Project description

Gernot Liedtke (TU Berlin, S-Professor, permanent)
Kay Mitusch (KIT Karlsruhe, Professor, permanent)
Wisinee Wisetjindawat (NITech Nagoya, Assistant Professor, permanent)

Shipper Agents and Interactions with Transport Markets

(Sub-project of package project "Shippers and Recipients in a Multi-Agent Framework for Commodity Transport Demand Modelling")

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1 State of the art and preliminary work

State of the art

The state of the art concerning commodity transport modelling in general, and in modelling carrier behaviour in particular, is presented in sub-project 1. This corresponds to the division of work in the overall project where sub-project 2 (= this sub-project) focuses on the Shipper agent, the Logistics Service Provider (LSP) agent, and on market interactions between these two agent types. The following literature overview relates to the behaviour of LSP and Shipper agents, as well as on modelling market interactions and mutual adaptations of agents. Adaptation does not only take place vertically, i.e. within individual demand and supply relationships on the market, but also among competing transport service providers. Depending on how strong competitors can influence each other, various market forms can been defined. We want to consider three special cases: Bertrand oligopoly, monopolistic competition, and two-sided markets. In these fields research has been undertaken in the form of analytical and simulation models. The latter have attracted more and more interest in the last two decades. During this time, "Agent Based Computational Economy" (ACE) has developed models for addressing complex interactions of economic agents.

(A) Models of Carrier behaviour In our view, the Carrier agent is responsible for the physical transport of commodities. For this purpose, she maintains a fleet of vehicles that is deployed in order to fulfil transport tasks efficiently. Literature about the Carrier agent is addressed in the state-of-the-art section of sub-project 1.

(B) Models of LSP behaviour In our understanding, the LSP agent is in charge of building logistics and/or transport chains. The distinction between logistics chains and transport chains follows the notion of Sjoested (2005): A *transport chain* is a sequence of two or several of the following activities: loading, unloading, transshipment, transport and transport-related buffering. A *logistics chain* is made up of the following activities: storage, warehousing, commissioning and forwarding. Thus, the LSP agent can both organise and perform transport tasks.

In reality, the role of the LSP agent differs depending on local legislation and commercial practice. Thus, there is no unique concept describing the behaviour of this agent type. Furthermore, there are many alternative expressions for a LSP such as third party logistics (TPL) provider or forwarder. Different strategies of TPL providers are examined in Hertz and Alfredsson (2003). Reviews on this topic are given by Selviaridis and Spring (2007) and Marasco (2008). Both claim a need for further research about the behaviour of TPL providers and of their clients, as well as about their interactions. We consider the LSP agent as a "one stop shop" for clients who want commodities to be forwarded. The question whether a LSP agent only organises a transport chain or also executes it, does not affect her behaviour towards the clients.

In the scientific literature there is a broad range of publications dealing with modelling the behaviour of agents equivalent to our LSP agent. This modelling can be performed at the macro level of interregional commodity flows but also at the micro level of individual logistics networks.

Macro level models are concerned with the distribution of flows between groups of producers, logistics facilities, and recipients. The classical macro approach to the modelling of logistics chains is based on a least-cost path-search in super- and hypernetworks. Examples of *transport* supernetwork models are NODUS (Jourquin and Beuthe, 1996) and the model of de Jong and Ben-Akiva (2007). The latter one complements a transport network model by a shipment size choice model. Tavasszy presents an example of a *logistics* network model (Tavasszy et al., 1998), where regions serve as logistics hypernodes representing the whole set of all distribution centres in that region. In order to achieve equilibria in the hypernetwork, convex cost functions need to be assumed for all links. This is the reason why fixed costs for transport links or logistics nodes are generally disregarded.

When it comes to the modelling of logistics networks at the *micro level of single firms*, the non-convexity of cost functions cannot be neglected. Consequently, elements of complex optimisation need to be applied. Crainic (2000) provides a general overview on operations research problems that occur when optimising a logistics network.

As Logistics Service Providers do not only perform the physical transport of goods but also act as an intermediary between shippers and carriers, they have to decide whether to commission a subcontractor or not. Therefore, research was done to extend the vehicle routing problem by a buy or make decision. Krajewska and Kopfer (2009) use a Tabu Search algorithm to solve the problem of routing own vehicles and making contracts with various external carriers. An agent based approach is shown by Chow et al. (2013) who model the operations of a third party logistics provider in air cargo.

(C) Models of shipper's choices In our understanding, the shipper agents represent the primary demand in the transport market. Therefore, a shipper agent either makes detailed choices considering the transport of goods directly or she contracts a forwarding company that settles the details. In economics and marketing research, choices are generally addressed by econometric models. In freight transport, such models typically deal with transport mode, carrier, and shipment-size choices. A pure shipment size model is presented by Combes (2009). He also analyses the systematic impact of shippers' characteristics on shipment size choices. Classical mode choice models are compiled in the Ph.D. thesis of Arunotayanun (2009) and in the project report by BVU et al. (2014). Among the models cited in these compilations, the ones of Arunotayanun and Polak (2011), Gopinath (1995) and Park (1995) stand out for their use of sophisticated discrete choice models emphasising the requirements of production and logistics systems on freight transport services through latent classes and latent variables. Choice models can be combined and implemented into agent-based models. Examples are given by Samimi et al. (2012), Cavalcante (2013) and Sharman and Roorda (2013). Econometric choice models are also sometimes embedded into micro-simulation modelling-systems such as SAMGODS (Ben-Akiva and de Jong, 2013).

Within certain transport modes, characteristics of services can vary significantly depending on how the carrier shapes her offers. In consequence, the chosen mode of transport is not determined solely either by the carrier or by the shipper alone; it often results from their interaction. Meixell and Norbis (2008) give an overview of criteria for the choice of an appropriate carrier. The importances of attributes of freight services – independently from a special transport mode – were examined by Danielis et al. (2005) in a stated preference study. Product differentiation within a certain mode of transport was addressed by Tsai et al. (2011) who set up a latent class model in order to delimit segments of customers and their requirements in air cargo markets.

(D) Micro-level operational interaction between shippers and transport companies In the section above, choices of shippers took into consideration the characteristics of carriers, but they were unidirectional in the sense that only the shipper takes action. However, in reality, transport solutions are often the result of negotiations of prices and other conditions between customers and suppliers of transport services. Moreover, shippers often make decisions only after having consulted the recipients or taking into account their requirements.

The interactions between shippers and other agents generally relate to the requirements that logistics makes to the transport. Logistics requirements, in turn, result from production or trade processes. In the model TAPAS, (Holmgren et al., 2012) combine simulation and optimisation in order to capture the interplay between production, logistics, and transport. In their conceptual model, Roorda et al. (2010) introduce the concept of business establishments that can both ship and receive goods. Each establishment – regardless of acting as a shipper or recipient, or both – has the possibility to make transport arrangements. For the purpose of assessing policy measures, Russo and Comi (2010) model the interaction between households and retailers in an urban area with respect to their demand of being supplied with commodities. In urban areas, the recipients usually strongly determine the requirements on transport services. Hence, if changes of the spatio-temporal pattern of freight movements are intended to be triggered, it is crucial that recipients modify their requirements. Therefore, Holguin-Veras et al. (2007) and Holguin-Veras et al. (2008) investigate incentives to change the delivery times at restaurants in Manhattan towards off-peak hours.

The supply-chain related literature focuses on cooperative lot sizing. This is often done by game theoretical considerations (compare, for instance, Cachon (1999)). There is a wide heterogeneity among shippers and thus, it is difficult to obtain empirical evidence on the validity of the theoretical logistics models. For this reason, Holguin-Veras et al. (2011) conducted an experimental study in which they reproduced the influences on shipment size and mode choice.

In reality, cooperative decisions are very common in the transport sector. Shippers and carriers have to arrive at an agreement on the terms and conditions of the transport service. Such interaction is modelled for instance by Roorda et al. (2010) who develop a framework for an agent based model of freight transport demand. There, production or trade companies select a business partner out of a set of logistics companies. They form contracts that specify the details of the transport. Baindur and Viegas (2011) set up a two region model in which road and sea transport companies compete for orders. Here also, contracts of various length are made which specify tariff, transport duration, punctuality and damage rate. On the spot market for transport capacity, online auctions are quite common. In such auctions, both shippers and carriers can try to adapt their behaviour to the observations they make about the market. Caplice and Sheffi (2003) model the interaction of shippers that make bids for truckload services in the presence of carriers that face spatial imbalances in demand. The carriers need to recover the cost for vehicle round trips by charging prices dependent on the utilisation. Internet auctions where the participants have the ability to learn from former periods are modelled by Figliozzi et al. (2008).

(E) Oligopolistic interaction between transport companies In markets where the optimisation of a supplier influences the decisions of all other active suppliers, oligopolistic interdependencies exist. A typical transport market with oligopolistic interdependencies is the market for liner services in container shipping.

Traditional industrial organisation models distinguish between price and quantity as strategic action parameters, which are chosen by each supplier in order to reach maximum profit. If there are economies of scale – as it can be assumed in the transport sector – costs depend on the provision and utilisation of resources. As full costs set a lower bound on prices in the long run, the determination of optimum prices is connected with the choice of suitable capacities. In such cases, price and quantity competition take place at the same time or sequentially (Kreps and Scheinkman, 1983).

Studying transport markets requires to consider the spatial dimension explicitly. In general, the expression "space" does not only refer to the positioning of firms in the geographical space; it can also include dimensions of the space of product characteristics. Oligopolistic interaction in case of price competition and heterogeneous products was analysed by Anderson et al. (1992). In their scenarios, consumers chose among producers according to a logit model.

There are several models of oligopolistic competition among transport companies. Adler (2005) and Adler and Smilowitz (2007) approach the problem of competition between hub networks in air transport using game theory. Bae et al. (2013) investigate duopolistic competition between hub ports for container transshipments. Oligopolistic competition between logistics networks is studied by Nagurney (2010) by means of a variational inequality approach. Also relevant to freight transport is the work related to the competitive facility location problem and, especially, the location of hub facilities (e.g. Sasaki, 2005). Another problem combines competitive location and pricing (e.g. Serra and ReVelle, 1999). A recent model is developed by Lüer-Villagra and Marianov (2013) who consider competitive hub location and pricing. Shah and Brueckner (2012) analyse price and frequency competition of carriers. A comprehensive model that analyses the interactions between customers and suppliers as well as those among suppliers is presented by Lee et al. (2013) who use a variational inequality approach to find a solution.

