ESTIMATION OF ROAD TRANSPORT EMISSION OF POLLUTANTS IN A DEVELOPING COUNTRY - POTENTIALLY IMPORTANT CHALLENGE

Vladimir Momčilović
Aleksandar Manojlović
University of Belgrade - Faculty of Transport and Traffic Engineering

1 INTRODUCTION

From numerous recent papers and research projects, a strong commitment of the European Union to achieve long-term decrease of pollutant and greenhouse gas (GHG) emissions in the field of road transport has been clearly exposed. Therefore, multiple thorough analyses of viable policy options, strategies and measures regarding individual (Rentziou et al., 2012), commercial passenger (Ruzzenenti & Basosi, 2009) and freight transport operations (AEA & Ricardo, 2011), (McKinnon, 2008), (Faber Maunsell|AECOM et al., 2008), have been realised during the last decade. Similarly, Republic of Serbia has shown its resolution to contribute to a global welfare by implementing voluntary measures in order to decrease road transport related emissions as a widely recognised factor.

In this sense recently an important raise of conventional fuel prices is observed, which efficiently influenced a decrease in average annual mileage of individual passenger cars. Such unfavourable fuel cost trend directly influences users' conscience and behaviour while deciding on "appropriate" transport mode selection (large or small passenger car versus public transport), with an impact on the reduction of the number of trips, trip lengths and total mileage, while increasing the overall energy efficiency. Simultaneously, transport companies and company vehicle fleets, under similar fuel cost impact, tend to optimise transport volumes per vehicle, either by increasing vehicle capacity utilisation by combining transport tasks (freight consolidation) or by adapting the vehicles to individual transport tasks based on load size (volume) and/or capacity.

As a first step, it is important to determine the reference state of pollutant and GHG emissions, the so-called national emission inventory. According to (IPCC, 2006): "*high quality national greenhouse gas inventories are those consistent with good practice are those which contain neither over- nor under-estimates so far as can be judged, and in which uncertainties are reduced as far as practicable.*" Such practice is indispensable in order to safeguard the objectivity of the emission assessment per different sources, even if it is not feasible to ensure a totally accurate emission assessment. Therefore, we

should tend to make as good assessments as possible, simultaneously minimising unreliability and inaccuracies of input data, consistent with circumstances and available resources, in line with the latest scientific development and high level in the relevant field of engaged expert knowledge.

For a sufficiently accurate and reliable assessment of road transport related emissions a comprehensive national vehicle database is required. The lack of certain vehicle related data, multiple systematic errors and inaccuracies in the official vehicle registration database of the Republic of Serbia were just few of the challenges faced by experts in charge of preparing the national road transport emission inventory by using COPERT[1] 4 software package. Meanwhile, even if some data were systematically and consistently registered in the database, not all were available to experts, i.e. could not be disclosed due to personal data protection issues, which further complicated data checking and correction processes.

Another challenge was to adequately assess the annual vehicle mileage travelled (VMT) per vehicle categories (required by COPERT), as a representation of average vehicle activity per classes. In a developing country, as Serbia, the average annual VMT within the national vehicle fleet, is an important factor of transport activity still dominant, which directly depicts population mobility and influences its development.

On the other hand, determining the fuel sales (deliveries) solely dedicated to road transport was not an easy task, as there were no records before 2003, but it was indispensable in order to fine tune the obtained vehicle activity related fuel consumption data. The existing records were not always adequately systematised, neither fully reliable nor consistent, since while compared between different sources: petroleum industry actors (producers, refineries and importers), relevant Ministries and official statistical institution emerged some nonnegligible differences. A number of experts from petroleum industry estimated that until 2013 still important quantities of fuel were imported to Serbian market illicitly. Since this fuel was not taxed, national authorities opted for the introduction of fuel marking legislation, imposing heavy fines and strict market monitoring since August 2013.

