A methodology for deploying VISEVA-W/VISUM for large area goods transport modelling

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Abstract. State of the art of commercial freight transport models is the combination of VISEVA-W and VISUM, both developed by PTV AG. However, VISEVA-W is designed to model urban or regional areas and is not intended for areas of the size as Germany.
The paper explains a methododolgy on how entire Germany can be modelled by making use of the transport modelling tools VISEVA-W/VISUM. Furthermore, it will be shown how two common indicators - tonne kilometers and vehicle kilometers - can be obtained.
The principal key of the method is a parallel modelling structure. While each model part shares the same equal behavioural groups, they simulate specific activities of these groups. Vehicle kilometers are directly displayed in VISUM. The indicator tonne kilometers was achieved by multiplying the trip matrix by vehicle type with an average fillrate of this vehicle type and the distance matrix of the network.
The paper shows the application of the method for the entire area of Germany in the year 2007. The method is suitable to modelling Germany with VISEVA-W/VISUM, as a comparison of the results with empirical data from 2007 revealed.
The method produces reasonable results. Recommendations for improvement are discussed in the conclusion of this paper. The key message is, the existing tool set VISEVA-W/VISUM is applicable for modelling freight transport on national level.

1 Introduction

Goods traffic is expected to increase within the next decades heavily [1], which is why adequate planning instruments are of great importance. Most often, traffic flows must be optimized on a large scale, e.g. accross whole nations. An important tool for that purpose are traffic models. So far, macroscopic and microscopic approaches have been developed by scientific institutions and/or commercial vendors. At DLR Institute of Transport Research, the primary focus is on the development of microscopic traffic models such as the implementation of WiVSim [2].

The institute's macroscopic approach employs VISEVA-W/VISUM, a commercial application considered state of the art (provided by PTV AG). However, the software toolkit is designed to deal with small areas [3]. Therefore, a methodology is needed for simulating goods traffic for large areas. The present paper demonstrates how VISEVA-W/VISUM can be utilized for such large area simulations, as demonstrated in an example for a simulation of Germany with a timeframe of 1 year.

The method's output features indicators for both tonne kilometers and vehicle kilometers.

2 Concept overview

We present a macroscopic concept suitable for modeling goods traffic in large areas, such as overall Germany. The VISEVA-W software from PTV AG is utilized for all sub steps including trip generation and distribution, route assignment with VISUM as well as the determination of indicators for tonne kilometers and vehicle kilometers.

First, a quick overview of all steps will be given. Then, each step will be discussed in more detail in designated sub sections. The overall process is displayed in figure 1.

1. **Creating initial sub models**
   In order to include a diversified representation of traffic participants, several separate sub models are set up. Each of them features the same set of participants, who are split into groups. Within a group all participants that feature similar intentions are pooled together, thus leading to a spectrum of groups, with each group representing distinct behaviour patterns.
2. **Determining parameters for trip distribution**
   The Viseva-W software segments the target area, here Germany, into different zones. Each zone receives attributes for feature sizes of trip generation and capacity of activity opportunities. The amount of trips is then later determined based on those attributes.
3. **Trip distribution**
   Next, all distances between zones are evaluated, so as to be linked accordingly. Weighting functions are utilized for the evaluation process. A weighting function returns the probability at which a certain distance is acceptable or not acceptable respectively. Thus, the flow of traffic between zones can be determined based on how many trips are leaving a zone, how many trips are attracted by a zone, and the distance evaluation between them. The outcome at this stage is a matrix for each sub model showing how many trips are conducted from zone to zone.
4. **Road network mapping**
   Within this step, route choices of vehicles are determined. All sub models should now be merged by groupwise summarization. This will help to keep the number of route assignment procedures low.