(F) Monopolistic competition models and their application in transportation science Monopolistic competition is a market form that combines elements of a market under perfect competition and elements of a supplier's monopoly. Its decisive property is that the number of active suppliers is determined endogenously by the market depending on the preference of consumers for heterogeneity in the range of suppliers and the strength of economies of scale in the considered sector (see Dixit and Stiglitz, 1977). Monopolistic competition is based on the assumptions of (i) free market entries and exits, (ii) goods that are perceived to be heterogeneous (iii) economies of scale, and (iv) the belief of firms that they are unable to influence the aggregate price level through their own price setting. The last assumption is justified in cases of many competitors, potential competition through market entries, and/or the inability of firms to act strategically as profit maximisers (for example due to limited market knowledge or due to cost-based price setting imposed by a regulator). Another reason for the perceived lack of market power could be price regulations that still allow a reasonable level of profit so that several companies coexist in the market without taking efforts to squeeze one another out[1]

The concept of monopolistic competition is used in transportation science to establish a link between economic activity and freight flows. Utility functions that reward or even enforce the consumption of a certain quantity of each available good are combined with the assumption that goods of different origin are perceived as having different properties (Armington, 1969). Spatial Economy studies the interdependence between commodity flows and regional economic development (Brakman et al., 2011). The New Economic Geography is based on the model of Krugman (1991), in which monopolistic competition, in combination with regional production functions that incorporate increasing returns to scale, is used to explain the appearance of centres of gravity for certain industries (for more details see Fujita et al., 1999). His concept has been extended to large-scale Spatial Computable General Equilibrium (SCGE) models, in which regions are interlinked by a transport sector using the iceberg approach of Samuelson (1954). Extending the conceptual articles by Bröcker (1995, 1998), sophisticated SCGE models have been developed, integrating the endogenous development of firms (such as RAEM 3.0 (Ivanova et al., 2007) and CGEurope (Bröcker, 2001)). All these models operate on the macro level as they work with representative agents that embody the corresponding sector in a region. However, there is a mismatch between the trade flows and the physical flows of the traded goods, and thus, there are first attempts to combine logistics network models with SCGE models (Jin and WSP Policy Research, 2005).

In the transport sector, there have been fewer applications of the concept of monopolistic competition, with the exceptions of the French INTERALP project (INTERALP, Accessed 2014/04/28) and the work of de Jong and Ben-Akiva (2007) who do not use the expression "monopolistic competition" explicitly but make use of its main characteristics – cost-oriented price setting, and market exits of transport connections. Baindur and Viegas (2011) develop a two region model with intermodal competition between road an sea transport, and with the number of road transport companies defined endogenously depending on profit and capacity utilisation. In this model, prices are based on competition in the sense that they are updated depending on the capacity occupancy rates of the vehicles and the number of active companies.

(G) Two-sided markets and their relevance for transport companies In a two-sided market two different user groups interact with each other via an intermediary or platform. The incentive for using the services of such an intermediary results from the large number of potential business partners that can be addressed. Hence a decisive property of a two sided trading platform is that its attractiveness on each side increases with the number of participants on the other side (Armstrong, 2006; Rysman, 2009).

[1] The term "variety of companies" is considered in a wide sense here. Variety can also result from various geographical locations of suppliers of goods.

In the transport sector, two sided platforms are present mainly in two cases. First, public infrastructure facilities such as airports are sometimes considered to constitute two-sided markets (e.g. Ivaldi et al., 2011; Gillen and Mantin, 2013). Airlines will serve such places where a high volume of passengers and/or cargo can be expected. Similarly, freight forwarders and/or passengers will route their shipments via infrastructure nodes where many directions are offered or competition of service providers keeps prices low. Second, freight forwarders themselves constitute two sided platforms. The more shippers they attract, the more freight carriers want to be subcontracted by them as a reliably high level of utilisation can be expected. And vice versa, a freight forwarder that cooperates with a wide range of carriers is able to cover a wide range of customer requirements with regards to directions, flexibility, and availability of special equipment. Research on intermediaries in freight transport has mainly concentrated on online platforms where shippers and carriers are matched. Up to now platforms have been addressed mainly from the point of allocating demand and supply via various forms of auctions (e.g. Nandiraju, 2006; Mes et al., 2013), whereas competition between such platforms has not been examined in the context of transport markets.

(H) Modelling economic systems with multi-agent models Traditional microeconomic models that can either be solved analytically or numerically are limited in their capabilities. In such models, either a solution in closed form has to exist, or the numerical solution algorithm has to converge provably. Agent Based Computational Economics (ACE) refrains from closed form solutions, exact individual optimums and unique market equilibria. Here, agents behave according to rules, heuristics, or learning algorithms. As Tesfatsion (2002) points out, ACE is a suitable instrument for building bottom up market models where emergent behaviour is likely and of interest. There has been a wide application of agent based models, and especially for the purpose of analysing the impact of changed institutions on short term market outcomes. There are applications for electricity wholesale markets, emission rights, some financial instruments, and on online trading platforms (Marks, 2006; Collins et al., 2010). Especially in the electricity markets (that share some spatial and temporal characteristics with the transport markets) a wide variety of simulation studies has been conducted (for a survey see e.g. Weidlich and Veit, 2008).

Learning or adaptive agents are at the core of many ACE models. There are basically two ways in which agents can learn: (i) Supervised learning, where the desired outcome is known to the agent to some extent and actions are evaluated against this outcome (such as OLS or gradient learning), and (ii) unsupervised learning, where the agent has to make the solution space accessible without having knowledge about the shape of the optimum solution. Brenner (2006) and Sen and Weiss (1999) provide reviews and hints concerning learning methods of agents. In most ACE models, unsupervised learning is applied.

An early example of a rule based model is Schelling (1978), who uses a cellular automaton to model residential choice of households according to their properties and those of their immediate neighbours and thus modelled emergence of land use patterns from interaction of individuals. As a very vivid example of a rule based approach, Price (1997) shows that the simple textbook problems of industrial organisation – such as the Cournot oligopoly – can equivalently be modelled by means of co-evolutionary algorithms. In doing so, he picks up the initial idea of Holland (1975), who introduces genetic algorithms not only for optimisation problems but also to model the adaptation of decision makers to their environment. Up to now, genetic algorithms are one of the most frequently applied concepts in agent based computational economics. Other learning heuristics are learning classifier systems (LCS) where the agents maintain a set of rules that are applied depending on stimuli from their environment. Here, the rules, which follow an "if-then" pattern, are updated by means of a genetic algorithm. Vriend (1995) equips consumers as well as producers with learning classifier systems in order to study the phenomenon of self organised markets. Schulenburg and Ross (2000) use a LCS to let agents learn their optimum behaviour with respect to the price of a certain stock that the agents can either hold or sell. In the meantime, learning classifier systems made their way into professionally applied automatic trading systems. A recent application of agents that learn about their environment and the actions of their competitors is the one of Wilson et al. (2013) who model lobster fishers in Maine.

ACE proved especially capable of handling game theoretic and industrial organisation problems (Riechmann, 2001). Also monopolistic competition problems were addressed, such as Catullo (2013) and Guerci et al. (2007). However, we do not know any applications of monopolistic competition in the freight transport sector up to now. Similar holds true for the case of two-sided markets where there are applications for example in the payment card industry (Alexandrova-Kabadjova et al., 2007). The possibilities to model adaptive agents come at the price of introducing additional parameters. Alkemade (2004) focuses on the robustness of the solutions with respect to the parameter values of the genetic learning algorithms to model various market settings.

Agent Based Computational Economics has also addressed spatial and transport problems. Approaches were made in several economic environments like the one of Graubner et al. (2011) who studies spatial markets for agricultural products. In transport and infrastructure modelling, Dimitriou and Stathopoulos (2009) address the competition of seaports and their hinterland in the Mediterranean Sea. Both models apply co-evolutionary genetic algorithms to deal with oligopolistic interaction of suppliers whose location is – beside the prices – a relevant characteristic for their customers. Heppenstall et al. (2007) model consumers' choices of gas stations depending on price and location and the reaction of the station tenants by means of a rule based simulation model.

(I) Recapitulation and identification of research needs As the popularity of agent based models in several economic and engineering disciplines and their application to transportation and electricity shows, there is a trend towards very detailed models. We want to contribute to this development by implementing agent types that represent the demand side as well as the supply side of the transport market. To capture the actions going on in reality, the agents need to be able to adapt to their environment as well as to each other. However, it remains a challenge to model the behaviour of both the demand side and the supply side of transport markets simultaneously, due to the large decision space of the actors and their mutual adaptation. As the literature study above shows, the adaptation of suppliers to customers as well as to competitors is often modelled by means of game theory. Such models solve various kinds of bi-level or multi-level problems in which the optimisation problem of one actor serves as a constraint for the others. Models from game theory search for a strategic equilibrium. However, in reality, most markets are not in an equilibrium. Such situations can be addressed by means of Agent Based Computational Economics (cf. Arthur, 2006)). We want to develop a model that makes use of the concepts of ACE as we intend to set up a model of agents pursuing their self interests.

As one can see in the subsequent section, the project applicants have profound experience in (i) the formulation of analytical monopolistic competition models in transport markets, (ii) formulating analytical oligopolistic competition models in network industries, (iii) behaviour modelling of freight agents, and in (iv) large-scale commodity demand modelling with multi-agent design with incorporated optimisation engines.

Own work: WIV

Prof. Liedtke contributes to the consortium the knowledge of agent-based commodity-transport demand-modelling. Since 2014 he is professor for commercial transport at the Technical University of Berlin and Head of the Department of Commercial Transport at the German Aerospace Center. Between 2008 and 2014 he leaded the working group on freight transport and economic logistics at the Institute for Economics (ECON). He has focussed on five areas relevant for the project in which he both supervised Ph.D. students, and contributed original research of his own.

(a) Analytical economic equilibrium models The habilitation treatise of Prof. Liedtke focuses on emergence phenomena that result from decentral interactions of actors in freight transport (Liedtke, 2012b). Such interactions are driven by economic deliberation of the involved agents and lead to dynamic equilibria in the long run. An approach to model such equilibria in a market under monopolistic competition is developed by Carrillo Murillo and Liedtke (2013). It is motivated by an example from econophysics and verified empirically for the case of intermodal hinterland terminals in Germany. Further, the analytical treatment of market equilibria under monopolistic competition is embedded into a dynamic simulation in the Ph.D. thesis of David Carrillo (Carrillo Murillo, 2010) which was supervised by Dr. Liedtke.

