MODELLING EFFECTS OF ADVANCED INFORMATION TECHNOLOGIES ON DECISION PATTERNS OF SHIPPERS AND FORWARDERS

Gernot Liedtke, and David Schmedding
Institute for Economic Policy Research, Transport and Communications Unit (IWW)
University of Karlsruhe (TH), Germany, Phone: ++49 721 608 4415
liedtke@iww.uni-karlsruhe.de

Abstract

Transport models are used to estimate the expected effects of traffic policy measures – such as infrastructure building and upgrading or the introduction of a highway toll – on the users of a transport system. The results of transport models are a necessary input for cost-benefit-analyses.

In passenger transport modelling, the activity-based approach links peoples' daily behaviour schedules with their movements through time and space. Traffic – as a macroscopic phenomenon – can so be explained as the resulting sum of many individual decisions. In the modelling of freight transport, the state-of-the-art method still is the aggregate or functional approach, which concentrates on regions/traffic cells and indicators (such as the value added by economic sector and region) instead of individual logistical decisions. The transports are losing their relation to the responsible decision-makers. There is still a lack of suitable actor-based micro-models in order to adequately model the freight transport system. Having a microscopic modelling base for the goods transport would be a significant improvement for transport forecasts and the assessment of policy measures.

This paper describes the some points for a microscopic modelling of the freight transport: The use of avilable data and the mapping of multi-agent decisions in freight transport. The simulation interLOG uses elements of actor-based programming and constraint logic programming (CLP) methods in order to model the generation and the operation of freight transport. It is especially designed for modelling the impact of information and communication technologies on transport decsiosions. The paper focuses on the description of market structures and behaviour patterns.

Keywords: Activity-based freight transport modelling; Economics of networks; Traffic assignment; Agent-based modelling; Shipper behaviour
Topic Area: D6 - Travel and shipper behaviour research

1. Introduction

In order to evaluate visons 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). One of the work items is the conception of an actor-based freight transport model and its software realisation. Experiences and some results of this modelling process are presented in this paper. It deals with calibration questions and with the description of the actor behaviour. First ideas for mapping this behaviour in a market simulation, are skteched.

2. The transportation market as a system

In order to develop a microscopic framework for modelling the freight transport, the model object itself and associated images shall be shortly presented. Before modelling the freight transport system, one should be aware, that it can be seen from different perspectives. Freight transport can be considered as:

- a combinatorial optimisation problem,
- a network: logistical network, hub-and-spoke, distribution system,
- a competitive game,
- a market,
- a production resource,
- as a part of logistics,
- as cause for traffic and congestion and
- as a relational, spatial directed process.

These views depend of the standpoint, e.g. if an economist, a logistics manager or a traffic planner describes the freight transport system.

From a system theoretical point of view, a system can be composed into a macro-level and a micro-level. In some systems, a meso-level must be taken into account, in cases when one cannot switch from the micro-level to the macro-level by simple summation. In transport, the micro-level corresponds to the single actor. These are individual companies and the carrier companies whose aims are to make profit. The macro perspective corresponds to the views of a traffic planner, a regional planner or a traffic system user confronted with congestion.

In freight transport, also a meso level and its structures should be considered in a microscopic modelling. Meso structures in transport correspond to regular and spontaneous emerging transport logistical structures, in which many actors are participating. An example is a tour, where loads from different origin-destination-relations are regularly consolidated. Transport shows some very strong system and network properties: The decisions of a single actor can have strong impacts on the whole transport logistics network, e.g. a logistic train may have to stop operating, when an important shipper switches to another mode, because the reduction of volume causes inefficiency. Another observation confirms the picture of the transport network as a system: In countries with low industrial density, the transportation market tends to regional monopolys whereas in the contrary case, a complete competition is established.

Because of the system properties of the transportation market it is not adequate to use the well-known economic concept of the “representative company” without its market interactions when trying to deduce traffic flows from the actors’ individual behaviour. The strong system property makes commodity transport modelling different from passenger transport modelling. However, the principle construction of a model concept “activity-based freight transport modelling” is possible.

3. Definition of the activity-based approach

From a scientific point of view, the use of the expression “activity” is not very appropriate, when describing the basic actions in freight transport. The human activity “shopping” as a process over time with a defined outcome cannot be compared with the decision concerning a shipment. However, as the expression “activity-based” is already used in the freight modelling context, a broader definition – with some tolerance – can be given.

> *Definition:* The activity-based modelling approach of freight transport explains, how individual operational decisions concerning logistics and transports are undertaken, in

order to give indications to a traffic planner, how the whole transport system reacts to trans-national and federal transport policy measures.

The activity based modelling approach is designed for supporting a traffic planner and a policy maker. It does not optimise companies' behaviour - it only describes it. The aim is to deduce complete traffic flows and at least exemplary actor reactions in the context of the whole system. It concentrates on single decisions and therefore on traffic point sources. That means, that generation rates instead of production functions are the starting point of traffic generation. As the number of companies of a certain type in a traffic cell is very small, a microscopic modelling is more suitable than a macroscopic transport generation with traffic cells.

