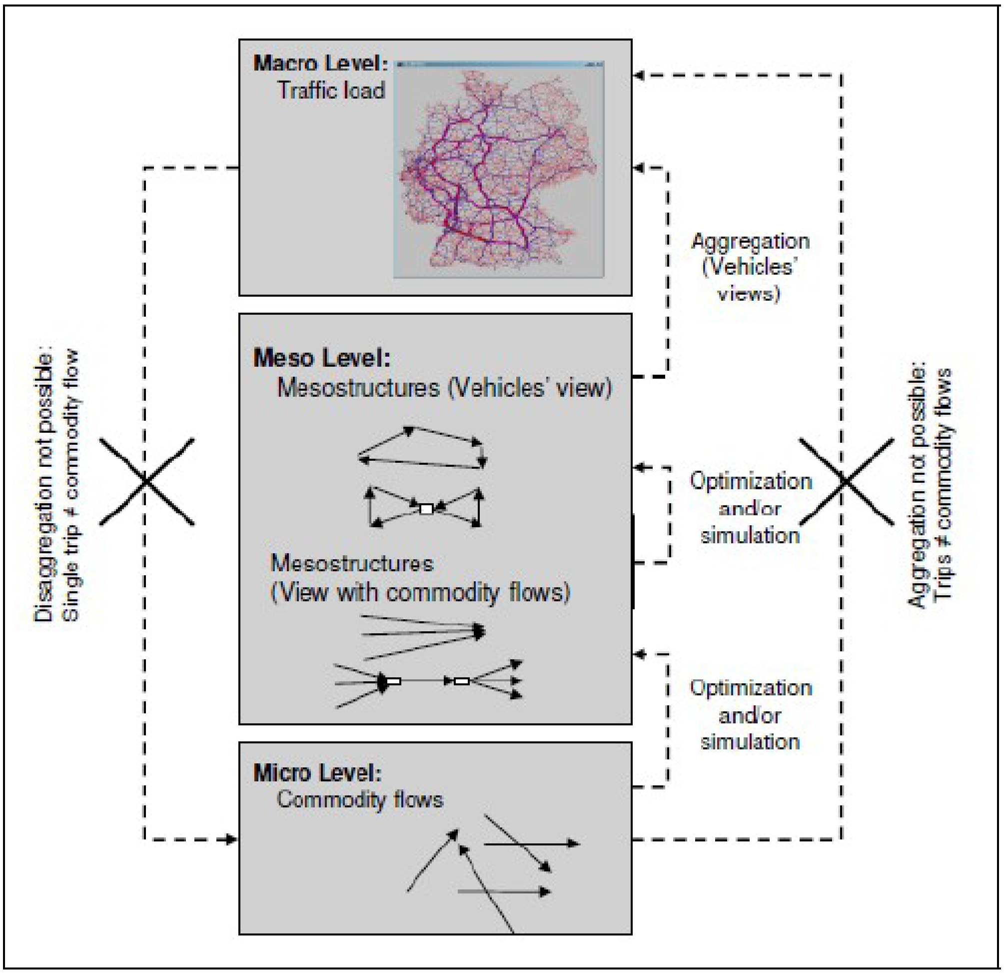

Figure 2: Visualization of the Macro-Micro gap in freight transport modeling

Source: Authors' own representation

The figure shows the micro-, meso- and macro-levels in freight transport. The macro-level on the top corresponds to the perspective of transportation planners and policy markers. This level deals with aggregate truck flows on infrastructure networks, market shares by segment or container throughput of ports. The micro-level corresponds to the perspective of individual decision makers. The flashes in space symbolize microscopic flows of goods or shipments between shippers and recipients. These flows are combined in groups to form so-called logistic mesostructures, which are entities belonging to meso-logistics.

From this meso level the link to the macro level can be established by summing up the vehicle tours or train operations. But to arrive at tour mesostructures, several actors and groups of actors are involved. They set up distribution systems or transport networks. There is competition between networks and systems as well as collaboration and sub-contracting. To model the emergence of mesostructures methods of optimization and simulation have to be applied.

Also Sjöstedt (2004) mentions this gap between micro and macro-level and the importance of a meso-level. He concludes that there "is still poor understanding of methods and data needs to handle the meso-level". Liedtke and Friedrich (2009) introduce the concept of logistic mesostructures to handle this meso-level in modelling.

Looking at the initially discussed importance of logistics in politics and the increased number of transport models that claim to include logistic aspects, the framework of choice levels and the concept of logistic mesostructures can be very useful. They can help to make transparent to what degree logistics is represented and what parts of logistic are represented. Based on this transparency challenges and limitations of modeling logistics in transportation models can be shown.

