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Integrating Road Transport and Emissions Modelling

REM Workshop Outcomes and follow-up investigation

Editors:

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Executive Summary

The European Commission's Joint Research Centre (JRC) organised a two day 'Road-transport and Emissions Modelling' (REM) Workshop, under the umbrella of the Enlargement and Integration Action 2015. The workshop was hosted by the Faculty of Mechanical Engineering of the University “Ss. Cyril and Methodius” in Skopje, on 10th and 11th of September 2015.

Traffic models and emission models are strongly interrelated. There cannot be emissions if there is no traffic, movement of people and goods - and transport mobility increases every year. But increased transport means increased emissions, and consequently increased pollution which is the main reason for climate change worldwide. It has been one of the main objectives of the REM 2015 Workshop, to provide the basics of transport and emission modelling and to promote their proper integration because scientists in the two disciplines hardly communicate in an effective way.

During the two days, 12 speakers presented their work on various topics related to road-transport and emissions modelling, according to the following agenda:

Day 1

- Introduction to the workshop - *M. Kjosevski (FME), B. Ciuffo (JRC)*
- The JRC Enlargement & Integration program - *L. Zanier (JRC)*
- European legislative background - *M.C. Galassi (JRC)*
- New and upcoming vehicle technologies - *L. Ntziachristos (LAT)*
- Impact of deterioration on emissions - *N. Ligterink (TNO)*
- Emission Factors development - *S. Hausberger (TUG)*
- ERMES Group - *M.C. Galassi (JRC)*
- ERMES approach for EFs - *P. Wüthrich (INFRAS), N. Ligterink (TNO), L. Ntziachristos (LAT)*

Day 2

- Introduction to transportation demand models - *V. Marzano (University of Naples)*
- Introduction to transportation and traffic models - *V. Punzo (University of Naples)*
- Consumption and CO2 emissions from road transport. CO2MPAS - *G. Fontaras, B. Ciuffo (JRC)*
- Calculating emissions from road transport in FYROM for 2012 using COPERT 4 model - *I. Trpevski (FINKI)*
- Traffic modeling in Skopje as a approach for pollution calculation - *A. Kostikj (FME)*
- Final remarks and closure of the workshop - *B. Ciuffo (JRC)*

Aim of this report is to present the key findings of the workshop, as well as the key conclusions from the discussion lead during the event and highlight its relevance for the enlargement countries to which the workshop was addressed. The report consists of three parts: the first one presents the JRC and its activities in support to the enlargement and integration process. The second part introduces the presentations given by the speakers and reports about the workshop conclusions. The third and last part addresses the status of road transport policies adopted in the enlargement and integration countries represented by the workshop participants.

Introduction

The Workshop was organized by **JRC/STU** in the framework of the **Enlargement and Integration Action (E&IA)** under the topic **"Road-transport & Emissions Modelling (REM)".** The workshop was held in **Skopje (former Yugoslav Republic of Macedonia)** from **September 10th to 11th** and hosted by the **Ss. Cyril and Methodius University (FME)** at the **Department of Mechanical Engineering**.

The Ss. Cyril and Methodius University in Skopje is the first state University in the former Yugoslav Republic of Macedonia, founded in 1949. Mechanical Engineering studies started in the autumn of 1959 at the Technical Faculty in Skopje, which now includes six Institutes (Production Mechanical Engineering; Mechanical Construction, Mechanization Machines and Vehicles; Thermo-technology and Thermo-energetics; Hydro-technology, Pneumatics and Automatics; Welding and Welding Constructions; Mechanics) and one Department (Mathematics and Information Technology).

Speakers of the workshop were selected from Academia (including two from the hosting institution), consulting companies and JRC. The workshop focused on two different but strongly interrelated topics, namely, i) **modelling emissions from road vehicles** and ii) **transportation and traffic modelling**. The objective was to provide the audience (composed by experts in the two fields) with an overview of the two topics and discuss possible ways of their proper integration. The workshop was organized in a way to dedicate one day to each topic.

Part I. The JRC and its role in the enlargement and integration program

1 The JRC (B. Ciuffo, JRC)

The Joint Research Centre (JRC) is the in-house science service of the European Commission, established in 1957: it provides scientific and technical support to the European Commission for the design and implementation of current and future policies in Europe. JRC is constituted by 7 institutes in 6 locations, with around 3000 staff, including PhDs and visiting scientists, and it is a networked organization with more than 1000 partners (Universities, public research organisations, industry groups, Member State governments, international organizations and European Parliament).

In addition to the activities and facilities used to support the policy process, JRC hosts seven reference laboratories (EURL – European Union Reference Laboratories) for:

- Feed additives
- Heavy metals
- Mycotoxins
- Polycyclic Aromatic Hydrocarbons
- GM Food and Feed
- Food Contact Materials
- Alternatives to animal testing

As part of a wide network, JRC contributes for:

- Training and mobility of researchers
- Access to scientific infrastructures
- Support to enlargement

2 JRC - Institute for Energy and Transport (B. Ciuffo, JRC)

The JRC **Institute for Energy and Transport (IET)** is based in **Ispra** and **Petten** and its mission is to provide support to European Union policies and technology innovation to ensure sustainable, safe, secure and efficient energy production, distribution and use and to foster sustainable and efficient transport in Europe.

The institute is composed by **8 units** distributed in the two IET sites:

- F1 - Site Management
- F2 - Energy Conversion and Storage Technologies
- F3 - Energy Security, Systems and Market
- F4 - Innovative Technologies for Nuclear Reactor Safety
- F5 - Nuclear Reactor Safety Assessment
- F6 - Energy Technology Policy Outlook
- F7 - Renewables and Energy Efficiency
- **F8 - Sustainable Transport (65 scientists, technicians, and administration)**

Unit F8 activities covers the major topics of the transport sector and it can count on 9 laboratories namely indicated as **VELA (Vehicle Emission LAboratories)**.

The main research topics of the unit are:

- Sustainable transport: Road transport, Electro-mobility, Aviation, NRMM
- Sustainable fuel: Well-to-wheel analysis, Alternative fuels, Indirect land-use change

In particular, under the sustainable transport activities, the unit role is mainly focused to:

Support the European Commission in the development of all latest regulations concerning

- Vehicle type-approval
- Emission limits from LDVs, HDVs and two/three wheelers
- CO2 targets for LDVs and eco-innovation scheme
- CO2 monitoring for HDVs

Promote and analyse new technologies

- Electric vehicles
- ITS solutions

Participate to international forums and research group activities

- ERMES
- MULTITUDE
- TFEIP/EIONET

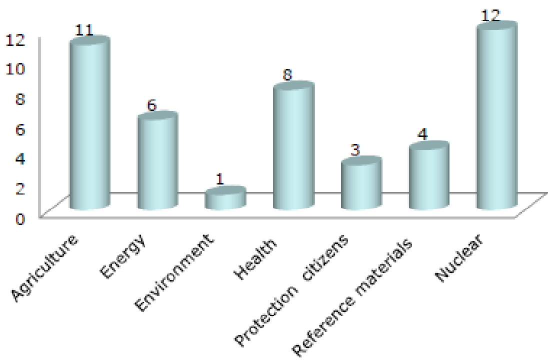
3 JRC Instruments and Actions (L. Zainer, JRC)

In its activity to support the macro-strategies from the scientific point of view, JRC launched its initiative to provide Scientific **Support to the Danube Strategy (EUSDR)** in 2011. This initiative is implemented via seven flagship clusters focusing on: water, land and soil, bio-energy, air, data exchange and harmonisation, smart specialisation and innovation and technology transfer. Each cluster is coordinated by JRC and also gathers scientists from various partner organisations of the Danube Region working together on concrete projects to support the Danube Strategy. The JRC is also partner of the Danube-INCO.NET project to support the Danube Region in the field of research and innovation (R&I). In this project, JRC focuses mainly on PA 7 "Knowledge Society" and PA 8 "Competitiveness". The project supports the policy dialogue, creates networks, and analyses and supports R&I activities.

A similar activity is the Scientific Support to the Adriatic-Ionian Strategy. All the best practice, outcomes and "lessons learnt" of the JRC Initiative Scientific Support to the Danube Strategy can be consider a resource for the new **EU Strategy for the Adriatic and Ionian Region (EUSAIR)** that has been launched in Brussels on 18 November 2015.

One more instrument is the **Enlargement and Integration Action (E&IA)**. Under this action a total of 44 activities have been approved. Besides these activities, the Enlargement and Integration Action organises or co-organises over 150 short courses and summer schools every year. Through the short courses, summer schools and lectures the JRC reaches 3000 participants every year. Most of short courses are organised in the areas of nuclear safety and security (38%), environmental and climate sciences (15%) and safety and security (14%).

Figure 1. Workshops' topics in 2013



Through the E&IA action, the Danube Innovation Partnership Summer School on Knowledge and Technology Transfer was organized in Belgrade, Serbia, in September 2014. During this 7 days summer school the following topics were covered: basics of intellectual property, patent drafting, and collaborative research, marketing and networking with industry, licensing, negotiation, dispute resolution, spin-of creation and support. In total 86 experts, researchers and policy makers from all the Danube macro-Region countries participated. The trainees were experts from research organizations members of the European TTO Circle, from World Intellectual Property Organisation (WIPO) and from the ISIS Innovation Centre from the Oxford University.

Through the same action, a workshop on The Future Role of Energy Storage in South Eastern Europe was organized in Tirana, Albania, in October 2014 . The workshop topics covered: Renewable Energy Sources for Electricity potential and integration challenges in the context of enlargement countries, case studies on Hydro pumped storage, case studies on small residential versus large scale storage, strategies for energy efficiency improvement in residential and office buildings and South Eastern Europe Perspective. In total 33 experts and consultants together with 17 professors, researchers, experts, analysts and consultants were part of this workshop.

During 2015 JRC launched two calls through the Enlargement and Integration Action. The first call was launched for EURATOM and 15 project proposals were received for a total amount of Euro 452,000.00. The second call was launched through HORIZON 2020 and 33 proposals were received for a total amount of Euro 1,141,852.00. The selection process was based on adherence to JRC Work Programme for Enlargement countries priorities.

Another tool is the **IPA TAC, the Travel Accommodation and Conference facility** (TAC) established by DG ELARG (now DG NEAR) for Western Balkans and Turkey. In the frame of IPA Instrument of Pre-Accession Assistance TAC, JRC organises several events and study visits for representatives of the Enlargement countries every year.

Through the Travel and Accommodation Facility IPA TAC 2014 three events were organized. A study visit of JRC Institute for Reference Materials and Measurements was organized in Geel, Belgium on 20th June 2014. A seminar on "JRC support to the Enlargement" was organized in Novi Sad, Serbia on 9th December 2014. A study visit of JRC Institute for Reference Materials and Measurements on the topic "Analysis of food and feed contaminants" was organized 27-28 January 2015.

Another important tool is the **Memorandum of Understanding** JRC has signed with some of Enlargement countries. The overall objective of the Memoranda is to improve cooperation in selected fields in the competence of the JRC and to host PhD students and post-doctors from these countries in the JRC institutes.

JRC has signed several Collaboration Agreements with the Republic of Serbia. The Memorandum of Understanding with the Ministry of Science and technological development of the Republic of Serbia was signed in 2010. This document enables exchange of information, hosting Serbian post-doc students at JRC Institutes, bilateral visits of Serbian delegations and JRC Institutes, establishing links between JRC Institutes and relevant Serbian research organizations, joint conferences information events and training workshops, dissemination information on JRC open calls for researchers or grant-holders and access to large infrastructure and user laboratories for researchers.

The European Radiological Data Exchange Platform (EURDEP) Memorandum of Understanding with the Serbian Radiation Protection and Nuclear Safety Agency was signed in 2011. This document sets definition of the conditions to assure effective data exchange between the parties during an emergency.

Every year the JRC provides on-the-job research training for 70 trainees and 50 PhD candidates. Majority of the PhD candidates carry out work in the areas of environmental and climate sciences (35 %) and nuclear safety and security (41%).

4 The JRC Enlargement & Integration program (L. Zainer, JRC)

In line with its mission, the JRC has been running the Initiative "Enlargement and Integration Action" since 1999. This initiative aims at providing scientific and technical support to countries on the road towards EU membership, New Member States and Associated Countries.. It supports the transfer of the EU legal framework (acquis communautaire) to national legislation and facilitates scientific and technical exchange, contributing to the development of the "European Research Area".

In the framework of the Enlargement and Integration Action, JRC offers specialised workshops, conferences and advanced training courses within its areas of competence, according to priorities identified together with the target countries. E&IA Activities are set up to allow competent organisations in the Enlargement Countries (new Member States, Candidate Countries, Potential Candidate Countries, …) to get acquainted with the scientific methods and techniques underpinning EU policy implementation. Such events also provide an opportunity for EU organisations to learn about the methods currently used in those countries and for both parties to discuss how the EU legislation should be implemented in the future.

The JRC is a member of the Inter-Service Group Enlargement and cooperates with DG ELARG in the framework of the accession negotiations as well as in the preparation of the annual enlargement package. The strategic objective of JRC is to help the candidate countries in dealing faster with the "EU acquis" in areas of its competence and to support the transposition of acquis communautaire to national legislation and facilitates scientific and technical exchange of the Enlargement countries.

All candidate countries, the potential candidate countries and the associated countries to Horizon 2020 (or in the process of association) have their representatives in the JRC Board of Governors. The Board helps with JRC strategic decision-making on scientific, technical and financial management. Individual Board members have also an important role in presenting the JRC activities in their respective countries.

Moreover there is an intensive networking activity with the JRC Enlargement National Contact Points (NCPs) appointed by the enlargement countries. Every year during the Annual Meeting with Enlargement NCPs the on-going cooperation is presented and discussed. The annual meeting is particularly relevant for further strengthening and improving the on-going cooperation with the Enlargement countries, for exchanging information about the activities we both are carrying out, discussing about priorities and plans.

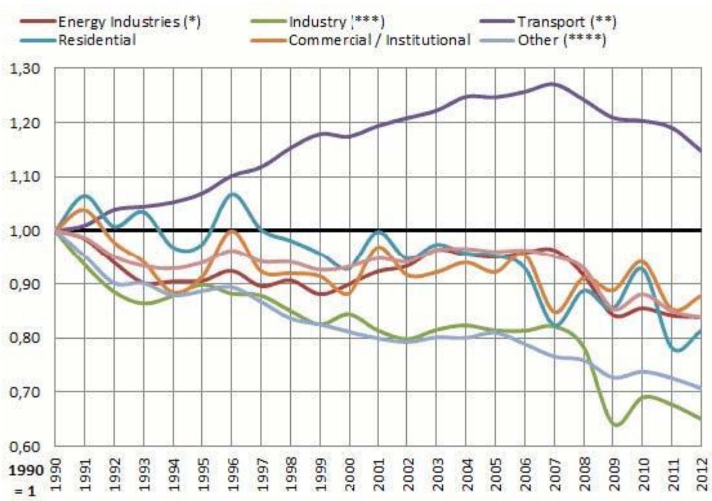
Part II. Road transport and emissions modelling

5 European legislative background (M. C. Galassi, JRC)

Air Quality problems still persist in many EU cities. Ozone (O_3) and particulate matter (PM) are the main factors responsible for climate change and health risks. According to EEA assessment, 20-30% of the European urban population was exposed to O_3 and PM levels above EU reference values in 2013.

Road transport has great influence on air quality: indeed, it is responsible for nearly 25% of EU GHG emissions and for around 20% of EU CO_2 emissions. According to EEA, road vehicles alone were responsible for 39% of NO_x and 15% of fine particulate matter ($PM_{2.5}$) emissions by anthropogenic sources in EU in 2014. Thus proximity and direct exposure to vehicle emissions in urban areas increases health risks.

