# COLLECTING AND IMPLEMENTING EMPIRICAL PROCUREMENT AND LOGISTICS DATA IN TRANSPORT MODELS

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## ABSTRACT

Compared to passenger transportation modelling, the field of freight modelling is relatively unexplored. To improve the basis for modelling transport operations, the knowledge about logistics in production networks and supply chains has to be enlarged. Hence, a research project analysing the relationship between procurement/logistics aspects and induced traffic has been accomplished. In a first step an empirical survey was initialised. Suppliers of the German automotive industry were asked about their company's business data (e.g., number of staff, turnover), produced products, procurement strategies, daily traffic volume as well as their transport organization. The surveyed data were analysed descriptively and by statistical tests. Hence, a lot of figures could be deduced and were implemented in a theoretical model. In addition several kinds of different clusters have been generated to distinguish magnitudes of companies. In general the model uses surveyed statistic distributions concerning the procurement characteristic of companies in the automotive industry. Finally the confirmed statistical interdependencies between different variables provide the improvement of input data for transport models because they contain logistical aspects to deduce generated traffics.

*Keywords: Transport modelling, logistics, procurement, empirical survey*

## INTRODUCTION

In production companies and trading companies logistics concepts and logistical structures gain in importance. This development is especially influenced by political and economical changes as well as technological innovations (Ruijgrok 2001). Political changes contain for example the deregulation of the transport market and the telecommunication market. Additionally the EU eastward enlargement as a political driven development has impact on production locations and commercial relationships (Sulogtra 2002). Technological innovations concerning logistics comprise especially information and communication technology. The increasing use of the e-commerce determines more direct shipments to customers and actually the internet provides global integrated logistics networks. Actually the economic growth and global trade causes more international transports and thus requires sophisticated logistics (Drewes Nielsen et al. 2003). The results of this development are special procurement strategies and sourcing concepts which impact the temporal and spatial development of commodity flows.

It is obvious that logistics directly impacts traffic. Nevertheless, logistical aspects are regarded insufficiently in freight transport models. The existing modelling approaches normally focus on key figures like the number of staff and the size of production area. But because traffic is especially influenced by different logistics strategies, it is necessary to implement logistical parameters in traffic models as well (Iddink, Clausen 2009). In the present work different (procurement-)logistics key figures were generated based on empirical data of the automotive supplier industry. They contain statistical distributions and correlations concerning size of company, value added levels as well as spatial distributions and delivery concepts. According to the classical four-step transport modelling approach the figures were implemented in a theoretical model.

# THE CLASSICAL FOUR-STEP-MODEL

The demand modelling for person travel has been dominated by the four-step-model for a long time. The application of this model is near universal. Nevertheless, simultaneously the model has a high degree of generalisation and standardisation (McNally 2000). Even approaches for freight transport modelling are based on the four step algorithm (De Jong, Gunn et al. 2004). The approach consists of the following four steps (figure 1):

- trip generation,
- trip distribution,
- mode choice,
- route assignment.

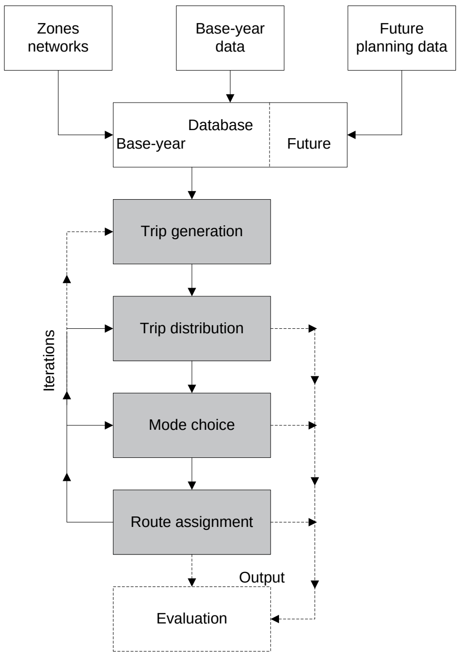



Figure 1 – Four-step-model, according to (Ortúzar, Willumsen 2001)