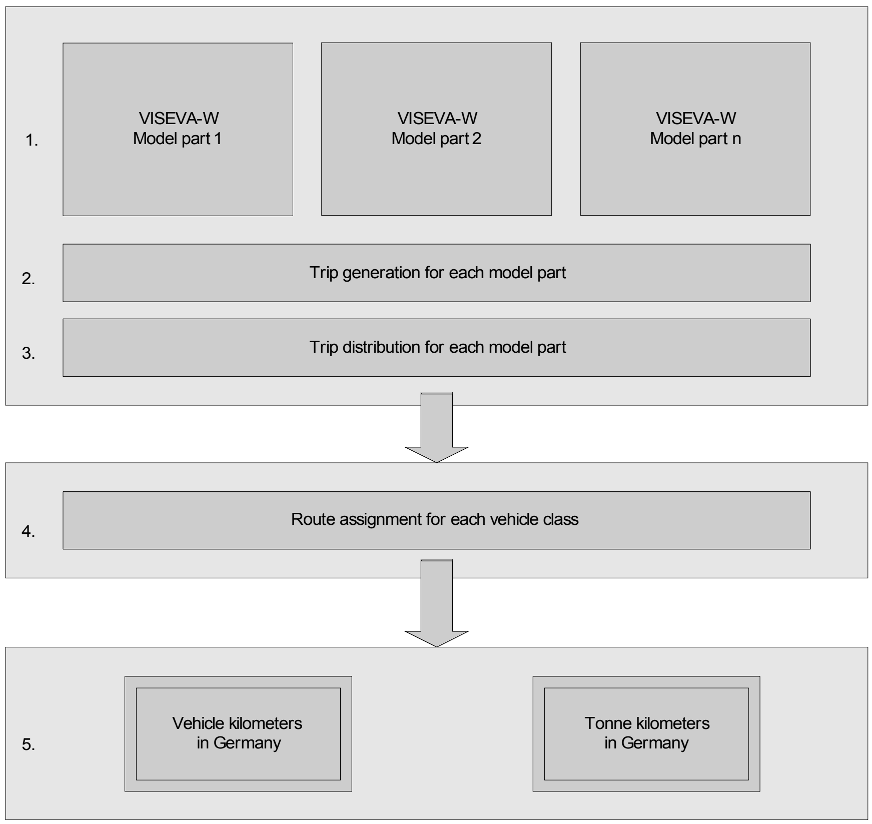

Fig. 1. Overview to the method. The figure shows the modelling steps on the flow.

5. **Deriving indicators**
   Indicators widely used for measuring the impact of actions taken are both vehicle kilometers and tonne kilometers. However, while vehicle kilometers are provided by VISUM out of the box, tonne kilometers can only be obtained by using VISEVA and VISUM combined.

3 Implementation

First of all, we will provide a short overview of the VISEVA-W workflow. VISEVA-W is a tool with which the modelling steps trip generation and distribution can be performed. The software does not differentiate modal split, thus we solely analyze road traffic. Round tours are the foundation of the traffic generation process. Each tour has a designated number of stops, and each stop has a specific type. Participants who share the same parameters are grouped together. The more behavioural homogeneous groups get declared this way, the better and more differentiated the model will work. Keeping driving time low is the main objective for simulated participants, therefore a trip's destination is chosen accordingly. To do so, weighting functions are utilized. Each behavioural homogeneous group can use a distinct weighting function [3].

The procedure described above is given and cannot be changed. In the following we will describe in detail how VISEVA-W can be used to simulate entire Germany.

3.1 Creating initial sub models

As already mentioned previously, behavioural homogenious groups must be created. Within VISEVA-W, those groups are named WVK and are defined as a combination of industry sector and vehicle type. 16 homogeneous groups result if for example a differentiation of 4 industry sectors and 4 vehicle types is desired.

$$WVK = industry\,type \times vehicle\,type$$

Homogenious groups are meaningfull, because all members of a group will share the same behaviour. The groups created for simulating goods traffic in Germany are displayed in table 1. Industry sectors were classified in line with the classification of the federal statistical office, see also [4]. All industry sectors then had to be further aggregated into 4 classes, so as to later obtain statistically valid behaviour parameters. Therefore, business sectors A to F (without E) were combined as primary sector, G and H (wholesalers and retailers as well as hotels and restaurants) were also grouped, sector I (haulage business) was kept. All remaining business sectors were put into a class that represents the tertiary sector.

For generating trips, VISEVA-W requires the following input parameters:

1. number of tours by behaviorally homogenious group

Table 1. Behavorial homogeneous groups of the sub models. All behavoral homogenous groups (in VISEVA named WVK) are listed. They result from combining vehicle classes with business classes (BK).

Truck Class	Business Class	WVK
$BK_1 = \{A, B, C, D, F\}$	Truck until 7,5t pmw*	1
	Truck from 7,5t to 12t pmw*	2
	Truck over 12t pmw*	3
	Semi-Trailer	4
$BK_2 = \{G, H\}$	Truck until 7,5t pmw*	5
	Truck from 7,5t to 12t pmw*	6
	Truck over 12t pmw*	7
	Semi-Trailer	8
$BK_3 = \{I\}$	Truck until 7,5t pmw*	9
	Truck from 7,5t to 12t pmw*	10
	Truck over 12t pmw*	11
	Semi-Trailer	12
$BK_4 = \{E, J, K, L, M, N, O, P, Q\}$	Truck until 7,5t pmw*	13
	Truck from 7,5t to 12t pmw*	14
	Truck over 12t pmw*	15
	Semi-Trailer	16

* permissible maximum weight

2. number of trips per tour
3. number of trips by feature size of trip attraction

At this point, several VISEVA-W models are created simultaneously with different behaviour settings for all 16 behaviour groups. Although all sub models share the same set of behaviour groups, they distinguish themselves in different behaviour functions. By using one single model only, artificial behaviour within the simulation would act far too simple and would therefore not reflect real life in a satisfactory manner. The approach of creating simultaneous sub models brings the advantage that several different activities of similar groups can be modelled much more differentiated. Parameters can be much better calibrated, e.g. kilometers driven.