The question of the optimal location choice is not part of the activity-based freight modelling framework. The mapped decisions can be described by following variables: shipment sizes, transport distances (sourcing relations), lorry types and tour types.

4. Selected challenges related with activity-based freight transport modelling

Because of the system properties of freight transport system, a variety of questions arise: What structures have to be mapped: senders, receivers, forwarders, operators and transport logistic providers (e.g. courier and express services), tours and how can they be categorised? The next question is, how the above-mentioned meso-structures can be taken into account. Are they "given" or do they "emerge". Which structures are relevant? Additionally, as economic data has special requirements concerning privacy, the question is where to find data sources.

Activity-based freight transport modelling is relatively simple when dealing with inner-agglomeration traffic caused by artisans, salesmen and distribution lorries etc., because the driver and the lorry describe daily closed loops: by tracing the lorry, the actor and his activities (loading, unloading, repairing, visiting…) are also followed; these activities themselves are the causes for the traffic activity. Because of this property of the "economic travel" some models similar to the passenger ones have been developed. But how for example should the largest market segment in freight transport, the long running transports with no special handling requirements, be treated?

In this market segment of freight transport, it is also important to keep some of the principal differences to the activity-based passenger transport modelling in mind. In passenger transport, the generator of an activity is always the one undertaking it as well. In the segment under consideration, the transport is generated by a receiver, how orders a commodity, which a sender generates. The conduction of the transport can be done by a group of several actors:

- The shipper himself using his own lorries,
- a hauling company, assigned by the shipper, transporting the goods themselves,
- a carrier, assigned by a hauling company or
- by a carrier, assigned by the shipper.

The explicit treatment of the actors is very crucial in large market segments, because the operations and the resulting traffic volume may be different (e.g. back load problems and transfer trips). A measure of a traffic planner can have very different affects on the actions of each of these actors, in effect distorting the effect of the traffic measure. Economically spoken, there exist various adaptation possibilities of the individuals on a policy signal. An activity-based transport model must therefore be goal-oriented and focus on the intended results and the addressed group. Especially when building a microscopic model for supporting traffic planning questions, there must be found an adequate level of resolution concerning the categorisation and the mapping of the market interactions and resulting meso-structures. The next sections are designed to describe the necessary steps to achieve the proper focus and to give answers on these questions by explaining important methodological spots of the model "interLOG".

4.1 Categorisation of the shippers

As the generator of a shipment (= the "activity" in freight transport), the shipper must be categorised according to his output of goods. The categorisation must focus on factors such as type of goods (important for the transport process), output rate and output frequency. A categorisation must be complete and disjoint. This means, that for each source and drain of transport a category must exist and it must be unique. Companies are classified according to their economic activity. In reality, companies have two roles: they consume and they produce goods (source and drain). The economic activity is generally expressed in terms such as: "production of household ceramics". The cpa-classification (**c**lassification of **p**roducts by **a**ctivity) is an international standard which is building a complete hierarchy (European Union, 2001) consisting of divisions, groups and classes. Important is the two-digital level (the divisions): The trade volume (in monetary units) between these divisions and the end consumer is available from the national accounts (input-output-matrix). The three-digital level is also very important: the information about companies, their address and the number of employees is available from regional sources or professional databases. The number of employees on a NUTS-3 level is also officially available. The cpa enables the description of companies by the product they produce. Table 1 gives some examples of output rates for some three-digital sectors. These have been generated by estimating the specific weight of the produced goods which are multiplied with the annual production which is available on a federal level (Friedrich, 2003). In many cases, the production in tons is directly available.

Besides the sector of a company, the size (to be measured e.g. in the number of employees) is also essential when characterising companies (Kaspar et al., 2000) points out.

Table 1: Examples for output rates. Source: IWW calculations based on the German production statistics.

Sector number	Description	Annual production in tons	Nb. Of employees	Annual tons per employee
159	Beverages	33.997.451	80.500	422
311	Production of electrical generators/motos	1.100.000	140.500	7
343	Automotive Supplier	6.856.552	209.600	32
365	Production of toys	190.000	14.800	12

However, using the cpa-classification, the trade and distribution is not adequately mapped. In order to achieve this, new classes of homogeneous drains must be defined. From a modelling point of view, there is no difference, if transhipment is performed in a distribution centre operated by a producing company or by trading companies. Although the trading companies are significant drains and sources for transports, a classification of them cannot be very fine because of the data availability. A very aggregate segmentation schema is given in Table 2: A suitable level of detail for grouping "similar" trade segments are groupes of the 4-digit cpa-level.

Table 2: Basic aggregated types for economic activities.