Figure 2. CO2 emission



(Source: http://ec.europa.eu/clima/policies/transport/index_en.htm)

Until 2008 there was a large increase in emissions from the transport sector, which was reflected in oil prices, increased efficiency of PC and slower growth in mobility. Yet transport is the only major sector in EU with still rising GHG emissions and the growing CO_2 emissions threaten EU meeting Kyoto protocol targets. Therefore EU developed polices to reduce emissions from a range of transport modes.

Motor vehicle emissions have been regulated in EU since early '70s for LDV and HDV separately [1]. From the beginning of the introduction of regulations till nowadays emission limits have been reduced by more than 90%. Summarizing:

- Originally:
  - **Directive 70/220/EEC** for **LDV**
  - **Directive 88/77/EEC** for **HDV**
- Amendments tightening limit values
- Nowadays:
  - Euro standards LDV, HDV, L-cat
  - **Regulation (EU) No 333/2014** on CO_2 emissions reduction from PC (2020 target)

The achievements with the introduction of Euro standards regarding emission regulation for LDV review are given in continuance:

- **Euro 1** applied to PC and LD trucks, and introduced mandatory use of **Three Way Catalyst (TWC)** and electronic fuel injection systems in vehicles equipped with positive-ignition (PI) engines;
- **Euro 2** lowered the applicable emission limits for LDVs. As a result, **Diesel Oxidation Catalysts (DOCs)** became common in diesel vehicles in order to reduce emissions of unburned hydrocarbons, carbon monoxide and the organic fraction of particulate matter (PM). DOCs however leave substantially unaffected soot and NOx emissions;
- **Euro 3-4** modified the test cycle by including the cold start, added NO_x specific limits besides combined HC+NO_x limits and **On-Board Diagnostics (OBD)** requirements for gasoline, LPG, NG and diesel vehicles.

More recently the Euro 5 and Euro 6 standards were introduced with lower limits for PM (Euro 5) and NO_x (Euro 6), and in particular:

- **Euro 5** mainly focused on particulate matter from diesel cars; it introduced for the first time an emission limit on particle number (PN, #/km) for compression ignition (CI) engines, complementing the already existing mass-based limit (PM, mg/km) which was lowered. The new provisions forced de-facto the use of **diesel particulate filters (DPFs)** to comply with the new standards for PM and PN;
- **Euro 6** lowered the limit for NO_x emissions from diesel engines (i.e., 80 mg/km, close to the 60 mg/km limit for petrol engines); moreover, the same PN emission limit for diesel vehicles ($6*10^{11}$/km) will apply in 2017 to direct injection gasoline vehicles in order to control the particle emissions of this technology that is expected to become more popular in the near future.

Similarly to LDV, emission regulations for HDV were introduced step by step since 1982 with the following main achievements:

- Euro I and Euro II standards applied to truck engines and urban buses;
- Euro III and Euro IV/V standards were set together with voluntary, more stringent, emission limits for extra low emission vehicles (known as "Enhanced Environmentally Friendly Vehicles", or EEVs);
- The amended Euro IV-V standards (**Directive 2005/55/EC**) introduced durability and OBD requirements and restated emission limits;
- Euro VI standard introduced PN emission limits, stricter OBD and durability requirements as well as provisions for off-cycle and in-use conformity testing. Moreover, with Euro VI two new operation cycles have been introduced: WHSC (Stationary Cycle) and WHTC (Transient Cycle). The transient cycle also implies control of cold start emissions for HD engines. The introduction of a PN limit will force the adoption of DPFs for HDV.

Emission regulation for L-category (**Moped and motorcycles**) vehicles was also introduced in 1999. Moped and motorcycles, due to their engine and performance calibration, are characterized by significant emissions of HC and CO.

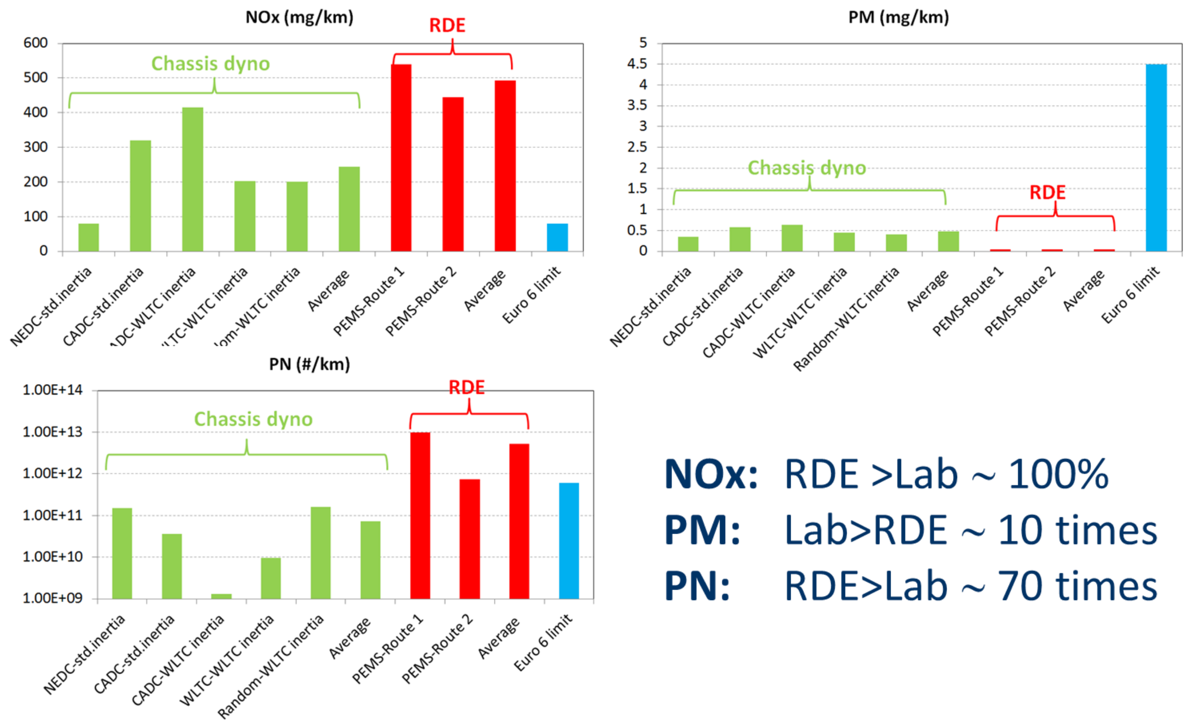
With **Directive 2006/72/EC** the Euro 3 limits for motorcycles were adjusted to the new driving cycle, while with **Directive 2013/60/EU** the same Euro 3 limits were introduced for mopeds. **Regulation (EU) No 168/2013** has defined the Euro 4 and Euro 5 for mopeds and motorcycles dividing L-category vehicles in 7 main classes, ranging from electric bikes to sub-M1 passenger cars.

The combination of air quality limits and GHG reduction targets create a very dynamic environment for road vehicle technology development. Different control strategies are possible to achieve combined reductions in both fronts: use of conventional vehicles with enhanced emission control technologies, introduction of enhanced combustion technologies and also introduction of new energy carriers as alternatives. Each of these strategies may be followed either individually or in combination with other strategies.

6 New and Upcoming Vehicle Technologies to fulfil demanding Regulations (L. Ntziachristos, LAT)

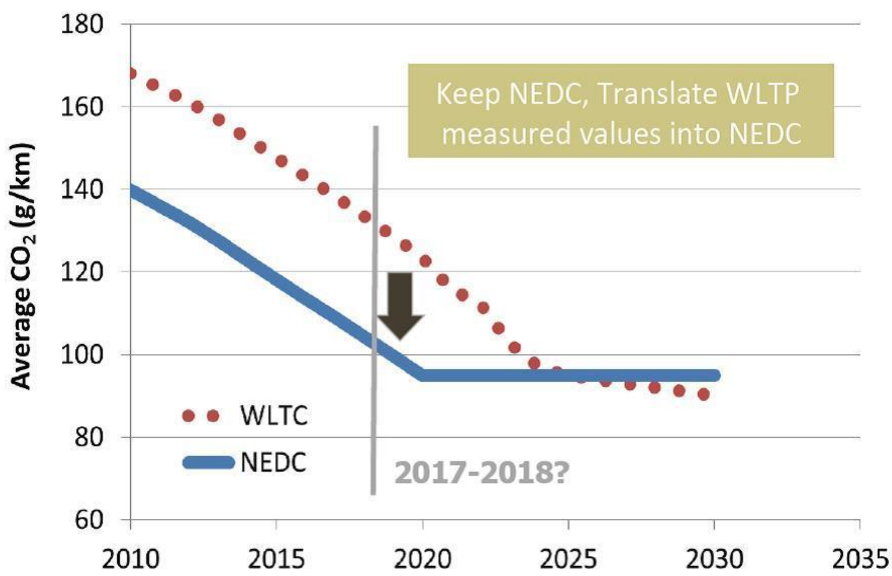
Despite the more and more stringent emission levels for HDV and LDV, the situation in EU countries for PM and NO_x reported in the Annual Mean Air Quality report of EEA shows high levels in many areas of the EU map. For HDVs, the introduction of the new WHTC cycle and PEMS (Portable Emission Measurement Systems) testing under Euro VI regulation, combined to the different conditions under HDV are used compared to LDV, will bring a significant improvement on the emissions reduction. For LDV, tests carried out in the lab under different testing conditions (NEDC – WLTC cycles, different inertia values) show emission levels in general accordance with the regulation limits while, when the tests are performed under Real Driving Conditions (RDE) with PEMS, the gap between real conditions and lab test shows an increasing trend. These criticalities need to be overcome with a revision of the actual vehicle test procedures (introduction of WLTP) in combination with a RDE regulation.

Figure 3. How do actual Euro 6 diesel cars behave in RDE (LAT)



WLTP (Worldwide harmonized Light vehicles Test Procedure) has been adopted by UNECE - GTR in 2014 and will replace NEDC (New European Driving Cycle) as a certification cycle. This will not affect directly euro standards, as limit values remain the same, and real driving emission are going to substitute chassis dynamometer in the long run. Therefore it is important to translate NEDC - based CO_2 targets of 2015 and 2020/21 to WLTP targets (see **Figure 4**). To address this issue, a CO_2 WLTP-NEDC correlation exercise was started running several laboratory tests on vehicles, coupled with a broad-scale vehicle technology simulation, in order to have a detailed database to feed a physical meta-model that will provide the CO_2 equivalent corresponding value.

Figure 4. CO2 WLTP/NEDC Translation (LAT)



The evolution of the emission standards required an evolution in technologies for air pollutants emission controls [2]. From the first Euro regulation until Euro 5 the technology evolution for Petrol and Diesel vehicles (LDV) is summarized in the following tables:

Table 1. Petrol LDVs

Emission Standard	Year Intro	Engine measures	Exhaust aftertreatment
Euro1	1992	Fuel injection	Three-way catalyst with lambda sensor (closed-loop)
Euro2	1996	Improved electronic control unit	Larger catalyst
Euro3	2000	On-board diagnostics	Pre-catalyst and dual lambda sensor
Euro4&5	2005	System optimisation	System optimisation

Further improvements were achieved moving the injection phase from the Port Fuel Injection (PFI), characterized by premixed combustion and no soot formation, to Gasoline Direct Injection (GDI), with benefits in terms of engine efficiency that comes from the combustion control but with the drawback of the soot formation. As possible emission control technologies, Lean-burn with NO_x control and Four-way catalyst (in which the particulate is combusted to CO_2) can be adopted.

With the latest Euro norm, the emission control system for Diesel engine is composed by several sub systems that generally includes DOC, NO_x-Trap or SCR, DPF and various sensors (lambda, Δp sensors) controlled by the ECU. With the future Euro6 implementation the emission systems will probably result in more complicated assemblies.

Table 2. Diesel LDVs

Emission Standard	Year Intro	Engine measures	Exhaust aftertreatment
Euro1	1992	Combustion chamber and intake system improvements	None
Euro2	1996	Direct injection, fuel pressure improvement	Oxidation catalyst
Euro3	2000	Exhaust Gas Recirculation (EGR)	Pre-catalyst and main catalyst, First Diesel Particle Filters (DPF)
Euro4	2005	Multiple injections, increase of injection pressure	Pre-catalyst and main catalyst, more expensive use of DPFs

Regarding the HDV scenario, the situation is summarized in the following table.

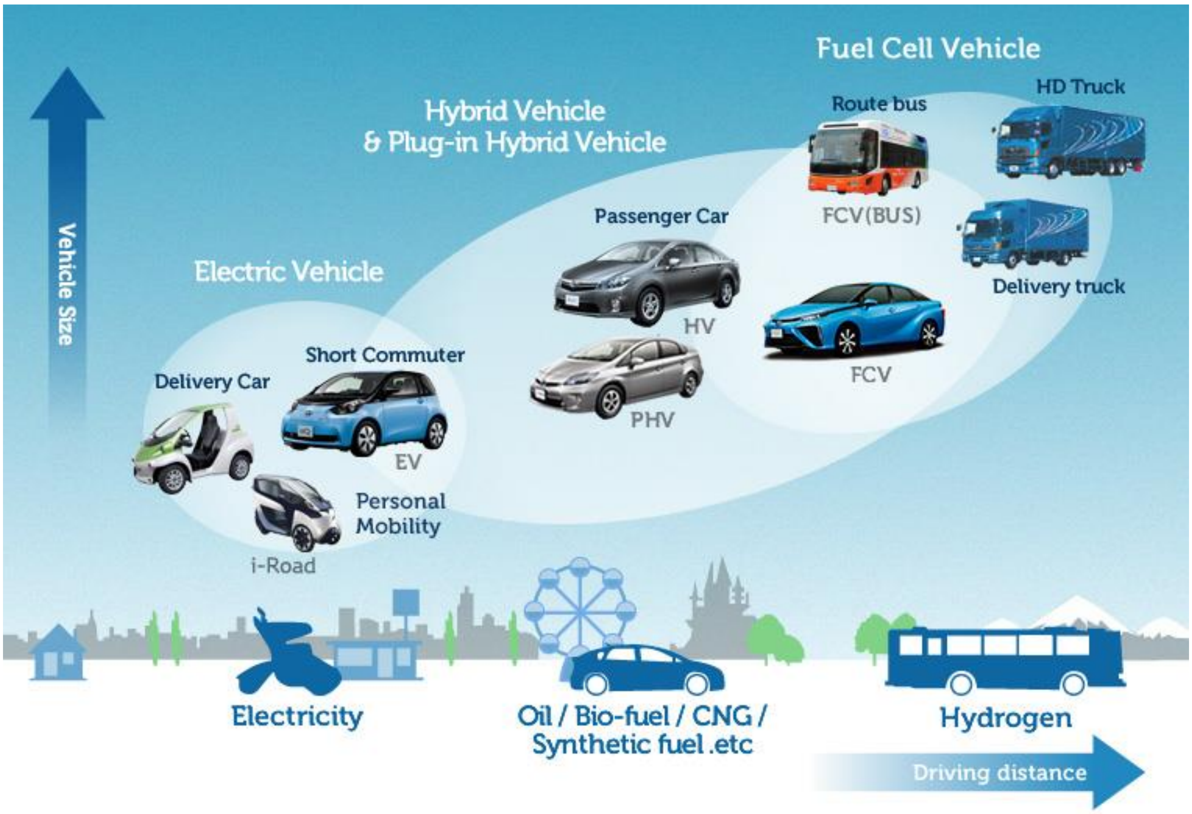
Table 3. Diesel HDVs

Emission Standard	Year Intro	Engine measures	Exhaust aftertreatment
Euro I	1992	Direct injection	None
Euro II	1996	Combustion chamber improvements	None
Euro III	2000	Fuel pressure increase	Urban buses: DOC
Euro IV	2005	EGR	SCR (30% of fleet)
Euro V	2010	Injection improvement	SCR (75% of fleet) EGR (25% of fleet)

With the introduction of the Euro VI regulation, the typical heavy duty emission control system includes EGR, DOC, DPF, SCR and a Slip-cat (to control the ammonia slip phenomenon).

For L-cat vehicles the regulations were recently updated with a significant reduction of the emission limits, together with a classification in various sub-categories.