To identify the transport demand the number of trips starting in one cell (sources) und the number of trips ending in one cell (sinks) is determined. This is done using an extrapolation based on previously recorded data (demographics, economic data, spatial structure and education data) taking into account certain factors such as the trip purpose, time of day or the group of person (Ortúzar, Willumsen 2001). A linear or log-linear relation between the population (per group) and the generated trips (per purpose) is assumed. The related trip rate matrix $r^p_h$ is determined by empirical surveys (Liedtke 2006). Where:

$$O_i^p = \sum_h r_h^p n_{hi}$$

$O_i^p$ - number of trips per time period with purpose p starting in zone i,

$n_{hi}$ - number of households of type h in traffic cell i,

$r_h^p$ - average number of trips with purpose p originating in a household of type h per time interval.

The second step contains the distribution of the generated trips to particular destination cells producing a trip matrix. The distribution problem can be solved by gravity models or entropy maximizing models. Within the trip matrix each cell $T^p_{ij}$ represents the traffic volume from cell i to cell j under consideration of purpose p. The total traffic volume of all cells is represented by T (Liedtke 2006). Where:

$$T = \sum_{ijp} T_{ij}^p$$

Depending on the aim of analysis, inland traffics in one cell are either described as $T^p_{ij}$ where i = j or completely neglected. Furthermore, the line total must be equal to the sum of all trips starting in this cell and the column total must be equal to the sum of all trips ending in this cell (Ortúzar, Willumsen 2001). Where:

$$\sum_{jp} T_{ij}^p = O_i$$

$$\sum_{ip} T_{ij}^p = D_j$$

The third step transforms the trip matrices of the trip distribution into mode-specific trip tables. That means every traffic flow $T^p_{ij}$ is distributed to the different available transport modes (e.g., car, train, bicycle, pedestrian). The base for mode choice modelling is the discrete choice theory (Liedtke 2006, Ortúzar, Willumsen 2001).

In the last of the four steps of the model an equilibration of demand and performance is determined and the vehicles are assigned to the traffic network. Therefore it has to be ascertained which route starting from source i and ending in sink j is chosen by which vehicle (route choice). This requires the application of routing algorithms which calculate the route depending on the aim of optimization (e.g., shortest path, fastest path). There is a multitude of assignment procedures like exact solving procedures and meta-heuristics (Liedtke 2006). The routing approach corresponds to the standard method of traffic assignment and is at this point not dealt with in greater depth. Further information can be found in Kutz (Kutz 2003).

The four-step-model is adapted analogously to freight traffic whereas the traffic volume is generated based on structural data like number of companies per cell and size of company. But this modification may not meet all requirements of freight transport modelling which is

due to the disparity between freight and passenger transport. An overview about existing freight transport models give Persson and Davidsson (Persson, Davidsson 2007).
There exist significant differences between freight and passenger transport. In contrast to passenger transport several decision-makers are involved in the transport process (e.g., sender, receiver, shipper, forwarder, LSP) (De Jong et al. 2002). Furthermore freight transport networks consist of a multiplicity of nodes and links and therefore they are more complex. Additionally, the items being transported are more diverse and range from small parcel deliveries with multistops to single bulk shipments (Clausen et al. 2008, De Jong et al. 2004). Another key differentiator is the availability of data concerning the behaviour of actors. In terms of freight traffic the data contains logistical information like procurement, production, warehousing and distribution strategies. For passenger transport modelling in many cases detailed knowledge and data concerning the autonomous agent behaviour of individuals exist. In contrast to that logistical statistics are available partially or aggregated due to data protection reasons (De Jong, Gunn et al. 2004, Ortúzar, Willumsen 2001).
It is obvious that there exist significant differences between passenger transport and freight transport. Hence, the modelling approach can not be copied completely analogously but requires modified modelling steps as well as partly different input data.

