A Network-economical Analysis of the Freight Transport Market

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Abstract

When modelling the freight transport market for transport infrastructure planning purposes, a lot of challenges appear, which can be treated with the concepts and modelling techniques of the Network economics. The paper summarises empirical findings from interviews with transport companies and statistics about the market. The transport market is characterised by several forms of network structures: infrastructure networks, logistics and production networks and institutionalised transport networks (cooperation between middle-sized forwarding companies). Beside these well-established networks, relation-networks, ad-hoc co-operations and self-stabilising meso-structures play an essential role in the transport market. One focus of the paper are the processes that lead to the emergency of behaviour patterns: forwarders and carriers have to repetitively solve a complex planning problem and have to communicate with the clients. The contact with other dispatchers significantly enhances the action space of a transport company, but these contacts have to be seen in a competition context.

With the empirical and analytical findings it is possible, to build a kind of mental model describing the transport market. This kind of model can explain, why new technologies and other innovations (e.g.

communication technologies and e-commerce applications) diffuse only very slowly or how the structures will develop in the future.

In a last step, it will be shown, how the “modelling-techniques” of Network Economics can be applied in order to achieve a actor-based simulation of the transport market. Algorithms of the Operations research and behavioural learning – i.e. algorithms form engineer science and economics – are merged in order to achieve a model which is able to map in a realistic and computable way the behaviour of actors (i.e. their local decisions) in a network context of the freight transport system.

Keywords: Road Transport Market, Transport Modelling and Economics of Networks

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1. Introduction

In order to evaluate visions for traffic management and new tools to enhance freight transport related operational decision and communication tools, the German Ministry for research and education has funded the project OVID (enhancing the availability of self-organisation of the transport system with information and communication technologies). In the passenger research part of this research, the well-known approaches of micro simulation of individuals can be used for modelling the mobility behaviour of people; such approaches are difficult to be implemented as the freight transport market is a network market. A detailed and relatively qualitative market analysis is carried out in the following with the aim of deducing mental and rule-based simulation models for mapping freight actors’ behaviour. The following analysis and representations are based mainly on interviews with experts and practitioners.

2. The freight transport market

2.1. Actors and networks

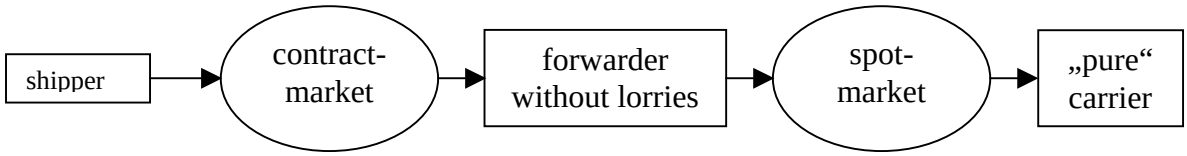
The freight transport market is a service market. The transport market consists – as each market– a certain number of suppliers and consumers. On the demand side, companies want to have goods moved in the space. On the supply side, transport companies offer transport capacities. These are the actors in this market and they behave according to their own interests. They are “optimisers” for themselves under consideration of the fact that the others are optimising their benefits for themselves.

- The *sender* or *shipper* is the source of a transport. A shipper is in the most cases a production side, a distribution centre or a trading company.
- The *receiver* is the sink / drain of a transport.

In most cases, either the sender or the receiver plays a more active part in the transport process than the other one, which means e.g. that he decides about the transport conditions or the transport company. On the supply side of the transport market, the most important players in transport are following actors:

- hauliers or carriers providing the physical transport service,
- forwarders negotiating between the shippers and the carriers (if involved) and more and more offering additional services to the customers and
- own-account-shippers operating their own lorry fleets (they fulfil a double function and are at least temporally "outside" of the transport market(s).

The general market structure is visualised in the Figure 1.