1	Agriculture
2	processing of agriculature products
3	trade with food and retailing
4	extraction and import primary resources
5	production of preliminary goods
6	Production of intermediate goods
7	Production of consumption goods (department store ware)
8	Production of consumption of long-living goods
9	Production of investment goods
10	Production of building materials
11	waste
12	Production of chemical base products
13	Production of chemical products
14	trade with daily consumption goods
15	trade with investment goods and building materials
16	trade with production goods

4.2. Definition of the transportation markets and pattern recognition methods for identifying market clusters

After having defined the sources and drains for transport as the companies - classified by the cpa - and distribution centres, the next step is to classify the market of transportation services into appropriate segments. These segments do not necessarily correspond to the categorization of the shippers, because the carrier does not care about the type of goods, as long as he can combine it in the current transport mode. Therefore, the transportation markets should be segmented according to the transport mode of the goods, which is defined by factors such as handling categories, distances, shipment size and the resulting combinability. Therefore, the transport market segmentation according to Klaus (2003) is a suitable basis for classifying transport operations:

- General cargo: requres no special handling and can be combined with any other general cargo. It is usually transported on pallets and makes up the largest part of the german tranportation market (in tkm). It can be divided into piece cargo of up to 1,5 t and larger loads.
- Bulk transport: mostly earth, stones and other construction goods. Makes up a large part of the transport volumina but is only transported over short distances.
- Silo goods: trickling-goods such as cement and other building material, chemical or agricultural goods.
- Tank goods: liquid goods that are transported in tank lorries such as agricultural products, mineral oil or chemicals.
- Specialised transports: transports that require special handling, personnel or equipment. This group can be subcategorised into numerous groups: frozen transports, transport of heavy goods, hanging-clothes transports.

Using this concept, it is possible to deduce a more affined schema, which comprises the most important markets from a door-to-door perspective of the sender (Table 3).

Table 3: Transportation market segmentation

Transportation market	Property I: Shipment size	Property II: Handling requirements	Remarks
Courier and express services	0…100 kg	Packets	Part of general cargo
Piece cargo	….	Palletised, others	Part of general cargo
General cargo	1,5 – 25 t	Palletised, others	Full load, consolidation
Mass food and fodder (tanker: liquid and dry)	5 – 25 t	Food	-
Chemical liquids	5 – 25 t	Chemical reactive, explosive, poison	-
Dry bulk: earth, coal	25 t	-	-
Distribution: retailers, supermarkets	1 – 15 t	Collies	Often operated by the retailing companies in special distribution tours.
Regional transports of different Goods	1 – 15 t	No special	Small low-distance carriers, short distances, rather low-value goods of different kind, no over-night trips.

The deduced markets are of course only the very important ones from a ton-kilometres perspective. According to the model requirements (such as the focus of the model and the model users' view), additional markets such as waste collection can be defined. The constitute independent transport supply layers, which can be added or removed according to the traffic planning region and task.

The transport markets are a key element for the microscopic freight transport modelling: Typical tour patterns (i.e. movements in time and space) are associated with each transport market. Transport markets traduce shipments into traffic flows. The tour types are an important clustering attribute when identifying markets in lorry-trip data. Table 4 illustrates the characteristics of some of the basic tour-types.

Table 4: Characteristics of the tour types.

	"Milkrunfactor"(*)	average distance between stops	Relative Distance variance
Regional Distribution	High	Short	
Consolidation	Middle	High	high
Full load general cargo	Low	High	Middle/high
Shuttle Tour	Low	-	zero
(*) high, when a continiously rising/falling of the transported load; zero, if a sequence of loaded – unloaded trips.			

This schema can further be affined when adding clustering characteristics. For example, the market cluster "general cargo" is characterised by the tour pattern "quadrangular-tour", "large lorry" and "many goods". The quadrangular tour is characterised by "middle number of stops". Technically, the tour types and markets can be identified in trip samples by using techniques of pattern recognition. Linguistic variables take on values defined in its term set - its set of linguistic terms (e.g. Witte (2002)). Linguistic terms are subjective categories for the linguistic variable. For example, for the linguistic variable "distance", the term set T(distance) may be defined as follows:

T(distance) = { "short distance", "middle distance", "long distance", "very long distance"}

Each linguistic term is associated with a fuzzy set, each of which has a defined membership function (MF). Formally, a fuzzy set A in U is expressed as a set of ordered pairs:

A = { (x, µA(x)) | x in U }

where µA(x) is the membership function that gives the degree of membership of x. This indicates the degree to which x belongs in set A. The following figure illustrates a linguistic variable distance with two associated linguistic terms "short distance" and "long distance" where x is the distance. Each of these linguistic terms is associated with a fuzzy set defined by a corresponding membership function.

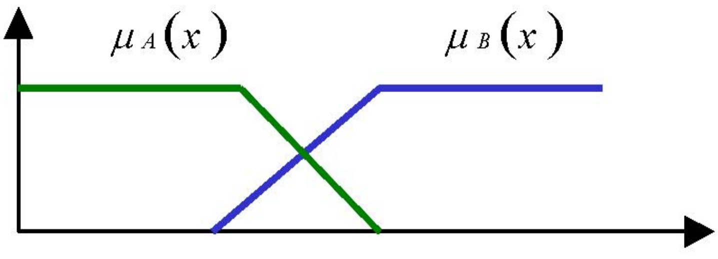

Figure 1: Basic principle of the fuzzy logic – the linguistic function.