# EMPIRICAL SURVEY

Against this background the established approach analyses the relationship between logistics and production induced transports by example of the automotive supply industry. Based on the analysis of existing commercial traffic models and various approaches describing the relation of logistics and transport (e.g., Wandel, Ruijgrok 1993, McKinnon, Woodburn 1993, McKinnon, Woodburn 1996) an extensive collection of transport influencing parameters has been developed. In the next step an empirical analysis was established to collect company data, which were evaluated statistically. The survey was aimed at 1.612 suppliers in Germany. Additionally, different hypotheses were defined to analyse the relation between logistics parameters and induced traffic. After that the significant results of the hypothesis testing were converted into statistical distribution matrices. Based on these and other statistical data a new approach to generate synthetical transport chains was developed.

## Logistical transport influencing parameters

There are a variety of parameters which impact transport. Hence, depending on the reached decision different traffics are induced. In general there exist three categories of transport influencing parameters that contain logistical aspects: “mean of transport”, “characteristics of the transport object” and “procurement strategies”. Especially due to the selected procurement strategy different transports are impacted (see Table I).
The first distinction of procurement strategies is based on the area concept. This describes the geographic area in which the procurement activity is conducted. A differentiation is made between local, domestic and global sourcing. Overall, the selected area concept mainly

impacts the length of transport. Presumably, the amount of vehicles is influenced as well, as bigger vehicles are normally used for longer distances.

Table I – Transport influencing procurement strategies

| Procurement strategy | Impact on transport |
|---|---|
| - area concept<br>  - local<br>  - domestic<br>  - global | - length of transport<br>- means of transport<br>- number of vehicles |
| - supply concept<br>  - sole<br>  - single<br>  - dual<br>  - multiple | - number of sources<br>- number of vehicles |
| - object concept<br>  - unit sourcing<br>  - modular sourcing<br>  - system sourcing | - number of sources<br>- amount of delivered goods |
| - time concept<br>  - advance purchasing<br>  - individual buying in case of need<br>  - just-in-time | - frequency of delivery<br>- amount of delivered goods |
| - delivery concept<br>  - direct transport<br>  - direct transport with consignment warehouse<br>  - area contract freight forwarder principle<br>  - milk-run<br>  - shipping warehouse<br>  - supplier park | - length of transport<br>- number of transhipment points<br>- means of transport |

According to the supply concept the procurement strategies differentiate between the number of suppliers, which provide a product. Basically the two main forms single and multiple sourcing are distinguished. Single sourcing is defined as the purchase of a product from a single supplier. A special form is known as sole sourcing, which is characterized by a monopolistic supplier and thus no alternative sources of supply exist. In contrast, in multiple sourcing a product is purchased from several suppliers. If a product is exclusively purchased by two suppliers it is called dual sourcing. In regard to transport modelling depending on the supply concept the amount of sources is impacted. Provided that no single or sole sourcing is used, multiple sourcing may influence the amount of vehicles because a smaller amount of goods will be transported starting from several different origins.
The differentiation of sourcing objects is based on the complexity of the goods. Three different types of object concepts exist which are called unit sourcing, modular sourcing and system sourcing. Products that are purchased by unit sourcing are characterized by a low

complexity, often small parts or components of an assembly. In contrast, systems and modules are more complex and assembled by suppliers. Depending on the object concept different transports result because the more system and modular sourcing is used the less relations between suppliers and receivers exist. Actually the amount of purchased goods and the amount of suppliers decreases.

The time concept distinguishes between stock sourcing, sourcing in case of need and just-in-time sourcing. The chosen concept affects transport modelling in the sense that different delivery frequencies and volume of goods can be expected.

In addition different delivery concepts within a supply network exist which differently affect the induced transport. The logistically simplest form is the direct transport. In this case goods are transported directly from the supplier to the customer (or conversely as pick-up). With a view of transport modelling the direct transport represents the connection between a source and a sink via an edge. A special form of direct transport is to deliver in a consignment warehouse. The consignment warehouse is usually located close to the purchaser and is served by the supplier. In comparison to the normal direct transport the transport via consignment warehouse contains one additional node. Another concept is the area contract freight forwarder principle which is used in the spatial concentration of several suppliers with low volume of goods. The goods are consolidated by a forwarder or logistics service provider in a transhipment point from where the goods are transported to the final destination. In case of collecting the goods route optimized during the pre-carriage and using temporal and quantitative restrictions the concept is called milk-run. Alternatively, there is also the possibility that different suppliers are located next to the production plant in a supplier park. In general, transport capacities can be used more economically by using transhipment points. Though, at the same time goods may be transported for longer distances depending on the location of the supplier and the transhipment point. Consequently the choice of the delivery concept has significant influence on the resulting traffic, especially depending on the number of used transhipment points.