Figure 5. Possible stratification for advanced technologies (LAT)



Divergence of regulatory targets and real-world performance is still present and has to be addressed. There are varieties of after-treatment systems that seem to enable very efficient control of air pollutants, but it is difficult to predict and estimate RDE emissions and long-term performance is not known. Also there is a variety of present and future (advanced) technologies that improve fuel efficiency (**Figure 5**); yet some of them require infrastructure investment and behavioural changes that are difficult to enforce. Anyway road transport will continue to be at the forefront of technological change.

7 Impact of deterioration on emissions (N. Ligterink, TNO)

The increased complexity of the aftertreatment devices require to evaluate the influence of aging and maintenance on the aftertreatment efficiency in real operating conditions [3][4].

There are two possibilities of "end-level" emissions: back-to-engine-out (problems with the emission control), which is typical for NO_x emissions (capped ~ 1.5 g/km); or higher than engine out (problems with the basic operation), which is typical for PM and CO emissions (no limit).

Typical causes for increasing PM are:

- High oil levels (i.e. overfilling of oil) can cause "burning lubricant"
- Foiled injectors generates larger droplets that facilitates PM emissions
- High sulphur fuel (mainly non road fuels used instead the specific ones) can destroy the catalyst
- Clogged EGR, removed DPF, limited AdBlue injection

All the issues mentioned above are caused by the long operating life of the vehicles together with the lack of correct maintenance for a large amount of vehicles.

The legislation impose a defined durability (from 80.000 to 160.000 km or 5 years) based on the assumption that the aging effect became stable after a certain cumulated mileage - but as revealed by experimental analyses, the worsening effect of aging is constantly increasing until the effect of the aftertreatment system become negligible.

Figure 6 shows statistics about euro level of cars in Amsterdam and Utrecht:

- More than 50% of the fleet is < Euro5
- Annual mileage decrease over the time: 50% during firsts 4 years, with an average scrapping age of 16 years
- Change in vehicle use scenario during the mileage decreasing: increase of the urban driving, with an increase of cold start effect

Limited measurements are available on vehicles at different mileages in the laboratories. Data coming from remote-sensing (RS) campaigns complement information on emission durability issues. For example, analysis performed by IIASA on long-running RS program in Zurich is reported in **Figure 7**.

Figure 6. Euro level of cars in use (TNO)

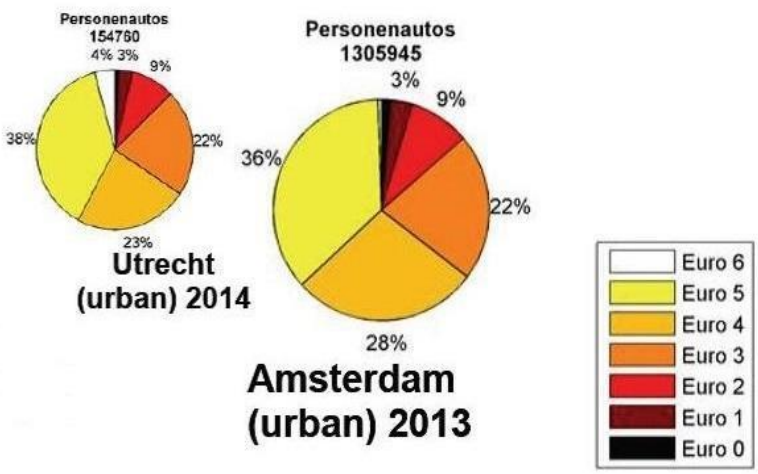
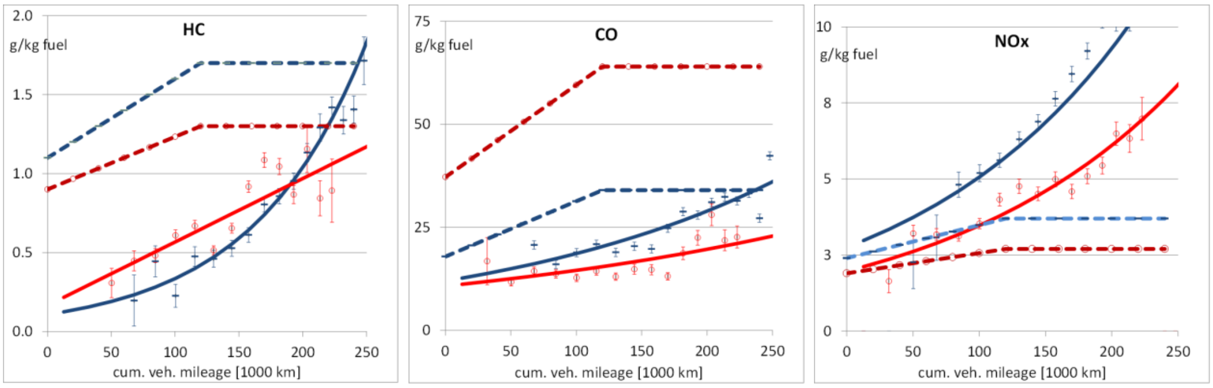


Figure 7. RS Emissions results (IIASA): HC - hot (left), CO (centre), NOx (right)



8 Emission Modelling (S. Hausberger, TUG; M. C. Galassi, JRC; P. Wuethrich, INFRAS; N. Ligterink, TNO; L. Ntziachristos, LAT; I. Trpevski, FINKI)

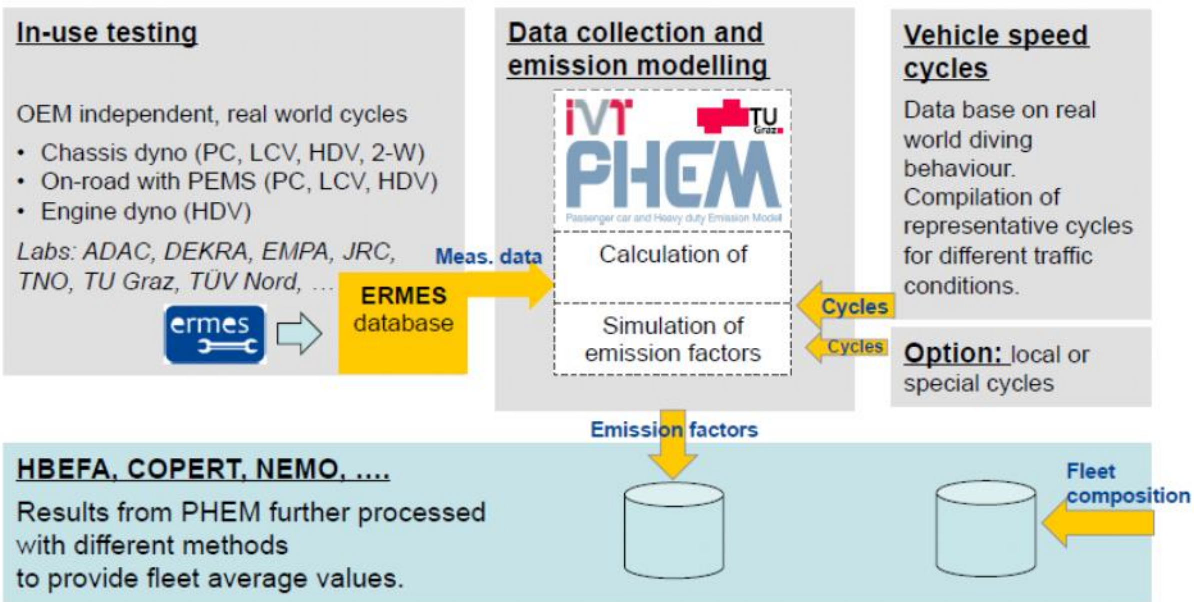
Reliable information on the emission behaviour of vehicles is necessary for identification of main sources for air quality problems, to develop and maintain emission inventories, and to assess the measures implemented to reduce environmental impacts. This information can be delivered through emission factors [g/km] for:

- Fleet in representative traffic conditions;
- Vehicle category, EURO class, technology;
- Improved traffic situations (speed limits, traffic light coordination, Eco-Drive trainings, etc…);
- Future (alternative) technologies (PHEV, downweighting, etc.).

Data sources are test stand measurements, on-board tests (PEMS), on-road remote sensing (RS) or simulation. Those measurements and data collection are coordinated within **ERMES** (**European Research on Mobile Emission Sources)** Group [5], which represents the international cooperation of research institutions and public authorities for model developments (**Figure 7**). ERMES unites more than 50 organizations involved and participants from 23 countries, even outside EU boundaries.

ERMES emerged in 2009 from the collaboration of two groups engaged in emission modelling since early 2000s: the **DACHNLS** group (headed by INFRAS and TUG) and the **EEA/JRC/LAT/Emisia** group, responsible for the development of the **HBEFA** and **COPERT** models respectively. It is coordinated and partly funded by JRC since 2009. Its first focus is on road transport. ERMES work aims at harmonizing the measurement procedure across laboratories and sharing data in a common format.

Figure 8. Data compilation and application within ERMES (TUG)



PHEM (Passenger Car and Heavy Duty Emission Model) was developed since 1999 in several international and national projects. PHEM calculates the fuel consumption and emissions of vehicles based on the vehicle longitudinal dynamics and on engine emission maps. PHEM simulates emission factors [g/km] per vehicle segment for all traffic situations needed. The results from PHEM are used in HBEFA (Handbook Emission Factors for Road Transport), in COPERT and for HDV also in VERSIT+.

For each vehicle segment, engine emission maps based on a representative number of vehicles tested shall be available. PHEM has average maps for all segments from more than 1200 tested vehicles. EURO 6, some LCV segments, HEV and BEV are yet poorly covered by test data and assessment of vehicle emissions representative for the fleet needs tests on a large number of vehicles.

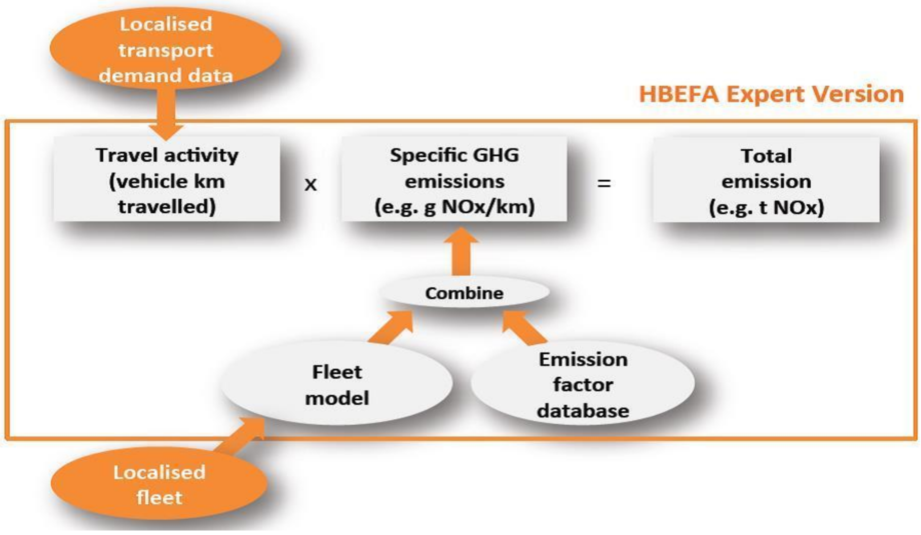
Availability of more PEMS test data is expected in the future and therefore adjusted methods will be needed (e.g. consideration of ambient conditions and driving dynamics). It is expected reliability of emission factors to increase when PEMS tests will be systematically integrated into PHEM data base.

HBEFA (Handbook of Emission Factors for Road Transport) [6] provides emission factors, i.e. the specific emission in g/km for all current vehicle categories (PC, LDV, HDV, buses and motor cycles), for a wide variety of traffic situations. HBEFA was originally developed on behalf of the Environmental Protection Agencies of Germany, Switzerland and Austria. In the meantime, further countries (Sweden, Norway, and France) as well as the JRC, also started supporting HBEFA development. HBEFA is developed since 1995 and since 2014 an adaptation for China is also available, supported by GIZ.

In HBEFA fleet model weighting of sub-segments is based on mileage. The input fleet data include: vehicle stock, new registrations, age, segmentation and the output is the weighting of fleet (veh – km - based).

The HBEFA emission model is linking traffic activity and emission factors, as shown in **Figure 9**.

Figure 9. HBEFA emission model (INFRAS)



HBEFA methodology comprises:

- Vehicle segmentation,
- Traffic situation approach,
- Definition of traffic situations,
- Traffic situations and cycles,
- Cycle parameters and
- Computation of emission factors.

Vehicle segmentation is based on vehicle categories, vehicle size, fuel types / technologies, emission standards and reduction technologies. The objective of traffic situation approach is to provide emission factors and model the complexity for real-world driving which will be resulting in traffic situation scheme, categorizing real-world driving into bins with similar emission behaviour (speed, dynamics). Traffic situation scheme is based on commonly available parameters: area, road type, speed limit and level-of-service. 276 traffic situations are available in HBEFA; each traffic situation is represented by a typical driving cycle by vehicle category, derived from real-world measurements (GPS). An example is given in **Figure 10**.

Figure 10. Example of traffic situations and cycles (INFRAS)

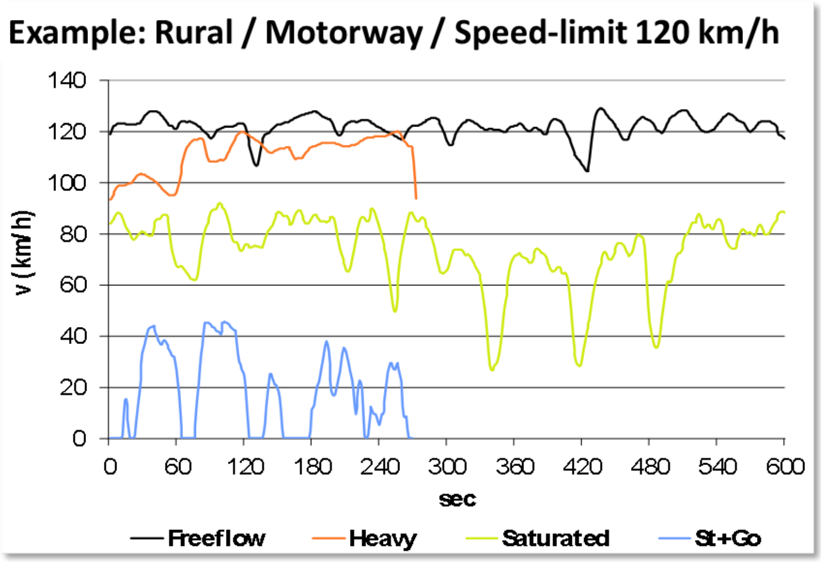
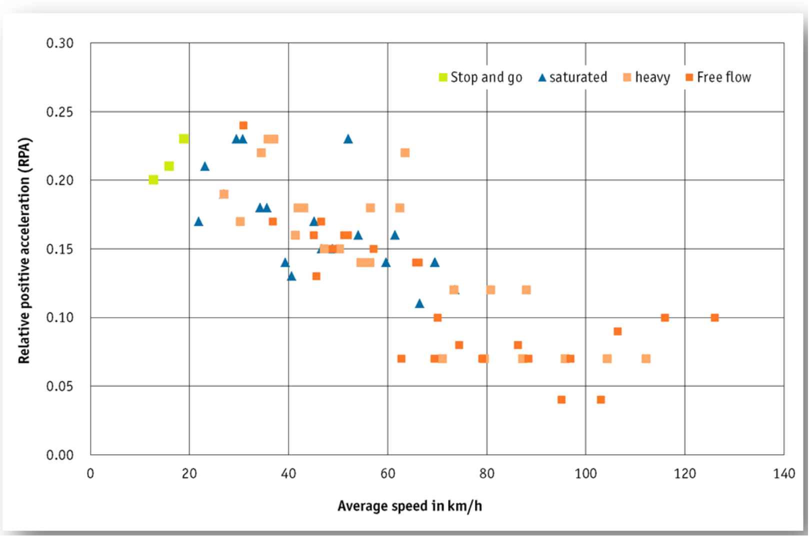


