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Traffic Emission Mapping with Toll System Assistance

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ABSTRACT

The paper presents a method of the traffic emission computing, mapping and its monitoring in relation to the system of the highway toll gates. The construction of an own mathematical model, built on secondarily used data variables of the toll gate system, is presented. The model construction allows describing a simple method for the estimation of traffic intensities and finally for modelling the emission load maps of the mobile sources.

KEYWORDS: highway toll system, traffic intensity, estimation, emission mapping, track inclination, indirect modelling, weather effects

1. Introduction

Continuously increasing road traffic causes a higher pollution in the vicinity of roads and spreads the emission depending on weather conditions. This effect has an impact on settled areas near the roads and brings worse environmental conditions in the neighbourhood of roads in general.

To deal with this effect, it is necessary to understand the existing pollution processes, be able to recognize particular pollutant sources, be able to realize and measure individual pollution factors etc.

Ideas are deeply extended in the field of toll gate system data, its availability, usage and accuracy. These are discussed in relation to the emission maps modelling and traffic intensities estimation.

Moreover, relevant data from the selected Czech highway toll gates were used to generate graphical outputs as examples. Across the paper, various generated emission maps present the model outputs for different emission factors.

2. Model

The model presented is a part of the starting project. The aim of the emission load model at this stage of development is to process the already captured data on these main measurable pollution factors: C20H12, NO2, PM10, SO2. The concept of the model is prepared as follows.

2.1. Emission Load Model Description

The emission load E_{dtpi} for day type d (Mon, …, Sun), time of day t, pollutant p and road inclination i is estimated using the model

$$E_{dtpi} = I_{dt} \times e_{pi} \qquad (1)$$

Symbol Idt denotes the average of traffic intensities in both directions for the given day type and time of day. By e_{pi} we denote a coefficient corresponding to a selected emission factor and given road inclination. (Coefficients e may depend, in general, on the car type and velocity, too.

In this state, our model is simplified, considering only registered heavy trucks at the speed of 80 km/h.)

3. Data

3.1. Data Input

Public available aggregated data sets from Czech D1 highway toll gate system of the time period from January 1, 2007 to March 6, 2007 were used. Registered intensities of the heavy trucks over 12 tons of weight were taken for model testing. A table with identification, kilometric and location localization of particular toll gates was attached to the data sets. Used coefficients for the emission factors were the output of a different project [7].

3.1.1. Traffic Intensity Estimation

Provided intensity data sets for heavy truck traffic can be easily represented in combined time-space graphs. The data file of intensities is arranged in the following format:

- Date (secondarily the day type as well),
- Time (when the intensity was taken),
- ID for the each toll gate,
- Intensity value.

Intensities in the original provided data sets are subdivided into two groups according to the traffic direction.

Each of the intensities, prepared for a separate traffic direction and for the assessed day type, is always created as the average value of all particular intensities on the same day type, specified in the source file by date. In our model, as already mentioned, an example for the day type "Friday" is presented.

A colour scale represents the average value of the intensity. The scale is organized from red through yellow, orange, green and blue to violet (values 0 – 130). Values of intensities are represented as the number of heavy trucks that passed the gate during each previous 15 minutes.

The final intensity I_{dt}, calculated with our model, is an average value, which consists of both average intensities for each of the particular directions at one toll gate at the same time and on the same day type. The model does not distinguish a separate emission load for each traffic direction, but calculates it as the overall emission load at the defined toll gate point. This is because we do not count separate directional intensities .

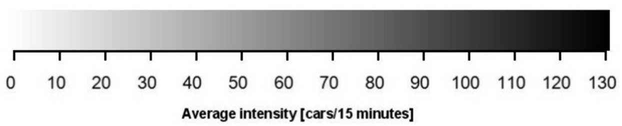

Fig. 1. Scale for the traffic intensity of heavy trucks (over 12 tons)
Source: [own work]

Table 1. Values of average vehicle intensities over 12 tons of weight in the direction from Prague to Brno

Min.	Q1	Med.	Avrg.	Q3	Max.
1.00	27.56	37.89	38.11	51.67	90.00

The number of vehicles cannot be exactly identified from the input data file. Cars pass through several toll gates in 15 minutes time periods, but details about this passing are not included. An estimate of the number of vehicles is thus determined as relative relation to the maximum intensity over the period of 15 minutes.

For the day type "Friday", the maximum intensity was recorded in the period between 14:00 and 21:00 at all the gates on the entire length of each traffic direction. Similarly, final estimates of average intensities were prepared for each day type.