The fuzzy relation "degree of equality" indicates, how much a given data set (in form of some parameters xi) belongs to a ideal pattern knowledge base. For example, the ideal pattern "distribution tour" can be expressed as:

Distribution tour = {"short distance", "many stops", "small vehicle"}

The degree of equality between an ideal pattern Ii = {Ai1xAi2…Ain} and the pattern to be classified (x1, x2,… xn) can be expressed as:

$$\mu_{A_1 x \ldots A_n}(x_1, \ldots x_n) = \min\{\mu_{A_i}(x_i)\} \qquad (1)$$

The classification of these tour types and the formulation of the ideal patterns in form of sets of linguistic functions is an iterative process, which considers possible market clusters and revealed trip data (for more information concerning the clustering approach see e.g. Astanin (2002)). The clustering techniques have been applied on a data set of about 1.7 million lorry trips belonging to 200.000 lorries in Germany. A detailed description of the ideal pattern is given in OVID (2004). The survey is described in KBA (2001). Instead of the classical distance distributions by goods type, new shapes appear. Figure 2 shows the distribution of transports with undefined transportation goods (mainly different piece goods) by tour type and by distance. Collection and distribution tours have a high importance in this goods class. Distribution processes have characteristic distances of about 50 – 250 km. In short distances, shuttle tours are dominating the trips.

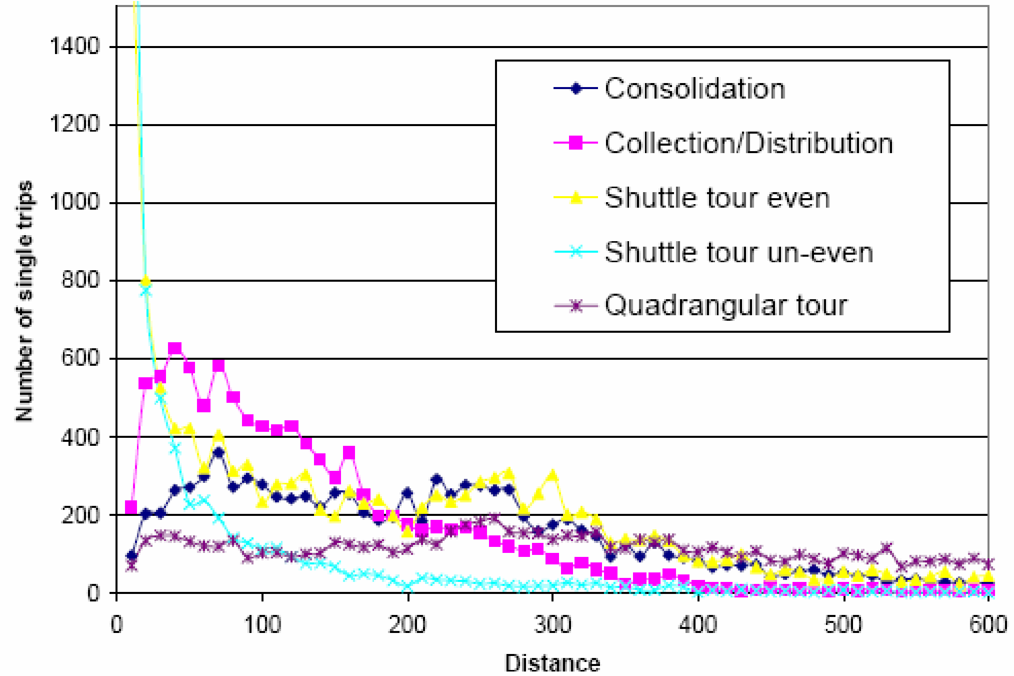

Figure 2: Distance distribution of trips with the NST/R group 999 by tour type. Source: own calculations.

While the number of shuttle tours without back-load decreases rapidly at higher distances, even shuttle tours (with back-load) are significant at higher distances. Tours with a limited number of pickup and delivery points being a sequence of loaded and unloaded trips ("quadrangular tours") are the most important trips of good class 999 at higher distances.
Now it is e.g. possible to deduce the importance of different operation schemes for the piece goods. In Table 5, the sum of the vehicle kilometers and of the transport performance grouped by tour type and handling category is indicated. In the case of the good group 999, only the handling category "no special" exists in a significant volume. Therefore it is possible to deduce the markets directly from the tour types as indicated in Table 5.

Table 5: Logistical structure (transport markets) of the NST/R commodity group 999.

Tour type	Handling category	Market	Billion vehicle-km	Part of the transport performance (vehicle- km)	Mean transport distance (km)
Complex pattern	No special	General cargo	3.2	0.32	340
Shuttle tour paired	No special	General cargo (*)	2.2	0.23	165
Collection/Distribution	No special	Piece cargo distribution / collection	1.1	0.11	117
Consolidation	No special	Consolidation	0.9	0.09	129
Shuttle tour unpaired	No special		0.8	0.08	75
(*) Can be named as "regularly line operations with load exchange".					

It can be seen, that about half of the transport performance (vehicle-km) of the piece goods is operated on line-like operations. The other half is transported on distribution tours and consolidation tours, which are a mixture between full-load-runs and distribution tours.

The analyses showed for example, that the NST/R-group 143 (milk and cream, fresh), is transported in following clusters: as liquid bulk is a collection distribution pattern an in palletised form in shuttle tours and in quadrangular tours. The clustering techniques make it possible to distinguish ingoing and outgoing freight to and from milkeries (Liedtke, 2003).