3. Logistics in freight transportation models

In this chapter we will give an overview on how logistics is included in existing freight transport models and what challenges a detailed modeling of logistics brings. An overview indicating the core characteristics of the models can only be done for a limited selection of models. It is therefore non-exhaustive and only concentrates on logistic aspects (for general overview papers we refer to Tavasszy (2006) or DeJong (2004)). The following description will be limited to if and how the logistic choice levels are represented. The models INTERLOG and SYNTRADE will be analyzed in more depth since they reflect logistics in a very detailed way and since the authors think that the learning from their experiences with these models are of general importance.

3.1 Overview

Different methods are used in transportation modeling and also scopes, levels of detail and objectives of models differ. Therefore, it is a challenging task to compare models using a common analytical framework (cf. the experiences of Liedtke et al. (2009)). This also accounts for the representation of logistics in freight transportation models. Therefore the overview of Friedrich (2009) used in this paper and shown in Figure 3 has to be handled with care, since it is very simplified. In the following it will be discussed shortly for each model.

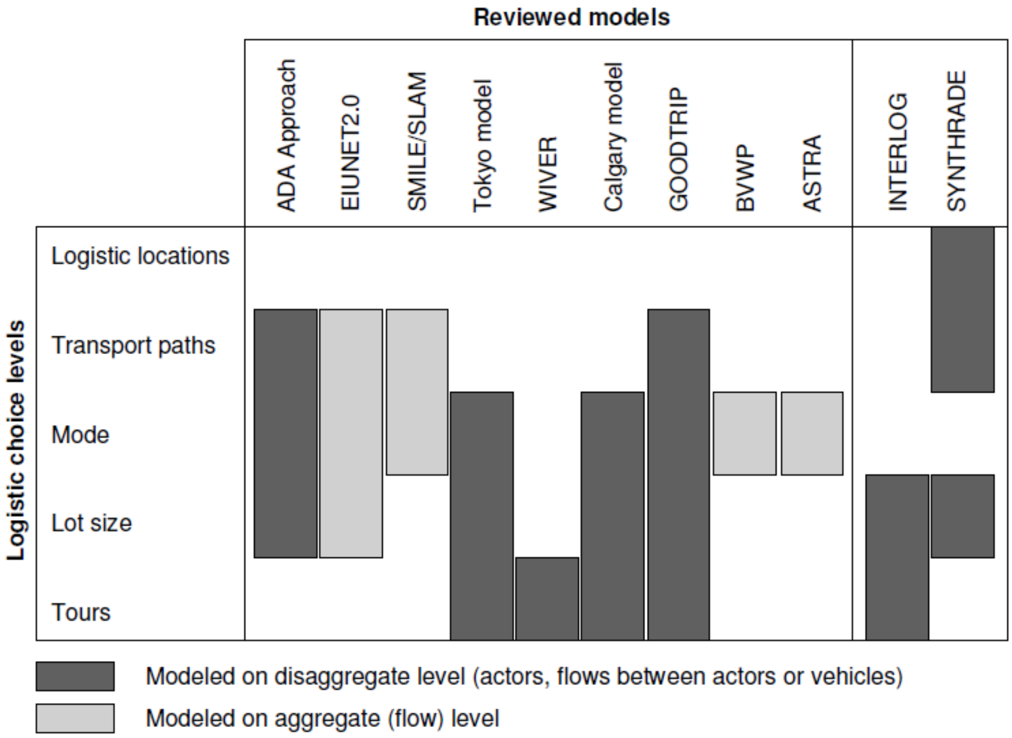

Figure 3: Overview on logistic choices covered by freight transportation models

Source: Friedrich (2009)

ADA approach

The ADA approach (aggregate - disaggregate - aggregate) was applied for the national freight models in Norway and Sweden. It aims to model national freight traffic including logistic aspects (De Jong and Ben-Akiva (2007) or DeJong and Ben-Akiva (2008)).

Four logistic decisions are modeled on a disaggregated level for samples of firm relations (to reduce runtime): transport path, mode, loading unit and shipment size. The logistic choices in the Norwegian model application are modeled with a deterministic cost optimization involving two steps: In the first step the optimal transshipment locations are determined (for different transport path types, origin and destination zones). In.the second step shipment sizes and transport chains (composed of legs with different transport modes and loading units on each leg) are determined for specific firm to firm commodity flows by enumerating available options and selecting the one with the lowest cost.

The emergence of logistic structures is not modeled explicitly – the model assumes logistic locations as given. Also it does not include the emergence of vehicle tours. It covers a large scope of about 100.000 sending and 400.000 receiving firms.