Source: Friedrich (2003)

Figure 1: The basic structure of the freight transport market

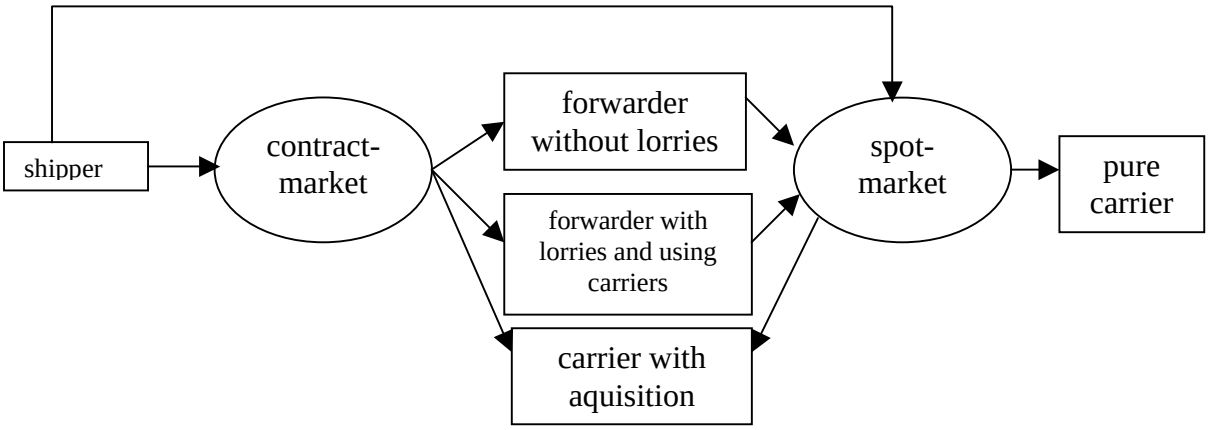
Shippers conclude contracts of durations between one year and two years (in the case of more specialised transports) with a forwarding company. The forwarding company assigns the shipments to carriers. Three basic operations can be roughly distinguished:

- Full-load: If the shipment is a full-load, not many coordination is necessary. The shipment is directly given to a carrier.
- Part-load: The forwarder tried to combine several shipments to an outgoing, consolidated lorry. From interviews carried out in OVID with logistics consultants and dispatchers, the most current operation schema is to collect the shipments in the forwarder's region using

small lorries during the day. The shipments are consolidated and assigned to the outgoing heavy lorries, which are send into the regions of activity of the forwarder, e.g. “the logistics specialist for Eastern-Europe”. The shipments are arranged in a way, that subsequent unloading at the receivers’ gates in the destination region is possible. The real value-adding lies in the disposition activity; the carriers get relatively low margins. They are also responsible for getting back-loads. Sometimes they are included in a reverse process, but often they have to look for loads on the spot-market, i.e. in a freight platform on the Internet.

- Piece-goods: These are shipments below 1,5 tons. They are collected in the region of the forwarder and consolidated according their destination. However, it would be too costly to use the large lorry for the distribution activities. Three possibilities are current practice: (1) There exits an office of the forwarding company in the destination region, (2) there is a piece-good network partner in the destination region and (3) a local partner must be assigned who however reduces the profit. In most cases, a direct transport to a network partner or a branch can take place. For about 10-20% of the transports pass through logistics centres operated by the network. In Germany, about 5 piece good networks exist and two large forwarding companies whose branches are covering the country.

In reality, the markets’ organisation is more complex. Forwarders are operating own lorries. Until the liberalisation at the beginning 1990ies, a relatively high price level for freight existed and operating the own fleet could make large profits. After the liberalisation, forwarders tended to concentrate on their core business, i.e. organising. However, some operations are highly regularly and paired and they can be operated more efficiently by the forwarder himself. There exist also forwarders, with shipment acquisitions, mainly full-loads. Figure 2 is a simplified representation of the “real” market.



Source: Friedrich (2003)

Figure 2: The expanded structure of the freight transport market

2.2. Selected network structures

In the freight transport, various kinds of network structures can be identified: These are the transport market as a network market, the supply-chain as a part of an inter-company-network and distribution systems as a intra-company logistics-network.

The transport market as a network-like market is organised as follows: a shipper generally knows more than one forwarder. A forwarder knows many shippers. The freight transport market in fact is a network market with generally two levels (cp.Figure 3).