For the example of Germany, 2 sub models were created. The first one simulates regular trips with load, while the second one addresses trips with no load.

3.2 Determining parameters for trip distribution

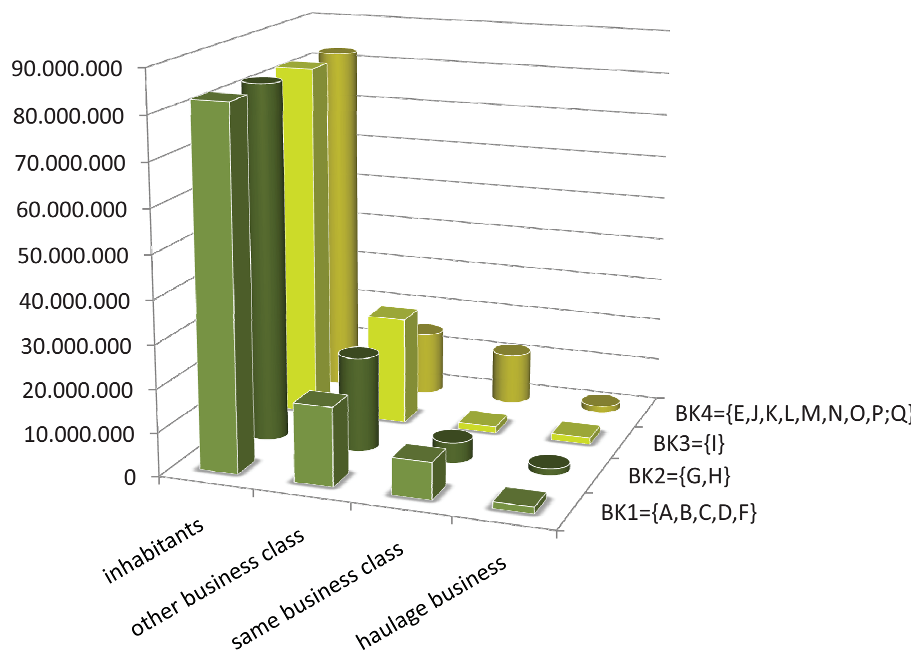

Fig. 2. Total number of feature sizes of the model. The figure shows total structural data of Germany based upon which parameters for trip generation and trip attraction are calculated ([5], [6], own calculation.)

feature size of trip generation and trip attraction Persons employed with liability to social insurance (SVB) of each business class were chosen as feature size of trip generation. Designated feature sizes of trip attraction are inhabitants, persons employed with liability to social insurance (SVB) of the same business class, SVB of all other business classes as well as SVB from haulage business. The relevant data is provided by federal authorities of Germany and was sorted to fit the structure of the traffic zones of the Validate network (which is provided by PTV AG). The values of the feature sizes are shown in figure 2.

Parameters for trip generation A top down approach was chosen to quantify the trip generation parameter. The base to a forthcoming disaggregation is the total number of trips by business class sorted by loaded and unloaded runs. This data is available through statistics of the Federal Motor Transport Authority (KBA). KBA surveys a sample of 5 ‰of in Germany registered goods vehicles, extrapolates the sample and releases reports by month and year [7]. See also table 2.

Table 2. Total number of trips sorted by business class. The presented number of runs is constituted as the base of our top down approach. They were disaggregated into trip per behavorial homogenous group (WVK) for each sub model. Calculation of the authors.

	Loaded runs [1 000 runs]	Empty runs [1 000 runs]
$BK_1 = \{A, B, C, D, F\}$	16299.9	9714.4
$BK_2 = \{G, H\}$	24854.9	13517.4
$BK_3 = \{I\}$	71111.7	39920.5
$BK_4 = \{E, J, K, L, M, N, O, P, Q\}$	103973.0	60034.3
total	216239.5	123186.6

Source: [7], page 44, 45

The next step addresses the allocation of total number of trips to vehicle classes, for which vehicle times business class was used. The relevant empirical data is also provided by KBA, see also figure 3. By multiplying the portion of vehicles by business class with total loaded trip numbers of business class we obtained the number of loaded runs by homogeneous behavioural group (WVK). The number of unloaded runs was derived with the same procedure.

With the proceeding described we determined the number of loaded and unloaded trips to all WVK in each sub model. Next, parameters of trip generation can be calculated.