Figure 11. Cycle parameters (INFRAS)

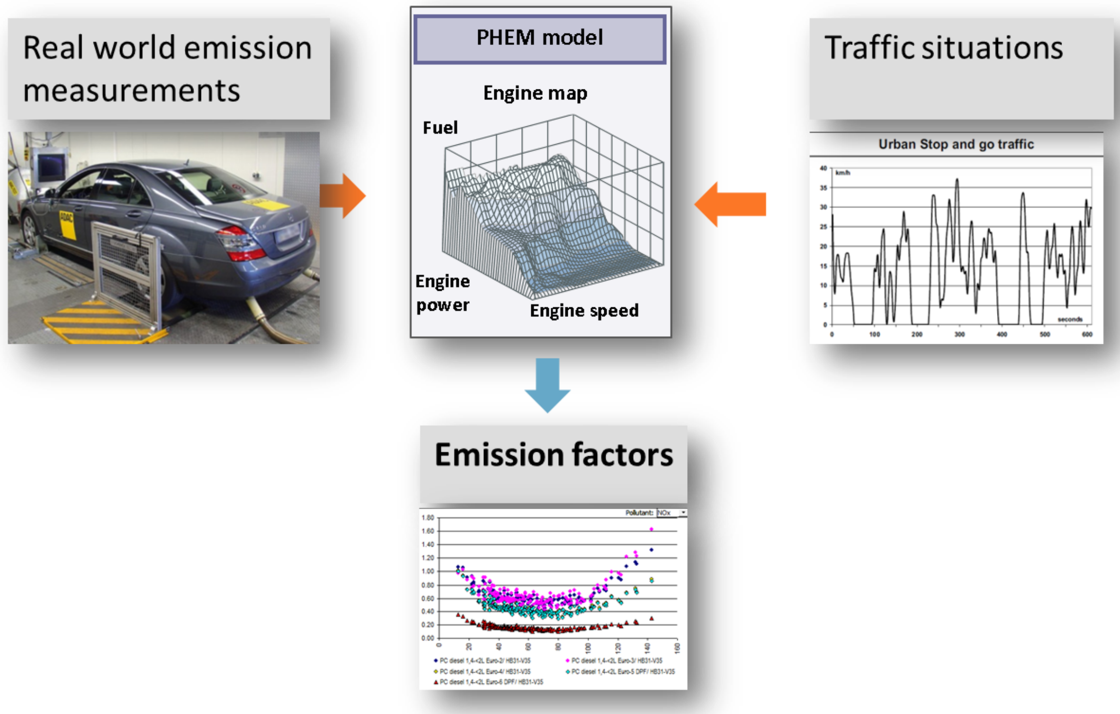


Each cycle (v - t - series) can be identified by average speed, relative positive acceleration (RPA) and percentage of stop – time (**Figure 11**).

The ideal concept of emission factors computation would be to perform emission measurement of each traffic situation (**Figure 12a**). But there are practical restrictions: emission measurement of all 276 traffic situation is hardly feasible as it would be very costly and time consuming. So HBEFA approach uses a computer model (PHEM) to derive emission factors for cycles, calibrated with emission measurements based on (real world) driving test cycles (**b**).

Figure 12. Computation of emission factors: theoretical (a) and HBEFA (b) approaches (INFRAS).

(a)



(b)

The approach can be used in different applications such as modelling of local and regional air quality based on HBEFA. Examples of connection of HBEFA to transport modelling data can be found about Berlin, Switzerland (freight) and Federal State Hessen.

VERSIT+ model [8] was introduced at TNO in 2007 to calculate Dutch national emission factors of road vehicles. This model is used to predict emission factors and energy use factors that are representative for vehicle fleets in different countries. Emission factors are differentiated for various vehicle types and traffic situations, and take into account real-world driving conditions. VERSIT+ is unique in that it yields consistent results on national, regional and local scales. It can be used for investigating national greenhouse gas reduction strategies, but also for local air quality improvement.

VERSIT+ Dutch national emission factors basic principles include:

- Representative emission measurements (preferably on-road)
- Minimal modelling for the conversion to emission factors (**Figure 13** and **Figure 14**)
- Average emissions (technology x usage x driving)
  - 335 vehicle types x 7 road types x 3 congestion levels
  - NOx NO2, CO, HC, NH3, CO2, PM, EC, wear, etc.
- Annual updates in case of new emission data, new pollutants, new technology, new vehicle categories, new speed limits, etc.

Figure 13. VERSIT emission model: fit of emission results (TNO)

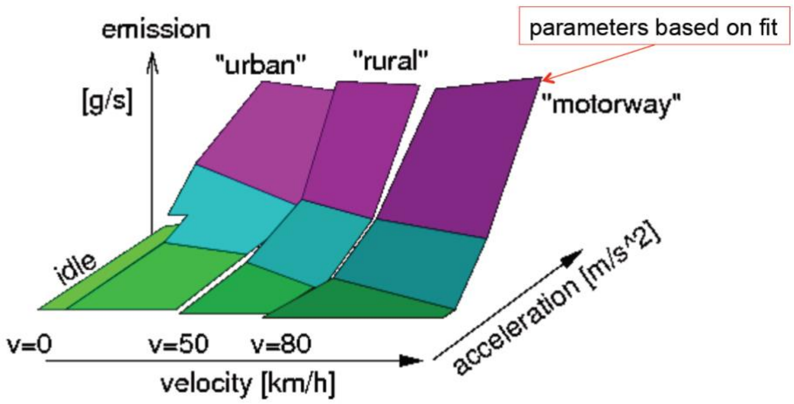
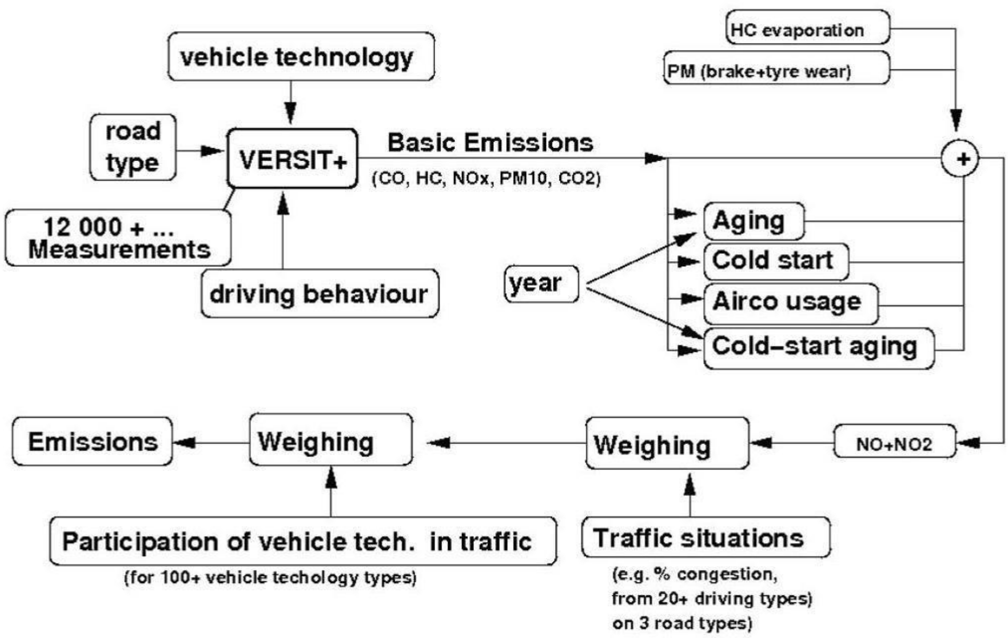


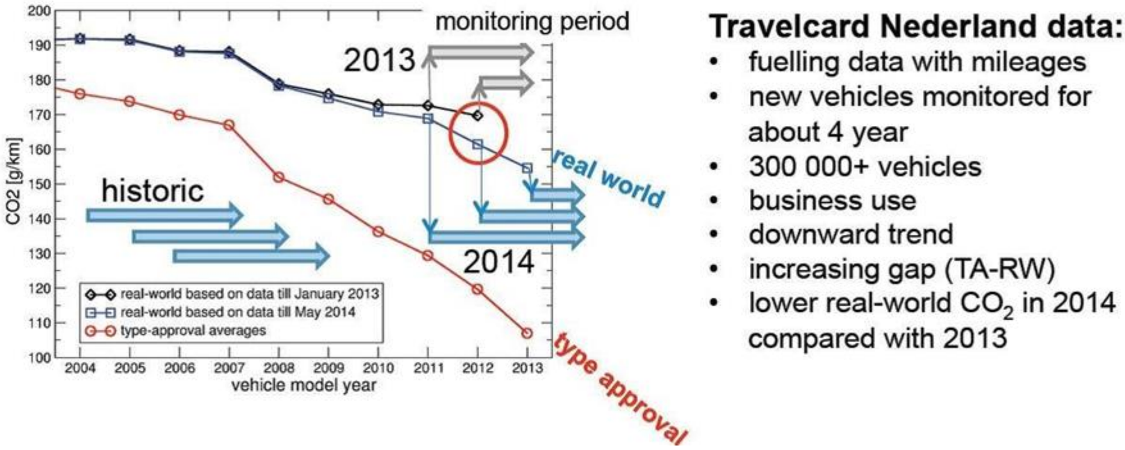
Figure 14. Flow chart VERSIT+ emission factors determination (TNO)



Recent updates relate to: LCV measurement program (more than 60% on passenger cars), Euro-V trucks split in D+E (pre 2009) and G categories and tractor-trailers into two total weight classes (distribution and long haulage). EC and NH3 were added to the emission factors list.

Simulation programs running in the Netherlands for fuel efficient cars show that the gap between real-world and type-approval CO2 emissions is increasing since 2005, 1%-1.5% a year (see **Figure 15**).

Figure 15. Fuel consumption and CO2 of passenger cars (TNO)



COPERT (COmputer Programme to calculate Emissions from Road Transport) [8] calculates emissions of all important pollutants from road transport. It can be used to produce total emission estimates from 1970 to 2030 and can be applied in all European countries, in Asia, South America and Oceania. COPERT provides a user friendly (MS - Office like) graphical interface to introduce, view, and export data.

COPERT 4 Version (fourth update of the original COPERT 85) incorporates results of several technology, research and policy assessment projects. The development of COPERT is coordinated by the European Environment Agency (EEA), in the framework of the activities of the European Topic Centre for Air Pollution and Climate Change Mitigation. The European Commission's Joint Research Centre supports the scientific development of the model.

As it is known exhaust emissions depend on vehicles' activity meaning number of vehicles (N) and traveled distance (M) and can be divided into hot emissions (eHOT) and cold emissions (β, eCOLD/eHOT). So, the total exhaust emissions equal (**Figure 16**):

$$\mathbf{E_{EXH} = E_{HOT} + E_{COLD}}$$

Figure 17 shows COPERT/HBEFA hot-start base EFs and how they are derived.

In addition, non-exhaust emissions must be accounted for:

- NMVOC from Fuel Evaporation $\mathbf{E_{EVAP} = E_{DIURNAL} + E_{SOAK} + E_{RUNNING}}$
- PM from tyre and brake attrition $\mathbf{E_{HOT} = N \cdot M \cdot e_{PM}}$

Figure 16. General Concept of Exhaust Emissions / Consumption Calculation (LAT)

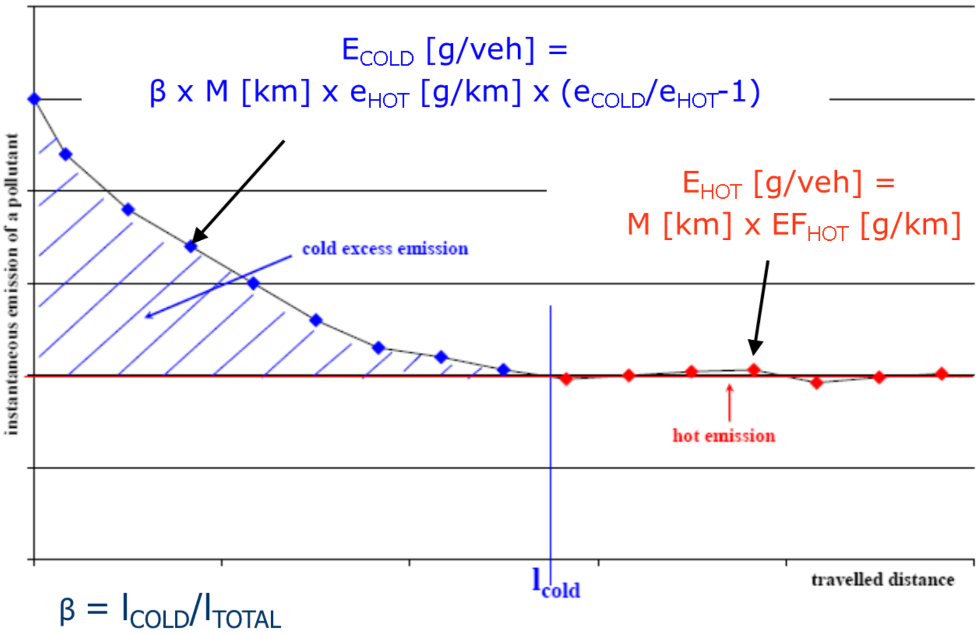


Figure 17. COPERT / HBEFA hot start base emission factors (LAT)

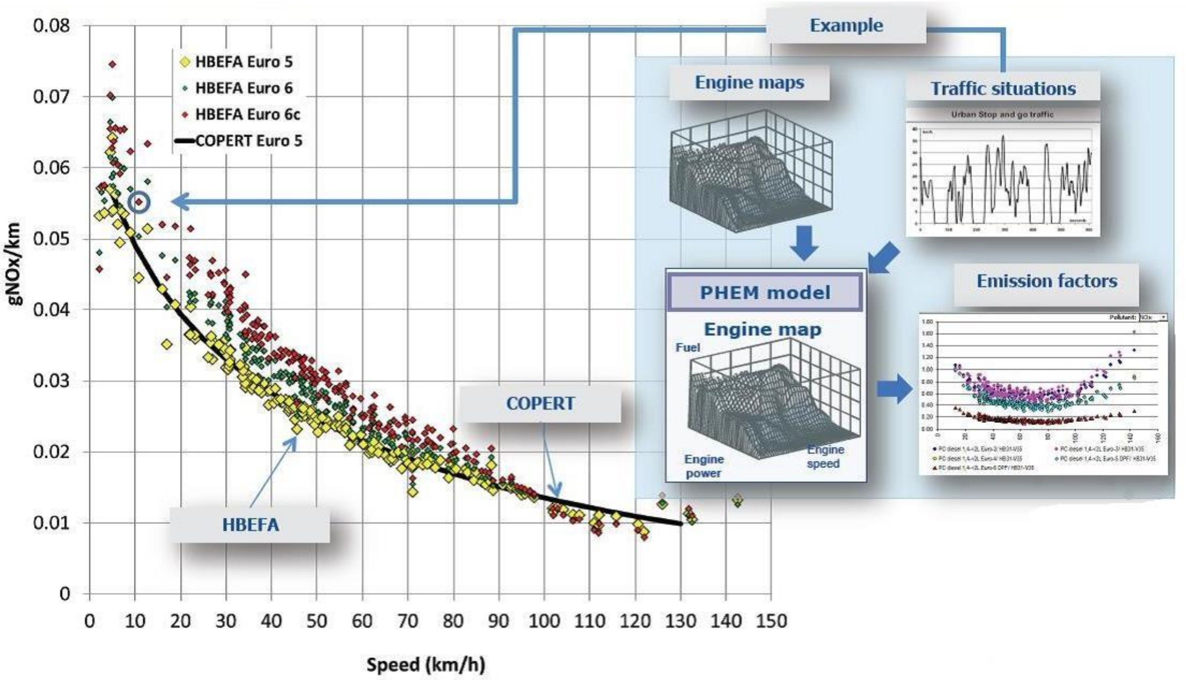


Figure 18 shows an example of COPERT and HBEFA application for NO_x emission calculation at urban scale in Madrid [9], while **Figure 19** shows an example of application to transport policy [10].