2 BACKGROUND

Republic of Serbia main socio-economic parameters are given in the following paragraphs, so as to facilitate the comprehension of the problem scope and situation. GDP per capita has brusquely decreased in 2001, as a result of the adjustment of Serbian dinar's (RSD) exchange rate. Afterwards, it has a

steady growth until 2008 when it reaches the maximum value of 4,445 EUR. A GDP decrease after 2008 was largely consequence of the world economic crisis. Still its slight recovery was noticed in 2011, when GDP per capita reaches 4,351 EUR. Nevertheless, this economic parameter declines again in 2012 to the value of 4,112 EUR. Regarding Serbian population, it has steadily decreased from 7.5 million in 2000 to approximately 7.2 million inhabitants in 2012.

The length of the categorized road network in Serbia (without Kosovo) was 44,613 km in 2012. The road network structure is as follows: 1st category national roads account for 10.54% (with 4,702 km), 2nd category national roads constitute 23.95% of the total network length (with 10,684 km), and municipal (local) roads that with 29,227 represent 65.51% of the network.

The motorisation rate, expressed in passenger cars (PC) per 1,000 inhabitants is constantly growing, from 111 in 1997 to reaching 238 PC's per 1,000 inhabitants which is far below the EU average that in 2011 was 477 PC's per 1,000 inhabitants (Figure 1).

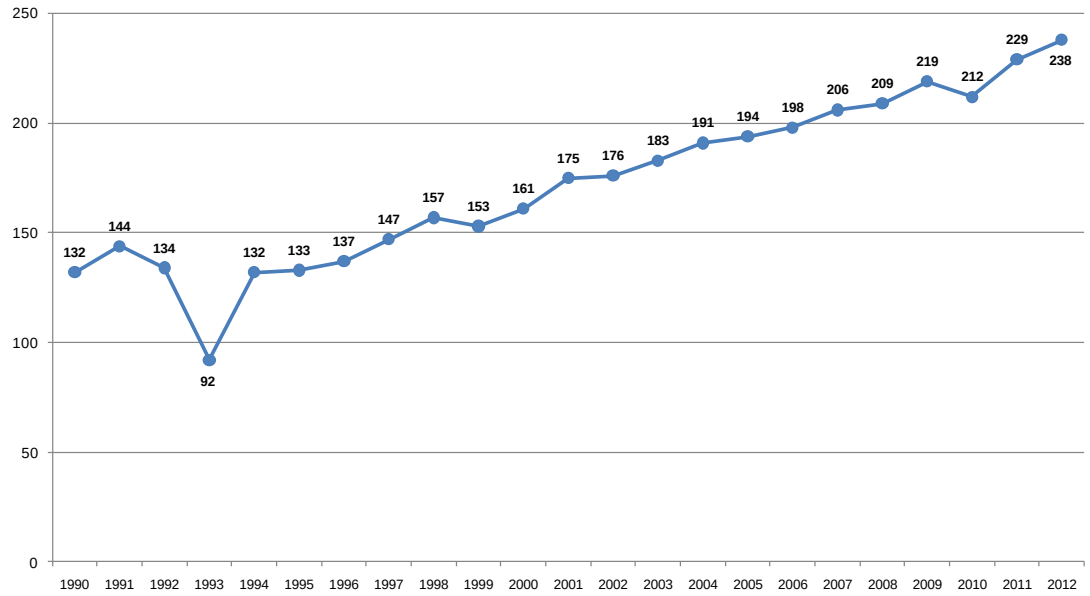

Figure 1 - Motorisation rate in the Republic of Serbia (1990-2012) in passenger cars per 1000 inhabitants

National vehicle fleet has grown from 1.165 in 1990 to 1.965 million vehicles in 2012. The passenger cars share, although dominant by far, is decreasing from initial 89.3% in 1990 to roughly 87.1% in 2012, but in absolute values has grown for around 70%. The HGV fleet have almost doubled in the same period (1990-2012) from 95.2 thousand vehicles, steadily growing from 2000 until 2008 when it slightly decreases, but reprises from 2011 to reach the

190.0 thousand vehicles. The fleet of buses and coaches varied significantly but ultimately decreased for about 16% from 9,861 to 8,288. The number of mopeds and motorcycles in 1990 was close to 19.7 thousand and has significantly and steadily grown (2.75 times) since 2005 to reach 54.4 thousand units. During years of national crisis (1993 and 1999) the number of registered vehicles decreased, especially in 1993 when it fell for around 30% compared to the previous year.

