Modelling Traffic Data for Calculation of Cold Starts Emission

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1. Project philosophy

The exact algorithms for calculation of overemissions data from car traffic cold starts have been known for long. However, it is still very difficult and ineffective to obtain accurate traffic data for external emission calculators, when trying to apply the algorithms in air pollution modeling in urban and rural areas.

In the Czech Republic, the amount of cold start overemissions for typical pollutants have long been calculated for large car parks, supermarkets, entertainment centers etc. However, their calculation for common roads and street networks in cities can still be difficult to carry out because of the absence of accurate data for individual road segments. To know accurate inputs for all major roads for the emission calculation, it is necessary to know more (in addition to the common data). That means:

- Distance traveled from origin to the evaluated road segment for each vehicle;
- The value of parking time before the start of the trip.

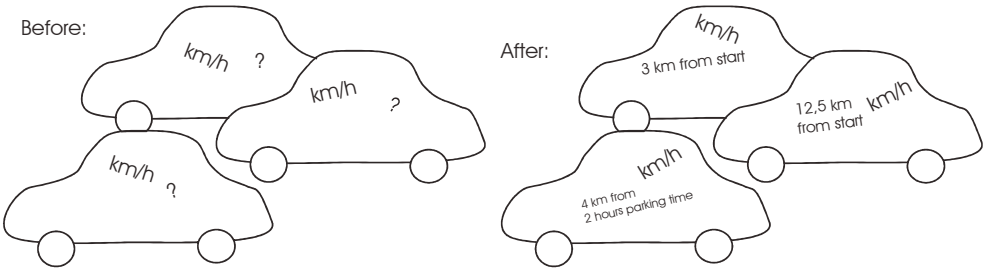

Figure 1: The state of knowledge of traffic flow characteristics on profile in traffic model (PTV VISUM software) was used and a special script was programmed by AF-CITYPLAN. After assignment, the script allows to compute these missing data for the entire traffic network and use it to perform accurate cold emission calculation.)

2. Mobility characteristics

The mobile characteristics in cities show that a **significant part of the journeys is performed in distance that is shorter than four kilometres, i.e. within a distance where the cold emissions are produced** by vehicles with combustion engine. If we look at the statistics of German cities, we see that 37.5 % of individual car trips are carried out on a distance of less than 4 km. In addition, on all longer trips, the first 4 kilometres lead to the production of cold emission as well, if the vehicle was stopped sufficiently long period before driving (cold engine).

Table 1: Shares by travelled distance (source: SrV 2008)

Trip length group [km]		Share on number of trips by transport mode				
more than	to	pedestrian	bike	pers. car	publ. tr.	Total
0	1	69.8%	24.2%	7.8%	3.6%	25.4%
1	2	20.2%	22.7%	10.6%	8.2%	14.3%
2	3	6.4%	17.8%	10.8%	12.2%	10.9%
3	4	1.6%	9.7%	8.3%	10.6%	7.2%
4	100	2.0%	25.6%	62.5%	65.4%	42.2%
Total		100.0%	100.0%	100.0%	100.0%	100.0%

From the available materials dealing with the theme of cold emissions in France – the outputs of MEET project are interesting. From the table, which indicates the proportion of journeys with cold emission is evident that the proportion of journeys with lengths up to 4 km is 35 %, which is comparable to that seen in the German survey in 2008 (37.5 %).

In the Czech Republic it is difficult to find relevant data directly to the subject of this project. However, we can at least get information on mobility characteristics in selected cities. The figure from the study of Charles University in 2008 (see histogram below: figure 1) shows, that the trips up to 2.5 km, 5 km and 7.5 km (first to third column in the histogram) are the most numerous. However, there are listed all trips without specification of means of transport.