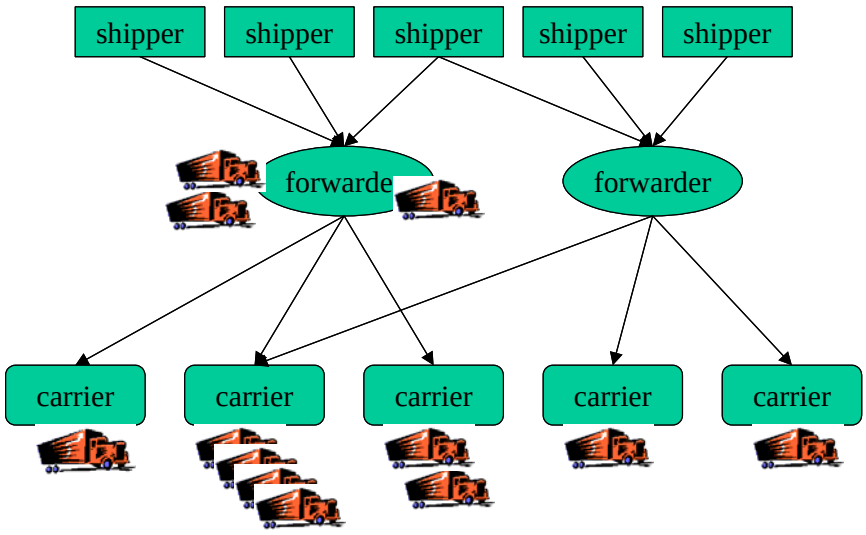


Figure 3: Transport market: Shipper - Forwarder - Carrier.

The forwarder-carrier relation can be described as a competition situation. The forwarders depend on the services offered by “their” carriers on certain relations. The forwarders often know the production schema of the carriers, i.e. on which relations they circulate and which other clients they have. Therefore, they have a good “feeling” for the costs of a shipment. They also know, where to “put” shipments. In interviews carried out, a typical statement of the forwarders is: “we give them just the money that they need for surviving”. The competition between the carriers is extreme and the offer is currently larger than the demand. It depends on the capacity of the carriers to find suitable and regular combinations of orders. Carriers with low “logistics competence” will fall out of the market in a close future.

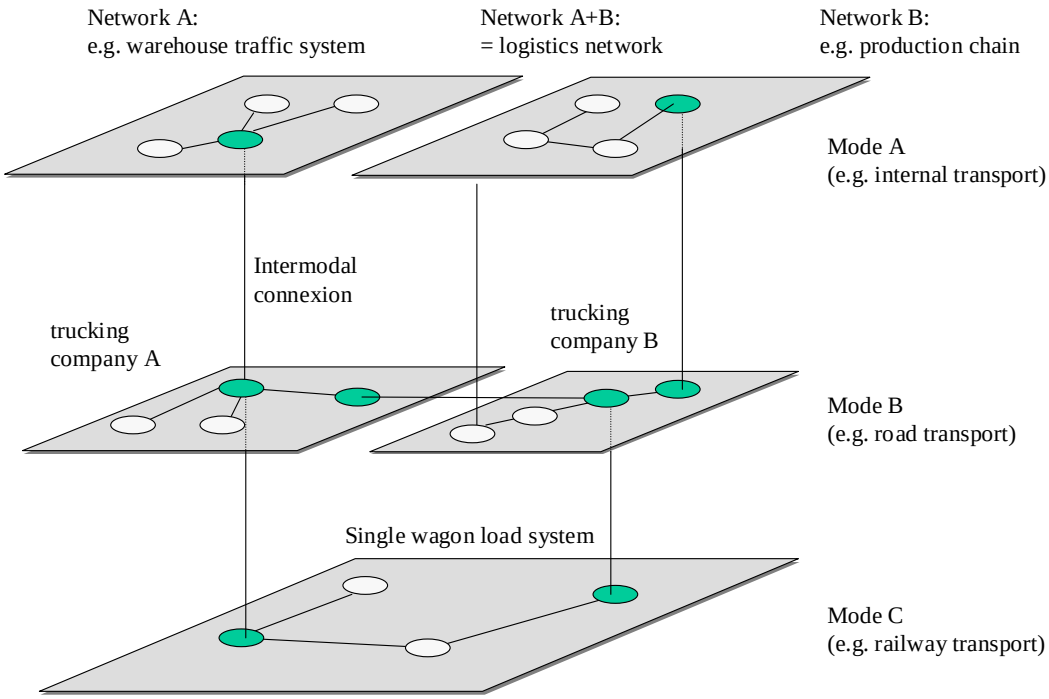
The companies however have generally no contact with the “pure carriers”. They depend on the know-how of the regional forwarder. In the context of new Information technologies such as the Internet freight exchanges, there is a strong opposition of the forwarders to prevent too much market transparency (Meder (2004)). In fact, the spot-market platforms are settled between the forwarders and the carriers; they deal only with back-load optimising – other ones would not be accepted in the sector. In the next section, it is discussed, how they can catalyse new relations and operation schemes – the meso-structures in transport.

