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Contents

3 Conference Proceedings – Posters

The present chapter includes the collection of the posters that were presented during the conference, Posters of this section:

- are structured on the basis of the thematic areas of the 23rd TAP conference, as defined in the final program of the conference,
- are listed in the order that were presented during the conference,
- are included in the version that was submitted by authors to the conference's website before the implementation dates of TAP 2019.

Table 12 provides the thematic sessions of TAP 2019 for posters, as well as the main topics in each session.

Table 12. Thematic sessions of TAP 2019 and their main contents.

	Thematic Sessions	**Main Contents**
3.1	Gaseous and particulate pollutants characterisation	• PEMS & dynamometer measurements • Emission factors' development • Vehicle technology compliance with emission standards
3.2	Marine and aviation emissions	• Shipping and aviation emissions' modeling & estimation • Impact assessment of traffic conditions and measures' implementation • Future trends
3.3	Air quality measurement, monitoring and modelling	• Dispersion and human exposure modeling • Impact assessment of traffic measures on air quality • New methods and techniques on air quality measurements
3.4	Energy optimization of transportation systems	• Measures and strategies for CO_2 and energy consumption reduction • Automation of road transport
3.5	Road transport management and emissions estimation	• Measures and strategies for emissions reduction • Road transport emissions' modeling and estimation
3.6	Alternative fuels, new powertrains	• PEMS & dynamometer measurements enabling alternative fuels • Air quality effects of alternative fuels • New powertrains, including electrics and hybrids
3.7	Remote sensing of vehicle emissions	• Emissions' measurements using remote sensing • New techniques in remote sensing • Remote sensing utilization for emissions' policy enforcement
3.8	Particulate Matter	• Exhaust and non-exhaust particulate matter • Dispersion of particulate matter • Air quality assessment & human exposure to particulate matter

	Thematic Sessions	Main Contents
3.9	Emission control technologies of primary air pollutants of road and non-road transport	• New on-board technologies for the reduction of vehicular emissions
3.10	New sensors and techniques	• Sensors, methods and techniques in vehicular emissions measurements and air pollution
3.11	Planning & projections	• Projections and future trends related to CO_2 and pollutant emissions of the transportation sector

3.1 Gaseous and particulate pollutants characterization

This section includes posters presented in the context of the “Gaseous and particulate pollutants characterization” sessions of the TAP conference. Table 13 provides an overview of these papers, as they are listed in the following sub-sections.

Table 13. Titles and authors of “Gaseous and particulate pollutants” posters

	Title	**Authors**
3.1.1	Temporal evolution of particle emissions from a HD SI gas engine during WHTC	P. Napolitano, C. Guido, C. Beatrice, V. Fraioli and S. Alfuso
3.1.2	Real-world emissions of black carbon from light-duty gasoline vehicles in China	L. He, X. Zheng, S. Zhang, Z. Li, X. Wu and Y. Wu
3.1.3	Real-world and type approval CO_2 of LD vehicles in a new context	R.F.A Cuelenaere, N.E. Ligterink, S. van Goethem, G. Kadijk, R.N van Gijlswijk and P. van Mensch
3.1.4	PN (< and ≥ 23nm) emissions of a Euro 6b GDI vehicle under WLTC and RDE conditions	M. Leblanc, A. Albinet and S. Raux
3.1.5	Fuel consumption and pollutant emissions analysis of a Diesel engine for interurban buses depending on ambient and operative conditions.	J.J. Ceballos, F.V. Tinaut and A. Melgar
3.1.6	Effect of high-speed driving conditions on SOA formation potential from GDI vehicle	N. Kuittinen, W. Peng, C. McCaffery, S. Zimmerman, P. Karjalainen, P. Roth, P. Simonen, J. Keskinen, T. Rönkkö, D. Cocker, R. Bahreini and G. Karavalakis
3.1.7	Integrating recent developments in road transport in HBEFA 4.1	B. Notter, H.-J. Althaus, B. Cox, A. Laederach, M. Keller, S. Hausberger, M. Rexeis et al.
3.1.8	Wind tunnel study of ultrafine particles infiltrating car cabin	A. Mehel and E. Rolin
3.1.9	Time-resolved emission measurements of organic gases for gasoline vehicles in China	J. Liu, X. Wu, Y. Wu and S. Zhang
3.1.10	WLTP and NEDC CO_2 emissions of new Euro 6D – Temp passenger cars in EU	A. Chatzipanagi, J. Pavlovic, D. Komnos, B. Ciuffo and G. Fontaras
3.1.11	Measurements of particulate matter (PM) concentrations in road tunnels taken between 2009 and 2018	B. Vidal, M. Yaghzar, J.F. Burkhart, J.P. Grand, J.F. Petit, G. Coulbaux and E. Hallemans

	Title	Authors
3.1.12	Sub-23nm particle emission investigation including driving behaviour on Euro 6d temp GDI, PFI and Diesel vehicles on laboratory and real-driving conditions	Z. Toumasatos, D. Kolokotronis, A. Kontses, S. Doulgeris, A. Raptopoulos, L. Ntziachristos, and Z. Samaras

3.1.1 Temporal evolution of particle emissions from a HD SI gas engine during WHTC

Temporal evolution of particle emissions from a HD SI gas engine during WHTC

Pierpaolo Napolitano, Chiara Guido, Carlo Beatrice, Valentina Fraioli, Salvatore Alfuso
Istituto Motori – CNR –Napoli, Italy

Motivation

- ✓ In the current need to rethink the engine technologies for a more sustainable mobility, gas engine represents an interesting alternative to Diesel technology.
- ✓ Interest in **alternative fuels** (CNG, LPG, etc.) due to their low soot emissions, low cost, wide spread reserves localizations.
- ✓ HD gas engine is a suitable option for **CO_2 curbing**.
- ✓ Future legislations on PN are going to regulate sub-23 **nanoparticles** for their well recognized adverse health effects.
- ✓ Clarifying the nature and the dimensional distribution of the emitted particles is still an open question and is necessary for their control.

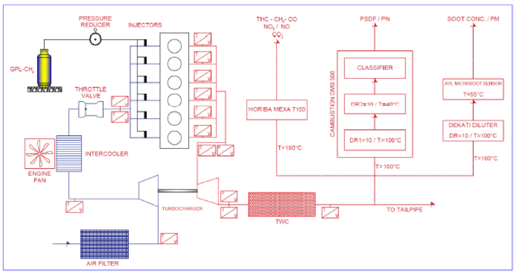
Aim of the work

- ✓ To investigate on particle emissions from a HD engine fed by CNG and LPG, during **real driving conditions**.
- ✓ To clarify possible relation between **transient phases** of the driving cycle and mass, number and sizing of the emitted particles.

EXPERIMENTAL SET-UP AND TESTING METHODOLOGY

Engine type	6 cylinders in-line
Certification	EURO VI prototype
Displacement	5883 cm^3
Bore x Stroke	102mm x 120mm
Rated torque	632 Nm @ 1500 rpm
Rated power	112 kW @ 1800 rpm
Compression ratio	10:1

- On-line soot concentration measurements by transient high sensitive photo-acoustic sensor.
- On-line PSDF and PN measurements by Differential Mobility Spectrometer.
- Fuels: LPG and CNG, made up of more than 98% of propane and methane.



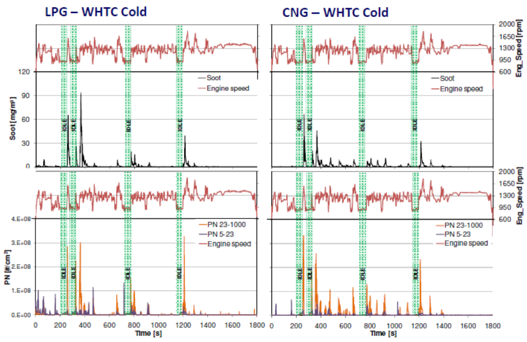
Engine tests:

WHTC (World Harmonized Transient Cycle)

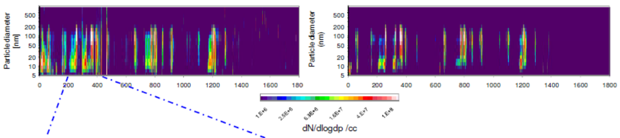
WHTC Cold
WHTC Hot } 5 repetitions

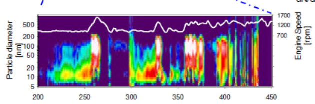
- Two different ECU calibrations for CNG and LPG engine feedings.
- Time evolution of emissions to highlight specific driving conditions responsible for the majority of the particles emissions.
- Different fuels to evaluate whether an intrinsic engine behavior or the fuel quality can determine the emissive performance.

SOOT AND PN EVOLUTION



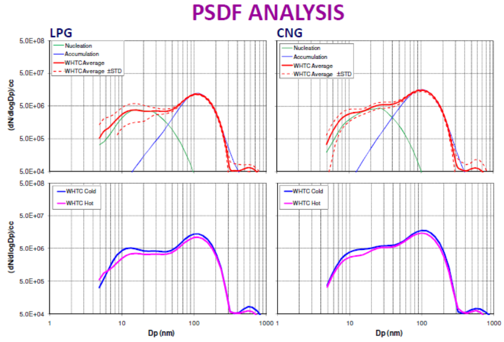
- The highest soot and PN peaks at the end of each long duration idle period, when engine speed and load started to increase.
- On the contrary, during the last portion of the cycle and in all the other driving conditions no soot and PN emission was detectable.
- The two fuels exhibited analogous tendencies.
- A possible source of the observed particles emissions could be related to the lube oil leakage, favored by the long idle phases.
- Similar behavior for cold and hot WHTCs.





- Acceleration phases → concentration peak with diameters ~ 100nm÷120nm (accumulation mode).
- Idle phases → gradual increment of nucleation mode particles, with diameters ~ 10nm÷20nm.
- Similar maps for CNG.

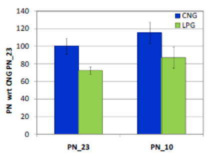
PSDF ANALYSIS



LPG	CMD (mean)	CMD (min–max)
PN _23 (nm)	94	91 ÷ 97
Nucleation Mode (nm)	20	17 ÷ 22
Accumulation Mode (nm)	103	99 ÷ 105

CNG	CMD (mean)	CMD (min–max)
PN _23 (nm)	85	83 ÷ 87
Nucleation Mode (nm)	21	19 ÷ 23
Accumulation Mode (nm)	93	90 ÷ 96

- PN_10 does not substantially alter the limit fulfillment issue; contribution of about 20% from particles in the range 10nm÷23nm.
- The particle emissions levels for the LPG tests – although lower – were of the same order of magnitude of the CNG ones, so confirming an analogous engine response to the fuel quality.



- Two dimensional classes are clearly identifiable.
- The average diameter for PN_23 lies in the accumulation mode.
- The amount of particles with diameters between 10nm and 20nm seems to be slightly higher in the cold start driving cycles.

An intensive analysis addressed to test a HD SI engine fuelled with LPG & CNG during WHTC (with both cold and hot starting conditions) was performed. The investigation correlated the engine emissive behavior with specific phases of the driving cycle, evidencing that the most part of PM and PN can be ascribed to emissions spikes in correspondence of the transition from engine idle to acceleration phases. The results evidenced substantially similar emissive behavior, not dependent neither on the adopted fuel nor on the cycle starting condition. Averaging the PSDF profiles over the whole WHTC, comparable concentration values from both nucleation and accumulation modes were detected, with PN_23 accounting for 80% of total PN. Lube oil could represent the main source of PN emissions.

The authors thank Mr. Alessio Schiavone and Mr. Roberto Maniscalco for their technical support in the engine testing.

3.1.2 Real-worl emissions of black carbon from light-duty gasoline vehicles in China

23rd International Transport and Air Pollution Conference 2019

TAP 2019 | THESSALONIKI, GREECE

Real-world emissions of black carbon from light-duty gasoline vehicles in China

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INTRODUCTION

Black carbon (BC) is not only an important component of aerosol highly associated with vehicle emissions, but also an short-lived climate forcing pollutant[1]. Vehicles contribute considerably to total anthropogenic BC emissions and urban BC concentrations[2].

There is much larger uncertainty in BC emission factors for light-duty gasoline vehicles (LDGVs) because of difference between dynamometer and real-world, cold-start and so on.

METHODOLOGY

This study applied a new portable emissions measurement systems (PEMS) by integrating an on-board aethalometer (Model AE-51, Magee Scientific Company, USA) to measure real-world BC emissions (see Figure 1) of eight gasoline vehicles (including 2 gasoline direct injection (GDI) passenger cars, 2 multi-port fuel injection (MPFI) passenger cars, and 4 MPFI taxis). These LDGVs are all complied with China 4 or China 5 emission standards.

Figure 1. A scene of the PEMS test.

The test routes were composed of arterial roads, sub-arterial roads and freeways, representing the typical driving routes of city vehicles in China (see Figure 2).

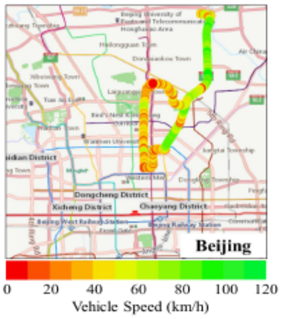

Figure 2. An example of test routes in Beijing.

RESULTS

Overview of BC emission factors

Our measurement results confirm that GDI vehicles have significantly higher emissions of BC than those of MPFI vehicles. Average BC emission factors under cold-start real driving conditions were 1.97±1.62 mg/km for GDI passenger cars (PCs, *N=2*), 0.045±0.047 mg/km for MPFI PCs (*N=2*) and 0.46±0.39 mg/km for MPFI taxis (*N=4*), respectively (see Figure 3). In addition, it turns out that a greater likelihood of deteriorated BC emissions than private cars, up to ten times of that for PCs in our study, due to the extremely high annual vehicle kilometers travelled (VKT).

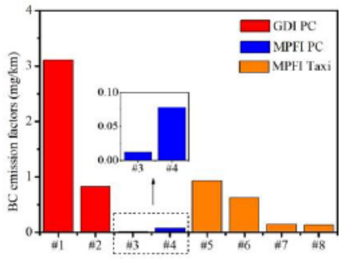

Figure 3. BC emission factors of eight tested LDGVs

Emission rates by operating modes

Similarly, GDI PCs have significantly higher emission rates of BC than those of MPFI PCs and Taxis, as shown in Figure 4. Average BC emission rates by operating modes get increased with vehicle specific power (VSP) in the three speed ranges. Furthermore, the impact from VSP bins pose more significant changes to BC emissions from MPFI vehicles than GDI vehicles.

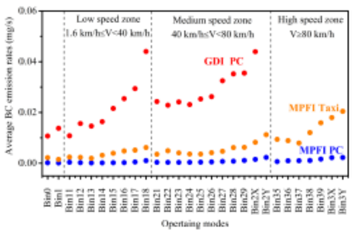

Figure 4. Average BC emission rates of three categories LDGVs. Bin 0 refers to deceleration or braking cycle, and bin 1 is idle cycle. In addition, Due to the vehicle speed lower than 80 km/h during our tests, there are no values for GDI PCs in high speed zone.

Using the low speed zone as an example, average BC emission rates increased by 4.1 times from bin 11 to bin 18 for GDI PCs, while 2.6 times for MPFI PCs and taxis.

Influence of cold start on BC emissions

Our study further quantify the real-world cold start effect. This result indicates that the cold start effect on MPFI vehicles are more significant than GDI vehicles, although GDI vehicles emitted higher BC[3]. Average BC emission factors under cold start tests are 1.34±0.50 times (*N=2*) for GDI vehicles and 3.52±2.70 times (*N=6*) for MPFI vehicles higher than those under hot start tests.

As Figure 5 illustrates, estimated γ values, representing the distance would need to travel between cold starts before hot-running emissions would exceed cold start emissions are 2.75-36.8 km for BC (*N=8*) in this study, which is basically consistent with Zheng et al.'s (2016)[4] in-lab dynamometer measurement results.

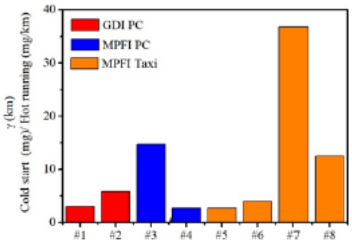

Figure 5. The ratios of extra start emissions (initial 300 seconds) to the hot running emission factors.

References

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[4] Zheng X, et al. *Environ. Pollu.* 2017, 231: 348-356.

Acknowledgements

This study was supported by the National Key Research and Development Program of China (2017YFC0212100) and the National Natural Science Foundation of China (NSFC) (No. 51708327).

3.1.3 Real-world and type approval CO2 of LD vehicles in a new context

Real-world and type approval CO_2 of LD vehicles in a new context

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innovation for life

INTRODUCTION

The gap between official type-approval CO_2 emission values and real world values, typically between 5 and 10% at the beginning of the Millennium, increased dramatically after the introduction of European CO_2 standards for passenger cars and light commercial vans in 2009. Particularly in the years ahead of the 2015 target the gap was a staggering 40-45% EU-wide and over 50 g/km in The Netherlands.

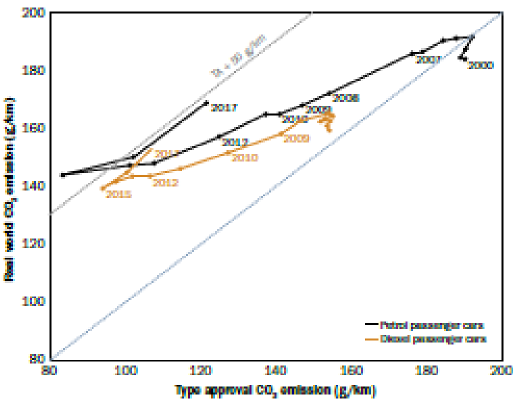

Figure 1. Average real-world CO_2 emissions versus average type approval value of new petrol and diesel cars in the Netherlands, by year of registration

WLTP

The major response of the European legislator to this growing gap was the introduction of the new WLTP test procedure. The WLTP brings new type-approval CO_2 values deviating from the former NEDC based values, even for WLTP vehicles that only marginally differ from their NEDC predecessor. This structural change of CO_2 values will impact the gap between type-approval and real world, as well as the stringency of the European CO_2 standards. Additionally, in The Netherlands with its vehicle taxation schemes based on official CO_2 values, WLTP might also impact total sales and market segmentation.

DEVELOPMENT OF WLTP TYPE APPROVAL VALUES

The increasing numbers of WLTP vehicle registrations, opens the possibility to analyze ex-post the impact of the NEDC to WLTP transition. First results have been published. WLTP CO_2 values of WLTP vehicles registered in the period up to and including August 2018, are on average 25 g/km higher than the NEDC CO_2 values of the same vehicles derived by the use of the CO2MPAS tool or by double testing. The NEDC CO_2 values of those vehicles are close to 10 g/km higher than values of the same vehicles derived by the use of the CO2MPAS tool or by double testing. The NEDC CO_2 values of those vehicles are close to 10 g/km higher than the CO_2 value of the best comparable previous NEDC model, partially explainable by different vehicle characteristics.

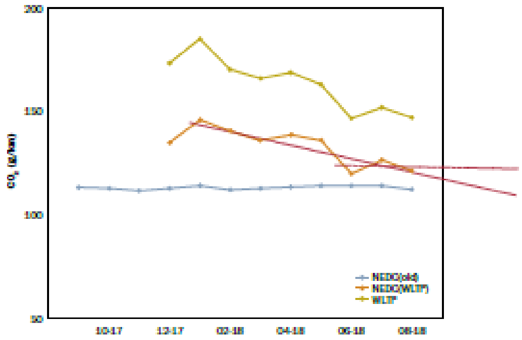

Figure 2. Average CO_2 values of both WLTP and NEDC registrations in The Netherlands.

DECOMPOSITION

A preliminary decomposition of observed trends has been made, in order to improve the understanding of the difference between WLTP and the former NEDC method. Better understanding is required in order to make meaningful predictions of the development of the gap between type-approval and real world CO_2 values and to assess, ex-ante, the impact of future WLTP-based CO_2 standards.

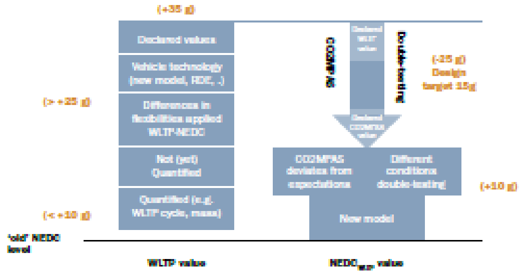

Figure 3. Preliminary decomposition of elements that determine the difference between WLTP and the former NEDC method.

DEVELOPMENT OF THE GAP

In the course of 2019 first results of the comparison of real world and WLTP type approval CO_2 values will become available.

ACKNOWLEDGEMENT

The authors would like to thank the Ministry of Finance in the Netherlands for commissioning this project.

3.1.4 PN (< and ≥ 23nm) emissions of a Euro 6b GDI vehicle under WLTC and RDE conditions

Sustainable mobility | New energies | Responsible oil and gas

PN *(< and ≥ 23nm)* emissions of a Euro 6b GDI vehicle under WLTC and RDE conditions

M.LEBLANC [1], A. ALBINET [2], S.RAUX [1]

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(2) INERIS - Parc technologique Alata, BP 2, 60550 Verneuil-en-Halatte, FRANCE

Context and Objectives

- *Current legislation focuses on solid particles with a ø ≥ 23 nm only*
- *A lower threshold diameter is expected, in the image of aeronautics for which a d_{50} = 10nm is already defined*
- *Aerosol conditioning process (volatile fraction removal, dilution), which may induce artifacts and solid particle losses, is a key step for a robust measurement of such smallest particles*

⇨ *These particulate emissions as well as the potential compatible protocols, still need to be evaluated and defined*

Vehicles description

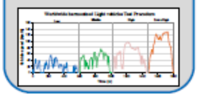
1 European Passenger car model, 3 versions :

n° 1	n° 2	n° 3
Euro 6b 1.2 GDI engine 3WC Mileage = 18 640 km	Euro 6d-TEMP 1.2 GDI engine 3WC + GPF Mileage = 13 880 km	Euro 6d-TEMP 1.5 Diesel engine DOC + SCRF Mileage = 5 646 km

Chassis dyno driving conditions

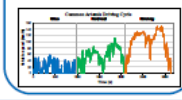
WLTC

Distance = 23,262 km
Duration = 1800 s



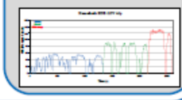
CADC

Distance = 51,687 km
Duration = 3143 s

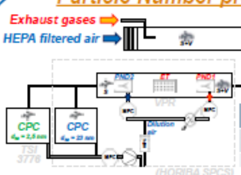


Homothetic RDE

Distance = 37,7 km
Duration = 2593 s



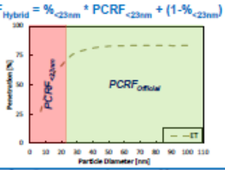
Particle Number protocol



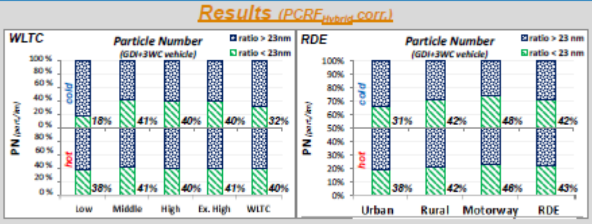
Settings	PND 1	ET	PND 2
Dilution factor (-)	100	-	15
T° (°C)	190	350	35

Particle Concentration Reduction Factor

- $PN_{ø \geq 23\,nm}$ (SPCS):
  - $PCRF_{Official} = (PCRF_{30}+PCRF_{50}+PCRF_{100})/3$
- $PN_{ø < 23\,nm}$ ($CPC_{TSI\,3776}$ - SPCS):
  - $PCRF_{<23nm} = (PCRF_{7}+PCRF_{10}+PCRF_{15}+PCRF_{20})/4$
- PN_{Total}:
  - $PCRF_{Hybrid} = \%_{<23nm} * PCRF_{<23nm} + (1-\%_{<23nm}) * PCRF_{Official}$



Results (PCRF$_{Hybrid}$ corr.)



Conclusions

- *Solid particle emissions < 23 nm have been evaluated on chassis dyno with current PMP protocol and CPC, waiting for an official future evolution of the PMP protocol*
- *VPR is a key parameter regarding to PN results, particularly for the smallest particles:*
  - *PCRF need complementary work to avoid under/overestimation due to particle size impact*
  - *Dilution Factor also, to avoid potential renucleation phenomenon which could be tricky in case of downstream DPF or GPF measurements, due to their lower need of dilution*
- *PN emissions of the Euro 6b GDI vehicle mainly consist of 60 % of particles with ø ≥ 23 nm*
- *Motorway phase of the homothetic RDE cycle slightly increases the ratio of particles < 23nm*
- *Cold start significantly increases the part of PN with ø ≥ 23 nm, reaching a ratio of 82 % on WLTC*
- *Homothetic RDE cycle offers an efficient and faster solution to reproduce RDE conditions on chassis dyno*

Ongoing work

- *Evaluation of the PMP parameters and particle emissions involved by the following versions of the model car, compliant with Euro 6d-TEMP, equipped with two additional powertrain and aftertreatment configurations: GDI with 3WC+GPF or Diesel with SCRF*
- *Pursue the work on particle composition (Black Carbon, particulate bound PAHs) and unregulated gaseous compounds*

Acknowledgements

This study has been performed in the framework of the RHAPSODIE project funded by the French Environment and Energy Management Agency (ADEME ; agreement 1766C0003).
The authors also acknowledge the JRC team (ISPRA) for providing the original RDE trip considered as a reference as well as, HORIBA and TSI teams for their support regarding to the particle counters coupling.

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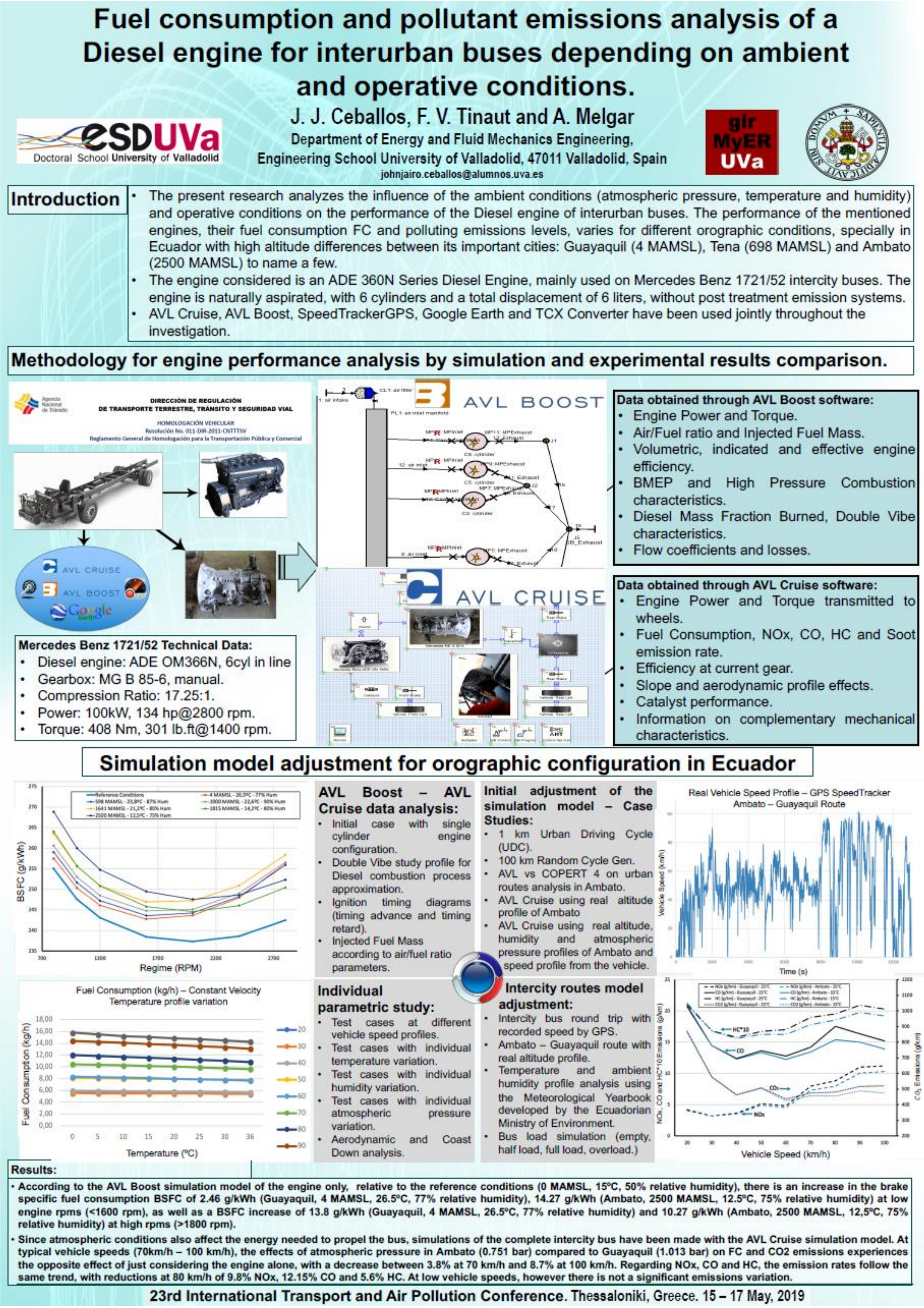
IFP Energies nouvelles

3.1.5 Fuel consumption and pollutant emissions analysis of a Diesel engine for interurban buses depending on ambient and operative conditions



3.1.6 Effect of high-speed driving conditions on SOA formation potential from GDI vehicle

Tampere University | UCR College of Engineering-Center for Environmental Research & Technology | UC RIVERSIDE

Effect of high-speed driving conditions on SOA formation potential from GDI vehicle

N. Kuittinen[1], W. Peng[2], C. McCaffery[2], S. Zimmerman[3], P. Karjalainen[1], P. Roth[2], P. Simonen[1], J. Keskinen[1], T. Rönkkö[1], D. Cocker[2], R. Bahreini[3], G. Karavalakis[2]

[1] Tampere University, Faculty of Engineering and Natural Sciences, Aerosol Physics
[2] Bourns College of Engineering, Center for Environmental Research and Technology (CE-CERT)
[3] University of California Riverside, Department of Environmental Sciences

Introduction

Exhaust from gasoline vehicles has been shown to be a source of secondary organic aerosol (SOA) [1-3], that further affects air quality and visibility. Recently, it has been suggested that modern gasoline direct injection (GDI) vehicles may produce more SOA compared to conventional port fuel injection [4]. In this study, attention is drawn towards the effect different driving patterns have in SOA formation. Studying SOA formation over transient conditions is enabled by oxidation flow reactors.

Methods

Testing was conducted on chassis dyno at CE-CERT Vehicle Emissions Research Laboratory.

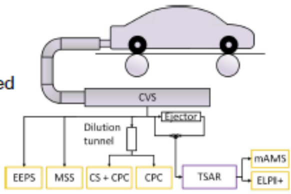


Figure 1. Measurement configuration.

Test cycles

Caltrans High Speed Test Cycles 1 and 2 are hot cycles including lower speed (0-88km/h) and high-speed (72-145 km/h) phases, and are designed to represent realistic driving conditions in urban areas and highways in California.

Vehicle

Light duty GDI (Hyundai Sonata, 2016) with wall-guided injection system and conventional three-way catalyst

Fuel

California E10 gasoline (octane 87 AKI, 23% aromatics)

TSAR (TUT Secondary Aerosol Reactor)

TSAR is an oxidation reactor designed to mimic photochemical aging of the exhaust precursor gases in the atmosphere up to 9 days. The operation principle is similar to Potential Aerosol Mass (PAM) reactor [5], but the reactor is optimized to fast response. Near laminar flow with a short residence time (40s) allows measuring secondary aerosol forming potential during transient conditions.

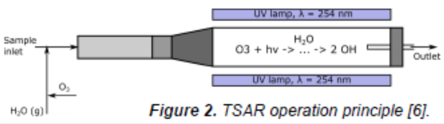


Figure 2. TSAR operation principle [6].

Results

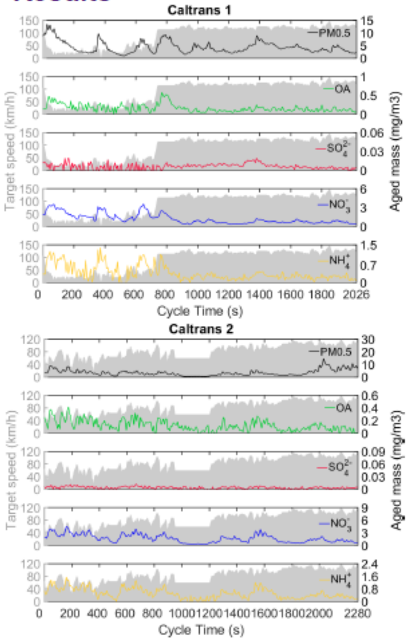


Figure 3. Aged PM species measured by ELPI+ (PM0.5) and mini Aerosol Mass Spectrometer. Concentrations refer to tailpipe.

For Caltrans 1, concentrations of organic aerosol, ammonium, nitrate, and total aged PM higher during the deceleration and accelerations at the beginning of the cycle than during high-speed phases. However, peak in organic aerosol during the steep acceleration between phases.

Primary PM and black carbon concentrations clearly elevated during high-speed driving.

For Caltrans 2, peaks in total aged PM, organic aerosol, nitrate, and ammonium coincide with accelerations, and concentrations are rather elevated during the low than high-speed part of the cycle.

However, couple more agressive accelerations in the end of the cycle show high aged particulate mass.

Conclusions

TSAR efficient tool to monitor SOA formation potential in realt-time during transient driving

Overall, SOA emissions fairly low compared to other exhaust components and eg. cold-start cycles

In most cases SOA formation potential higher during slow speed phases corresponding to urban driving conditions

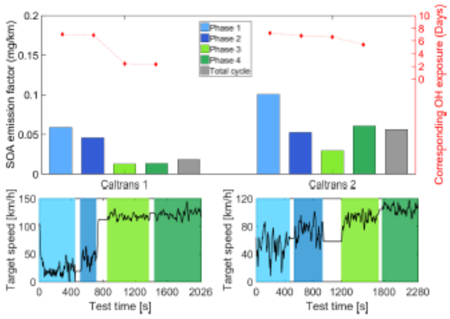


Figure 4. SOA emission factors for low speed and high speed phases of the cycles.

References

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[5] Kang et al. (2007). *Atmospheric Chemistry and Physics Discussions*, 7, 9925-9972.
[6] Simonen et al. (2017). *Atmospheric Measurement Techniques*, *10*(4), 1519-1537.

Acknowledgements

CARTEEH (Center for Advancing Research in Transportation Emissions, Energy, and Health) is gratefully acknowledged.

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3.1.7 Integrating recent developments in road transport in HBEFA 4.1

Integrating recent developments in road transport in HBEFA 4.1

B. Notter[1], H.-J. Althaus[1], B. Cox[1], A. Laederach[1], M. Keller[2], S. Hausberger[3], M. Rexeis[3], M. Dippold[3], C. Matzer[3], S. Lipp[3], K. Weller[3], M. Röck[3], M. Schwingshackl[3], W. Knörr[4], Ch. Heidt[4], K. Biemann[4], M. Jamet[4], M. Allekotte[4], H. Steven[5], E. Ericsson[6], H. Lindblom[6]

What is «HBEFA»? What is it used for?

The Handbook of Emission Factor for Road Transport (HBEFA) contains emission factors for all relevant road vehicle categories, differentiated by vehicle type and traffic situation. Authorities, consultants and researchers use HBEFA for environmental impact assessments and as a basis for policies such as the Low Emission Zones in Germany.

Key characteristics

- HBEFA accounts for fleets and traffic situations in 6 European countries, efficiency developments, as well as mileage, ambient temperature and fuel quality effects.
- HBEFA is regularly updated to account for current developments such as new technologies or emission standards.
- At the same time, the HBEFA is designed as simple as possible, in order to keep the complexity for its use at an acceptable level.

Empirical basis

The hot emission factors are developed based on measurements from laboratories within the European Research Group on Mobile Emission Sources (ERMES) using the vehicle emission model «PHEM» from the Graz Technical University (Austria).

Challenges for Version 4.1

Recent incidents such as the Dieselgate scandal or the increasing relevance of electric vehicles have led to new effects on emission factors that are accounted for in the new version HBEFA 4.1 (release planned in summer 2019). Some of these pose new challenges, such as accounting for SCR catalyst or battery state on entry into a given traffic situation. Such effects were implemented in HBEFA in a pragmatic way that resulted in the least possible additional complexity for its users.

[1]INFRAS Research and Consulting, 3012 Bern, Switzerland; [2]MK Consulting GmbH, 3012 Bern, Switzerland; [3]Institute of Internal Combustion Engines and Thermodynamics, Graz Univ. of Technology, 8010 Graz, Austria; [4]Institute for Energy and Environment (ifeu), 69121 Heidelberg, Germany; [5]HSDAC, 52525 Heinsberg, Germany; [6]WSP Sverige AB, 20125 Malmö, Sweden

Fig. 1: Well-to-Tank and Tank-to-Wheel emission factors

Including electric vehicles requires accounting for upstream emissions. HBEFA 4.1 offers WTT EF for CO_2 equivalents. The chart below shows CO_2e emissions for PC using an average EU energy mix.

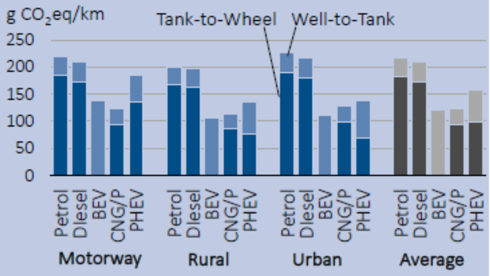


Fig. 2: Calibration of real-world CO_2 emissions

The gap between type approval and real-world CO_2 emissions (example: petrol PC, Switzerland) is addressed using a calibration method that tunes real-world CO_2 emissions of the new car fleet of a country to the CO_2 monitoring values plus updated real-world excess values (forthcoming study by ICCT, INFRAS, TUG, and ifeu).

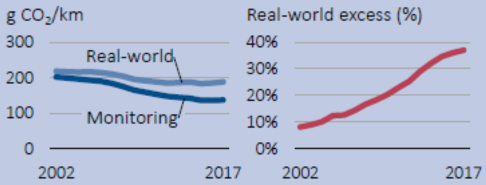
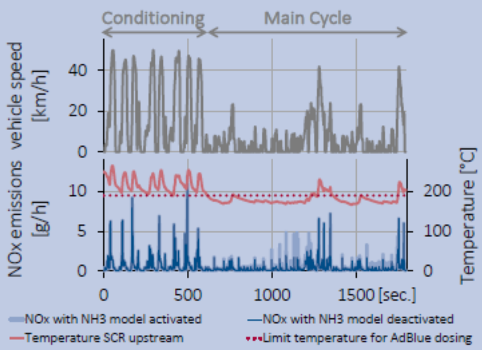


Fig. 3: Conditioning cycles and PHEM NH_3 model

Conditioning cycles and an updated NH_3 model within PHEM account for SCR temperature on entry into a given traffic situation and NH_3 storage effects. Below: Example of an urban stop-and-go cycle.