(b) Network planning models Transport logistics networks of individual companies are the result of emergent phenomena as described above. The choice of appropriate methods to combine the modelling of network formation and freight transport (Liedtke and Friedrich, 2012) is a subject of ongoing research activities. Moreover, Prof. Liedtke supervised two Ph.D. theses that dealt with the application of optimisation methods for explaining logistics structures in freight transport (Scholz, 2012; Friedrich, 2010). Both deal with the optimisation of the network of a single company without interaction with competitors. The thesis by Scholz (2012) was awarded the Carl-Pirath-Award 2013 of the Deutsche Verkehrswissenschaftliche Gesellschaft (German Association of Transport Sciences).

(c) Multi-agent models Liedtke (2006) and Liedtke (2009) started the research on multi agent models with the detailed description of the demand side in freight transport. During the project City2000W (Liedtke and Nagel, 2010–2015), the multi-layer agent hierarchy "Freight Transport Lab" was developed (Schröder et al., 2012). Here, the interactions between shippers and carriers were formalised. The carrier was equipped with a versatile tour planning intelligence. This enables the detailed analysis of transport companies in the LTL (Less than Truckload) sector. A case study was set up to demonstrate the effects of policy measures on the organisation of the supply of grocery stores in Berlin (Schröder and Liedtke, 2014). The perspectives opened by that work were one major reason for the present proposal.

(d) Decision engines in multi-agent models An important rationale for applying agent based simulation models is the wide variety of possibilities to model the decisions of the involved agents. In this area work was done on the formation of lot sizes in freight transport (Liedtke, 2012a). Furthermore, the influence of the characteristics of the logistics system on lot size choices has been addressed on the verge of contributing to the German federal infrastructure development masterplan (supervised thesis of Brendle, 2013). The study also resulted in a data driven exogenous segmentation of shippers according to their different logistics requirements for each transport mode (BVU et al., 2014).

(e) Applied transport policy In various contract research projects, Prof. Liedtke has dealt with questions of transport policy. Welfare effects of various policy measures were addressed. Special attention was paid to questions of transport infrastructure funding (Liedtke and Carrillo Murillo, 2012; Planco et al., 2015). Moreover, values of time and reliability, i.e. the rate of substitution between time or punctuality and money, were deduced (BVU et al., 2014).

Own work: ECON

Prof. Mitusch brings to the consortium the knowledge of microeconomic modelling in various kinds of network industries such as railways, mobile phone and internet. He has a rich experience on modelling strategic interactions between suppliers in this field. In particular, he addresses multi-stage problems concerning strategic capacity choices in networks. Having a traditional microeconomic background, he assures a consistent formulation of the agents' behaviour rules and interactions. The main strengths of Prof. Mitusch regarding the proposed project are in the following three areas:

(a) Competition in network industries Prof. Mitusch has a long experience in game theoretical and industrial organisational analysis of competition in network industries. Special peculiarities of these industries, such as the effects of economies of scale and congestion on pricing and demand, are in the focus of his research. He deals with various kinds of duopoly models of communication network suppliers under equilibrium and welfare aspects (Baake and Mitusch, 2009a). Besides pure price and quantity competition, the endogenisation of capacities, as it will be addressed in work package 3.3, is a central topic. Moreover, competition between incumbents and contestants in the telecommunication industry as well as the negotiation between competitors about access charges for incoming calls from other networks are modelled (Baake and Mitusch, 2009b).

(b) Combinatorial auctions in railway networks After the liberalisation of railway transport, various problems concerning the access regime to the railway networks arose. In the project "Trassenbörse", funded by the Federal Ministry for Education and Research, Prof. Mitusch contributed to a model of combinatorial auctions for slots on railway tracks (Tanner and Mitusch, 2011). The auction solves the problem of coordinating the interests of competing railway companies both among each other as well as with the network operator (Mitusch, 2007). The task of his research group in the framework of the larger project was the development of a flexible language that allowed railway companies to specify their demands for slots in a way that they were both understandable for them as well as for the auction model. The project showed that from an efficiency standpoint certain types of list prices led to results that were quite similar to the results generated by the complex auction.

(c) Large-scale strategic transport models In his function as the tenured professor for the chair of network economics, Prof. Mitusch supervised various project employees that dealt with the modelling of large-scale transport models. In the project ETISplus (Szimba et al., 2012), funded by the European Community, a pan-European O/D-matrix for passenger transport on rail and road was generated based on a four-step model. The results are partly used in the ongoing project HIGH-TOOL (Szimba et al., 2013) in which a software for preliminary assessments of international transport policy measures is developed.

Own work: NITech

Dr. Wisetjindawat participates in the consortium, as she has a long experience with the development and estimation of econometric behaviour models and their embedding in microsimulations. Her simulation models are gradually extended towards multi-agent models. At the moment she belongs to a small community of researchers that have covered all modelling steps of generation and distribution of commodity flows on the micro level, their division into single shipments, and the assignment to vehicle tours on the road network.

(a) Demand modelling in urban freight transport Microscopic freight transport models require a description of demand agents at the level of single companies. For this purpose, Dr. Wisetjindawat transfers models also used in passenger transport to create synthetic populations of companies. Starting from aggregate statistics, groups of firms are generated by iterated proportional fitting (IPF). Single companies are created from these groups by Monte Carlo simulation (Wisetjindawat et al., 2009). These companies produce and consume goods of several different kinds. The selection of trading partners is done by means of a spatial autocorrelated mixed logit model (Wisetjindawat et al., 2006).

(b) Agent based simulation In order to describe freight flows on the basis of single agents, Dr. Wisetjindawat departed from the classical 4-stage-model. With the obtained micro-data from above, steps were taken towards an agent based simulation of urban freight transport and the related upstream decisions (Wisetjindawat et al., 2007). In freight transport, the way that shipments take between shippers and recipients often differ from the direct connection. This results from the transportation of shipments in tours. Raothanachonkun et al. (2007) build trip chains that resemble observed tour patterns. By doing so, also empty trips are incorporated into the transport model.

(c) Optimisation in urban logistics Optimisation in urban logistics was addressed by Dr. Wisetjindawat on various occasions. Agents in the simulation of transport demand were equipped with optimising behaviour. Optimisation covered the selection of trade partners, the overall quantity of traded goods, the optimum size of shipments and the selection of a vehicle type for transport. Transport cost that serves as a decision criterion is derived by a vehicle routing algorithm (Wisetjindawat et al., 2005). Optimisation is also dealt with in a non-agent based scenario. A vehicle routing problem is solved in Wisetjindawat et al. (2012) in order to remove rubble from a city after an earthquake.

1.1 Project-related publications (up to 10)

1.1.1 Articles published by outlets with scientific quality assurance, book publications, and works accepted for publication but not yet published

Baake, P. and K. Mitusch. Competition with congestible networks. *Journals of Economics*, 91, 151–176, 2009a.

Baake, P. and K. Mitusch. Mobile phone termination charges with asymmetric regulation. *Journal of Economics*, 96, 241–261, 2009b.

Carrillo Murillo, D. G. and G. Liedtke. A model for the formation of colloidal structures in freight transportation: The case of hinterland terminals. *Transportation Research Part E: Logistics and Transportation Review*, 49(1), 55–70, 2013.

Carrillo Murillo, D. G. and G. Liedtke. Where supply meets demand: The spatial location of inland terminals. *Journal of Transport Economics and Policy*, 49(2), 295–315, 2015.

Liedtke, G. Estimation of the benefits for shippers from a multimodal transport network. *Logistics Research*, 4(3–4), 113–125, 2012.

Liedtke, G. and H. Friedrich. Generation of logistics networks in transport models. *Transportation*, 39(6), 1335–1351, 2012.

Liedtke, G., T. Matteis, and W. Wisetjindawat. Impacts of urban logistics measures on mutiple actors and decision layers: A case study. *ransportation Research Record, Journal of the Transportation Research Board*, 2478, 57–67, 2015.

Schröder, S. and G. Liedtke. Modeling and analyzing the effects of differentiated urban freight measures – a case study of the food retailing industry. Tech. Rep. 14-5015, 2014.

Wisetjindawat, W., F. Marchal, and K. Yamamoto. Methods and techniques to create synthetic firm's attribution as input to microscopic freight simulation. In *Proceeding of the Eastern Asia Society for Transportation Studies*, vol. 7. 2009.

Wisetjindawat, W., K. Sano, S. Matsumoto, and P. Raothanachonkun. Micro-simulation model for modeling freight agents interactions in urban freight movement. In *Paper presented at the 86th annual meeting of Transportation Research Board*. Washington D.C., 2007.

2 Objectives and work programme

2.1 Anticipated total duration of the project

36 months

2.2 Objectives

In this sub-project, the main goal is to develop a model of the Shipper/Recipient agent that embodies the demand side in a market for transport services. Furthermore, an agent type called "LSP agent" (= logistics service provider agent) will be developed in close cooperation with sub-project 1. Both agent types will be equipped with the ability to make certain decisions. These decisions are related to logistics and the market for transport services. The coupling of the model with already existing components allows studying the effects of transport policies and traffic conditions on upstream logistics decisions. Furthermore, a step towards modelling the emergence of spatial structures in the freight transport market will be done.

The distribution of activities between the two sub-projects can be seen in Fig. 1: This sub-project deals mainly with the two agent types Shipper/Recipient agent and LSP agent and with their interactions.