Fuel deliveries for road transport from energy balance from 2009 to 2012 are given on the following Figure 2.

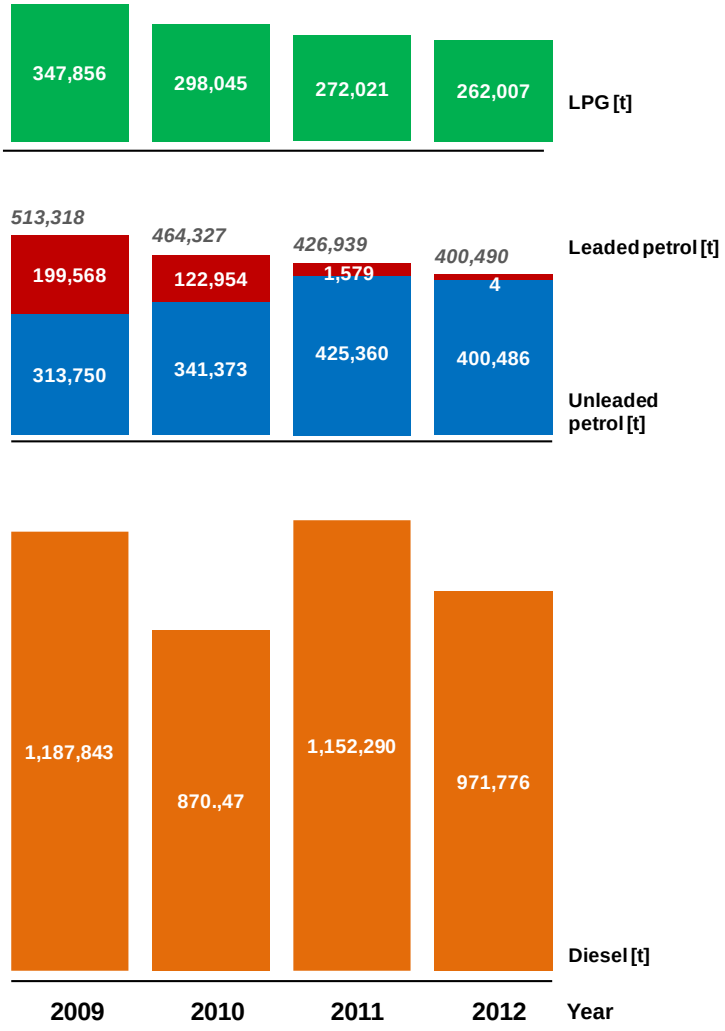

Figure 2 - Fuel sales in the Republic of Serbia (2009-2012)

Although Serbia was one of the last countries in the world to ban the leaded petrol production and sales in 2011, there were still some remaining quantities on the market in 2011 and even in 2012, as shown on the previous figure.

3 RESEARCH METHODOLOGY

3.1 Average Annual VMT Survey and Assessment

Although the data on vehicle's annual VMT is obligatorily recorded on the periodical (annual) roadworthiness test, it does not make part of the vehicle registration database and therefore is not available for further expert analyses. Basically, assessment of the average annual VMT of road vehicles expressed in vehicle kilometres [km] is needed and should be based on the realisation of several complementary surveys involving (UNECE, 2007): a) direct odometer reading and mileage recording from the vehicles, b) interviews of vehicle users and drivers, c) countings on road sections (traffic volumes), and d) fuel deliveries and consumption data (fuel sold / consumed).