Beside the vertical relation networks in the freight transport market, other networks structures can be identified.

Transportation networks arise from operations planned by an actor between harbours, airports, transhipment points etc. (Rodrigue (2004)). Physical infrastructure elements are only selected components of the superior transport network.

Production lines or value adding chains – can also be considered as a networks. The so-called *supply chain* is a integrated interplant value adding system which generates goods for a certain market (Net-Lexikon (2004)). When interring the expression “chain” in a narrow sense, the supply chain is a “cut” of the tree structure. In general, companies have different suppliers and customers. A *distribution system* of the good flows consisting of one or several levels of transhipment and storage centres is an example of an ideal tree structure. In the same way, also the logistics chains and the tree-like structures are parts of a super ordinate network structure and between companies (cp. Berster (1993)).

The transport networks and the logistics networks interact in reality. However, this is often a weak interaction. The “transfer conditions” are fixed in form of a contract. For daily operations, a so-called “time-window” describes the interlinking of two independent planning systems. Figure 4 visualises the relation between inter- and intra-company logistics networks, transport networks and the door-to-door transport chain that is build by a transport logistician between different transport networks on different modes.



Source: Adapted from Ohnell (2003)

Figure 4: The relation between logistics networks (intra- and inter-company) transport networks.

In the preceding two figures it is possible to recognise a kind of *complementarity* between the logistics and the transport systems, which was identified by Sjösted (2004). In this context, complementarity means, that when analysing or modelling the transport or the logistics system, the information about the structure of the complementary system is automatically getting lost. The *logistician* is interested in a reliable flow of products and information. The logistician does not “see” the transportation system as a whole, but he considers only some “cuts” of it. For him, it is not from interest, how and where a good is transhipped or how the carrier deal with the problems on the roads. The carrier must be cheap, reliable and flexible. As Sjöstedt points out, that one logistics system is generally served by one or

several transportation suppliers. The *transportation supplier* on his part does not "see" the logistics systems as a whole. He only knows the transfer points and the related operations.

2.3. Market structure in freight transport

In spite of the complementarity between the transport supply and demand side, shippers chose explicit markets when shipping something and transport companies can be classified according to a certain market activity. A transport market is characterised by the good characteristics (mass-good, unitised), the behaviour and tour-patterns and sometimes the institutional form of the customers.

The first distinction refers to the lorry being used and to the combination of shipments. The second distinction is important for traffic planning purposes, as different time-space-patterns result form the tour-patterns. The third distinction refers to the observation, that in trade, the retailing companies have dedicated distribution tours which are given in form of contracts or which are operated by own-account. The schema presented in Table 1 has been developed with regard to a microscopic freight transport model by Liedtke and Schepperle (2004) and is based on the concepts of Klaus (2003).