The work program of this sub-project is divided into five work packages (WPs). Starting from two different preparatory work streams, in the end a variety of policy measures are analysed both in stylized

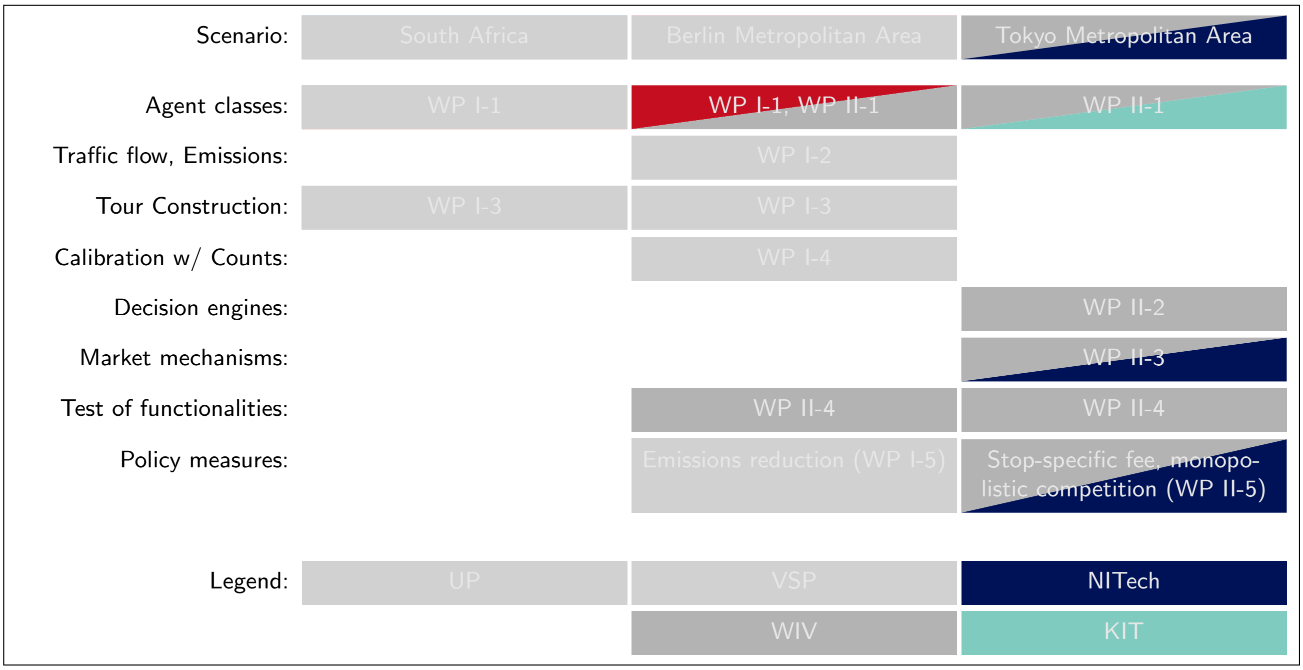

Figure 1: Structure of the package project "Shippers and Recipients in a Multi-Agent Framework for Commodity Transport Demand Modelling" – Tasks within sub-project 2. In those cases where three or more partners are involved in a WP, only the two most important contributors are shown.

and in realistic settings. Both the demand side and supply side of the market are specified in WP1. As far as the supply side – the LSP agent – is concerned, this happens in cooperation with sub-project 1. For each of the agent types, decision engines are modelled in WP2. Both threads of work will feed into in the market simulation in WP3. The results are tested in WP4. With the achievements of these work packages, realistic scenarios and policy measures are addressed in WP5. There, two scenarios will be modelled: Mixed cargo transports in the Tokyo Metropolitan Area (Tokyo), and retail transport chains in Berlin.

Approach

For the thorough understanding of the freight transport market, a bottom up approach is employed, in which the observed market is assembled from its smallest reasonable components, i.e. economic agents. In our proposal, "agent-based modelling" means that each agent in the simulation mimics one agent in reality. The agents will be modelled in the programming language Java in such a way that their shape and behaviour will be as generic as possible. In doing so, later extensions and enriched behaviour models can be added more easily. When specifying the agents, a close coordination with sub-project 1 is intended and of crucial importance (see Fig. 1). This is due to two facts: First, the behaviour of the agents will also be specified partly in sub-project 1, and second, the code to be developed has to fit to the already existing software.

Relevance to fields other than science

The research is closely connected to policy-making in the fields of transport policy, economic policy, and environmental policy. Components of the multi-agent simulation system can be used as side products in policy consulting. The studies of policy instruments, which are part of the proposal, will help urban planners to make better decisions with respect to land use planning, air quality, and noise. Components of the multi-agent simulation system can also be used in logistics consulting. For example, the economic model can help transport companies to adjust their pricing policies or to develop new types of logistics services.

2.3 Work programme including proposed research methods

WP 1: Specification of the LSP- and the Shipper/Recipient agent In the present proposal, the LSP agent acts as an intermediary between Shipper agents and Carrier agents. In selected cases – for instance the traditional German forwarder ("Spedition") – the LSP agent also operates her own vehicles, while possibly still hiring independent carriers on the market in addition. To cover all these aspects, the LSP agent serves as a flexible shell to implement all kinds of coordinators between the demand for and the execution of transport logistics services.

Since shipping may be triggered or even organized by the recipient, we will consider a generalized Shipper/Recipient (S/R) agent. This agent is the economic entity which ensures the supply of a manufacturing line, in the case of the manufacturing sector, or of a point of sale, in the retail sector. To do so, she implements certain warehouse policies.

The present work package specifies the LSP agent and the S/R agent. Both agents are modelled as constructs that contain a number of standardised items from which more complex units can be established. In the case of the LSP agent, these are the physical assets of a transport and logistics network such as warehouses or transshipment facilities. In the case of the S/R agent, these are the various delivery relationships that exist with other shippers respective recipients.

WP 1.1: Specification of the LSP agent and its interface to the S/R agent [WIV, ECON] LSP agents collect shipments from the Shippers and pass consolidated shipments on to Carriers that finally perform the physical transport operations. An LSP agent maintains one or several facilities to process the shipments (consolidation, buffering, transshipment). In the short run, an LSP agent determines cost minimising paths for the shipments through her own network, based on short-term marginal cost or average cost determined by an activity-based costing schema. In the long run, an LSP agent improves her network by opening or closing facilities.

The LSP agent interacts closely with the Carrier agent which has already been developed in the preceding 2000W-City project (Liedtke and Nagel, 2010–2015) and which will be enhanced by sub-project 1. Concerning the implementation of the LSP agent, there is a clear division of labour between the two sub-projects: sub-project 1 is in charge of the operational planning of the logistics network including the employment of different carriers. The present sub-project 2 is in charge of modelling the coordination interfaces of the LSP agent with the transport demand side and of modelling strategic long-term decisions.

The connection to the demand side is performed via transport offers for which the Shipper agents can call. As these offers require a detailed knowledge of the cost connected to the transport operations, the LSP agent has to be equipped with the ability to track cost and assign it to single shipments. Strategical decisions include pricing policies and logistics network design. These will be implemented in the work packages 2 and 3.

WP 1.2: Specification of the Shipper/Recipient (S/R) agent [WIV] The Shipper/Recipient (S/R) agent represents the demand side of the freight transport market. Each micro commodity-flow originates from a contract between two merchants. The characteristics of such a shipper-recipient relationship are modelled based on the work of Wisetjindawat et al. (2007), which considers the business partners as nodes and the flows as edges in a relationship network. Shippers and recipients are proxies for business facilities in which flows of goods start or end. The main purpose of the S/R agent is to store information on the outgoing and incoming

flows of goods, and to divide the flows into individual shipments. The choices with respect to lot size and of contracted LSP agent might depend on the type of good, the requirements of the shipper and/or recipient, and their respective bargaining power.

Adding shippers to a multi-agent commodity transport demand model increases considerably the requirements on the model's architecture, since the challenge of dealing with market interactions emerges. Mechanisms need to be developed that allocate total transport demand to the LSP agents. For this purpose we will apply choice mechanisms that are well established in Agent Based Computational Economics and in transport economics: The Shipper/Recipient agents will be endowed with decision engine for the choice of an LSP agent (see WP 2).

We will implement mechanisms that create a synthetic population of shippers. For this purpose, the area under examination will be divided into several zones. In each of them a number of different firms in various industry sectors will be created by means of an iterative proportional fitting approach (e.g. Beckman et al., 1996). Moreover, the generation and attraction of certain commodities by these firms has to be modelled. This will be done in a simplified way by assuming identical production and consumption behaviour for each company of a certain sector. The planned procedure is a further development of the work of Wisetjindawat et al. (2006). It will be generalised in order to cope with different types of data and data availability, and in particular with German data.

WP 2: Specification of decision engines for the agents The focus of this WP lies on the creation of decision engines that help the agents to achieve their goals. Assuming profit maximisation, these decisions include cost-minimisation, pricing, and network design. A simulation environment is developed in which various settings can be placed. For this reason, the characteristics, actions, and interactions of the agents are to be held as atomistic as possible. The same holds for the collected and logged data in the course of simulation iterations. In pursuing this strategy, agents can then be equipped with more complex behaviour. Thus, the work packages 1 and 2 build the foundation for the implementation of the models in the work packages 4 and 5.

WP 2.1: Decision engines for the S/R agent [WIV] It is not always clear who makes the logistics decisions in relation to a micro commodity flow: Sometimes the shipper is in charge of those decisions and sometimes the recipient. It is also quite common that decision making is distributed between both types of agents. These questions have to do with market and bargaining power, but also with logistics competences and interactions with other decision problems.

For these reasons, we do not intend to make a structural distinction between the shipper and the recipient. Instead, the S/R agent represents an abstract decision making entity, which is responsible for a certain flow of goods or a bundle of them. For each flow of goods, an optimum shipment frequency and an LSP agent in charge of forwarding the shipments need to be determined. For these two types of decisions, various decision engines will be considered and – if suitable – implemented. At the moment, the following procedure seems to be convincing:

The LSP agent is chosen according to a multinomial logit model with prices and a heterogeneity parameter as the sole arguments. As far as the parametrisation of the model is concerned, we intend to use the SP (stated preference) and RP (revealed preference) data set from a former project (BVU et al., 2014). Shipment size is chosen according to a total logistics cost minimisation approach similar to the approaches of Combes (2009) and Brendle (2013). In these models, shipment sizes mainly depend on the fixed cost per order. Such fixed order costs vary between various LSP agents, as they depend on the demand that each LSP agent faces. For this reason, the Shipper/Recipient agent will be equipped with a decision engine that tracks market prices for transport services. From these prices, expected order fixed cost will be deduced and used for the calculation of the regular shipment size. Another possibility consists in implementing a discrete choice model (e.g. De Jong and Johnson, 2009) which can deal with any type of cost function.

The decision engines mentioned so far assume given freight flows between each shipper and recipient. In order to set these relationships up, a further decision engine will be added that specifies the choice of a supplier for a certain good. This decision engine is suited to create trade relationships between the members of the synthetic demand population that has been set up before (see 1.2).

WP 2.2: Decision engines for the LSP agent [WIV] In this sub-project, the behaviour of the LSP agent is modelled mainly under economic aspects and relates to the generation of offers (prices), the routing of shipments through logistics facilities, and the performance of the activities in and between these facilities.

We intend to implement the following decision engines:

- The **cost allocator engine** implements an actual costing system. We can imagine the following cost allocation schemas: activity-based costing, or simulated Shapley values (see Liedtke and Scholz, 2009).