The objective is to determine the range of the average annual VMT per vehicle classes. The vehicle classes are set in the EEA methodology starting from categories (e.g. passenger cars, light commercial vehicles, buses, etc.), via subcategories (e.g. powered by petrol, engine capacity up to 800 cm^3) to classes based on emission control standards (PRE-ECE… Euro 1, Euro 2… Euro 5, Euro 6).

VMT assessment is based on a survey covering passenger cars and light commercial vehicles realised on vehicle inspection stations consisting of direct odometer reading and a short interview of drivers on periodic roadworthiness tests. Therefore, only vehicles subject to periodical roadworthiness tests in the selected (average) months were included in the survey and interviews. The odometer reading consists of either two consecutive annual mileage values (if the vehicle returned to the same vehicle inspection station the following year) or only one mileage calculating the average value for the effective lifecycle (at the moment of the survey) and according to age group trends as observed in (Ntziachristos, et al., 2008). This survey and interviews were realised in 2009, 2012 and 2014. The 2009 survey involved 8,650 vehicles (Papić, et al., 2010), the 2012 survey involved 2,376 vehicles and the 2014 survey 2,490 vehicles on 20 vehicle inspection stations.

Another dedicated survey of buses and coaches' VMT was sent to several passenger transport companies (involving operators of urban, suburban and interurban passenger transport services). This survey consisted of 2,745 buses and coaches from 9 companies all over Serbia, which in average enclosed 31.1% of the Serbian bus and coach fleet, encompassing from 3.9% of midibuses to as much as 68.2% in urban articulated buses subcategory.

Regarding freight transport vehicle fleets, mainly the companies dealing with international haulage operations were truly cooperative in the dedicated freight transport VMT survey – therefore regarding national freight operators a lack of data occured. The survey encompassed 20 transport companies with 472 articulated trucks.

In the mentioned surveys and interviews we obtained the total VMT of national fleet as on the national road network, as well as abroad. As for the road network countings, they are realised on the 1st and 2nd categories national roads, involving all traffic domestic and foreign on national roads (but not involving local road sections and urban streets). Whenever the survey data did not involve a representative number of certain vehicle classes the value from (Ntziachristos, et al., 2008) was adopted subject to further expert correction. Since important discrepancies arisen among company and individual vehicles VMT's in the survey, a need for further subdivision into company vehicles and individual passenger cars was made after the realisation of the survey. Company vehicles involve also business related usage of passenger cars (such as taxi, company cars, etc.). The principle of average annual VMT assessment consists of determining company versus individual car ratios in each vehicle class and multiplying it by corresponding VMT's obtained in surveys.

3.2 Pollutant Emission Estimation Methodology

Serbian Environmental Protection Agency has adopted COPERT 4 as a tool for the estimation of road transport related emissions of pollutants, which was created based on European Environment Agency (EEA) methodology (EEA, 2009). The authors of this paper participated in the first project (Papić, et al., 2010) aimed at producing pollutant emission estimation for the Republic of Serbia between 1990 and 2009. Public Enterprise "Roads of Serbia" initiated a study (Momčilović, et al., 2014), in December 2013, intended for updating the road transport related pollutant emission estimation for 2010-2012, as well as obtaining a methodology for pollutant's atmospheric emission estimation on different road categories (per sections) based on relevant vehicle fleet structure and related traffic flow features.

In order to assess (calculate) national road transport related emissions using COPERT 4, it is indispensable to collect the following input data regarding: a) quantities of fuel sold and consumed per different fuels, b) reference vehicle fleet and its characteristics (with analysis of the emission control technology, vehicle technical condition and maintenance), c) specific climatic conditions on the survey area and national climatic data (average monthly low

and high temperatures, atmospheric pressures and humidity), and d) shares of VMT per different road and traffic conditions (urban, extraurban and highway) with corresponding average speeds for each vehicle class.