3.1.8 Wind tunnel study of ultrafine particles infiltrating car cabin

ESTACA
ECOLE D'INGENIEURS

Wind tunnel study of ultrafine particles infiltrating car cabin

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Context:

- Air pollution is responsible of adverse health effects [1]
- Commuting using road vehicle contribute to a large daily exposure
- Pollutants can infiltrate the vehicle cabins with health issues for drivers and passengers
- Accumulation of UltraFine Particles (UFP) under certain conditions leading to high levels of exposure [2,3]

→ Characterizing the infiltration process in term of particles dynamics in correlation with the flow topology

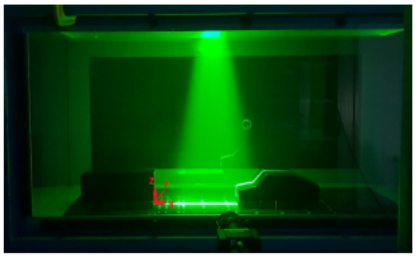

Fig.1. Wind tunnel investigation for UFP infiltration assessment (Ahmed body upstream model in the left and downstream Mira model (right)

Methodology and objectives of the present study :

1) Ahmed body wake flow characterization using PIV;
2) Injection at the Ahmed body model tailpipe of carbon particles in the size range of 20-100nm generated using a PALAS DNP2000;
3) UFP dispersion investigation through the Particle Number Concentration (PNC) measured using an Electrical Low Pressure Impactor (ELPI – Dekati)
4) Assessment of the Influence of vehicle queuing on flow topology and hence on UFP dispersion in the Ahmed body wake flow;
5) Assessment of infiltration rates in the downstream Mira model as a function of Air intake position
6) Ahmed body with dimensions: H=99mm, L=297.7mm, and W=116.7mm. MIRA body model: Hm=88.6mm, Lm=320.7mm, and Wm=100mm

Results and discussion:

- Two distinct areas characterize the Ahmed body near wake flow: the recirculation zone (red) and what is outside it (blue) (Fig. 3a);
- The recirculation length (characterizing the recirculation size) is about 1,48
- The dispersion of the emitted UFP by the upstream Ahmed body model is enhanced in the vertical direction in the recirculation zone (Fig. 3b);
- The presence of the second model at a distance x/H>3,33 does not influence the Ahmed body model wake flow topology (the recirculating length still the same);
- UFP Infiltration in the MIRA model is more pronnonced from the central air ontake, then from the left one and finally from the right one → this is in correlation with outside maximum PNC that is situated between y/H=-0,33 (tailpipe transversal position) and y/H=0,25

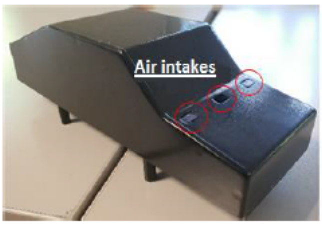

Fig.2. MIRA model for UFP infiltration investigation

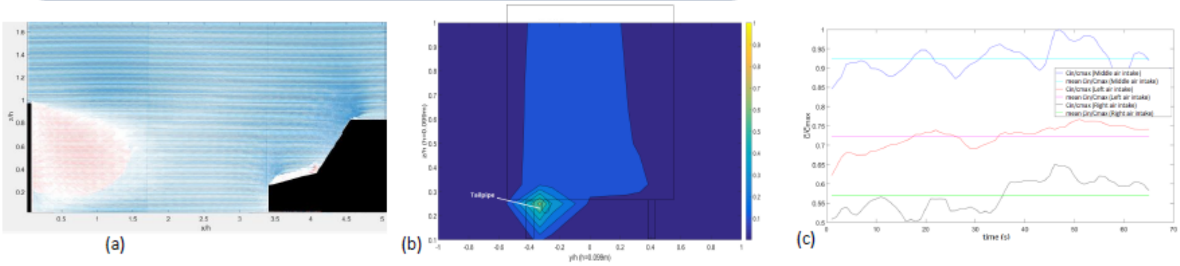

Fig.3. Flow topology in term of velocity vectors (a), UFP Concentrations in the recirculation zone at x/H = 0,5 (b), Non-dimensional PNC function of opened air intake

Conclusions and future works :

- The presence of a downstream vehicle does not influence the upstream wake flow at x/H =3,33;
- Vortical structures have strong influence on UFP dynamics;
- Air intake position has an impact on UDP infiltration in car cabins

References
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3.1.9 Time-resolved emission measurements of organic gases for gasoline vehicles in China

Time-resolved emission measurements of organic gases for gasoline vehicles in China

Tsinghua University

Jiaqian Liu, Xian Wu, Ye Wu, Shaojun Zhang
School of Environment, Tsinghua University

Background

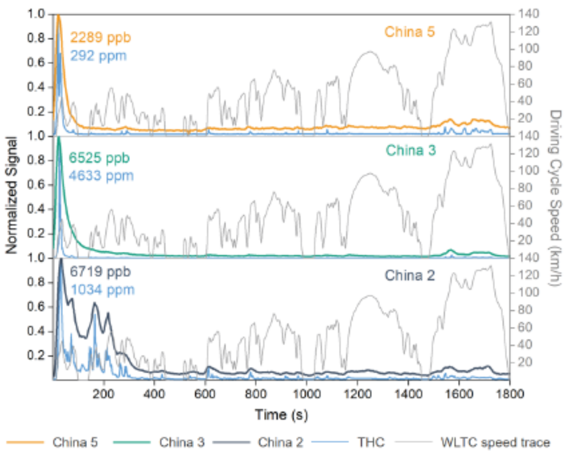
Vehicles are responsible for primary emissions of organic air toxics, which also contribute significantly to formation of secondary pollutants. Previous studies reveal that cold-start emissions from gasoline vehicles contribute a major part of organic gases emissions as well as secondary organic aerosol (SOA) production. Highly time-resolved measurements of organic gases, such as detailed emission profiles associated with cold-start and other dynamic driving conditions, are essential to improve understand air quality impacts from gasoline vehicles. However, such high time-resolution measurement studies on organic gases are limited.

Methods

This study investigated time-resolved emissions for three gasoline cars complying with varying standards from China 2 to China 5. The emissions tests were conducted over a chassis dynamometer following the World Harmonized Light Vehicles Test Cycle (WLTC). For organic gases, we applied hybrid approaches to obtain comprehensive emission characteristics. First, one flame ionization detector (FID) was used to measure total hydrocarbons (THC) second by second. Second, we employed Summa canisters to collect gaseous samples by cycle phases, and then analyze phase-averaged emissions for more than 90 organic species with a gas chromatography-mass spectrometer (GC-MS). Furthermore, we introduced a Selected Ion Flow Tube Mass Spectrometry (SIFT-MS) to target ten typical organic species, and capture their emission dynamics at a frequency of approximately 0.2 Hz. Thus, the time-resolved emission characteristics, including detailed cold-start emissions of typical species, were derived for each vehicle, which further were applied to estimate the ozone formation potentials (OFP) by species and driving conditions.

Conclusions

Emissions profiles of THC and toluene in high-time resolution for three vehicle samples are presented below. The results indicate that major emission spikes occur almost exclusively during the cold-start phase, plus a few minor spikes associated with aggressive driving conditions (e.g., high speed, sharp acceleration). We could observe that the increasingly stringent standards influence the cold-start emission patterns. The China 2 vehicle has longer cold-start duration over 200 s, and highest peak value of THC emissions. By contrast, cold-start emissions have been required in China's emission regulations since China 3. The cold-start duration for the newest China 5 vehicle is less than 100 s, and the peaks of both THC and toluene are much lower than those for older vehicles.



We express the contribution of cold-start emissions by using the term of excess emission equivalent driving distance (γ, km/start). For each organic species, γ is calculated as the ratio of extra cold-start emissions (g/start) to hot-running emission factors (g/km). Our results indicate that γ values vary greatly across different organic species with SIFT-MS measurement profiles. The median γ value for all target organic species in this study is identified as 31 km/start. This level is much higher than the average trip distance in Beijing (14.1 km, Gong et al., 2018), suggesting that great emissions contribution from cold-start than from hot running.

This work was supported by the the National Key Research and Development Program of China (2017YFC0212100).

3.1.10 WLTP and NEDC CO2 emissions of new Euro 6D – Temp passenger cars in EU

European Commission

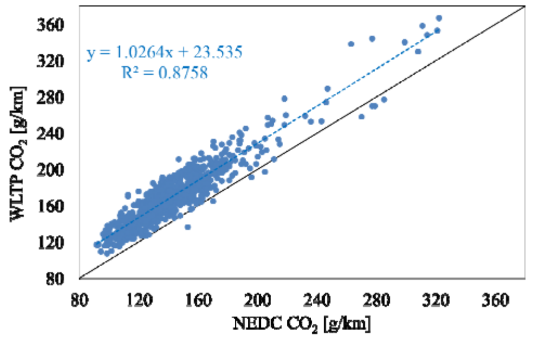
WLTP and NEDC CO_2 emissions of new Euro 6D – Temp passenger cars in EU

Chatzipanagi A., Pavlovic J., Komnos D., Ciuffo B. and Fontaras G.

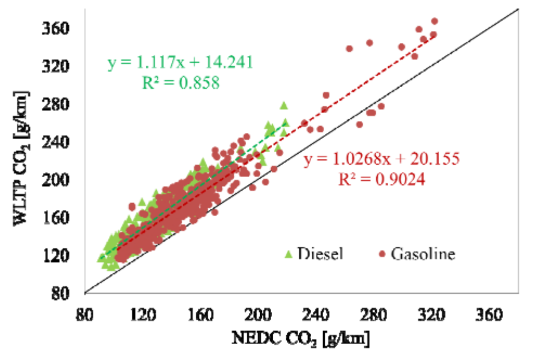
INTRODUCTION

As of September 2017, emissions of passenger cars are being determined according to the new testing procedure, the WLTP (World-wide harmonized Light duty Test Procedure), as defined in 2017/1151/EU. WLTP replaced the old type-approval procedure that was based on the New European Driving Cycle (NEDC). Differently from other gaseous pollutants, CO_2 emissions will be reported until 2021 over both WLTP and NEDC. This work analyses the impact of WLTP introduction on CO_2 emissions for different vehicle types and technologies (gasoline, diesel, ICE, NOVC, OVC). The investigation included the analysis of 205 Type Approval (TA) reports (plus 61 Revisions and Corrections) uploaded to the ETAES (www.etaes.eu) electronic platform. In total, 730 Interpolation (IP) families that comply with Euro 6D-Temp standards were analyzed. The interpolation family (new concept introduced with WLTP) is composed of vehicles with identical powertrain configuration (engine type and capacity, transmission, number of powered axles, etc.). For a given family, the vehicle H and L are identified that correspond to the worst and best case vehicle, respectively, in terms of CO_2 emissions. The CO_2 emissions shown below are the official, type-approved values.

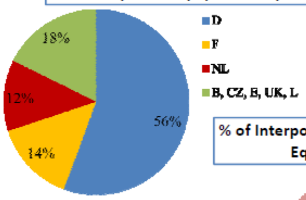
WLTP versus NEDC CO_2 emissions for all IP families analyzed.



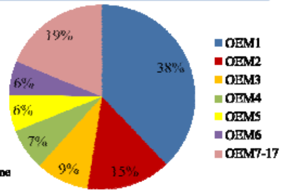
WLTP versus NEDC CO_2 emissions for all Diesel and all Gasoline vehicles of the analyzed IP families.



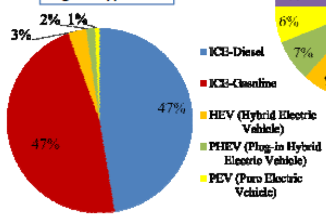
% of Interpolation (IP) families per Member State (MS).



% of Interpolation (IP) families per Original Equipment Manufacturer (OEM).



Engine Type.



Average (median, standard deviation) WLTP/NEDC CO_2 ratio for different vehicle technologies.

Engine Type	Vehicle HIGH (H)	Vehicle LOW (L)
ICE-Diesel	1.27 (1.26, ±0.07)	1.18 (1.18, ±0.05)
ICE-Gasoline	1.19 (1.17, ±0.09)	1.14 (1.14, ±0.07)
HEV	1.18 (1.21, ±0.07)	1.08 (1.06, ±0.13)
PHEV-CS	1.25 (1.24, ±0.10)	1.19 (1.16, ±0.10)
PHEV-Weight. Comb.	1.09 (1.25, ±0.37)	0.98 (1.09, ±0.35)

RESULTS AND CONCLUSIONS

The new WLTP test procedure compared to the old NEDC:

- affected more diesel vehicles compared to gasoline vehicles (~8.5% more for vehicle configuration H and ~4% more for vehicle configuration L)
- had a bigger impact on the PHEVs (charge-sustaining mode) than the HEVs (~7% more for configuration H and ~11% for configuration L)
- had almost no significant impact (average ratio 1.09 for vehicle H) or indicated benefits (average ratio 0.98 for vehicle L) on the overall OVC HEV results where both charge-sustaining and charge-depleting modes are weighted.

https://ec.europa.eu/jrc/

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Joint Research Centre

3.1.11 Measurements of particulate matter (PM) concentrations in road tunnels taken between 2009 and 2018

TAP2019
23rd International Transport and Air Pollution Conference

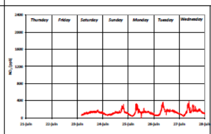
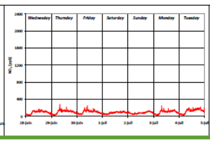
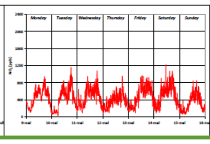
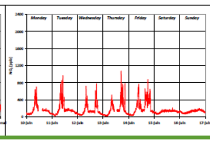
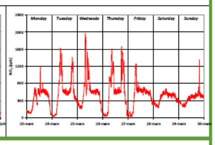
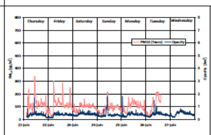
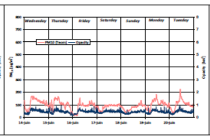
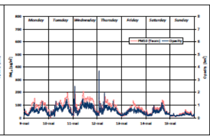
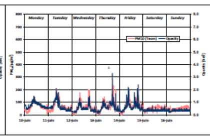
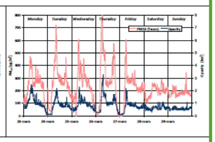
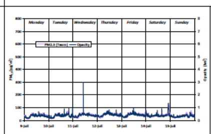
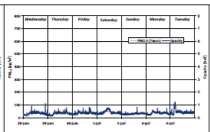
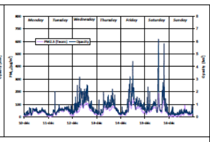
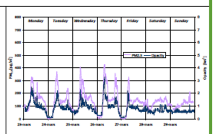
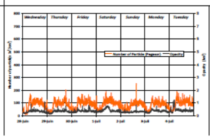
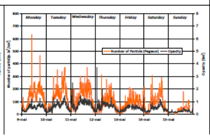
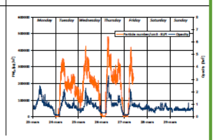
THESSALONIKI, GREECE
15-17 May 2019

Measurements of particulate matter (PM) concentrations in road tunnels taken between 2009 and 2018

Given the health challenges of fine particulate matter air pollution, the Euro 5 standard set particulate emission thresholds for diesel passenger cars that made it essential to install particle filters from January 2011. This technology had started to unfold gradually from the early 2000s, and it is estimated that in France, in 2020, 75% of all diesel vehicles will be equipped with particle filters.

Due to their semi-confined nature, tunnels concentrate the emissions from vehicles travelling through them. They thus present higher pollution levels than on the outside and road traffic can often be considered to be the sole source of pollutant emissions. Consequently, measurements in tunnels can give precise information about the characteristics of road traffic pollution, including exhaust pipe emissions, non-exhaust pipe emissions, but also particle resuspension.

MAIN RESULTS FROM THE MEASUREMENT CAMPAIGNS

Year	2018	2017	2016	2013	2009
Tunnel name / Road	La Defense (Paris) / A14		Mont Blanc / N205-E25	Guy Môquet (Paris) / A86	Landy (Paris) / A1
Traffic / % HDV	35 000 veh/day / 11% HGV		5 000 veh/day 50% HGV	65 000 veh/day 13% HGV	90 000 veh/day 7% HGV
Length / Measurement site (distance from the entrance portal)	4 100 m / 1 200 m from the tunnel entrance		11 600 m / 4 000 m from the north entrance	560 m / 400 from the tunnel entrance	1 400 m / 1100 m from the tunnel entrance
Sanitary ventilation system	Transverse (*)		Transverse(**)	Longitudinal(*)	Transverse(*)
NO_2 Monitor	CLD (Chemiluminescence)				
NO_2 concentrations					
Opacity Monitor	SIGRIST Visguard (based on scattered light intensity measurement)				
PM_{10} monitor	TEOM (Tapered Element Oscillating MicroBalance)				
PM_{10} concentrations and opacity levels					
$PM_{2.5}$ monitor	TEOM (Tapered Element Oscillating MicroBalance)				
$PM_{2.5}$ concentrations					
Other PM monitors	AE 33 (equivalent Black Carbon)	PEGASOR (Particles numbers)			ELPI (Dekati)
PM concentration					

(*) Without any supply of fresh air through the sanitary ventilation system - (**) Very low sanitary ventilation rate

This study shows :

- Taking into account traffic and air renewal in the tunnels, these experimental results confirm that opacity and particles concentrations globally tended to decrease in road tunnels during the last decade. Rather, nitrogen dioxide concentrations are still an issue at rush hours when traffic congestions occur ;
- Non exhaust particles rates in road tunnel aerosol are known to increase, but further investigations on Black Carbon levels in road tunnels should be interesting to confirm this trend ;

- Correlations between PM_{10} or $PM_{2.5}$ measuring devices and the PEGASOR (that is a very rugged tool and that can provide fast measurement – up to 10 Hz) will be very useful to build correspondence tables (dedicated to road tunnels) between the reference measurements of PM concentrations and the numbers of particles delivered by the PEGASOR. These correspondence tables will find a direct opportunity to operate the PEGASOR to perform exploratory on-board measurements. Such studies would lead to a better understanding of the impact of sanitary ventilation in road tunnels.

B. Vidal[1], M. Yaghzar[1], J.F. Burkhart[1], J.P. Grand[1], J.F. Petit[2], G. Coulbaux[2] and E. Hallemans[2].
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Cerema

3.1.12 Sub-23nm particle emission investigation including driving behaviour on Euro 6d temp GDI, PFI and Diesel vehicles on laboratory and real-driving conditions

Sub-23nm particle emission investigation including driving behaviour on Euro 6d temp GDI, PFI and Diesel vehicles on laboratory and real-driving conditions

Zisimos Toumasatos[1], Dimitris Kolokotronis[1], Anastasios Kontses[1], Stylianos Doulgeris[1], Anastasios Raptopoulos[1], Leonidas Ntziachristos[2], Zissis Samaras[1]

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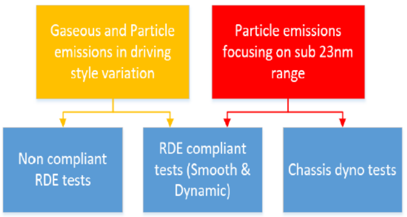
Introduction and main objectives

Particle emission study focusing on:

- Effect of driving behavior change on particle emissions
- Measurements beyond regulation limit (solid particles greater than 23nm)

Methods of accomplishment:

- Non-compliant and compliant RDE driving cycles were used
- Selection of vehicles representative of the E.U. fleet
- Chassis dyno sub 23nm particle investigation measurements
- Inclusion of NEDC, WLTC driving cycles along with steady state points



Equipment, Vehicle and testing Methodology

Car Segment	C	B	A
Fuel type / Injection	Diesel / DI	Gasoline / DI	Gasoline / PFI
Engine architecture	4 in-line turbocharged	3 in-line turbocharged	4 in-line atmospheric
Engine capacity [cm³]	1597	998	1400
Max power [kW]	88	74	
Start-stop	Yes	No	No
Transmission	Manual, 6 gears	Manual, 6 gears	Manual, 6 gears
Euro standard	Euro 6d-temp	Euro 6d-temp	Euro 6d-temp
After-treatment system	DOC, LNT, DPF	TWC, GPF	TWC
Mileage (prior testing) [km]	7661	1074	1044

Parameter	RDE Smooth	RDE Dynamic	Non-compliant RDE	Regulation limits
Trip Distance [km]	75	75	65	>48
Trip duration [min]	95.33	92	~125	90-120
Maximum speed [km/h]	126.67	128.33	~140	145
Altitude difference end-start [m]	52.6	54.37	6	±100
Road type sequence	Urban-Rural-Motorway	Urban-Rural-Motorway	Urban-Rural-Motorway	Urban-Rural-Motorway
Road type distance share (Urban-Rural-Motorway) [%]	35.67-36.33-28	36.67-36.67-27.33	Approximately 34-34-33 (10% deviation is allowed)	Approximately 34-34-33 (10% deviation is allowed)

RDE compliant driving cycles

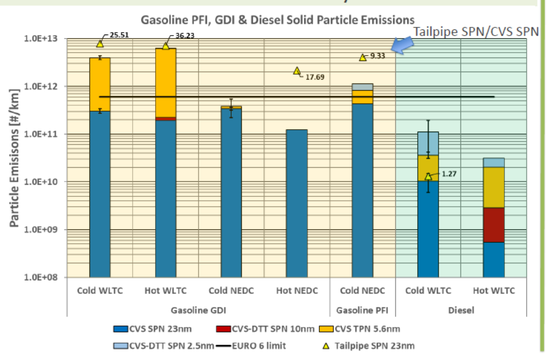
- Smooth (low speed limit)
- Dynamic (high speed limit)

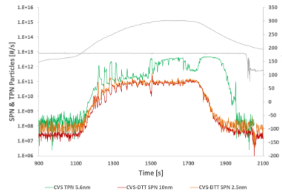
Extended RDE

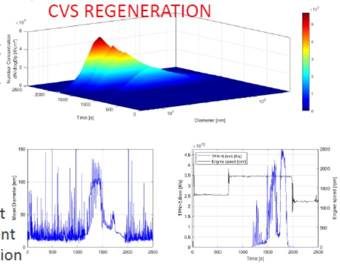
- Non-compliant with regulation
- Driving simulation of heavy traffic
- Aggressive accelerations/decelerations

Results and discussion

PN emission results on chassis dyno tests



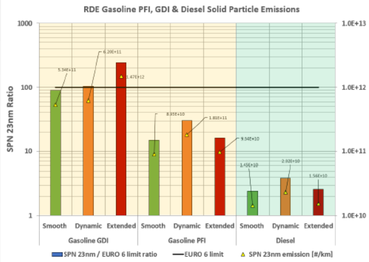


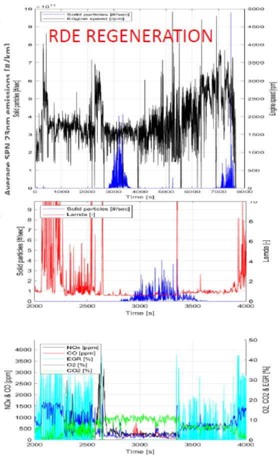


Regeneration event under steady state test

- GMD below 20nm at the end of the event
- High levels of volatiles during regeneration

PN emission results on RDE tests





- Gasoline DI high SPN 23nm emissions during rural and motorway part
- Diesel higher particle emissions on motorway part (excluding regeneration)
- No significant high particle emissions in PFI vehicle

Conclusion

- GDI solid particle emissions (SPN>23nm) were on average 145% higher than the baseline EURO 6d temp limit (9e11 #/km) during RDE extended
- Diesel and PFI was steadily below limit during all on road tests
- With except to GDI vehicle, results indicates that driving variability impose no change on particle emission performance.
- GDI & PFI vehicles were above EURO 6 limit in the sub 23nm particle detection range.
- Diesel vehicle has the lower sub 23nm particle emissions which were constantly below EURO 6 limit.

Parameter	Gasoline DI	Gasoline PFI	Diesel DI
Effect of driving behavior on SPN 23nm particle emissions	√	-	-
CVS Sub 23nm particle emissions beyond EURO 6 limit	√	√	-

This research is co-financed by Greece and the European Union (European Social Fund- ESF) through the Operational Programme «Human Resources Development, Education and Lifelong Learning» in the context of the project "Strengthening Human Resources Research Potential via Doctorate Research" (MIS-5000432), implemented by the State Scholarships Foundation (IKY)»

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3.2 Marine and aviation emissions

This section includes posters presented in the context of the “Marine and aviation emissions” session of the TAP conference. Table 14 provides an overview of these posters, as they are listed in the following sub-sections.

Table 14. Titles and authors of “Marine and aviation emissions” posters

	Title	**Authors**
3.2.1	Integrated Benefit Assessment of the Port-Railway Combined Transportation Strategies for the Port of Shenzhen, China	J. Zhang, S. Bao, S. Zhang, Y. Wu and J. Hao
3.2.2	Validation of particular LTO phases times in polish conditions using flight simulator	M. Galant, M. Maciejewska, M. Kardach and M. Nowak
3.2.3	Comparison of the ecological profitability of jet aircrafts of various capacities	M. Kardach, P. Fuć, M. Galant and M. Maciejewska
3.2.4	Adaptation of the LTO cycle to the operational conditions of the most commonly used aircrafts on Polish market	M. Maciejewska, P. Fuć, M. Galant and M. Kardach
3.2.5	Contributions of traffic and shipping emissions to city scale NO2 and PM2.5 exposure in Hamburg	M. O. P. Ramacher, M. Karl, A. Aulinger, J. Bieser, V. Matthias and M. Quante
3.2.6	Ship emission scenario modeling	J-P. Jalkanen and L. Johansson

3.2.1 Integrated Benefit Assessment of the Port-Railway Combined Transportation Strategies for the Port of Shenzhen, China

Integrated Benefit Assessment of the Port-Railway Combined Transportation Strategies for the Port of Shenzhen, China

Jingran Zhang[1,*], Shuanghui Bao[1], Shaojun Zhang[2], Ye Wu[1] and Jiming Hao[1]

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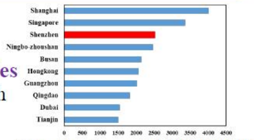
E-mails: zhangjr17@mails.tsinghua.edu.cn

INTRODUCTION

- The escalating concerns regarding air pollution problems around **port cities** have created many research attentions.



Total port handling capacity in 2017, 10000TEU

- The total port handling capacity of **Port of Shenzhen** has climbed to **25 million twenty-foot equivalent units (TEU) by 2017**, only third to Shanghai and Singapore in the global ranking.
- It is estimated that the capacity will continue a growth reaching **30 million TEU by 2025**.
- **70%** of freight transportation demand is conducted by **on-road trucks**, leading to serious traffic congestion, road accident and air pollution issues in Shenzhen.
- According to the source apportionment results, freight trucks could be responsible for **27% of local NOx emissions and 23% of PM in 2017**.
- It is essential to develop effective strategies to tackle port-related environmental and social challenges.

METHOD

- An integrated strategy by promoting **rail-based systems** to replace on-road trucks in Shenzhen.
- **Inland ports** are considered to be built in north Shenzhen in 2025, which will be connected by express cargo railways to the port areas.
- The total processing capacity of inland ports : **6.5 million TEU per year**, one quarter of the current volume for the Port of Shenzhen.

Original and new on-road routes from 4 typical terminals

- The original port-related transportation routes in north Shenzhen would change greatly.
- The on-road distance of the new routes will be **shortened by 31%-62%** than the current routes.
- To evaluate **the environmental benefits of Port-Railway** Combined Transportation Strategy in 2025, we employed a **transportation demand model**, TransCAD6.0, to estimate the changes of link-based truck activities.
- **Baseline traffic profiles in high temporal and spatial resolutions** were developed based on local traffic data (details available in TAP2019 paper by Yifan Wen).
- A **localized vehicle emission model** was further applied to calculate link-level emissions of on-road vehicles.

DISCUSSION

- Our results indicate that the implementation of **multi-modal transportation systems** could significantly **reduce truck volumes** on **major freight corridors in Shenzhen**, except for some roads adjacent to the inland ports.
- The reduction for **major freight corridors** could be responsible for **more than 50%**.

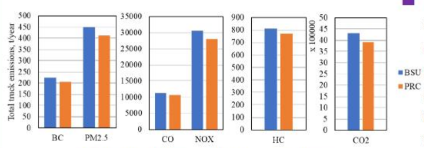
The reduction of truck volume for freight corridors

- Daily emissions: **NO_X & $PM_{2.5}$**
  - Right : Business as usual (BSU)
  - Left : Port-Railway Combined strategy (PRC)

Daily NO_X emissions of road traffic source pollutants (including all vehicles on the road),kg/km, BSU & PRC

Daily $PM_{2.5}$ emissions of road traffic source pollutants (including all vehicles on the road),kg/km, BSU & PRC

- Annual truck emissions in Shenzhen could be reduce by **2528 t/year for NO_X** and **37 t/year for $PM_{2.5}$**, respectively, accounting for nearly **9%** of the total truck emissions.



Annual emissions of road traffic source pollutants (including all trucks on the road), t/year

- With strict new vehicle standards and high degree of vehicle electrification achieved in 2025, the emission reduction by multi-modal transportation systems could be **significant**.

CONCLUSION

- Our research indicates that a **shift** from traditional road transport to **cleaner and more efficient rail transport** could deliver **environmental benefits** for **port cities**.

ACKNOWLEDGEMENT

- Thanks to Xiaomeng Wu, Daoyuan Yang and Yifan Wen from School of Environment for their help in methodology and data. Thanks to Tianzheng Xiao and Yongbo Zhang from Department of Civil Engineering for their help in traffic methodology.

3.2.2 Validation of particular LTO phases times in polish conditions using flight simulator

23RD INTERNATIONAL TRANSPORT AND AIR POLLUTION CONFERENCE 15-17 MAY 2019

TAP 2019 | THESSALONIKI, GREECE

Validation of particular LTO phases times in polish conditions using flight simulator

Marta GALANT, Marta MACIEJEWSKA, Monika KARDACH, Mateusz NOWAK

INTRODUCTION

The air transport evolution forecasts are published annually. The Airbus Global Market Forecast indicates that the air traffic doubles every 15 years. It means that problem with emissions from air transport will be more noticeable. Standard procedure to estimate aircrafts impact on immediate vicinity of the airport is LTO test. This is a very good tool for the emission assessment of aircraft engines, because by defining the time of individual phases and the load on the drive unit, it is possible to ensure repeatable conditions. However to determine local emission it is necessary to adapt parameters to specific conditions.

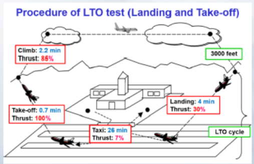
CKAS MOTION SIM 5 SIMULATOR

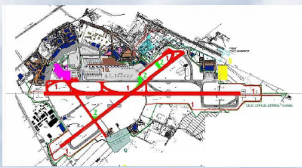
- the Simulation Research Laboratory,
- four generic types of light aircraft:
  - a piston single-engine aircraft,
  - a piston twin-engine aircraft,
  - a light twin-engine turboprop aircraft
  - a light jet.
- not intended to simulate a particular aircraft model, but rather to represent a typical aircraft of each class in its handling qualities and features,
- control over the flight simulator environment such as weather, positioning, malfunctions as well as real-time tracking and flight recording,

- a four-seater platform with two sets of flight controls,
- 200° × 40° viewing angle,
- electrical motion system with six degrees of freedom,
- move in every possible direction at an angle of 18° and move for 150 mm,
- take operations from and to almost every airport in the World.

LTO PROCEDURE AND ADAPTATION

Chosen to the further analysis Warsaw Chopin Airport is the biggest airport in Poland. It has two crossing runways. According to AIP (*Aeronautical Information Publication*) to the noise emission limitation the preference system has been established: for arrivals RWY 33, RWY 11, RWY 15 and RWY 29; for departures: RWY 29, RWY 15, RWY 33, RWY 11. It means that it is possible to create 16 scenarios of RWY using, characterised in different taxiing time.

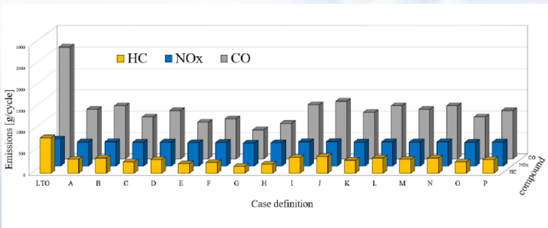


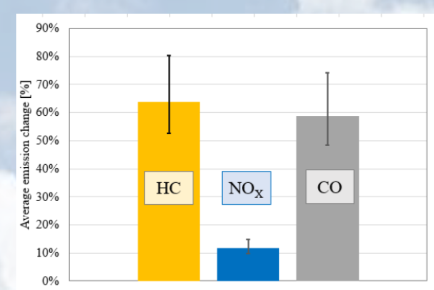


Arrival / Departure	RWY33	RWY11	RWY15	RWY29
RWY29	A	B	C	D
RWY15	E	F	G	H
RWY33	I	J	K	L
RWY11	M	N	O	P

COMPARISON OF HARMFUL EXHAUST EMISSIONS IN THE LTO TEST AND REAL FLIGHT CONDITIONS

- The regulations showed in AIP includes fact, that to general aviation is designated Apron 1. This apron is located at north part of airport, nearby to RWY 15. For the purposes of the analyses, the 16 scenarios were adopted – the longest taxiway takes 6.8 km, the shortest 1.9 km and the average occurs 4.8 km. Its caused that taxi time is from 3 to 11 minutes, not as in the LTO 26 minutes.





In the figure 3 the percentage differences are presented. For dedicated LTO parameters reduction in HC emission gain more than 60% (maximum 80%, minimum 53%), and for CO slightly less than 60% (maximum 75%, minimum 50%). Differences in NOx emission are about 10%.

CONCLUSION

Based on the presented analysis, it can be stated, that it is possible to proceed the LTO test using the CKAS MS5 simulator. The results indicated that the actual emission obtained during the tests is lower than the one calculated in accordance with the procedure in the range of 10% to even 80%.

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ACKNOWLEDGEMENTS: The study presented in this article was performed within the statutory research (contract No. 05/52/DSMK/0288)

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3.2.3 Comparison of the ecological profitability of jet aircrafts of various capacities

23rd International TAP Conference 15 – 17 May 2019 Thessaloniki, Greece

TAP 2019 | THESSALONIKI, GREECE

COMPARISON OF THE ECOLOGICAL PROFITABILITY OF JET AIRCRAFTS OF VARIOUS CAPACITIES

Monika KARDACH, Paweł FUĆ, Marta GALANT and Marta MACIEJEWSLA
Poznań University of Technology, Faculty of Transport Engineering, Poznan, Poland

The emission of harmful exhaust gas compounds from combustion engines depends on operating conditions. The development of tests, aiming to assess pollutant emissions from various means of transport, is the key to minimize the human impact on the environment. An example of the test is LTO cycle mentioned in ICAO (International Civil Aviation Organisation) Annex 16 about aircrafts' emission and noise.

The LTO procedure was created to assess emission of harmful exhaust compounds from civil aircraft engines. The flight of the aircraft is mapped by four phases. Each of them has a different duration and power setting (tab. 1). For civil aircrafts the phases are: take off with 100% thrust, climb out with 85% thrust, approach with 30% thrust and the longest with 7% thrust. The whole test lasts about 30 minutes. The durations of individual phase are proportional to the one in real conditions. The emission in LTO cycle is defined as mass of the harmful compound per mass of used fuel.

Table 1. List of parameters in the LTO cycle

Phase	Duration [min]	Power setting [%]
Approach	4	30
Take off	0,7	100
Climb out	2,3	85
Taxiing	26	7

The LTO cycle is used for aircrafts over 27.6 kN of thrust and does not includes cruising phase above 3000 ft.

Research and results

In this paper it was decided to focus on nitrogen oxides (NOx) which is a result of the high temperature in combustion chamber and carbon monoxide (CO) resulting from local oxygen deficiency. Its' aim was to compare a common jetliner with 189 passenger capacity flying on two CFM engines and a very light jet business aircraft designed to carry up to 8 people on board. The emission factor and Fuel Flow Rate necessary to make calculations come from ICAO emission databank. The carried-out analysis showed that the NOx emission per passenger in Very Light Jet (VLJ) is three times higher than in common jet airliner, furthermore there is 15 times difference in CO emission (Fig. 1).

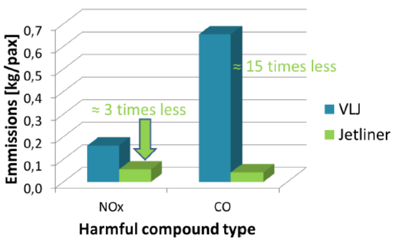

Figure 1. This is a comparison between VLJ and jetliner's CO and NOx emission per passenger

As it can be noticed (Fig. 2) according to NOx emission it is better for ecological reasons to fly 8 VLJ with 8 people each than one jetliner with the same number of people on board. However, considering CO emission the number of ecologically efficient flight is limited to 1.

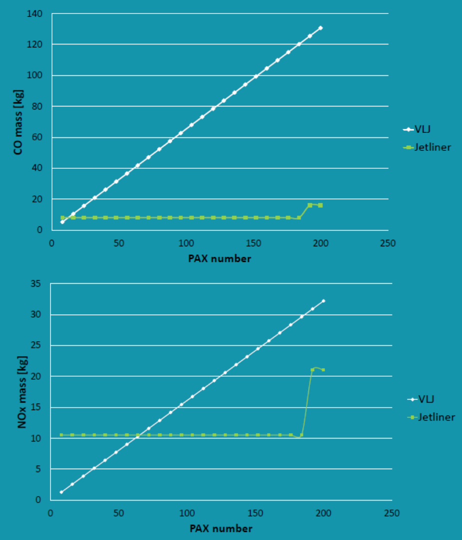

Figure 2. This is a comparison between VLJ and jetliner's CO and NOx total emission per number of passengers

Based on the results of the analysis, it can be stated that it is appropriate to extend the certification of engines to smaller units as well as to adjust the LTO test beyond laboratory conditions.

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3.2.4 Adaptation of the LTO cycle to the operational conditions of the most commonly used aircrafts on Polish market

ADAPTATION OF THE LTO CYCLE TO THE OPERATIONAL CONDITIONS OF THE MOST COMMONLY USED AIRCRAFTS ON POLISH MARKET

TAP 2019 | THESSALONIKI, GREECE

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Introduction

The LTO cycle (Landing and Take–off cycle) is a research method used for jet engines certification. The measurements are performed in stationary conditions. With the development of aviation, the LTO test started to be carried out more often, but not for its' original purpose. A new aim was an assessment impact of aircraft movement on environment in airports area. LTO cycle consists of four phases [3]: take–off, climb out, approach and taxi/idle. Each of them assigns different thrust and duration time. This methodology is unmatched to conditions prevailing on airports. Analysing regulations it should be noted, that duration time don't reflect real conditions during each phase. Every airport has different infrastructure, what affects on time during basic flight operations like taxi or landing or approach. Duration time should be adjusted to every single airport.

As research area Poznań–Ławica Airport was adopted, which is located in Poland. Using the times of the individual phases of the LTO test calculated for the airport in Poznan (table 1), it was put in order to calculate the emission from the most commonly used aircraft. Aircrafts, which are mostly used at Poznań – Ławica Airport are: B737-400, B737-800. A320 and A321. These models were chosen based on fleet of airlines with the largest traffic at Polish market, belong to LCC (*Low cost carriers*).

Table 1. List of regulations and reseach parameters in the LTO cycle [1]

PHASE	THRUST [%]	DURATION TIME [min]	
		REGULATIONS	RESEARCH
Take - off	100	0,7	0,67
Climb out	85	2,2	1,88
Approach	30	4	5
Taxi/Idle	7	26	9,9

It should be noted, that calculated duration time each of LTO phases (fig. 1) is most different at two phases: approach and taxi/idle. The approach phase is 25% longer than in regulations and taxi/idle phase is 62% shorter than in regulations [1]. It can significantly affect to emissions at airport area. Based on parameters calculated specially for Poznań–Ławica Airport (table 1) it is possible to computed emission from the mostly used aircraft.

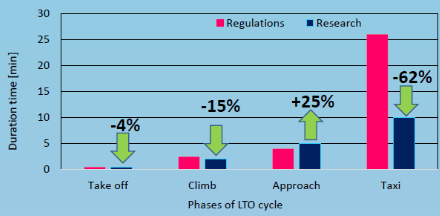


Figure 1. Differences between LTO time phases in regulations and research [1]

Methodology

Methodology was concern on computed toxic exhaust fumes emission using the LTO cycle. Emission in LTO cycle is calculated using formula [4]:

$$EPC_{pol,mode} = (TIM \cdot 60) \cdot FFR \cdot EF \cdot NE$$

$EPC_{pol,mode} - emissions\ per\ cycle$
$for\ a\ particular\ mode\ [g/faze]$
$TIM - Time\ in\ Mode\ [s/faze]$
$FFR - Fuel\ Flow\ Rate\ [kg/s]$
$EF - Emission\ Factor\ [g/kg]$
$NE - Number\ of\ enigines\ on\ aircraft\ [-]$

Based on Aircraft Engine Emissions Databank from 2018 year [2] calculated emission toxic exhaust fumes for following aircrafts: B737-400, B737-800, A320 and A321. Calculations were carried out for emissions in regulations LTO cycle and research LTO cycle.

Research results

As a research result total emission characteristic of each component is presented. Regulation–yellow. Research–Grey. On figure 2 and figure 3 are total emission HC, CO and NOx from Boeing and Airbus models.

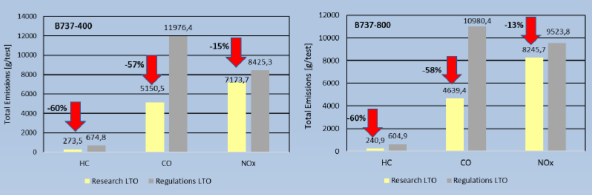


Figure 2. Total mass of individual exhaust compounds in LTO test for B737 – 400/800

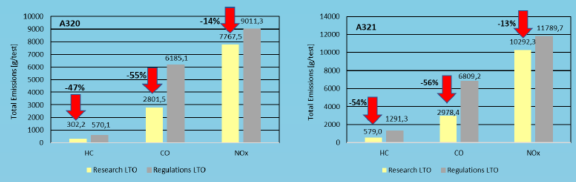
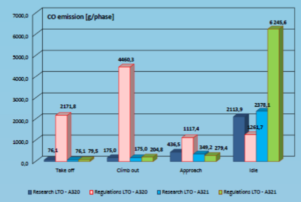


Figure 3. Total mass of individual exhaust compounds in LTO test for A320 and A321

Analysing the characteristics, it should be noted that the change in the time of individual phases of the LTO cycle has a significant impact on the volume of emissions from particular types of aircraft. For HC and CO, emissions are reduced by 60% (Figure 2,3). Analyzing the NOx emission, the differences are smaller, which is caused by the highest emission of this component during take-off, and in this phase the duration time was slightly reduced.

It can be noticed that the asorbed in the LTO test times appropriate to the Poznań – Ławica Airport significantly affects the differences in the emission of toxic compunds, mainly HC and CO (Figure 4). The differences between Regulations and research LTO cycle can be seen in CO emission. Results in regulations LTO test predicted much more CO consumpiton in each phase of LTO cycle, esspecially for Airbus A320.