The percentage ratio of the number of vehicles in the case of drive limitation between 14:00 and 21:00 for the day type "Friday" is defined as the portion of recorded intensity during the referred time and the total day intensity of vehicles in the whole day time period (00:00 - 24:00).

3.1.2. Intensity Data Analysis

As we can see in Figure 2, all-day traffic is visible from the graph. At night hours the traffic is almost constant and during the day time it increases. Multiple growth is especially visible in the vicinity of Prague (km 0 – 20) and Brno (km 180 – 196).

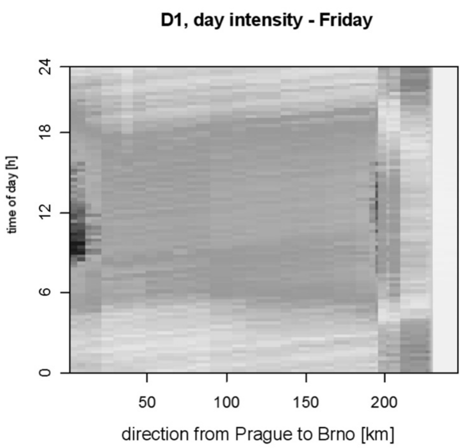

Fig. 2. Average day intensity for the day type "Friday" in the direction from Prague to Brno
Source: [own work]

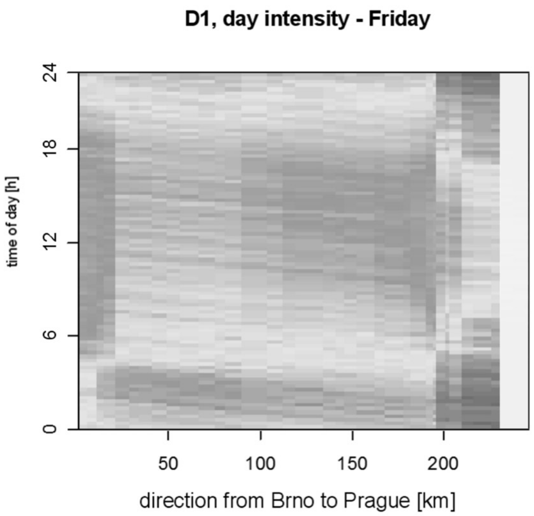

Fig. 3. Average day intensity for the day type "Friday" in the direction from Brno to Prague
Source: [own work]

Table 2. Values of average vehicle intensities over 12 tons of weight in the direction from Brno to Prague

Min.	Q1	Med.	Avrg.	Q3	Max.
1.00	17.56	26.78	26.87	36.33	64.00

Past the exit to Ceske Budejovice (km 21) we notice a significant intensity fall. In the following sections the traffic load is more or less constant.

Near Humpolec (km 90) it slightly increases again. On the exit to D2 highway past Brno (km 196), in the direction to Vyskov (km 230), the traffic significantly decreases (especially during night hours). Moreover, towards to Vyskov, the traffic decreases to a minimum (even during the day).

In the graph, in the direction to Prague, an all-day traffic is visible again. At night hours it is smaller than in the opposite direction. From the whole ratio of highway network traffic the traffic in this direction (and for this day) is 5% lower than in the direction to Brno.

Intensities across the highway are very similar to the opposite direction. Again, there is a perceptible connection from Ceske Budejovice (km 21) and the intensity outflow from Humpolec (km 90).

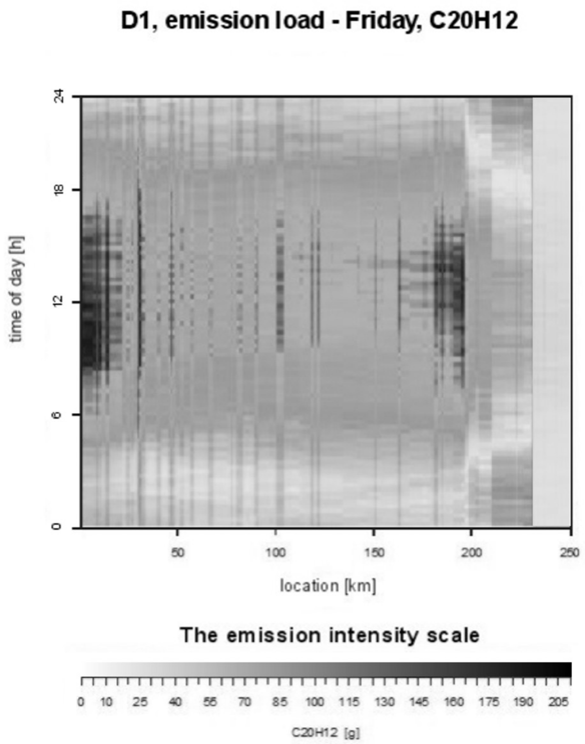

Fig. 4. Example of the output chart of the emission load estimate for C20H12
Source: [own work]