Trips by tour of loaded runs In order to obtain the average number of trips per tour for each WVK, the survey "Kraftfahrzeugverkehr in Deutschland" (KiD) from 2002 was evaluated.

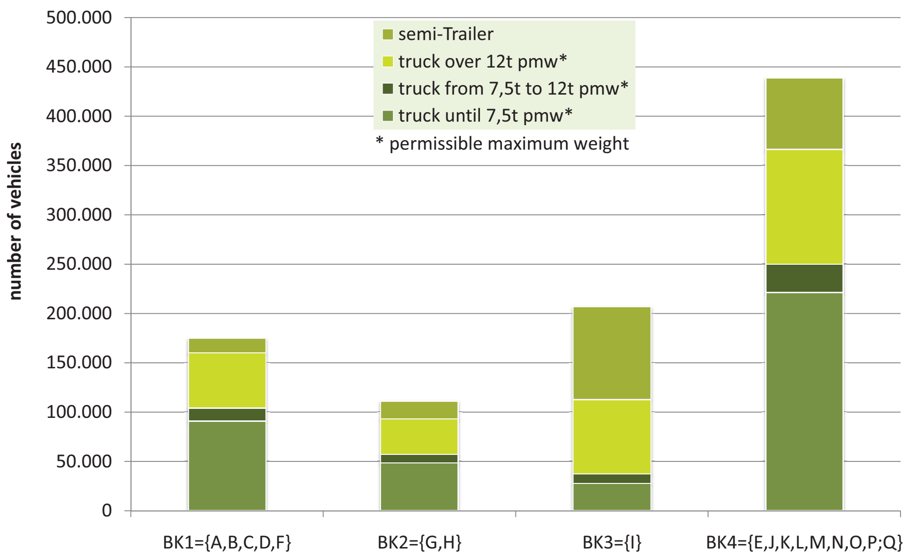

Fig. 3. Inventory of vehicles per business class. The portions of the inventory by business class was used refer ammount of trips to WVK. Calculation of the authors based on [8].

KiD is a large-scale study on mobility behavior and was conducted for Germany in 2002. Mobility patterns were raised by requesting vehicle owners to log their vehicle's movements for one day. A remake of the study is expected to be realized in 2009 and will have a similar design as in 2002, allowing to apply the same procedures presented here to the new data.

Figure 4 shows the average number of stops per tour for loaded trips.

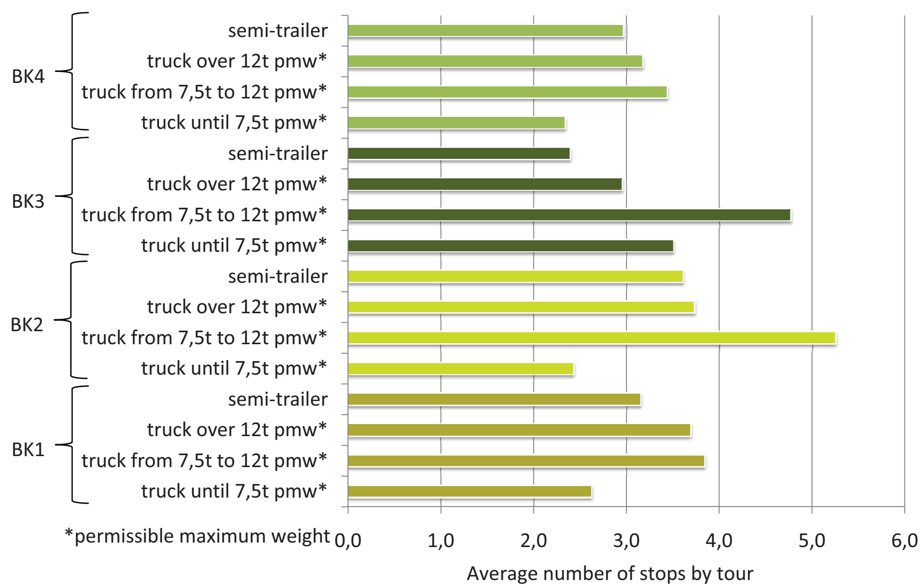

Fig. 4. Avarage number of stops by tour. The values were taken to characterize the tour pattern of each WVK. Calculated by the authors based on [9].

Unloaded runs by tour The parameter "2 trips per tour" was set for trips without load, since drivers naturally avoid trips without load in real life. Thus they usually carry out only one empty trip until reaching the next load opportunity. Later, the matrix need to be devided by 2 in order to simulate a direct trip.

Yet another parameter called "trips by tour" in combination with "number of total trips" determines the second parameter of trip generation named "number of tours". The formula presented below calculates "tours by employees liable for social insurance" based on both loaded and empty trips.

$$tours\ by\ SVB(WVK) = \frac{\frac{trips(WVK)}{trips\ by\ tour(WVK)}}{\sum SVB}$$

At this stage, the amount of shipping is quantified. Succeedingly, the amount that can be potentially delivered must be determined in yet another step.