- The **marginal cost calculator** determines the additional cost caused by an additional shipment. It can be implemented in several ways: One possibility uses a modified activity-based costing schema. The other possibility is to calculate the cost of tours before and after inserting a new shipment in a transport logistics network.
- The **price-elasticity sensor** collects information about the probability that an offer will be accepted by a customer as a function of its price.
- The **shortest logistics path calculator** computes the path of shipment cases through the logistics network including the employment of different hubs and/or carriers.
- The **network reconfiguration engine** opens and closes logistics facilities. We intend to model network optimisation in a very simplified fashion. Concerning the network configuration engine we intend to limit ourselves to pure hub-and-spoke networks. In recent years, an increasing professionalism in the LTL segment could be observed. With the aim of reducing complexity, associations of transport companies have been founded that maintain nationwide networks of transshipping facilities. These networks have more or less an ideal hub-and-spoke shape. Thus, assuming idealised hub-and-spoke networks means to model the prevailing spatial structures in the LTL segment.

WP 3: Specification and implementation of market mechanisms In reality, shippers can choose between a variety of different logistics service providers. Which one they choose depends on their preferences, prices, and the supply in both spatial and temporal respects. For this reason, we will model the behaviour of both supply and demand agents under various make forms. We start from the assumption that the only observable criterion according to which shippers choose logistics service providers is the price.

Using the decision engines specified before, we address three kinds of market forms: (1) A duopoly of LSP agents, (2) the LSP agent acting as a platform in a two sided market, and (3) a market under monopolistic competition as described by Dixit and Stiglitz (1977). It will also be examined to which extent the assumptions of these three market forms are justified. Data on this topic can, for example, be obtained from the German federal competition authority.[2]

WP 3.1: Market in a price-based duopoly [WIV, ECON] In the case of an oligopoly, every LSP agent has to solve a bi-level problem of maximising its profit under the restriction of facing a competitor that acts in the same way. For the agent-based analysis of such problems in a spatial setting, co-evolutionary algorithms have provided good results in the past (e.g. Graubner et al., 2011; Dimitriou and Stathopoulos, 2009). A heuristic will be developed that calculates prices for each of the transport solutions that the LSP offers. Prices are based on marginal cost with mark-ups resulting from the oligopolistic market interactions. The sum of all prices requested by an LSP agent is then compared to the total costs of all necessary shipment activities.

In the course of many iterations, an equilibrium should emerge. As the costs and hence prices depend on the configuration as well as the load of the transport chains, changes in their configuration have consequences on the market. The model can thus serve to examine competition between transport chains of long established LSPs and newcomers in a market segment. The consumers are deciding on lot size and/or the choice of the appropriate LSP agent. Both decisions allude to the application of discrete choice models from the logit family based on the work of Anderson et al. (1992). For a real-world case study, see WP 5.2.

WP 3.2: The Logistic Service Provider as a two-sided platform [WIV, ECON] A topic of special interest is the role of the LSP agent as a platform in a two-sided market. As mentioned in WP 1, the LSP agent can act as an intermediary that brings together shippers and carriers. Hence, she can both act as a buyer of transport space and a supplier of transport services at the same time and in doing so constitutes a two sided platform (see Armstrong, 2006). We intend to investigate how behaviour

[2] The authority publishes sector inquiries if there is reason to suspect that restraints of trade can occur. See: `http://www.bundeskartellamt.de/EN/AboutUs/Publications/Sectorinquiries/sectorinquiries_node.html`
Especially for (but not limited to) the transport sector, the German Monopoly Commission regularly publishes reports on several network industries. See `http://www.monopolkommission.de/sonder_e.html`.

of LSPs in such a market could be addressed by a future extension of our model. Therefore, we look for possible decision engines that have to be added to the ones that are already at hand. This will especially concern the LSP agent. She will then have to interact with the Carrier agent in a more sophisticated way than only handing the shipments over for transport.

WP 3.3: Market under monopolistic competition [WIV, ECON] Next, a market under monopolistic competition will be examined. In such a situation, suppliers (i.e. LSP agents) do not care about the strategies and reactions of their competitors but rather assume that they have a monopoly to some extent.

A population of similar LSP agents is generated whose facilities will be placed via an adapted Monte Carlo approach. If agents cannot sustain competition, they will be withdrawn from the market, and new suppliers will smoothly be integrated from time to time. The equilibrium concept here is a dynamic equilibrium, which is achieved when the number of active LSP agents remains unchanged for a longer period of time. For a real-world case study, see WP 5.1.

WP 4: Test of functionalities In this WP, emphasis is put on applications of the concepts from the previous WPs in scenarios that are simple and traceable. In addition to the pure model application, data collection and selection of policy measures are needed. The aim is to display the propagation of both policy measures and logistics trends through the sequence of decisions. The micro model of agents allows to assess the consequences on different stakeholders.

WP 4.1: Test of functionalities with synthetic examples [WIV] After the market behaviour mechanisms have been specified and implemented in WP 3, they are tested with synthetic examples. Experience shows that when new developments in agent based modelling are applied for the first time, concise and traceable scenarios are useful for illustration and testing. For this reason, we will set up a scenario with only a few demand agents and a schematic spatial arrangement following a checker-board shape. Besides the focus on testing the developed models, the main rationale behind this procedure is that the results with respect to the economic interactions should not be blurred by a potentially complex scenario in which they occur. The subworkpackage also includes the search for suitable examples that are applied in related fields of research as the CAB (Civil Aeronautics Board) and AP (Australian Post)

data sets in hub location problems (they can be obtained from Beasly, 1990). We will focus on economic behaviour on the strategic and tactical level here. Traffic on the road network will be excluded in this first step. Pickup and delivery times will be restricted to normal working hours.

Thus, the model refrains from going too much into detail as far as temporal restrictions are concerned but rather focuses on spatial economic issues. Even without going too much into detail, this would be a step towards closing the well known micro-macro-gap in freight transport.

WP 4.2: Test of Interaction Dynamics and Update Procedure [WIV] The interaction of all agents implemented in the WPs before entails some potential problems: A multi-layer model causes simulation runs of every layer of agents plus runs of the traffic flow simulation in each iteration. We want to model a system in an equilibrium state, and as we do not know how this equilibrium will look like, we start at random values for the decision variables of the agents. Therefore, it will take many iterations to reach such an equilibrium. There exists the possibility that many time-consuming and probably unnecessary re-runs of MATSim and jsprit are necessary to reach an equilibrium after a reasonable time. Therefore, we look for ways to reduce the reruns of MATSim and jsprit during the market simulation. We intend to do it as follows: All activities of agents as specified in the WPs 1 and 2 cause costs. These costs are determined and allocated to the single activities by parametrised cost functions. The parameter values are regressed from the results of previous simulation runs. An update of the parameter values does not occur after each iteration but according to some rules (for instance, after a considerable change in the number of customers or a relocation of a hub facility) or after a certain number of iterations. This helps not only in shortening the model's runtime, but it also can be argued that strategic decisions in reality, such as location choice, are also based on aggregate data. We have collected positive experience with such a procedure already in Liedtke et al. (2013).

WP 5: Illustrative scenarios and policy analyses The application of the findings will take place in various case studies. The case studies in WP 5.1 will be performed in collaboration with Wisinee Wisetjindawat. She has developed a reference scenario for freight transport demand in urban areas that is worldwide unique and that can not be reproduced for a German city. There have been several successful collaborations in the past (Liedtke et al., 2009, 2013). For the case studies in WP 5.2 we can access data and experience that have been collected in former and ongoing projects, such as 2000W-City (Liedtke and Nagel, 2010–2015) or KEP-City (Schröder and Liedtke, 2015).

WP 5.1: Urban freight – Tokyo [WIV, NITech] This case relates to the Tokyo Metropolitan Area. For this region we have the complete material necessary to construct two coherent studies. The first one relates to a monopolistic competition market. The second one studies the propagation of effects from fine-tuned transport policy measures to the levels of upstream logistics decisions. Both case studies use the data provided by Wisinee Wisetjindawat. It includes a synthetic population of shipper/recipient relations, a shipment-size choice model, and an LSP choice model. To our knowledge, this is the only existing comprehensive data source on such a detailed level, so that a large-scale, behaviour-sensitive micro-model can be established. In this application, all of the partners can profit from each other and have the possibility to gain insights that could not be gained otherwise.

In the agglomeration area of Tokyo, two scenarios will be examined:

- The first scenario relates to a market under *monopolistic competition* as modelled in WP 3.3. It is analysed how many LSP agents will serve an area if their number and location is left to de-central market decisions. This is especially interesting as it will be compared to an imposed last mile delivery organisation granted the sole access to certain areas for reasons of congestion reduction. There is strong evidence that although there are only a few active companies in the mixed cargo segment, each of them can act independently to a certain extent, i.e. the central criterion of monopolistic competition is fulfilled. It is reasonable to construct this scenario based on the demand model of Wisinee Wisetjindawat, because it meets exactly the assumptions for the demand side in a market under monopolistic competition – a population of business establishments that are heterogeneous in location, size and business sector, commodity types, and quantities of annually exchanged goods. Therefore, a certain valuation for variety concerning transport services exists. The commodity flows occur between single companies so that they can be split into shipments by the application of one of the decision engines of WP 2.2.
- The second scenario considers the *propagation of effects* along the line of decisions from the Shipper/Recipient agent via the LSP agent to the Carrier agent, and vice versa. For this purpose, the effects of an introduction of a stop-specific fee (e.g. in the form of a loading bay management concept) is demonstrated. A stop-specific fee penalises each delivery activity, and thus, it encourages the consolidation of shipments.

  The analysis of a stop-specific fee will be carried out together with sub-project 1. This sub-project provides a lot-size choice model and the Shipper agents, while sub-project 1 deals with calculating the impact on vehicle employment and emissions. In this way, the analysis of the stop-specific fee contributes to demonstrating the ability of the multi-agent model to deal with the "3-level problem" of carriers, LSP agents, and shippers.

WP 5.2: Urban freight – Berlin [WIV, NITech] The second case relates to the city of Berlin. In two scenarios, the behaviour of Shipper/Recipient agents after the implementation of an emissions toll and the choice between competing transport chains will be addressed. Both case studies will be carried out in close cooperation with sub-project 1. The focus of this sub-project is on the behaviour of upstream actors, as the TSP- and Shipper-agents.

- The first scenario considers the *propagation of effects* of an artificial emissions toll. Sub-project 1 examines the effects of such a toll on the LSP agents. The work package here addresses the question if and to which extent the introduction of such a toll influences the behaviour of the Shipper/Recipient agents. For example, the latter are expected to change either their shipping frequencies, or choose an LSP with environmentally friendly vehicles. Recipient agents will represent retail stores that need to replenish their stocks. Goods that come from outside the city have to be delivered from distribution centers to the stores. There the way in which the recipients (i.e. the store owners or managers) like to have their orders delivered is decisive for the success of any regulatory measure that considers the last mile.