EUNET2.0

EUNET2.0 (Williams et al., 2005) is an aggregate model on a national level that aims to model future (freight) traffic flows on the infrastructure. The model uses a spatial input-output model (SIO) extended by dividing flows from producer to consumer in logistic stages for different commodity categories. A "logit segmentation" is used to model the allocation of flows to logistic chain types. Mode choice and choice of vehicle size are done by a hierarchical logit model. Since this is an aggregate model also the decsisions are modeled for aggregate flows only. The model assumes locations as given. Supply paths are chosen within the extended IO model for aggregate flows. Mode choice and lot size choice is modeled in an integrated fashion for aggregate flows. Vehicle tours are not modeled.

SMILE and SLAM

SMILE (Tavasszy et al., 1998) is a model on a national level that aims to model future (freight) traffic flows on the infrastructure by explicitly modeling supply path choices for aggregate flows between regions. SLAM (SCENES, 2002) is the logistic module of an EU-level transport model developed in the SCENES project, describing the supply path choice with a similar approach as used in the SMILE model.

SMILE and SLAM are aggregate models; logistic choices are hence only modeled for aggregate flows. The supply path choice is modeled together with mode choice on different supply-path alternatives with a logit model. This logit model is based on logistic costs including inventory, handling and warehouse cost. Lot size distributions are assumed given and fixed for different logistic families and hence are not modeled endogenously. The same accounts for warehouse locations that are assumed as given (or available in each region). Tour construction is also not modeled.

Tokyo model

The Tokyo model (Wisetjndawat et al., 2007) aims to describe commercial traffic in the Tokyo metropolitan area. The levels of mode choice, lot size choice and tour building are modeled out of the perspective of microeconomic actors. The study relies on very rich data sources. Therefore extensive statistical modeling and only few normative modeling approaches (optimization models) are used. Lot size and frequency are determined based on linear (or logarithmic) relationships to distance (determined by a regression analysis). Carrier and vehicle choice are modeled with a nested logit model. Finally, vehicle routing is modeled by optimization routines reflecting the vehicle routing problem. Logistic locations are assumed as given and fixed. Supply paths including more than one transport link are not considered.

WIVER

WIVER is an urban commercial traffic model that aims to reproduce vehicle flows on transport infrastructure (Sonntag, 1996). The model concentrates on the emergence of tours. The generation of tours, number of stops and destination points is calculated based on trip rates. Logistic location choice and supply paths are not modeled. Also lot sizes are only covered in form of different vehicle types. Mode choice is limited to four road vehicle types that are directly allocated to the origin destination sector pairs. Only tours are modeled explicitly. The savings heuristic, a heuristic for the vehicle routing problem, is applied to connect starting point with several destination points.

Calgary model

This model is an urban commercial traffic model for Calgary (Hunt, 2007). It aims to reproduce commercial vehicle flows on transport infrastructure. The model concentrates on the emergence of tours. Location and supply path choices are not modeled. Four road vehicle types are considered. Tour planning is modeled explicitly but not in form of planning (optimizing procedure) but in form of tour building (a tour "grows" by repeatedly choosing the next stop purpose and stop duration). Logit models are used to determine the probabilities for tour purpose, vehicle types, next stop purpose and next stop location. Lot sizes and vehicle choice are modeled in an integrate fashion.

GOODTRIP

GoodTrip (Boerkamps and Van Binsbergen, 1999) is an urban commercial transport model that was applied to evaluated alternative distribution concepts (traditional distribution, urban distribution centers and underground logistic systems) for the city of Groningen (medium town with 170,000 inhabitants).

In GoodTrip logistics chains are reproduced. Based on consumer demand the volume of goods consumed in each zone is calculated. The flows are then determined upstream through retail locations, distribution centers to production facilities based on probabilities that represent the corresponding activities in space. Thus the model describes disaggregated flows, microeconomic actors and their decisions are however not modeled.

BVWP

The model implemented for the German infrastructure plan (BVWP) aims to predict future traffic flows on a national level (BVU et al., 2001). The model follows the traditional aggregated four stage approach and thus works on the level of aggregated flows. Mode choice is the only choice level covered explicitly described by a nested logit model. The model assumes lot sizes as given in form of three lot size categories.

ASTRA

ASTRA (Schade, 2005) is an aggregate model aiming to describe the overall economic activity. The model contains a mode choice model (logit model) for aggregate flows, the other choice levels are not represented explicitly**.**

Summary

The overview shows:

- The emergence of tours is often modeled in commercial traffic models. However, usually this is done out of the perspective of vehicles and not out of the perspective of logistic decision makers.
- The choice on lot sizes is already part of many models. However, the details of representation differ significantly. Sometimes this decision is carried out jointly with other decisions on vehicle types or transport paths.
- The modal choice traditionally is part of transportation models, therefore already well captured by many models.
- The supply path decision or at least the decision on transport paths (not including warehousing) is part of new partly aggregate modeling approaches (ADA or EUNET2.0) that interpret this as their main logistic component.