It is obvious that the different procurement strategies are important logistical aspects that impact transports and that should be implemented in freight transport models. In the following, only selected parameters are integrated into the empirical survey and the resulting model.

## Survey results

The survey was aimed at companies in the automotive supply industry, which has been a pioneer with regard to the use of complex logistics concepts for a long time and also has a high degree of interconnectivity. A survey design was established based on the defined parameters to derive (procurement) logistic key figures as well as statistical correlations. In the following part, only those results are introduced that are implemented in the theoretical approach. The expected relevant parameters are:

- size of company,
- company location,
- range of products,
- level of added value,
- logistical concepts.

## *Descriptive analysis*

The left chart in figure 2 shows that most companies (24.8 %) belong to the category with 11 to 50 employees which is the enterprise category “small” according to the European SME definition. In combination with the first category (1 to 10 employees) approximately 30 % of companies belong to the micro and small enterprises and a total of less than 50 % to the big enterprises.

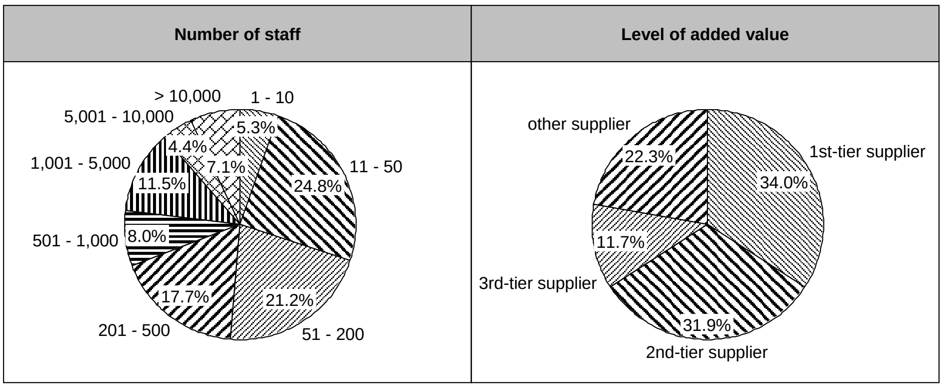



Figure 2 – Company characteristics

Additionally companies can be distinguished by their level of added value. The so called tier-concept is no official term but a common used descriptive term and mostly indicates who the end user of that company’s product is. Consequently the 1st-tier supplier would be a company who makes products specifically for one of the OEMs. The survey indicates that 34 % of all companies are classified in the category of 1st-tier suppliers and the 2nd-tier suppliers with a ratio of 31.9 % have a comparable size. The category of companies on the fourth or lower value-added level has a higher ratio than the third.
The analysis of the area concept shows that 74.7 % of the suppliers are located in Germany (see figure 3). 23.6 % of these German suppliers are located within a radius of 50 km (local sourcing) and 39.7 % within a radius of 200 km. The remaining ratio of German suppliers (36.7 %) is located in the residual federal territory. Further 16.6 % of suppliers supply from other European countries. Although the Asian region is often mentioned as a supplier location, the survey result shows a comparatively small ratio of 4.5 %.