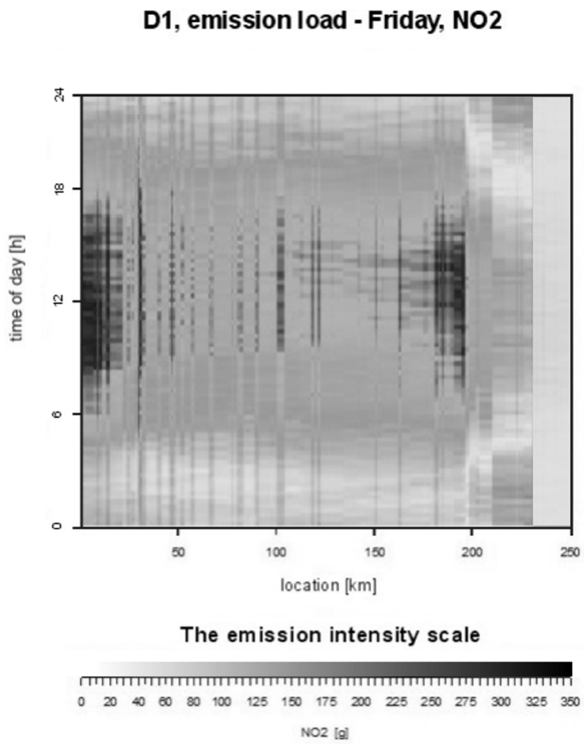

Fig. 5. Example of the output chart of the emission load estimate for NO2
Source: [own work]

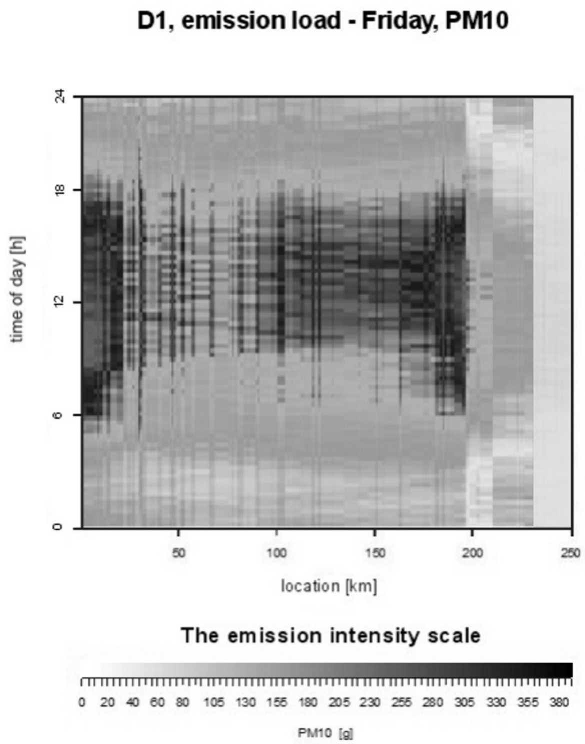

Fig. 6. Example of the output chart of the emission load estimate for PM10
Source: [own work]