Paramters describing a trip's destination Finally, every trip must get a destination assigned. Again, the survey "Kraftverkehr in Deutschland" was taken as a basis. The logbooks contained therein feature 7 possible destination types. However, not all can be carried on to the present methodology, since for some of them the number of occurances is not sufficient. Thus, those destination types were aggregated in an appropriate fashion, as displayed in figure 5. The figure also shows percentages by WVK. Note that the aggregation scheme as displayed in figure 5 was applied to all sub models.

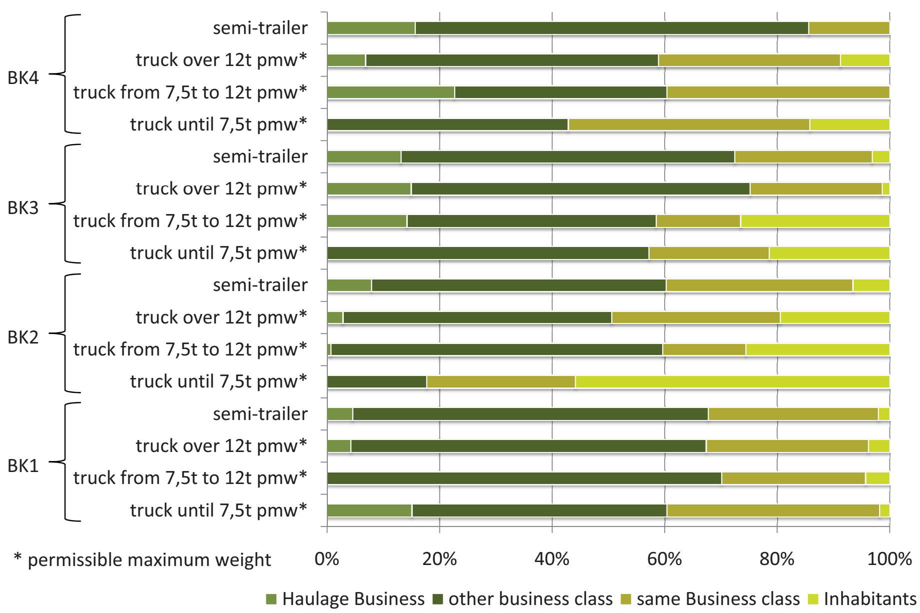

Fig. 5. Factor of portion by feature size and WVK. The figure shows how destination types were segmented by WVK. Own calculation based on [9].

The parameters for for trip attraction are determined as follows:

$$Trip\ attraction\ per\ feature\ size(WVK) = \frac{trips(WVK) \cdot factor\ of\ portion}{\sum feature\ size}$$

Traffic generation for each sub model can be done based on the behavioural homogenious groups from VISEVA-W and feature sizes by traffic zone. The outcome of this step is a matrix showing the number of ins and out of each zone. Trips will be generated based on this data in the following step.

3.3 Trip distribution

Two parameters handle the connection of zones through traffic flows and define the origin destination matrix. The first parameter is the potential of trip attraction of a traffic zone. It was determined in the process trip generation. The second parameter is the likelyhood of each traffic zone to be selected as a destination by another traffic zone. The likelyhood is implemented by a weighting function which decides wheather shipping times between traffic zones are acceptable or not. The weighting function is necessary for all behavioural homogenous groups in each sub model. Furthermore, different kinds of weighting functions exist based on different kinds of trips in a tour as displayed in figure 6.

We implemented the standard functions EVA and EVA2 [3], which come with VISEVA-W.

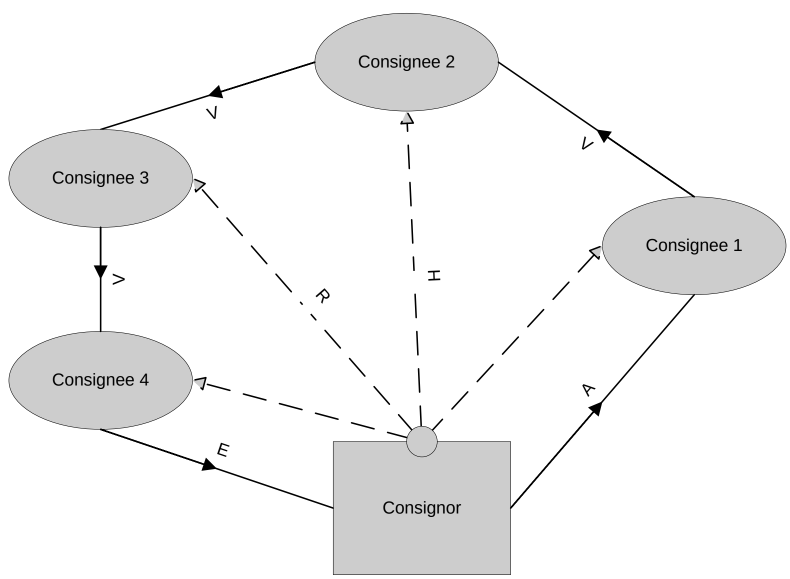

Fig. 6. How trip distribution works. The figure shows a typical tour with the reference of different types of implented weighting functions.