- The second scenario addresses the choice of *competing transport chains* by Shipper/Recipient agents. Picking up the results of WP 3.1, the competition of LSPs that maintain transport chains for the replenishment of retail stores is analysed. These chains have different characteristics with price being the most decisive. Recipients choose the LSP that they find to be most suitable according to their preferences. The aim is to figure out under which conditions innovative transport solutions such as cargo bikes can be competitive.

2.4 Data handling – not applicable

2.5 Other information

Dr. Wisinee Wisetjindawat, of the Department of Scientific and Engineering Simulation at the Nagoya Institute of Technology (NITech), is a partner to the proposal. She spent a research visit at the DLR Institute of Transport Research in Berlin by arrangement of Gernot Liedtke and Prof. Dr. Barbara Lenz. There, she worked on the modelling of spatial freight transport demand based on data of Gernot Liedtke. This collaboration is very important to the proposal since Dr. Wisetjindawat has access to comprehensive data for freight transport demand that otherwise we would not have at the moment.

2.6 Descriptions of proposed investigations involving experiments on humans, human materials or animals – not applicable

2.7 Information on scientific and financial involvement of international cooperation partners – see Sec. 2.5

3 References

Adler, N. Hub-spoke network choice under competition with an application to western europe. *Transportation Science*, 39, 58–72, 2005.

Adler, N. and K. Smilowitz. Hub-spoke network choice under competition with an application to western europe. *Transportation Research Part B*, 41, 394–409, 2007.

Alexandrova-Kabadjova, B., A. Krause, and E. Tsang. An agent-based model of interactions in the payment card market. In H. Yin, P. Tino, E. Corchado, W. Byrne, and X. Yao, eds., *Intelligent Data Engineering and Automated Learning - IDEAL 2007*, vol. 4881, pp. 1063–1072. Springer Berlin Heidelberg, 2007.

Alkemade, F. *Evolutionary Agent-Based Economics*. Ph.D. thesis, Technische Universiteit Eindhoven, 2004.

Anderson, S. P., A. De Palma, and J.-F. Thisse. *Discrete choice theory of product differentiation*. MIT Press, Cambridge, Mass. [u.a.], 1992.

Armington, P. A theory of demand for products distinguished by place of production. International Monetary Fund Staff Papers, XVI (1969), 159-178, 1969.

Armstrong, M. Competition in two-sided markets. *RAND Journal of Economics*, 37(3), 668–691, 2006.

Arthur, B. W. Out-of-equilibrium economics and agent-based modeling. In L. Tesfatsion and L. Judd, Kenneth, eds., *Handbook of Computational Economics, Volume 2, Agent-Based Computational Economics*, vol. 2, chap. 32, pp. 1551–1564. Elsevier B.V., 2006.

Arunotayanun, K. *Modelling Freight Supplier Behaviour and Response*. Ph.D. thesis, Centre for Transport Studies, Department of Civil and Environmental Engineering, Imperial College of London, 2009.

Arunotayanun, K. and J. W. Polak. Taste heterogeneity and market segmentation in freight shippers mode choice behaviour. *Transportation Research Part E: Logistics and Transportation Review*, 47(2), 138–148, 2011.

Baake, P. and K. Mitusch. Competition with congestible networks. *Journals of Economics*, 91, 151–176, 2009a.

Baake, P. and K. Mitusch. Mobile phone termination charges with asymmetric regulation. *Journal of Economics*, 96, 241–261, 2009b.

Bae, M. J., E. P. Chew, L. H. Lee, and A. Zhang. Container transshipment and port competition. *Maritime Policy & Management*, 40, 479–494, 2013.

Baindur, D. and J. M. Viegas. An agent based model concept for assessing modal share in inter-regional freight transport markets. *Journal of Transport Geography*, 19, 1093–1105, 2011.

Beasly, J. E. Or-library: distributing test problems by electronic mail. *Journal of the Operational Research Society*, 41(11), 1069–1072, 1990.

Beckman, R., K. Baggerly, and M. McKay. Creating synthetic baseline populations. *Transportation Research Part A*, 30(6), 415 – 429, 1996.

Ben-Akiva, M. and G. de Jong. The aggregate-disaggregate-aggregate (ADA) freight model system. In M. Ben-Akiva, H. Meersman, and E. Van de Voorde, eds., *Freight Transport Modelling*, chap. 4, pp. 45–68. Emerald, 2013.

Brakman, S., H. Garretsen, and C. v. Marrewijk. *The new introduction to geographical economics*. Cambridge Univ. Press, Cambridge [u.a.], 2011.

Brendle, S. Ökonometrische Modellierung und Analyse von Einflussfaktoren auf die Losgrößenwahl im Güterverkehr. 2013. Bachelor Thesis, Karlsruhe Institute of Technology.

Brenner, T. Agent learning representation: Advice on modelling economic learning. In L. Tesfatsion and L. Judd, Kenneth, eds., *Handbook of Computational Economics, Volume 2, Agent-Based Computational Economics*, vol. 2, chap. 18, pp. 895–947. Elsevier, 2006.

Bröcker, J. Chamberlinian spatial computable general equilibrium modelling: a theoretical framework. *Economic Systems Research*, 7(2), 137–149, 1995.

Bröcker, J. Operational spatial computable general equilibrium modelling. *The Annals of Regional Science*, 32(3), 367–387, 1998.

Bröcker, J. Trans-european effects of trans-european networks: results from a spatial cge analysis. In F. Bolle and M. Carlberg, eds., *Advances in Behavioral Economics, Essays in Honor of Horst Todt*, pp. 141–157. Heidelberg: Physica, 2001.

BVU, TNS Infratest, and KIT. Vorläufiger Endbericht: Entwicklung eines Modells zur Berechnung von modalen Verlagerungen im Güterverkehr für die Ableitung konsistenter Bewertungsansätze für die Bundesverkehrswegeplanung. Draft final report for reserach project fe-projektnr.: 96.1002/2012, BVU Beratergruppe Verkehr + Umwelt GmbH and TNS Infratest GmbH and Karlsruher Institut für Technologie, 2014.

Cachon, G. P. Managing supply chain demand variability with scheduled ordering policies. *Management Science*, 45, 843–856, 1999.

Caplice, C. and Y. Sheffi. Optimization-based procurement for transportation services. *Journal of Business Logistics*, 24(2), 109–128, 2003.

Carrillo Murillo, D. G. *Demand and supply interactions in transport models: The case of hinterland transportation*. Ph.D. thesis, Fakultät für Wirtschaftswissenschaften, Universität Karlsruhe, 2010.

Carrillo Murillo, D. G. and G. Liedtke. A model for the formation of colloidal structures in freight transportation: The case of hinterland terminals. *Transportation Research Part E: Logistics and Transportation Review*, 49(1), 55–70, 2013.

Catullo, E. An agent based model of monopolistic competition in international trade with emerging firm heterogeneity. *Journal of Artificial Societies and Social Simulation*, 16(2), 7, 2013.

Cavalcante, R. A. *Freight Market Interactions Simulation (FREMIS): An Agent-Based Modelling Framework*. Ph.D. thesis, Graduate Department of Civil Engineering, University of Toronto, 2013.

Chow, H. K., W. Siu, C.-K. Chan, and H. C. Chan. An argumentation-oriented multi-agent system for automating the freight planning process. *Expert Systems with Applications*, 40, 3858–3871, 2013.

Collins, J., W. Ketter, and N. Sadeh. Pushing the limits of rational agents: The trading agent competition for supply chain management. *AI Magazine*, 31(2), 63–80, 2010.

Combes, F. *The choice of shipment size in freight transport*. Ph.D. thesis, Université Paris-Est, 2009.

Crainic, T. G. Service network design in freight transportation. *European Journal of Operations Research*, 122, 272–288, 2000.

Danielis, R., E. Marcucci, and L. Rotaris. Logistics managers' stated preferences for freight service attributes. *Transportation Research Part E: Logistics and Transportation Review*, 41, 201–215, 2005.

de Jong, G. and M. Ben-Akiva. A micro-simulation model of shipment size and transport chain choice. *Transportation Research Part B*, 41(Special Issue on Freight Transport), 950–965, 2007.

De Jong, G. and D. Johnson. Discrete mode and discrete or continuous shipment size choice in freight transport in sweden. In *Proceedings of the European Transport Conference 2009*. 2009.

Dimitriou, L. and A. Stathopoulos. Optimal co-evolutionary strategies for the competitive maritime network design problem. In *Applications of Evolutionary Computing: EvoWorkshops 2009: EvoCOMNET, EvoENVIRONMENT, EvoFIN, EvoGAMES, EvoHOT, EvoIASP, EvoINTERACTION, EvoMUSART, EvoNUM, EvoSTOC, EvoTRANSLOG,*. Tübingen, Germany, 2009.

Dixit, A. K. and J. E. Stiglitz. Monopolistic competition and optimum product diversity. *The American Economic Review*, 67(3), 297–308, 1977.

Figliozzi, M. A., H. S. Mahmassani, and P. Jaillet. Repeated auction games and learning dynamics in electronic logistics marketplaces: Complexity, bounded rationality, and regulation through information. In D. Helbing, ed., *Managing Complexity: Insights, Concepts, Applications Understanding Complex Systems*, pp. 137–175. Springer, 2008.

Friedrich, H. *Simulation of logistics in food retailing for freight transportation analysis*. Ph.D. thesis, Fakultät für Wirtschaftswissenschaften des Karlsruher Instituts für Technologie (KIT), 2010.

Fujita, M., P. Krugman, and A. J. Venables. *The spatial economy: cities, regions, and international trade*. MIT Press, Cambridge, Mass. [u.a.], 1999.

Gillen, D. and B. Mantin. Transport infrastructure management, one- and two-sided market approaches. *Journal of Transport Economics and Policy*, 47, 207–227, 2013.

Gopinath, D. A. *Modeling Heterogeneity in Discrete Choice*. Ph.D. thesis, Department of Civil and Environmental Engineering, Massachusetts Institute of Technology, 1995.

Graubner, M., A. Balmann, and R. J. Sexton. Spatial price discrimination in agricultural product procurement markets: A computational economics approach. *American Journal of Agricultural Economy*, 93(4), 949–967, 2011.

Guerci, E., S. Ivaldi, M. Raberto, and S. Cincotti. Learning agents in a monopolistic competition framework. In *Proceedings of the IEEE Congress on Evolutionary Computation (CEC 2007)*. Singapore, 2007.

Heppenstall, A. J., A. J. Evans, and M. H. Birkin. Genetic algorithm optimisation of an agent-based model for simulating a retail market. *Environment and Planning B: Planning and Design*, 34, 1051–1070, 2007.

Hertz, S. and M. Alfredsson. Strategic development of third party logistics providers. *Industrial Marketing Management*, 32(2), 139–149, 2003.