4.3. Meso-structures in freight transport

Some of the most important transport markets (in ton-kilometres), the operations are organised in form of meso-structures. They are an important object of the actor-based transport modelling (Sjösted, 2004). An example of a meso-structure is following: A forwarding company has reported a tour from southwest Germany to Manchester every Tuesday and once a week, with subsequent unloading of the freight between London and Manchester. A half-load is then transported from Manchester to London. A second half-load is additionally picked up in London (Friday, late afternoon). On Saturday very early morning, one half-load is transhipped 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.

If a carrier or forwarder has found "ideal" complex combinations with regular offers, structures may become very efficient. It is then not possible for a competitor to offer a better price – unless he does it below his cost-covering level.

As the meso-structures restrict the combinatorial planning problem of dispatchers and determine the price offered to shippers in calls for tender, they are a key-element for microscopic simulations

4.4. The transportation market as a simulation – the pattern-building processes

When simulating the transportation market, some characteristics of this market must be considered:

. the large number of often "small" actors who try to maximise their individual profits,
. the strong agent – agent communication on an operational level and
. the existance of the meso-structures.

The most adequate way for dealing with these characteristics is to use agent based simulation models. Actor-based modelling techniques (agent-based simulation, micro-simulation) have their origins in different scientific disciplines, e.g. the general system theory, physics (synergetics (Haken, 1983) and socio-dynamics (Weidlich, 2000)) and informatics (objectoriented programming).

For an activity-based approach, one also needs to consider the type of market, where the transportation services are traded. The traditional transport relationship implies a rather strict separation between the shipper and the carrier (s. Figure 3).

Figure 3: traditional roles of the transport market. Source: IWW.

Modern ITS-technologies and E-Commerce provide a larger selection possibility for shippers, thus reducing transaction costs and diminishing information inequalities. E-Commerce solutions such as transport portals also provide trucking companies with a larger radius of activity and the potentiality of greater efficiency and better back hauling (Friedrich, 2003). The "real" market structure is presented in Figure 4.

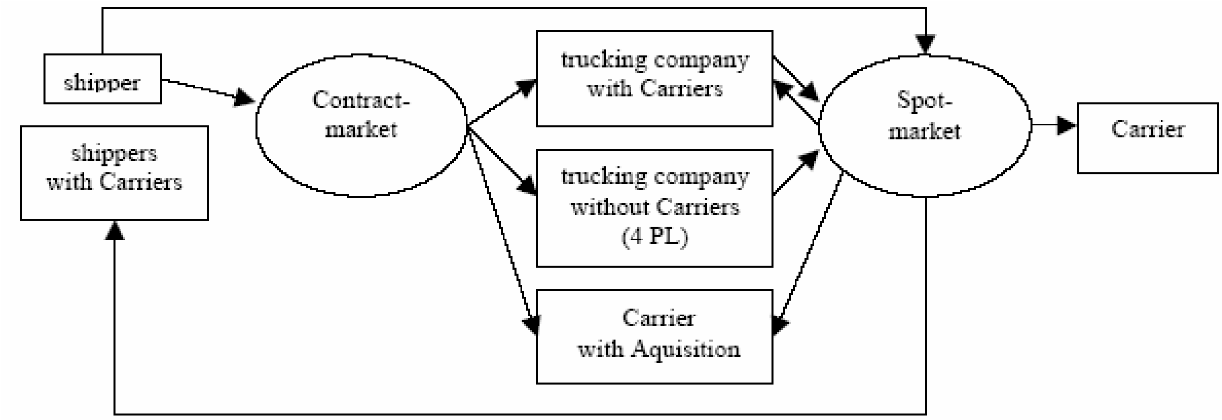

Figure 4: Non-idealised transport markets. Source: IWW.

The interaction of actors in a transport market with modern possibilities of information and communication is much more complex. The project OVID is currently working on the model interLOG to simulate this complex interaction, including the learning of individual actors, price development using auctions and other price building mechanisms, freight allocation and route configuration.

The learning aspect of the individual actors poses a particular challenge. Because of past experiences and the results of undertaken decisions, different actors can behave completely different, even if they are of the same group. This can lead to varying results in different situations, up to the refusal of interactions. A trading communication process may be composed into following steps: ask for transaction – express willingness – ask for an offer – give offer – accept offer. This is a rather declarative way of programming. Most of the relevant modelling techniques for network markets can e.g. be found in the concept of the Economics of Networks (Cohendet et al., 1998).