Table 1: The Transport Markets

Segment	**Sub-segment**	**Further sub-segmentations with regard to transport generation part**
General Cargo	Full-lorry loads part loads	Investment goods Consumer goods Production goods Production goods
Piece Goods		
Courier and express parcel services		
Liquid bulk transports	Food Chemicals and fuels	Collection Full-load Distribution Full-load
Solid bulk transports	Food (e.g. wheat) Sand, eath, stones and ores Scrap Waste full-load	
Own account inter-plant transports		According the type of industry
Contract Logistics Consumption	Non-food discounter distribution Vegetables distribution Frozen-goods distribution Beverages distribution	
Contract Logistics consumer durable	low value White & Brown-ware, furniture	
Frozen-goods full-load		
Vegetables full-load (cold)		
Container transports	Swap-bodies Sea-container	
domestic waste collection		
relocation		
other (mainly regional transports)		

2.4. The role of meso-structures and behaviour patterns

This section analyses the causes and processes which are responsible for the building and emergence of the logistics and transport systems, which are designated as the *meso-structures in the freight transport.* Sjöstedt points out the importance and the impact of these meso-structures in the context of transport modelling. Meso-structures in transport correspond to regular and spontaneous emerging transport logistics structures – they are either the result of a network planning (for network planning in logistics s. e.g. Domschke et al. (2002)) or be generated by the emergency of behaviour routines of the actors (for the concept of self-organising networks s. e.g. Kirman (1992)).

A pattern is in general a set basic characteristics of objects or more abstractly “a set of rules”, which can be used for classification and “generation of objects”. The simplest patterns are “based on repetition” of the same template (wordiq.com (2004)). The importance of recognition, learning and behaviour pattern emergency in the context of analysing the transport system was recently pointed out by Manheim (1999). A behaviour pattern in transport and logistics is defined as a regularly repeating operational transport logistics decision and the resulting process and which can be identified (in a similar way) at many actors.

Which patterns can be distinguished? First of all, transport logistics behaviour patterns describe the way a transport company acts on the market. Concretely, this means before all the planning behaviour, which includes the way of communication with the customers (i.e. the shippers), the planning and complex combination of tours (i.e. tour-building heuristics) and the organisation of the transport itself (i.e. communication with the drivers, short-term reactions). There is a certain (but not unique) relation between the behaviour pattern and the transport market segment, in which a transport company is active. For example, in the piece good market segment, a typical behaviour pattern can be observed all over Europe: The requests for shipments are coming in the day before the intended pickup into the regional dependency. The pickups in the area of the dependency are put together to pickup-tours, which are similar from day-to-day (e.g. south-tour, northwest-tour, Frankfurt-tour). This type of operation will be designed as the *pickup-pattern*, which can be found in other transport markets.

In the afternoon, the lorries come in and their freight is sorted according to destination directions. In order to transport the shipments, several possibilities can be observed: Either, a regular shuttle service

is organised between the dependencies of the transport company or between partners, which organise the deliveries (*shuttle-tour pattern*). In this case, the containers or semi-trailers are often exchanged with the corresponding lorry at half-distance. Or the goods are transported to a central logistics centre in which a following sorting and consolidation procedure occurs. The third possibility is to deliver the goods directly in the destination region with the long-distance lorry and to unload the shipments successively at the customers' gates (*consolidation pattern*).

The combination of different shipments and the feed-backs in form of the price to the customers result in a selection and stabilisation of certain ("suitable") operation patterns. For example, the forwarding company ITC near Stuttgart reports from its experience a regularly tour in which it participates: A trucking company only serves a tour to Britain once a week. It starts from southwest Germany to Manchester every Tuesday and the shipments (around ten to fifteen) are subsequently unloaded between London and Manchester. Regularly, at least a half load is then transported from Manchester to London. A second half-load is additionally picked up in London on Friday at the late afternoon. On Saturday, very early at the morning, the first of these half-loads is transferred to a French partner, who will carry it to Lyons. In exchange, small boxes bound for Munich are loaded. This load is later transferred to some other partner at the starting point in southwest Germany. This complex collaboration of transport partners, which is regularly repeated, could be considered as a meso-structure in transport. Once, such an operation schema is found, it has a good chance to survive over a long time, because it minimises the communication (transaction costs) and the price. Even for a European big player it is difficult to offer better conditions to the partners – unless he does below cost covering level. Therefore, these meso-structures may become extremely stable for a certain time. They break off, when one of the participators exits. Because of the meso-structures, sometimes the decisions of a single actor can have strong impacts on the whole network. An example is rail freight networks: if one or more elements are stopping shipments by rail, operations on whole sub-networks (e.g. a regional branch line) are influenced and sometimes stopped. Concluding, it can be stated that the meso-structures in transport are the result of try and error operations over time, where the total costs (including planning and transaction costs) are minimised. They influence the way, lorries move on the infrastructure networks. Therefore, they must be considered in the microscopic freight transport