Holguin-Veras, J., M. Silas, J. Polimeni, and B. Cruz. An investigation on the effectiveness of joint receiver-carrier policies to increase truck traffic in the off-peak hours part i: The behavior of receivers. *Networks and Spatial Economics*, 7, 277–295, 2007.

Holguin-Veras, J., M. Silas, J. Polimeni, and B. Cruz. An investigation on the effectiveness of joint receiver-carrier policies to increase truck traffic in the off-peak hours part ii: The behavior of carriers. *Networks and Spatial Economics*, 8, 327–354, 2008.

Holguin-Veras, J., N. Xu, G. de Jong, and H. Maurer. An experimental economics investigation of shipper-carrier interactions in the choice of mode and shipment size in freight transport. *Networks and Spatial Economics*, 11, 509–532, 2011.

Holland, J. H. *Adaptation in natural and artificial systems: an introductory analysis with applications to biology, control, and artificial intelligence*. University of Michigan Press, 1975.

Holmgren, J., P. Davidsson, J. Persson, and L. Ramstedt. Tapas: A multi-agent-based model for simulation of transport chains. *Simulation Modelling Practice and Theory*, 23, 1–18, 2012.

INTERALP. Accessed 2014/04/28. `http://www.predit.prd.fr/predit4/upload/syntheses/41219.pdf`.

Ivaldi, M., S. Sokullu, and T. Toru. Airport prices in a two- sided framework: an empirical analysis. In *CSIO/IDEI, "10th Joint Workshop on Industrial Organization"*. Toulouse, France, 2011.

Ivanova, O., C. Heyndrickx, K. Spitaels, L. Tavasszy, W. Manshanden, M. Snelder, and O. Koops. RAEM: version 3.0 first report. Tech. rep., Transport & Mobility Leuven, 2007.

Jin, Y. and WSP Policy Research. The eunet2.0 freight and logistics model. Tech. rep., WSP Policy Research, London: Department for Transport, 2005. Regional Pilot for Economic/Logistic Methods. DfT Contract PPAD 9/134/24.

Jourquin, B. and M. Beuthe. Transportation policy analysis with a GIS: The virtual network of freight transportation in Europe. *Transportation Research C*, 4, 359–371, 1996.

Krajewska, M. A. and H. Kopfer. Transportation planning in freight forwarding companies: Tabu search algorithm for the integrated operational transportation planning problem. *European Journal of Operations Research*, 197(2), 741–751, 2009.

Kreps, D. M. and J. A. Scheinkman. Quantity precommitment and bertrand competition yield cournot outcomes. *The Bell Journal of Economics*, 14, 326–337, 1983.

Krugman, P. Increasing returns and economic geography. *Journal of Political Economy*, 99(3), 483–499, 1991.

Lee, H., M. Boile, S. Theofanis, S. Choo, and K.-D. Lee. A freight network planning model in oligopolistic shipping markets. *Cluster Computing*, 2013. Published Online: 11 October 2013.

Liedtke, G. *An actor-based approach to commodity transport modelling*. Ph.D. thesis, Fakultät fär Wirtschaftswissenschaften, Universität Karlsruhe, 2006.

Liedtke, G. Principles of micro-behavior commodity transport modeling. *Transportation Research Part E: Logistics and Transportation Review*, 45(5), 795–809, 2009.

Liedtke, G. Estimation of the benefits for shippers from a multimodal transport network. *Logistics Research*, 4(3–4), 113–125, 2012a.

Liedtke, G. *Modelling and Assessment of the Emergence of Logistics Networks*. Habil.-Schrift, Karlsruhe Institute of Technology (KIT), 2012b. KIT-Bibliothek, Signature: 2014 E 138.

Liedtke, G. and D. G. Carrillo Murillo. Assessment of policy strategies to develop intermodal services: The case of inland terminals in Germany. *Transport Policy*, 24, 168–178, 2012.

Liedtke, G. and H. Friedrich. Generation of logistics networks in transport models. *Transportation*, 2012.

Liedtke, G. and K. Nagel. Beiträge des Verkehrs zur Verwirklichung einer 2000W-City [Contributions of traffic to the realization of a 2000W city]. Project, German National Science Foundation (DFG), 2010–2015.

Liedtke, G. and A. B. Scholz. A life cycle cost approach to infrastructure cost calculation and allocation. *Transportation Research Record: Journal of the Transportation Research Board*, 2121, 13–21, 2009.

Liedtke, G., L. Tavasszy, and W. Wisetjindawat. A comparative analysis of behaviour-oriented commodity transport models. In *88th Meeting of the Transport Research Board (TRB)*. Washington DC, 2009.

Liedtke, G., W. Wisetjindawat, S. Schröder, and T. Matteis. Large scale multi agent simulation of regional freight transport with incorporated price signals. In *Proceedings of the 13th World Conference on Transport Research*. Rio de Janeiro, 2013.

Lüer-Villagra, A. and V. Marianov. A competitive hub location and pricing problem. *European Journal of Operational Research*, 231, 734–744, 2013.

Marasco, A. Third-party logistics: A literature review. *International Journal of Production Economics*, 113, 127–147, 2008.

Marks, R. Market design using agent- based models. In L. Tesfatsion and K. L. Judd, eds., *Handbook of computational economics volume 2: agent-based computational economics*, pp. 1339–1380. Elsevier, 2006.

Meixell, M. J. and M. Norbis. A review of the transportation mode choice and carrier selection literature. *The International Journal of Logistics Management*, 19, 183–211, 2008.

Mes, M., M. van der Heijden, and P. Schuur. Interaction between intelligent agent strategies for real-time transportation planning. *Central European Journal of Operations Research*, 21, 337–358, 2013.

Mitusch, K. Trassenzuteilung und konfliktlösung nach der neuen eibv: Anmerkungen aus volkswirtschaftlicher sicht. In M. Ronellenfitsch and R. Schweinsberg, eds., *Aktuelle Probleme des Eisenbahnrechts XII, Vorträge im Rahmen der Tagung am 6.–7. September 2006 in Tübingen*, pp. 196–197. Verlag Dr. Kovac, Hamburg, 2007.

Nagurney, A. Supply chain network design under profit maximization and oligopolistic competition. *Transportation Research E*, 46, 281–294, 2010.

Nandiraju, S. *Strategic Freight Transportation Contract Procurement*. Ph.D. thesis, University of California, Irvine, 2006.

Park, J.-K. *Railroad marketing support system based on the freight choice model*. Ph.D. thesis, Department of Civil and Environmental Engineering, Massachusetts Institute of Technology, 1995.

Planco, ITP, and TUBS. Grundsätzliche Überprüfung und Weiterentwicklung der Nutzen-Kosten-Analyse im Bewertungsverfahren der Bundesverkehrswegeplanung. Endbericht FE Projekt Nr. 960974/2011, Planco GmbH, Intraplan Consult GmbH, TU Berlin Service GmbH, 2015. Im Auftrag des BMVI. Auch VSP WP 14-12, see `http://www.vsp.tu-berlin.de/publications`.

Price, T. C. Using co-evolutionary programming to simulate strategic behaviour in markets. *Journal of Evolutionary Economics*, 7, 219–254, 1997.

Raothanachonkun, P., S. Kazushi, and W. Wisetjindawat. Estimation of truck origin-destination based on commodity flows. *Journal of the Eastern Asia Society for Transportation Studies*, 7, 1099–1113, 2007.

Riechmann, T. Genetic algorithm learning and evolutionary games. *Journal of Economic Dynamics and Control*, 25, 1019–1037, 2001.

Roorda, C., Mattew, R. Cavalcante, S. McCabe, and H. Kwan. A conceptual framework for agent-based modelling of logistics services. *Transportation Research Part E: Logistics and Transportation Review*, 46(1), 18–31, 2010.

Russo, F. and A. Comi. A modelling system to simulate goods movements at an urban scale. *Transportation*, 37, 987–1009, 2010.

Rysman, M. The economics of two-sided markets. *The Journal of Economic Perspectives*, 23(3), 125–143, 2009.

Samimi, A., Z. Pourabdollahi, A. Mohammadian, and K. Kawamura. An activity-based freight mode choice microsimulation model. In *91st Annual Transportation Research Board Meeting*. Washington D.C., 2012.

Samuelson, P. The transfer problem and transport costs, ii: Analysis of effects of trade impediments. *The Economic Journal*, 64(254), 264–289, 1954.

Sasaki, M. Hub network design model in a competitive environment with flow threshold. *Journal of the Operations Research Society of Japan*, 48(2), 158–171, 2005.

Schelling, T. *Micromotives and Macrobehaviour*. Norton, New York [u.a.], 1978.

Scholz, A. B. *Network structures of cargo airlines: An empirical and a modelling approach*. Ph.D. thesis, Fakultät für Wirtschaftswissenschaften des Karlsruher Instituts für Technologie (KIT), 2012.

Schröder, S. and G. Liedtke. Modeling and analyzing the effects of differentiated urban freight measures – a case study of the food retailing industry. In *Paper presented at the 93rd annual meeting of Transportation Research Board (Preprint Number: 14-5015)*. Washington D.C., 2014.

Schröder, S. and G. Liedtke. Towards an integrated multi-agent urban transport model of passenger and freight. In *Proceedings of the URban freight and BEhavior change conference, October 1st - 2nd 2015, Rome, Italy*. 2015.

Schröder, S., M. Zilske, G. Liedtke, and K. Nagel. Towards a multi-agent logistics and commercial transport model: The transport service provider's view. *Procedia – Social and Behavioral Sciences*, 39, 649–663, 2012.

Schulenburg, S. and P. Ross. An adaptive agent based economic mode. In P. L. Lanzi, ed., *Learning classifier systems: from foundations to applications*, no. 1813 in Lecture notes in computer science;, pp. 263–282. Springer, Berlin, 2000.

Selviaridis, K. and M. Spring. Third party logistics: a literature review and research agenda. *The International Journal of Logistics Management*, 18, 125–150, 2007.

Sen, S. and G. Weiss. Learning in multiagent systems. In G. Weiss, ed., *Multiagent systems: a modern approach to distributed artificial intelligence*, pp. 259–298. MIT Press, 1999.

Serra, D. and C. ReVelle. Competitive location and pricing on networks. *Geographical Analysis*, 31(1), 1999.

Shah, N. and J. K. Brueckner. Price and frequency competition in freight transportation. *Transportation Research Part A: Policy and Practice*, 46, 938–953, 2012.