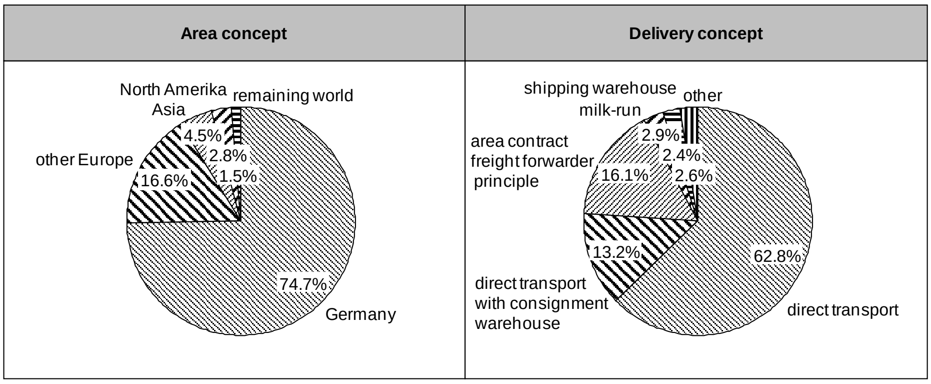
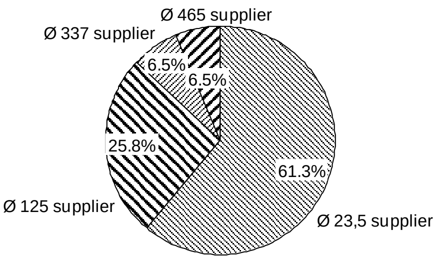



Figure 3 – Procurement characteristics

In addition, the use of different delivery concepts has been analysed. In average 62.8 % of all companies’ deliveries will be operated by direct transports. Further 13.2 % of deliveries are operated via consignment warehouse. A delivery with consolidation by area contract freight forwarder principle is used with a ratio 16.1 %. Only 2.9 % of the deliveries are operated using the milk-run approach.

To avoid predetermined class boundaries the participating companies were allowed to state their number of suppliers as free text. The analysis of the number of suppliers showed significant differences between median and arithmetic mean. Hence, clusters have been generated and class boundaries could be defined statistically by the two step cluster analysis to aggregate comparable companies (see figure 4). Most companies (61.3 %) focus on a few suppliers, on average 23.5, and 25.8 % of the companies get their products from 125 suppliers on average. A smaller ratio of companies (each with 6.5 %) has a statistical average of 337 or 465 suppliers.

**Number of suppliers**

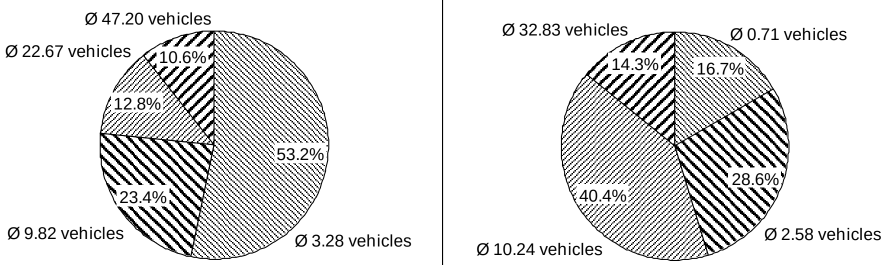



| | min. | max. | Ø |
|---|---|---|---|
| Cluster 1 | 2.0 | 50.0 | 23.5 |
| Cluster 2 | 90.0 | 150.0 | 125.0 |
| Cluster 3 | 324.0 | 350.0 | 337.0 |
| Cluster 4 | 430.0 | 500.0 | 465.0 |

Figure 4 – Number of suppliers

Analogously to the cluster analysis of the number of suppliers, the amount of vehicles has been clustered as well. Within the delivery traffic 53.2 % of the companies will be delivered on average by 3.28 vehicles per day. 23.4 % of the companies have 9.82 incoming vehicles daily. An above-average number of 22.67 vehicles per day is determined at 12.8 % of the companies and finally 10.6 % of all companies have an average of 47.2 vehicles.

**Number of ingoing vehicles per day** | **Number of outgoing vehicles per day**




| | min. | max. | Ø |
|---|---|---|---|
| Cluster 1 | 0.0 | 6.0 | 3.28 |
| Cluster 2 | 7.0 | 13.0 | 9.82 |
| Cluster 3 | 19.0 | 30.0 | 22.67 |
| Cluster 4 | 40.0 | 67.0 | 47.20 |

| | min. | max. | Ø |
|---|---|---|---|
| Cluster 1 | 0.0 | 1.0 | 0.71 |
| Cluster 2 | 2.0 | 4.0 | 2.58 |
| Cluster 3 | 5.0 | 21.0 | 10.24 |
| Cluster 4 | 24.0 | 40.0 | 32.83 |