A Weighting function for the first trip of a tour based on shipping time
E Weighting function for the last trip of a tour based on shipping time
V Weighting function connective trips (between destinations) based on shipping time
H Weighting function of spatial distribution from actual traffic zone to home based in shipping time
R Weighting function of spatial distribution from destination traffic zone to home based in shipping time

3.4 Route assignment

All traffic flow matrices were compiled into trip matrices through a VISEVA standard operation. We aggregated the matrices of loaded and unloaded runs of each vehicle class. That happened to reduce the number of transport systems and successive assignment procedures in VISUM. The route assignment was implemented in VISUM. Within the prepartion of the procedure we have to account for the road charge for vehicles with a permissible maximum weight over 12 tonnes on federal motorways. This charge can be realized by the generalized cost (C) of a link. With mono-criteria assignment procedures in VISUM all cost component are in the unit second.

$$C = \sum c_i = shipping\ time + charge$$

Hence, the charge has to be compiled into second as well. To implement this we accounted three parameters: the charge, a Value of Time (VoT) and the flow velocity on a link (v). The derivation of the charge in unit second is shown next:

$$VoT \cdot v = \left[\frac{ct}{s}\right] \cdot \left[\frac{km}{s}\right] = \left[\frac{ct \cdot km}{s^2}\right]$$

$$\frac{charge}{VoT \cdot v} = \frac{\left[\frac{ct}{km}\right]}{\left[\frac{ct \cdot s^2}{s^2}\right]} = \left[\frac{ct \cdot s^2}{km^2 \cdot ct}\right] = \left[\frac{s^2}{km^2}\right] = \left[\left(\frac{s}{km}^2\right)\right]$$

$$charge\ in\ seconds = \sqrt{\frac{charge}{VoT \cdot v}} \cdot length\ of\ link = \sqrt{\left[\left(\frac{s}{km}\right)^2\right]} \cdot [km] = [s]$$

This formula was utilized in VISUM on federal motoway for charge liable vehicles with a charge of 12 ct/km, a Value of Time of 28 EUR/h [10] and a speed of 89 km/h. The assignment procedure was an equilibrium aligned standard operation in VISUM.

3.5 Deriving indicators

Common indicators are vehicle kilometers and tonne kilometers.

VISUM returns vehicle kilometers by default. What the software does is to multiply the number of vehicles per vehicle class with the length of each link passed. By accumulating all links/trips, vehicle kilometers of the according vehicle class are obtained.

On the contrary, tonne kilometers are not provided by default. Therefore, the following procedure was applied:

The trip matrices sorted by vehicle class of loaded runs have to be multiplied with an average fill rate of this vehicle class. Next, these matrices can be stored as tonne-generation-matrices, since they contain information on how many tonnes

Table 3. Indication values of German Traffic in 2007. The indications average load, verhicle kilometer and tonne kilometer are presented sorted by vehicle class. All values are surveyed in Germany in 2007. Own calculation.

	million vehicle kilometers	million tonne kilometers	Avg. load [t]
Truck until 7,5t pmw*	0.231	316	1.86
Truck from 7,5t to 12t pmw*	1.84	4280	2.82
Truck over 12t pmw*	10.37	89484	10.18
Semi-Trailer	13.08	167353	17.87

* permissible maximum weight
Source: [7], page 16

are shipped from traffic zone to traffic zone. Further, it is possible to generate a distance matrix from VISUM which tells the average distance between traffic zones. By multiplying the distance matrix with the tonne-generation-matrices, we finally receive the indicator tonne kilometers. Total tonne kilometers are displayed in the column sums of the matrix in VISEVA.

The values described and fill rate factors used are shown in table 3

4 Results for the year 2007

The steps described were implemented in VISEVA-W/VISUM and the indicators vehicle kilometers as well as tonne kilometers were calculated. The results are shown in figure 7 and figure 8 respectively.