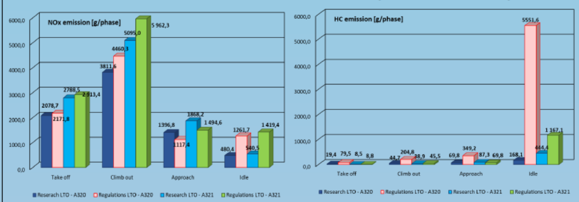
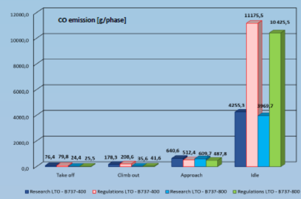


Figure 4. Total emission of individual exhaust compounds for all phases in reserach and regulations LTO test for A320 and A321

It can be seen that for B737-400 and B737-800 the asorbed in the LTO test times appropriate to the Poznań – Ławica Airport significantly affects the differences in emission in Idle phase. CO and HC emission are in regulations test over twice as large as in research LTO cycle. In oder phases the differences are insignificant. sults in research LTO test predicted much smaller consumption of NOx in each pahase.



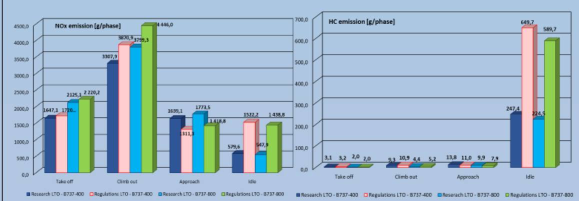


Figure 5. Total emission of individual exhaust compounds for all phases in research and regulations LTO test for B737-400 and B737-800

Conclusions

The research confirms the validity of the thesis that parameters of flight phases adopted in the LTO test performed for the purpose of testing emissions in airport areas are not equal. For this type of research, individual parameters should be special for each airport to get results much closer to the actual local emission.

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3.2.5 Contributions of traffic and shipping emissions to city scale NO2 and PM2.5 exposure in Hamburg

Contributions of traffic and shipping emissions to city scale NO_2 and $PM_{2.5}$ exposure in Hamburg

Helmholtz-Zentrum Geesthacht
Centre for Materials and Coastal Research

Martin O. P. Ramacher, M. Karl, A. Aulinger, J. Bieser, V. Matthias, M. Quante // Helmholtz Zentrum Geesthacht

Motivation & Goal

- Urban air quality management strongly depends on information about the spatial distribution of emissions and their sources, concentrations and exposure to health related pollutants.
- This study investigates the spatial distribution and contribution of four major **NO_2 & $PM_{2.5}$ emission** sources (industry, road traffic, shipping and residential heating) on air quality and **population exposure** in the North European harbor city Hamburg with a local scale Chemistry Transport Model (CTM) system.

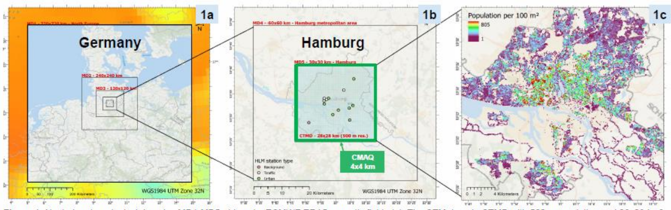

Figure 1: Nested meteorological domains MD1-MD5, driven by ECMWF ERA5 synoptic fields (a). The CTM domain CTMD with 500 m resolution and 28x28 km² extent is nested within MD5 and uses by 4x4 km² CMAQ regional boundary conditions (b). Population density for Hamburg 2011 with 100x100 m² resolution.

Method & Model setup

Local scale Chemical Transport Model (CTM) study to

(1) calculate hourly 3D NO_2 & $PM_{2.5}$ concentrations in 500 m resolution,
(2) identify contribution of sector emissions by perturbation with four scenarios.
(3) investigate exposure to NO_2 & $PM_{2.5}$ with gridded population counts (Fig 1c).

CTM system setup	
Coupled meteorological & CTM system	TAPM (Hurley et al. 2009)
Meteorological module setup	5 nested meteorological domains
Synoptic meteorology at outer domain	ECMWF ERA5 with assimilation
CTM module setup	1 CTM domain, 500 m resolution, 28x28 km extent
Background concentrations	CMAS CMAQ 4x4 km

Emissions inventories

Detailed emissions inventories have been gathered, enhanced, created to simulate the contribution of the 4 major contribution emission sectors in Hamburg (Fig. 2):

(1) Traffic – 15851 line sources based on calculations for the road network in Hamburg by Lohmeyer (2010)
(2) Ships – Daily emissions for all shipping activities in the port area of Hamburg (Aulinger et al. 2016)
(3) Industry – 2011 emission reports (11. BImSchVG) and emission model GRETA (UBA 2017)
(4) Residential heating – temperature dependent area emissions based on GRETA (UBA 2017)

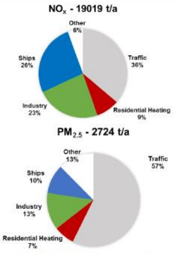

Figure 2: Total emissions NO_2 & $PM_{2.5}$ and source apportionment in Hamburg 2012.

Comparison with observations

Modeled concentrations show good statistical performances at urban stations but strongly underestimate NO_2 at traffic stations (3a). For $PM_{2.5}$ regional concentrations are the main contributor to the total AQ situation, while for NO2 the local sources play a more important role. The source contribution at fixed sites identifies traffic and industry as major sources $PM_{2.5}$.

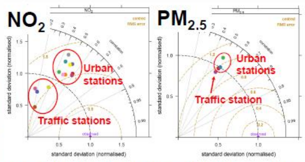

Figure 3a: Model performance for NO_2 & $PM_{2.5}$ at HLM monitoring sites.

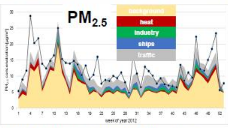

Figure 3b: Weekly average $PM_{2.5}$ time series for centrally located station 13ST.

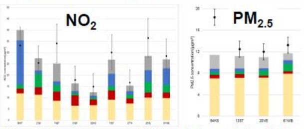

Figure 3c: Simulated source contributions at urban monitoring sites for NO_2 & $PM_{2.5}$ (see left legend for sector identification).

Modeled $PM_{2.5}$ concentrations

The **modeled $PM_{2.5}$** and NO_2 concentrations show hot spots in the harbor and industrial area of Hamburg, which is mainly due to shipping (30-40%) and industrial (40%) activities. The city center also shows higher concentrations, which can be allocated to traffic sources (20-30%).

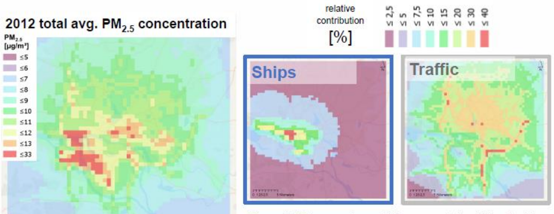

Figure 4: Total averaged annual $PM_{2.5}$ concentration (left) and relative source contributions for industry, residential heating, shipping activities and traffic (right) in Hamburg 2012, calculated with the TAPM model.

$PM_{2.5}$ exposure & source apportionment

Road traffic is the major source of $PM_{2.5}$ and NO_2 pollution and exposure (10-30%) during the entire year and in almost all populated areas in Hamburg, followed by industrial and shipping emissions. The major road traffic influence is in the densely populated city center, while shipping has a big impact at the NW side of the Elbe river and industrial activities influence the population of Wilhelmsburg. When it comes to the impact of residential heating there are higher concentrations and exposure in winter. Nevertheless, the **regional background accounts for 30-50% of all NO_2 and 50-80% of all $PM_{2.5}$** pollution in populated areas of Hamburg.

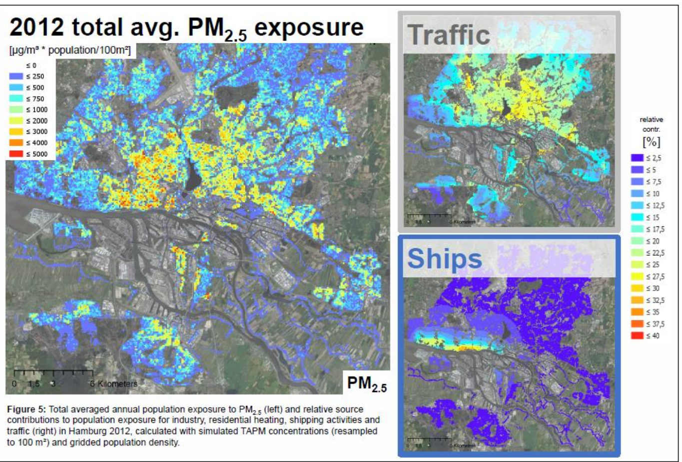

Figure 5: Total averaged annual population exposure to $PM_{2.5}$ (left) and relative source contributions to population exposure for industry, residential heating, shipping activities and traffic (right) in Hamburg 2012, calculated with simulated TAPM concentrations (resampled to 100 m²) and gridded population density.

UHH · Helmholtz-Zentrum Geesthacht · Centre for Materials and Coastal Research

Literature:
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Hurley et al. 2009 - Hurley, Peter/Edwards, Mary/Luhar, Ashok (2009): Evaluation of TAPM V4 for Several Meteorological and Air Pollution Datasets. In: Air Quality and Climate Change, 43 (3), pp. 19–24.

Acknowledgements: David Carslaw and K. Ropkins for the openair R package, the Umweltbundesamt Germany, the BUE Hamburg, the CTM department at HZG & the SICSS school.

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3.2.6 Ship emission scenario modeling

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Baltic Earth

Ship emission scenario modeling

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Ship emission inventories constructed using Automatic Identification System (AIS) data allow new possibilities to develop advanced scenarios. This paper gives three examples of such work which deal with NOx, SOx and greenhouse gase (GHG) scenarios. In the past, future emissions have been mostly developed using a constant annual growth rate for emissions without considering features like regional rules, energy efficiency improvements and fleet developments. The use of vessel level modeling using AIS data allows new possibilities for this work.

Introduction

The future of ship emissions looks complicated. In addition to global rules, like the global 2020 Sulphur cap set by the International Maritime Organsation (IMO), there are regional and local requirements, which go beyond the large-scale developments. Even the simplest scenario, business as usual (BAU)needs to be conducted in a manner which goes beyond the scaling of emission totals with an annual growth rate.

Linking emissions growth to global development of gross domestic product may lead to problems, especially with countries for which the economic growth does not rely only on manufacturing and exporting goods but has a significant contribution from services and other non-physical commodities. In all cases there exists several pathways how to comply with new regulation and these need to be described in a realistic manner. For example.

This paper outlines various aspects of ship emission scenario modeling, which should be considered in constriction emission scenarios. The work described in this paper is a synthesis of results obtained in ten different research projects during the last decade.

Materials and methods

Modeling approach

All examples of this paper were based on vessel level modeling of ship emissions. Vessel activity was described with Automatic Identification System (AIS) and technical dat for the fleet were obtained from IHS Markit. The energy needs and emissions as a function of time were predicted with the Ship Traffic Emission Assessment Model (STEAM) of the FMI (Jalkanen et al., 2009; 2012, 2016; Johansson et al., 2013, 2017)

Energy consumption for propulsion is predicted using the Hollenbach resistance prediction method which is a parametric semiempirical model. Predictions for auxiliary power and boiler need are described as a function of vessel type and operating mode. Regional regulations, technical limitations of engines and fuel features are included along with emission abatement techniques.

Weather impact on vessel propulsion power is not included, although it can be taken into account and has been tested in our previous work (Jalkanen et al., 2009).

Considerations

Regional rules like Emission Control Areas and vessel type specific restrictions need to be considred in the scenario work. Blind application of scaling factors based on fuel consumption or CO_2 should be avoided.

SO_x

Sulphur (Emission Control Area, SECA) scenarios are relatively straightforward, because they concern all ships in an area at the same time once the implementation date is agreed. However, it is not advisable to simply scale the pre-SECA inventories with a constant based on fuel sulphur content before and after the SECA implementation, because

1) Existing regional rules may contain overlapping requirements, which need to be considered. These include the mandatory switch to low sulphur fuels in port areas,
2) special rules for passenger vessels,
3) different start dates for ECAs and
4) technical features of ships' engines which may prohibit the use of residual marine fuels.

An example of work where these things were included is the global 0.5% sulphur cap study of Sofiev et al (2018; Figure 1).

NO_x

Scenarios for nitrogen oxide emissions are different from the sulphur case, because the regulation only applies to new ships built after a certain date. Tighter rules are only applied to new ships, which leads to gradual decrease of NOx emissions when the vessel fleet is renewed. It may take 30 years to to see the full effect when the whole fleet has undergone one renewal cycle (Karl et al., 2019).

Modeling ship emissions at vessel level offers insight on the fleet age structure and facilitates emission scenarios which apply to only part of the fleet. This is especially important for NO_x Emission Control Area scenarios, because accurate description of vessel renewal with Tier III compliant ship has a direct impact on predicted emissions. Just like in the case of SO_x mitiation, there exists several paths for compliance, like adoption of LNG, catalytic conversion and combinations of other Tier II techniques (fuel emulsion, exhaust gas recirculation). Some of these paths lead to side effects, like ammonia and methane slip, which need to be evaluated as well.

Greenhouse Gases

The cost of emission reductions of NO_x and SO_x will be less than GHG mitigation (Figure 2). IMO has already introduced the Energy Efficient Design Index (EEDI) to guide vessel designs to more energy efficient direction. However, EEDI is not applied to every ship, only certain ship types are included. It is very unlikely that EEDI efforts are even able to negate the effect of traffic growth (Figure 3).

The modeled scenarios for GHG emissions from ships should account for (at least) three different mechanisms which include:

a) vessel size growth (**shipbuilding**); limitations to length, draft, breadth andTEU capacity (Figure 4)
b) increase in number of ships (**transport demand**)
c) Efficiency gains which EEDI requires (**regulatory**)

Summary

Scenario work is never easy, but solid links to reality can be made. It should be noted that this paper deals only with air pollution, but also discharges may be altered as a result of air emission abatement, like the case of SO_x scrubbing.

The examples provided in this paper indicate that in order to construct emission scenarios for ships, dialogue with industry and maritime authorities is useful. There may be alternative pathways to comply with proposed changes and side effects which need to be studied in detail. It will also avoid the most evident pitfalls which may occur if unrealistic assumptions are used in scenario construction.

Acknowledgements

This paper builds on the experience of a number of projects, like BONUS SHEBA, EnviSuM, CSHIPP, MERSU, BSR InnoShip, GLORIA, SNOOP, The Third IMO GHG study, EPITOME and ShipNOEm..

Financial support from Academy of Finland, Nordic Council of Ministers, EU Regional Development Fund, Finnish Transport Safety Agency, BONUS programme and Finnish Prime Minister's Office are greatly appreciated.

This summary is built on the work conducted with more than 150 researchers. Lessons learned would not have been possible without their contribution.

Figure 1. Composite of the geograhical distribution of the most significant shipping lanes (blue lines) and human health effetcs of ship emissions (green). Image adapted from the results of Sofiev et al., Nature Comms., 9 (2018) 406.

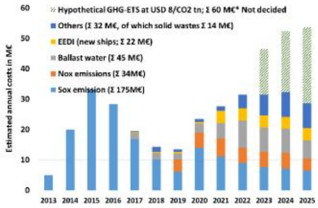

Figure 2. Annual cost of changes in international maritime regulation to the Finnish economy. SECA (Blue bars), NECA (Orange), BWMC (Grey), EEDI (Yellow), GHG-MBM (Green), Others (Blue). Potential future emission trading (MBM) was estimated with 8 USD/tonne CO2 price (Repka et al., 2017).

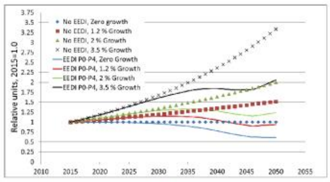

Figure 3. Estimated impact of gradually tightening energy efficiency requirements (EEDI) of the global fleet. Phases 0-3 are currently agreed, phase 4 is planned. The EEDI will be barely able to negate the effect of annual traffic growth and it cannot be used to reach the 50% GHG reduction target of the global shipping.

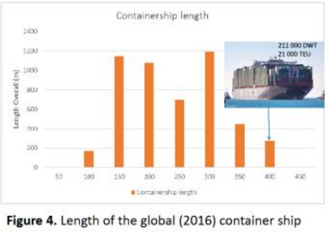

Figure 4. Length of the global (2016) container ship fleet. The biggest ships of this class are 400 m long and carry over 21 000 containers.

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3.3 Air quality measurement, monitoring and modelling

This section includes posters presented in the context of the “Air quality measurement, monitoring and modelling” sessions of the TAP conference. Table 15 provides an overview of these posters, as they are listed in the following sub-sections.

Table 15.Titles and authors of “Air quality measurement, monitoring and modelling” posters

	Title	Authors
3.3.1	EMISSION: Environmental monitoring integrated system using an IoT network	N. Papadakis, D. Stouraitis, A. Bartzas, E. Gerasopoulos, G. Grivas, E. Athanasopoulou, I. Stavroulas, P. Syropoulou, A. Agrafiotis, I. Christakis, T. Migos, I. Stavrakas and K. Ioannidis
3.3.2	The necessity of air pollution monitoring system and diffusion of information to the public: The case of Ioannina, NW Greece	G. Markozannes, O. A. Sindosi, E. Rizos and E. Ntzani
3.3.3	Characterisation of atmospheric pollution at local scales: Implementation of a downscaling method	I. Makni, I. Coll, A. Elessa Etuman and T. Bennoussaid
3.3.4	The interaction of meteorological boundary data for modelling of PM-episodes and its impact of traffic emissions on air quality in Germany	M. Thürkow and M. Schaap
3.3.5	Air quality measurements in Stuttgart using tethered balloon	A. Samad, U. Vogt, A.Panta and D. Uprety
3.3.6	PolluRisk, an innovative platform to investigate the impact of Air Quality on Health: a comparison between Beijing and Paris cases	P. Coll, M. Zysman, M. Cazaunau, J-F. Doussin, et al.
3.3.7	Ultrafine particles measurement in Wallonia, Belgium	C. Luthers, R. Laruelle, G. Gérard and S. Fays
3.3.8	Road traffic vs. waste incineration: local-scale air quality impact assessment at municipality level in Northern Italy	G. Lonati, A. Cambiaghi and S. Cernuschi
3.3.9	Using Python and the RapidAir dispersion model to simplify air quality modelling	N. Masey, S. Hamilton and A. Lewin
3.3.10	Simultaneous analysis of emission of air pollutants in Brazilian urban roads	W.F.L. Quintanilha, D.R. Cassiano, B.V. Bertoncini and J.P. Ribeiro
3.3.11	Health Canada’s assessment of TRAP – Exposure, health effects & population health impacts	M. Rouleau

	Title	Authors
3.3.12	Project Borée: controlling road-tunnel ventilation by means of a network of microsensors, in order to reduce the exposure of the local population to pollutants Background and methodology	M. Yaghzar, B. Vidal, J.F. Burkhart, D. Robin and S. Castel

3.3.1 EMISSION: Environmental monitoring integrated system using an IoT network

EMISSION : Environmental monitoring integrated system using an IoT network

Nikos Papadakis[1], Dimitris Stouraitis[1], Alexandros Bartzas[1], Evangelos Gerasopoulos[2], Georgios Grivas[2], Eleni Athanasopoulou[2], Iasonas Stavroulas[2], Panagiota Syropoulou[3], Apostolos Agrafiotis[3], Ioannis Christakis[4], Theologos Migos[4], Ilias Stavrakas[4], Kostas Ioannidis[5]

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[2]Institute for Environmental Research and Sustainable Development, National Observatory of Athens, I. Metaxa & V. Pavlou, 15236, P. Penteli, Athens, Greece
[3]Draxis Envrironmental SA 54-56 Themistokli Sofouli st 54655, Thessaloniki ,Greece
[4]Electronic Devices and Materials Laboratory, Department of Electrical and Electronic Engineering, University of West Attica Athens, Greece
[5]ENCO 32 Ach. Paraschou str., GR- 114 73,Athens , Greece

Background :

- Current air quality monitoring systems in the urban area are based on fixed monitoring stations
- Issues:
  - High cost of deployment and maintenance
  - Limited spatial resolution of published pollution maps
- Restricted access to data
- Open data are aggregated
  - Static deployment
  - Coarse-grained monitoring
  - Scalability issues

Motivation / Challenge :

- The quality of air is a remarkable concern in modern cities
  - Effects of pollutants on human health and ecosystem
- Observing the concentration trend of atmospheric pollutants in different urban areas would allow to:
  - detect potential alarm scenarios
  - suggest appropriate countermeasures
  - support urban management
- Integration of air pollution monitoring component to an overall SmartCity ecosystem

Expected Results :

- Extending the atmospheric pollution-monitoring network to include more representative and extensive coverage;
- Optimization of pollutant monitoring tools using technologically advanced reliable low cost equipment and software;
- Contributing to compliance to air pollutant-monitoring regulation;
- Calculation of user friendly/oriented air quality indices combining high spatiotemporal density measurements plus end user input.
- Directly informing the public through the information Web platform and mobile application

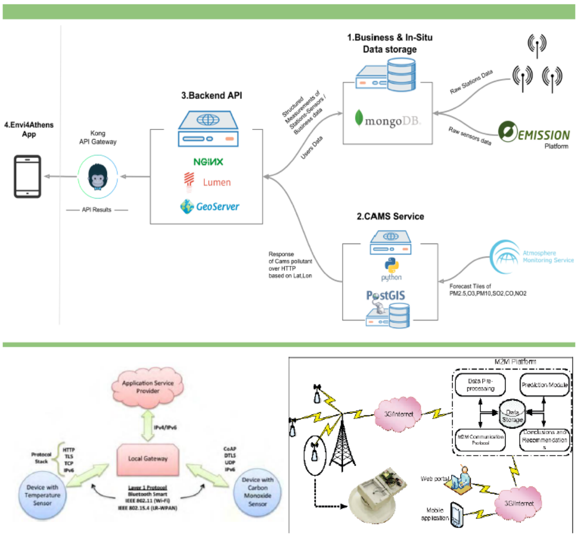

Fig 1.EMISSION physical architecture.
Industrial air pollution monitoring system based on wireless sensor network and calibration reference station that enables sensor data to be reliably delivered to a centralized infrastructure.

Fig 2. NOA's mobile Air Quality monitoring station will be operated for the periodical calibration and intercomparison of the EMISSION mid- and low-cost devices. The mobile station hosts state of the art instrumentation measuring in real time, gases and particulates alike (O_3, CO, SO_2, NO_x, $PM_{10\text{-}2.5\text{-}1}$ and Black Carbon).

Fig. 4. The Thissio Supersite, located in the Athens downtown urban background environment. Key gas phase (O_3, NO_x, SO_2, CO, CO_2, CH_4) and particulate (PM_1, $PM_{2.5}$, PM_{10}, Black and Brown Carbon) pollutants are monitored in real time along with important information on the physical and chemical properties of the atmospheric aerosol (e.g. size distribution, light absorption and scattering, chemical composition, oxidative potential). Calibration of the EMISSION mid- and low-cost devices will be performed against the Supersite's reference instruments.

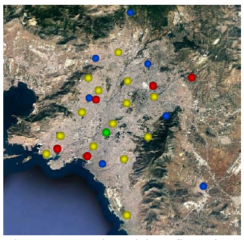

Fig. 3. Proposed spatial configuration of the urban background combined air quality monitoring network in the Athens Basin. EMISSION low-cost and mid-cost stations in yellow and red respectively. Blue dots represent the NAPMN network, while the green dot is the Thissio Supersite operated by NOA.

The Air Quality Monitoring System -Main Components:

- Sensor nodes, each provided with a microcontroller, communication devices and sensors:
- NO_2
- O_3
- $PM_{1\text{-}2.5\text{-}10}$

Sensor calibration with Air Pollution Reference Station

- Cloud infrastructure receive data from each node and forwards them to the central server
  - Alternatively a gateway node can be included to supported other wireless networks (LoRa,Sigfox etc)
- Central server, store gathered data, ensuring integrity, security and availability
- Mobile application to provide information about
  - urban traffic forecast and management
  - Individual daily route planning

Key points :

- Air Pollution GIS Monitoring Web based Platform
- Measurement and Analysis of Environmental gases (NO2 , O3) and Particulate matter (PM parameters)
- Reference Air Quality Monitoring station operation
- Deployment of Low-cost battery enabled monitoring units capable of generating environmental and pollution based
- data for processing, verification and visualization
- Data collected is sufficiently accurate to determine the state of air quality, pollution hot spots and pollution sources
- The units can be deployable in cities with no 3G coverage using alternative radio units available (LoRa,Sigfox)
- and difficult operating conditions
- Mobile application and Web portal shall be developed to leverage participatory sensing concept among smart city citizens

The work in this paper is financed by the Greek Secretariat of Research and Technology (GSRT) under EDK program, project EDK00242

3.3.2 The necessity of air pollution monitoring system and diffusion of information to the public: The case of Ioannina, NW Greece

The necessity of air pollution monitoring system and diffusion of information to the public: The case of Ioannina, NW Greece

University of Ioannina

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Introduction

- The aggravating effect of air pollution on health is well documented, with the impact being more profound in vulnerable populations.
- The onset of the Greek economic crisis was accompanied by a significant decrease of conventional fuel used for heating due to high taxation, resulting in increased biomass burning[1], thus contributing to particulate matter emission.
- The effects of the Greek economic crisis on air pollution are well documented in the two biggest cities (Athens and Thessaloniki), however the knowledge is limited for smaller cities.
- To our knowledge, an evidence-based and easily accessible tool to inform the general population about the air pollution in real time, is absent in Greece.

Aim

- We aimed to evaluate the detrimental effects of financial recession (particularly the taxation of fuel used for heating and transport) on the air quality regime in Ioannina, a medium sized town of NW Greece, where industrialization is mild and the where main sources of wintertime air pollution being traffic and residential heating.
- Furthermore, we aimed to create an evidence-based and low-cost mobile technology in order to inform and motivate the general population about the air pollution conditions in the town in real time.

Methods

- Air pollution in Ioannina is monitored on an hourly basis by the urban background station (39.65ºN, 20.85ºE, 485m) in the center's town (Figure 1).
- The monitoring station records the pollutants: Particulate matter with diameter less than 10μm and less than 2.5μm (PM_{10} and $PM_{2.5}$), NOx, O_3 and Benzene, with a temporal coverage from 2010 to 2017.
- We evaluated the regime of air pollution in Ioannina against the European Union Air Quality Standards (Table 1).
- We used data about energy consumption derived from the Hellenic Statistical Authority (HSA) for the greater Ioannina area and for the period 2010-2017.
- We performed a literature review in order to identify relevant Air Quality Indices that have been proposed in literature or adopted in some countries.
- We propose the development of a new low-cost mobile technology in order to diffuse up-to-date air pollution information to the general population.

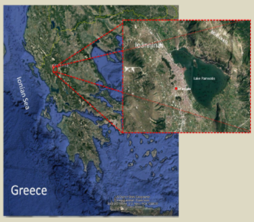

Figure 1: Map of Greece and Ioannina. Red bullet indicates the location of the monitoring station for pollutants.

Results

Overview of the air pollution regime in Ioannina during the Greek economic crisis

- In Ioannina, after 2010, the number of days that exceed the mean daily EU standards of 50μg/m³ for PM_{10} was greater than 35.
- Mean annual concentration of NO_2 did not exceed the annual threshold of 40μg/m³.
- $PM_{2.5}$, O_3 and Benzene levels did not exceed the EU standards in any year, but these data were limited to the period up to 2012.

Table 1: European Union permitted exceedances/year for PM_{10}, $PM_{2.5}$, NO_2, O_3 and Benzene concentrations.

Pollutant	Concentration (μg/m3)	Averaging period	Permitted exceedances for each year
PM_{10}	50	24 hours	**35***
	40	1 year	n/a
$PM_{2.5}$	25	1 year	n/a
NO_2	200	1 hour	18
	40	1 year	n/a
O_3	120	Maximum daily 8-hour mean	25 days averaged over 3 years
Benzene	5	1 year	n/a

Numbers with * and in bold indicate when the pollutant's concentration is exceeded the European Directives' threshold

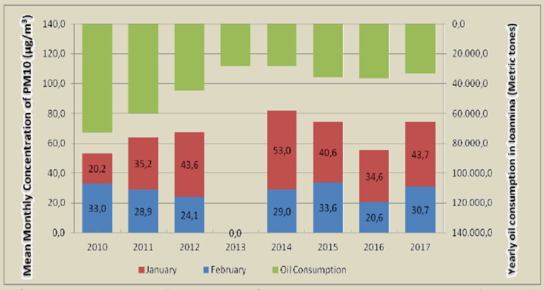

Figure 2: Intra-annual variation of mean PM_{10} concentrations and annual consumption of heating oil in Ioannina. *source: Hellenic Statistical Authority*

The effect of heat oil consumption on Particulate Matter concentration

- In greater Ioannina area, the consumption of heating oil was reduced during crisis and it was about 51% lower in 2015 relatively to 2010 (Figure 2).
- According to the data recorded by the monitoring station PM_{10} concentrations were increased about 40% in the first two months of 2015, relatively to the same period of 2010.

The prolonged episode of December 2015

- During December 2015 an intense and prolonged pollution episode took place in Ioannina.
- In 21 of 23 days with reliable data, mean daily PM_{10} concentrations were higher than the threshold set by the European Union (50μg/m³).
- The first daily maximum can be attributed both to traffic and residential heating while the second and main maximum primarily to residential heating (Figure 3).
- In December 2015, the mean difference between the two maxima was almost 100μg/m³, indicating the important role of residential heating in the building of the episode.
- Similar pollution episodes took place in Ioannina during the last years of crisis.

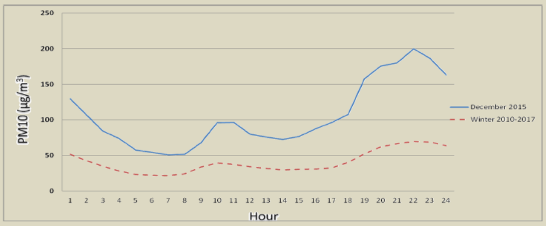

Figure 3: Mean hourly concentrations of PM_{10} for December 2015 and Winter 2010-2017 in Ioannina.

The necessity of an information-warning system

- The necessity of a warning system which will communicate information about air pollution conditions in the town is evident.
- We aimed to create a low-cost mobile technology to inform and motivate the general population.
- This system will communicate information about air pollution conditions in the town in order for the citizens to modify their behaviour, thus contributing to the prevention of adverse health outcomes.
- Based on the literature review, we chose the European Air Quality Index (EAQI) as the one being the most pertinent to the town of Ioannina.
- The index indicates the air quality based on the NO_2, O_3, PM_{10} and $PM_{2.5}$ using a five-band categorization ranging from "Good" to "Very Poor" (Table 2).
- The application will draw data from the air pollution station of Ioannina using the latest available information form the monitoring station.
- The application will also provide periodic alerts when pollutant levels exceed the EAQI thresholds (colour-coded accordingly), while the users will also be able to personalize these alerts by providing individual characteristics such as age, gender and health status.
- This application is expected to increase general population's awareness regarding the city's air quality, leading to behavioural changes and potentially to:
  - Reduce aggravation of vulnerable groups' health
  - Reduce hospital admissions due to air pollution
  - Reduce human practices that intensify the problem.

Table 2: The European Air Quality Index (EAQI).

Pollutant	Index level (based on pollutant concentrations in μg/m3)				
	Good	Fair	Moderate	Poor	Very poor
PM_{10}	0-20	20-35	35-50	50-100	100-1200
$PM_{2.5}$	0-10	10-20	20-25	25-50	50-800
NO_2	0-40	40-100	100-200	200-400	400-1000
O_3	0-80	80-120	120-180	180-240	240-600
SO_2*	0-100	100-200	200-350	350-500	500-1250

NO_2, O_3 SO_2: Hourly concentrations; PM_{10}, $PM_{2.5}$: 24-hour mean
*SO2 is used if measurements are available

Conclusions

PM_{10} concentrations in Ioannina frequently surpassed the thresholds set by EU, with traffic and wintertime residential heating being the main sources of air pollution. The decrease of conventional fuel used for heating due to high taxation during economic crisis was accompanied by biomass burning contributing to PM enhancement. It is obvious that the operation of a warning system about air pollution conditions is necessary for the prevention of adverse health effects.

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3.3.3 Characterisationn of atmospheric pollution at local scales: Implementaion of a downscaling method

CHARACTERIZATION OF ATMOSPHERIC POLLUTION AT LOCAL SCALES IMPLEMENTATION OF A DOWNSCALING METHOD

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The development of dense urban areas led to increased attention towards local air pollution experienced by the population. The near proximity of urban population and emissions sources, favored by the structure of buildings and the omnipresence of roadways, indeed raises serious concerns about the population's daily exposure to pollutants. In particular, a multitude of studies has shown the important role of road traffic over the past decades. Long-term exposure to pollutants from road combustion such as nitrogen dioxide (NO_2) and particulate matter (PM_{10}) is now recognized to contribute to health degradation with specific impacts on the respiratory system and on the occurrence of cardiovascular diseases. In order to asses health risks, it is essential to be able to describe exposure levels of pedestrians and road users. However, today's current models do not allow the simulation of hourly evolution of these values at street level, for a large domain at once and for a long period of time.

In this work we aim to recreate concentration gradients to calculate the dynamic exposure of individuals by coupling fine scale concentration maps with their daily trajectories.

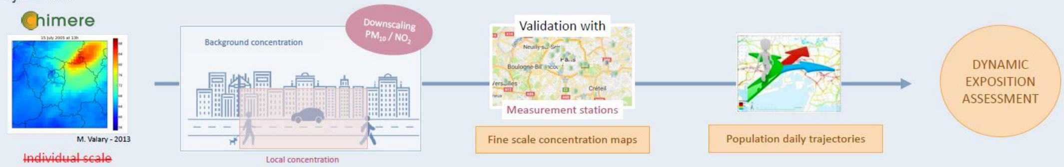


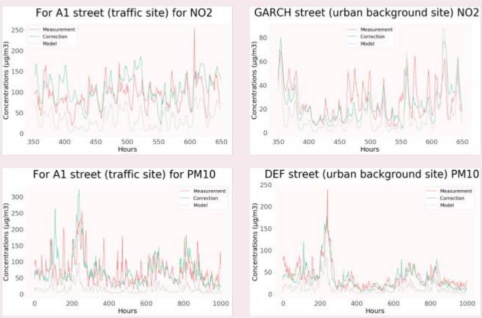
Figure 1 – Successive steps of the modeling process

Downscaling method

The downscaling is done by an iterative python script.
The local pollutant concentration is described as the sum of a background concentration and a local one. A correction coefficient is assigned to each of them. We set up an algorithm that identifies the combination of coefficient that provides the lowest RMSE value when compared with measurements.

$$C_{proximity} = [(C_{bg} * n) + (C_{local} * m)] * [1 + Wind\_condition]$$

Validation: $$RMSE = \sqrt{\frac{\sum (C_{model} - C_{measurment})^2}{N}}$$



NO_2	A1	GARCH
Annual mean concentration (µg/m³)	92.9 28.2 82.6	23.8 14.9 22.7
RMSE	69.6 37.0	16.7 14.0

PM_{10}	A1	DEF
Annual mean concentration (µg/m³)	58.7 10.3 50.5	29.0 9.6 26.1
RMSE	54.0 28.5	24.1 13.8

Figure 2 – Comparison of the temporal evolution of the initial model (grey) vs the corrected one (green) compared to the measurements (red) for two types of sites (traffic and urban background).

The equation has different coefficients depending on the type of site we are considering. Results for both traffic and urban background sites are very satisfactory.

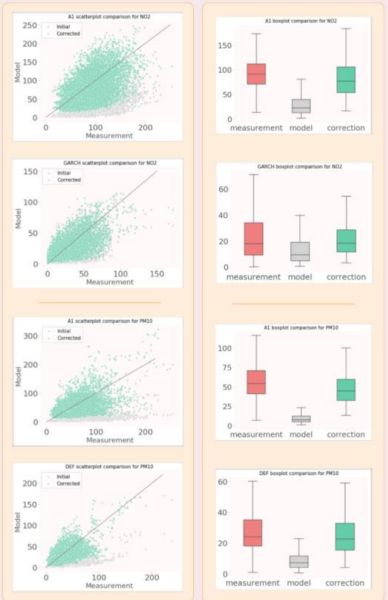


Figure 3 – Scatter plots (left) and boxplots (right) comparing measurements to the initial (grey) and the corrected (green) model outputs.

Dynamic exposure

Fine scale concentration maps will be used to assess the population daily exposure to NO_2 and PM_{10}.
Exposure maps are usually done by coupling concentration maps to population density maps. However, this method doesn't take into account individuals mobility along the day.

It is possible to adjust the exposure assessment by using the mobility matrixes from a model called OLYMPUS to get the population trajectories across the domain in addition to information about the individuals.

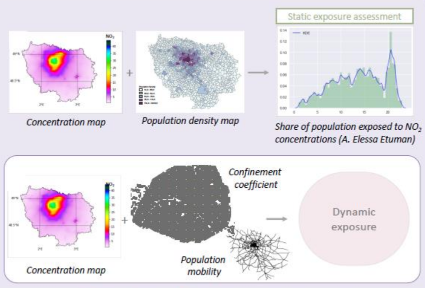


Figure 4 – Method of dynamic exposure assessment.

Acknowledgements and reference

This work is supported by the Val-de-Marne general council (CIFRE grant) and by the French National Agency for Research (ANR-14-CE22-0013).

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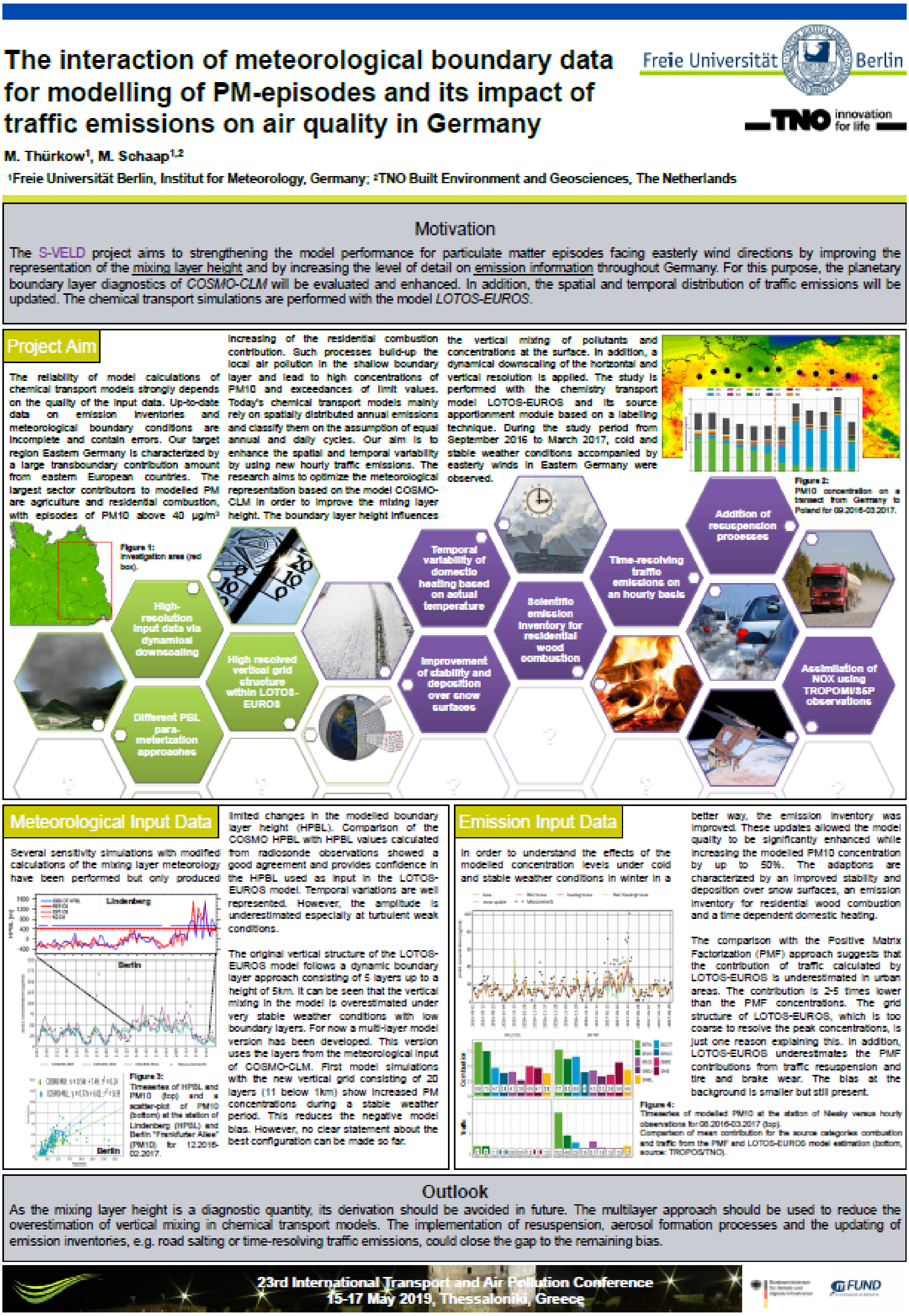
3.3.4 The interaction of meteorological boundary data for modelling of PM-episodes and its impact of traffic emissions on air quality in Germany



The interaction of meteorological boundary data for modelling of PM-episodes and its impact of traffic emissions on air quality in Germany

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[1]Freie Universität Berlin, Institut for Meteorology, Germany; [2]TNO Built Environment and Geosciences, The Netherlands

Motivation

The S-VELD project aims to strengthening the model performance for particulate matter episodes facing easterly wind directions by improving the representation of the mixing layer height and by increasing the level of detail on emission information throughout Germany. For this purpose, the planetary boundary layer diagnostics of *COSMO-CLM* will be evaluated and enhanced. In addition, the spatial and temporal distribution of traffic emissions will be updated. The chemical transport simulations are performed with the model *LOTOS-EUROS*.