The models mentioned above do not model the emergence of complex logistic structures like spatial structures of logistic locations or tours that result out of actors' interaction. In the following the experiences of two models that try to focus explicitly on these points will be discussed in more detail.

3.2 Detailed analysis of two selected models

In this subsection we will appraise the experiences of two bottom-up model developments mapping the emergence of tour-structures and of warehouse structures. Based on the experiences the typical challenges of modeling logistics in transport models shall be shown.

3.2.1 INTERLOG Model for Mapping the Emergence of Tour Structures

The INTERLOG simulation tool generates a huge amount of individual tours of trucks as the result of a perpetual interaction between shippers, forwarders and carriers. All actors seek at lowering cost. To do so, shippers can modify their regular lot sizes and choose alternative carriers. Carriers can improve their tours; in addition they can also decide not to accept certain transport cases. Due to dynamic interaction between all actors, transport policy, road regulation and traffic situation can influence the behavior of both the carriers and the shippers. Thus, INTERLOG is designed as a simulation platform to carry out hypothetical behavior experiments for assessing behavior-influencing transport policy.

An INTERLOG simulation consists of several steps, which are called “modules” (Figure 4). The modules consecutively generate actors, determine their static behavior parameters and let them interact. The behavior of the actors and objects participating in the transport market interaction simulation module are mapped as behavior models. Additionally, the characteristics of the infrastructure network are represented in a network model. Each module uses input information in the form of statistical data, the results of previous modules and behavior rules (left-hand-side of the figure).

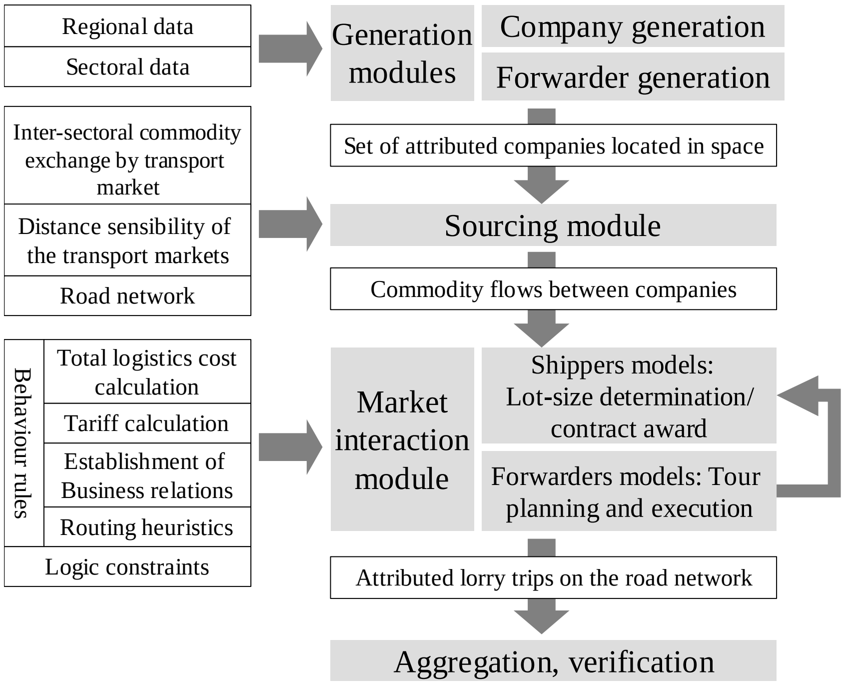

Figure4: INTERLOG models and course of the simulation

The *generation module* creates the artificial actors with a statistical Monte Carlo simulation. It equips them with static behavior parameters based on statistical sources. As a result, a scaled production "landscape" is established with a realistic distribution of companies according to their spatial position, size and economic activity.

The *sourcing module* maps how companies try to satisfy their need for production goods. The results are microscopic flows of goods (in [tonnes/year]) between the actors. The generated spatial company distribution as well as the simulated supplier-consumer relationships are supposed to be constant during a simulation.

The nucleus of the object-oriented simulation framework – the *market interaction module* – models the process of market coordination. In the simulation module, various system parameters are endogenously simulated. The module consists of two classes of objects to be instantiated and then assigned:

The class *transport contract* bundles the pre-defined cargo objects to be loaded and unloaded at certain locations as well as numerous constraints (lot-size, delivery frequency, time windows, weight, compatibility, ordering).