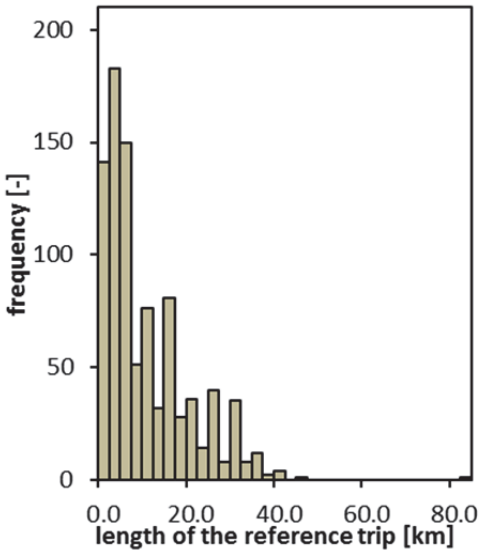

Figure 2: Histogram – length of reference trip (source: study by Comenius university in Prague, 2008)

3. Traffic model and used city models

To create a traffic model and execute traffic assignment for evaluated variants the transport-planning software suite PTV VISION was used (product of PTV Company, Karlsruhe). Software VISEM® was used for modelling of transport demand and VISUM® for traffic assignment.

The base model of a road network was taken from the model of private transport of the Czech Republic in detail up to III. class roads, including basic roads of European importance abroad. This model is continuously updated and used for purposes of macroscopic models of regions and cities by AF-CITYPLAN Company.

Traffic model consists of transport demand model, which is represented the matrix of transport relations (origin-destination matrix) for different types of traffic and traffic supply model, which contains a parameterized road network.

In this study, city size models were used, which are based on the national model. In this sub-models are conducted further calculations and analysis. When the partial transport model is developed on the background of the national transport model, it is possible to take into account changes in the calculation of traffic volumes entering the roads on the model border due to completion of a road network throughout the Czech Republic. In the urban traffic model therefore are included all relations that occur in real traffic. 8 cities were chosen for further analysis.

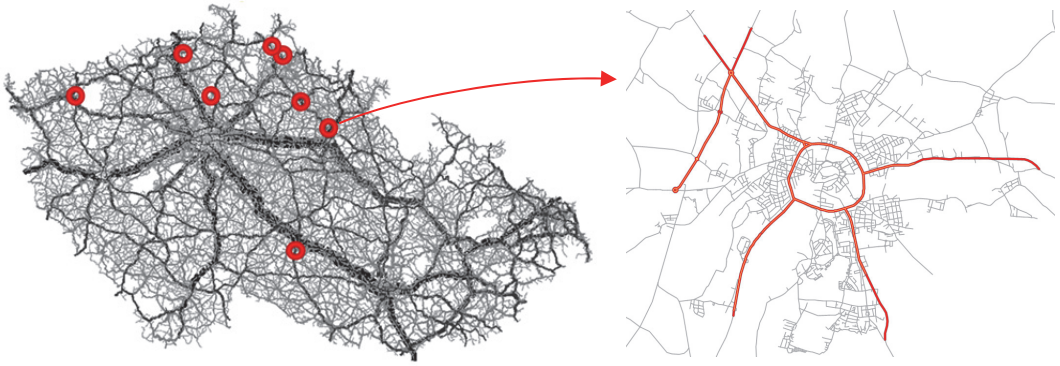

Figure 3: Traffic model of the Czech Republic and 1 of 8 used city models (Hradec Kralove)

4. Software toll for data production for cold starts emission calculation

For calculation of the specialized data for subsequent calculation of cold emissions it was necessary to extend the basic functionality of the VISUM software and therefore it was created a unique script in python language. This script calculates from basic data (calculated in VISUM software) in conjunction with other input data, the percentage of vehicles on individual road segments (links) of the model in dependence on:

- Vehicle category (car, light duty vehicle, heavy duty vehicle…)
  Computation follows the demand segments set in VISUM traffic model. In this study 6 demand segment were used aggregated into 3 main demand segments)
- Traveled distance from the origin to the road segment - to the start point, middle point or end point of the road segment. Five distance categories are defined: less than 1 km, 1-2 km, 2-3 km, 3-4 km and more than 4 km)
- Type of the origin zone:
  Residential complex, administrative, manufacturing corporation, store – specialized, store – supermarket, store – hypermarket, restaurant, P+R facility, city center.