COPERT assessment implies that fuel statistics (sold and consumed quantities per different fuels) is well-known, which will then serve as a correction factor. The objective is to calibrate and further fine tune VMT values to be consistent with fuel statistics and therefore give reliable atmospheric emission quantities. If fuel statistics were totally reliable, which is not the case in Serbia, all the other parameters would need to be in accordance with this value.

For the assessment of road vehicle fleet emissions on the national territory there are two alternatives in the selection of the reference vehicle fleet applicable to asses pollutants' atmospheric emissions: national (domestic) vehicle fleet (with *a priori* known characteristics) on the entire annual VMT (on all territories – not only national) and "mixed" vehicle fleet solely on national territory (including the emission of foreign vehicles in Serbia, and excluding emissions of domestic vehicles on foreign territories), i.e. mixed traffic emissions from strictly national refuelling stations. Since fuel is sold equally to domestic and foreign vehicles, as well as to vehicles that stay or to those that leave the country and continue driving on another national territory, part of the fuel will be definitely consumed abroad either by domestic or by foreign vehicles. Similarly, unknown part of fuel is "imported" each day from abroad in vehicle tanks. The methodology prescribes that whenever the country of fuel purchase is different from the country of fuel consumption the emission of such vehicle should be attributed entirely to the country of purchase. This means that if the vehicle is fuelled in one country and crosses another without refuelling its emissions will be accounted only to the fueling country. Therefore, the fuel purchases in countries with high fuel prices will be probably minimised especially by those who manage to cross with less than one tank. The main reasons lie in the fuel statistics, which will serve as calibration factors, influencing emission composition only in the country of fuel purchase. This will prevent so-called "double accounting" for the same emissions in both: country of fuel origin and country where VMT is realised.

4 MAJOR CHALLENGES

4.1 Vehicle Data Validation and Correction Issues

Multiple problems have arisen from the database of approximately 2 million vehicles. The most often error is inadequate vehicle category / subcategory /

class definition. After comprehensive data control and exhaustive corrections in this registry of systemic, singular errors or missing data. The following general deficiencies were observed during data analysis for all vehicle classes: a) lack of the original engine Euro emission standard, b) evidence of (potential) retrofitting to a different fuel/powertrain (without adequate trace in the database) and to which “new” Euro standard, c) lack of VMT usually available on periodic roadworthiness test and in vehicle inspection stations, and d) missing or erroneous data on year of manufacture, fuel type or powertrain that do not exist in production or in operation in Serbia (e.g. electric energy, without hybrids or CNG) engine capacity, engine power, make and type of vehicle.

As a result of personal data protection it was impossible to reliably split into company and individual cars, which potentially influences good (acceptable) average annual VMT assessment (vehicle leasing to individuals is also registered as "company owned" vehicle – because we are missing an existing record of the “vehicle user”), etc.

Therefore, it was necessary to improve the systematisation of the database with regard to their technical and operation characteristics, i.e. a database enhancement by introducing new significant data for quality estimation of pollutants emission (e.g. alternative fuels/drives, Euro standards, annual and total VMT, etc.) and a new national fleet classification compliant with the requirements of the model COPERT 4 for motor vehicles’ emission assessment.

Until 2010 there were separate databases for Vojvodina, Central Serbia and Kosovo. The Ministry of interior in charge of its maintenance and update. Since 2011 all vehicles were gathered in a unique vehicle registration database. A serious problem for database accuracy is caused by vehicles whose registration has expired without its timely renewal, since they remain in the “regular” registration database until written-off or scrapped. The vehicle owner in such a way will evade his/hers duties (paid only if/when registering the vehicle) since no taxes, duties, nor sanctions are prescribed for unregistered vehicles not being written-off. For that reason, although their VMT should remain 0, they will “act” as if travelling the average VMT value for their corresponding vehicle class. This problem has been slightly lessened in 2010 during the substitution of license plates, which then in 2011 enabled a “removal” of vehicles that did not substitute their old license plates with new ones. Neverthless the problem will continue to arise as vehicle users and

owners habits did not change and won't without proper incentives or sanctions.