Using such an agent-based tool, it is possible to verify results of data examinations and also to simulate and evaluate the effects of a traffic planners measures on the transportation market. The emerging of transportation patterns can be looked at from three views: In the public opinion, there is a focus on transhipment operations and on infrastructure use. A standard question is "why do the goods not take the railway parallel to the highway?" This view does not take into account the individual optimisation and operation processes. The second view focuses on the large, planned transportation networks of the large courier express-service operators. These are centrally planned structures with several hierarchical levels or hub-and-spoke systems. The third access to the patterns stems from observations on the highways or the presentation of carrier companies: "The expert for Eastern-Europe" or "Daily shuttle between Milan and Hamburg". Forwarders, carriers and drivers generally have some standard routes and standard markets in terms of origin-destination and corridors. Even if these specialised structures become less important (because of communication possibilities), these patterns build highly specialised and optimised sub-markets. By simple personal contact between actors, the markets of a forwarder can be significantly enlarged. The knowledge of a dozen carriers would it make possible to build up a network all over Europe. This fact may explain, why the big operators have their difficulties in extending their market shares in offering “own” advanced transportation networks: For a small carrier with good staff, it is relatively easy to offer high quality logistics which is both near to the client and covers large markets by a simple cooperation which may be catalysed by a forwarder.

Now, the question is discussed, how the emerging of the logistical meso-structures and patterns can be mapped in the actor-based framework: The key question is, how the patterns are stabilsed and how they also can be cracked. Patterns become stable because they are less costly than other operations. Cost elements are:

- transportation costs consisting of driver costs, lorry depreciation and use,
- loading and unloading costs, waiting times,
- transaction costs (communication, personal contacts),
- planning and re-planning costs,
- geographical knowledge of the driver and other know-how and
- other risk elements.

In the market simulation of interLOG, the pattern building process is mapped by following “techniques”:

In the case of the spot market, a carrier accepts an order at least at a price where he can carry it at marginal costs when other following operations are already planned. In the case where he has no orders for the next time period, the minimal acceptable price consists of cost-recovery calculations and forecasts for loads starting in the destination region (so-called trucking segment).

In the case of contracts, a carrier will accept them, when it fits into the activity field. A first condition is that constraints in form of lorry type, field of activity and other requirements are fulfilled. If this is the case, a minimal acceptable price can be calculated by inserting the orders in some preceding tour patterns and calculating the additional marginal costs. An important practical question in modelling is the following: marginal costs don’t cover the total costs and the advantages of better operations must given to all clients (especially to the first ones who had the highest costs). The way for solving this problem is to adjust carefully all prices over the calculation period. When the price changes because of the overall calculation, the danger exists, to lose clients. However, good patterns become more and more stable.

The described procedure of a mix of object-oriented programming, constraint solving and market simulation is fully compatible with the ILOG constraint solver and the dispatcher add-on.

The tour-patterns posses also some limits concerning the scaling-effects: If they become too large, they become too complex, and additional scale-effects are not significantly realised. In every case, they are the result of heuristics and decentralised decisions. Especially in the general cargo segment, carriers possess about some 25 to 100 lorries (or subcontractors’ lorries which they steer). Also the piece good and courier and express good markets in Western Europe show, that some networks may exist parallel and that the largest ones are not necessarily those with the largest profits.

4.5. Route choice and tour building

The market interactions and optimisations of the different actors already lead to significant requirements on computer power and speed. It is therefore suggested to de-couple the traffic modelling part from the market simulation. An approach for handling the shortest path search especially for lorries and from the point of view of a dispatcher and his experience will be sketched. In the classical assignment-applications, freight is treated as a base charge; this is justified by the fact, that lorries are less sensible to flow-speed differences. The maximal speed is about 80 km/h in large traffic density regimes. Only at a high flow density, stop-and-go waves emerge or little perturbations such as accidents cause severe congestion.

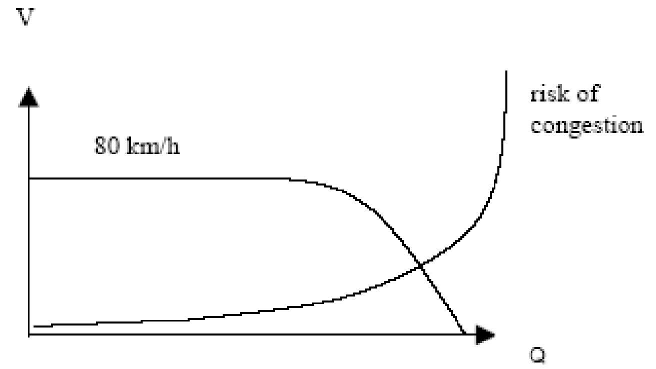

Figure 5: The fundamental diagram; speed (V) as a function of the traffic density (Q) and risk of congestion.

When the model focus lies on the freight transports and not on the whole traffic, the congestion phenomena should more adequately considered. Dispatchers and lorry drivers possess often a large experience of the traffic situation in their region of activity. In interviews with carriers, whole one-week tour patterns have been reported which are "congestion optimised".

Aside from the shortest path search dealing with congestion risks, the second point refers to the tour building process itself, i.e. bringing orders into a sequence of pickups and deliveries. Aside from capacity constraints, the sequence of the different loads must be considered. Because of the complexity of this problem, dispatchers here use a simplified strategy in building routing plans: the sequence of pickup points is determined by crow-flight distances; after the pickups, generally a long distance trip is performed and then the deliveries are planned. Attention has to be paid also to the sequence of the loads. In order to map these processes adequately, following strategies are implemented in interLOG: Instead of calculating a time dependent travel-time matrix, the routes are calculated subsequently:

- Calculation of the distances between the delivery-points on the basis of a network containing only the crossing nodes (time independent).
- Tour building with a simple insertion heuristic starting with the delivery closest to the start and ending with the farest one, this is ideally the point where a back-load is found or a big city where the probability for back load is high.
- The travel time and congestition probability can then be calculated time dependent on the basis of the finer network with a finer resolution of the links. Only if constraints are hurt, the route must be at least partly re-build.