Figure 5 – Number of vehicles

The distribution of the outgoing traffic is shown in the right chart in figure 5. The largest ratio of companies (40.4 %) has 10.24 vehicles as outgoing traffic. The second cluster contains 28.6 % of all companies and represents those with an average of 2.58 vehicles leaving daily. 16.7 % of all companies have outgoing traffic with less than one vehicle (0.71) per day. 14.3 % of the companies have an average of 32.83 vehicles per day.
In figure 6 the ratios of different vehicle categories are shown, distinguished between ingoing and outgoing traffic. It is obvious that mostly heavy trucks are used. It is also striking that 30.8 % of incoming traffic are operated by light trucks up to 7.5 tons. In comparison this vehicle category is only used about 11 % for outgoing traffic.

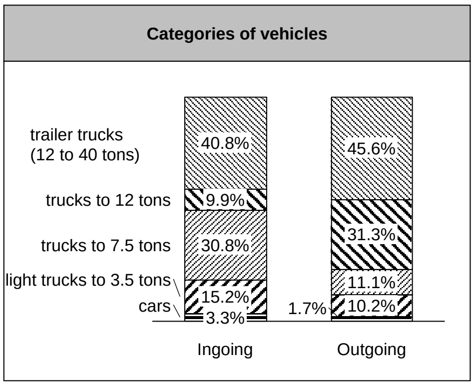


Figure 6 – Categories of vehicles

The resulting descriptive data represent arithmetic means and statistical distributions to describe companies' behaviour concerning transports and purchasing which can be used as input parameters for modelling freight traffic.

## *Analytical analysis*

Overall fourteen hypotheses have been defined within the project and tested in regard to identify interdependencies between procurement and traffic. For analysing the direction and strength of interrelations, the correlation analysis can be applied. Prerequisite for the application of this method is that the variables are at least ordinal. In contrast to proportionality the correlation only identifies statistical relations. Hence, the determined coefficients can be used to assess the relation qualitatively. Two of the identified correlations have been implemented in the approach. The hypotheses are named as follows:

$H_{11}$: Size of company and number of vehicles are related.
$H_{12}$: Level of added value and number of suppliers are related.

Within the correlation analysis the associated null hypotheses have been tested. The results are shown in table II.

Table II – Results of hypothesis testing

| Hypothesis | Coefficient of correlation | Statistical significance |
|---|---|---|
| $H_{01}$ | 0,595 | 0,000 |
| $H_{02}$ | -0,527 | 0,002 |

Both results are very significant which corroborates the hypotheses $H_{11}$ and $H_{12}$. Consequently there exists a relation between size of company and the number of vehicles and a relation between the level of added value and the number of suppliers. These facts give the opportunity to derive the amount of vehicles and the number of sources based on given data.

The identified causalities provide an improvement compared with existing input parameters. The implementation of these parameters into the four-stage model is described below.

# IMPLEMENTATION OF DATA

Based on the surveyed data and the identified correlations a theoretical approach to derive synthetic transport chains has been established. The aim is to generate improved input data for transport modelling and simulation, especially concerning logistical activities, by using the empirical statistics data. In figure 7 the theoretical approach is illustrated. Within the scope of modelling, different processes have to be passed, dedicated to the four modelling steps. Generally the developed approach is based on random distributions using the statistical key figures in figures 2 to 6.

## Trip generation

In the first step geographic nodes were generated based on statistical distributions of company locations (e.g., register of companies). Subsequent to the generation different attributes were allotted randomly to the nodes (also based on statistical distributions). The first attribute is the magnitude of companies, which is operationalised by the number of staff and is allocated using the statistical distribution in figure 2. It is important to distinguish between different magnitudes of companies because depending on the magnitude different amounts of vehicles occur which was verified by the significant statistical correlation. For generating synthetic transport chains it is also necessary to distinguish between the different levels of added value (second attribute) to connect the nodes reasonably (see figure 2). The traffic volume (third attribute) is differentiated in originating traffic and terminating traffic for each node and statistically divided in clusters. The allocation of these clusters to the nodes, is based on the correlation between the amount of staff and the amount of vehicles. That means the higher the magnitude (the more staff) the higher the referable amount of vehicles.