Project Aim

The reliability of model calculations of chemical transport models strongly depends on the quality of the input data. Up-to-date data on emission inventories and meteorological boundary conditions are incomplete and contain errors. Our target region Eastern Germany is characterized by a large transboundary contribution amount from eastern European countries. The largest sector contributors to modelled PM are agriculture and residential combustion, with episodes of PM10 above 40 µg/m³ increasing of the residential combustion contribution. Such processes build-up the local air pollution in the shallow boundary layer and lead to high concentrations of PM10 and exceedances of limit values. Today's chemical transport models mainly rely on spatially distributed annual emissions and classify them on the assumption of equal annual and daily cycles. Our aim is to enhance the spatial and temporal variability by using new hourly traffic emissions. The research aims to optimize the meteorological representation based on the model COSMO-CLM in order to improve the mixing layer height. The boundary layer height influences the vertical mixing of pollutants and concentrations at the surface. In addition, a dynamical downscaling of the horizontal and vertical resolution is applied. The study is performed with the chemistry transport model LOTOS-EUROS and its source apportionment module based on a labelling technique. During the study period from September 2016 to March 2017, cold and stable weather conditions accompanied by easterly winds in Eastern Germany were observed.

Figure 1: Investigation area (red box).

Figure 2: PM10 concentration on a transect from Germany to Poland for 09.2016-03.2017.

Meteorological Input Data

Several sensitivity simulations with modified calculations of the mixing layer meteorology have been performed but only produced limited changes in the modelled boundary layer height (HPBL). Comparison of the COSMO HPBL with HPBL values calculated from radiosonde observations showed a good agreement and provides confidence in the HPBL used as input in the LOTOS-EUROS model. Temporal variations are well represented. However, the amplitude is underestimated especially at turbulent weak conditions.

The original vertical structure of the LOTOS-EUROS model follows a dynamic boundary layer approach consisting of 5 layers up to a height of 5km. It can be seen that the vertical mixing in the model is overestimated under very stable weather conditions with low boundary layers. For now a multi-layer model version has been developed. This version uses the layers from the meteorological input of COSMO-CLM. First model simulations with the new vertical grid consisting of 20 layers (11 below 1km) show increased PM concentrations during a stable weather period. This reduces the negative model bias. However, no clear statement about the best configuration can be made so far.

Figure 3: Timeseries of HPBL and PM10 (top) and a scatter-plot of PM10 (bottom) at the station of Lindenberg (HPBL) and Berlin "Frankfurter Allee" (PM10) for 12.2016-02.2017.

Emission Input Data

In order to understand the effects of the modelled concentration levels under cold and stable weather conditions in winter in a better way, the emission inventory was improved. These updates allowed the model quality to be significantly enhanced while increasing the modelled PM10 concentration by up to 50%. The adaptions are characterized by an improved stability and deposition over snow surfaces, an emission inventory for residential wood combustion and a time dependent domestic heating.

The comparison with the Positive Matrix Factorization (PMF) approach suggests that the contribution of traffic calculated by LOTOS-EUROS is underestimated in urban areas. The contribution is 2-5 times lower than the PMF concentrations. The grid structure of LOTOS-EUROS, which is too coarse to resolve the peak concentrations, is just one reason explaining this. In addition, LOTOS-EUROS underestimates the PMF contributions from traffic resuspension and tire and brake wear. The bias at the background is smaller but still present.

Figure 4: Timeseries of modelled PM10 at the station of Niesky versus hourly observations for 08.2016-03.2017 (top).
Comparison of mean contribution for the source categories combustion and traffic from the PMF and LOTOS-EUROS model estimation (bottom, source: TROPOS/TNO).

Outlook

As the mixing layer height is a diagnostic quantity, its derivation should be avoided in future. The multilayer approach should be used to reduce the overestimation of vertical mixing in chemical transport models. The implementation of resuspension, aerosol formation processes and the updating of emission inventories, e.g. road salting or time-resolving traffic emissions, could close the gap to the remaining bias.

23rd International Transport and Air Pollution Conference
15-17 May 2019, Thessaloniki, Greece

3.3.5 Air quality measurements in Stuttgart using tethered balloon

University of Stuttgart Germany | ifk

Institute of Combustion and Power Plant Technology

Prof. Dr. techn. G. Scheffknecht

Federal Ministry of Education and Research

[UC]²: B-3DO

Air Quality Measurement in Stuttgart Using Tethered Balloon

M.Sc. A. Samad, Dr.-Ing. U. Vogt, M.Sc. A. Panta, M.Sc. D. Uprety

- The air quality measurements in Stuttgart are performed under the project "Urban Climate Under Change – $[UC]^2$ " which aims to develop, validate and apply an innovative urban climate model for entire cities
- This project emphasizes to collect comprehensive observation data on weather, climate and air quality in three German cities, namely Berlin, Stuttgart and Hamburg
- The balloon measurements provide the vertical profile of meteorological parameters and air pollutants
- Local flow systems as well as inversion layers and its effect on pollutants are also investigated

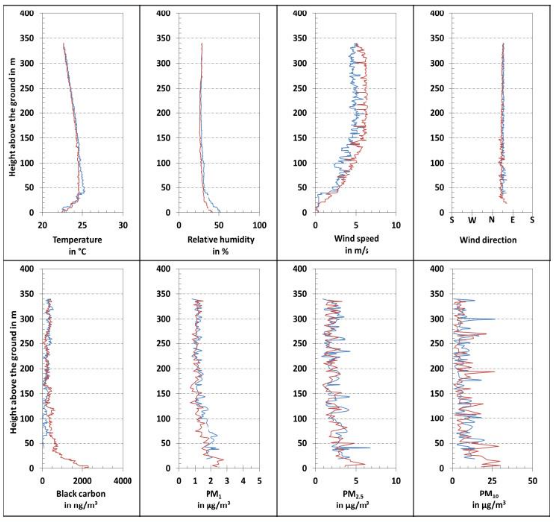
Instrumentation of the Balloon

- **Meteorology:** Wind speed, wind direction, temperature, relative humidity, air pressure
- **Gas pollutants measured:** O_3, NO, NO_2, NO_x
- **Particles measured:** Ultrafine particles (size range 0.01 to >1.0 µm), fine particles (size range 0.3 to 20 µm) and Black Carbon

Results: Vertical Profiles

Balloon measurements performed at “Stuttgarter Schlossgarten” on 08.07.2018. The sounding started at 20:52 CEST and ended at 21:20 CEST. The blue line shows the values during ascent and the red line during descent. The results show the following:

- Temperature inversion at around 50 meters above ground
- Lower wind speeds closer to the ground due to obstacles
- Stable wind direction during the whole sounding
- Relatively higher black carbon and particle concentration near the ground till the inversion layer as compared to the concentrations above the inversion layer
- Stable conditions above the inversion layer for the wind as well as for the pollutants

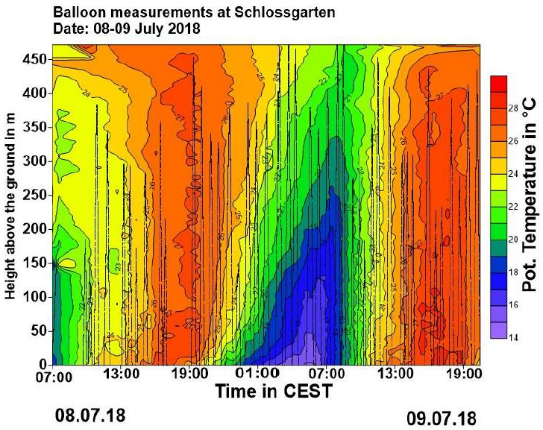


Result: Isopleth

Balloon measurements performed at “Stuttgarter Schlossgarten on 08.07.2018 and 09.07.2018. The isopleth provided an overview during the whole measurement campaign. The potential temperature helps to understand the stability of the atmosphere. The black lines show the actual soundings while the rest is interpolated using kriging model.

- The temperature varied from 14 °C to 30 °C with higher temperatures during the day and lower during the night
- A temperature inversion from the night of 08.07.2018 till the morning of 09.07.2018 was observed
- The height of the surface inversion increased during the night culminating in the elevated surface inversion with a maximum height of 300 m above ground at 07:00 CEST on 09.07.2018
- Stable atmosphere during the inversion period

Potential Temperature Isopleth



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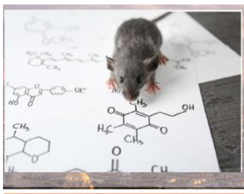
3.3.6 PolluRisk, an innovative platform to investigate the impact of Air Quality on Health: a comparison between Beijing and Paris cases



Pollu-Risk, an innovative platform to investigate the impact of Air Quality on Health: a comparison between Beijing and Paris cases

Patrice Coll[1], Maéva Zysman[2], Mathieu Cazaunau[1], Jean-François Doussin[1], Geneviève Derumeaux[2], Maria Pini[2], Aline Gratien[1], Claudia Di Biagio[1], Edouard Pangui[1], Sophie Hüe[2], Frédéric Relaix[2], Audrey Der Vartanian[2], Paola Formenti[1], Isabelle Coll[1], Gilles Foret[1], Adela Amar[1], Margaux Mäder[1], Cécile Gaimoz[1], Vincent Michoud[1], Jorge Boczkowski[2] and Sophie Lanone[2].

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ABSTRACT: The World Health Organization (WHO) estimated that there were 3.7 million premature deaths due to air pollution in 2014, confirming that air pollution is a great environmental risk to health. Air pollution is responsible for a loss of more than 3% of productivity (via premature death, incapacity for work due to diseases, etc.). The studies conducted so far show that the effects of air pollution on health depend not only on the quality of the surrounding air, but also on the subjects exposed and their individual vulnerability (asthma, COPD, obesity, etc.). Despite the evidence on the adverse health effects of exposure to air micro-pollutants there are still uncertainties about the nature of these effects and progress to be made on their quantification. This limitation of our knowledge is mainly attributed to the complexity of the polluted atmospheres, and to the great difficulty to model the impact of realistic situations of exposure. Among the constituents of air pollution individually associated with deleterious effects on health, we consider gaseous pollutants (O_3, SO_2, CO, NOx, VOC …) and particles (PM10, PM2.5, ultrafine). In order to realistically simulate atmospheric mixtures in all their complexity in the laboratory, environmental chemists have developed photo- reactors that are equipped to reproduce and control atmospheric processes such as solar radiation, concentrations of species and the timely injection of aerosols and gases. These atmospheric chambers thus offer the possibility of studying the myriad of products resulting from the atmospheric oxidation of primary compounds. Using CESAM, an atmospheric simulation chamber (cesam.cnrs.fr), we have developed a totally innovative platform for exposing mice to realistic atmospheric conditions. Here we present the first toxicological analyses of the organs of these mice after 48 hours of exposure, carried out as part of feasibility experiments aimed at testing this experimental concept.

CHALLENGES

It is now recognized that it is necessary to understand our environment in order to be able to isolate its causes of various human pathologies. In this context, the environmental related pathologies are those not associated with genetic or behavioural (e.g. eating or smoking) dispositions or food contamination. On the basis of this definition, chronic pathologies linked to the environment range from hormone-dependent and non-hormone-dependent cancers to developmental diseases, including impairment of fertility, neurological diseases, obesity, cardiological diseases and respiratory diseases, autoimmune diseases, and allergies for example.

Approaches to conducting studies in this area of the toxicological impact of the environment are diverse (i.e. by organ, pathology, source, substance, mechanism, etc). These xenobiotic studies are subdivided into 3 main axes, namely:

- toxicity by chemical reactivity or direct physical interference (the most "classical" route)
- stress adaptation toxicity (metabolic reactions)
- the toxicological impact of homeostasis (endocrinology)

From the point of view of health, the constituents of air pollution individually identified as being associated with deleterious effects are gaseous pollutants (ozone - O_3, sulfur dioxide - SO_2, carbon monoxide - CO, nitrogen oxides - NOx, volatile organic compounds - VOCs, including benzene, etc.) and particulate matter (PM). We distinguish mainly 3 classes of PM concentrations, categorized according to their size: coarse (PM10, diameter between 2.5 and 10 microns), fine (PM2.5, diameter between 0.1 and 2.5 microns) and finally ultrafine (PM0.1, with a diameter of less than 0.1 µm). However, the relevance of an approach based on the study of components isolated from pollution is undermined by the lack of consideration of the suspected synergy between the different constituents of air pollution. Another approach to studying the effects of air pollution on health is to expose living organisms to outdoor air under real conditions. The main defect of this approach is the diversity of pollution rates to which organisms may be exposed, due to the high temporal variability of emission, meteorology and atmospheric dispersion, as well as the difficulty in finely controlling reproducible experimental conditions. A complementary approach is to propose "exposomes", i.e. to realistically simulate, in the laboratory, an atmospheric mixture in all its complexity. In this context, and in order to study the myriad of products resulting from the atmospheric oxidation of primary organic compounds, environmental chemists have developed atmospheric simulation chambers. These chambers are equipped with photo-reactors, with protocols that mimic atmospheric conditions such solar radiation, realistic concentrations, the injection primary aerosols and the formation of secondary aerosols.

The LISA (Interuniversity Laboratory for Atmospheric Systems, UMR CNRS 7583) has been developing such equipment for more than twenty years and has become a world- renowned player in experimental atmospheric simulation (for example, LISA coordinates the European infrastructure network of atmospheric simulation chambers, EuroChamp 2020 (www.eurochamp.org)). In the early 2010s, LISA in particular completed the development of the CESAM chamber (http://cesam.cnrs.fr), which now has the status of National Instrument INSU/CNRS, to study multiphase atmospheric chemistry by controlled generation of particulate pollution mixtures. It is this reactor with its unique performance that we use as part of our PolluRisk project (Fig. 1).

Figure 1: atmospheric experimental simulation using the CESAM chamber (cesam.cnrs.fr)

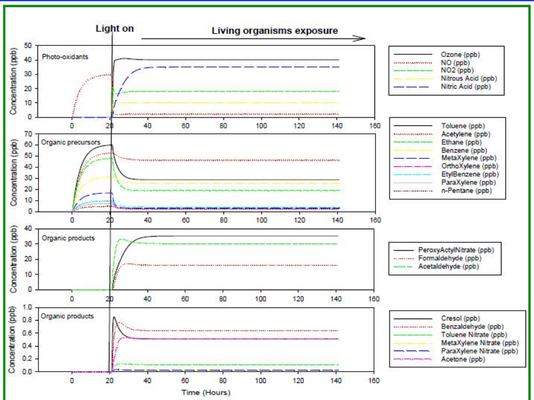

Figure 2: Numerical modelling of the chemical activity inside CESAM chamber, describing the photo-stationary concentrations for the photoproducts (as cresol or acetone plot on bottom graph), 20 hours later than the injection of 9 precursors.

INNOVATIVE PROTOCOL (Fig 4.)

The innovative approach we set up to support such studies is to realistically simulate, at the laboratory, the atmospheric mixture in all its complexity, thus keeping the ability to control, reproduce and carefully characterize the experimental conditions. We used the CESAM chamber (4.2 m^3 stainless steel atmospheric simulation, evacuable down to a few 10^{-7} atm, temperature controlled between +15°C and +60°C) in order to study the myriad of products arising from the atmospheric oxidation of primary organic compounds.

The experimental protocol consists in the continuous injection of relevant mixtures of primary pollutants (mainly nitrogen oxides, organic compounds from a representative mix of anthropogenic emissions, sulphur dioxide, soot, inorganic salts and potentially mineral dust particles if needed - e.g. to simulate Beijing's atmosphere -) at low concentrations (ppb levels) in air in the CESAM simulation chamber operated as a slow flow reactor. The residence time of simulated air parcels in the experimental volume is fixed to 4 hours, in order to represent air masses of regional scale. During this time the synthetic mixture is exposed to an artificial solar irradiation, allowing secondary pollutants such as ozone, nitric acid, formaldehyde, peroxyacetyl nitrate (PANs) as well as complex polyfunctional organics including SOA (Secondary Organic Aerosol) to be produced and to reach their chemical steady state. Living organisms are exposed to constant flows of such a mixture during time scales of week to test their effect on living organisms.

In order to scale the pollutant concentrations in the initial mix, we were able to run a predictive model to estimate the concentrations of all gaseous and particulate species in CESAM, after a residence time of 4 hours in the chamber. Below is an illustration of such a modelling in the case of an atmosphere relevant to the Paris area (Fig. 2).

The model takes into account the injection of 9 precursors (gaseous chemicals) in the simulation chamber: nitrous acid, toluene, acetylene, ethane, benzene, meta-xylene, ortho-xylene, para-xylene, ethyl-benzene and n-pentane. After 20 hours of flowing and mixing in the chamber (this duration can be reduced to some hours by increasing the concentrations and flows of precursors) the targeted concentrations of pollutants are obtained (here in reference to what was measured on the field by [4]). Then the light simulating the sunlight irradiation is switched on, and taking into account in the order of 1500 reactions involving around 3000 chemicals the model predict what will be the photo-stationary concentrations in the chamber for any of those photoproducts. We then plot some of them as an illustration, as cresol or acetone (bottom graph).

Once the requested steady-state CESAM experimental conditions are reached then a desired volumetric flowrate is transferred to the compartment where the living organisms are exposed, due to a pressure of 11 millibars inside CESAM. In each experiment, the compartments undergo a constant air flow from the simulation chamber. Furthermore, we make sure the path between the chamber and the exposure devices is minimized, in order to preserve the numerous reactive chemicals present in the simulated atmosphere.

The CESAM laboratory is equipped with a comprehensive set of analytical instruments and benefit from the instrumental environment dedicated to atmospheric chemistry provided by CNRS-LISA (http://www.cesam.cnrs.fr), especially gaseous pollutants analysers (O_3, NO, NO_2, SO_2, CO, CO_2, COV…) and aerosols properties (mass and size distributions, hygroscopicity…). This allows us to accurately and precisely measure the time evolution of the pollutants concentrations within the different exposure compartments, as shown in the Fig. 3 for aerosol particles:

There are three different ways to introduce solid particles in the CESAM chamber:

a) inorganic aerosols : inorganic particles are continuously injected in CESAM from a salt(s) solution (e.g. $(NH_4)_2SO_4$ solution in the $10^{-4}/10^{-3}$ Mol.l^{-1}) using a commercial atomizer (TSI 3076 atomizer), with a transfer rate to CESAM relevant to the targeted final concentration.

b) Soot introduction: for the control of continuous soot introduction in CESAM, a second chamber is used as a "soot reservoir". This chamber will be named "CAC" ("CESAM Auxiliary Chamber") in the rest of the text. CAC has a volume of 2 m^3 and is equipped with a pumping system, a fan and a 0-1000 Torr pressure sensor. It is directly connected to CESAM by a 1/4 "Stainless Steel tube. During the introduction of soot into the tank enclosure, the two chambers are isolated from each other. The use of a miniCAST (model 5201A) allows us to fill the tank enclosure with a known mass of soot. This quantity is determined according to the final quantity desired in CESAM. When the introduction is complete, the two chambers are connected and a fixed nitrogen flow allows the introduction of soot continuously from the CAC to CESAM. The frequency of introduction of soot by the CAST is determined according to the dilution rate in CESAM.

c) dust particles : about 15 g of soil sample (Gobi desert soil in the case of Beijing's simulation) is placed in a Büchner flask and shaken for about 30 min at 100 Hz by means of a sieve shaker (Retsch AS200). The dust suspension in the flask is then injected into the chamber by flushing it with N_2 at 10 L min^{-1} for about 10–15 min, whilst continuously shaking the soil. This injection is done as needed (for the example of our Beijing's simulation it is once per day, as a simulation of a daily dust storm arising Beijing.

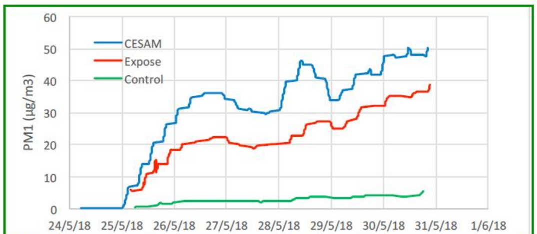

Figure 3: Evolution of the total particles concentration as a function of time, successively measured in the different compartments: in blue in CESAM chamber, in red in the compartment where living organisms are exposed, in green in the "reference" compartment.

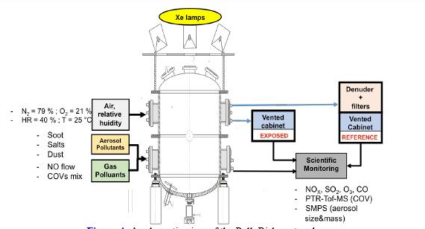

Figure 4: A schematic view of the PolluRisk protocol

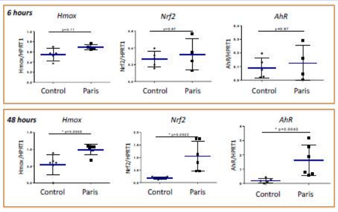

Figure 5: In the lung, few modifications were observable after 6 hours of exposure, but a typical response attesting the presence of oxidative stress (increased expression of Hmox and Nrf2) and xenobiotics (Ahr) was detected at 48h.

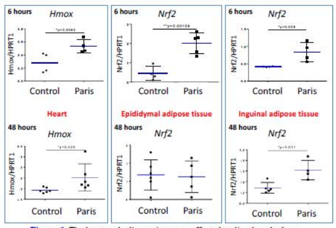

Figure 6: The heart and adipose tissue are affected earlier than the lung.

PRELIMINARY INVESTIGATIONS/RESULTS: Taking benefit of this PolluRisk platform, we ran an experiment (reproduced 2 times) where murine models have been exposed to a Paris simulated atmosphere for 48h. Mice were separated in 2 different batches. One was exposed in a dedicated compartment to the atmosphere directly arriving from CESAM (see upper section), and the other exposed in another dedicated compartment to a "reference atmosphere" (Atmosphere from CESAM passing through several filters removing all micro-pollutants, both in gaseous and atmospheric phase). In each compartment, animals were installed in exposure cages (5 adults maximum per cage), provided by ©Techniplast. These cages contain clean litter, and the animals were supplied with water (baby bottles) and food. The exposure time was 2 days, which did not require the change of animals between the beginning and the end of the experiment. The temperature and hygrometry inside the exposure chamber were monitored continuously (in the range [30%-50%] for the relative humidity and in the range [21°C-26°C] for the temperature). On the other hand, a day/night cycle of 12 hours was simulated with lights located inside the exposition enclosure. An orifice in the door of the exposure chamber makes it possible to check the activity of a cage (which serves as an "activity indicator" for all the stands) continuously. Throughout the exposition, the animals were monitored by means of cameras present inside the exhibition hall. If an anomaly was observed (lack of movement of the mice, insufficient food or water, signs of distress etc), the enclosure was opened and action taken to correct the anomaly. Fig. 5 and Fig. 6 summarize part of the results that mainly concern toxicological analyses of organs or tissues sampled on mice after their exposure.

Ethics: The project (file number 17-087, n°APAFIS 2017113013439718) received a favourable opinion from the ComEth on December 12, 2017. The project is valid for 5 years.

Acknowledgements : This project/work has received funding from the European Union's Horizon 2020 research and innovation programme through the EUROCHAMP-2020 Infrastructure Activity under grant agreement N° 730997. We also thank CNRS/INSU, INSERM, Région Ile de France and UPEC.

3.3.7 Ultrafine particles measurement in Wallonia, Belgium

Ultrafine Particles Measurement in Wallonia, Belgium

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1. Context

UFP (Ultrafine Particles) measurement has been developed recently in the air quality networks in Europe. UFP are particles with a diameter smaller than 100 nm. UFP, contrary to PM10 and PM2.5 particles (defined as the fraction of particles with an aerodynamic diameter smaller than respectively 10 and 2,5 µm), are currently not subject to a limit value in ambient air at European level. This lack of standard is due, in particular, to the lack of epidemiological studies and constant monitoring of UFP in European air quality networks. Although UFP contribute only slightly to PM10 and PM2.5 mass fraction, they represent more than 85 % of PM2.5 particle number [1]. This high number concentration combined with a large surface-to-mass ratio results in a large bio-available surface and therefore to greater availability to adsorb or condense toxic air pollutants (oxidizing gases, organic compounds and metals) on the particle surface [2].

ISSeP (Institut Scientifique de Service Public), in charge of the air quality network in Wallonia (Belgium), has been measuring continuously UFP (ultrafine particles) in a rural background station since 2013. This station is equipped with a IFT-SMPS analyzer. The measurement range is from 10 nm to 850 nm. Two mobile stations (trailers) were also equipped with this type of SMPS and have been set up on several places in Wallonia (urban background, city center and close to a motorway) in order to determine UFP number concentration and size distribution. Results obtained during these studies were compared in order to characterize the different environments regarding UFP issue. ISSeP is also equipped with a portable SMPS (TSI 3910) to perform indoor air measurements and to study ultrafine particle transfer that may occur between outdoor and indoor environments. It was also important to assess the comparative reliability of these different instruments to ensure the quality and comparability of the data gathered.

2. Instrumentation

ISSeP uses two IFT-SMPS whose operating diagram is shown in Figure 1. Their measurement range vary from 10 nm to 850 nm. These SMPS are regularly calibrated by their manufacturer TROPOS (Leibniz institute for tropospheric research). Various factors (line length, curves, sampling line diameter, flow rate, etc.), which can lead to losses during sampling, are studied and taken into account when processing data. In addition to these calibrations, trailers equipped with these SMPS are compared each other before installation to ensure the validity of the whole equipment (SMPS itself and the sampling line).

In order to measure UFP both in indoor and outdoor environments and to highlight possible transfers from one environment to the other, ISSeP acquired a second model of SMPS, TSI 3910 (Figure 1). This device can measure UFP from 10 nm to 420 nm. It is calibrated every year by the manufacturer TSI. SMPS TSI 3910 was compared with one of IFT-SMPS (Figure 2). A good correlation for total particles count is observed whereas channel-to-channel counting shows some differences in the extremities of the size distribution.

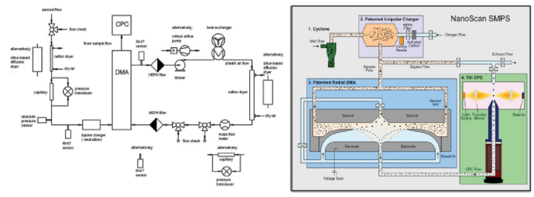

Figure 1 – Schematic overview of the IFT-SMPS (left) [3] and SMPS TSI 3910 (right) [4].

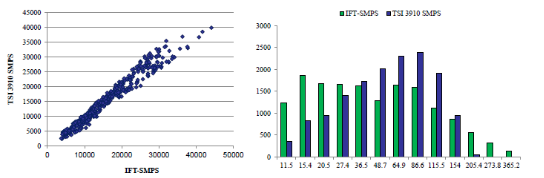

Figure 2 – Comparison of total particles count between IFT-SMPS and TSI 3910 SMPS. Coefficient of determination is 0.97 (left). Particle count average per channel for the two types of SMPS (right).

3. Measurements in Wallonia

3.1 Levels and size distribution comparison between locations

Measurement stations equipped with IFT-SMPS were placed during long periods (at least one month) in different environments in Wallonia. A first site is located in Liège and can be described as an urban background. A second station was set up near a busy crossroads in Namur City. Finally, two stations were placed 5 meters away on both sides from the E411 motorway (linking Namur and Brussels). Figure 3 shows UFP mean levels obtained for these different sites compared to those obtained with comparable measurement instruments on three other European sites classified as urban background (Amsterdam, Leicester and London) [5]. There is a good correlation between UFP levels and the type of studied sites. The size distribution of UFP varies from site to site (Figure 4). Proportion of very small particles increases as a function of traffic exposure and especially for the 10-20 nm fraction. UFP data were also compared to conventional measured parameters such as nitrogen oxides or *black carbon*.

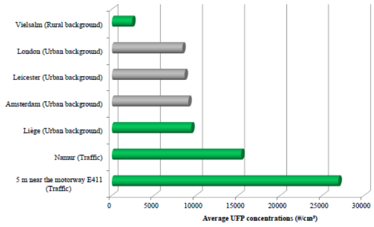

Figure 3 Total UFP measured at four sites in Wallonia (in green) compared to those obtained at three sites in the study of J. Hofman et al. (2016) (in gray).

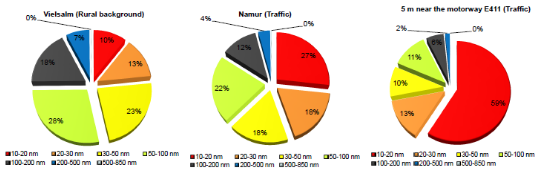

Figure 4 – Size distribution (%) for a rural background station (left), Namur (city center) and 5m away from a motoway (right).

Average daily profile of UFP concentrations calculated for Namur and E411 sites show a traffic-related profile with well-marked morning and evening peaks and intermediate concentrations during midday (Figure 5). When UFP levels increase, a decrease in the average particle size is observed. The particle size average is lower along the motorway than in Namur city center. These results could be explained by the variety of sources encountered in an urban center compared to the almost exclusive source of traffic at the edge of the motorway.

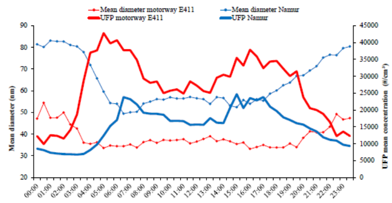

Figure 5 – Average daily profile of total UFP concentrations and average diameter for Namur city center station and those located near the E411 motorway.

3.2 Outdoor/indoor air transfers

A series of measurements were carried out to evaluate UFP transfers between indoor and outdoor environments. Two IFT-SMPS-equipped stations were placed outside an administrative building in which portable SMPS TSI 3910 was placed. Results show a difference between concentrations measured inside and outside (Figure 6). Average UFP concentrations outside are 15 % higher than those observed inside. This difference is particularly marked during the morning peak related to the resumption of human activities. During measurements, the room's ventilation has been stopped twice. A clear decrease (60 %) in concentrations is observed during these episodes. Once aeration restored, concentrations measured in the room quickly return to their usual values.

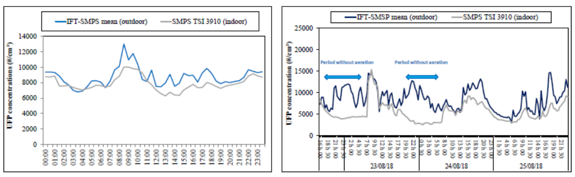

Figure 6 – Average daily profile of outdoor vs indoor UFP concentrations (left). Evolution of outdoor vs indoor UFP concentrations (right).

4. Conclusion

UFP levels measured in various locations in Wallonia are comparable to those obtained for the same type of environment in other european countries. UFP levels and size distribution vary greatly from site to site. Of course, closest the site is to a traffic source, higher UFP concentrations are. But the most interesting fact is that this observation can be explained by an increase of the 10-20 nm range concentrations, the main part emitted by traffic. This result shows the importance of measuring this fraction in environments under traffic influence. Now, ISSeP wants to investigate more precisely UFP transfers issues, between outdoor and indoor environment, as well as UFP sources characterization for the whole territory.

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3.3.8 Road traffic vs. waste incineration: local-scale air quality impact assessment at municipality level in Northern Italy

23rd International Transport and Air Pollution Conference 15-17 May 2019, Thessaloniki, Greece

Road traffic vs. waste incineration: local-scale air quality impact assessment at municipality level in Northern Italy

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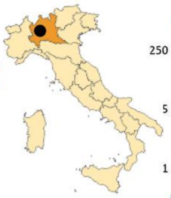
Background & scope

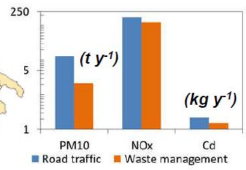
- Waste-to-Energy (WtE) plants frequently face strong protests from local communities because of the concern on possible adverse health effects due to the emission of organic and inorganic toxic pollutants
- Risk perception in most of the public opinion is biased by a number of factors because proper environmental education (i.e.: levels of risk awareness and knowledge) is still scarce
- A correct perception of the risk can profitably derive by the comparison of the real impact of WtE plants on local air quality with the impact of other common sources (e.g.: road traffic, domestic heating through biomass burning), not perceived by the public opinion as a threat for human health
- This work is intended to:
  - assess the actual impact of a WtE plant on local air quality based on its real emission data;
  - compare the impact on local air quality of the WtE plant emissions with the impact of road traffic

Study area

Desio municipality: a 40000-dweller town, about 15 km North of Milan in Lombardy region



Annual emission in Desio

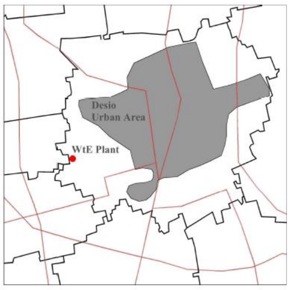


Methods

Road traffic emissions

- Split between main road traffic and urban traffic
- Dedicated study for traffic flows on the main roads in and around Desio, based on both transport supply system data (road network structure) and mobility demand data (O-D trip matrix)
- Hourly emissions from traffic flow data and emission factors data
- Urban traffic emissions = inventory data for traffic - main road emissions

Study area



Fleet-averaged emission factors

	Cars	LDV	HDV
PM10 (*) (mg km^{-1})	39.9	77.4	217.9
NO_2 (**) (mg km^{-1})	152.8	347.9	598.3
Cd (**) (µg km^{-1})	0.7	0. 9	2.4
PCDD/F (***) (pg$_{TEQ}$ km^{-1})	21.3	39.6	49.4

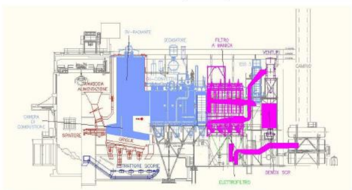
(*) Lombardy region emission inventory (ARPA Lombardia, 2018)
(**) Road traffic emissions factors database in Italy (ISPRA, 2017)
(***) EMEP/EEA emission inventory guidebook 2016 (EMEP, 2016)

Road traffic emissions in Desio

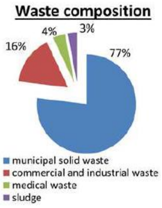
	Inventory	Main roads	Urban traffic
PM10 (t y^{-1})	12.9	9.2	3.7
NOx (t y^{-1})	168.1	116.2	51.9
Cd (g y^{-1})	222	144	78
PCDD/F (mg$_{TEQ}$ y^{-1})	-	4.5	1.8 (*)

(*) No inventory data for PCDD/F. Estimated based on PM10 data

WtE plant emissions



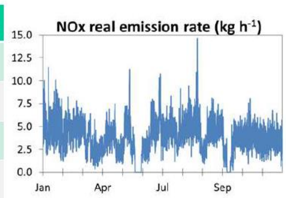
Waste composition



- WtE plant (200 t day^{-1}) with two combustion lines operating with Combined Heat and Power energy recovery scheme
- Flue gas dry treatment line: electrostatic precipitator + baghouse filtration unit; double alcali injection system for acidic gases control; activated carbon injection for dioxins (PCDD/F) control; two-stage SNCR/SCR system for NOx control
- Real emission data from the 2017 emission monitoring system records: flue gas temperature and speed, PM10, NOx, Cd, PCDD/F hourly concentrations

WtE plant real emission rates

	Annual mean	Range	Max Auth.
PM10 (g h^{-1})	20.9	1.4 - 72.7	1,100
NOx (kg h^{-1})	4.0	0.2 - 14.5	22
Cd (mg h^{-1})	22.2	4.5 - 29.4	5,500
PCDD/F (ng$_{TEQ}$ h^{-1})	39.9	1.8 - 110.2	11,000



Results and conclusions

- CALPUFF air quality model simulations for year 2016
- Sources' contributions to annual average concentration levels
- WtE plant's emissions do affect the air quality in the urban area of Desio

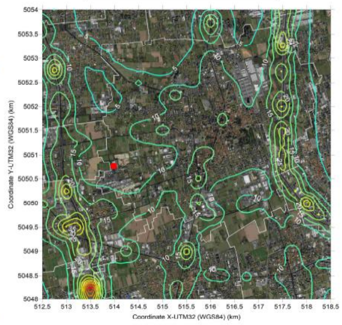
Range of contributions from WtE plant and road traffic: annual average concentrations in Desio residential area

	PM10 (µg m^{-3})	NO_2 (µg m^{-3})	Cd (ng m^{-3})	PCDD/F (fg$_{TEQ}$ m^{-3})
WtE plant	2 - 3.5 (x10^{-4})	5 – 7 (x10^{-2})	3 - 4 (x10^{-4})	5 – 7 (x10^{-4})
Road traffic	4 - 6	10 - 15	0.06 - 0.08	1.3 - 2.2
AQ limit (annual avg.)	40 (*)	40 (*)	1 (*)	150 (**)

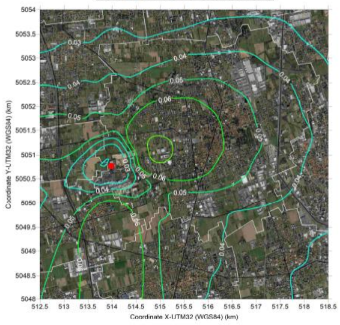
(*) Directive 2008/50/EC (**) German Länderausschuss für Immissionsschutz

NO_2 annual average concentration (Desio 2016: 46.4 µg m^{-3})

Road traffic contribution



WtE plant contribution



- The real emissions from WtE plant are well below the authorized values: on average, 5.5 times less for NOx, 52 times less for PM10, 250 times less for Cd, and 275 times for PCDD/F
- In the residential area of Desio:
  - road traffic impact on air quality for any of the investigated pollutants is at least two orders of magnitude higher than the impact of the WtE plant
  - on annual average basis, road traffic is responsible for about 20% of NO_2, for 10% of PM10 and Cd, and from a few percentage points up to 20% of PCDD/F

3.3.9 Using Python and the RapidAir dispersion model to simplify air quality modelling

Using Python and the RapidAir dispersion model to simplify air quality modelling

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Ricardo Energy and Environment

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Introduction

There is an increasing amount of data available for air quality studies, driven by the desire to achieve both high spatial and high temporal model estimates of pollution. This volume of data can be a challenge for data management, manipulation and interpretation.

Python has many packages allowing simple but powerful solutions to be produced in a few lines of code. This allows complex calculations and data transformations to be carried out reproducibly and for large volumes of data with minimal user input after initial development and QA of the code. There are also geospatial packages to allow manipulation of spatial data.

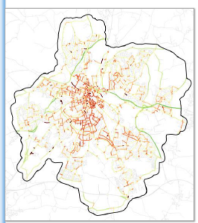
Benefits of Python include:

- Open source
- Active online community
- Flexibility
- Reproducible
- Reusable solutions
- Efficient

Traffic model processing

Traffic models and GPS (e.g. speed) data are often used as inputs to air quality models. This data can be messy, mixed numerical and string formats, many rows and not in the correct input format for use in the later steps of the modelling process.

The key package to manipulate data formats is **pandas**



1) Load GPS speed data in pandas

```
traffic_master_data = dd.read_csv('TrafficMaster/*.csv')
```

2) Merge GPS observations to roads using link_ids

```
model_link_toids = link_refs.merge(traffic_master_data,
                    on = 'link_ref',
                    how='left')
```

3) Convert journey time to speed

```
model_link_toids['Speed_kph'] =
            (model_link_toids['length(m)'/1000]) /
            (model_link_toids['av_JT']/360000)
```

4) Calculate average speed on link

```
grouped_model_link_toids =
            model_link_toids.groupby(['link_ref'])
```

Reduced >130 million traffic speed observations into 4800 link specific average speeds for use in emissions calculations.

	link_ref	count	mean	std	min	25%	50%	75%	max
0	5263705	1.0	29.000456	NaN	29.000456	29.000456	29.000456	29.000456	29.000456
1	5263706	0.0	NaN	NaN	NaN	NaN	NaN	NaN	NaN
2	5301732	1867.0	33.301271	13.792499	0.500000	25.002007	37.005348	43.011050	79.948652
3	5301733	3897.0	34.665771	12.010428	0.500000	26.004175	36.000000	43.011050	73.012896
4	5301828	6388.0	31.998397	15.005594	2.000000	20.000000	32.304856	42.993865	80.986133

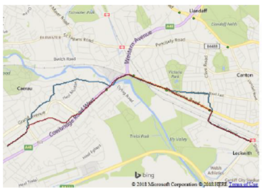
Similar processing can be used to process Automatic Number Plate Recognition camera data to capture detailed information about local fleet.