The dispatcher class accounts for coordination of the above-mentioned transport contracts through tour planning and realization of the transports in a constrained environment. The dispatcher executes tour planning on a daily basis, whereas decisions about acceptable transportation contract prices in calls for tender are supported by a database containing operations of previous planning periods. The dispatcher's knowledge base gives information about unpaired transport flows or regular delivery days of individual shippers.

Through simulated calls for tender in which shipper choose their forwarding companies the actors are reassessing their decisions and behavioral patterns supported by experiences that they have been accumulated during past day-to-day simulations. This feedback loop unlashes a self-organization process. The transport markets are simulated as local markets with evolving relational network structures (Fig. 5).

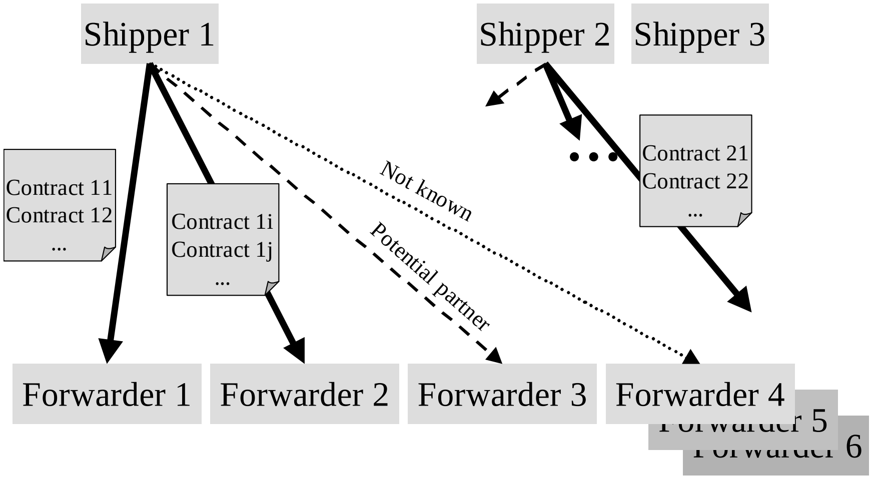

Figure5: Model of the transport markets with interaction networks

The model shows some typical challenges in behavioral commodity transport modeling and some strategies to solve them:

The first challenge is the simple fact that several actors are involved in decisions on the exchange of commodities. For some actors, the types of decisions can be clustered into a hierarchy. In INTERLOG this challenge is addressed by consequent agent-based model architecture.

The second challenge is typical for freight transport: When looking at the actors' decision problems and at the coordination between actors we can identify many combinatorial problems, examples are:

- Bundling of articles and commodity flows influenced by different aspects like demand variations or perishability.
- Choice between different logistic service providers or combinations of logistic service providers.
- The design of spatial warehouse system or intermodal transport systems.
- Tour construction and allocation of shipments to tours.

The INTERLOG example shows how by a micro simulation tool can adress some of these problems: The choice of logistic service providers is addressed with a market interaction simulation. In this simulation, stable business relationships can emerge. The tour-construction problem is addressed by a simple heuristics. However, modeling these combinatorial problems limits the scope: the maximum numbers of actors simulated with INTERLAG were 1000 companies (shippers and receivers) and 200 carriers. Therefore, we consider to model market interaction as competition equilibrium instead of simulating individual market participants.

3.2.2 SYNTRADE model for generating Distribution Structures

The SYNTRADE model (Friedrich, 2009) aims to simulate logistic structures in food retailing for the estimation of freight transport demand. The food retailing sector is in the focus of the model where more detailed input data is used. The model periphery is modeled simplified and in a more generic fashion. It covers the dependencies of the food retailing system with surrounding logistic systems. It contains the distribution of all consumer products.