User interface of the script is seen in the figure below (see figure 4). It requires setting the following points:

1) The way of calculation of distance traveled - from origin to the beginning, middle, or end of the link (respectively from origin to the initial node or to the middle of the link or to the end node);
2) The range of calculation - for the entire network or only for the selected route or set of routes designed using flowbundle functionality in VISUM (the range of calculation affects the speed of calculation significantly);
3) Saving of calculated values into link attributes (user defined attributes category in VISUM) - for the entire network or just for the active links (determined by standard filter functionality in VISUM);
4) Selection of demand segments for calculation - if the model contains more demand segments (more demand matrices), it is possible to select those for which the calculation will be performed (check boxes on the left) and then select the column according to the prefix. Prefix allows you to get the results separately for each demand segment or aggregate demand segments into groups or categories (e.g. matrix results from cross-border and inland traffic can be grouped together by vehicles category);
5) Definition of the table of parking time - the script contains predefined values according to Czech standard TP 219, but can be changed directly according to your own values or values from survey, if they are available.

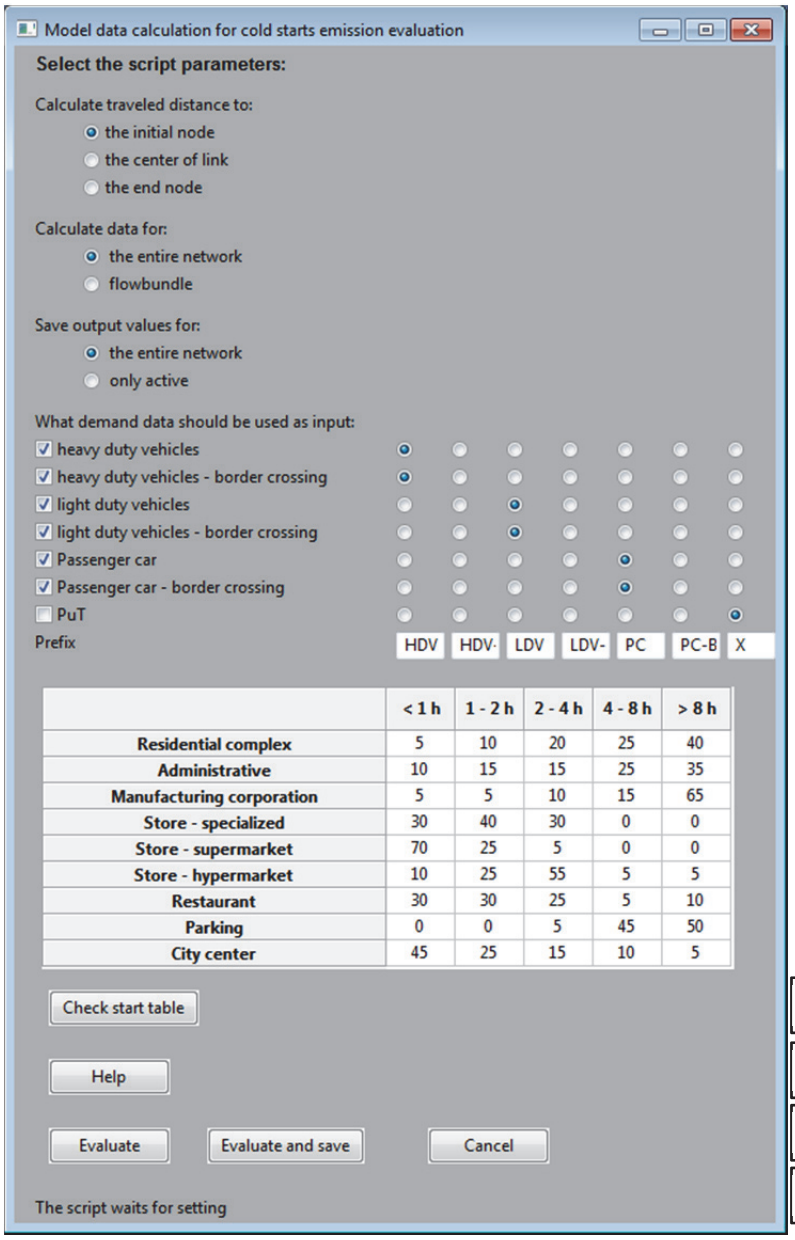

Figure 4: Developed script tool for data calculation for evaluation of cold emission (works with PTV VISUM software)

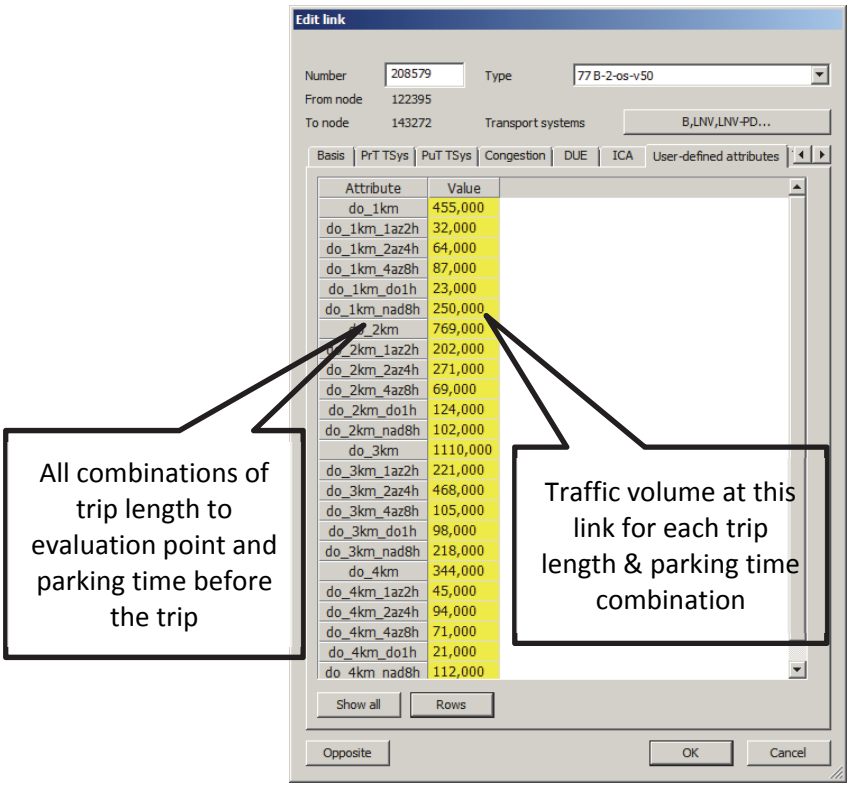

Figure 5: Output data from the script after run in VISUM software – window for one selected network segment (link)