Output is clean dataset in correct format ready for emissions calculations

Route planner

A routing algorithm has been developed using the **skimage** package. Two routes are produced between the points – one with lowest pollution and another with shortest distance.

1. All the points connected to the start coordinate are identified
2. If one of these is the target end point the search stops.
3. If none of these are the end point step 1 is repeated using the newly identified nodes as a starting point until the end point is reached.



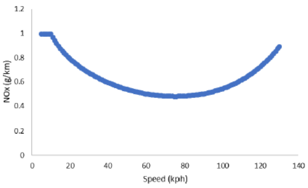
A 'cost' is calculated for each route which is either distance, or pollution, and this is minimised during the route generation.

The red route shows the shortest distance between the points, while the blue route shows the route with the lowest pollution.

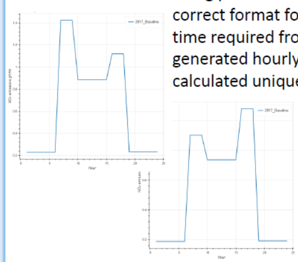
Emissions processing

Calculations of unique emissions for individual road links can be computationally challenging, especially if pre- and post- processing of data is required.

Functions describing the relationship between emissions and speed for > 150 vehicle classes. **pandas.merge** is then used to match the speed and vehicle data to the activity data.



The emissions can be joined to a shapefile using **geopandas.merge**

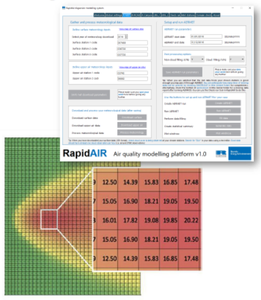


Using pandas to manipulate the traffic data into the correct format for emissions calculations minimises time required from user to create inputs. We have generated hourly traffic inputs using Python and then calculated unique emissions for each link every hour.

A key package is **shutil.copyfile**, which is used to move files to required locations for calculations and then backing up the results of the emissions calculations

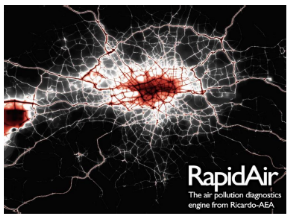
RapidAir® dispersion model

The drive for highly spatially resolved concentrations adds computational time to modelling when modelling city-scale concentrations. RapidAir[1] has been developed to model city-scale concentrations at high (< 5 m) resolution. The RapidAir model is well suited to scenario development and testing as a result of the fast run times



1. Calculated shapefile of emission are transformed into gridded emissions using **gdal**
2. A dispersion kernel is generated from AERMOD
3. The kernel is passed over every cell in the emissions raster using **scipy.fftconvolve**
4. Street canyon concentrations can be calculated using pandas if required, and combined using **gdal**

This produces concentration estimates for every cell in the study domain. For example, 3m concentration estimates can be produced for London in less than 10 minutes.



1 Masey, N., Hamilton, S., Beverland, I. (2018) Development and evaluation of RapidAir® dispersion model, including the use of geospatial surrogates to represent street canyon effects *Environmental Modelling & Software* **108** 253-263

Conclusions

Some applications of Python in air quality studies are highlighted in this poster. These are in no way exhaustive but aim to highlight the variety of applications Python can be applied to.

Many of the methods shown here would not be possible with traditional analysis methods.

Python gives the freedom to develop your own methods and apply these reproducibly to multiple datasets.

3.3.10 Simultaneous analysis of emission of air pollutants in Brazilian urban roads

SIMULTANEOUS ANALYSIS OF EMISSION OF AIR POLLUTANTS IN BRAZILIAN URBAN ROADS

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Department of Transportation Engineering, Federal University of Ceará, Fortaleza, Ceará, Brazil

GTTEMA
Grupo de Pesquisa em Transportes, Trânsito e Meio Ambiente

1. Introduction

The growing number of vehicles, mainly of the flex fuel type, which now accounts for 35% of the Brazilian fleet, associated with inefficient urban planning, generates several negative impacts on society, especial ly regarding air quality due to emission of air pollutants through combustion. This emission is associated with the interaction of the vehicle dynamics with the environment and it is influenced by several other factors.

2. Objectives

This research proposes evaluating the influence of road functional classification on this dynamic, considering areas of different urban densification, land use patterns and variation in the period of the day for the formation of vehicular emissions.

3. Methodology

On-board collections were carried out in the field using an OBD and a PEMS to obtain real instantaneous vehicular parameters, and CO_2 and NO_x emissions in two areas of Fortaleza-CE/Brazil (Figure 1), considering:

- Area 1: less densified and with more mixed land use;
- Area 2: more densified with more commercial land use;
- Three types of roads: arterial, collector, and local;
- Two periods of the day: peak and off peak.

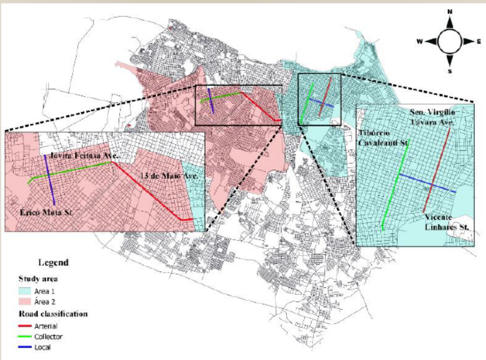


Figure 1. Study Area

4. Results

Figure 2 displays the average emission factors obtained for Area 1, and Figure 3 for Area 2.

It is observed that arterial roads present more constant CO2 emissions in both areas, whilst collector and local roads present higher variation, but with a different profile of average emission depending on the area. In Area 1, collector and local roads presented a similar profile to arterial during off-peak, displaying a growth on peak period. In Area 2, they presented the opposite behaviour.

However, hypothesis testing (α=5%., H0: μ1-μ2=0) did not provide sufficient evidence to reject the null hypothesis in any case. This may be explained by a higher frequency of stop-and-go events on local and collector roads that result in higher emissions and offset the higher volume in arterial roads.

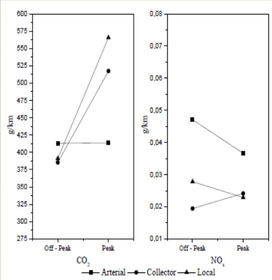


Figure 2. Emission values for Area 1

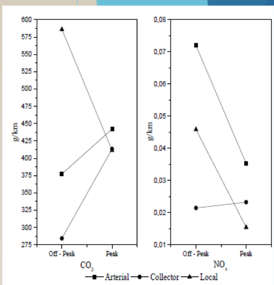


Figure 3. Emission values for Area 2

Regarding NO_x emissions, it is observed that Area 1 presented a more constant profile, comparing roads and times of the day, while Area 2 presented more variations. Despite of the area, collector roads did not vary their emissions significantly. This may be explained by the moment of collections in each road, with which may vary the concentrations of NO_x in the atmosphere (Gasmi et al., 2017), consequently in the admission air, which may increase the concentration emitted..

- Urban density was not sensitive to compare regions of different densities, but provided indications of vehicular behaviour in the roads.
- In commercial/mixed lots and after signalized intersections, there were peaks of CO_2; stop-and-go events interfered with NO_x, but the variation of it was more sensitive to the time of collection.
- Arterial roads suffered little influence over time, as opposed to collector/local roads.

5. Conclusion

It is concluded that an aggregated analysis may not provide sufficient sensitivity regarding the behaviour of emissions due to the type of road since it disregards characteristics of the region and the surroundings of the road, which have proved to be important in this phenomenon

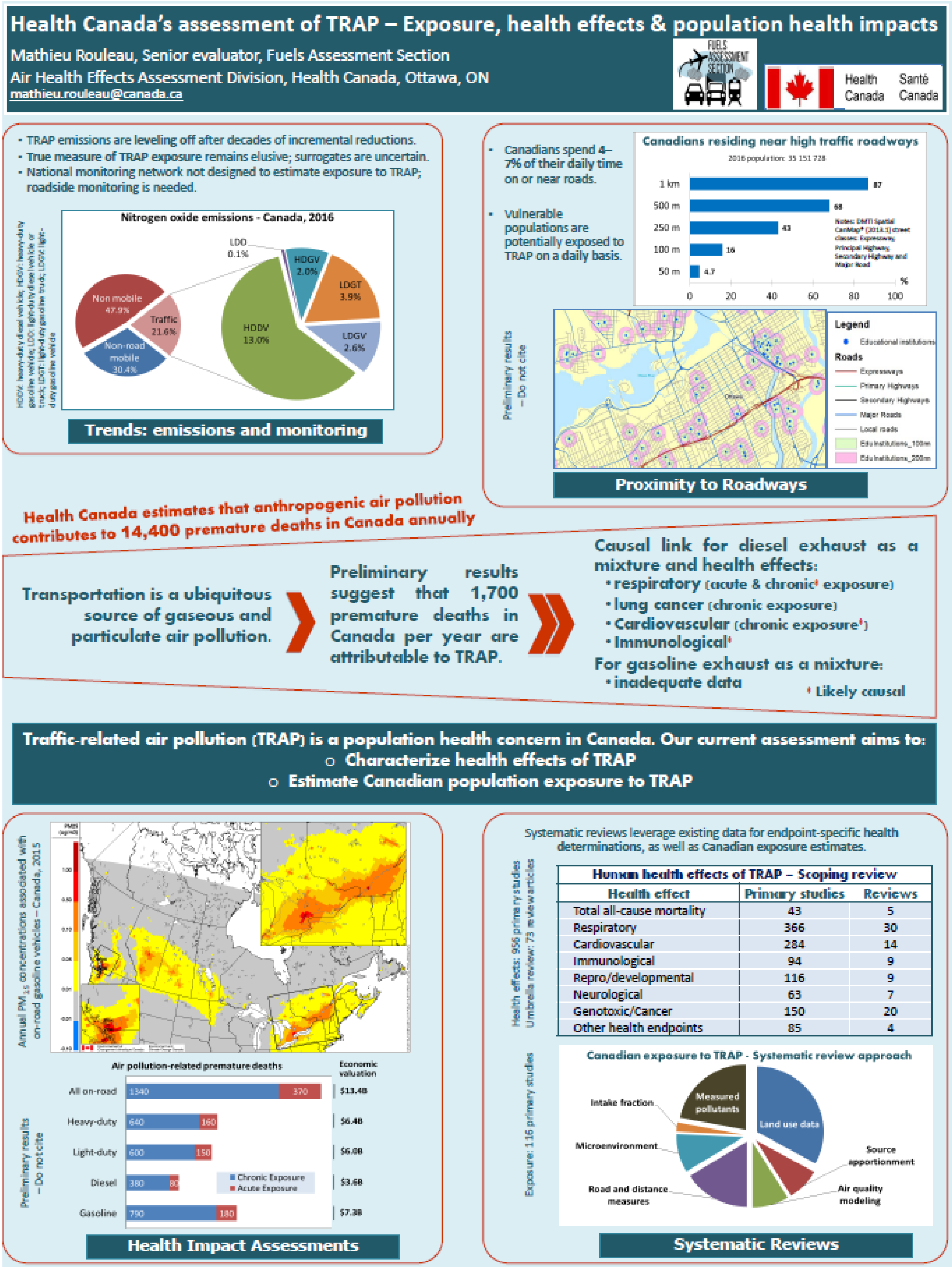
6. Acknowledgements

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001, CNPq and supported by Cobli.

7. References

Gasmi, K., Aljalal, A., Al-Basheer, W., Abdulahi, M. (2017) Analysis of NOx, NO and NO2 ambient levels in Dhahran, Saudi Arabia, Urban Climate.

3.3.11 Health Canada's assessment of TRAP – Exposure, health effects & population health impacts



3.3.12 Project Borée: controlling road-tunnel ventilation by means of a network of microsensors, in order to reduce the exposure of the local population to pollutants Background and methodology

Project Borée

Controlling road-tunnel ventilation by means of a network of microsensors, in order to reduce the exposure of the local population to pollutants

Background and methodology

M. Yaghzar[1], B. Vidal[1], J.F. Burkhart[1], D. Robin[2] and S. Castel[2]

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The over-ventilation of road tunnels to disperse discharges and so reduce the impact of tunnel pollution on the areas around their portals is one of the first measures to be considered for the management of air quality. However, this strategy for dispersing pollutants has never been implemented in conjunction with the continuous measurement of pollution levels in the neighbourhood potentially impacted by tunnel discharges. Recent advances in metrology mean that today a complete over-ventilating system can be put in place using measurements from sensors on the exterior of the tunnel.

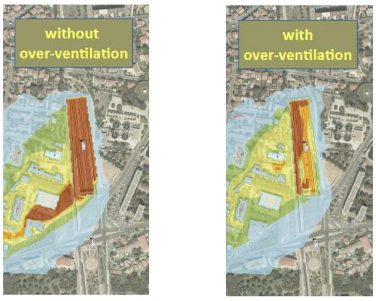
Rocade L2 – High traffic – Highly urbanized area - Marseille

The Rocade L2 is a 10 km ring road that connects the A7 motorway (north of Marseille) to the A50 motorway (to the East) in order to bypass the city centre.

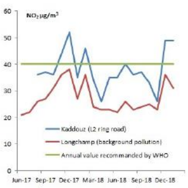
- 8 cut-and-cover tunnels
- L2 East opened in November 2016
- L2 North opened in October 2018
- More than 100 000 vehicles/day in both directions

Many sensitive sites in terms of air quality: establishments receiving the public (primary school, crèche, middle school), numerous professional or commercial buildings, and a large population living in the vicinity of the tunnel portals.

Impact of Montilvet and Saint-Barnabé cut-and-cover tunnels on the quality of the air



CFD modelisation of NO_2 concentrations around the portal of the Montolivet cut-and-cover tunnel in particular wind conditions (1,5 m/s NE) without (left) or with (right) over-ventilation of Montolivet tunnel
Source : the state commitments monitoring committee on July 7, 2016



Background pollution / Rocade L2 comparison

Near the portal, pollution levels are on average 10 µg/m³ higher than the background level over the agglomeration.

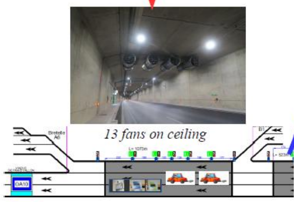
Test of an impact reduction system by using over-ventilation

South portal of Montolivet cut-and-cover (1 075 m)

The most innovative aspect of the experiment is the automatic control of tunnel ventilation based on real-time measurements of NO_2 concentrations taken around the southern portal.

Centralized technical management / Oversight

Activation of ventilation



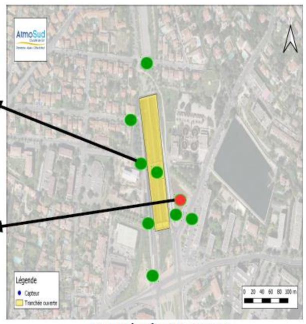
13 fans on ceiling

NO2 levels around the portals

Pollutant levels inside tunnel

AQ mesh sensors

Kaddouz measuring station



Network of microsensors

The project initially intends to test the system, with a focus on both its conditions of implementation and its effectiveness, by forcing the ventilation at given times before engaging automatic mode so that the ventilation is set according to the measurements of NO_2 concentrations taken on the outside.

Planning

May-October 2019 Phase I Exploratory measures without over-ventilation	→	November 2019-April 2020 Phase II Measures with over-ventilation on request	→	May 2020-November 2020 Phase III Measures with over-ventilation on microsensors alert

MINISTÈRE DE LA TRANSITION ÉCOLOGIQUE ET SOLIDAIRE

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146 rue Paradis
Bât. "Le Noilly Paradis"
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3.4 Energy optimization of transportation systems

This section includes posters presented in the context of the “Energy optimization of transportation systems” sessions of the TAP conference. Table 16 provides an overview of these posters, as they are listed in the following sub-sections.

Table 16. Titles and authors of “Energy optimization of transportation systems” posters

	Title	Authors
3.4.1	Dynamic Traffic Events Management at a Signalized Intersection for the Evaluation of Smart Infrastructure Operation	M. Zoi and I. Politis
3.4.2	RUMOBIL – improving public mobility in rural areas	A. Nitschke, D. Sitányiová and F. Misso
3.4.3	Potential Use of VECTO for the Evaluation and Optimization of Public Transport CO2 Emissions	O.Özener, M.Özkan, A.Kılıcaslan, N. Zacharof, G. Fontaras and Z. Samaras
3.4.4	Improving Environmental and Traffic Effects of Green Navigation by Combining Traffic Control Measures and Eco-Driving	Y. Wang and A. Monzon
3.4.5	Evaluation of impacts of traffic to and from shopping centers and planning of collective transport: a case study	C. Trozzi and E. Piscitello

3.4.1 Dynamic Traffic Events Management at a Signalized Intersection for the Evaluation of Smart Infrastructure Operation

Dynamic Traffic Events Management at a Signalized Intersection for the Evaluation of Smart Infrastructure Operation

Maria Zoi[1] , Ioannis Politis[2]

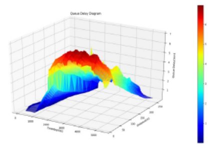
1 Aristotle University of Thessaloniki, Civil Engineering Department, Traffic Engineering Laboratory, marlamzoi@civil.auth.gr
2 Aristotle University of Thessaloniki, Civil Engineering Department, Traffic Engineering Laboratory, pol@civil.auth.gr

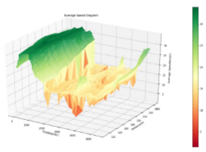
Area of Study – Description of the problem

The intersection studied is located in the center of the city of Thessaloniki. It is the intersection of a central artery of the city, **Egnatia Street, with 3rd September.** The main problem of the intersection is presented in morning and afternoon peak hours, at the descent of 3rd September (from Ag. Dimitriou Street). During these hours there is intense traffic congestion in the street, resulting in the creation of a queue of vehicles and extensive delays.

The three dimensional diagrams below indicate the operation of the intersection in the existing situation as it was simulated in Vissim microsimulation software as a function of time and distance. The **left chart** shows the delays of the vehicles due to the queue (min) and the **right chart** shows the average speed of the vehicles (km/h).

Table: Three-dimensional Vehicle Delay Diagram (min) – Three dimensional Average Speed Diagram (km/h) in existing situation





Developing Alternative Scenarios

In the purpose of smoothening the intersection's operation **four new** dynamic event response scenarios were developed in Python programming language and incorporated into the Vissim traffic microsimulation software. The "smart" scenarios change part of the program's parameters, which were originally designed to operate in a certain repeatability. For example, in case of traffic congestion in one access, signaling changes to better serve this access. The above smart scenarios are executed automatically by the program and are called "event-based scripts". In this way, the interaction between vehicles and infrastructure is accomplished and the intersection's operation is improved.

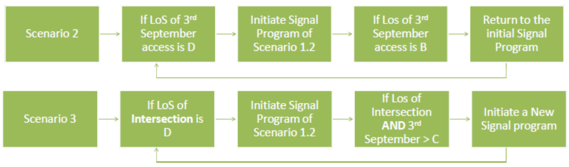
The first two scenarios are Scenario 1.1 and Scenario 1.2. In these scenarios the **signal program of the intersection** is recalculated based on **Webster's method**. Their difference is the duration of the signal program's period. The chart below, shows the comparison of some traffic characteristics such as delay time, gaseous emissions etc., among the existing situation and the aforementioned scenarios.

Table: Comparison of Existing Situation – Scenario 1.1 – Scenario 1.2

	Existing Situation (Scenario 0)	Scenario 1.1 (85 sec Period)	Scenario 1.2 (75 sec Period)
Total Travel Time (sec)	526,422.30	349,562.20	347,786.20
Delay Time (sec)	58.88	46.91	45.57
Emissions CO (kg)	19.73	15.15	14.76
Emissions Nox (kg)	3.83	2.95	2.87
Emissions VOC (kg)	4.57	3.51	3.42
Fuel consumption (lt)	1068.40	820.49	799.47

The results appear improved in both aspects of Scenario 1, with Scenario 1.2 being slightly better. The signal time period of 75 seconds is therefore, considered as the best solution. The last **two scenarios are event – based** and they were developed through the Python programming techniques and incorporated in Vissim. In the following, simplified flow charts, the procedure followed in each Scenario, is presented. **Their main difference** is that Scenario 2 focuses on smoothening 3rd September's operation, whilst Scenario 3 examines the intersection as a whole, interdependent system.

Table: Simplified Flow charts of Scenario 2 - Scenario 3



Economic – Environmental Analysis

The results regarding the traffic characteristics were really encouraging in both Scenarios. In the context of an integrated evaluation an economic and environmental analysis was conducted.

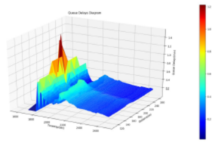
Exported results from the simulation software are presented for further comparison. In particular, travel time and delays, emissions of gaseous pollutants and fuel consumption are reported.

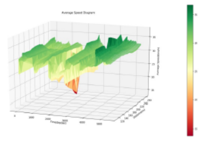
Table: Comparison of Traffic Characteristics Scenario 0 - 2

	Existing Situation	Scenario 2	Difference(%)
Total Travel Time (min)	8,773.71	5,702.92	-35.00%
Delay Time (sec)	58.88	33.54	-43.04%
Emissions CO (kg)	19.73	14.77	-25.13%
Emissions Nox (kg)	3.83	2.87	-25.03%
Emissions VOC (kg)	4.57	3.24	-29.08%
Fuel consumption (lt)	1068.40	799.96	-25.13%

The **results of Scenario 3** are presented in the two following charts. The same charts were provided for the existing situation as well. Scenario 3 presents the optimal solution for the intersection's operation regarding its traffic condition

Table: Three-dimensional Vehicle Delay Diagram (min) – Three dimensional Average Speed Diagram (km/h) in Scenario 3





Results

A simplified **Cost – Benefit analysis** was formed to examine the proposed test-bed. Initially the cost of the intervention was identified and then the benefits from both Time Travel savings and Environmental profits were also calculated. Subsequently, some methods for evaluating investments were used such as: Payback Period, IRR, Net Present Value and Benefit – Cost ratio. All the economic indicators that have been calculated lead to the conclusion that any intervention in the signaling of the studied intersection will bring great benefits directly to users and the environment. The results for the last two scenarios are shown below, indicating the necessity of such an intervention both in traffic and environmental terms.

Tables: Financial Indicators of Scenario 2 - Scenario 3

Financial Indicators of Scenario 2			
Total Cost 1	17,236.00 €	Payback Period	0.14 (2 months)
Environmental Profit	23,282.89 € / year	Internal Rate of Return (IRR)	730.31 %
Fuel Consumption Profit	914,832.96 € / year	Net Present Value	1,717,430.30€
Travel time Profit	572,395.26 € / year	Cost – Benefit Ratio	99.64
Total Profit	1,510,511.11 € / year		

Financial Indicators of Scenario 3			
Total Cost 1	17,236.00€	Payback Period	0.14 (2 months)
Environmental Profit	14,944.82 € / year	Internal Rate of Return (IRR)	689.76 %
Fuel Consumption Profit	827,514.20 € / year	Net Present Value	1,633,708.70 €
Travel time Profit	584,189.09 € / year	Cost – Benefit Ratio	94.78
Total Profit	1,426,648.12 € / year		

References

Frantzeskakis, I., Giannopoulos, G. (2005). Transportation Design and Traffic Engineering, Thessaloniki: Epicentre Publications.

European Environment Agency. (2004), Transport and Environment in Europe.

Victoria Transport Policy Institute. (2015). Transportation cost and benefit analysis II – Air Polution costs.

3.4.2 RUMOBIL – improving public mobility in rural areas

REAL TIME INFOMOBILITY FOR A DRT SERVICE

European Union

Interreg CENTRAL EUROPE

RUMOBIL

aMo
Agenzia per la Mobilità di Modena

Overview

Region:	Emilia-Romagna, Italy
Costs:	40.000 €
Implementation:	09/2017 - 08/2018
Type:	Public Transport Service
Partner:	Agency for mobility and public transport of the province of Modena

Challenges

- Offer mobility in rural areas not covered from traditional public transport services
- Supply a real time infomobility service in order to make the DRT service more accessible
- Increase the usage of the DRT service with more users and more trips

Approach

- Overcome one of the main limitations of the DRT services which is the lack of information on the service
- Close contact with the main Stakeholders to create a truly useful service
- Build an entire system useful for all the subjects involved In the use and implementation of a DRT service

Outcome

- The number of trips (and incomes) is increased of 13.3% and is steadily increasing the number of users
- Users of the DRT service now have a highly appreciated and used infomobility system
- Useful data are now available to make analyzes that were not possible before the project

Contact
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3.4.3 Potential Use of VECTO for the Evaluation and Optimization of Public Transport CO2 Emissions

Potential Use of VECTO for the Evaluation and Optimization of Public Transport CO_2 Emissions

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Presenting author: Nikiforos Zacharof
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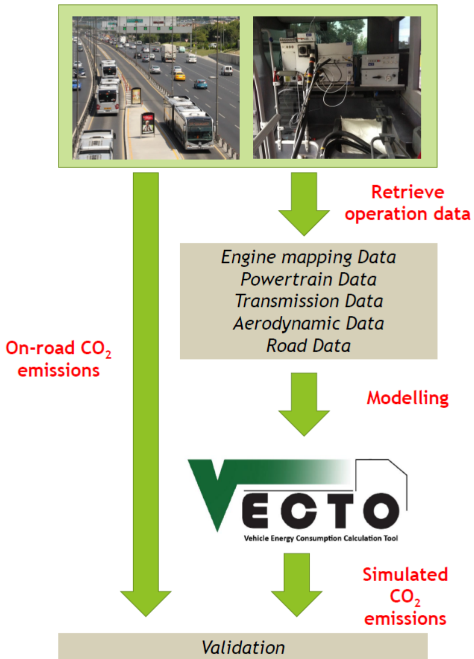
Introduction

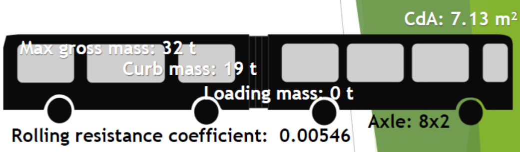
The demand for public transportation increases having a significant impact on urban air quality and becoming one of the main contributors to greenhouse gas emissions. The European Commission has already set a framework to regulate pollutant emissions and is underway to monitor and regulate CO_2 emissions with the use of VECTO. VECTO is a vehicle simulation tool developed for the certification and monitoring of fuel consumption and CO_2 emissions from heavy-duty vehicles. Trucks will be certified using VECTO already in 2019 while work is on-going for extending the tool and methodology to buses and coaches. The Yildiz Technical University conducted a series of on-road measurements on city bus over one metropolitan route in Istanbul. The measurements were subsequently used to create the respective VECTO models, which were validated against the on-road measurements.

Methodology

The investigation first measured CO_2 emissions from a city bus with the use of PEMS over a route in Istanbul and it retrieved OBD data from the vehicle, which presented the vehicle's operating conditions. The data was analyzed in order to be used as input in VECTO, where it would replicate the vehicle real-world operating conditions.

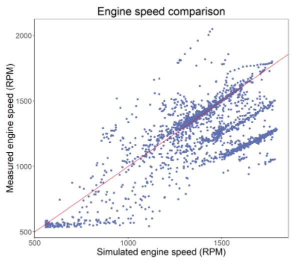


The figure below presents the vehicle characteristics that were used as VECTO input.



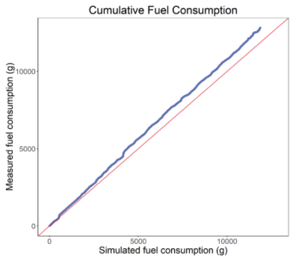
Results & Discussion

The figure below present a comparison between the simulated engine speed and the measured engine speed.



Run	Mean RPM	Difference
Measured	1150	-7.82%
Simulated	1248	

There is a divergence as the mean RPM was ~100 RPM higher in VECTO than in the on-road measurements. In addition, the engine speed comparison shows an issue in gearshifting strategy. This led a divergence in the fuel consumption as it is shown in the figure below that presents the cumulative fuel consumption.



Run	Fuel Consumption (g)	Difference
Measured	12817.6	-7.37%
Simulated	11872.38	

The divergence could be also attributed to the auxiliary use, as the investigation took into consideration the standard VECTO auxiliaries. However, the use of the most sophisticated bus auxiliaries module could provide improved results.

Conclusion

VECTO shows potential to calculate fuel consumption from an on-road trip, but the model should be improved further to address gearshifting issues and also to make use of the bus auxiliaries module.

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Acknowledgements

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Bus image from petersirka under CC

3.4.4 Improving Environmental and Traffic Effects of Green Navigation by Combining Traffic Control Measures and Eco-Driving

Improving Environmental and Traffic Effects of Green Navigation by Combining Traffic Control Measures and Eco-Driving

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1. RESEARCH BACKGROUND AND OBJECTIVES

Research Background:

Green Navigation system (**GN**, also named eco-routing), which is designed to provide route guidance to drivers based on real time information and following a minimum fuel consumption criterion. The previous studies show when GN system applied it reduces of CO2 and NOx in the whole network, but it leads up to 20% increasing on the population's exposure to NOx simultaneously. This paper is looking for solutions to compensate the negative impacts of GN by combining other ICT (Information Communication Technologies) measures.

Research Objectives:

- to expand the knowledge to design and evaluate **combined transport measures** that compensate for *negative effects* caused by green navigation (eco-routing) system.
- to study on the *additional negative impacts on* **population exposure** to air pollutants which is often overlooked in the evaluation stage.

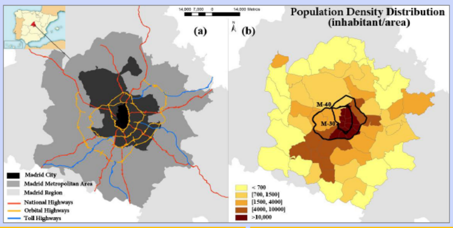
ICT Measures

Variable Speed Limits (VSL)
- Traffic management measure
- Re-distribute traffic flow
- Reduce road congestion

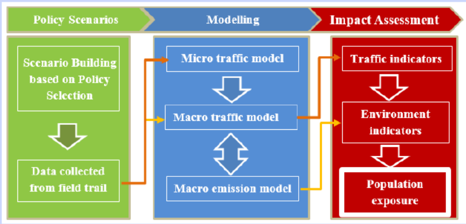
Eco Driving (ED)
- Driving pattern measure
- Easy to apply
- Reduce fuel use/CO2

Urban Toll (UT)
- Pricing measure
- Reduce road congestion
- Eliminate air pollution

Case Study – Madrid Metropolitan Area



Methodology Framework



2. SCENARIO BUILDING

FIVE SCENARIOS: 4 policy scenarios comparing with 1 Base scenario

- Scenarios with Transport Measures
  - Single GN
  - Combined Measures with GN
    - GN+VSL
    - GN+ED
    - GN+UT
- Base Scenario (BC)

3. MODELLING

Input

- Using **Traffic Model** to obtain the changes of traffic flow in each link:
  Micro simulation model: VISSIM (behavior change to BRP parameters)
  Macro simulation model: VISUM (assignment based on less fuel-use)
- Using **Environment model** to calculate CO2 and other pollutants changes:
  Macro model: COPERT
- **Defining indicators** to assess the impacts of the 4 policy scenarios

Output

Traffic Indicators and Environment Indicators

- VKT (Vehicle Kilometres Travelled)

$$VKT_i = \sum_{i}^{N} I_i l_i$$

- VEH (Vehicles per Hour)

$$VEH_i = \sum_{i}^{N} I_i t_i$$

I is the traffic intensity (vehicles/hour) in a specific link of the network for an average hour in the time period considered; *l* is the length (km) of the link; *i* represents the link of the network.

The environmental impact is evaluated in terms of tons of CO2, NOx and PM. EF(v) comes from the COPERT model, m represents vehicle classes (fleet composition), depending on vehicle fuel technology, engine type and technology, and k is the type of emission considered (CO2, NOx or PM).

$$Emissions_{i,k} = \sum_{i}^{N} EF(v)_{k,m,i} I_i l_i$$

Population Exposure Indicator (PEI)

$$PEI_{j,k} = \left(\frac{0.5 * NO_x + 1 * PM}{1.5}\right)_j * d_i = \left(\frac{0.5 * NO_x + 1 * PM}{1.5}\right)_j * \frac{\sum_i^N A_j P_j}{\sum A_j}$$

PEI represents the population exposure to air pollution (NOx and PM), weighting transport exhaust emissions of NOx and PM with population density.
A is the area of the census section j, P is the number of population in the census section j, and N is the total number of census sections crossed by the link i.

4. RESULTS AND DISCUSSION

Scenario	VKM (veh*km)	VEH (veh-hour)	CO_2 (kg)	NO_x (Kg)	PM (kg)	PEI (kg*hab/km²)
GN	-7.8%	15.0%	-5.3%	-7.1%	-7.9%	3.3%
GN+VSL	-7.9%	14.6%	-5.3%	-7.2%	-8.0%	3.4%
GN+ED	-7.4%	10.5%	-5.9%	-7.9%	-8.3%	1.7%
GN+UT	-6.3%	28.3%	-0.9%	-2.4%	-3.2%	-0.6%
	Conflict		No influence			Synergy

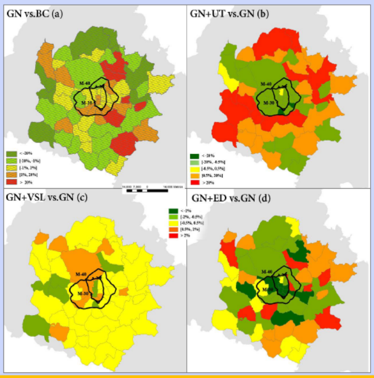
Scenario	VKM (veh-km)	VEH (veh-hour)	CO_2 (kg)	NOx (Kg)	PM (kg)	PEI (kg*hab/km²)
Area inside of M-30 (including M-30)						
GN	0.3%	25.6%	6.1%	4.8%	3.3%	5.0%
GN+VSL	-0.3%	24.3%	5.3%	4.1%	2.6%	4.3%
GN+ED	7.8%	1.8%	4.8%	3.5%	5.1%	3.4%
GN+UT	-2.0%	17.5%	2.2%	1.1%	-0.1%	1.5%
Area between M-30 and M-40 (including M-40)						
GN	-4.0%	17.2%	-0.2%	-1.0%	-1.8%	5.9%
GN+VSL	-4.6%	16.6%	-0.7%	-1.6%	-2.3%	5.7%
GN+ED	-3.6%	13.4%	-1.4%	-2.6%	-2.7%	5.5%
GN+UT	-24.3%	15.1%	-17.4%	-18.7%	-19.3%	-3.7%
Area outside of M-40 (the rest of MMA)						
GN	-9.3%	14.6%	-7.5%	-9.4%	-9.8%	5.1%
GN+VSL	-9.4%	14.3%	-7.6%	-9.5%	-10.0%	5.1%
GN+ED	-9.2%	16.5%	-7.3%	-9.4%	-9.9%	6.0%
GN+UT	3.1%	48.0%	8.4%	6.1%	4.7%	19.5%

Two tables present the 1) changes comparing with base scenario (BC), then 2) show the synergies and conflict impacts between the combined scenarios with single GN by indicators.

All reduce VKM, but increase VEH.
GN+VSL: not much difference comparing to GN
GN+ED: more **synergies**, less conflict
GN+UT: mostly conflict, but good in PEI than others

Inner area more synergies, outside more conflicts
GN+VSL: compensate slightly
GN+ED: more **synergies**, would harm the PEI
GN+UT: **aggressive measure**, discreetly applying

This figure illustrates the PEI variation between scenarios. The changes of PEI between GN and the base scenario (figure 3 a), and the differences between combined measure scenario and GN (b, c and d).
GN+VSL: effective in less population area
GN+ED: mostly good, slightly increase PEI
GN+UT: good in toll area, but worse PEI outside



5. CONCLUSIONS

The results demonstrate that **combined policy measures** can compensate for the **negative effects** of green navigation system, but *depends on the areas* where the transport measure applied.

- The GN+VSL scenario reinforces the reduction of traffic flow, emissions and PEI inside the inner ring road but its effects are declining in outside areas.
- **GN+ED** scenario shows the best performance in the whole MMA as a result of less traffic and lower emissions. However, it increases a great proportion of traffic inside of inner ring and outside of outer ring owing to it would decreases road capacity. Thus the ED measure should be carefully adopted in the area where more traffic demand and less road capacity have.
- The GN+UT scenario as a new combination which has not been assessed before shows its superiority to **reduce travel demand** as well as emissions inside of the charged area. It is a useful tool to restrict the PEI increasing as the application of GN. However, its major negative impacts in the border areas of the charged cordon should be taken into account when this measure is used to complement the impacts of other measures.

23th International Transport and Air Pollution Conference (TAP) . 15-17 May. Thessaloniki, Greece

3.4.5 Evaluation of impacts of traffic to and from shopping centers and planning of collective transport: a case study

23rd International Transport and Air Pollution Conference
15-17 May 2019, Thessaloniki, Greece

Techne Consulting
Environment and Energy Knowledge

Evaluation of impacts of traffic to and from shopping centers and planning of collective transport: a case study

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THE CONTEXT

The number of shopping centers continues to grow worldwide, led by Asia Pacific (AT Kearney, 2018). In Europe as of July 2017, traditional ones are the most common type, with over 7,085 installations. In addition, there are 2,214 retail parks and 247 factory outlets (ICSC, 2017). It is true that e-commerce can reduce the space for shops, but there are those who expect that in the future the centers that remain will no longer be "shopping". Instead, they will be "dining, leisure and entertainment" centers, where shopping is an adjunct (and a desirable outcome) but not necessarily the reason to go there in the first place (Jon Bird, 2018).

CASE STUDY

- A specific case study was conduced in Italy to assess the impacts of, and planning collective transport to and from, the shopping centers and attractive recreational centers, identified as one of the pressure elements of the area, in the frame of Pescara-Chieti agglomerate air quality management plan. A valuation was also carried out for the shopping center of L'Aquila air quality maintenance zone, in the Pile area.
- Specifically, the activities was aimed at evaluating the emissions linked to traffic to and from shopping centers and recreational centers and to evaluate possible reduction hypotheses by analysing the costs and benefits of the solutions.

METHODS AND INSTRUMENTS

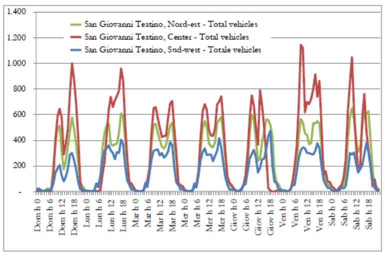
- In the first phase of the project, a direct survey was carried out, using a specific questionnaire, directed at the shopping centers management, about the number of presences (vehicles and / or customers) per day.
- Subsequently, specific campaigns were made to measure the number of vehicles entering and leaving the centers by a specific detection system.
- Emissions were estimated using the "Guidebook" methodology (EMEP/EEA, 2016), with E^{2}Road model (Techne Consulting, 2018).
- The legislation to limit the proliferation of shopping centers and the solution to the problems of congestion in the area with fixed connections and in particular railway services is finally analysed.

SITE INSPECTION, & SURVEY

At beginning of the project, after the selection of the sites through stakeholder consultations and inspections, a direct survey was carried out, using a specific questionnaire, directed at the shopping centers management, about the number of presences (vehicles and / or customers) per day.

TRAFFIC COUNTING

Three traffic monitoring campaigns lasting one week each, with evaluation of cars and commercial vehicles entering different areas, were carried out in three shopping centres. MobilTraf 300 from FAMAS, a counting, classification and traffic monitoring device capable of managing 1 or 2 lanes, was used. The device is "stand alone", and is able to detect the fir each transiting vehicle: date and time, lane, direction, speed and length. Typical transit weeks are elaborated (see picture on right) for the different locations.



LOCAL AREAS AND TOTAL MILEAGES EVALUATION

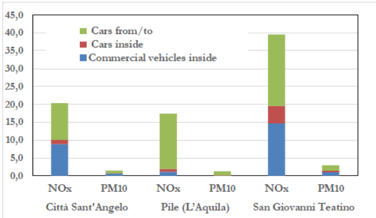
Starting from the count of the number of vehicles per type, the distances travelled in the local areas was assessed by assigning the length to the various sections travelled. Alongside the average distance, the average length of the journey (round trip) that the individual vehicle has to travel to reach the areas from surrounding inhabited areas has been evaluated. It is clear that an evaluation of this type has a high degree of uncertainty, but it provides us with an order of magnitude suitable to evaluate the effectiveness of an intervention and to establish an order of priority of the interventions themselves.

EMISSION FACTORS

The used emission factors represent the average of the categories of cars and commercial vehicles obtained as the average of the emissions of the different types of vehicles, regulations, displacement and speed and the total mileage; they therefore represent regional reference averages.
Two groups of emission factors are used: for circulation in the area of major shopping centers, where traffic detection campaigns were carried out, urban traffic speed profile was used to define average emission factors; for the traffic to and from the same centers extra-urban speed profiles are used.

EMISSIONS

The emissions generated in the areas, and from and towards the areas taken into consideration are very important (up to 40 Mg/year nitrogen oxides)



CONCLUSIONS

Particular attention must be given to the aspects of mitigating the effects of the presence of centers. Priority should be given to the development of rail transport for shopping centers with the establishment of a high-frequency shuttle service for moving from stations to centers. For the isolated shopping centers it is desirable to increase the frequency of connection and their diversification. The procedures relating to strategic environmental assessment, as referred to in the EC Directive 01/42/EC, must be applied to planning procedures for the definition of areas suitable for hosting large sales areas. Finally the behavior and practices of citizens are of great importance in relation to the attitude toward mobility to and from shopping centres. The EC funded Horizon 2020 ClairCity project is developing methods and tools to integrate citizens behaviour in city policies and ensure that future city policies are reflective of citizen's visions for their future city.