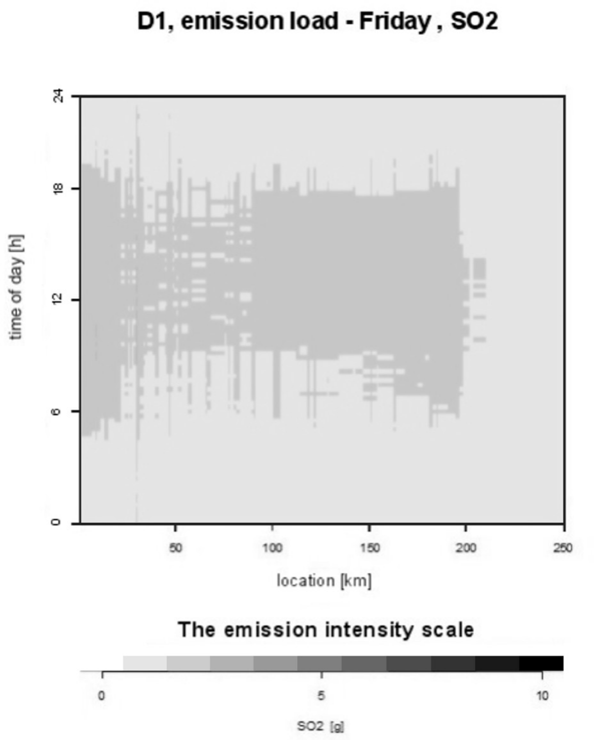

Fig. 7. Example of the output chart of the emission load estimate for SO2
Source: [own work]

A significant increase in the intensity is visible in the vicinity of Brno, again, especially after the D2 highway connection (km 196). Other connections are visible in km 210 (the traffic from Uherske Hradiste) and then very strong intensity increase at km 230 (the traffic from Vyskov).

3.2. Output Data

The output of the model calculations is given as the average emission load of the monitored road segment, in [g/km] (see examples in Figures 4-7). The output values are presented in a graph form.

4. Model Results

Figures 4-7 show examples of the model graphic output. In these outputs, special charts for each of the emission factor type were created. Similar charts have been prepared for each day type .

Peaks of the heavy truck traffic are very well visible on the graphs. They can be easily recognized in increasing concentration of the appropriate emission factor. Alternating strips (more or less emission factor concentration) along the road distance intervals display influence of the road changing inclination.

5. Conclusion

The output of the present model has been utilized for the calibration of fuzzy models predicting the effect of toll gate systems implementation.

Moreover, the model will become a building block of more complex models in the future. Such models may, for instance, help to distinguish relative impacts of the road traffic and other sources of pollution on the environment.

Finding, formulating and implementing more constraints to the model will lead to more accurate results. Further development of the model presented in the future should be able to give a better resolution especially in mobile emission factors, mainly by implementing a weather module.

5.1. Other Possible Use

The emission factors, with respect to the ratio of the measured emission level, may be involved in the road toll level. The aim of such regulation method should be seen as proportionally distributed traffic in relation to its impact on the surrounding. There could by various types of toll fee reductions, depending on different road classes usage.

For example, the toll fee could be higher for the first, second and third road class in opposition to the highway network. This solution would effectively move the passing traffic from the close attached settled areas to the highway network. Thus the solution would overall calm down and partially clear settled localities.

For these purposes it is necessary to find and further develop methods for a suitable way of measuring emission factors of mobile sources in the surroundings of other road types, than on the highway network (used here). Contrary to the measuring method at toll gates, in points, it is also necessary to find other and more accurate ways to measure emission factors in general.

Acknowledgments
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Bibliography

[1] CICERO-FERNANDEZ P., LONG J.R., Grades and Other Load Effects on On-Road Emissions: An On-Board Analyzer Study, Fifth Annual On-Road Vehicle Emissions Workshop, San Diego, California, 1995.

[2] GAMMARIELLO R., CARLOCK M., Development of Hourly Vehicle Activity for Estimating Vehicle Emissions, Seventh CRC On-Road Vehicle Emissions Workshop, San Diego, California, April 1997.

[3] HRUBEŠ P., KAZMAROVÁ H., KEDER J., HELMUT T., POTUŽNÍKOVÁ D., The study Run limitation of selected trucks on weekends - an impact and benefits analysis, Research report LSS 337/08, part III., 33, 20-32, Czech Technical University in Prague, Prague 2008.

[4] HRUBEŠ P., VLČKOVÁ V., ČARSKÝ J., KUMPOŠT P., BRABEC M., PELIKÁN E., The study Weekend trip limitations of selected heavy trucks - an impact and benefits analysis, Research report LSS 337/08, part I., 129, 5-84, Czech Technical University in Prague, Prague 2008.

[5] SVÍTEK M., STÁREK T., HRUBEŠ P., KANTOR S., DERBEK P., Intelligent Transport Systems (ITS) and Their Impact on Sustainable Development, (ID OC194), Annual Report, 26, 15-18, Czech Technical University in Prague, Prague 2008.

[6] ZITO P., CHEN H., BELL M., Predicting real-Time Roadside CO and NO2 Concentrations Using Neural Networks, IEEE Transaction on Intelligent Transportation Systems, Vol. 9, No. 3, September 2008.

[7] http://www.env.cz/AIS/web-pub.nsf/$pid/MZPMSF437BOZ