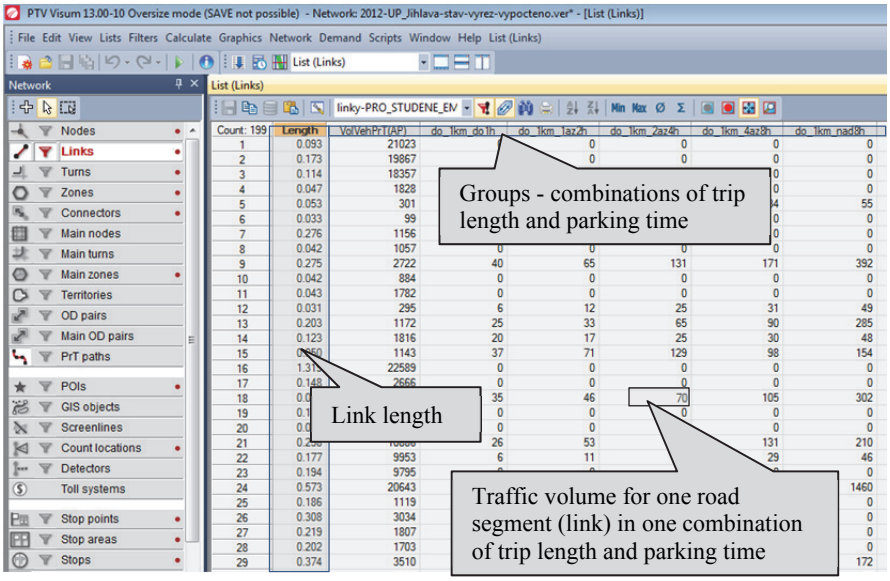

Figure 6: Output data in VISSUM after run of the script for selected group of links (network segments)

These data then allow you to create matrices of data for each road segment (link) or to calculate the average values for the group of segments (e.g. selected corridor or I. class roads etc.). Then these data are used for calculation of cold emissions.

Table 2: Data matrix – weighted average for main local roads: output from script used in VISUM software (Example from City of Karlovy Vary, main local roads, weighted by segment length)

		Vehicles distribution by parking time before the start of the trip					
		< 1 h	1 - 2 h	2 - 4 h	4 - 8 h	> 8 h	Total
Vehicles distribution by trip length (from origin to evaluation point)	< 1 km	2,4%	2,9%	4,8%	5,0%	9,0%	24,2%
	1 - 2 km	2,1%	2,7%	4,5%	5,1%	8,8%	23,2%
	2 - 3 km	1,5%	1,8%	3,0%	3,4%	6,0%	15,7%
	3 - 4 km	1,2%	1,4%	2,2%	2,5%	4,5%	11,7%
	> 4 km	1,6%	2,8%	5,4%	5,8%	9,6%	25,2%
	Total	8,8%	11,6%	19,9%	21,8%	37,9%	

5. Analysis of model outputs

The analysis was performed by statistical evaluation of the model results for each city by dividing by the length of the trip and the parking time before the start of the trip. There were 2 reasons for this approach:

1) To test the developed script tool;
2) To collect and compare data for cold emission calculation from several Czech cities.

Output data matrices were transformed into tables and figures, some of them are listed below.

Table 3: Example – City of Karlovy Vary, weighted by segment length (weighted averages)

		Vehicles distribution by parking time before the start of the trip					
		< 1 h	1 - 2 h	2 - 4 h	4 - 8 h	> 8 h	Total
Vehicles distribution by trip length (from origin to evaluation point)	< 1 km	2,4%	2,9%	4,8%	5,0%	9,0%	24,2%
	1 - 2 km	2,1%	2,7%	4,5%	5,1%	8,8%	23,2%
	2 - 3 km	1,5%	1,8%	3,0%	3,4%	6,0%	15,7%
	3 - 4 km	1,2%	1,4%	2,2%	2,5%	4,5%	11,7%
	> 4 km	1,6%	2,8%	5,4%	5,8%	9,6%	25,2%
	Total	8,8%	11,6%	19,9%	21,8%	37,9%	