Acknowledgments
The study was carried out as part of the update of the Italy Abruzzo Region Air Quality Plan in compliance with EU Air Quality Directive (EU Directive 2008/50/EC) and national derived legislation.

References

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Techne Consulting (2018), E^{2}Road Model

3.5 Road transport management and emissions estimation

This section includes posters presented in the context of the "Road transport management and emissions estimation" sessions of the TAP conference. Table 17 provides an overview of these posters, as they are listed in the following sub-sections.

Table 17. Titles and authors of "Road transport management and emissions estimation" posters

	Title	Authors
3.5.1	High-resolution mapping of traffic emissions for a megacity by using open-accessed traffic congestion index (TCI) data	Y. Wen, S. Zhang and Y. Wu
3.5.2	The applicability of macroscopic emissions' estimation approach on assessing Cooperative Intelligent Transport Systems' (C-ITS) environmental effects	S. Mamarikas, E. Mintsis, J.M. Salanova Grau and E. Mitsakis
3.5.3	Coupling mobile crowdsensing and on-road measurements to improve evaluation of real-driving emissions	L. Thibault, P. Dégeilh, L. Voise, G. Sabiron, J. Kermani, S. Rodríguez, K. Thanabalasingam and G. Corde
3.5.4	Comparison of traffic emission models for urban hot-spot applications	C. Quaassdorff, R. Smit and R. Borge
3.5.5	Road Traffic Model and Emission Assessment for the City of Ozalj	M. Pečet, M. Bunjevac, P. Ilinčić and Z. Lulić
3.5.6	On the density of GPS data for microscopic car emissions models	J.M. Salanova, N. Boufidis, P. Tzenos and G. Aifadopoulou
3.5.7	Bottom-up calculation of Slovenian vehicle traffic emissions	M. Markelj, P. Dolšak and R. Vončina
3.5.8	Fuel consumption assessment on an urban arterial from GPS and on-board data: comparison of consumption models at different scales	D. Lejri, M. Makridis, L. Leclercq, G. Fontaras and B. Ciuffo
3.5.9	Implementation of a Low Emission Zone (LEZ) in the Ile-de-France area: prospective assessment of the impact on road transport emissions, air quality and population exposure	F. Joly, J. Vigneron, C. Kimmerlin, L. Moulin, F. Dugay and C. Honoré,
3.5.10	Modelling urban bus fleet emissions with machine learning boosting methods: Madrid city	A. García, N. Fonseca, J. Mira and Z. Mera

	Title	Authors
3.5.11	Application Development for Processing Real Driving Data on MATLAB Environment	P. Kyriakos, E. Tzirakis, V. Lavouta, G. Tsamis and F. Zannikos

3.5.1 High-resolution mapping of traffic emissions for a megacity by using open-accessed traffic congestion index (TCI) data

High-resolution mapping of traffic emissions for a megacity by using open-accessed traffic congestion index (TCI) data

Yifan Wen [1]*, Shaojun Zhang [2] and Ye Wu [1]
[1] School of Environment, Tsinghua University
[2] Sibley School of Mechanical and Aerospace Engineering, Cornell University

Significance

✓The increasing adoption of intelligent transportation system (ITS) in smart-city has offered unprecedented opportunities for improving transportation air quality management.

✓Based on open-access traffic congestion index (TCI) as well as dynamic traffic flow model, we construct a highly resolved inventory of hourly fluxes of CO, HC, NOx, and $PM_{2.5}$ from on-road vehicles on whole road network in Shenzhen, China for the year 2016.

✓This study provides a universal data source and analyze method for high-revolution vehicle inventory in all kinds of cities in China, especially for medium and small cities suffering from the data-sparse situation, further strengthening the intelligence and accuracy of vehicle emission management.

Methods & data

✓We used one mainstream navigation APP, Baidu Map, to download real-time traffic congestion index (TCI) for roads in Shenzhen. The TCI data are freely accessed from such commercial services, which inform users of road traffic congestions by different colors and cover almost all the cities in China.

✓Polynomial regression models for various road types were developed based on co-current traffic congestion index in the entire city and speeds of representative roads. They were validated with good accuracy and applied to estimate link-level speeds for the entire domain.

✓Traffic volume investigations were carried out in Shenzhen. The traffic count data were used to localize traffic density functions (i.e., relationship between speed and volume) and fleet mix profiles. We then generated high-resolution traffic profiles using real-time TCI and local traffic density functions.

✓Finally, we used the EMBEV model (Wu, 2017) to develop local speed-dependent emission factors, which were incorporated with link-level, hourly traffic profiles for mapping vehicle emissions in Shenzhen.

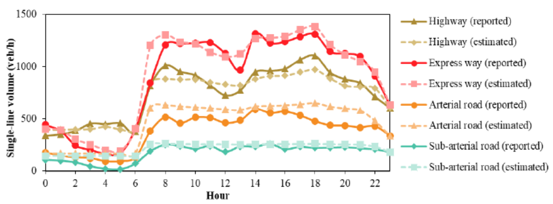

Fig. 1. The comparation of reported and estimated 24-hour single-line traffic flow of different road types

Conclusions

✓The results indicate that the 24-h emissions are estimated 292.2 t of CO, 38.7 t of THC, 164.6 t of NO_X, 5.2 t of $PM_{2.5}$, respectively, during an average weekday in 2016. They are slightly higher than estimated weekend emissions by approximately 2% because of lower traffic speeds and higher traffic volumes in weekdays.

✓Figure 2 illustrates the diurnal emission patterns in Inner districts (CBD area) and Outer districts of CO and NO_X. The temporal profiles of CO emissions represent a large contribution by light-duty passenger vehicles (LDPVs), and appear two peaks during rush hours. By contrast, heavy-duty diesel vehicles are responsible for a major part of NO_X emission. Diesel fleets have different travel behaviors than LDPVs, in particular heavy-duty trucks (HDTs) that are frequently used during nighttime.

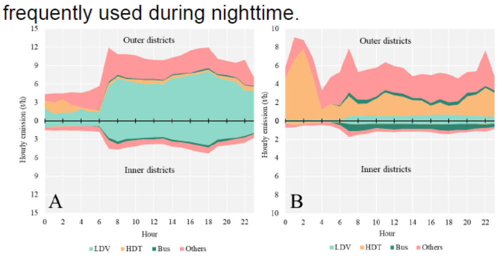

Fig. 2. Diurnal variations in (A) CO and (B) NO_X by region and vehicle category

✓Figure 3 visualizes the distinctive emission characteristics between CO and NO_X. CO emission intensity is significantly higher during rush hours, and the enhancement is more apparent in Inner districts due to high traffic volumes and serious traffic congestion. However, hotspots of NO_X emissions are identified along major freight corridors, which are consistent with the HDT activity.

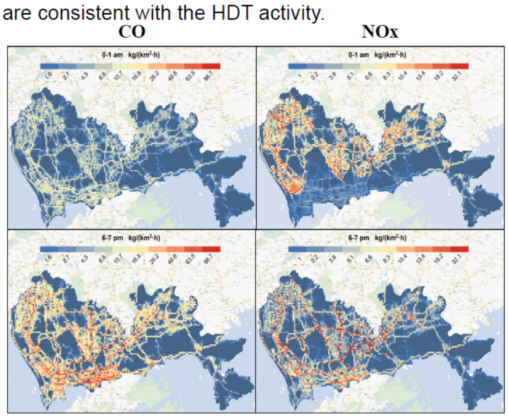

Fig. 3. Grid-based emission intensity of CO and NO_x in two typical hours

3.5.2 The applicability of macroscopic emissions' estimation approach on assessing Cooperative Intelligent Transport Systems' (C-ITS) environmental effects

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Aristotle University of Thessaloniki

LHTEE
Laboratory of Heat Transfer & Environmental Engineering

The applicability of macroscopic emissions' estimation approach on assessing Cooperative Intelligent Transport Systems' (C-ITS) environmental effects

S. Mamarikas[1], E. Mintsis[2], J.M. Salanova Grau[2], and E. Mitsakis[2]

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2. Hellenic Institute of Transport, Centre for Research & Technology Hellas, Thermi, 57001, Greece

INTRODUCTION

This paper focuses on Cooperative Intelligent Transport Systems (C-ITS), examining a system entitled Energy Efficient intersection (EEIS) that provides energy optimized speed advices to drivers close to intersections in order to pass through, without stopping. The examination mainly targets on the potential of extrapolating the evaluation of EEIS performance, regarding their environmental effect at wide spatial resolutions.

Macroscopic emission modeling gathers many advantages on realizing the evaluation at large scales, while limitations exist in the capability of existing macroscopic emission models on capturing ITS effects. Thus, the target is compiled to the following two questions that the paper seeks to answer:

1. Is it possible to assess EEIS effect on emissions using macroscopic emission estimation approaches, rather than the demanding microscopic one?

2. If the latter is possible, which are the necessary steps and preconditions to scale-up at spatial dimension the effects of EEIS?

METHODOLOGY

Different EEIS application scenarios have been modelled in the microscopic traffic simulation software Aimsun with the use of an external C-ITS test-bed, through which the speed advice algorithm (as described in Barth et al.) is been replicated during each simulation time-step. The CO2 emissions have been calculated with the use of the instantaneous speed-based emission model Enviver/Versit+micro (Ligterink et al. 2009). Second-by-second trajectories of all simulated vehicles, as output from the traffic model, were fed in Enviver, so that emissions for each vehicle to be estimated on the basis of instantaneous speed and acceleration. The process is presented in Figure 1.

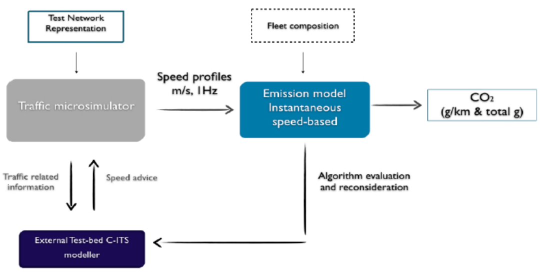

Figure 1. Integrated modeling process

The comprehensive analysis of the macroscopic emission behavior of EEIS follows the logic of average-speed emission factors development (Ntziachristos & Samaras, 2000), which is applied twice; Once for conventional traffic flow (without the application of the ITS) and once for traffic flow affected by the application of EEIS. This process is schematically presented in Figure 1. Total CO2 emissions of each vehicular trajectory are divided by the travelled distance. Each vehicular emission rate is correlated with the respective average speed. All CO2 emissions – average speed combinations are plotted and best-fit curves are applied.

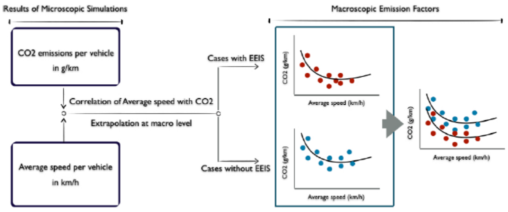

Figure 2. Process of extrapolating EEIS emission effect at macro level

RESULTS

In general, the effect of the system on vehicles' behavior is depicted in Figure 3, that presents the time-space graphs of vehicular trajectories, before and after a 100% penetrated EEIS application. Almost all vehicles do not stop at the intersection, mostly decelerating several meters before the intersection implementing the indicated speed profile in order to pass without stopping.

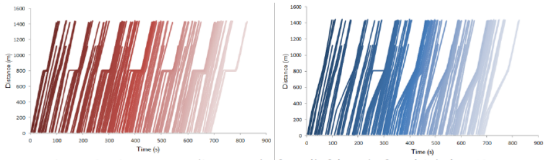

Figure 3. Time-space diagrams before (left) and after (right) EEIS

Regarding the macroscopic analysis, two EEIS penetration scenarios have been examined: a 40% and a 100%. Average speed remained the same, while CO2 were decreased in both penetration scenarios, compared to normal traffic flow (Table1).

Table 1. Effect of EEIS on CO2 emissions and average speed

Penetration Scenario of EEIS	% Difference in CO_2 emissions, compared to normal flow	% Difference in flow's average speed, compared to normal flow
100%	-3,4 %	0 %
40%	-1,3 %	0 %

Applying the process of extrapolating at the macro level, results show that the formation of two discrete emission curves, as presented in Figure 4, revealing the potential of macro emission modeling for EEIS.

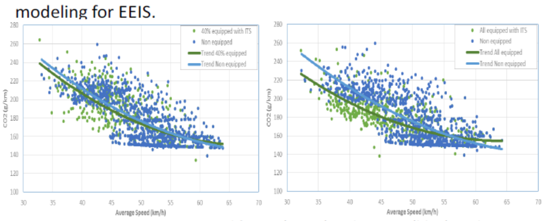

Figure 4. CO2 vs Average Speed for ITS (green) and non ITS (blue) application

Based on the formed curves shape, macroscopic speed-dependent EFs can be developed. Macrocroscopic emission estimations could be performed through the transition from one curve to another, given the average speed, before and after EEIS implementation.

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3.5.3 Coupling mobile crowdsensing and on-road measurements to improve evaluation of real-driving emissions

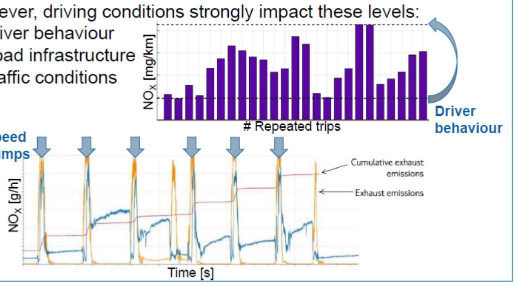
Coupling mobile crowdsensing and on-road measurements to improve the evaluation of real-driving emissions

L. Thibault, P. Dégeilh, L. Voise, G. Sabiron, J. Kermani, S. Rodríguez, K. Thanabalasingam and G. Corde

IFP Energies nouvelles, Institut Carnot IFPEN TE

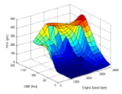
1: Context

- Vehicle emissions levels are mainly tackled by evolution of powertrain technologies and regulations.
- However, driving conditions strongly impact these levels:
  - Driver behaviour
  - Road infrastructure
  - Traffic conditions



2: State of the art

- Macroscopic simulators
  - Suitable year emissions inventories
  - Easy to use
  - Driver behaviour not included
  - Poor precision at the scale of a road segment
- Microscopic simulators



  - High spatio-temporal resolution
  - Driver behaviour included
  - Need speed profiles and vehicle data as input parameters
  - Offline tool
- On-road measurements

  - Precision
  - Driver behaviour included
  - Information limited to one vehicle & location
  - Cost

3: Objectives

- Helping to understand and reduce vehicle emissions
- Representing real-world driving emissions
- Integrating data from thousands of non-professional drivers

4: Approach

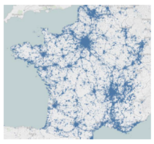
- Coupling on-road measurements and crowdsensing data
- Physical modelling of the powertrain
- Cloud computing from real-time GNSS data

5: Methodology

REAL-WORLD CONNECTED VEHICLES

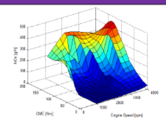
- Smartphone app : Geco Air, +20k users
- Used to collect representative real-world data

REAL-DRIVING CONDITIONS DATABASE



- +1 Million trips
- +35 Millions of kilometers
- 1Hz GNSS Signals
- Detailed vehicle specifications
- Data aggregated to create real-world speed profiles

MICROSCOPIC EMISSIONS ESTIMATION API

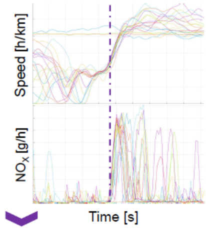


Real-world speed profiles | Real-world model calibration

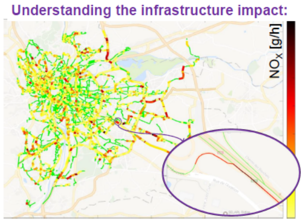
Fitted model of vehicle emissions: Vehicle model → Engine model → Aftertreatment model

Real-driving emissions maps

REAL-DRIVING EMISSIONS MAPS



Understanding the infrastructure impact:



ON-ROAD MEASUREMENTS

- Pollutant emission database used to recalibrate real-world emissions model
- PEMS, RSD, SEMS, Embedded sensor, …

6: Benefits

- For the cities
  - Real-time mapping of vehicle emissions
  - Understanding the impact of the infrastructure
  - Optimising traffic management
- For the legislators
  - Understanding « normal » driving conditions
  - Assessing real-world efficiency
  - Completing existing on-road measurements

7: Contributions

GNSS-based vehicle emissions estimation API

- Easy coupling with other GNSS data sources
- API available on demand

Smartphone application

- Involving thousands of citizens in a crowdsensing campaign
- Providing a feedback on the environmental footprint of mobility

Database of real-world driving conditions

- Real-time vehicle emissions maps

3.5.4 Comparison of traffic emission models for urban hot-spot applications

23rd International Transport and Air Pollution Conference
15 – 17 May 2019. Thessaloniki. Greece

TAP 2019 | THESSALONIKI, GREECE

COMPARISON OF TRAFFIC EMISSION MODELS FOR URBAN HOT-SPOT APPLICATIONS

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Introduction

The accurate estimation of exhaust emissions from road transport under real driving conditions is a topic that has been discussed for several years. High temporal and spatial resolution estimations are based on individual vehicle acceleration-deceleration patterns that are significantly influenced by congestion. Models are a useful and cost-effective tool for traffic impact studies when it is too expensive and time-consuming – or simply not feasible – to obtain direct measurements of exhaust emissions for a complete vehicle fleet. They also are essential to design and assess air quality strategies and anticipate the efficiency of traffic-related emission abatement measures. For these reasons different traffic emissions models have been developed in recent years for diverse purposes.

The main differences between these emission models are related to the scale of application and how traffic congestion is considered into the model formulation. For microscale studies, it is essential to explicitly consider congestion through a detailed representation of actual driving behavior. This type includes cycle-variable models where the emission factors are related to driving cycle variables and modal models where the emission factors are calculated by engine or vehicle operating conditions.

The aim of this work is to clarify what are the practical implications of using alternative models and what are the key issues to take into account when compiling road traffic emission inventories regardless the specific model used.

Microscale emission estimation methodology and results

This study compares the results of two modal emission models, the Australian PΔP (Power-delta-Power) (Smit, 2013 and 2014) and the simplified version of the European PHEM (Passenger Car and Heavy Duty Emission Model), PHEM-light model (Hausberger & Krajzewicz, 2014) with the cycle-variable model VERSIT+$_{micro}$ (Smit et al., 2007).

Firstly, driving patterns for individual vehicles were generated with the traffic micro-simulation model VISSIM (Fellendorf & Vortisch, 2010) providing speed-time profiles with 1 second resolution (Fig. 1) under different traffic congestion conditions (Quaassdorff et al., 2016) for two hot-spot areas located in Brisbane (Australia) and Madrid (Spain).

To understand the response of these emission models, vehicle classes considered in both modal models were mapped to a common classification (using power-to-mass ratio) to ensure a consistent comparison.

Nevertheless, in addition to differences on vehicle classification, large differences in the emission results are observed due to Power-to-Mass ratios.

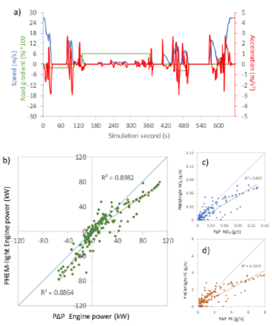

Fig. 1. Representation of an individual trip in Brisbane under saturated traffic conditions (peak hour). (a) Corresponding speed-time-acceleration and road gradient profile, (b) engine power calculation, (c) NO_x emissions and (d) Fuel consumption calculation calculated with emission class PHEM-light LCV_II_D_EURO4 and PΔP PC-ML-diesel-ADR79-02

Instantaneous emission profiles for individual driving patterns are highly sensitive to speed-acceleration profiles, vehicle mass (+loading) and road gradient. These parameters have a strong influence on the power computation (Fig. 1), which is the main variable for emission and fuel consumption calculation in PΔP and PHEM-light.

However, the test suggest that satisfactory results can be achieved with any of the models if reliable information of vehicle fleet composition and vehicle characteristics is provided.

Detailed estimations of NOx emissions and fuel consumption for relevant vehicle types were compared in order to assess differences in the emission calculation and suggesting that PΔP is more sensitive to variability in driving conditions (Fig. 2).

The second-by-second emission results provided by both modal emission models and the cycle-variable model coupled to the instantaneous position provided by the traffic simulation model can produce emission maps with meters and seconds resolution in order to know the location of the emission peaks (Fig. 3).

This methodology has been successfully applied to different typologies of road networks and different congestion patterns. Nevertheless, specific validation studies are needed in order to obtain independent real-world emission measurements of sufficient sample size to verify emission factors and total emissions estimates.

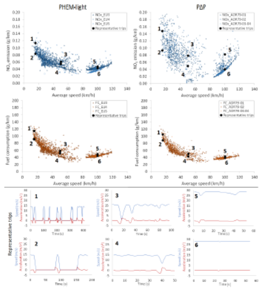

Fig. 2. NO_x (above) and fuel consumption (middle) emission factors (g/km) Vs trip average speed (km/h) for PHEM-light PC-G EURO3 to EURO5 (left) – PΔP PC-S-petrol ADR79-02 to ADR79-04 (right). Trips are taken from the Brisbane off-peak hour scenario. Black dots are representative trips with speed-time-acceleration profiles (below) for average speed span of 1) and 2) 15 km/h, 3) and 4) 50 km/h and 5) and 6) 100 km/h

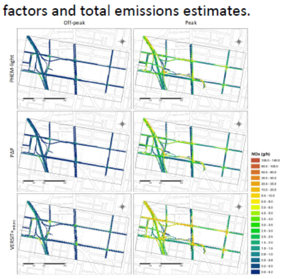

Fig. 3. NO_x emission results for Brisbne off-peak (left) and peak (right) scenarios computed to a spatial resolution of 5 m x 5 m with PHEM-light, PΔP and VERSIT+$_{micro}$

Cycle-variable models are useful for applications where second-by-second resolution in not needed. However, the information generated by the modal emission models is suitable to generate emission maps with temporal resolution up to one second and also very high spatial resolution (1 m x 1 m) that could be coupled to very detailed air quality models based on Computational Fluid Dynamics (CFD) to provide an accurate distribution of pollutants concentrations.

Conclusions

According to the results, similar emission estimations can be achieved with any of the models, if reliable and accurate information on the vehicle fleet composition and vehicle characteristics is provided. The main differences between models may relate to differences in engine and vehicle characteristics and also emission control technology, which suggests that local calibration of traffic emission model is essential for accurate modelling.

Instantaneous emission information generated by modal models is suitable to generate emission maps with high spatial and temporal resolution of up to 1 m x 1 m and 1 Hz. They are a good option to provide emission estimates for different traffic scenarios for non-stationary CFD air quality modelling in urban areas and constitute an interesting future research line. Nonetheless, further validation is required to determine the accuracy of each approach.

Acknowledgements

Results of an international research stay in The University of Queensland (UQ) in the scope of the TECNAIRE-CM research project (S2013/MAE-2972) and co-funded by the Madrid City Council. VISSIM was made available by PTV, and PΔP, PHEM-light and VERSIT+micro were licensed by Transport Emission Research, TU Graz and TNO, respectively.

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3.5.5 Road Traffic Model and Emission Assessment for the City of Ozalj

23rd Transport and Air Pollution Conference, Thessaloniki 2019

University of Zagreb Faculty of Transport and Traffic Sciences

Road Traffic Model and Emission Assessment for the City of Ozalj

M. Pečet[1,2], M. Bunjevac[3], P. Ilinčić[3] and Z. Lulić[3]

1. Introduction

Population and economic growth come with an increase in traffic demand and increased levels of congestion and accompanying delays, pollution, and a decrease in safety. There are several strategies to reduce congestion, keep cities liveable, clean and safe and limit travel time increase. Examples are encouraging people to travel using modes of transport that put less stress on the transportation network, to encourage people to travel at different times or on different routes, to apply traffic management to use roads more efficiently or to expand the road network. For all these measures, it is important to know how traffic flow will look: where and when will there be congestion, what are the bottlenecks and where is the road capacity already sufficient? Traffic flow models support this assessment by describing and predicting traffic on roads. For example, they model the number of vehicles on the road and their speeds. Using the models, travel times and congestion can be predicted.

2 The Aim of the Study

There is no traffic model or emission assessment publicly available for any city in the Republic of Croatia. The idea is to present the methodology for developing traffic model and estimation of emission from road transport sector for the City of Ozalj.

2.1 City of Ozalj General Data

Location: Central Croatia
Population: 6 873 people
Area: 179,4 km^2

3 Method for the Development of the Traffic model

Traffic flow modeling is a largely inductive process: traffic observations are used to build a theory about the behaviour of individual drivers and vehicles or traffic flow in general. Subsequently, that theory is used to build a model, discretise it and apply it in simulations. To create the traffic model classic four-step traffic model shown in Figure 1 was used and simulations were executed in software package PTV Visum.

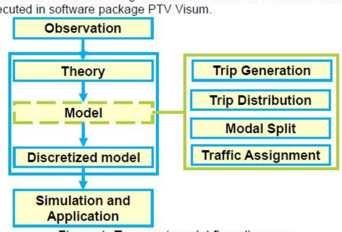


Figure 1. Transport model flow diagram

3.1 Trip Generation

The trip generation stage of the classical transport model aims at predicting the total number of trips generated by (Oi) and attracted to (Dj) each zone of the study area. This can be achieved in a number of ways: starting with the trips of the individuals or households who reside in each zone or directly with some of the properties of the zones: population, employment, number of cars, etc.

3.2 Trip Distribution

Trip generation models can be used to estimate the total number of trips emitted from a zone (origins, productions) and those attracted to each zone (destinations, attractions). Productions and attractions provide an idea of the level of trip making in a study area, but this is seldom enough for modelling and decision making. What is needed is a better idea of the pattern of trip making, from where to where do trips take place, the modes of transport chosen and the routes are taken. The pattern of travel can be represented, at this stage, in at least two different ways. The first one is as a 'trip matrix' or 'trip table'. This stores the trips made from an Origin to a Destination during a particular period; it is also called an Origin-Destination (O-D) matrix and may be disaggregated by person type, and purpose or activity was undertaken at each end of the trip. Such representation is needed for all assignment models.

3.3 Modal Split

The choice of transport mode is probably one of the most important classic model stages in transport planning. Almost without exception travelling in public transport the rest of the car users would benefit from improved levels of modes uses road space more efficiently and produce fewer accidents and emissions than using a private car. Furthermore, underground and other rail-based modes do not require additional road space and therefore do not contribute to road congestion. The issue of mode choice, therefore, is probably the single most important element in transport planning and policy making. It affects the general efficiency with which people can travel in urban areas, the amount of urban space devoted to transport functions, and whether a range of choices is available to travellers.

3.4 Traffic Assignment

Three main reasons for the spread of routes between each O–D pair were identified. The first one is the different objectives of drivers: time or cost minimisers for example. The second is imperfect perceptions of drivers about travel and link costs. The third reason resides in congestion effects, and Wardrop's principles were used as a general framework to discuss this issue. Wardrop's first principle states that under congested conditions drivers will choose routes until no one can reduce their costs by switching to another path; if all drivers perceive costs in the same way, this produces equilibrium conditions where all the routes used between two points have the same and minimum cost and all those not used have equal or greater cost.

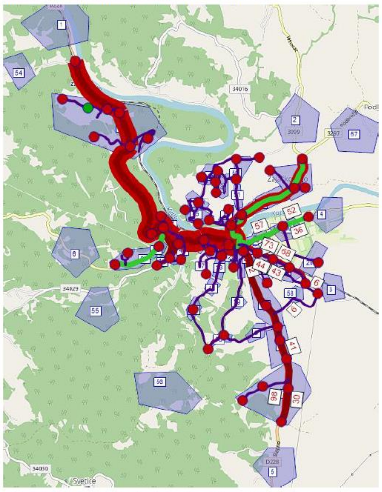


Figure 2. Traffic network with assigned trips

3.5 Vehicle Fleet Data

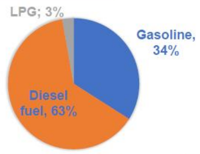


Figure 3. Vehicle fleet (M1 and N1 category) by fuel, Source: Center for Vehicles of Croatia

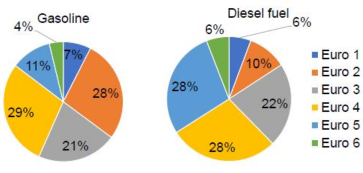


Figure 4. Vehicle fleet (M1 and N1 category) by Euro emission standard, Source: Center for Vehicles of Croatia

4 Emissions Calculating and Results

Calculations were conducted in software package *COPERT: Street Level* for three traffic development scenarios and three fleet structure scenarios. Emissions were calculated for CO_2, NO_X, CO and PM at morning peak hour and result are shown in Tables 1 to 4.

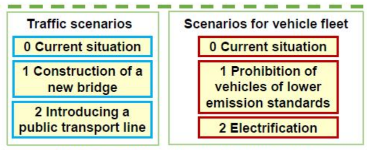


Figure 5. Scenarios for calculating emissions

Table 1 Scenarios matrix

		Vehicle fleet scenario		
		Case 0	Scenario 1	Scenario 2
Traffic	Case 0	C 0.0	S 0.1	S 0.2
	Scenario 1	S 1.0	S 1.1	S 1.2
	Scenario 2	S 2.0	S 2.1	S 2.2

Table 2 CO_2 calculation

CO_2, kg		Vehicle fleet scenario		
		C 0	S 1	S 2
Traffic scenario	C 0	394 (0%)	400 (+1,50%)	343 (-12,9%)
	S 1	273 (-30,6%)	227 (-42,4%)	239 (-39,3%)
	S 2	393 (-0,2%)	397 (+0,8%)	342 (-13,2%)

Table 3 NO_X calculation

NO_X, g		Vehicle fleet scenario		
		C 0	S 1	S 2
Traffic scenario	C 0	865 (0%)	730 (-15,6%)	614 (-29,0%)
	S 1	600 (-29,9%)	506 (-41,5%)	426 (-50,8%)
	S 2	862 (-0,2%)	724 (-16,3%)	612 (-29,2%)

Table 4 CO calculation

CO, g		Vehicle fleet scenario		
		C 0	S 1	S 2
Traffic scenario	C 0	565 (0%)	267 (-52,7%)	420 (-25,7%)
	S 1	392 (-30,6%)	185 (-67,3%)	291 (-48,5%)
	S 2	564 (-0,2%)	265 (-53,1%)	419 (-25,8%)

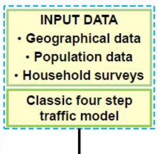
Table 5 PM calculation

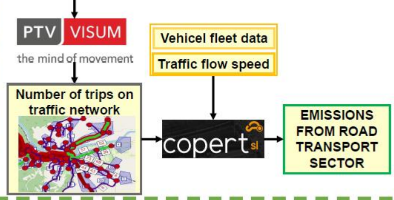
PM, g		Vehicle fleet scenario		
		C 0	S 1	S 2
Traffic scenario	C 0	33 (0%)	20 (-39,4%)	23 (-30,3%)
	S 1	23 (-30,3%)	14 (-57,6%)	16 (-51,5%)
	S 2	33 (-0,2%)	20 (-39,4%)	23 (-30,3%)

The most significant reduction of emissions is achieved through the construction of a new bridge and the prohibition of traffic for lower emission standard vehicles.

5 Conclusion

After creating a mathematical model, simulations were made in PTV Visum to determine the number of trips on the traffic network. With a known structure of the vehicle fleet, emissions were calculated by using COPERT: Street Level. Three scenarios of traffic and three scenarios of the vehicle fleet. The most significant reduction of emissions is achieved through the construction of a new bridge and the prohibition of lower emission standard vehicles.





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3.5.6 On the density of GPS data for microscopic car emissions models

On the density of GPS data for microscopic car emissions models

TAP 2019 | THESSALONIKI, GREECE

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INTRODUCTION

Sustainable transportation systems by definition need to be environmentally friendly. In this context, numerous vehicle emissions models that vary in input requirements and output detail have been developed to quantify the impact of transportation policies and traffic operations strategies (Shorshani *et al., 2015*). According to the detailed literature review on emission models by Forehead *et al.* (2018), microscopic emissions models with high spatiotemporal detail are more capable of capturing the complexity of congested traffic. Development of such models in large scale is considered feasible due to rapidly increasing rates of data availability and computational power.

OBJECTIVES

This study examines the performance of a microscopic emissions model in a variety of cases with different data granularity. Starting at the highest detail, a model for estimating instantaneous pollutants' emissions for each second is defined. Those estimations are the baseline for comparisons to more coarse-grained cases with lower signal frequency.

METHODOLOGY

The instantaneous emissions model is based on the general function for pollutant emission proposed by Panis *et al* (2006):

$$E_n(t) = max[0, f_1 + f_2 v_n(t) + f_3 v_n{}^2(t) + f_4 a_n(t) + f_5 a_n{}^2(t) + f_6 v_n(t) a_n(t)]$$

Tests are conducted utilizing two large sets of **Floating Car Data** (FCD) generated by a fleet of taxis. The first dataset was recorded in the center of Thessaloniki, Greece, at Tsimiski and Polytechniou streets, in the context of the pilot tests of the finalized EU Project **COMPASS4D**, during which a cooperative Intelligent Transport System was developed. It offers advices on travel speed according to traffic light current and future status. The second dataset has been collected in the framework of the ongoing Horizon 2020 Program Project **SAFER-LC**, which introduces innovative solutions and measures to improve safety standards around the meeting points between road and rail (level-crossings). The proposed solution includes a mobile application that alert drivers near LCs and informs them about the estimated time of arrival of approaching trains. Both services has been/are being tested by a fleet of taxis and a dedicated mobile application recording FCD for system monitoring and evaluation.

taxi way

The database used to store both datasets has built-in mechanisms that anonymize records following the directive of the General Data Protection Regulation (GDPR). **The combined size of the raw datasets is over 520K records, each corresponding to one vehicle GPS pulse. The recording frequency is 1Hz and processing algorithms enable the extraction of unique vehicle trajectories,** 1.9 km long in the city center and 200 meters long near LCs. Numerous trajectories at the city center were considered problematic, and thus were filtered out, for multiple reasons including missing GPS pulses due to internet connectivity issues, waiting at taxi stops for customers or significant location error due to low quality in GPS connection. For the clean trajectories, instantaneous speeds and corresponding timestamps enable the calculation of acceleration, to build **the microscopic emissions model for the baseline, second-by-second scenario (S1). Three lower frequency scenarios (S2, S3, S4) have been artificially set up by deleting pulses to alter the time interval between pulses to 2, 5 and 10 seconds.**

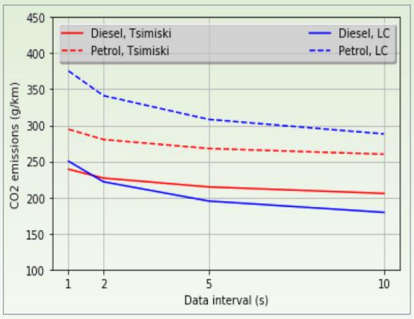
CONCLUSIONS

Results reveal a clear pattern of CO2 emissions estimations decreasing, as the time interval between recorded GPS datapoints increases, for both diesel and petrol engine cars and both types of vehicle trajectories, in the city center and around the level crossings (Table 1). **Significant deviations from the baseline measurements are present.** Differentiations amongst the scenarios are more profound around the LC area, where trajectories are short and vehicle kinematics (speed and acceleration) constantly change in comparison to the longer and more smooth (speed-wise) Tsimiski str. trajectories.

Comparison between mean CO2 emissions for all scenarios and trajectories

		City center		Level Crossing	
	Frequency scenario	Petrol Engine	Diesel Engine	Petrol Engine	Diesel Engine
Total CO_2 emissions (g)	S_1	530	430	75	50
	S_2	504	408	68	44
	S_3	482	386	61	39
	S_4	467	369	57	35
CO_2 emissions per km (g/km)	S_1	294	239	375	250
	S_2	280	226	341	221
	S_3	267	214	308	195
	S_4	259	205	288	179

For each second the interval is increased, the emission estimation is decreased at a rate of 5% to 15%.



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ACKNOWLEDGMENTS

The data utilized for this study have been recorded during the pilot tests of the finalized, EU funded project COMPASS4D, and SAFER-LC project which has received funding from the European Union's Horizon 2020 research and innovation programme under grand agreement No 723205

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23rd International Transport and Air Pollution Conference (TAP2019), 15-17 May 2019, Thessaloniki, Greece

3.5.7 Bottom-up calculation of Slovenian vehicle traffic emissions

Bottom-up calculation of Slovenian Vehicle Traffic Emissions

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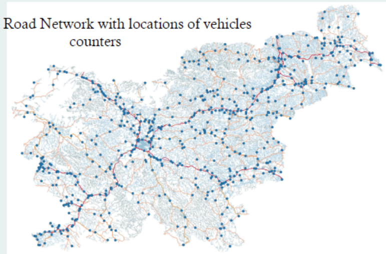
GOAL:
Road traffic emissions estimation

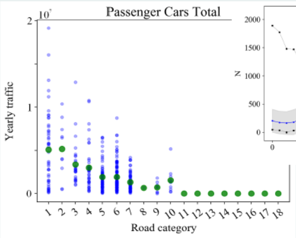
INPUT DATA:
Road network
Traffic counters
National registry of vehicles

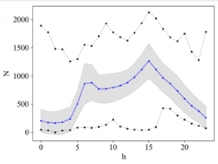
METHOD:
COPERT 5
Developed a traffic model – CIP model

Slovenian Road Network with locations of vehicles counters



Number of passenger cars in 2016 on all traffic counters separated by road category.





Number of passenger cars in 2016 on a particular traffic counter separated by hour in a day.
Maximum, minimum, average and 70th percentile.

Table: Default weights (w0) for each road category.

	Highways		Regional roads					Urban roads						Other	
	1	2	3	4	5	6	7	8	9	10	11	12	13	17	18
L-Category Total	66	75	100	97	68	76	44	30	12	6	6	6	6	2	2
Passenger Cars Total	99	100	66	58	37	37	26	10	6	3	3	3	3	1	1
Buses Total	100	51	52	35	34	31	20	5	3	2	2	2	2	0	0
Light Commercial Vehicles Total	100	73	43	36	22	18	12	2	2	1	1	1	1	0	0
Heavy Duty Trucks Total	100	61	47	34	26	23	14	2	2	1	1	1	1	1	1

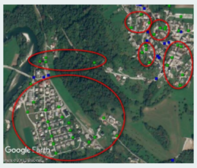
CIP model

Traffic model CIP is used to estimate number of passing vehicles within each of 5 vehicle categories on every road segment for every hour. First shapefile of road network is analyzed to detect all intersections that are used as nodes in a graph. Graph is composed from nodes (intersections) that store spatial coordinates and connections (connecting roads) that store road segment ID, lenght and category.

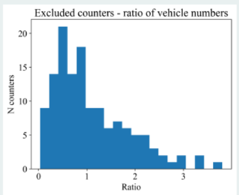
For every intersection the lenght of roads of same or higher category that can be reached without travelling on segments of lower category is calculated and named background for that road segment. The weight of a road segment is calculated using equation below by accounting for it's default weight and background.

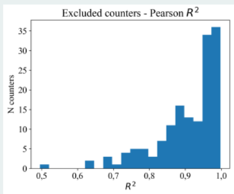
$$w = w_0 \cdot (1 + 0.5 \cdot (1 - e^{-\frac{background}{w_0 \cdot 1000}}))$$

Finally information from traffic counters is propagated through graph using a linear relationship between number of vehicles and weight of the segment.



Intersections are colored by their road categories. Intersections encircled by red line are groups of higher category roads, that contribute to background of lower category roads.





Verification of the CIP model was conducted by excluding 150 of 550 available traffic counters and comparing calculated and counted numbers of vehicles on the 150 roads. Pearson's correlation coefficients show good agreement in temporal trends, while comparing sums of calculated and counted vehicles (ratio) shows a need for model calibration.

COPERT 5 model

National registry of vehicles
Categorized by:
- passenger cars,
- light and heavy duty trucks,
- buses and
- motorcycles;

and therefore also by EURO standards (1 to 6).