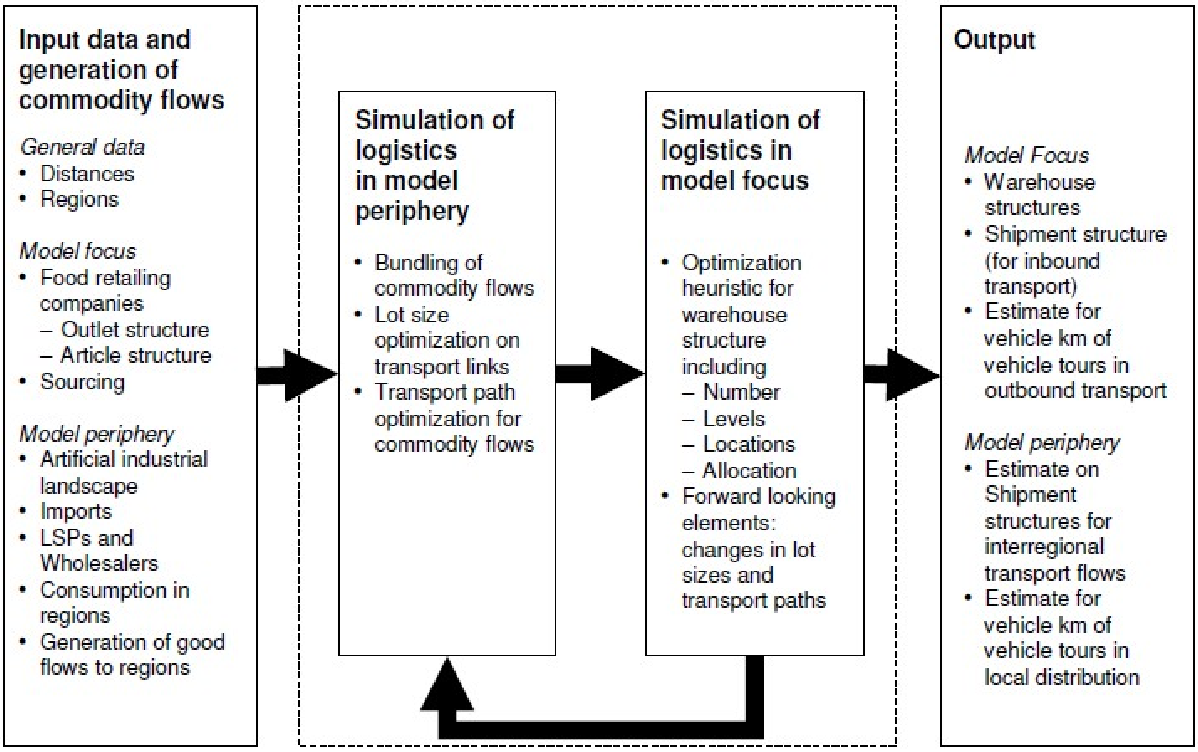

Figure 6: Incoming commodity flows in SYNTRADE

Source: Friedrich (2009)

The model can be divided into three steps (see figure 6):

- The economic environment is generated based on macroscopic statistics and sectoral data. The Furness method, Monte Carlo simulation and a gravity model are applied to simulate a realistic company distribution in space as well as realistic microscopic flows of goods between the producers and stores.
- The immediate logistic environment of food retailing companies is simulated (model periphery). This environment consists of suppliers, logistic service providers and wholesalers that together offer alternative supply path from the producers down to the stores in the region. The supply path decision that incorporates also the lot size decision for commodity flow bundles on transport links determines the characteristics of the logistic environment, which is thus represented in a simplified fashion.

- Finally, the optimization of the logistic system structure of the retailing companies is mapped. The optimization engine determines the warehouse structures (stratification, number, location, allocation of points of sales) in form of a forward looking decision including changes in supply path choices and delivery frequencies.

The output of the model has again to be divided into focus and periphery. The main output are warehouse structures in food retailing. The model was calibrated on a set of warehouse structures of specific companies. With the remaining warehouse structures the model could be validated. It shows a very high quality on the overall German level (as can be seen in figure 7) as well as on the level of individual companies. This holds especially true for larger companies since effects not caught by the model like historical location choice or inaccuracies in data do not change significantly the results if the number of entities modeled is high.