It can be seen that there are deviants from target values to calculated values. The gap is shown in figure 7 and 8. While the indicator vehicle kilometers is precise (readed by multiplying length of the link with the number of vehicle by vehicle class), tonne kilometers are blurred, because of the average factor load of vehicle. The fill rate of a trip may differ by trip length or other variables. Particularly to semi-trailor with high capability and a resultant wide opportunity of fill rate, these effects are present. This explains that we fall below the rate of vehicle kilometers by -2.4 % and exceed tonne kilometers by 20.5 %. The total amount is heavily influenced by semi-trailers. All other indicators do have right tendencies or are on point.

While the example calculation didn't return a perfectly calibrated model, we weren't aiming for one either. Instead, the workflow and functionality of the modelling concept was shown.

5 Conclusion

Splitting a model in different parts turned out to be a successful approach for modelling the entire area of Germany.

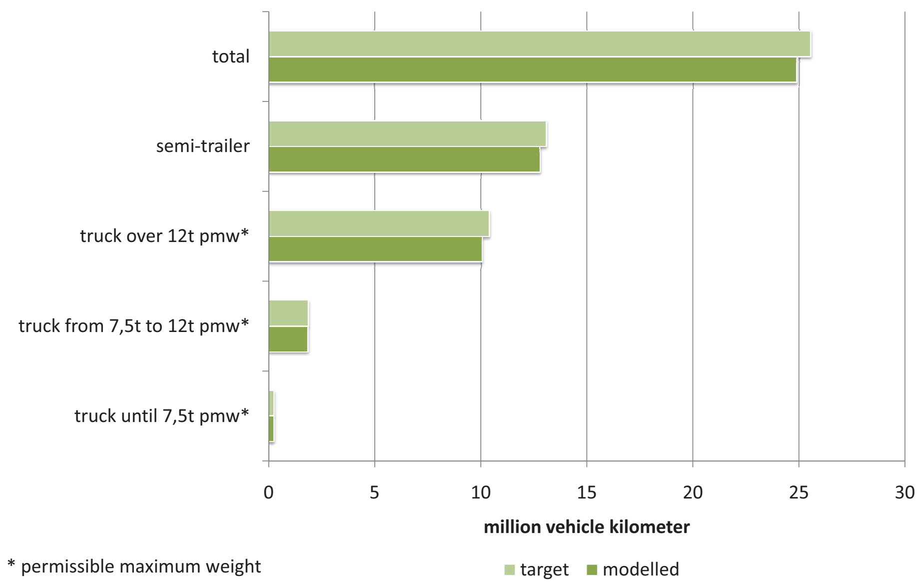

Fig. 7. Modelling results of vehicle kilometers. The graphic shows modelling results by the indicator vehicle kilometers. The percental deviation per vehicle class is -1.3 % for trucks until 7,5t pmw*, -0.3 % for trucks from 7,5t to 12t pmw*, -3.1 % for trucks over 12t pmw*, and -2.4 % for semi-trailers. The total deviation is -2.6 %.

*permissible maximum weight

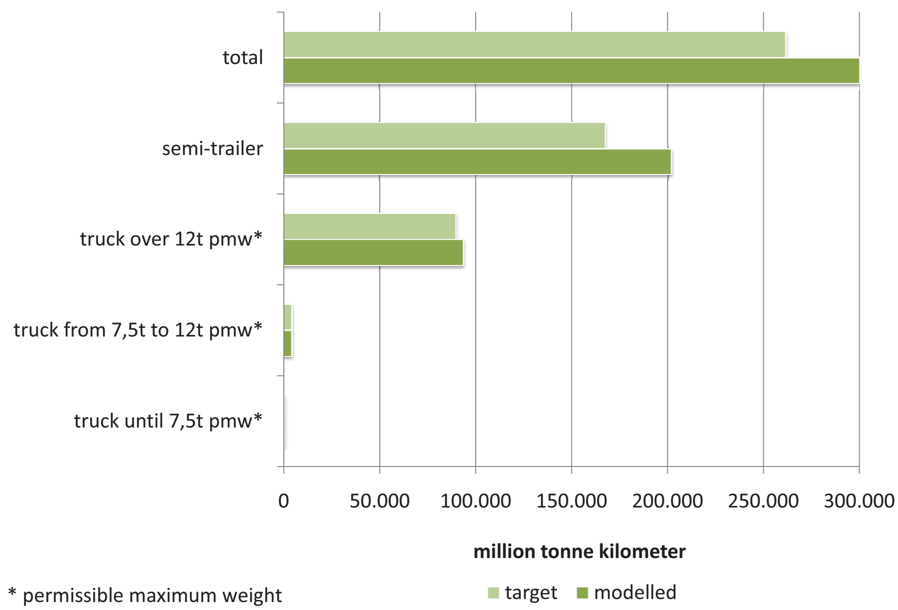

Fig. 8. Modelling results of tonne kilometers. The figure shows the modelling results for the indicator tonne kilometers. The percental deviation per vehicle class are 3.5 % for trucks until 7,5t pmw*, -0.3 % for trucks from 7,5t to 12t pmw*, 4.5 % for trucks over 12t pmw*, and 20.5 % for semi-trailer. The total deviation is 14.7 %.