modelling. The emerging meso-structures depend strongly on the degree of regulation of the transport market, its history and the spatial structures: In countries with a low population and industry density such as Ireland, some markets are served by only one or two transport operators, because they can build up one or two own meso-structures, which are more efficient as the set of meso-structures of several companies. In contrary, in densely settled countries such as Germany, several companies without any significant cost difference could operate the same transport order. The building of the meso-structures can be considered as the effect of a self-organisation process in the transport system. The functional chain between the decisions of the shippers, forwarders and carries leads to the emergency of self-organised transport system structures, which may also influence the building of the infrastructure. By this way, also the building of infrastructure can be partly considered as the result of a self-organisation process in the transport system Information and communication technologies

3. What can rail learn form the road?

The meso-structures play an important role in the road sector. In the railway industry, national and monopoly thinking resulted in the a concentration on a massification, standardisation and centralisation. A main concentration of the railways is to bundle freight flows between the marshalling yards. In contrast, the regional access to the railroad infrastructure is getting more and more worse. This approach corresponds to the hub-and-spoke concepts of the large, mainly (ex-)state-own airway companies. However, in this sector, the two strategies “building of a centrally planned network” and “direct flights” are existing and will probably exist also in future.

In railways, contradicting approaches to the massification production form are the so-called Logistics-Trains and private wagon-load-networks. Private wagon-load-network were introduced, because of the withdrawal of established railways from the market segment of single-wagonload transports. In a first step, these networks were took over the collection and handling in one certain area. Long distance transports were offered via the (former) state railroad. The exchange of freight-wagons took place at major marshalling yards. Due to the low rates, complex handling and difficult infrastructure access, most of these networks failed in the market. In a second step, branch specific networks came up. In the last couple of years companies serving the chemical, steel, automotive, oil, paper and lumber industry have entered the marked. Most companies serve mainly only one or two of the named industries. All

of these logistics-networks are national; some have spread out all over Europe. Key for the success is a deep understanding of the logistical processes of the relevant industry. Because of the relatively small amounts of clients, customers can be informed continuously about progress or failures of the transport chain. There is no need to be afraid, that all kind of actors – such as regional railways, wagon-load-network operators – are not able to build up efficient ad-hoc meso-structure-like production forms. However, road transportation as well as air transportation shows, that it is possible and necessary, that both "self-organised" and "centrally-planned" structures must exist in parallel (e.g. the piece-goods exchanged directly between network partners and the piece-good passing through a central logistics centre). As the large railway operators have a monopoly, there is a need for regulation until parallel production networks exist.

Another lesson can be won by comparing market structures of the road sector in low-density countries such as Ireland or Sweden. In these countries, regional monopolies emerge in the piece-good collection and distribution. The situation of the rail sector outside of the large agglomerations can be compared with the road sector in rural countries.

The third lesson concerns the internal structure of the German Railways, which now has been split into branch specific freight transport companies. If there is no "communication" between the sector railways and production forms, meso-structures i.e. closed, fast circulations cannot be established and many empty-running is resulting.

4. Simulation model of the freight transport market

A microscopic simulation of the transport system is made difficult by the complementarity between the logistics and transport system: when micro-modelling the behaviour of a supply chain together with the road-transport-related decisions, also other shippers and demand systems must be considered in a micro-model. However, when applying operations optimisation models for simulating the actors' decisions and the tour-planning,

In eight interviews carried out with established middle-sized forwarding companies (e.g. Friedrich (2003)), in any case, an automated dispatching system was applied. Instead, the personal intuition and

negotiations at the telephone played an important role. The building of meso-structures is more important than a process optimisation.