Another "malpractice" is that annual vehicle fleet statistics determine the "relevant" vehicle fleet size on just one day, usually December 31st of the current year, instead of at least two. Therefore, vehicles written-off or scraped on December 30th will not appear in the fleet although potentially used, and those newly registered on December 31st without single kilometre travelled will be accounted for. This is considered negligible because of the previously mentioned habit of vehicle owners not to write-off and scrap their vehicles (importantly lowering the probability of such event) and a small number of vehicles being newly registered by the end of the year because of later unfavourable "reselling" price of used cars caused by "slightly older" first registration calender year. As such errors are over-estimating emissions the competent ministry considers it of minor importance, nevertheless it is inacceptable from the point of view of UNFCCC principles.

As an example, error recognition regarding year of manufacture can be hardly removed only for evident cases of makes and models not being produced (before starting or after finishing production or similar. Such a mistake could be easily removed in case of availability of vehicle identification number (VIN) to experts. Another example is a missing remark / note on type approval of powertrain when needed, with data on original and retrofitted fuels (powertrain). Besides, from initial 9 fuel types (0 without fuel and 8 fuels) up until 2011, the number of fuel types has grown to 12 in 2012. This caused an overlapping of all two digit fuel ID's (10, 11 and 12) with fuel ID 1 because the field was formatted for export according to its previous length (1 character), which is insufficient and misleading.

During the data analysis rearding HGV besides the mentioned general deficiencies, the following specific were observed and corrected (whenever possible): a) inadequate HGV classification (especially missing classification according to construction on tractors and rigid trucks), b) discrepancy between the actual and selected vehicle category (within the vehicle database), and c) missing or erroneous data on weight and load (freight) capacity (i.e. often wrong interpretation of the term maximum permissible weight, net weight and load (freight) capacity) and number of axles.

In view of buses and coaches it has been noted that data on vehicle weight, number of seats and standing places, as well as bus or coach primary purpose (urban / suburban, interurban / tourist, etc.) are missing or erroneous.

In the passenger car category alone, found and corrected errors were in the field of engine capacity, fuel and vehicle category.

Due to the lack of data about actual emission control technology applied on vehicles (the Euro emission norms) in vehicle registration database, a principle consisting of manufacturer data regarding implementation of Euro emissions norms and vehicle production year was adopted.

4.2 Survey Challenges

Road vehicles VMT assessment is based on four segments: domestic vehicles on the national territory (1) and abroad (2) and foreign vehicles on the national territory (3) and abroad (4). The first two segments are included in the interview and survey on the vehicle inspection stations, meanwhile the first and the third segment are included in the traffic countings on national and local roads. The problem remains regarding the “unknown” characteristics of the foreign vehicle fleet, which could be assessed indirectly. The assessment of the VMT of domestic (national) vehicle fleet (segments 1 and 2) represent relatively straightforward task especially because it is based on obligatory annual roadworthiness tests. The problem of double accounting of the same emission could remain in the second segment which could be accounted for in the referent foreign countries, as well as the third segment which could be accounted for in the country of origin of foreign vehicles. Therefore there is a need for a consistent approach of all countries in order to prevent the challenge of double accounting for the same emissions.