INPUT FILE

COPERT 5

$E_{total(PM_{2.5})} = E_{hot} + E_{cold} + E_{non\ exhaust\ emissions}$

E_{hot} = EF * number of vehicles * mileage per vehicles

$E_{total} = E_{urban} + E_{rural} + E_{highway}$

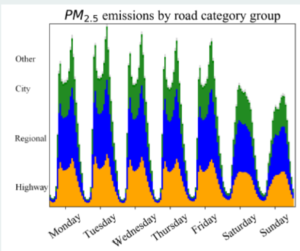
OUTPUT FILE

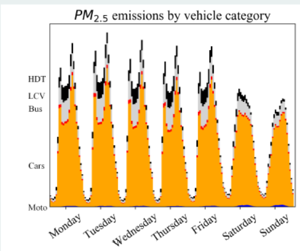
Calculated EF for $PM_{2.5}$

$PM_{2.5}$ g/km	Highways	Regional roads	Urban roads	Urban roads - rush hours
L-Category	0.01	0.02	0.02	0.02
Passenger Cars	0.03	0.02	0.03	0.03
Buses	0.10	0.11	0.13	0.15
Light Commercial Vehicles	0.08	0.05	0.06	0.07
Heavy Duty Trucks	0.07	0.08	0.09	0.11

COPERT 5 is a well-known vehicle emissions model developed by company Emisia SA. National registry emissions was used to create an input data in year 2016 for COPERT 5. The main principle of the model is to calculate hot, cold and non-exhaust emissions from each type of car separately. They are also separated by regional (rural), urban, urban-rush hours and highways. COPERT 5 results are emission factors for $PM_{2.5}$ in unit g/km, which was additionally used as input information in CIP model.

Results





Plots to the left show the amount of the $PM_{2.5}$ particles emitted by the transport in the year 2016. Hourly emissions are shown separated by day in a week and by road category on spatial perspective or by vehicle type which indicate reason for travel. HDT and LCV are mostly used for goods transport, while buses, cars and motorcycles are used for personal mobility.
Emissions on regional and city roads show larger morning and afternoon peaks than on highways. On weekends morning and afternoon peaks are absent, but are replaced by a morning peak on Saturday and evening peak on Sunday, possibly caused by migrations associated with short weekend holidays.
Personal transport by passenger cars is by far the dominant source of $PM_{2.5}$ emissions. Results show a noticeable increase in motorcycle use on weekends.

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This project was made as part of EU cohesion project Sinica (Slovenian Environmental Agency)

3.5.8 Fuel consumption assessment on an urban arterial from GPS and on-board data: comparison of consumption models at different scales

Fuel consumption assessment on an urban arterial from GPS and on-board data: comparison of models at different scales.

D. Lejri[1], M. Makridis[2], L. Leclercq[1], G. Fontaras[2] and B. Ciuffo[2]

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Fuel consumption on an urban arterial with high traffic dynamics remains challenging . The objective here is to compare different modelling approaches for FC assessment with OBD estimates.

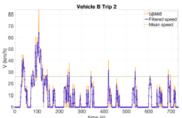
Vehicle	Type	Trips
A	RENAULT CLIO IV 1.5 dCi (2012)	9
B	RENAULT CLIO IV 1.5 dCi (2012)	9
C	RENAULT MEGANE III 1.5 dCi	9
D	NISSAN Qashqai 1.5 dCi (2010)	6
E	RENAULT CLIO IV 1.5 dCi (2012)	7

Experiment site
Gambetta boulevard in Lyon
1.6km long ; 12 traffic lights

Field measurements

GPS data → Speed profiles and traffic variables

OBD parameters → FC_{OBD}



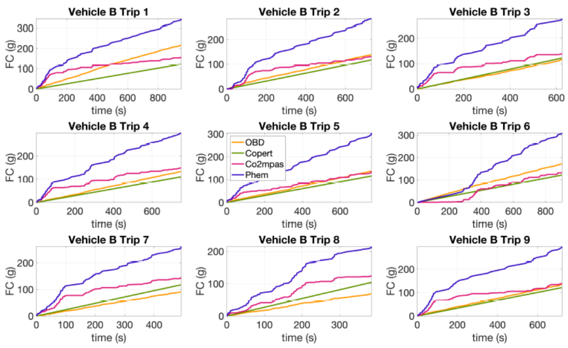
FC Co2mpas

FC Phem

FC Copert

Model estimates

Comparison at trip level

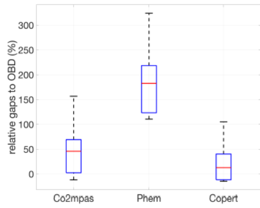


Cumulated Fuel Consumption over the 9 trips of vehicle B

OBD FC estimate

$$FC_{OBD} = a + b\ Airflow^{c}\ Engine\ load^{d}$$

Comparison at vehicle level



FC relative gaps to OBD estimate over the 9 trips of vehicle B

Results and future researches

- ✓ Phem estimate is always the highest
- ✓ Co2mpas estimates are mainly higher than Copert ones
- ✓ High dispersion over the various trips of the same vehicle

In the future we will

- ✓ further analyze the dispersion over the trips regarding the speed profiles quality
- ✓ compare these results with a traffic simulation coupled with the same consumption models

Main references

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3.5.9 Implementation of a Low Emission Zone (LEZ) in the Ile-de-France area: prospective assessment of the impact on road transport emissions, air quality and population exposure

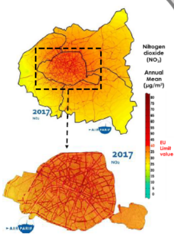
Implementation of a Low Emission Zone (LEZ) in the Ile-de-France area: prospective assessment of the impact on road transport emissions, air quality and population exposure

F. Joly, J. Vigneron, C. Kimmerlin, L. Moulin, F. Dugay, C. Honoré,

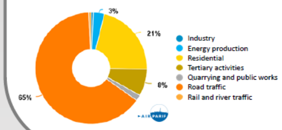
Airparif, Air quality observatory in the Ile-de-France region, Paris, France

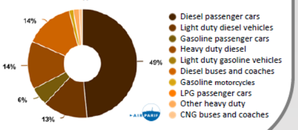
1. Context and aim of the study

Particulate matter (PM) and nitrogen dioxide (NO_2) levels within the Paris region remain a problematic issue due to substantial exceedances of EU limit values (Air quality in the Paris area 2017, Airparif 2018). Airparif accompanied the Paris City Council to carry out a prospective assessment of the impact on air quality of its LEZ project to reduce pollution related to traffic.



The importance of traffic contribution in NO_x Paris emissions:





2. Methodology

A chain of modelling tools was used to study the expected impacts of road traffic restriction scenarios on vehicle pollutant emissions (nitrogen oxides (NO_x), PM_{10}, $PM_{2.5}$, CO_2), on the air quality (NO_2, PM_{10}, $PM_{2.5}$ concentrations) and on population exposure.

LEZ perimeters

Perimeter of study

Calculations have been run on the whole Ile-de-France region to assess impacts in and out of the LEZ

Studied cases

For each stage, the impact of the LEZ was assessed by comparison with a "Business-as-usual" (BaU) scenario of the same year (future situation with no specific restriction measure), that only integrates the "natural" evolution of the technological park. For each scenario, technological parks were derived based on local data collected for Paris and the Ile-de-France area.

Definition of regional road traffic
- Vehicle fleet
- Technological park
- Traffic (speed and flux)

→ **Road traffic calculations**
« Business-as usual» (BaU) and « LEZ scenarios »
Taking into account
- Deviated itineraries
- Technological park renewal

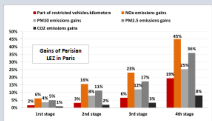
→ **Traffic emissions simulation**
- Atmospheric pollutants
- Greenhouse gases (GHG)

→ **Concentrations simulation with « ADMS urban »**
- Hourly calculation
- Annual mean reconstitution

→ **Indicators calculation**
- Exposed population
- Km of road exposed
- Exposed schools, hospitals and sports facilities

3. Results

3.1. Emissions decreases



Decreases are more important on NO_x because of its significant road traffic contribution.

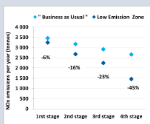
PM decreases are lower than NO_x due to elevated abrasion contribution (roads, tyres, and breaks abrasion represent respectively 51 % and 36 % of PM_{10} and $PM_{2.5}$ emissions).

$PM_{2.5}$ gains are higher than PM_{10} because modernization of the technological park influences combustion more than abrasion.

Gains of CO_2 are also assessed. LEZ is beneficial for air quality and global warming.

LEZ leads to the acceleration of the renewal of the technological park, in Paris and beyond its perimeter.

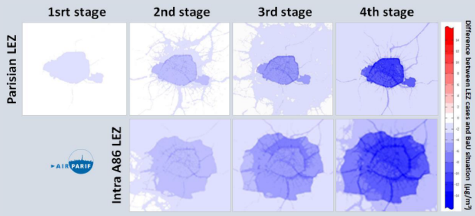
The anticipation induced on BaU emissions ranges from 1 year for the 1st stage, to 9 years in the 4th stage.



Comparison of NO_x BaU emissions and NO_x LEZ emissions

3.2. Impacts on concentrations

For the Parisian LEZ, mean gains in NO_2 range from 1 µg/m³ (1st stage) to 10 µg/m³ (4th stage) in the city.

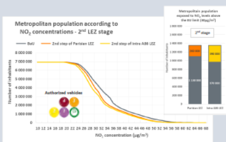


Cartographies of differences in NO_2 between LEZ situations and BaU situations for the Parisian LEZ (up) and the LEZ extended to intra A86 (bottom) for the four studied steps.

In the intra A86 perimeter, the 4th Parisian LEZ stage induces an annual mean decrease of 2 µg/m³. The 4th intra A86 LEZ stage enables a 9 µg/m³ gain on NO_2 annual mean.

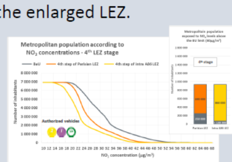
PM decreases are less important. 4th LEZ stage leads to an annual mean decrease of about 1 µg/m³ of PM_{10} in Paris. Gains are higher close to the traffic lanes.

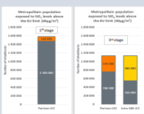
3.3. Gains in population exposure



The highest levels which metropolitan population is exposed to are estimated to 59 µg/m³ in the BaU case versus 54 µg/m³ in the 2nd stage and 42 µg/m³ in the 4th stage of the enlarged LEZ.

Metropolitan population exposed to NO_2 concentrations above the EU limit values decrease by 19 % (2nd stage) and 73 % (4th stage) thanks to the Parisian LEZ.





Gains reach 90 % in the 4th stage of the extended LEZ leading to less than 100 000 Metropolitans exposed to NO_2 levels exceeding the regulations.

Conclusion

The implementation of the Paris LEZ leads to a reduction in pollutant emissions in the LEZ perimeter and beyond, due to the impact of the accelerated renewal of the technological park in the whole region.

Due to its important contribution to regional road traffic emissions, NO_2 is the most sensitive pollutant to the measure.

Gains intensify with the restricted Crit'Air categories. LEZ enlargement to intra A86 perimeter induces more significant gains and widens the area of benefits.

Acknowledgments: *This study was funded by the City of Paris* *Road traffic data were computed by DRIEA* *Population data come from IAU*

3.5.10 Modelling urban bus fleet emissions with machine learning boosting methods: Madrid city

Modelling urban bus fleet emissions with machine learning boosting methods: City of Madrid

A. García[1], N. Fonseca*[2], J. Mira[1], and Z. Mera[1,3]

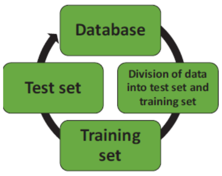
Objetives

The purpose of this work is to assess the applicability of this technique to the modelling and prediction of instantaneous CO_2, NO_x and PM emissions from urban buses in the city of Madrid.

Theoretical basis

Boosting method

- ✓1 "strong" classifier from a lot of "weak" classifiers
- ✓**Weak learner** ≡ regression model
- ✓**∑ weak learners ≡ ENSEMBLE**



Methods

1. Measurement campaign of real-world emissions

- One Euro IV diesel bus of the Madrid Municipal Transport Company (EMT)
- Round-trips of the most representative routes of the city: C1, 27, 63 and 115 routes
- Different weight loads: complete, half and zero loads
- Portable Emissions Measurement System (PEMS) Horiba OBS 2200 + GPS. Data synchronized @ 1 Hz.

2. Modelling

$$error_m = \frac{\sum_{i=1}^{N} w_i \cdot I(y_i \neq G_m(x_i))}{\sum_{i=1}^{N} w_i}\ ; \ \propto_m = \log\left(\frac{1 - error_m}{error_m}\right)$$

$$w_i \rightarrow w_i \cdot \exp[\propto_m \cdot I(y_i \neq G_m(x))]$$

$$G(x) = sign\left(\sum_{m=1}^{M} \propto_m G_m(x)\right)$$

where, x and y are input and output variables, M is number of iterations, $G_m(x)$ is the base learner of the m^{th} iteration, and $\propto_m$ is the final contribution of the base learner from the m^{th} iteration to the final model

- Search the best combination of kinematic variables: vehicle speed (v), acceleration ($\boldsymbol{a}$) and slope; and ambient variables: temperature, atmospheric pressure (p_0), based on specific tractive power in (W kg^{-1}):

$$pt = v \cdot (\boldsymbol{a} + g \cdot \sin(\alpha) + r_r + f_{xa} \cdot v^2)$$

where, g is the gravitational acceleration, α the slope, r_r the specific rolling resistance and f_{xa} is the specific drag resistance.

3. Prediction errors

$$MSE = \frac{\sum_{i=1}^{n} (\hat{x}_i - x_i)^2}{n} \qquad MAPE = \frac{1}{n}\sum_{i=1}^{n} \frac{|x_i - \hat{x}_i|}{x_i}$$

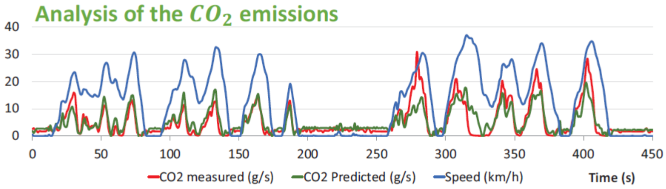
$$EF_{error} = \frac{Predicted\ EF - Real\ EF}{Real\ EF}$$

$$MRE = \frac{Known\ value - Prediction}{Maximum\ real\ value}\%$$

Results

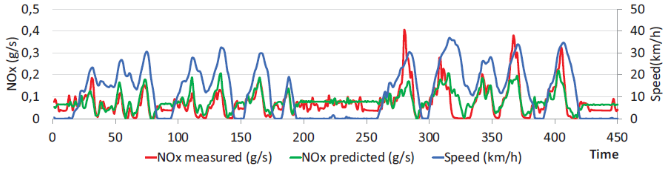
A) Training (75%) and testing (25%) in only one route,
B) Training (91%) with all routes and testing (9%) with one trained route,
C) Training (87%) with all routes and testing (13%) with one untrained route

Analysis of the CO_2 emissions



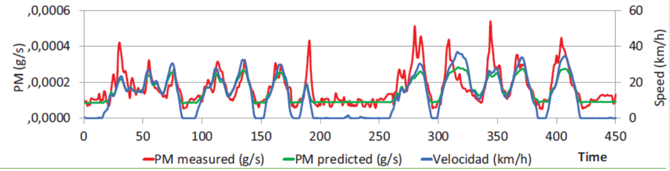
Case	Model	MRE [%]	EF_{error}[%]	MSE	MAPE
A	$\alpha + v \cdot \alpha + v \cdot \boldsymbol{a} + v^2 + p_o$	0,8	-3,5	12,9	2,0
B	$\alpha + v \cdot \alpha + v \cdot \boldsymbol{a} + v^2 + p_o$	1,5	-6,6	9,1	1,8
C	$\alpha + v \cdot \alpha + v \cdot \boldsymbol{a} + v^2 + p_o$	5,3	-24,0	7,1	1,8

Analysis of the NO_x emissions



Case	Model	MRE [%]	EF_{error}[%]	MSE	MAPE
A	$\alpha + v \times \boldsymbol{a} + p_o$	0,5	-2,3	0,002	2,0
B	$\alpha + v \times \boldsymbol{a} + p_o$	2,0	-11,4	0,002	2,0
C	$\alpha + v \times \boldsymbol{a} + p_o$	1,0	-5,7	0,001	1,9

Analysis of the particles emissions (PM)



Case	Model	MRE [%]	EF_{error}[%]	MSE	MAPE
A	$\alpha + v \times \boldsymbol{a} + p_o$	0,7	-2,9	~ 0	0,2
B	$\alpha + v \times \boldsymbol{a} + p_o$	0,7	-2,8	~ 0	0,2
C	$\alpha + v \times \boldsymbol{a} + p_o$	6,6	-26,7	~ 0	0,3

Conclusions

- Prediction errors of instantaneous emissions (MAPE and MSE) show acceptable levels of accuracy. However, it is important to observe the cumulative effect of these instantaneous errors quantified by EF_{error}.
- Negative errors in all EF_{error} indicate a bias towards the underestimation of all predicted emissions.
- In case C, which is the most difficult to predict, CO_2 and PM had high EF_{error} (-25%), but NO_x showed acceptable errors (-6%), demonstrating the potential of the models to predict EF avoiding overfitting.

Acknowledgment

This work was supported by the Spanish Ministry of Economy and Competitiveness - State Program of Research, Development and Innovation Oriented to the Challenges of Society. National plan 2016-2018. TRA2015-68803-R. Research project: *Optimization system for urban driving cycles, application to the generation of patterns adapted to environmental requirements and vehicle fleet exploitation situations.*

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3.5.11 Application Development for Processing Real Driving Data on MATLAB Environment

Application Development for Processing Real Driving Data on MATLAB Environment

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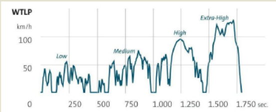
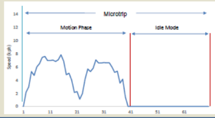
The purpose of this paper is to showcase the development of a statistical tool for filtering and analysing real driving data, with an aim to be used in real driving cycle creation and decision making. Real-world driving data were collected from the city of Athens, during the performance of daily driving routines. Research focuses on creating an accurate vehicle-driving profile, that can embody indispensable information about the impact of driving behaviour, on-road conditions and urban planning on the derivative driving cycles. With further study, this statistical tool will correlate the effects of previous parameters with energy consumption and fuel emissions. During this stage, the program should be considered under development.

Real World Driving Cycles are created by on-road measurements of vehicle parameters during real driving conditions. Through the analysis of collected data, a representative speed-time profile is formed. In recent years R.W.D.C.s have become the new standard of vehicle testing for legislative purposes.

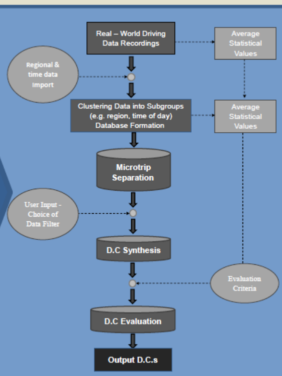


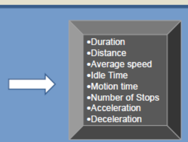


A **microtrip** is defined as a portion of the speed-time traces of data, bounded by an idle mode (zero speed) at both ends.

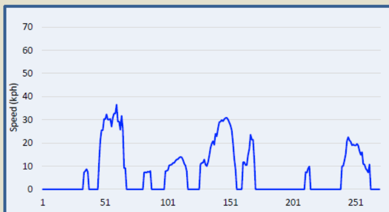
- Vehicle motion data were filtered and distributed into databases according to their respective city region or day time of recording
- The microtrip method was implemented in order to develop a MATLAB application that automatically analyzes the collected data and outputs the most representative cycle for each category , according to the users choice.
- Through filtering the resulting driving cycles, the aim is to capture as many information as possible about the driving behaviour of a certain combination of vehicle-driver and the conditions that transpired during on-road motion. It is suggested that the inclusion of this method of analysis will result in more accurate predictions about the environmental impact of everyday driving.

Due to major progress in GPS and cellphone technology during the recent years, the equipment used was kept fairly simple. The recording setup consisted of the following 1) an OBD (*On Board Diagnostics*) device which was used to acquire information from the vehicle's sensors 2) A common cellphone with Android operational system 3) An ANDROID data recording application. The regions that were frequently visited by the recording vehicle, were delimited on the map using Google map pins and exploited for the analysis.

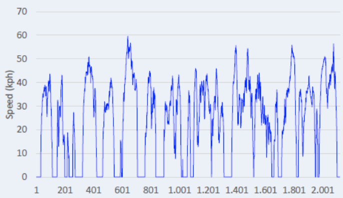




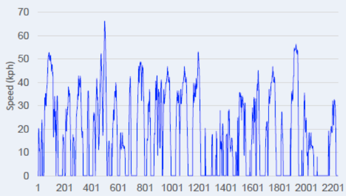
- Flow diagram of the program developed in MATLAB for the creation of Driving Cycles presented in this paper.
- Recordings are separated into microtrips
- Microtrips are filtered into subcategories
- Cycles are formed for each category
- Using the average statistical values as criteria, the most representative cycle is elected



Athens Center Ring DC



Athens DC



Athens DC during Rush Hours

Deviation of driving cycle average values from recorded driving data

Characteristic	Data Average Values	Athens Ring DC
Duration(s)	254	271
Motion time Percentage (%)	47	43
Avg. speed (kph)	9,61	7,42
Avg. Driving speed (km/h)	20,66	17,32
Acc. Time Percentage (%)	28,96	24,72
Decc. Time Percentage (%)	29,89	32,1
Idle time Percentage (%)	53	57
Distance (km)	0,6	0,56

Characteristic	Data Average Values	Athens DC
Duration(s)	1980	2119 (7%)
Motion time Percentage (%)	71	74 (3%)
Avg. speed (kph)	25,1	23,7 (5,6%)
Avg. Driving speed (km/h)	34,4	32,2 (6,4%)
Acc. Time Percentage (%)	37,38	36,15 (1,23%)
Decc. Time Percentage (%)	42,26	40,21 (2,05%)
Idle time Percentage (%)	421	421(100%)
Distance (km)	13,7	13,9 (1,5%)

Characteristic	Data Average Values	Athens DC during Rush hour
Duration(s)	2178	2235
Motion time Percentage (%)	58,01	60
Avg. speed (kph)	17,28	16,18
Avg. Driving speed (km/h)	29,77	28,08
Acc. Time Percentage (%)	43,44	34,6
Decc. Time Percentage (%)	54,19	58,7
Idle time Percentage (%)	41,99	40
Distance (km)	10,5	10,41

By comparing the driving cycles created by the usage of different data filtrations, their formation divergence becomes evident. The significant differences observed in the previous cycles are a result of the varying driving behaviour and road conditions occurring in the different areas and day times of the recordings. The Athens Ring cycle is short, contains smaller microtrips, has high ratio of stops in accordance to its duration and low speeds. DC for rush hours lasts longer and is characterized by many stops, but involves higher speeds and abrupt speed changes. The master cycle created by the sum of data recorded showcases some of these characteristics in parts, but differs in form from the aforementioned cycles. In that vein, the program developed by filtering the collected data and by creating region/time specific cycles, parallel to the master cycle, is able to provide more insight about on-road conditions. Thus, a more detailed driving profile for the specific combination of driver-vehicle can be obtained.

23th International Transport and Air Pollution Conference 2019
15-17 May 2019, Thessaloniki, Greece

3.6 Alternative fuels, new powertrains

This section includes posters presented in the context of the “Alternative fuels, new powertrains” sessions of the TAP conference. Table 18 provides an overview of these posters, as they are listed in the following sub-sections.

Table 18. Titles and authors of “Alternative fuels, new powertrains” papers

	Title	**Authors**
3.6.1	Investigation of Particle Number (PN) emissions from gasoline, diesel, LPG, CNG and hybrid-electric light duty vehicles under real-world driving conditions	A. Kontses, G. Triantafyllopoulos, L. Ntziachristos and Z. Samaras
3.6.2	Potential of Natural Gas to reduce road transport emissions: Case study with a Euro 6 passenger car	A. Dimaratos, G. Triantafyllopoulos, Z. Toumasatos, A. Kontses, L. Ntziachristos and Z. Samaras
3.6.3	Analysis of hybrid electric vehicle behaviour in real traffic conditions	N. Fonseca, T. Larrosa, J. Casanova and J.M. López
3.6.4	Well to Wheel Greenhouse Gas Emissions Analysis of Different Powertrain Technologies	G. Mellios, Z. Samos, J. Demuynck, D. Bosteels

3.6.1 Investigation of Particle Number (PN) emissions from gasoline, diesel, LPG, CNG and hybrid-electric light duty vehicles under real-world driving conditions

ARISTOTLE UNIVERSITY THESSALONIKI
SCHOOL OF ENGINEERING
DEPT. OF MECHANICAL ENGINEERING

LABORATORY OF APPLIED THERMODYNAMICS

Investigation of Particle Number (PN) emissions from gasoline, diesel, LPG, CNG and hybrid-electric light-duty vehicles under real-world driving conditions

A. Kontses, G. Triantafyllopoulos, L. Ntziachristos and Z. Samaras

Introduction & Objectives

- PN emissions focus is currently on Diesel and GDI vehicles but which are the technologies contributing to total PN emissions on the road?
- Over 15 millions LPG vehicles in Southern and Eastern EU; majority are retrofits. What do we know of their contribution to PM/PN?
- How do older technologies compare with latest options?

Objectives

- Evaluate PN emissions from diesel, gasoline, CNG, LPG and hybrid-electric vehicles under real-world driving conditions.
- Determine the contribution of each fuel type and powertrain/aftertreatment configuration to vehicular PN emissions.

Methodology

Test vehicles and measurement equipment

#	Vehicle segment	Engine specs	Fuel and injection type	Euro Std.	Exhaust after-treatment	Reg. year	Mileage [km]
V1	J	2.0l, 105kW, NA	LPG | PFI Gasoline | PFI	EU3	TWC	2003	230k
V2	B	1.4l, 58 kW, NA	LPG | PFI Gasoline | PFI	EU4	TWC	2007	220k
V3	J	1.6l, 94kW, NA	LPG | PFI Gasoline | PFI	EU6	TWC	2015	41k
V4	C	1.5l, 134kW, Turbo	Gasoline | DI	EU6	TWC	2017	15k
V5	C	1.4l, 81kW, Turbo	CNG | PFI Gasoline | DI	EU6	TWC	2017	3k
V6	C	1.8l, 73kW, Atkinson	Hybrid Gasoline | DI	EU6	TWC	2015	34k
V7	C	1.4l, 66kW, Turbo	Diesel | DI	EU6	2x LNT | DPF	2017	42k
V8	C	1.6l, 88kW, Turbo	Diesel | DI	EU6	DOC | DPF | SCR	2015	30k

- Horiba OBS-One PN PEMS (CPC-based) for $SPN_{>23nm}$ emission measurements, in vehicle trunk.
- Sampling raw exhaust from vehicle tailpipe.
- Engine and vehicle data from OBD
- Route characteristics from GPS and ambient temperature and humidity sensors

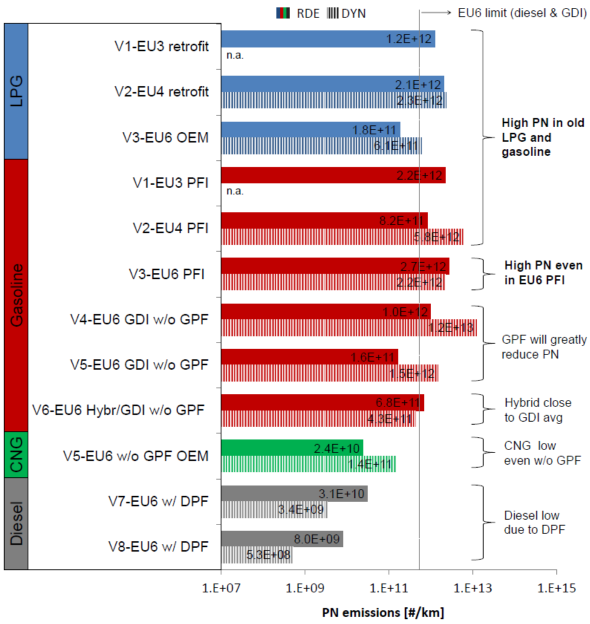
Test routes

Trip characteristics	RDE	DYN	Regulation limits
Trip duration [min]	100	50	90 – 120
Stop duration [% of trip]	22	20	> 10
Trip distance [km]	77	54	> 48
Urban distance share [%]	37	30	29 – 44
Rural distance share [%]	33	36	23 – 43
Motorway distance share [%]	30	34	23 – 43
Urban avg speed [km/h]	21	30	15 – 30
Rural avg speed [km/h]	83	75	60 – 90
Motorway avg speed [km/h]	118	110	100 – 145
Max altitude [m]	115	530	< 700
Positive elevation gain [m/100km]	507	1600	<1200
Total altitude gain [m]	-7	0	± 100

- Cold-start RDE route is fully compliant with regulation requirements.
- DYN reflects a route of more demanding driving, including high elevation gain.
- Route parts definition
  - Urban: V ≤ 60km/h
  - Rural: 60km/h < V ≤ 90km/h
  - Motorway: V ≥ 90km/h

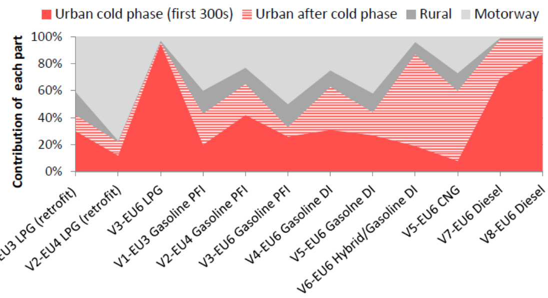
Results and discussion

Average PN emissions (RDE and DYN routes)



Vehicle	LPG or CNG compared to Gasoline RDE | DYN
LPG-V1-EU3 (retrofit)	↓ | n.a.
LPG-V1-EU4 (retrofit)	↑ | ↓
LPG-V3-EU6-OEM	↓ | ↓
CNG-V5-EU6 OEM	↓ | ↓

Contribution of each route part on PN emissions (RDE route)



Summary and conclusions

- Gasoline and LPG vehicles, especially the older ones, are the highest polluters
- Diesel and CNG vehicles are the lowest
- Significant contribution of urban part and especially cold phase (first 300s) in overall PN emissions.
- Further study: PN emissions in the sub-23nm area. High $SPN_{<23nm}$ emissions are expected for GDI and CNG engines

This research is co-financed by Greece and the European Union (European Social Fund-ESF) through the Operational Programme «Human Resources Development, Education and Lifelong Learning» in the context of the project "Scholarships programme for post-graduate studies – 2nd study cycle" (MIS-5003404), implemented by the State Scholarships Foundation (IKY)

Operational Programme Human Resources Development, Education and Lifelong Learning
Co-financed by Greece and the European Union
ΕΣΠΑ 2014-2020

3.6.2 Potential of Natural Gas to reduce road transport emissions: Case study with a Euro 6 passenger car

ARISTOTLE UNIVERSITY OF THESSALONIKI GREECE

LAT LABORATORY OF APPLIED THERMODYNAMICS

LHTEE LABORATORY OF HEAT TRANSFER AND ENVIRONMENTAL ENGINEERING

TAP 2019 | THESSALONIKI, GREECE

Potential of Natural Gas to Reduce Road Transport Emissions: Case Study with a Euro 6 Passenger Car

A. Dimaratos, G. Triantafyllopoulos, Z. Toumasatos, A. Kontses, L. Ntziachristos, Z. Samaras

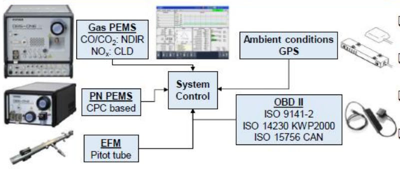
Introduction & Objectives

- Road transport responsible for ~25% of global CO_2 emissions, major contributor to degraded urban air quality
- Natural gas as one of the major alternative fuels for transportation
  - ✓ Lower cost compared to gasoline and diesel
  - ✓ Availability throughout the world, exceeding liquid fossil fuel reserves
- Main benefits of Compressed Natural Gas (CNG) as fuel in Internal Combustion Engines
  - + Great potential for CO_2 emissions reduction
  - + Applicability in both SI (mono/bi-fuel) and CI (dual-fuel) engines
  - + Slightly increased efficiency in bi-fuel engines, usually optimized for gasoline
  - + Potential for significantly higher efficiency in engines optimized for CNG (higher CR)
- Present and future challenges
  - — Emissions of regulated pollutants and CH_4
  - — Refueling infrastructure, facilities and logistics
- Objectives
  - → Evaluate CO_2, NO_x, PN and CO emissions with CNG and conventional fuels
  - → Assess the effects of different driving profiles

Tested Vehicles, Fuels & Equipment

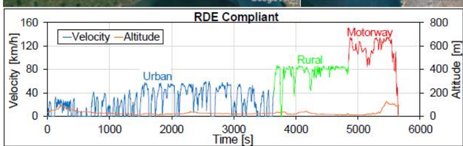
Vehicle Specification	Vehicle A	Vehicle B
MY / Segment / Chassis type	2018 / C / Sedan	2016 / C / Hatchback
Engine	Spark-ignition, 4-cyl	Compression-ignition, 4-cyl
Fuel	CNG and Gasoline	Diesel
Max power [kW]	81	66
Number of gears	6	6
Drive & Transmission	FWD, Manual	FWD, Manual
Engine capacity [cm³]	1395	1364
Aftertreatment system	TWC	2 LNTs, DPF
Emission standard	Euro 6b	Euro 6b

Property	Diesel B7	Gasoline E0	CNG
Density [kg/m³]	832	750	0.654
CN [—]	56	—	—
RON [—]	—	95	130
LHV [MJ/kg]	43.0	43.4	49.0
C content [%]	86.4	86.2	75.0
H_2 content [%]	12.9	13.8	25.0
O_2 content [%]	0.7	—	—
C/H ratio [—]	0.56	0.52	0.25
A/F_s [—]	14.6	14.7	17.2

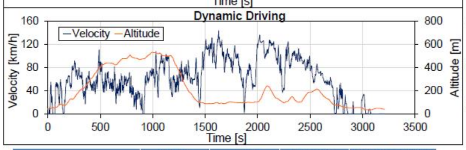


- ❑ Horiba Gas and PN PEMS, in the trunk, SPN>23nm
- ❑ EFM, connected to the tailpipe
- ❑ GPS and ambient sensors, on the roof
- ❑ Engine & vehicle data from OBD port

Testing Routes & Driving Profiles



- Within limits
- Standard road type sequence: Urban (U) – Rural (R) – Motorway (M)



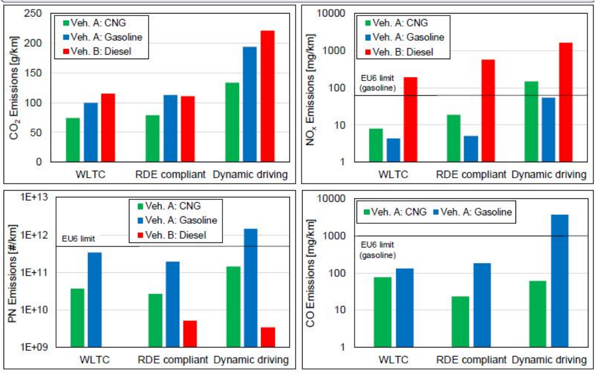
- Shorter duration than RDE
- Non-compliant with regulation
- Mixed road type sequence

Parameter	WLTC Class 3b	RDE compliant	Dynamic driving	RDE Regulation limits
Trip distance [km]	23.3	76.5	53.8	>48
Trip duration [min]	30	90-100	50	90-120
Maximum speed [km/h]	131	130	145	<145
Altitude difference end-start [m]	—	50	2	<±100
Maximum slope (Up-/Down-hill) [%]	—	4.2/6.5	11.7/17.6	—
Cumulative positive elevation gain [m/100km]	—	400	1600	<1200
Road type distance share [%]*	U:38% R:26% M:36%	U:37% R:33% M:30%	U:25% R:34% M:41%	U:29%-44% R:23%-43% M:23%-43%

- WLTC test with realistic road load

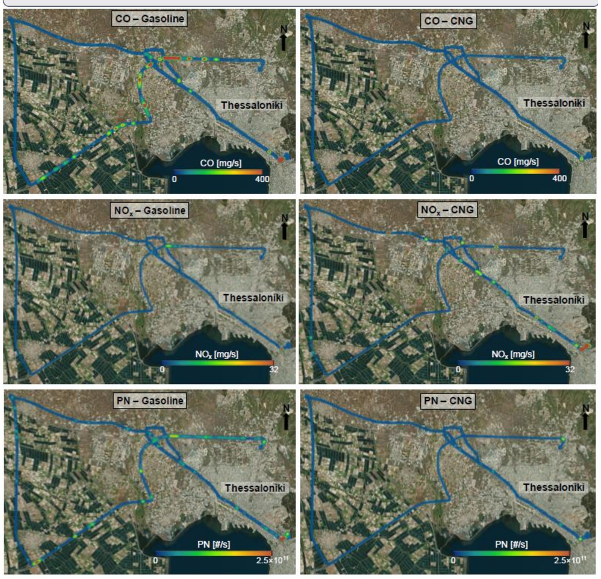
*Road type definition
U: V ≤ 60km/h
R: 60km/h < V ≤ 90km/h
M: V ≥ 90km/h

Overall Emission Levels



- CO_2: Lower emissions with CNG – lower C/H ratio, higher LHV, higher efficiency
- NO_x: Higher emissions with CNG, compared to gasoline. Diesel: highest NO_x emitter
- PN: Lower emissions with CNG than gasoline. Diesel: lowest PN emitter, DPF dominance
- CO: Lower emissions with CNG, in all conditions below Euro 6 limit with CNG

Localization of Emissions – CNG vs. Gasoline



- Significant reduction of CO levels with CNG
  - Cold start emissions for both fuels in urban area, due to low catalyst temperature
  - High emissions for gasoline in motorway, mainly in the uphill part
- Higher NO_x emissions with CNG in urban part, after cold start period
- Lower PN levels with CNG, both in urban and motorway parts

Outlook

Species	CNG vs. Gasoline	CNG vs. Diesel
CO_2	↓	↓
NO_x	↑	↓
PN	↓	↑
CO	↓	No data

- Great potential of CNG to mitigate greenhouse gas emissions.
- Challenge: Increased NO_x emissions
- Further study needed: CH_4 emissions

This research is co-financed by Greece and the European Union (European Social Fund-ESF) through the Operational Programme «Human Resources Development, Education and Lifelong Learning» in the context of the project “Reinforcement of Postdoctoral Researchers” (MIS-5001552), implemented by the State Scholarships Foundation (IKY)

Operational Programme Human Resources Development, Education and Lifelong Learning
Co-financed by Greece and the European Union
ΕΣΠΑ 2014-2020

Analysis of hybrid electric vehicle behaviour in real traffic conditions

N. Fonseca*[1], T. Larrosa[1], J. Casanova[2] and J.M. López[3]

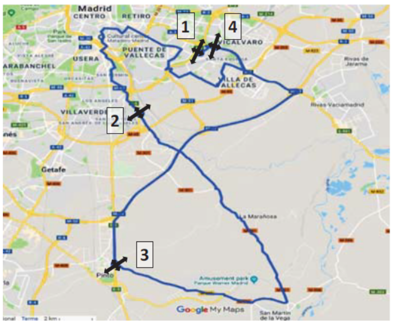
Objetives

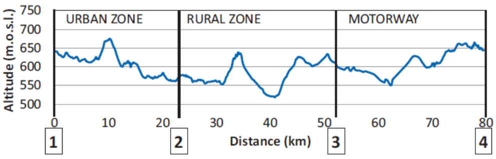
This study is a new contribution to investigate the behaviour of the hybrid powertrains of light-duty vehicles in real traffic, dealing with fuel consumption, CO_2 and NO_x emission factors measured in real driving emissions (RDE) tests in Madrid and its surroundings. It is analysed operative conditions: when the vehicle is in thermal engine and in zero emissions modes.

Measurement campaign

- One Euro 6b Toyota RAV4 Hybrid equipped with 114 kW - 2494 cm³ indirect injection gasoline engine and two electric engines (143 and 68 kW) with series-parallel hybrid configuration. Model year 2017 with 13600 mileage at the beginning of the tests. Vehicle equipped with EGR+TWC.

- The route was designed according to Real Driving Emissions (RDE) protocol (EU Regulation 2016/427), with a total of 79.4 km including urban, rural and highway track sections.



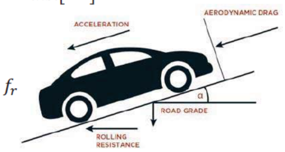


- Five tests were done in May 2017 using normal driving style.
- Exhaust gas flow, NOx and CO2 instantaneous emissions and vehicle kinematics were measured using MIVECO PEMS V3.0. Data was recorded and synchronized @ 10 Hz. [1, 2].