*permissible maximum weight

The next step is to differentiate short-distance and long-distance model parts as shown in figure 9. We accomplished the preparation of a database for each sub model with data of [7] and [9].

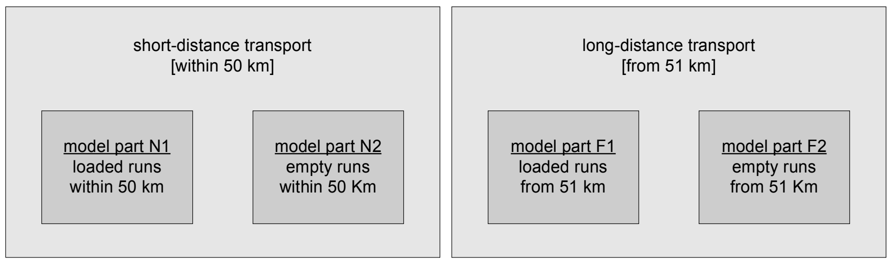

Fig. 9. Recommended sub models. We recommend to devide the model for good transport in Germany in the 4 presented sub models.

The challenge to implement an weighting function for long-distance transport still remains. This weighing function starts at a definable value of time resistance (w) and has to be modifiable in the course of the graph. Such a function is shown in figure 10 with:

$$F(w) = \frac{(p_3)^{p_2} \cdot (w)^{p_2}}{(w)^{p_2} - (p_1)^{p_2}} \quad \text{where } w = time - resistance$$

p_1 fixes the intersection with abscissa (minimum time-resistance)
p_2 influences the convergence to the abscissa
p_3 controls the maximum time-resistance

In order to further develop the concept of using parallel sub models, the route assignment process should be adapted. The main aspect of route assignment is that each vehicle (transport system) assigned influences the route choices of following vehicles. Free speed on a link is available only within the first assignment process, therefore only transport systems assigned in the first step are not limited through other transport systems. The unwanted effect is that transport systems assigned to a later point are highly affected through previous ones, while the first ones enjoyed less congestion. With the desire to reduce the distortion, we aggregated trip matrices as far as it seemed appropriate, so as to flatten the hierarchy of transport systems. We therefore recommend an additional approach to route assignment, in which the assignment process is performed in shares over all transport systems incrementally rather than assigning transport system completely one after another.

Besides the effect of getting a similar base of route choices for the transport systems, the indicator tonne kilometers could be taken by a further enhanced

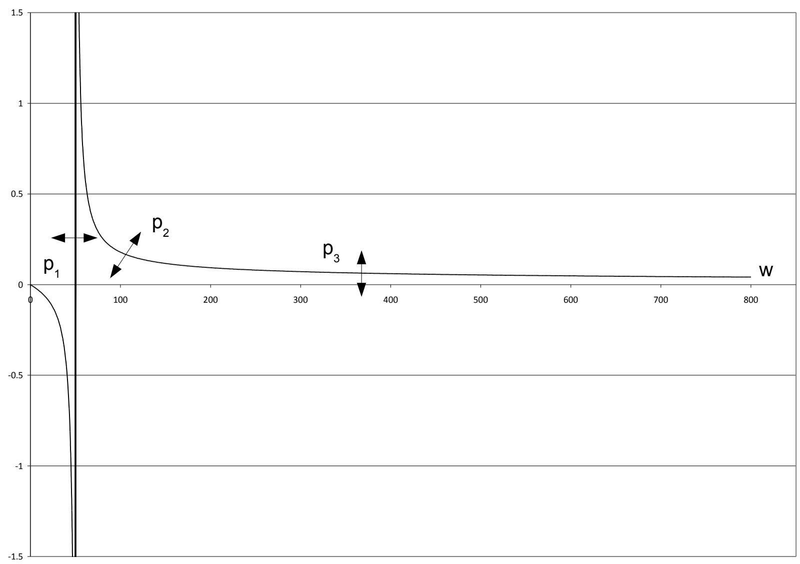

Fig. 10. Weighting function for long-distance transport. The function can be used to assess time resistants for long-distance. Short-distances are excluded.

method than the one described above. It is more precise to multiply the number of vehicles by transport system (loaded) with the length of the link and an average load.

The results of the work may transfer to passenger transport modelling. The functionalities described might get implemented into trip generation and trip distribution software for enhancing usability. This suggestion extends the scope of application of VISEVA(-W) and VISUM. Particularly engineering offices or institutes without own modelling software can participate in projects regarding large planning areas.

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