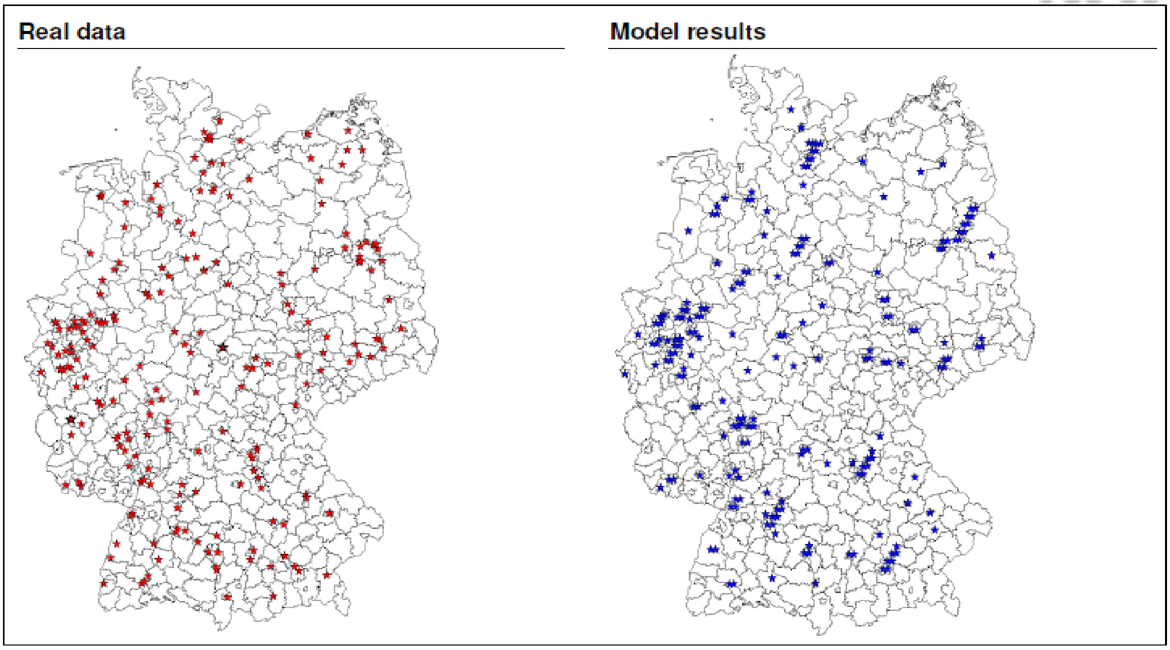

Figure 7: Warehouse locations: real data versus model results of SYNTRADE

Source: Friedrich (2009)

The model shows two typical challenges in modeling logistics in freight transportation models:

The first typical challenge is the huge data demand to model the heterogeneity in the economic landscape, which is needed to reflect differences in logistic behavior. For the model periphery this is solved with "standard" procedures that are also applied by other models: Detailed data on mean values and distributions of parameters from statistics or surveys is combined with Monte Carlo simulation to reproduce disaggregate data. The generation of establishments bases, for instance, on detailed employment and establishment data. More interesting is the model focus: To model logistic specifics in food retailing additional data demand occurs. In our case this means data on assortment structures, company structures or perishability of articles. For this data additional sources were made accessible: Sectoral statistics and data from research institutions or commercial data providers. Probably such sources do also exist in other sectors.

The second challenge is the level of logistic complexity modeled. In the model two approaches can be identified: In the model periphery only logistic choices are modeled that cause low demand of computer processing capacity. The supply path decision is taken between three path options; a special lot size model was developed to include changes in transportation costs depending on distance and lot size while keeping the model solvable analytically. The transport supply side was modeled by a representative transport cost matrix. The second approach is the modeling of the warehouse structure decision in the model focus. Here a complex combinatorial problem is solved for a limited number of companies using heuristics. The level of complexity in this model is chosen in a way that full processing capacity of a personal computer is used; a larger scope of the model would therefore either need more processing capacity or a simplification of the modeling of logistic decisions.

4. Conclusion

The awareness and importance of logistics in the political discussion has increased in recent years. Therefore also modern freight transportation models try to cover more and more logistic aspects. Logistics represents the link between economic activity and the transportation system and is therefore anyhow crucial for models that want to follow the causal relationships in reality. Logistics is the driving factor determining demand and behavior in freight transport. If a national transport policy wants to improve the efficiency and competitiveness of the logistics industry, the interrelation between policy and logistics must be considered. Changes of “transport-behavior” are always linked with logistics adaptations.

Traditional transport models hardly represent logistics aspects with the exception of mode choice. Recent modeling systems usually only consider a limited number of logistics choices. It could be speculated that this deficit results from the focus of transport system analysis on passenger transport – the deduced domineering 4-step framework focusing on trips of individual passengers ignores the logistics meso-level which is crucial to understand freight transportation. But there are other additional reasons that could explain why logistics enters slowly into freight transport models. These are the high data demand caused by the high heterogeneity of actors (their roles, their sizes, their interconnections with other actors) and the increased need of processing capacity if combinatorial problems have to be modeled for a high number of cases or actors.

In the paper some approaches have been identified and developed to cope with these cahllenges:

- The main approach is to represent only non-combinatorial choices or to simplify the solution procedures of combinatorial problems in a way that large numbers of cases are computable. Examples are the representation of supply path choices in ADA or EUNET2.0 or the simplified generation of tours in urban commercial traffic models. The main disadvantages are that these models cannot cover behavioral changes resulting from other not covered choice levels and an high data demand for example in form of warehouse location or trip rate data.