Sharman, B. W. and M. J. Roorda. Multilevel modelling of commercial vehicle inter-arrival duration using gps data. *Transportation Research Part E: Logistics and Transportation Review*, 56, 94–107, 2013.

Sjoested, L. A conceptual framework for analyzing policymaker‘s and industry roles in the context of sustainable goods transportation. In P. Rietvelt, ed., *Barriers to Sustainable Transport*, pp. 198–222. Taylor and Francis Group, London, 2005.

Szimba, E., J. Ihrig, and M. Kraft. Inception report, high-tool deliverable d10.2. D10.2, Karlsruhe, 2013. Project co-funded by the European Commission under the 7th Framework Programme.

Szimba, E., M. Kraft, A. Schimke, J. Ihrig, O. Schnell, Y. Kawabata, S. Newton, T. Breemersch, R. Versteegh, J. van Meijeren, J.-X. Hu, C. de Stasio, and F. Fermi. Etisplus database content and methodology, etisplus deliverable d6. Tech. Rep. Reference: R20130045/C0002600/SNE/LJO/D6FINAL, ETIS PLUS Consortium, Zoetermeer, 2012. Project co-funded by the European Commission under the 7th Framework Programme.

Tanner, A. and K. Mitusch. Trassenvermarktung: Auktion versus listenpreisverfahren. *Internationales Verkehrswesen*, 63(3), 2011.

Tavasszy, L., B. Smeenk, and C. Ruijgrok. A dss for modelling logistic chains in freight transport policy analysis. *Int. Trans. Oper. Res.*, 5, 47–459, 1998.

Tesfatsion, L. Agent-based computational economics: Growing economies from the bottom up. *Artificial Life*, 8(1), 55–82, 2002.

Tsai, M.-C., C.-W. Yang, H.-C. Lee, and C.-W. Lien. Segmenting industrial competitive markets: An example from air freight. *Journal of Air Transport Management*, 17, 211–214, 2011.

Vriend, N. J. Self-organziation of markets: An example of a computational approach. *Computational Economics*, 8, 205–231, 1995.

Weidlich, A. and D. Veit. A critical survey of agent-based wholesale electricity market models. *Energy Economics*, 30, 1728–1759, 2008.

Wilson, J., J. Hill, M. Kersula, C. Wilson, L. Whitsel, L. Yan, J. Acheson, Y. Chen, C. Cleaver, C. Congdon, A. Hayden, P. Hayes, T. Johnson, G. Morehead, R. Steneck, R. Turner, R. Vadas, and C. Wilson. Costly information and the evolution of self-organization in a small, complex economy. *Journal of Economic Behavior & Organization*, Volume 90, Supplement, S76–S93, 2013.

Wisetjindawat, W., S. Kazushi, and S. Matsumoto. Commodity distribution model incorporating spatial interactions for urban freight movement. In *85th Annual Meeting of the Transportation Research Board, January 22-26, 2006. Washington D.C.* 2006.

Wisetjindawat, W., F. Marchal, and K. Yamamoto. Methods and techniques to create synthetic firm’s attribution as input to microscopic freight simulation. In *Proceeding of the Eastern Asia Society for Transportation Studies*, vol. 7. 2009.

Wisetjindawat, W., K. Sano, and S. Matsumoto. Supply chain simulation for modeling the interactions in freight movement. *Journal of the Eastern Asia Society for Transportation Studies*, 6, 2991–3004, 2005.

Wisetjindawat, W., K. Sano, S. Matsumoto, and P. Raothanachonkun. Micro-simulation model for modeling freight agents interactions in urban freight movement. In *Paper presented at the 86th annual meeting of Transportation Research Board*. Washington D.C., 2007.

Wisetjindawat, W., K. Yamamoto, and F. Marchal. A commodity distribution model for a multi-agent freight system. *Procedia - Social and Behavioral Sciences*, 39, 534–542, 2012.

4 Requested modules/funds

4.1 Staff costs

	WIV	ECON	NITech
1.1 Specification of the LSP agent and its interface to the S/R agent [WIV, ECON]	3	3	0
1.2 Specification of the Shipper/Recipient (S/R) agent [WIV]	3	0	0
2.1 Decision engines for the S/R agent [WIV]	4	0	0
2.2 Decision engines for the LSP agent [WIV]	4	0	0
3.1 Market in a price-based duopoly [WIV, ECON]	4	3	0
3.2 The Logistic Service Provider as a two-sided platform [WIV, ECON]	0	3	0
3.3 Market under monopolistic competition [WIV, ECON]	4	3	0
4.1 Test of functionalities with synthetic examples [WIV]	3	0	0
4.2 Test of Interaction Dynamics and Update Procedure [WIV]	3	0	0
5.1 Urban freight – Tokyo [WIV, NITech]	4	0	0
5.2 Urban freight – Berlin [WIV, NITech]	4	0	0
	36	12	0

WIV (Liedtke)

- **36 PM doctoral researcher (100%).** This position will be filled by Tilman Matteis (TM) (Dipl.-Wi.-Ing.; CV included). He has been working at DLR since February 2014. Before, he worked at ECON. He has experience with projects addressing questions of modelling demand in freight transport. In the course of the project he is going to complete his ongoing dissertation project.
- **36 PM student student research assistant (80h/month).** Student research assistants will support the doctoral researchers. They will primarily run the simulations and prepare the analysis of the results. If possible, they will participate in the programming.

ECON (Mitusch)

- **12 PM doctoral researcher (100%).** This position will be filled by Li Zhang (LZ) (Dipl.-Inf., CV included). She will work mainly in WP 3 that addresses questions of how to display questions of industrial economics in an agent based model. She has been working at ECON since February 2011 and programmed an agent based market model for road freight transport in Germany.
- **12 PM student student research assistant (80h/month).** Student researchers will perform supportive work, such as literature pre-search and data collection.

NITech (Wisetjindawat)

Dr. Wisetjindawat contributes to the project mainly by providing data on the firm population for the case studies in WP 5.1. This population data exists and is ready to use. The main work of Dr. Wisetjindawat will be the implementation and adaptation of a method for the generation of a synthetic firm population, its application to German data, and support in a population on a set up case study. These works will be done during intended mutual visits in Germany and Japan. Moreover it will be elaborated to which extent the methods for creating a synthetic firm population are adaptable to German data. The work with the data will also take place during a research visit, as there is the need for personal presence of both sides as the data sources are mainly in German.

4.2 Scientific instrumentation

Laptop 1 laptop × €1200 / laptop = **€1200** (see quote). We are planning an extended visit (30 days) with Dr. W. Wisetjindawat in Japan. The visit will be used for the execution of a joint case study. It is thus imperative that simulations can be run with fast turn-around. Bringing a laptop with a pre-installed system results by far in the most efficient use of the time of the visit. The laptop cannot be procured from base funding, since the corresponding position will be at TU Berlin where Gernot Liedtke, as S-professor, does not have any base funding of his own.

4.3 Consumables: not requested

4.4 Travel

The doctoral researcher (TM) will visit at least one international conference, e.g. Annual Meeting of the Transportation Research Board, International Conference on City Logistics, or the European Conference of Transport Research Institutes (ECTRI) , per year, and two (more local) workshops per year. We also request funding for one major conference and one workshop for the PI (G. Liedtke), and for one major conference and two workshops for members of the work group of K. Mitusch (KM) (combined). We estimate the cost of a conference on average as €1700 (averaging over European and international conferences, 5 days, travel €800, accommodation €400, conference fees €500). Concerning a (more local) workshop we estimate on average €1000 (travel €300, accommodation €400, fees €300).

Furthermore, we request funding for **research visits**:

- TM will visit Dr. Wisinee Wisetjindawat, in **Japan** once. The expected cost for the research visit are €3100 (30 days, travel €1500, accommodation €1600).
- Dr. Wisinee Wisetjindawat will visit Germany three times. The expected cost for each research visit are €3100 (30 days, travel €1500, accomodation €1600). The visits are necessary for the works on the development of a synthetic freight demand structure for Germany as outlined in the work schedule. Personal presence is necessary, as data sources are partially only available in German.

The overall travel costs are summarized here:

$3+1+1$ conferences for TM + PI + KM	€	8500
$6+1+2$ workshops for TM + PI + KM	€	9000
4 research visits	€	12400
total	**€**	**29900**

4.5 Publication costs

€ 750/yr × 3 yrs = **€ 2 250**.

4.6 Running costs for materials: not requested

4.7 Other costs: not requested

5 Project requirements

5.1 Employment status information

Mitusch, Kay, Professor, KIT Karlsruhe, permanent
Liedtke, Gernot, Professor, TU Berlin, permanent
Wisetjindawat, Wisinee, Assistant Professor, Nagoya Institute of Technology, permanent

5.2 First-time proposal data: not applicable

5.3 Composition of the project group

The department of commercial transport currently consists of 5 postdocs and 11 doctoral researchers. Some of them work on topics that are related to this proposal:

- Stefan Schröder, doctoral researcher, currently funded by the DFG project KEP-City (DFG reference number: CL 318/18-1 & LI 1729/3-1), will serve as a contact person for questions regarding the freight components of MATSim and the vehicle routing library jsprit.
- Daniela Luft, doctoral researcher, currently funded by the internal project PAKT III will be in charge of the calibration of tour planning as specified in WP3.1 of subproject 1.
- Tilman Matteis, doctoral researcher, currently funded by the internal project PAKT III will be in charge of the work in subproject 2.

5.4 Cooperation with other researchers

5.4.1 Researchers with whom you have agreed to cooperate on this project

Both sub-projects together involve four institutions that will be in tight collaboration. We will have, in addition, the usual scientific exchanges at conferences and through mutual visits, e.g. with H. Friedrich, E. van de Voorde, and T. Beckers.

5.4.2 Researchers with whom you have collaborated scientifically within the past three years

(This lists only scientists who have at least a Ph.D. Many of them are not related to freight transit modelling but are listed for completeness according to the instructions.)

Beckers, T.; Clausen, U.; Friedrich, H.; Furmans, K.; Pfohl, H.-C.; Raskob, W.; Schultmann, F.; Fichtner, W.; Weinhardt, C.; Winter, M.; Crozet, Y.; Macario, R.; Jochem, P.; Guihery, L.; Meersman, H.; van de Voorde, E.; Heinitz, F.; Rothengatter, W.; Celebi, D.

5.5 Scientific equipment

not requested

5.6 Project-relevant interests in commercial enterprises

not applicable

List of attachments

- CVs of principal investigators
- CVs of Dipl. Wi.-Ing. T. Matteis and Dipl.-Inf. L. Zhang, who are expected to work on the project
- Price quote for laptop
- Letter of intent from Dr. Wisinee Wisetjindawat