Figure 18. COPERT application in atmospheric environment (LAT)

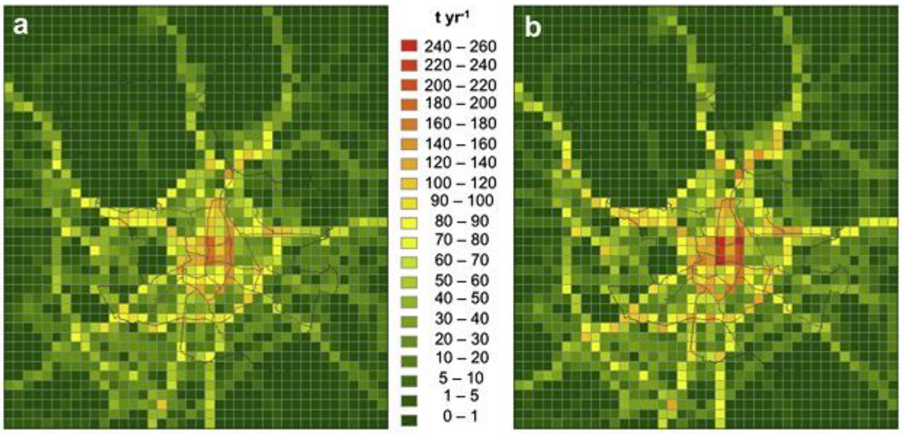


Fig. 4. Distribution of the NO_X emissions (ton yr^{-1}) according to COPERT (a) and HBEFA (b).

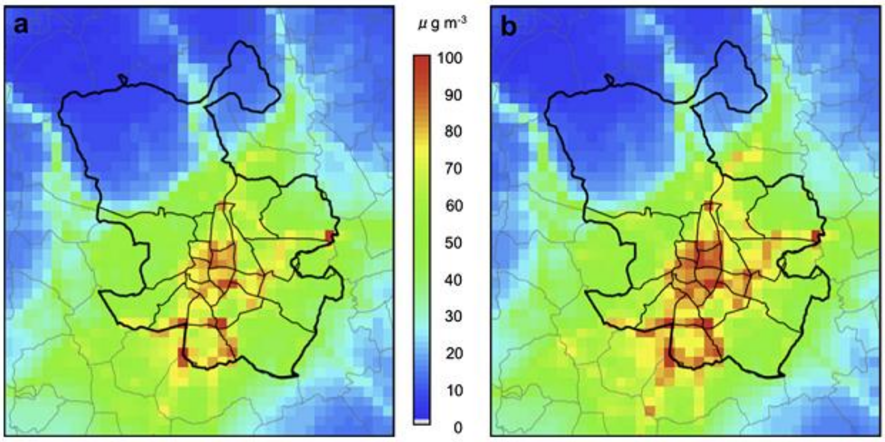


Fig. 8. Predicted NO_2 annual mean ($\mu g\ m^{-3}$) concentration by CMAQ when fed with emission datasets from COPERT (a) and HBEFA (b).

Figure 19. COPERT application in transport policy (LAT)

Table 3
Timing (shaded) of the implemented measures and the a priori expected impacts (striped). The impact on new vehicle purchases, the composition of the existing fleet and the kilometres driven is indicated on the right-hand side (x).

scenario	measure	year 2010	year 2015	year 2020	year 2025	Impact on new vehicles	Impact on existing fleet	Impact on vehicle kilometres
realistic	a					x	x	
	b							
	c					x		
	d					x	x	x
	e						x	
	f						x	
progressive	a					x	x	
	b					x	x	x
	c					x	x	x
	d							
	e					x	x	

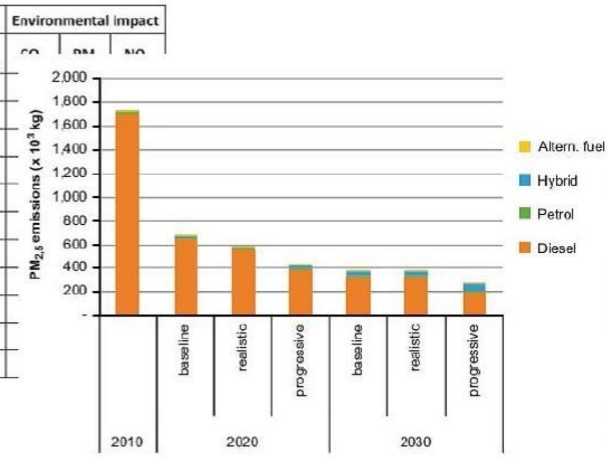


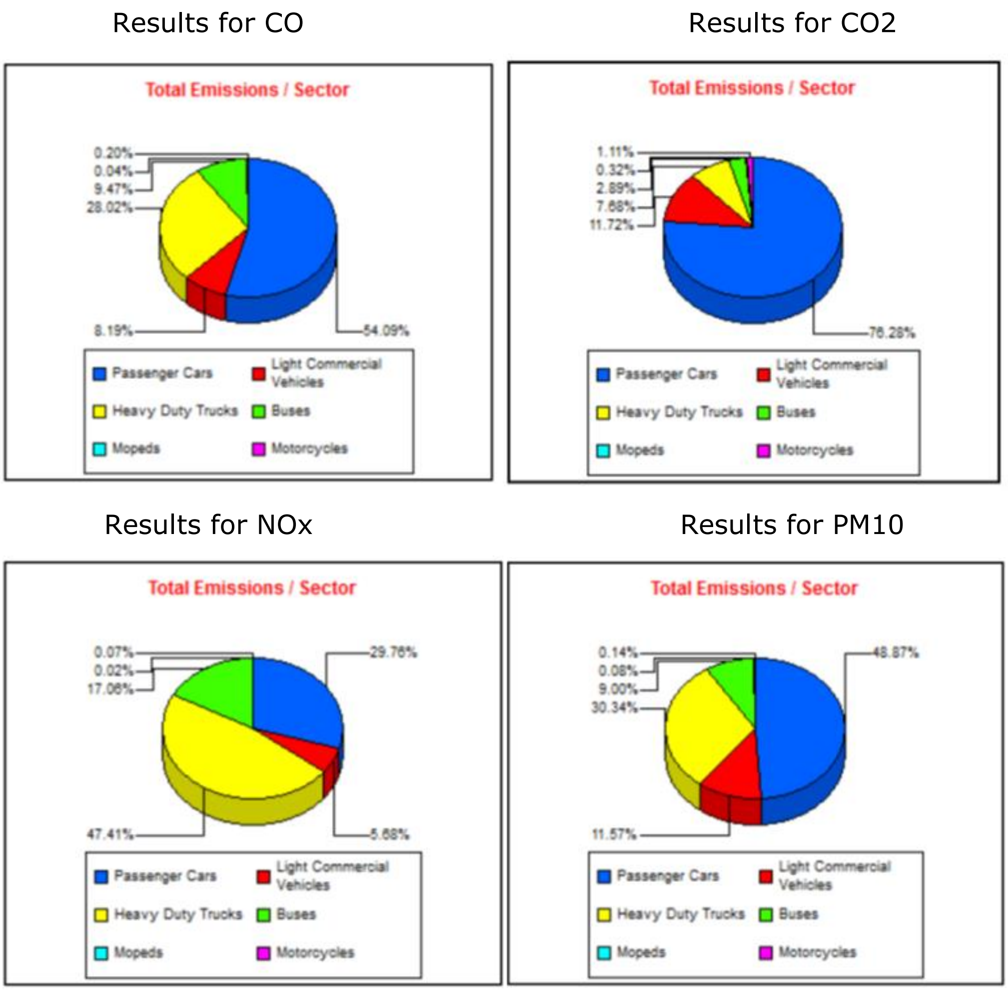
Fig. 4. Emissions of $PM_{2.5}$ (exhaust) per fuel type & drive train.

The key methodology updates in COPERT 4 are related to: the broader range of fuels handling possibilities; improved GHG calculation; the incorporation of two modelling scales (Tier 2: Simplified emission factors; Tier 3: Detailed emission factors and methodology); an extended list of vehicle types; the distinction of urban speed to peak and off-peak.

COPERT 4 model was used at the University of St. Cyril and Methodius of Skopje for calculating emissions from road transport in former Yugoslav Republic of Macedonia for 2012. Air pollution in several cities of the former Yugoslav Republic of Macedonia is well above the limits and before that study there was no other significant evaluation of air pollution from road transport. Another purpose of the study is to assess the significant increase in second-hand vehicles since 2010 due to policy shift: in particular, diesel cars number in 2012 triplicated respect to year 2000. Some of the results are summarized in **Figure 20**.

The study showed that the major source of pollution is represented by recently imported Euro 1 and Euro 2 vehicles, yet the trend of importing them continued through 2013 and 2014. Such results emphasize that a shift in policy strategies is needed to stimulate replacement of older vehicles.

Figure 20. COPERT 4 case study for Skopje, former Yugoslav Republic of Macedonia (FINKI)



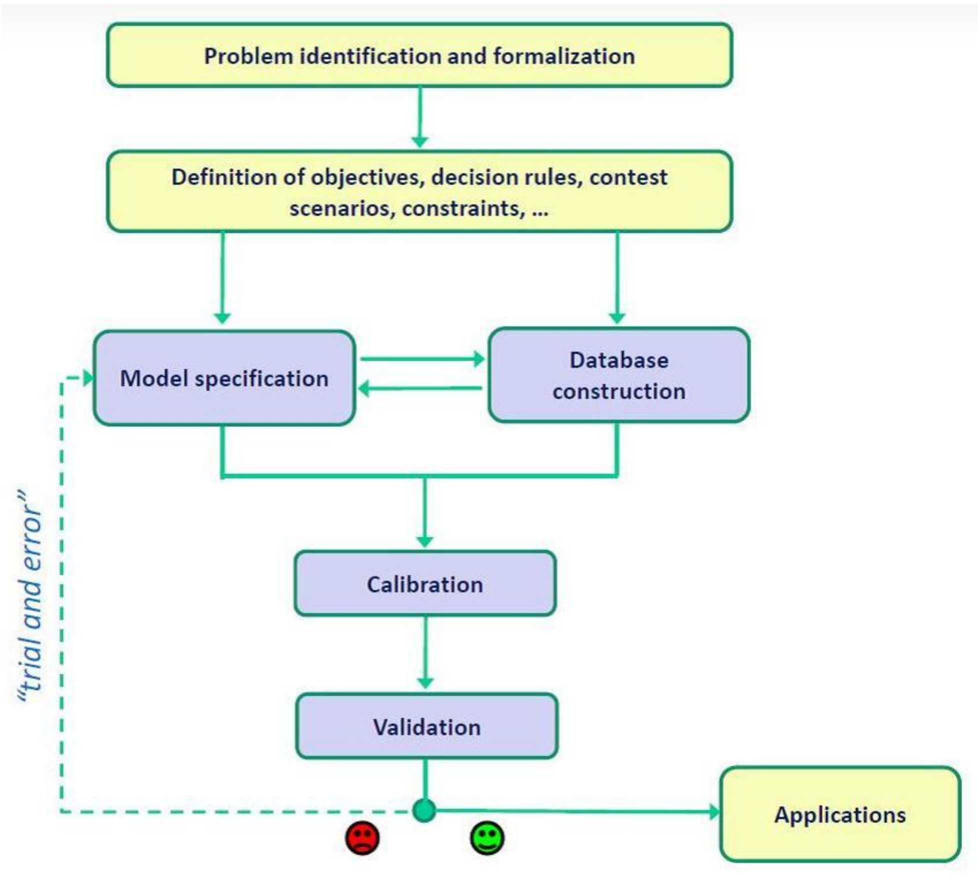
9 Transport demand models (V. Marzano, UniNA)

The travel demand is defined through its flow, which is defined as trips made by people (and freight) between origins and destinations. A trip is the effect of a series of choices made by transport system users. Trips can be characterized spatially by grouping them by place (zone or centroid) of origin and destination; demand flows can be arranged in OD (origin-destination) matrices. Travel demand estimation can be done by direct estimates (census, surveys, smartphone, GPS, Google, etc.) or by model-based estimates (transport demand models). Transport demand models are actually abstract, simplified representation of the ground-truth:

$$d_{od}[K_1, K_2, \ldots, K_n] = d(\mathbf{SE}, \mathbf{T}, \beta)$$

where the left-hand side represents the average number of trips with given characteristics, in a time interval. In the right-hand side, SE is the socio-economic variables vector (households, job positions …); T is the level-of-service attributes of the transportation supply system vector (travel time, monetary cost…); β represents other coefficients or parameters. **Figure 21** shows the structure of the model implementation road map.

Figure 21. Model implementation road map (UniNA)

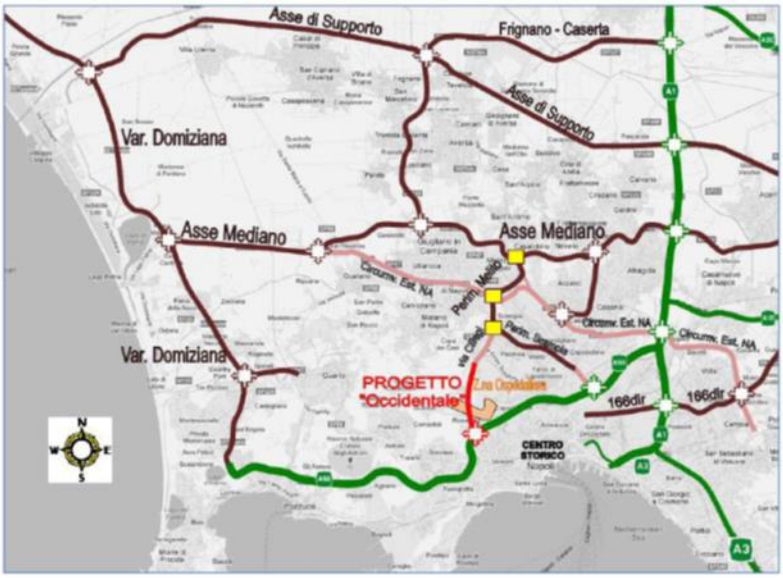


In detail, fundamentals of discrete choice modelling, basic 4-step travel demand model and OD flows correction/updating were presented, based on a practical example: **Italian A56 motorway** traffic analysis (**Figure 22**).

The limitations of trip-based method are: the demand for trip making rather than for activities; the use of person-trips as unit of analysis; decisions (choices) for each trip independent of those made for other trips - which is reasonable only when the journey is a “round-trip” with a single destination and two symmetric trips. More complex approaches are available:

- trip chain,
- tour-based,
- activity based

Figure 22. Italian A56 motorway traffic analysis (UniNA)



In activity-based models travel demand is derived from demand for activities, trip chains/tours are interdependent and people face time/space constraints limiting their activity schedule. Activity and travel scheduling decisions are made in the context of a broader framework. However, these are complex models with larger choice set, they are computational burdensome with network equilibrium properties not established. Also, model validation and sensitivity to input factors are not well established.

Another possibility is the agent-based demand modelling. The agent based model shown in **Figure 23** is constituted by 4 sub-systems: service networks design model, resource-technology network (RTN) model, agent-based micro-simulation model of urban activities (AMMUA) and layout model.

A city generates on average about 0.1 delivery/pick-up movements per person/day, 30 ÷ 50 tons of goods per person/year. In Europe 30% of freight trips are within 50 km. The growth rate of freight movements is higher than passengers' mobility. Urban freight represents 10÷15% of equivalent miles travelled in urban areas, but it has remarkable externalities (e.g. ≈ 50% of PM10) and strong interaction between passenger and freight vehicles.