- A second approach can be seen in the study of Friedrich, that includes sectoral knowledge into transportation modeling. The data and processing capacity problems can be limited through additional data sources on this level of detail and a simplification of combinatorial problems through the use of heuristics that represent actor behavior in reality. The disadvantages of this approach are that the model scope increases significantly through the level of detail and the necessity to accumulate know how for different sectors.
- Finally the work of Liedtke shows that the modeling of markets and market interaction is necessary to describe the emergence of tour structures in national truck transport. On the other hand this study also showed that modeling this market interaction with combinatorial models is very limited in scope. Therefore it could be imagined to model different logistic markets directly as competition equilibrium instead of simulating individual market participants. The actors could perceive aggregate indicators of the other side of the market as expected average values which then can enter into their own decision problems.

References

Ben-Akiva, M. and De Jong , G.: 'The Aggregate-Disaggregate-Aggregate (ADA) Freight Model System'. In: Ben-Akiva, M., Meerseman, H. and Van de Voorde, E.: 'Recent Developments in Transport Modelling.' Emerald, Kap. 7, (2008).

Boerkamps, J. and Van Binsbergen, A.: 'GoodTrip, A New Arrpoach for Modelling and Evaluation of Urban Goods Distribution', paper presented at the 2nd KFB-Research Conference, Lund, (1999).

BVU; IFO ; ITP ; PLANCO: ‘Verkehrsprognose 2015 für die Bundesverkehrswegeplanung’ (“traffic forecast 2015 for the Germany motorway masterplan”) – project on behalf of the German Ministry for Housing and Transport, (2001).

De Jong, G., Gunn, H., Walker, W.: ‘National and International Freight Transport Models: An Overview and Ideas for Future Development’, Transport Reviews, **24**(1), pp 103-124, (2004).

De Jong G. and Ben-Akiva, M.: A micro-simulation model of shipment size and transport chain choice, Special issue on freight transport of Transportation Research B, 41, pp. 950-965, (2007).

Friedrich, H.: ‘Modelling freight transport demand in food retailing'. University of Karlsruhe, Institut fürWirtschaftspolitik undWirtschaftsforschung (IWW), Dissertation, (2009).

Hunt, J.D., Stefan, K.J.: ‘Tour-based microsimulation of urban commercial movements’. Transportation Research Part B, Vol. 41, Issue 9, pp 981-1013, (2007).

Liedtke, G :‘An actor-based approach to commodity transport modelling’, Nomos-Verlag, Baden-Baden, (2006).

Liedtke, G and Friedrich, H.:‘ Logistic Mesostructures as concept for Freight Transport Modelling', paper transmitted for review, Transportation, (2009).

Liedtke, G., Wisetjindawad, W., Tavasszy, L.A.: A Comparative Analysis of Behavior-Oriented Commodity Transport Models, Paper presented at the annual meeting of the TRB, WashingtonD.C., January 2009, (2009).

Manheim, Marvin: Fundamentals of Transportation Systems Analysis. The MIT Press, Cambridge, Massachusetts, (1979).

SCENES: European Transport Scenarios, Deliverable 4 European Transport Forecasting Model and Appended Module, SCENES project consortium, European Commission, (2002).

Schade, W.: 'Strategic Sustainability Analysis: Concept and Application for the Assessment of European Transport Policy', PHD thesis, University of Karlsruhe, Institut für Wirtschaftspolitik und Wirtschaftsforschung (IWW), (2005).

Sjöstedt, L.: 'A conceptual framework for analyzing policy-maker’s and industry roles', In: Rietfield, Piet (Hrsg.); R., Roger (Hrsg.): 'Barriers to Sustainable Transport', Tylor and Francis Group, London, (2004).

Sonntag, H.: 'Entwicklung eines Wirtschaftsverkehrsmodells für Städte', In: 'Berichte der Bundesanstalt für Straßenwesen', Verkehrstechnik, (1996).

Tavasszy, L., Smeenk, B. and Ruijgrok, C.: ‘A DSS for modeling logistics chains in freight transport analysis’. Paper presented at the Seventh International Special Conference of Information Systems in Logistics and Transportation, Goteborg, (1997).

Tavasszy, L.A.: ‘Freight Modelling – An Overview of international experience’s’. Paper presented at the TRB Conference on Freight Demand Modeling, (2006).

Wisetjindawad, W., Sano K., Matsumoto, S., and Raothanachonkun, P.: 'Micro-Simulation Model for Modeling Freight Agents Interactions in Urban Freight Movement', Paper presented at the 86th annual meeting of Transportation Research Board, Washington DC (2007).

Williams, I. Jin, X., Deane, G., Zhu, Y.: 'The EUNET2.0 Freight and Logistics Model - Final Report', WSP, Project for Department for Transport, England (DFT) Contract PPAD 8/134/24, (2005).