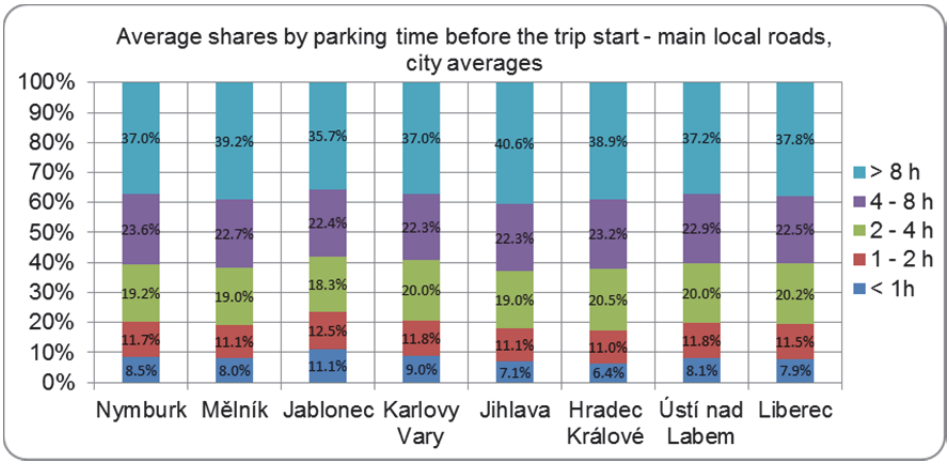

Figure 7: Average shares by parking time before the trip start - main local roads

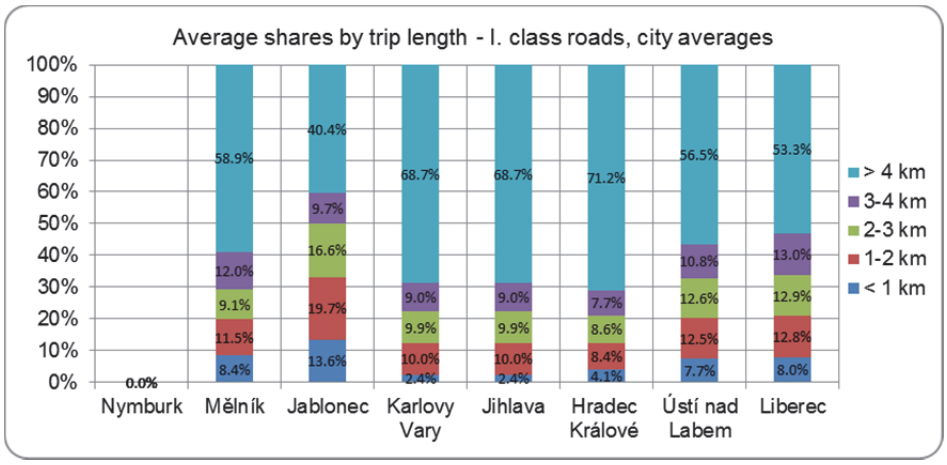

Figure 8: Average shares by trip length (from origin to evaluated profile), I. class roads

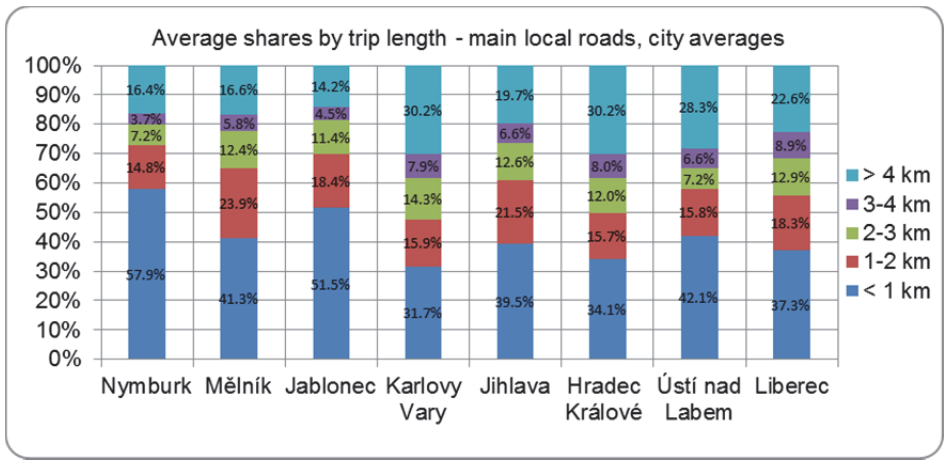

Figure 9: Average shares by trip length (from origin to evaluated profile), main local roads

6. Conclusion

The results of model calculations presented in this study are based on the traffic models of 8 selected cities in the Czech Republic processed by AF-CITYPLAN Company in Prague.