Modelling approaches for urban freight can be demand-driven (pull) or supply-driven (push). In the demand-driven methodology, persons/establishments express freight demand and trigger production, transport and logistics activities. In the supply-driven approach, persons/establishments generate freight supply and trigger demand, transport and logistics activities. The same establishment/person can push and pull (also for reverse logistics and waste disposal). Four-step travel model adaption to freight demand is shown in **Figure 24**.

Figure 23. Agent-based model (UniNA)

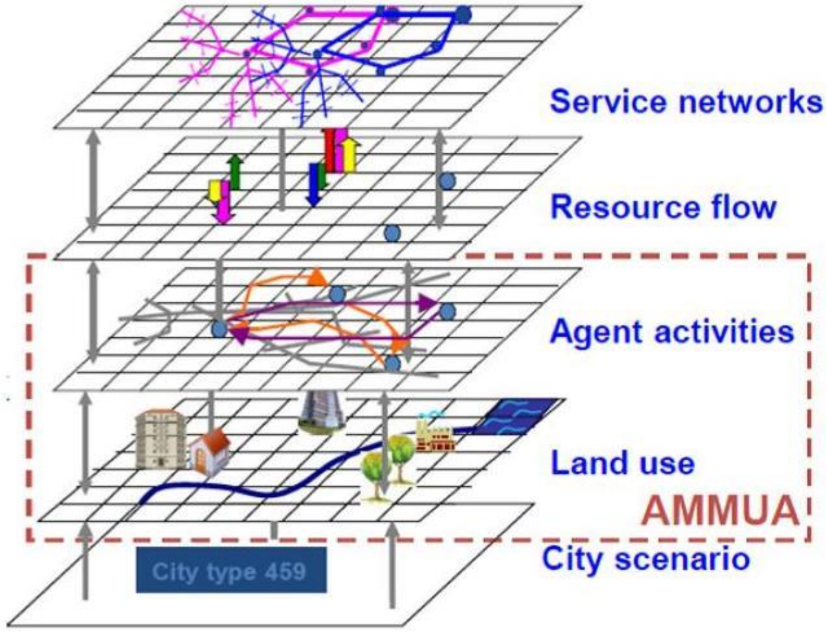
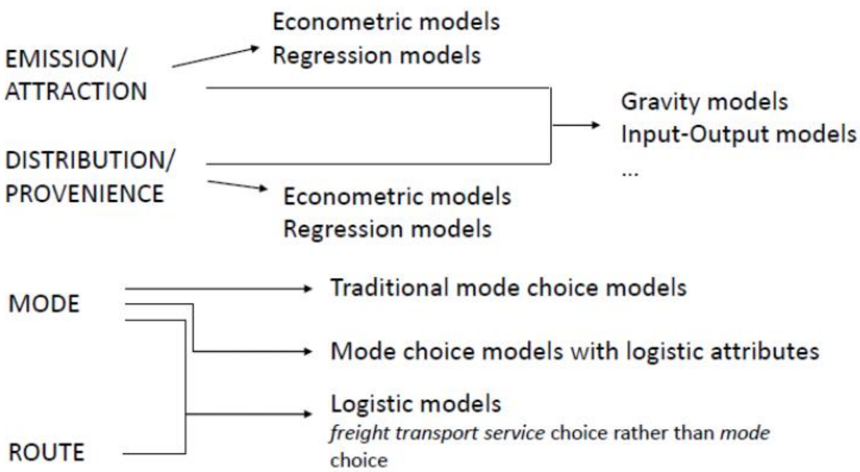


Figure 24. 4-step model adaptation for freight demand (UniNA)



GPS/OBD-based commercial vehicles' survey was carried out through system setup for data collection in Singapore. On-Board Diagnostic (OBD) port to connect to vehicle's engine has been used. Data has been collected second-by-second (GPS location, vehicle speed, fuel consumption and engine parameters like engine rpm, air intake temperature, etc.). The system provided information about route, stops, driver behaviour, idling, fuel use and emissions.

10 Transportation and traffic models (V. Punzo, UniNA)

Trajectory of each single vehicle is observed in time-space domain. Time series of quantities at point detectors can be acquired from the perspective of a stationary observer. What can be derived is the traffic flow and time mean speed. Data about density and space mean speed can be derived from aerial measurements. Finally, point-to-point measurements can give information about travel times of individual vehicles. The representation of these three point measurements is given in **Figure 25**.

Data and information about the Next Generation Simulation (NGSIM) are available in references [11] and [12]. An example of NGSIM-like data is presented in **Figure 26**.

Figure 25. Different point measurements (stationary observer, left - aerial observer, centre - point-to-point measurements, right) (UniNA)

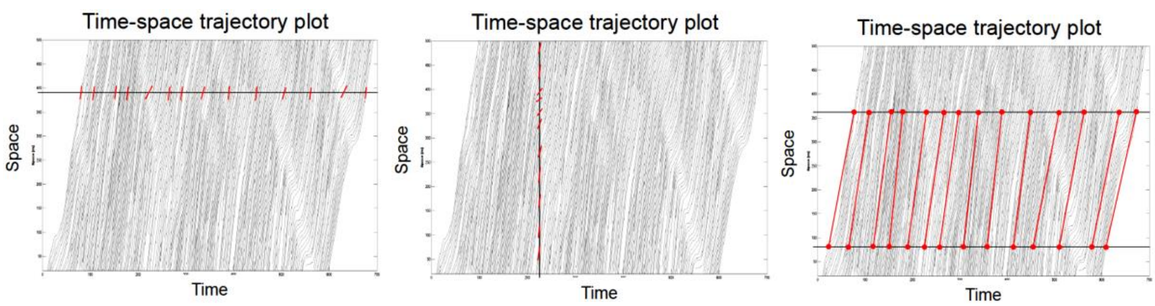
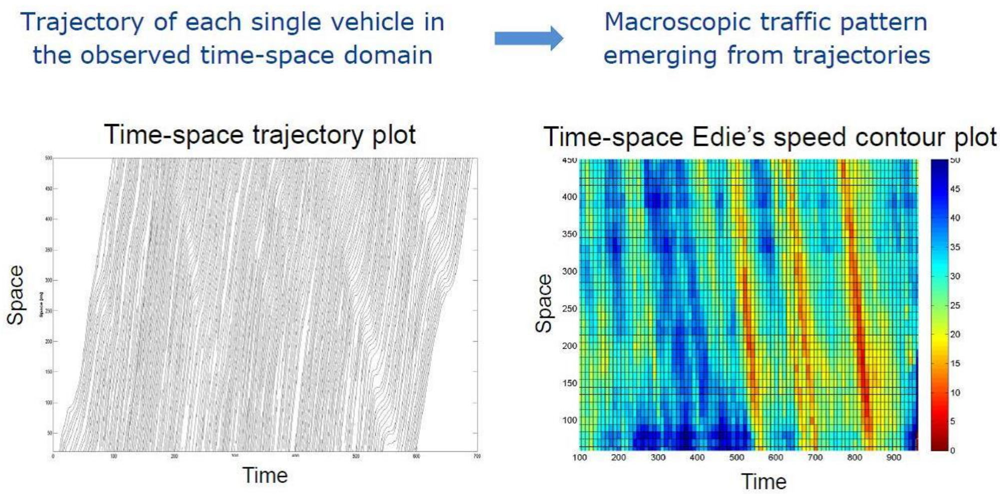


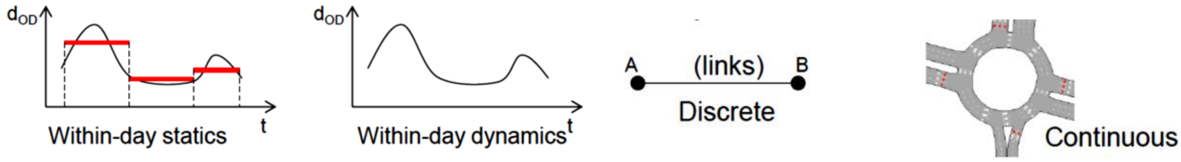
Figure 26. Twofold representation of traffic: Next Generation Simulation –like data (UniNA)



Transportation supply models ([13]-[15]) can be static or within-day dynamic models. As of the levels of representation it can be time represented (**Figure 27a**) or space represented (**Figure 27b**).

Transportation services can be continuous, services which can be accessed at any location and time, like car, motorcycle, walking or non-continuous (scheduled) services which can be accessed at certain locations and times, like bus, airplane, train.

Figure 27. Levels of representation of transportation supply models (UniNA)



a) b)

Supply models components of the static model are:

- Graph models: ordered pair of sets G(N,L) representing network connections.
- Network flow propagation models: simulate how path flows induce link flows.
- Link performance models: simulate how link flow affects link performances.
- Path performance models: simulate how link performances induce path performances and path costs.

Static traffic models are not an accurate representation of traffic, because inflow always equals outflow, volume/capacity ratio is greater than 1, there are no lanes and can be calibrated either for volumes or for travel times. Advantages are that static models can load any amount of demand, they allow fast calculation, there are few parameters and inputs, and outputs are easy to analyse.

On the other hand, dynamic models can capture the true causes of congestion and can be calibrated for flows and travel times. They reproduce the fundamental diagrams, capture the time dimension and consider queues and blockages. Dynamic models can emulate ITS and other operational aspects. Different types of within-day dynamic models are summarized in **Figure 28**.

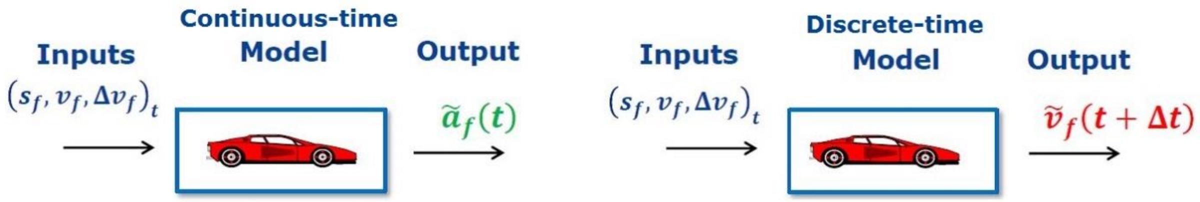
Two basic microscopic models are car-following and lane changing models. Car-following models simulate longitudinal motion along a road; it is a time and space continuous mono-dimensional representation. Lane changing models simulate lateral motion on a road; it is a discrete space representation (lanes).

Figure 28. Within day dynamic simulation models (UniNA)

Flow Representation	***Performance functions***		
	AGGREGATE (explicit capacity)		*DISAGGREGATE*
CONTINUOUS	**MACRO-SIMULATION**		•
	space discrete	*space continuous*	
DISCRETE	**MESO-SIMULATION**		**MICRO-SIMULATION**

Car-following model describes the follower's response as a function of the inputs. In continuous-time models the follower response is usually an acceleration function and in discrete-time models a speed function (**Figure 29**).

Figure 29. Car-following model output (UniNA)



Beside the basic dynamics of the vehicles the model should include rational driver behaviour, plausible car-following behaviour, realistic acceleration/deceleration profiles and reproduction of disaggregate and aggregate characteristics of traffic (e.g. bivariate relationships, shock-wave speed, and backward propagation of congestion).

The requirement for accident free model is taken with a safety assumption that at instant ***t***, the follower plans the speed for the lagged instant ***t***+***τ*** in order to be able to safely stop even in case the leader had started to break at instant ***t***. Everything is modelled and expressed in mathematical terms, including the formulation of traffic stream models (conservative and aggressive behaviour).

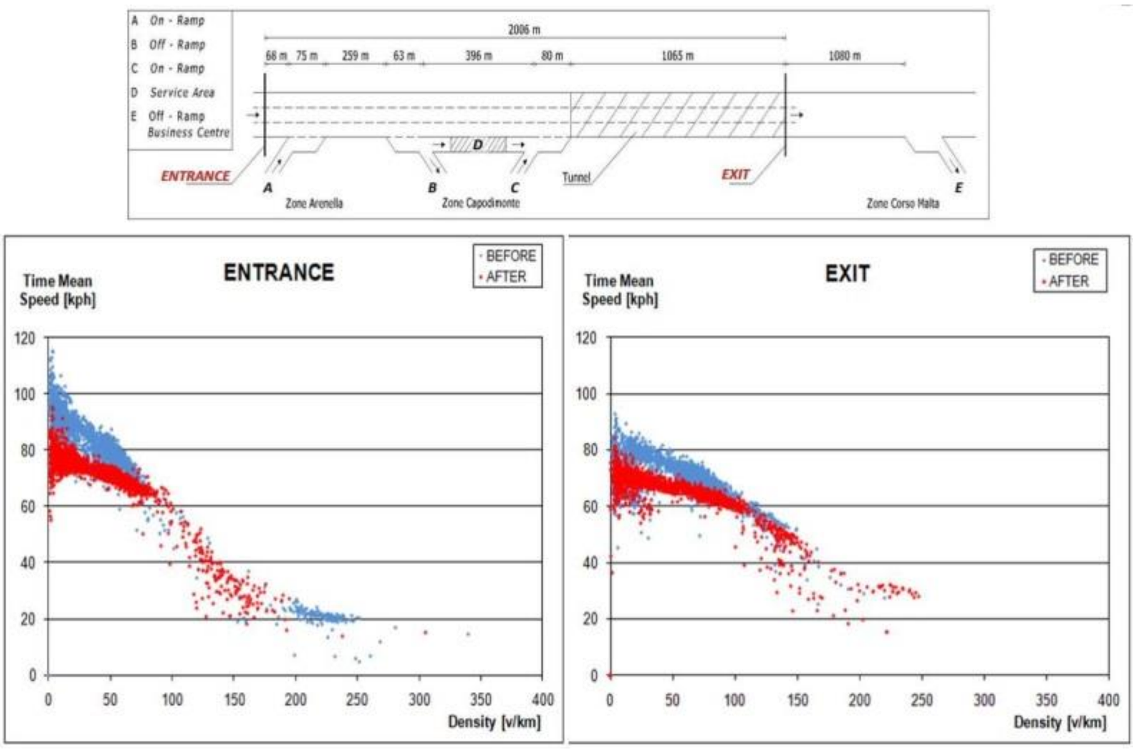
Coupling traffic models and pollutant emission models has been done in case study of a P2P speed enforcement system [16]. The study was done for **A56 – Naples urban toll way in 2009**. Information on the route:

- Annual average daily traffic: 267,000 vehicles
- Length: 20.2 km
- Number of lanes: 3 per carriageway
- Interchanges: 14 (24 on ramps, 24 off ramps)
- Speed limit: 80 km/h
- Highest rate of accidents per km among Italian urban highways.

The P2P Speed Enforcement System includes seven stretches – 3 consecutive westbound stretches (W1, W2 and W3) with total length of 5.0 km and 4 consecutive eastbound stretches (E1, E2, E3, E4) with total length of 5.0 km 13.0 km. The speed Limit is homogeneous: 80 km/h. Available data come from point detectors (data per lane, per vehicle class) which count 5 min. aggregation and time mean speeds 5 min. aggregation. P2P data (data per vehicle) give the average travel speed (ATS).

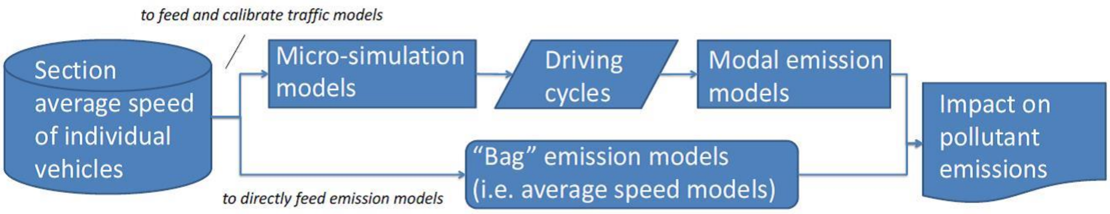
The before-after comparison study showed different effects for uncongested and congested stretches. Lower speeds and lower speed variance was observed for uncongested stretches; also for congested stretches lower speeds were observed, but with higher speed variance, which is inconsistent with expectation and visual inspection.