Therefore, an adequate solution for modelling the freight transport system is the so-called agent-based approach: actors are simulated in form of software objects which plan their individual logistics or transport system and which interact. They have an own intelligence. This task is currently carried out at the IWW. Instead of solving highly complex operation tasks, a market is getting simulated. The explicit use of the concept of meso-structures has following advantages:

- The dispatcher and the carrier remembering solutions form the past can use them for as knowledge for actual decisions.
- Routing with “insertion” concepts is an adequate and reality-like heuristics for modelling a large number of decisions makers and lorries.
- Decisions under uncertainty can be modelled because in a situation of dynamic routing past outcomes give decision indications.
- Calculation (simulation) time becomes reasonable.

Actually, the simulation model has following (very simplified) object structure:

- Network: responsible for shortest-path-search, the “memory” of the shortest paths and for the structural data, which is used to generate companies using a Monte-Carlo-algorithm.
- Forwarders: they are operating the lorries, have dependencies and can memorise routing solutions. The roles of carriers and forwarders are mixed.
- Shippers: they are generating shipments according to their output-rates and try to bring them in form of contracts to the transport market. As the production rates are outcome-defined, the supplier-consumer relation generation is not entirely a supplier-search. The shipments are generated applying simple production-planning algorithms (optimal lot-size calculation).

A screen-shot of the actual model is shown in Figure 5.

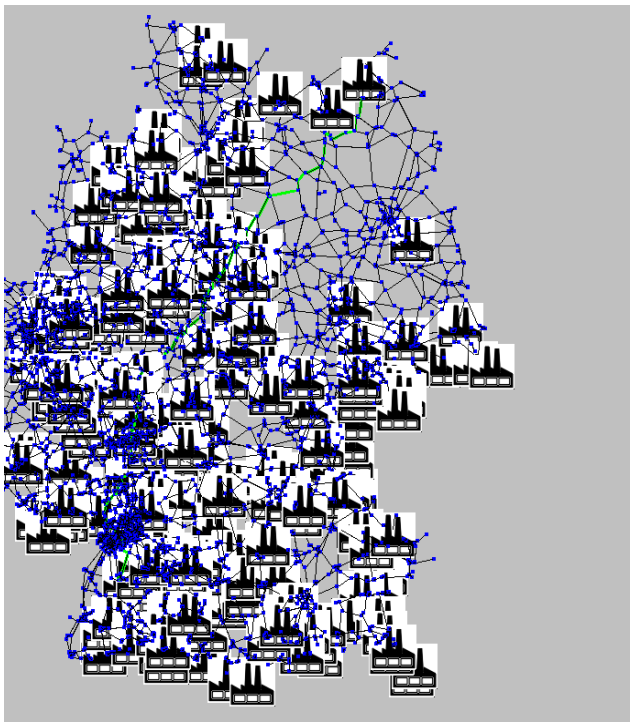


Figure 5: Screen-shot from the actor-based freight simulation model at the IWW.

Conclusion

The paper started from the observation that the transport market is characterised by more than two groups of actors – shippers, receivers, forwarders, carriers etc. Because of this multi-agent property and the tasks of logistics and transport, network-link structures emerge on the demand and supply side. For system analysts, a certain complementarity between the systems arises from the property, that there are in few cases unique relations between the networks. However, in policy planning concerning freight transport, this properties of the freight transport market must be kept in mind. From a special interest are the meso-structures of transport, which explain, why the sector is very resistant to new technologies, to a further acceleration of the processes – because these organisation structure offers a minimisation of planning costs (mental capacities), a flexible network-building and the accumulation of specific knowledge which is important for the actors (e.g. a shipper must not know the traffic conditions and the best path for his freight).

The thinking in meso-structures enables the possibility to critically re-think policy in the rail sector and it opens the way for building up simulation models of the transport market. A future task remains in the traducing of human heuristics into computer-ones.

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