The analysis of trip lengths and the parking time of vehicles and comparison of various cities indicate that:

- The values of each road category varies considerably in distribution by length of trips (from origin to evaluation point);
- The distribution by parking time (before the start of the trip) shows only small differences between the road categories.

The actual calculated values are shown in the results tables separately for each city. **The concept of finding the average value** of the shares of vehicles by travelled distance and parking time for the road type based on the average data from several cities **have several drawbacks:**

- Traffic behaviour in individual cities may vary significantly;
- Values can have considerable variance depending on the positions of the origins and destinations of transport;
- The results may show significant differences in outcomes according to whether it is in a few large or many small employers (the effect on linear path structure and geographical distribution);
- To achieve sufficient accuracy of the model results – high demands on the structure of the model are needed. On the other hand, the results in the form of averages decrease the achieved accuracy.

The results of this study can be used for calculations in other cities in several ways:

- Use of results tables of city, which is similar type (in terms of road network) and structurally similar to the assessed city;
- Use of average summary tables of the results of several cities in the same category (with categorization e.g. based on population).
- Not to take average data of other cities, but to use created script tool in combination with a city transport model for the direct calculation of values.
- For the analysis of lanes or streets not to create an average value of many network segments (links), but to work with specific calculated values for individual road sections (links).

The best possible solution, which we also recommend, it the establishment of values for each road segment (link) evaluated on the basis of direct model data from the relevant road sections. This is currently possible and facilitated by the **script developed** and used in this study (it extends the functionality of the basic modelling software VISUM). The accuracy of the results is dependent (among other factors) on the detail of the model and on its structure. This should be consistent with the conditions contemplated in the calculation of cold emission.

The advantage of this procedure is very substantial approximation of the results of emission models and dispersion studies to the reality. Especially in the cities can be expected to obtain much more accurate and credible results and based on them also to take adequate measures to improve air quality. Clearly, we can say that this revised calculations will not ever touch the emissions from motorways and expressways (out of the city), on the other hand will mean a significant increase in model results in the vicinity of resident and business areas. More accurate traffic model calculation means a small correction of economic models as well, especially in the consumption of fuel on selected roads.

References

AHRENS, Gerd-Axel. TECHNISCHE UNIVERSITÄT DRESDEN, Lehrstuhl Verkehrs- und Infrastrukturplanung. *Sonderauswertung zur Verkehrserhebung, Mobilität in Städten – SrV 2008': Städtevergleich*. 2009.

ANDRÉ, Michel, Ulf HAMMARSTRÖM a Isabelle REYNAUD. Driving statistics for the assessment of pollutant emissions from road transport: *Methodologies for estimating air pollutant emissions from transport (MEET)*. 1999, 194 s.

INFAS INSTITUT FÜR ANGEWANDTE SOZIALWISSENSCHAFT GMBH, Deutsches Zentrum für Luft- und raumfahrt e.V. institut für Verkehrsforschung. *Mobilität in Deutschland 2008: Ergebnisbericht Struktur – Aufkommen – Emissionen – Trends.* 2010. vyd.

UNIVERZITA KARLOVA V PRAZE, Centrum pro otázky životního prostředí. Analýza každodenního dopravního chování dospělého městského obyvatelstva a nástroje regulace dopravy: *Závěrečná zpráva z projektu MD 24/2006-430-OPI/3*. Praha, 9/2008.