These steps are performed using the goal formulation of constraint-logic programming, which can be characterised as a guided branch-and-bound search with parallel domain reduction and early cutting off of branches when constraints are violated.

Now the question to be examined is, how an experienced dispatcher or an advanced routing program deals with congestion at each point of a tour, especially before building it. The following three cases must be distinguished:

. It is almost certain that a severe congestion will happen on a link. This is the case of commuter flows in the large agglomerations. The variance of the travel time is rather small and a user equilibrium is established because the majority of users have enough time to “improve” their daily patterns. An improvement towards the system equilibrium is only possible with policy measures such as regimentations and pricing.

. There is a high risk of congestion with a highly variable congestion time. For example, in three out of five days, the traffic collapses. This information may be very important for the dispatcher of long-running trips because he could chose a longer path with lower risk. A whole distribution function of the daily travel-time can be constructed. This is the case of a highly charged inter-city highway.

. There is a small risk of congestion on a link: the congestion takes place only in case of weather conditions or very heavy accidents (unforeseeable) or in the case of a route closing (foreseeable). In some cases, by reducing the capacity of a road, the risk of congestion becomes “high” (previous case). The congestion on a long route is rather a “Poisson-process”.

The suggestion for dealing with congestion uncertainty is following: A path is estimated by following three criteria:

$$tt_R = \sum_{k \in R} tt\Big|_{t_k} = \sum_{k \in R} \frac{l_k}{v_k \big|_{t_k}} \qquad (2)$$

$$l_R = \sum_{k \in R} l_k \qquad (3)$$

$$Var(tt_R) = \sum_{k \in R} Var(tt_k) \qquad (4)$$

where:

ttR = travel time on the Route R.

ttk | t = travel time on link k at the moment t.

Var(tt) = variance of the travel time.

Applying the law of large numbers, the variance of the travel time can be calculated as the simple sum of the variances on the links. In this case, the Dijkstra algorithm (or a related algorithm) can be applied for estimating the “shortest path” to the adjacent nodes as:

$$Dist(ij)\Big|_t = \sum \alpha \cdot tt_{ij} + \beta \cdot l_{ij} + \gamma \cdot Var(tt_{ij})\Big|_t \qquad (5)$$

However, as the event “congestion” is a scare one and the resulting distribution of the travel time is not of the Laplace-Gauss-type, this property cannot always be guaranteed, especially in the case of short trips on highly charged links. On long trips with scare events and when treating congestion as a Poisson-process, the approach of estimating the risk of congestion by the sum of part-variances holds because of fundamental characteristics of the Poisson-law. Summarising, it can be noted, that the above-presented approach is a first suitable and adapted approach for including “congestion risks” in the shortest-path-search. The congestion risk is calculated separately and can be treated in the same way as distance, time and volume as an additional dimension in the CLP-Problem. The presented treatment of the route choice as a fast learning and adaptation process compared to the building up of market relations results from the specialisation of carriers on relations and their cost-rational behaviour.

5. Disadvantages of conventional freight transport modelling compared to the activity-based approach

In the domain of freight transport, the classical functional approach is still the state-of-the-art. In the direct demand approach, traffic flows T (in tons) between rather large traffic cells i and j are modelled with terms of the the type $T_{ij} = f(a_{1i}, a_{2i},\ldots a_{ni},b_{1j},\ldots b_{mj})$, where a_n and b_n are macroeconomic indicators of the origin and destination cell, which are classically the GDP by economic sector and the number of inhabitants. By forecasting the economic indicators, the development of the traffic volume is deduced. An actual example for this approach is given by Herry (2000) for Austria. However, the functional macroscopic approach possesses a variety of limitations concerning their explainatory value and forecast quality:

. There exists only a small methodological and empirical base for modelling the traffic generation in small traffic zones (such as communes) or even in single point sources (companies). As a result, passenger and freight transport models become incompatible, because it is not possible to assign lorries' movements to their local destination / or origin.

. In most freight transport models, the question, how goods flows are assigned to vehicles is not sufficiently answered and consists of a crude parameter fitting described with nebulous formulations. Especially, the question of explaining empty running of vehicles (when they operate complex tours) is not solved in a satisfying way. In the rarest cases a backload is found at the same point as the delivery. As a result empty running is generated, that cannot be separeted in the traffic matrice from other empty runnings of local operating vehicles.

. The sum over all transport volume starting in cell i is not equivalent to the sum of goods produced in traffic cell i. When a distribution tour starts in i, the mean load weighted over the distance is noted in the statistics. When the lorry is on a

. consolidation tour, at each stop inside the traffic cell, the already loaded weight and the addition load is summed up at each pickup point.

. Another problem exists, when transhipment / cross docking happens in the traffic cell. The good is counted several times.