Since the main source of motor vehicle related information is the periodical roadworthiness test, certain (high) level of accuracy and comprehensiveness is expected regarding the national vehicle fleet. The comprehensiveness is secured by the obligatory nature of the test and its annual frequency which allows for regular data update. The data accuracy is though often suspicious because of the lack of serious consequences in case of errors and missing data, even in case of fraud. The inaccuracy is due to the method of annual VMT input on certain vehicle inspection stations, which sometimes allows for user approximate information about the vehicle total mileage (not always consisting of odometer value reading). During the realisation of the interviews, we have observed such practice in several stations. Nevertheless if such shortcoming is eradicated in the future and the acquired VMT data is totally accurate, still some uncertainties will remain: lack of spatial-temporal distribution of the mileage split on the specific road network sections (lack of geographic data), and especially important regarding commercial vehicles

(light commercial vehicles – LCV, HGV, buses and coaches) lack of precise capacity utilisation data.

Another important input data required by COPERT is to assess the average trip length which influences the percentage of "cold start" effect in the cold seasons (Favez, et al., 2009). Temporal analysis is important due to seasonal variations and, especially on urban road network, daily and hourly distribution of traffic flows (working day, weekend and holiday / peak and off-peak periods), required as to assess the participation of vehicles in traffic congestion, which will be approximated in the model by average speeds on different road and streets categories.

Besides following issues regarding odometer readings were observed (UNECE, 2007): a) errors and rounding of figures to the closest thousand (even tens of thousands), which can mislead and even produce negative or falsely high annual VMT (between two consecutive readings), b) five digit odometers restarting from 0 after 99,999 km (especially for older commercial vehicles), c) illegal odometer tampering either by increasing (upon import of used (second hand) vehicles to lower the vehicle residual value) either decreasing total VMT (for sale), and d) modification in usage pattern between two periodic roadworthiness tests (e.g. taxi or company car becoming individual vehicle or viceversa).

While conduction interviews the following problems have arisen: irrelevance of the interviewee, imprecise or inaccurate memory regarding VMT and other travel pattern details, rounding (often up) of VMT or shares on different road categories, skiping questions or lowering assessment in order to speed up the interview.

4.3 Emission Estimation Challenges

During the assessment of pollutant emission per vehicle categories, VMT and road sections, three main challenges were surmounted: a) vehicle classification in the national vehicle database upon categories requested per COPERT 4 methodology, with correction of inadequate/erroneous data or filling up the missing parameters (as Euro emission norms), b) determine the relevant vehicle fleet structure (mixed domestic and foreign) on the 1st and 2nd category road network, and c) determine quantities of fuel sold/consumed in Serbia (as a correction parameter), as well as a referential fuel quality (sulphur and lead content).

5 CONCLUSIONS AND LESSONS LEARNT

Several challenges regarding national vehicle database, VMT determination survey and emission assessment were observed and overcome in the process of estimation of road transport related pollutants emission on the territory of the Republic of Serbia.

One of the lessons learnt in the process of overcoming barriers was that in Serbia, where a lot of things are not regular, the correction of certain parameters and values was not always easy nor straightforward. A special attention was given to fuels consumed where aside from evident errors some inconsistencies appeared. Although type approval system was set up by laws, modifications on vehicles and especially retrofitting of powertrains were not always subject to certification until 2009. Several modifications of powertrain were a very common practice just for cost savings (diesel engines replaced petrol, and later LPG/ petrol replaced diesel), but the problem was in the safety procedures, measures and often professionalism of such interventions. In the 1990's the replacement of petrol engines with compression-ignition engines (powered by diesel) was very common especially in company cars and taxis. An opposite trend arisen in the 2000's when the price of LPG was importantly lower than diesel – then the compression ignition engines were once again replaced by spark ignition ones in order to switch to this novel and cheaper powertrain. The tracks of those changes were known only to vehicle owners and not to vehicle inspection authorities, who due to a heavy economic crisis at the time did not enforce certification procedures. Therefore, manufacturing specifications were not useful but only the knowledge of the number of vehicles and quantities of fuel sold.

This is another reason to approach with care with solving all challenges and to try to overcome them in an appropriate and relevant manner, and not to repeat the errors in the future so as to keep track of all the modifications in the vehicle database.

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NOTES

[1] Computer Programme to calculate Emissions from Road Transport