Figure 30. Impact on traffic dynamics - A56 – Naples (UniNA)



Two alternative approaches for evaluating the impact of ASSES on pollutant emissions by means of individual section speeds are given in **Figure 31** [17].

Figure 31. Two alternative approaches for evaluating the impact of ASSES on pollutant emissions (UniNA)



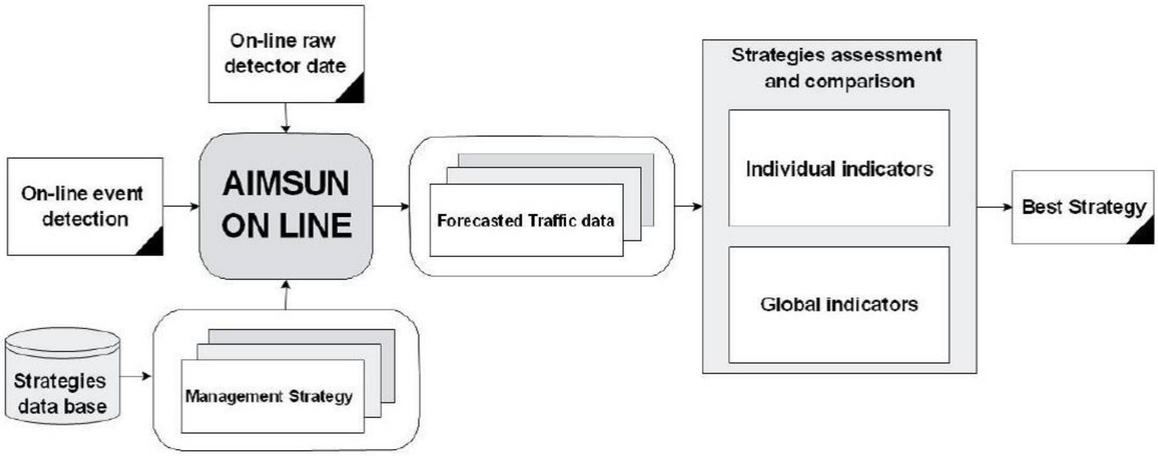
Advanced applications of traffic models imply online traffic management. The requirements for these applications are:

- Network status forecasting and monitoring;
- Help control centers to take decision and to inform road users;
- Basis for ATIS and ATMS applications.

Aimsun Online is a real-time decision support system for traffic management. Its dynamic, high-speed simulation of large areas allows traffic operators to "see" traffic conditions before they actually unfold and anticipate future events. This system is implemented in Madrid. The architecture of the system is sketched in **Figure 32**.

Some of the future challenges of Aimsun Online are integration into the available new data systems associated with new technologies (individual vehicle tracking), a single database for automatically updating data (infrastructure, public transport …), ITS/Navigation systems (rerouting), etc.

Figure 32. Aimsun Online System Architecture (UniNA)



Another real-time model is **PTV Optima**. This model-based solution offers real-time traffic information for the entire traffic network and produces reliable forecasts for the next 60 minutes. The process is based on a transport model created in **PTV Visum** which represents each "typical day" (e.g. working days or weekends) for the transport area of interest.

11 Traffic modelling in Skopje as approach for pollution calculation (A. Kostikj, FME)

Main factors of traffic pollution in urban areas are congestion, traffic lights desynchronization and driving styles. There are many practical solutions for reduction of traffic pollution in the existing infrastructure: powertrain measures; aftertreatment; alternative fuels, hybrid vehicles, electric vehicles and also concepts of energy efficient driving.

A case study of traffic modelling in Skopje was presented as an approach for pollution calculation, based on the concept of energy efficient driving. The study was performed for the longest boulevard of the city and comprises experimental research, virtual modelling and simulation, model calibration and validation, results analysis. The comparison between real and harmonized traffic stream was then performed. Results for the energy efficiency and emissions are summarized in **Figure 33**.

Figure 33. Energy efficiency and emission in Skopje traffic (FME)

Real traffic stream					
Measure	*Sim. 1*	*Sim. 2*	*Sim. 3*	*Sim. 4*	*Sim. 5*
Required energy [MJ]	439,0	441,0	498,1	496,4	422,4
Required fuel [l]	41,84	42,03	47,46	47,31	40,25
Total fuel consumption [l]	58,05	57,85	61,92	62,02	55,34
Av. fuel consum. [l/100km]	11,42	11,38	12,19	12,21	10,89
CO2 emission [g/km]	282	281	300	301	268
Harmonized traffic stream					
Measure	*Sim. 1*	*Sim. 2*	*Sim. 3*	*Sim. 4*	*Sim. 5*
Required energy [MJ]	424,6	412,3	475,3	452,4	411,6
Required fuel [l]	40,46	39,28	45,29	43,11	39,22
Total fuel consumption [l]	50,5	49,17	55,33	53,05	49,24
Av. fuel consum. [l/100km]	9,942	9,68	10,89	10,44	9,69
CO2 emission [g/km]	245	239	268	257	239

12 Vehicle simulation for Regulating CO2 emissions (G. Fontaras, JRC)

Experimentally testing many vehicles has 2 drawbacks, it does not cover all possible configuration of the vehicle and many operating conditions, and it is expensive and time consuming. Therefore the approach of combined vehicle simulation and measurements is extensively used in industry, with models of existing vehicles, for calculating CO_2 and pollutants emission over different conditions.

Consumption/efficiency maps (engine, gearbox, motor, other) are tables containing fuel consumption/component efficiency values for pairs of RPM – Torque. The vehicle model retrieves the fuel consumption/efficiency value depending on calculated RPM, Torque or Power at each calculation step (e.g. each sec). There is no physical model of engine/component to react in certain technology changes. To assess technology changes, new tables need to be provided (or old ones modified) by the user or dedicated component simulation tool.

There are technologies/combinations that can be accurately and effectively simulated in common vehicle simulation software (vehicle resistances - tyres, aerodynamics, mass influence; gearbox ratios, driveline components, increased gear number, clutches; auxiliary units; etc.) based on relevant efficiency maps or other inputs. But there exist also CO_2 reduction technologies which cannot be directly simulated with common vehicle simulation software (component specific technologies - e.g. effect of particular injector, engine heat recovery; complex control logics and respective functions, after treatment system technologies). In such cases dedicated and more complicated component simulation software or measurements need to be used.

This lack of knowledge is a barrier to the purchase of more efficient HDVs and is a gap that needs to be addressed. To this end the Commission has put great effort in recent years into developing the **VECTO (Vehicle Energy consumption Calculation Tool)** [18] computer simulation tool to estimate HDVs' fuel consumption and CO_2 emissions for the whole vehicle. Accordingly, the first priority is to close the knowledge gap on these emissions and to start their registering and monitoring. CO_2 measurements are easier for passenger cars than for HDVs, also due to the huge variety of vehicle types this category includes. Through the "declaration mode" of VECTO, all generic data and the test cycle are allocated automatically as soon as the vehicle class is identified. Through the "engineering mode" instead the user can select and change all input data, to allow recalculation of test data (e.g. for model validation). VECTO's inputs are component information as:

- Vehicle configuration and class (rigid truck, articulated truck, bus, coach etc., no. of axles/powered axles);
- Road load factors (aerodynamic characteristics, rolling resistance of tyres, mass and loads);
- Component related inputs (gear ratios, engine fuel consumption map, gearbox / axle loss maps, auxiliary component losses and temperature control systems);
- Driver & vehicle controls (shifting maps, ECO-roll, look – ahead coasting).

The model consists of four main modules: driving cycle pre-processing, driver pre-processing, power calculation and fuel consumption calculation.

Considering the increasing discrepancy between the CO_2 emitted by LDVs in real life conditions and the certification values that has highlighted in the recent past the need to develop a more realistic test procedure. The result of the work is the WLTP (Worldwide harmonized Light-duty Testing Procedure) that includes a new testing cycle (WLTC) together with the testing procedure (still in evolution), that will be introduced in 2017.

Due to this introduction, there is the need to provide a robust correlation between the new WLTP CO_2 values with the old NEDC values in order to take in to account that the actual CO_2 targets for each OEM defined for 2020 are derived from NEDC tests. In 2019, a new WLTP-based target for 2020 will be identified per each OEM, on the basis of their distance from the NEDC-based one. In order to deal with this issue, JRC developed **CO_2MPAS (CO_2 Model for PASsenger cars)[19]**. CO_2MPAS design is based on simple use, minimum number of input variables (available in TA), accuracy of the ΔWLTP-NEDC in the order of 2-2.5 gCO_2, minimizing statistical approaches and calculations and allowing the assessment of as many future technologies as possible.

CO_2MPAS comprise two main calculation modules:

1) Power – RPM module (communicated as CO_2MPAS v0.1 & JRC Gear v0.5.5)

- Simple longitudinal dynamics (WLTP-GTR)
- Engine power and RPM calculated @ 1hz – If RPM not provided from OBD
- Inclusion of Mechanical or Electrical loads where needed
- Generic start-stop logic

2) FC module (communicated as CO_2MPAS FC 2.0.1)

- Calculation of FC - Indicative instantaneous approach
- Semi-physical empirical cold start model
- Calibration - Optimization based on WLTP results

Results will help OEMs avoiding double testing and reducing the economic efforts for type approval.

13 Final remarks and closure of the workshop (B. Ciuffo, JRC)

Both traffic and emission models have reached significant levels of complexity. On the one hand emission models had significantly evolved, taking into consideration many relevant input parameters both for what concerns the vehicle (vehicle category, used technology) and its operations (speed/acceleration profiles, traffic conditions, driving parameters, etc.). On the other hand great progress is also achieved in developing traffic models. Microscopic traffic simulation models (based on car-following and lane-changing logic) are able to simulate the trajectory of every vehicle moving on a road network at very high resolution. This suggested the possibility to use traffic models as input to the emission models in order to calculate fuel consumption and emissions from traffic. This is particularly important as any investment and/or policy applied to the transport sector requires the analysis of the connected costs and benefits, which, in turn, require the estimation of the induced environmental impact that, in the case of road transport, mainly mean evaluating the impact on pollutant emissions and CO2/fuel consumption.

Several examples of traffic/emission models integration have been showed during the workshop, involving various models environmental (HBEFA, PHEM, COPERT) and traffic (AIMSUN, VISSIM, Paramics, VISUM; Transcad) applied to different cities, proving and justifying the efforts of public instruments support (particularly interesting was the assessment of introducing the "Safety Tutor" – a P2P speed enforcement system – on A56-Naples' urban toll way [16]).

In this light it can be concluded that, at the current stage, the integration of traffic and emission models can be used for the assessment of long term projects and wide-scale contexts as the underlying uncertainty of such a type of studies is certainly wider than the ontological limitations of the two families of models.

For real-time applications (e.g. ITS solutions), however, additional research efforts are necessary. In the summary presentation, the case study of a 2050 scenario is outlined. In the case study a real time emission monitoring system reveals picks of pollution concentrations due to road traffic in certain areas of a city. In the same scenario, the real-time traffic management system is required to reallocate vehicles in order to reduce the persistence of the pollution picks. In the scenario, the hypothesis of full knowledge of the position and the destination of all vehicles moving on the road network is made (which is possible considering the levels of connectivity and automation of vehicles in 2050). Objective of the traffic management system is to reduce pollution without dramatically increasing travel times. The following modelling gaps are identified:

- traffic simulation models do not take into consideration detailed vehicle operations such as gear-shifting which are both crucial in the calculation of emissions and in the detailed simulation of vehicle trajectories. In this light their integration with emission models does not necessarily provide reliable estimation of emissions and consumption.
- Traffic simulation models to do not take into account technological differences among vehicles. Their effect on traffic and emissions is therefore not considered.

As a conclusion, limitations of current model would not allow the traffic management system to reallocate traffic in order to reduce the pollutant concentrations. The development of a new generation of traffic simulation models is therefore invoked. The computational limitations that have led to the development of simplified traffic models do not hold any longer and therefore new more sophisticated and realistic approaches are expected. However, if the research community does not recognize this need (as it seems today) new generation of models will hardly arrive. New connected and automated vehicles which promise to close the loop between vehicles and traffic would suddenly make the existing models unsuitable for simulating traffic.

14 Conclusions

The main benefit of REM 2015 Workshop can be derived from the discussions opened during the sessions. Participants had the opportunity of hearing from renowned EU experts about main issues regarding road transport and emissions. The means for gathering necessary information and the approach used in the created models/software opened many questions between the experts from different areas about the relevancy of parameters which should be taken into consideration during the simulations or calculations of emissions. The relevant parameters for both sides are the key component for better integration between traffic and emission modelling. Through the presented examples of application, the workshop fostered the discussion about 'gaps' into the process of integration of traffic and emission models, which opens a front for further improvement and development.

The question that still arises is about tomorrow's transport and emissions control solutions. There are varieties of present and future advanced technologies that improve fuel efficiency and emissions. Some require infrastructure investment and behavioural changes that are difficult to enforce; some imply performance disadvantages compared to current technologies; others predict that mobility will become a service and will turn the transportation sector into ICT industry.

Part III. Road transport policies in the enlargement countries represented by the workshop participants. (D. Danev, M. Kjosevski)

15 Albania

Albania began tracking urban air quality in the mid-1970s. The focus had been on sulphur dioxide, in response to the law on environmental protection, in place at the time. Since the early 2000s the attention of air quality monitoring has refocused to address the changes in the sources of pollution. In major cities, the air quality is poor and can exceed national and EU air pollution standards, due to a significant rise in car ownership and decrease in urban greenery, as well as major construction.

In Albania, the transport sector has continuously increased energy consumption. In 1990 it consumed 6% of the total energy, peaking to a value of 32% in 2005. Freight transport by big and small trucks consumes much more fuel oil/per ton-km compared to rail transport. The responsible ministries (Ministry of Transport and METE) needed improvements of the performance of the transport sector, through: better management of energy (in both passenger and freight transport), energy efficiency policies, promotion of public transport and promotion of freight transport by big trucks and trains.

Regarding pollutants emission caused by the road and non-road vehicles, based on the Law on Air Protection from Pollution from 16.5.2002 "On the protection of air from pollution" and DCM No.6527 from 24.12.2004 "On admissible values of elements of air pollution in the environment by the emission of gasses and noises caused by the road vehicles and the manner of controlling them", Albania has taken the measures to improve the situation.

Albania, within the framework of National Environmental Action Plan (NEAP) 2002, takes into account the need to integrate environmental considerations into other sectors and foresees the development of a strategy and action plan for sustainable transport. The Albanian National Transport Plan approved in 2006 and the National Strategy for Transport 2008-2013 were developed to make the control of the vehicle exhaust emissions compatible with EU standards by 2009. So, they reviewed all transport related legislation to put it in line with EU acquis communautaire, and automotive emissions and vehicle efficiency were perceived as important issues in the country.

Annual technical control is compulsory for all vehicles in Albania and in order to apply the Directive 2009/40/EC "On roadworthiness tests for motor vehicles and their trailers", in 2009 the Ministry of Public Works, Transport and Telecommunications signed a 10 year concession agreement with a Swiss private company on the annual compulsory technical inspection services for the vehicles operating in Albania. Evaluation of the technical condition of vehicles, with regard to atmospheric pollution due to gaseous emissions and noises, as a component of the vehicle technical control system is not on a satisfactory level partly because the Government has transferred vehicle inspections to the private sector.

The 2004 Guidelines of MoPWTT and MoEFWA, on "Permitted values of atmospheric polluting elements in the environment resulting from gas emissions and noises caused by vehicles and the ways for controlling them", No. 6527, in effect since 08.06.2005 were amended by 2010 "Guidelines on amendments and addenda to 2004 guidelines on permitted values of atmospheric polluting elements in the environment resulting from gas emissions and noises caused by vehicles and the ways for controlling them", No. 6527, No. 12, accompanied by the "Manual of vehicles control". Monitoring of atmospheric pollution from the release of gases resulting from motor vehicles is undertaken by entities which control the roads.