. The direct demand approach has also another disadvantage: It does neither respect the origin not the destination bordary-sums. However, when important structural changes take place in the economy such as the changes of supply relations because of a new market integration, the volume on existing relations is not replaced.

. It is principally not possible for aggregate models to forecast the impact of changes in logistic structures (microscopic behaviour changes, structural changes) and on the freight traffic.

. The diversity of actors and their decision situation (i.e. their choice set) often depends from the company type and the logistics task. It is a critical proceeding to apply disaggregate choice function on inter-zonal transport flows.

Especially when calculating the effects of changing distribution structures, changing sourcing processes and the effects of information systems, the only adequate way is the activity based approach because it establishes the link between transports and the economic activity behind them. Especially the numerous adaptation processes of the actors as a reaction on policy signals could be modelled in a very comprehensible way.

6. Conclusion

Activity based models are the modern method for modelling transport systems. They have successfully been applied in the field of passenger transport planning. In the field of freight transport, some additional difficulties for the actor-based modelling exist: in general, more than one actor is involved in a transport; actors have several roles and different functions. A transport company can operate for several types of shippers and a shipper can transport his commodities on several types of transport markets. When only concentrating on “suitable prototypes” of single shippers or single carriers, reality-like lorry flows are not captured by the model, because the relevant actions of freight transport such as “collecting,” “consolidating”, “transportation”… do not happen. They are often the result of interactions, which lead to the emergency of meso-structures. Because of this, an actor-based approach is suggested, which uses a actor classification according to the cpa for the demand side and a transport market segmentation for the supply side.

The agent-based approach is also very related to the classical microscopic cost-benefit analysis and it is less sensitive to input parameter variations, because it considers several adaptation processes and it is rule-based.

In order to calibrate such new forms of freight transport micro-models, two strategies can be applied: either the collection of micro-data or a clustering approach, which contains some fuzziness.

The agent-based approach is a reality-like way in order to solve highly incalculable combinational problems by dividing it into a solvable number of individual decisions. Mapping the transportation flows becomes now a problem of mapping a market. There is a need to map individual optimisation problems in a simplified way, e.g. under a restraint view of the whole market. These individual decisions are mainly the decisions of the dispatchers concerning the acceptance of contracts and spot-market orders and an eased route building. Already existing meso-structures can be used as a data-base for the artificial dispatcher, when they have to calculate prices in tenders. A simplified route-building with congestion risk has been suggested for mapping the planning of complex routes.

The model interLOG realises and combines techniques of operations research, artificial intelligence and well-known elements of transportation modelling to deal with these challenges. The presented micro-approach enables also the “generation” of the so-called meso-structures in transport. Only when understanding these structures, phenomena such as empty running and the effects of new information and communication services can analytically be understood and simulated.

There is still a need for adequate data concerning market behaviour and the role of transportation market patterns. In the future, there must be a better interaction between data collection and freight model development. A possible design for empirical analyses of the transport demand and supply sides basing on the transport market classification has been presented.

References

Astanin, S., 2002. An Organisation of Logic deduction on the basis of sequents fuzzy calculus, Paper at the IEEE 2002.

Cohendet, P., Stahn H., Umbhauer, G., 1998. The Economics of networks, Springer Verlag.

European Union, 2004. DG Energy and Transport: Statistical Tables and other pages, http://europa.eu.int/comm/energy_transport/etif/index.html

European Union, 2001. COMMISSION REGULATION (EC) No 204/2002 of 19 December 2001 amending Council Regulation (EEC) No 3696/93 on the statistical classification activity (CPA) in the European Economic Community.

Friedrich, H., 2003. Voraussetzungen für eine Aktivitäten-basierte Güterverkehrs-Modellierung, diploma thesis, Universität Karlsruhe (TH).

Haken, H., 1983. Synergetik – eine Einführung, Springer-Verlag Berlin.

Herry, M., 2000. Generalverkehrswegeplan Österreich, Fortschreibung des Güterverkehrs, project on behalf of Austrian Bundesministerium für Verkehr, Innovation und Technologie.

Klaus, P., 2003. Die Top 100 der Logistik, Deutscher Verkehrs Verlag Hamburg.

Liedtke, G., 2003. Segmentation of the transportation market with regard to activity based freight transport modelling, proceedings of the LRN-Conference 2003.

Kaspar, C. Laesser, C., Meister, J., 2000. Verladerverhalten, Ministry for Transport, Bern, 2000. – Memorandum for the National Research Programme Swizterland NRP 41.

KBA, 2001. Verkehrsleistung deutscher Lastkraftfahrzeuge - Methodenband, Kraftfahrzeug-Bundesamt / Bundesamt für Güterverkehr, Flensburg / Köln

Sjöstedt, L., 2004. Personal note at the occasion of the workshop „goods transport modelling“ in Hamburg.

Weidlich, W., 2000. Sociodynamics: a systematic approach to mathematical modelling in the social sciences , Harwood Academic Publ., 2000. - XII, Amsterdam.

Witte, René, 2002. Architektur von Fuzzy-Informationssystemen. BoD, Norderstedt, Germany, ISBN 3-8311-4149-5.