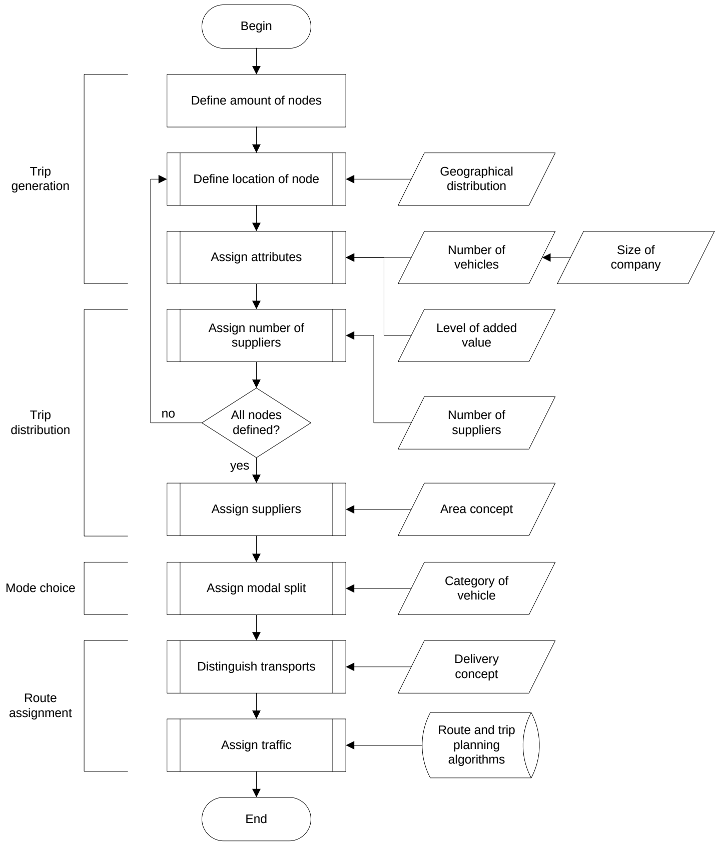



Figure 7 – Modelling approach to generate synthetic transport chains

## Trip distribution

Within the trip distribution nodes are connected to each other by traffic flows. The sources have to be determined by the number of suppliers (figure 4) and their spatial arrangement has to be defined with the aid of the statistical distribution of the area concept (figure 3). The assignment of the amount of suppliers per company is similar to the traffic volume using clusters. Because of the statistical relation between level of added value and amount of suppliers more suppliers are assigned to companies on a low level. In the present approach the lowest level of added value represents the one of the 1st-tier suppliers. There was no relation identified statistically between the level of added value and the use of global sourcing. Hence, the same area concept is randomly assigned to every node. Regarding the distribution of the traffic volume the restriction has to be observed that the sum of all ingoing trips is equal to the sum of all outgoing trips in the whole system.

## Mode choice

The mode choice contains the distribution of the traffic volume per node on the different vehicle categories. Besides the approach distinguishes between originating traffic and terminating traffic because differences between both were surveyed. It is intentionally neglected that the sum of originating traffic and terminating traffic per vehicle category will be irregular because not all transports are done directly. The difference rather verifies transhipments and the change of vehicle types during the transport process.

### Route assignment

The present work provides the opportunity to distinguish between different delivery concepts using the statistical distribution based on the empirical survey. A distinction is made between direct shipments and transport chains with transhipments. According to the statistically assigned delivery concept additional synthetic logistics nodes (transhipment points) can be generated and implemented in the routing. Thus, multilevel transports based on real data result.

## CONCLUSION AND OUTLOOK

Generally logistical aspects are implemented insufficiently in freight transport models. The existing models are often exclusively based on aggregated figures like the number of staff and the production area of a company. But especially based on companies' procurement strategies the induced transports are influenced.
The paper shows that transport modelling can be improved even with simple modifications using statistical distributions based on real empirical data. Thus, a contribution to explain traffic is made which is of importance especially for economy. In particular, due to the identification of causal relationships between logistics concepts, business characteristics and traffic volume new input parameters could be obtained.

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