Furthermore, in March 2014, Albania adopted a package of road safety measures, but has still not reached a satisfactory level. Further efforts are needed in the areas of vehicle inspection and education and training of road users, and also legislation regarding dangerous goods has not yet been adopted. Besides, it is necessary to raise public awareness in the country, not only through the increase of police control and penalties, but through campaigns of eco-driving and environmental education.

Lastly, Albania ratified the UNFCCC in 1995 and the Kyoto Protocol at the international level; it has aligned with the Copenhagen Accord but did not formulate pledges for greenhouse gases (GHG) emissions' reduction. Albania has two official documents: First and Second National Communication which includes GHG Inventory. Albania's second national GHG inventory considers three direct GHGs (CO_2, CH_4 and N_2O) and indirect GHGs (CO, NO_x, SO_x and NMVOC). Albania is now preparing its third National Communication to UNFCCC. One of the EU funded projects in Albania is SELEA 2012–2014 to support the Ministry of Environment, Forests and Water Administration (MEFWA) to enhance its capacity to implement and enforce environmental legislation.

16 Croatia

Croatia is a new EU member country. Its integration process is underway. Having in mind that, motor vehicles constitute an "heavily regulated area", following significant review and negotiation prior to Croatia full EU membership. At this stage the country share the duty of each full EU member state to adopt and implement all harmonized documents of EU legislation.

Croatia, as the other countries from Former Yugoslavia, has become an UNECE contracting party by succession, and is bearing ECE Number E25. Reviewing available documents showing Croatia's attitude towards environment protection on the field of transport, one could notice significant efforts of the country. The document "Assessment of climate change policies in the context of the European Semester Country Report: Croatia" is a report of external contractor based on information policy available as of November 2013. The report provides an overview of emission trends and progress towards targets as well as policy developments that took place over the period from February 2013 to November 2013.

Key policy development in 2013 consisted in encouraging fleet fuel efficiency, adding a "special duty" tax to the VAT for vehicle purchases: this duty is tied to the vehicle's emissions, with more efficient vehicles being taxed less.

Transport accounts for over 20% of Croatia's total GHG emissions, but fuel taxes remain among the lowest in the EU. Instituting a CO2-based bonus/malus system for calculating total VAT in vehicle purchasing is a positive development, but more could be done to encourage emissions reductions in the transport sector at a faster pace by addressing areas beyond new car purchasing, including amending vehicle registration and ownership taxes for more efficient vehicles.

Table: Existing and additional measures as stated in the 2011 GHG projections related to transport area

Existing Measures (only important national measures)	**Status of policy in November 2013**
Act on Biofuels for Transport (OG 65/09, 145/10, 26/11, 144/12): Production, trade, use and storage of biofuels; decision on the percentage of biofuels in total share of fuel (OG 52/08) setting up a percentage of biofuels in total fuel energy consumption.	The Energy Action Plan has set specific quotes per year (revised if needed by the minister responsible for energy) starting with 1.58 % share of biofuels in 2012 to 10.05 % share of biofuels in 2020 (6).
Programme of decreasing the negative traffic impact on the environment: The Programme covers number of measures with aim to reduce the harmful gases emission from traffic sector and, amongst other, grant funds for replacement of non-ecological vehicles for passenger and goods with new vehicles with EURO 4 and EURO 5 standard.	The programme received financial resources from the government equal to 50 million HRK in 2010 (app. € 6.5 million).

The 2015 REPORT ON PROJECTIONS OF GREENHOUSE GAS EMISSIONS – addition REPUBLIC OF CROATIA (June 2015) shows that the transport sector accounts for approximately 33% of the total final energy consumption. The largest share of energy consumption is in the road transport with almost 90%. In the area of road transport, about 60% of energy consumption refers to passenger cars and 37% for the light and heavy duty vehicles. The report presents a quantitative estimates of the effect of policies and measures on emissions by sources and removals by sinks of greenhouse gases for years 2015, 2020, 2025, 2030 and 2035 (ex-ante assessment) for three scenarios:

1. The 'without measures' scenario implies a development of final energy consumption in line with market trends and consumers' habits, without government interventions, but assuming the usual application of new, technologically advanced products that over time appear on the market. In this scenario, the increase in energy consumption affects growth in the number of passenger and goods transport, which is caused by increase in GDP based on historical relations. In addition, the increase affects increasing number of vehicles, increased distance travelled per car and fewer passengers per car. A decrease in energy intensity is a result of technological improvements and increased efficiency of cars on the market.

2. The 'with measures' scenario includes measures to reduce greenhouse gas emissions arising from existing regulations and the transfer of the EU acquis:
    - energy efficiency in accordance with the Third National Action Plan for Energy Efficiency of Croatia for the Period 2014 – 2016:
    - introducing the obligation to provide information on fuel economy and CO2 emissions of new cars,
    - encouraging the replacement or purchase of new energy-efficient vehicles,
    - financial incentives for the purchase of hybrid and electric vehicles,
    - development of infrastructure for electric vehicles in urban areas,
    - development of sustainable transport systems in urban areas,
    - encouraging turnover of vehicles to LPG and CNG,
    - increasing the efficiency of new vehicles, including a significant proportion of hybrid vehicles,
    - labelling obligation on fuel economy and CO2 emissions of new cars,
    - renewable energy sources in accordance with the National Action Plan for Renewable Energy Sources by 2020:
    - obligation to place biofuels on the Croatian market,
    - obligation to purchase or lease vehicles that can use biofuels in public transport and public sector,
    - encouraging the production of biofuels,
    - electric vehicles
    - financial incentives for the purchase of hybrid and electric vehicles

3. The ‘with additional measures’ scenario assumes the following measures:
   - energy efficiency
   - continued support to energy efficiency after 2020, with the same dynamics as to 2020 by introducing the energy efficiency obligations for energy distributors as defined by the Law on Energy Efficiency (Official Gazette 127/14) and the Third National Action Plan for Energy Efficiency,
   - renewable energy sources
   - support for biofuels even after 2020,
   - change of vehicle structure and fuel for cars
   - enhancing the attractiveness of rail transport,
   - use of inland waterway transport,
   - encourage the use of bicycles.

17 The former Yugoslav Republic of Macedonia

Building its attitude towards environmental challenges in road transportation, the former Yugoslav Republic of Macedonia has taken a significant step towards adopting EU legislation. Namely, it has continued being a contracting party to the 1958 agreement (by succession of Former Yugoslavia), now under number E40 (WP29 – UNECE).

Additionally, in 2007, due to a Government decision, a project of adopting EU legislation in the process of vehicle approval was initiated. The first results of this project were made evident in late 2008 through the adoption of a new law on motor vehicles, fully based on the EU Directive 2007/46/EC. It was followed by a number of bylaws and technical specifications in the years 2009 and 2010. In the end, the former Yugoslav Republic of Macedonia had a new legislative platform for motor vehicles, fully compatible with EU legislation in the area of road vehicles approvals (two, three, four and more wheel vehicles) and also for agricultural and forestry tractors, their trailers and machinery. This was also the case for vehicle inspections. This process also included the establishment of the necessary bodies (approval authorities), technical services (inspection bodies and test laboratories), and capacities for vehicle inspection.

At the same time, the former Yugoslav Republic of Macedonia established an Institute of Standardization with a technical committee (TK10) in charge of motor vehicles. By its activity all old conflicting standards were removed and EU norms and ISO standards were adopted.

Moreover, the end-of-life of vehicles (ELV) directive was adopted together with the law on motor vehicles. Due to the need to change the vehicle fleet in the country, a specific bylaw has been introduced for import and registration of second-hand cars.

Furthermore, one of the newer policies adopted foresees the mandatory information of customers of new cars about their CO2 emission.

The country has also adopted distribution of financial support to the customers who have bought new electric or hybrid cars in the form of release from the duty of paying excise tax, related to the price of the car. This measure lead to increase offer of such vehicles, yet with still limited interest among customers.

For what concerns taxation, there have been a lot of activities and significant effort has been put in the direction of adopting a tax policy for already registered vehicles. The diversity and age of the vehicles fleet is still preventing the country from adopting modern policies in this area. Electrical and hybrid electrical vehicles are recognized as categories which should be encouraged, while old vehicles with large engines are to be discouraged. A specific problem arises for policies related to CO2 emissions since a very small percentage of the vehicle fleet has that emission declared (due to the average age of all the vehicles registered).

The main needs at the moment are reviewing and updating the actual level of the legislation, mostly in terms of the technical level of regulations in the process of vehicle approval.

18 Serbia

During the period 1990 – 2000, and still today, some of the key problems in Serbia with respect to energy efficiency, environmental protection and transportation safety are due to the old age of the vehicle fleet, the importation of low–quality fuels, and similar. Larger cities in developing countries like Serbia are facing more severe traffic congestions each day and therefore an increase in exhaust emissions compared to 1990s levels. Yet today they still not reach a level of transport related emissions and atmospheric pollution comparable to the one of developed countries in the beginnings of the 90s.

Although Serbia follows the OECD countries regarding environmental policies and actions attentively, the implementation rate is not adequate because of lack of dedicated funds, and since there are plenty of measures with a questionable rate of return on the market.

The total GDP value as well as the GDP per capita had a growing trend since 2001 until 2008. Afterwards, due to the economic crisis (now evidently only in its first wave) started to decline. Nevertheless, the number of passenger vehicles (unlike all other categories) continues to grow, as well as the rate of motorization. In Serbia, there are currently about 2.4 million motor vehicles, and this number is expected to double in the near future. The combustion of fossil fuels in the transport sector (roads, railways, rivers, and domestic aviation; IPCC Source Category 1.A.3) resulted in 3,876 Gg CO2eq of GHG emissions. Consequently, the contribution of the transport sector to the total GHG emissions was 5.84 %.

Additionally, harmonized Vehicle Emission Standards are in place in the former Yugoslav Republic of Macedonia, Serbia, Bosnia and Herzegovina and Albania for new and/or used vehicles. As of April 2014, used vehicles standard in place in Serbia is Euro 3. The standard for new vehicles is Euro 5 starting from 2010. The progress of the country regarding the adoption of policies for fuel quality is great. It has adopted policies for fully unleaded fuel and policies for low sulphur fuels.

Over the last couple of years, important changes have occurred in the transport policy and their adoption in the Republic of Serbia. The results of those changes are still not evident, but the implementation of a new legislative and strategic framework is expected to improve the situation in the sector considered, as well as to reduce the associated negative environmental impacts. The most significant measures for the mitigation of the expected increase of road transport and the associated GHG emissions are the following: re–establishment of an efficient international rail transport; refurbishment of the road infrastructure, above all on the most important international corridors; increase of the level and the efficiency of river transport, primarily along the River Danube; modernization of the motor pool with up to date and highly efficient motor vehicles; cessation of the production of leaded gasoline and an increase of the share of TNG; and a suitable economic environment.

19 Turkey

In December 2003 the Turkish government approved regulations for passenger cars on the basis of EU Directive 1999/94/EC on the mandatory labelling of vehicle fuel economy and CO2 emissions. From January 2008 on, the Turkish standards require passenger vehicles to display labels classifying cars by their comparative fuel efficiency and carbon dioxide emissions per kilometre.

Air pollution is a major issue in Turkey. SOx emission intensity is over three times higher than the OECD average and intensity of NOx is estimated to be over 50% higher than OECD average. The major contribution to NOx comes from mobile sources e.g. vehicles (44%) but also industrial combustion and power stations are large contributors.

Environmentally related taxes in Turkey include taxes on fuels and on vehicles (among the highest in OECD). Large revenues come from taxes that can be related to environmental issues. However, these taxes were not designed for environmental purposes. Turkey's greenhouse gas (GHG) emissions rose by 75% between 1990 and 2004 due to steady population growth and industrialization after the mid-1990s. However, Turkey's per capita emissions are still below the world and OECD averages and in 2004 Turkey accounted for 0.8% of the global emissions. Nevertheless, with the GDP projected to grow at over 6% per year over the next 15 years emissions are expected to rise significantly, increasing at 6.3% annually, and reaching over 600 million tons/year by 2020.

Turkey plans to minimize GHG emissions through a combination of measures that aim at: improving energy efficiency and encouraging conservation measures (demand side management (DSM)); allowing for fuel switching from high carbon to low carbon fuels; increasing the share of renewable energy sources in its energy supply. The approximation process also demands an increasing integration of climate change policy into policies governing energy, transport and water, infrastructure, land use planning and development co-operation. The Kyoto Protocol is part of the EU's acquis communautaire; therefore its adoption is part of the joining process. The bill to ratify the Kyoto Protocol was submitted to the Turkish parliament on June 5 in 2008, with parliament due to debate the bill in early 2009. Despite the progress achieved, Turkey's growing economy and energy demand and increasing levels of GHG emissions pose particular problems in relation to emissions targets.

The Republic of Turkey has taken many steps in recent years regarding air quality management and at an increasing pace since its formal acceptance as a candidate country to join the EU. Co-financed by the European Union and the Republic of Turkey, the 'Improving Emissions Control' Project was designed to assist the Turkish Government to transpose the NECD. The Technical Assistance (TA) component (March 2011 – November 2012) focused on providing technical support to the MoEU, which was the main beneficiary.

A National Energy Efficiency Law is in force and it covers the transport sector, but it does not include specific targets for the reduction of CO2 emissions - just recommendations. The Turkish government is in the process of developing a national action plan and formulation of CO2 reduction goals covering transport and building sectors. Campaigns on eco-driving and fuel efficient vehicles are organized by private companies to demonstrate the importance of automotive emissions and more efficient vehicles at national level. The government is planning to include eco-driving in respective law. Also, GHG standards are intended to be developed in the nearest future. Otherwise, Turkey is following EU vehicle emissions standards.

Moreover, the By-law on Principles and Procedures Regarding Energy Efficiency in Transportation was published on 9 June 2008. Practices intended for reducing the unit fuel consumption of domestically produced transport vehicles, increasing efficiency standards in vehicles, expanding the use of public transportation vehicles and establishment of advanced traffic signalization systems have been launched under the regulation issued by the Ministry of Transport and Communication.

In transportation, practices oriented to reduce unit fuel consumption in nationally produced motor vehicles and increase their efficiency standards, spread public transportation and install advanced traffic signalling systems have been included under the scope of the regulation enforced by the Ministry of Transport and Communication.

Turkey is a vehicle production powerhouse – among the top 20 in the world by units produced – and is an export hub for major brands, mainly to European markets. Vehicles have been Turkey's major export since 2006, reaching 180 countries. In early 2011, Turkey adopted the European fuel quality standards (going to 10 parts per million sulphur in both diesel and petrol), and Euro 5 LDV standards have been in place since 2010, with Euro VI heavy-duty vehicle standards effective January 2015. As of 2000, all imported and domestically produced cars are equipped with catalytic converters to reduce conventional pollutants.

New Vehicles must meet Euro 5/VI emission standard. The importation of used vehicles is banned in Turkey. The total tax burden on the pre-tax value of fuel is 195% for petrol and 134% for diesel (in 2009).

In an attempt to reduce pollution, Turkey ran a vehicle buy-back/scrappage program in 2003-2004, which resulted in a reduction of 4.9% in CO_2 emissions from the vehicle sector for those two years.

Vehicle taxation is proportional to engine size, with larger engines taxed more heavily. This affects the fleet composition, wherein smaller engine cars (below 1600 cc) make up about 60%.

The EC Vehicle Labelling Directive was transposed into national legislation. MIT, in cooperation with the Ministry of Environment and Forestry, is responsible for vehicle efficiency and emission standards implementation and enforcement in the country. The Directive has been transposed into Turkish legislation by the by-law on Informing Consumers on Fuel Economy and CO_2 Emissions of New Passenger Cars (Official Gazette: 28 December 2003 No. 25330) and entered into force on 1 January 2008. According to these articles the manufacturers of the passenger cars are responsible for the preparation of this label.

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