Data processing

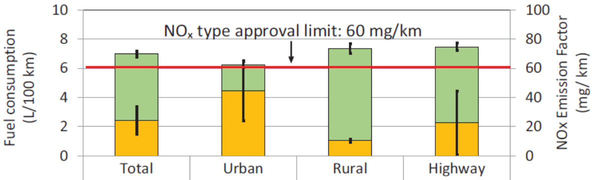
- Fuel consumption factor: $FC[\mathrm{L/100\,km}] = \dfrac{\sum \dot{m}_F[\mathrm{g/s}]\Delta t}{dist[\mathrm{km}]} (\rho_F[g/L])^{-1} \cdot 100$
- NOx emission factor: $FE_{NO_x}[\mathrm{g/km}] = \dfrac{\sum \dot{m}_{NO_x}[\mathrm{g/s}]\Delta t}{dist[\mathrm{km}]}$
- Traction power:

$$P_T = v \cdot F_T = v(m\frac{dm}{dt} + m \cdot g \cdot \sin a + m \cdot g \cdot f_r + \frac{1}{2} \cdot Cx \cdot A_{vb} \cdot \rho_a \cdot v_{viento}^2)$$



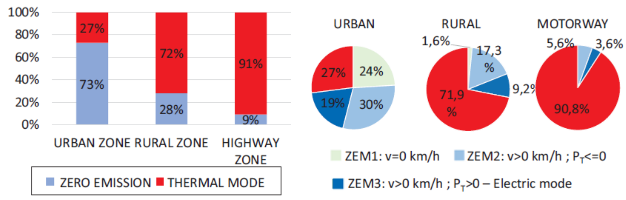
Results

- **Fuel consumption and NOx emission factor**

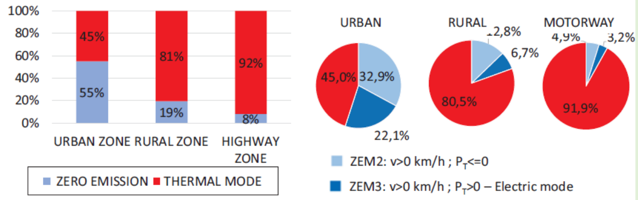


	Total	Urban	Rural	Highway
FC	7,0	6,3	7,3	7,5
NOx EF	24,3	44,6	10,4	22,6

- **Time percentage in Zero Emissions Mode (ZEM)**



- **Distance percentage in Zero Emissions Mode (ZEM)**



Conclusions

- Hybrid vehicles that combines gasoline engines with electric motors in series-parallel configuration has great environmental advantages especially in urban traffic because of its lower NOx emissions, lower fuel consumption and therefore lower CO_2 emissions, with high time and distance percentages in zero emissions mode.

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1. Fonseca González, N., Casanova Kindelán, J., López Martínez, J.M. (2016) Methodology for instantaneous average exhaust gas mass flow rate measurement. Flow Meas. Instrum. 49, 52–62. https://doi.org/10.1016/j.flowmeasinst.2016.04.007.

2. Casanova Kindelán, J. & Fonseca González, N. (2013) Dispositivo universal, no intrusivo, de medida en tiempo real de emisiones contaminantes de motores, embarcable en vehículos. Spanish Patent ES 2398837_B2.

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POLITÉCNICA INSIA TAP 2019 | THESSALONIKI, GREECE

3.6.4 Well to Wheel Greenhouse Gas Emissions Analysis of Different Powertrain Technologies

emisia
CONSCIOUS OF TRANSPORT'S IMPACT

Well to Wheel Greenhouse Gas Emissions Analysis of Different Powertrain Technologies

G. Mellios (Emisia), Z. Samos (Emisia), J. Demuynck (AECC), D. Bosteels (AECC)

Introduction

Electrified powertrains such as BEV, HEV, PHEV, and FCEV tend to be promoted as zero or very low GHG emitting vehicles. This might be misleading, as the actual carbon footprint of a vehicle:

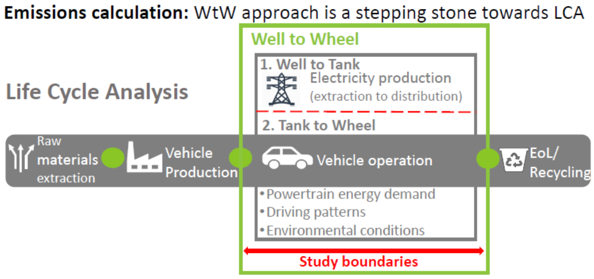
1. Includes upstream emissions (not only tailpipe)
2. Depends also on other GHG such as CH_4 and N_2O
3. Emissions measured under legislative tests are underestimated

Study objective: Quantifying GHG emissions (CO_2, CH_4 and N_2O) based on a WtW approach and considering real world consumption data of different powertrain technologies to make a more reliable comparison across different technologies.

Methodology

Vehicle selection: Representative medium vehicle models (segment C-models year: 2015) selected covering various powertrain technologies.

Emissions calculation: WtW approach is a stepping stone towards LCA



General equation for calculating GHG emissions of any powertrain:

$GHG_{WtW} = GHG_{TtW} + GHG_{WtT(ICE)} + GHG_{WtT(Electric)}$

- WtT part: activities from resource extraction through fuel production to delivery of the fuel to vehicle.
- TtW part: energy expended from the vehicle operation.

WtW Total GHG emissions = **WtT Upstream emissions** + **TtW Tailpipe emissions**

Electricity generation GHG intensity

GHG intensity values vary significantly across the EU Member States due to different fuel mix used for electricity generation.

MS	CO_2	CH_4 [g CO_2eq/kWh]	N_2O
FR	34.8	0.05	0.44
GR	829.9	0.29	2.24
EU28	275.9	1.49	2.16

WtT emission factors

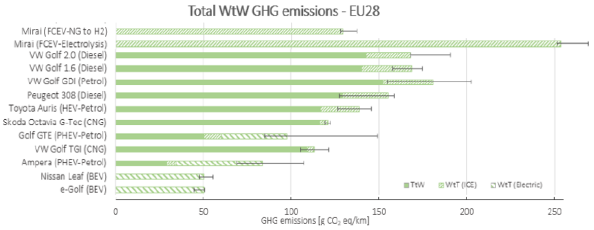
GHG emissions that produced in the steps required to turn a natural resource into fuel and bring that fuel to a vehicle.

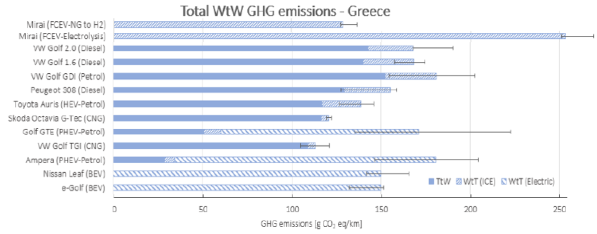
Fuel	CO_2	CH_4 [g CO_2-eq/MJ]	N_2O
Petrol	13	0.7	0.01
LPG	7.6	0.4	0.02
CNG	8.5	4.5	0.09
Diesel	14.6	0.7	0.01
Hydrogen thermal process (NG to H_2)	107.1	7.8	0.29
Hydrogen electrolysis	211	12.5	2.86

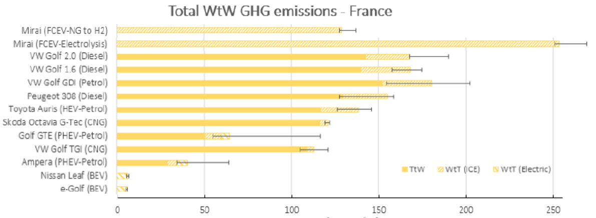
TtW emission factors

Instead of using officially reported values, **real-world** fuel and electric energy consumption data was collected by a large variety of sources.

Results and discussion







*Mirai belongs to segment D

- Total GHG emissions of a vehicle can not be expressed as a single value. Several factors such as fuel mix for electricity generation, carbon footprint for fossil fuels production, driving patterns and environmental conditions greatly affect GHG emissions.
- BEVs are not zero emission vehicles since they are responsible for the “upstream” GHG emissions from electricity generation.
- The WtW GHG emissions of BEVs and PHEVs vary significantly across EU Member States. In some countries, their GHG emissions levels are similar to those of conventional vehicles.
- CNG vehicles perform very well in terms of emissions. Excluding France, their GHG emissions are in the same range with PHEVs.
- The energy-intensive process needed to produce hydrogen, results in similar GHG emissions from conventional and FCEVs.
- There is high uncertainty in the CH_4 and N_2O data. Typically, TtW emission factors for these GHG are not publicly available.

Conclusions

- WtW analysis enables fair comparisons across different vehicle powertrain technologies. Still, this approach can only be seen as a stepping stone towards LCA as it ignores the production and end-of-life treatment of the vehicle.
- GHG emissions differences between conventional and electrified vehicle technologies are much lower than the tailpipe type-approval values suggest.
- Until the GHG intensity of electricity generation drops drastically, the ICE-based powertrains will remain competitive to electrified vehicle technologies in terms of GHG emissions. Even then, ICE could be competitive if a sustainable fuel is used.

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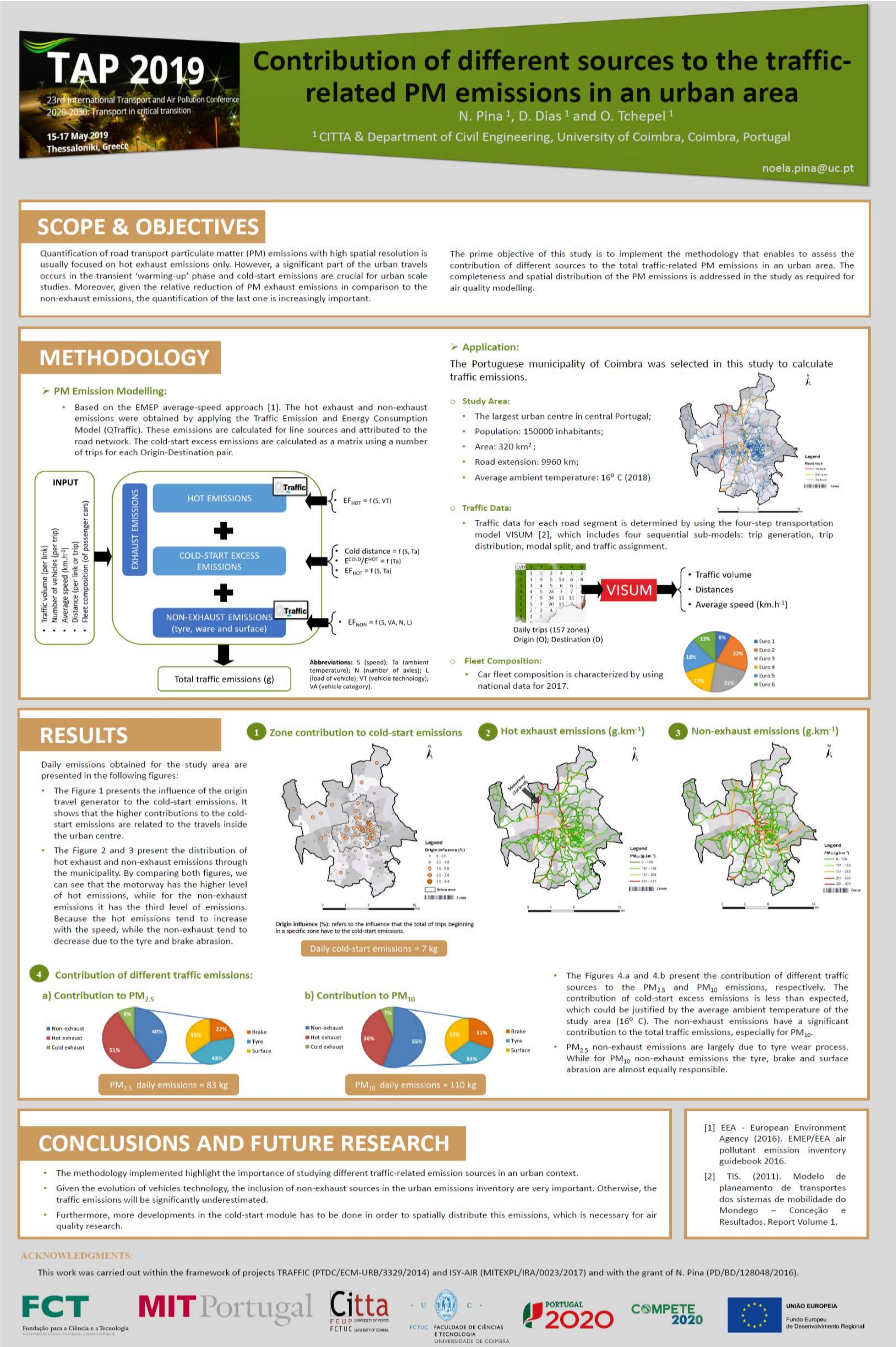
3.7 Particulate Matter

This section includes posters presented in the context of the “Particulate Matter” sessions of the TAP conference. Table 19 provides an overview of these posters, as they are listed in the following sub-sections.

Table 19. Titles and authors of “Particulate Matter” papers

	Title	**Authors**
3.7.1	Contribution of different sources to the traffic-related PM emissions in an urban area	N. Pina, D. Dias and O. Tchepel
3.7.2	On-road measurements of size-resolved particle number and potential secondary aerosol emission factors on European motorways	M. Dal Maso, J. Heikkilä, M. Olin, P. Simonen, A. Rostedt, E. Saukko, H. Kuuluvainen, J. Kalliokoski, O. Potila, A. Järvinen, M. Poikkimäki, T. Rönkkö and J. Keskinen
3.7.3	Advanced air cleaner system integrated into vehicles for removal of submicron and ultrafine particles	Y. Cha, E. Helin, A. Fodor and N. Hallgren

3.7.1 Contribution of different sources to the traffic-related PM emissions in an urban area



3.7.2 On-road measurements of size-resolved particle number and potential secondary aerosol emission factors on European motorways

Tampere University

On-road measurements of size-resolved particle number and potential secondary aerosol emission factors on European motorways

M. Dal Maso[1], J. Heikkilä[1], M. Olin[1], P. Simonen[1], A. Rostedt[1], E. Saukko[1*], H. Kuuluvainen[1], J. Kalliokoski[1], O. Potila[1], A. Järvinen[1], M. Poikkimäki[1], T. Rönkkö[1] and J. Keskinen[1]

[1] Aerosol Physics, Faculty of Natural Sciences, Tampere University of Technology, P.O. Box 692, 33101 Tampere, Finland
[*] Now at PEGASOR Oy, Hatanpään valtatie 34, 33100 Tampere, Finland

Motorway driving at high engine loads may cause above average emissions of both primary and secondary particulate matter. Highways carry a high fraction of all traffic, making them a significant source of air pollutants.

We present data from three trans-European measurement expeditions that were carried out on highways reaching from Southern Finland to the Mediterranean, covering in total close to **8'000 km of European highways during 2015-2016.**

Instrumentation

- aerosol size distribution (Dekati ELPI)
- aerosol number concentration (TSI and Airmodus CPC:s and an Airmodus PSM),
- trace gas detectors (CO_2, NO_x, O_3),
- fast-response oxidation flow reactor developed at TUT (TUT Secondary Aerosol Reactor, TSAR) allowing the study of transient effect during driving (Simonen et al., 2016)

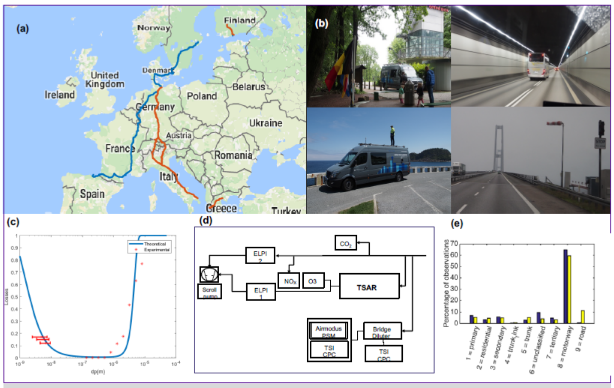


Figure 1: **(a)** A map of the routes driven during the 3 expeditions, the 2015 route in blue and the two 2016 expeditions in orange; **(b)** varying environments sampled during the expeditions; **(c)** the computed and measured penetration efficiencies for particles in the mobile laboratory for 30 lpm sample flow; **(d)** the instrumentation setup during the expeditions; **(e)** the distribution of road types sampled during the expeditions

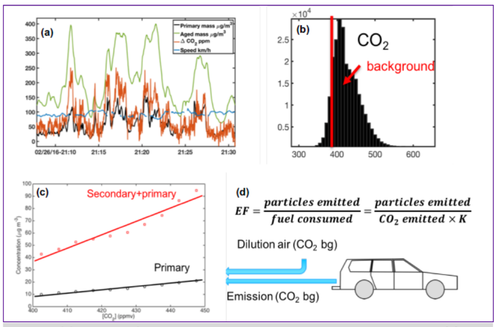


Figure 2: **(a)** example of primary and secondary mass measurement along with CO_2 data **(b)** frequency distribution of carbond dioxide observations **(c)** averaged primary and aged mass concentrations as a function of CO_2 concentration, used for the computation of emission factors as shown in **(d).**

Methods

Fast-response instruments and TSAR, together with concurrent CO_2 measurements allows determining a fuel-based emission factor for particle number and potential secondary aerosol during driving and during different driving conditions (Fig 2).

Number emission factors

As reported by Rönkkö et al. (2017, PNAS), we found high concentrations of sub-3 nm particles (nanocluster aerosol, NCA) which were emitted by traffic. The average total particle number emission factor was $1.1 \cdot 10^{16}$ #/kg_{fuel} and the emission factor of NCA was $3.5 \cdot 10^{15}$ #/kg_{fuel}. Motorway driving, and generally higher driving speed was associated with markedly increased emission of NCA and <100 nm particles (Fig 3 and Fig 4a-b).

The observed emission factors show that at least for urban areas, **traffic is comparable or may dominate as a source for NCA particles over regional photochemical nucleation processes.**

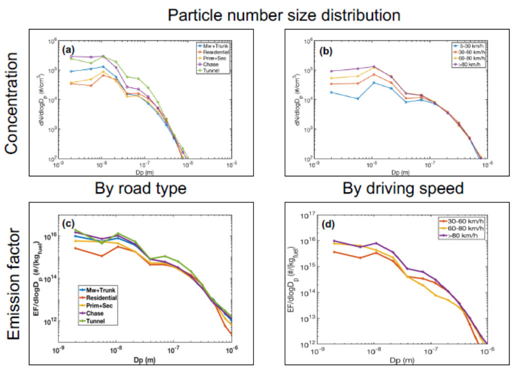


Figure 3: Observed particle number size distributions, for different road types **(a)** and diffferent driving speeds **(b);** Size-resolved number emission factors for different road types **(c)** and different driving speeds **(d).**

Secondary and primary mass ratio

Figure 4 (c-d) shows the observed mass emission factors. Potential secondary mass emission is highest at lower driving speeds and residential areas. The motorway secondary-to-primary ratio was between 4 and 6.

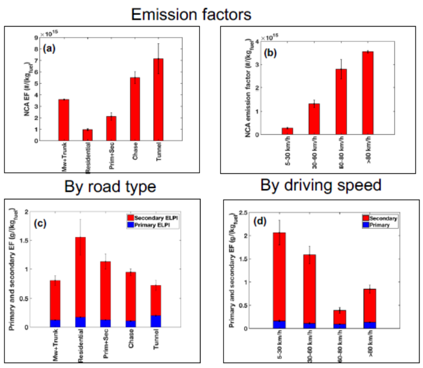


Figure 4: Sub-3nm (NCA) emission factors for different road types **(a)** and diffferent driving speeds **(b);** Primary and secondary mass emission factors for different road types **(c)** and different driving speeds **(d).**

3.7.3 Advanced air cleaner system integrated into vehicles for removal of submicron and ultrafine particles

Advanced air cleaner system integrated into vehicles for removal of submicron and ultrafine particles

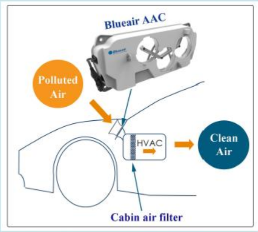
Yingying Cha, Emil Helin, Attila Fodor, and Niklas Hallgren
Blueair Cabin Air AB, Karlavägen 108, Stockholm, Sweden

Abstract

High voltage ionization technologies were integrated into ventilation systems of vehicles to develop advanced air cleaner (AAC) systems capable of removing air pollutants from outdoor air. The filtration performance of 11 selected Blueair AAC systems were verified by laboratory tests, with test methods in accordance with standards for air filters, e.g. DIN 71460-1 but using DEHS as test aerosol. With the active ionization technologies, all tested AACs were shown to significantly enhance the performance of the filtration especially on ultrafine particles (< 100 nm). The boost effect in filtration efficiency is significant on both new and aged filters.

Introduction

Airborne particulate matter concentrations in vehicle cabins are higher compared to background levels. A recent study revealed that the exposures were the highest for car drivers and passengers (Dons et al., 2012). Air recirculation with high-efficiency air filters has been reported as the most effective measure to lower air pollutant levels inside cabins (Xu, et al., 2016). However, when people occupy confined spaces, air recirculation can lead to carbon dioxide (CO_2) accumulation which can potentially lead to deleterious effects on cognitive function (Torres, 2014; Mathur, 2016). With the aim of providing people in vehicle microenvironments fresh air with lower levels of particles without increasing CO_2 concentration, Blueair Cabin Air AB (referred to Blueair herein) developed an integrated advanced air cleaner (AAC) system to increase filtration performance of cabin filters without increasing pressure drop over the ventilation system. A specific AAC unit is placed in front of the cabin filter (at the fresh air intake) to actively charge the particles passing by and trap them in the filter. This study investigated the contribution of Blueair AACs to particulate filtration of different types of cabin filters.

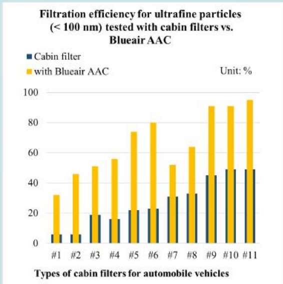


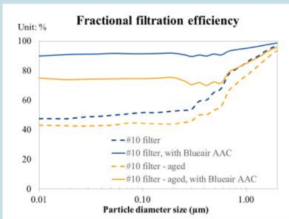
Method

Particle filtration tests were performed in Blueair laboratory for 11 pieces of automotive cabin filters for different cars, as well as custom-made AAC systems for the corresponding car models. The test rig was built according to DIN 71460-1. Test aerosol used for all tests was DEHS liquid, which is recommended as the reference aerosol for a particle size range of below 1 µm in ISO 16890-2. A Grimm MiniWRAS model 1.371, enabling the measurement of particles between 10 nm and 35 µm, was used to measure particle number concentrations. All filters were tested with and without Blueair AACs under the same specified test condition (airflow rate at 300 m^3/h, input high voltage of 7 kV). Each device under test was tested 2-4 times to ensure a repeatable result.

Results

All the Blueair AAC prototypes were shown to have significantly increased the filtration, efficiency of cabin filters especially in ultrafine size fraction. The filtration efficiency of different cabin filters varied, with an average efficiency varying between 19% and 67% for particles in the size range of 0.01-2.5 µm. With Blueair AAC systems, these values are remarkably increased to up to 95%. The increase in the efficiency by using a Blueair AAC is even greater for ultrafine particles, from 6% - 49% for original cabin filters, to 42% - 95% in combination with an AAC prototype. Results also showed that an AAC system can greatly enhance the filtration performance of an aged filter (aged in a highly polluted road tunnel environment). Different types of AAC performed differently, which is related to the output current depending on specific layouts of prototypes.





Conclusions

This study shows the possibility to improve indoor air quality of vehicles with a recently developed Blueair AAC system based on ionization technologies. A Blueair AAC system, as the first product designed to integrate into different types of vehicles, has been proven to significantly enhance the filtration efficiency of cabin filters, especially for ultrafine particles. The current available filters on the market usually have a filtration efficiency ranging from less than 10% to around 60%, which can be remarkably improved to up to around 95% by using an AAC prototype. The AAC technology was even shown to have a significant boost effect on aged filters. However, this study does not include any investigation on the removal of other types of air pollutants in vehicle cabins, such as bacteria, virus, and gas pollutants, which would be of great interest for future work.

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Acknowledgements

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About Blueair Cabin Air AB

Blueair Cabin Air AB provides air purification systems to everyone on the go. We exist to provide people on the road, on trains and on other public transportations, with clean air to breathe.

Blueair Cabin Air AB has R&D facilities in Stockholm, Sweden and in Shenzhen, China, including air quality and air flow lab, electronics lab and a prototype workshop.

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3.8 Emission control technologies of primary air pollutants of road and non-road transport

This section includes posters presented in the context of the “Emission control technologies of primary air pollutants of road and non-road transport” sessions of the TAP conference. Table 20 provides an overview of these posters, as they are listed in the following sub-sections.

Table 20. Titles and authors of “Emission control technologies of primary air pollutants of road and non-road transport” posters

	Title	**Authors**
3.8.1	Primary results of OBD tests collected during PTI of vehicles in Croatia	M. Rešetar, G. Pejić, P. Ilinčić and Z. Lulić
3.8.2	How to reduce engine exhaust related secondary organic aerosol formation potential?	P. Karjalainen, P. Simonen, H. Timonen, S. Saarikoski, P. Aakko-Saksa, M. Lauren, T. Rönkkö, and J. Keskinen
3.8.3	Simulation of DPF failures for vehicle type-approval of PM On-Board Diagnostics	S. Geivanidis, D. Kontses, D. Katsaounis and Z. Samaras

3.8.1 Primary results of OBD tests collected during PTI of vehicles in Croatia

TAP 2019

15th to 17th May 2019
Thessaloniki, Greece

23rd International Transport and Air Pollution Conference

Primary results of OBD tests collected during PTI of vehicles in Croatia

M. Rešetar [1], G. Pejić [1], P. Ilinčić [2], Z. Lulić [2]

[1] Centre for Vehicles of Croatia, Capraška 6, Zagreb, HR-10000, Croatia
[2] Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb, Ivana Lučića 5, Zagreb, HR-10002, Croatia

Introduction

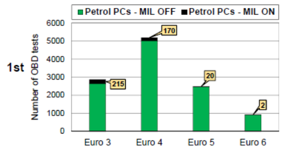
Due to resolution or measurement precision limitations, existing emission testers used in periodic technical inspection (PTI) stations often cannot measure neither the CO volume fraction of Euro 6 petrol engine vehicles, nor the opacity of the Euro 6/VI diesel engine vehicles. The fact is that it is much more difficult to measure smoke opacity in DPF equipped vehicles. (Giechaskiel et al., 2014). Therefore, the application of these devices to the Euro 6/VI vehicles becomes less important. Also, today's electronic units continuously control the correct operation of several exhaust system components as well as the emissions. For vehicles complying with emission classes Euro 6/VI, OBD systems are becoming more effective in assessing emissions. According to the Directive 2014/45/EU, for roadworthiness tests the OBD test can be used as an equivalent to standard tailpipe emission testing for vehicles of emission classes Euro 6/VI (Official Journal of the European Union, 2014).

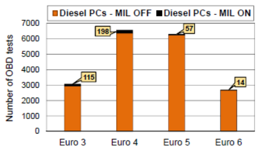
Effective from 1st January 2019 OBD testing methods are implemented in Croatia. An OBD connection is required in vehicles belonging to emission classes Euro 3 and newer wherein the following data are collected: MIL status, Readiness-code status, number of DTCs, coolant temperature and engine speed. In addition to the OBD test, the classic tailpipe test is also performed on vehicles of all Euro classes. Data on the passenger car (PC) fleet that underwent PTI during January 2019 was gathered from the database of Centre for Vehicles of Croatia (CVH), the company whose primary activity is performing PTI on vehicles in Croatia. Tailpipe and OBD test results were processed for both petrol and diesel PCs, as shown below.

OBD test results

The lower the Euro emission class is, the higher is the percentage of PCs with MIL status ON (1st row). These vehicles do not undergo the tailpipe test but nevertheless are declared technically defective.

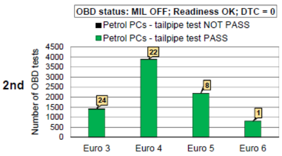
1st

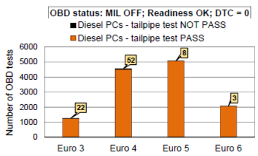




Vehicles with MIL status OFF undergo both OBD and tailpipe tests. The majority of vehicles meets the following requirements: MIL OFF, Readiness OK and DTC counter = 0. There is a certain number of PCs that, despite passing the OBD test, did not pass the tailpipe test. The data also shows the following: The lower the Euro emission class is, the higher is the percentage of PCs which did not pass the tailpipe test (2nd row).

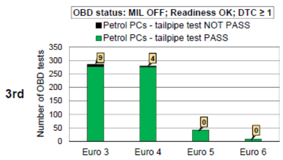
2nd

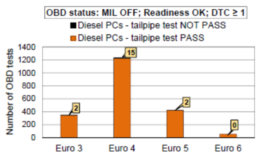




Vehicles with OBD status MIL OFF, Readiness OK and DTC counter ≥ 1 also passed the OBD test. There is also a certain number of PCs that, despite passing the OBD test, did not pass the tailpipe test (3rd row).

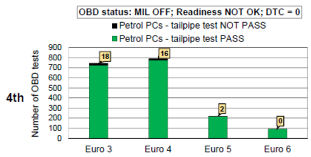
3rd

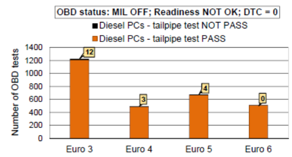




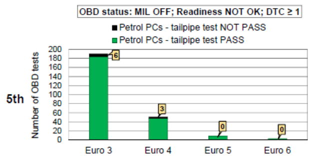
All Euro 6 vehicles with OBD status MIL OFF and Readiness NOT OK passed the tailpipe test (4th and 5th row).

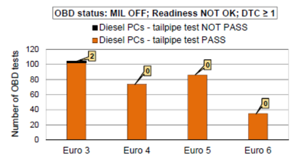
4th





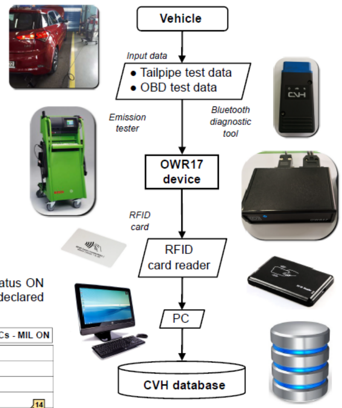
5th





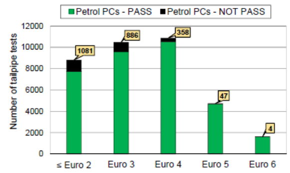
Method

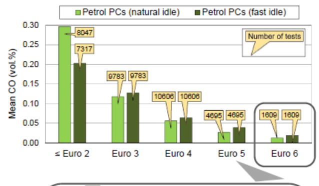
During the PTI, the emission tester and OBD diagnostic tool should be connected to the vehicle. Tailpipe and OBD test results are collected and stored on the OWR17 device. Then all the collected data is transferred to CVH database using RFID card. Tailpipe and OBD test data collecting procedure is shown below.

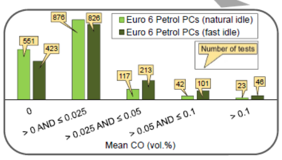


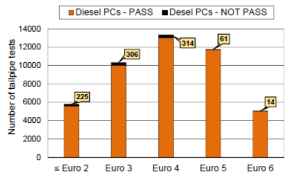
Make	Number of OBD tests				
	Total	MIL OFF (%)	MIL ON (%)	0 DTC (%)	≥ 1 DTC (%)
VOLKSWAGEN	5442	96.88	3.12	94.06	5.94
OPEL	3156	96.29	3.71	92.55	7.45
RENAULT	3104	98.84	1.16	75.10	24.90
PEUGEOT	1918	97.91	2.09	68.98	31.02
ŠKODA	1781	97.25	2.75	92.59	7.41
CITROEN	1717	96.68	3.32	68.55	31.45
FORD	1550	98.00	2.00	93.61	6.39
AUDI	1367	97.59	2.41	93.78	6.22
MERCEDES	1243	96.86	3.14	87.77	12.23
BMW	1242	98.79	1.21	86.55	13.45
HYUNDAI	1120	98.04	1.96	91.43	8.57
TOYOTA	1064	98.12	1.88	95.49	4.51
FIAT	783	96.81	3.19	68.33	31.67
MAZDA	716	96.79	3.21	91.34	8.66
KIA	615	99.51	0.49	96.91	3.09
CHEVROLET	575	95.65	4.35	86.09	13.91
SEAT	516	95.35	4.65	90.12	9.88
NISSAN	455	98.68	1.32	83.96	16.04
DACIA	405	99.01	0.99	83.21	16.79
SUZUKI	390	97.69	2.31	94.62	5.38
HONDA	275	98.91	1.09	88.73	11.27
VOLVO	236	97.46	2.54	81.78	18.22
SMART	151	91.39	8.61	84.11	15.89
ALFA ROMEO	96	92.71	7.29	82.29	17.71
MITSUBISHI	83	93.98	6.02	85.54	14.46
MINI	77	97.40	2.60	85.71	14.29
JEEP	46	97.83	2.17	89.13	10.87
LAND ROVER	37	100.00	0.00	97.30	2.70
LANCIA	24	91.67	8.33	83.33	16.67
DAEWOO	21	85.71	14.29	71.43	28.57
SUBARU	21	100.00	0.00	100.00	0.00
JAGUAR	17	76.47	23.53	76.47	23.53
PORSCHE	16	100.00	0.00	100.00	0.00
CHRYSLER	12	91.67	8.33	58.33	41.67
SAAB	11	100.00	0.00	90.91	9.09
SSANGYONG	10	90.00	10.00	30.00	70.00
All other	32	94.00	6.00	81.25	18.75
Σ	30324				

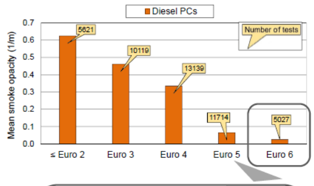
Tailpipe test results

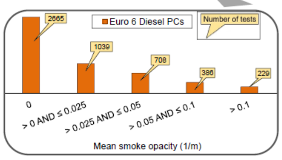












Discussion and conclusions

In order to ensure a higher quality of PTI of vehicles, it is necessary to introduce new testing methods. The OBD test can be a viable method of verifying proper operation of a large number of electronic devices and components in a vehicle, including the devices and components that affect the quality of exhaust emissions. This research includes OBD test results gathered from the PTI of PCs in Croatia, collected during January 2019. Before the implementation of OBD tests, an inspector could check the MIL status only visually on the dashboard. This is why owners whose MIL would turn on would often thinker with the system so as to conceal the MIL status. Using the OBD test, the amount of unprofessional tinkering has been greatly reduced because the necessary information is gathered straight from the ECU, regardless of the MIL status on the dashboard. The ECU is also used to gather the VIN, which makes it easier to ascertain whether it matches with the VIN in the documents and on the chassis itself. The OBD system can also show the vehicle's Readiness-code, according to which it is possible to establish which of the vehicle's systems were checked during the diagnostics procedure. Furthermore, the DTC counter shows the total number of faults in the system. It is planned to integrate other functions, i.e. the OBD2 PID codes used to request data available from the vehicle, into existing OWR17 devices. The implementation of OBD tests not only improves the quality of PTI procedures, but also adds to the overall traffic safety. Finally, these tests can help reduce the negative impact of exhaust emissions on the environment and human health.

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3.8.2 How to reduce engine exhaust related secondary organic aerosol formation potential?

Tampere University

How to reduce engine exhaust related secondary organic aerosol formation potential?

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[2]Atmospheric Composition Research, Finnish Meteorological Institute, Helsinki, Finland
[3]VTT Technical Research Centre of Finland, Espoo, Finland
[4]Turku University of Applied Sciences, Turku, Finland

Introduction

The particle emissions of automotive sources can be characterized to include fractions that are present in hot exhaust aerosol, in fresh exhaust aerosol after emission, and components that are formed in the atmosphere due to oxidation processes. The formation of secondary organic aerosol (SOA) in the atmosphere takes place through oxidation processes that tend to lower the saturation vapor pressures of organic species. The more oxidized compounds are more likely found in the particle phase (Robinson et al., 2007). Most of the secondary aerosol work has been focused on SOA, as the fresh exhaust contains numerous organic compounds (Gentner et al., 2017). The amount of SOA precursors at the end of tailpipe is dependent on the various properties of the engine, fuel type and exhaust aftertreatment (EAT) system. Here we present findings related to the effects of various vehicle technologies on secondary aerosol formation in the tailpipe, and introduce methods to reduce the SOA burden on air quality.

Methods

We have studied the SOA formation for different vehicle/engine types listed in Table 1. The idea in the experiments has been to change only one parameter (one vehicle technology) at the time (fuel or EAT) in order to understand how each technology change will affect the SOA formed.

Table 1. Technologies studied for the reduction of SOA formed.

Vehicle/engine type	Varied technology
Gasoline direct injection (GDI) passenger car	Fuel (E10, E85, E100)
Heavy-duty non-road diesel engine	Fuel (fossil, paraffinic) EAT (DOC, SCR, DPF)

The aerosol characterization has been performed with extensive instrumentation (Karjalainen et al., 2019; Timonen et al., 2017). The dilution system consisting of a porous tube diluter (PTD) as the first stage has been used in these measurements to simulate atmospheric exhaust dilution and nanoparticle formation conditions. Secondary aerosol formation has been studied with a Potential Aerosol Mass (PAM) chamber (Kang et al., 2007; Lambe et al., 2011), and further characterized with extensive online instrumentation including e.g. Soot Particle Aerosol Mass Spectrometer (SP-AMS).

Results

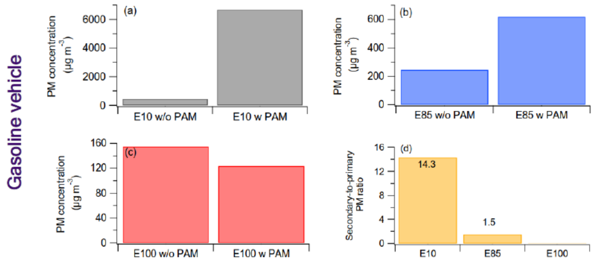

Figure 1. The PM concentrations of GDI exhaust measured w/o and w/ the PAM chamber for fuels E10 (a), E85 (b) and E100 (c). The secondary-to-primary PM ratios (d). (Timonen et al., 2017)

We observed that for a gasoline vehicle the change of fuel affected majorly the SOA formation potential over the regulation test cycle of Europe (NEDC) (Figure 1). With typical European fuel E10 the SOA PM was almost 15 times the PM measured without the PAM chamber, but in the case of E100 the formed SOA was negligible.

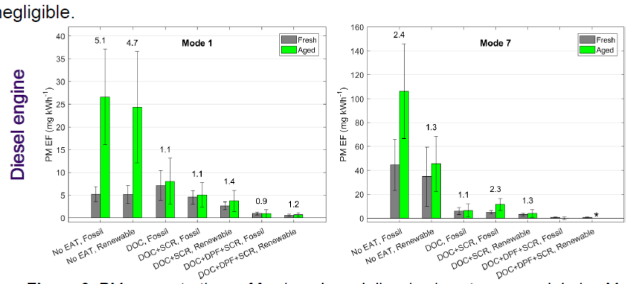

*Figure 2. PM concentrations of fresh and aged diesel exhaust measured during Mode 1 (high load) and Mode 7 (medium load). Numbers above the bars are the calculated aged/fresh PM EF -ratios. * indicates missing data point. (Karjalainen et al., 2019)*

For a diesel engine, we did not see such a great effect of fuel change to formed SOA, but dominant reduction of precursors was measured downstream extensive EAT system (Figure 2). The formed SOA potential reduced gradually when oxidative EAT systems were used, so that SOA formation downstream a modern EAT consisting of oxidation catalyst and particle filter was found negligible. Also Chirico et al. (2010) have shown that an oxidation catalyst reduces SOA formation from a diesel engine. However, Pieber et al. (2018) did not observe such reduction in SOA formation when equipping a gasoline vehicle with an additional catalyzed particle filter.

Future research should focus on studying the most severe SOA pollution sources and trying to identify the means to reduce these emission levels.

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Acknowledgements

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3.8.3 Simulation of DPF failures for vehicle type-approval of PM On-Board Diagnostics

LABORATORY OF APPLIED THERMODYNAMICS
ARISTOTLE UNIVERSITY OF THESSALONIKI
DEPT. OF MECHANICAL ENGINEERING

Simulation of DPF failures for vehicle type-approval of PM On-Board Diagnostics

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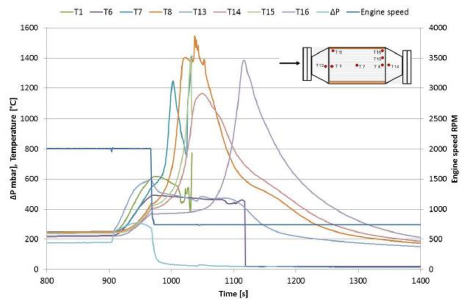
[2]Vehicle Technology Laboratory, Dept. of Mechanical Engineering, Technological Educational Institute of Central Macedonia, Terma Magnesias, Serres, 62124, Greece

Introduction

- For the type-approval of their OBD systems, vehicles need to be proven to be able to detect DPF failures that would lead to exceedance of the OBD threshold limits (OTL) set by legislation.
- For the needs of type-approval, an artificially failed DPF called "qualified deteriorated component" (QDC) is required to be created and installed on a vehicle that leads to exceedance of the OTL when the test vehicle is driven over the type-approval driving cycle.
- Protocols to artificially damage a DPF were investigated such as submission of the DPF to severe thermal stress by drop-to-idle operating conditions as well as removal of material (plugs) from the DPF.

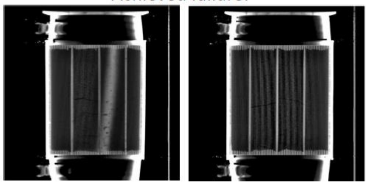
Drop-to-Idle DPF failure technique

The DPF is loaded up to a very high soot loading level, over the limit for safe regeneration. Then an uncontrolled regeneration starts by activating the post injection mode of the engine. The DPF inlet temperature increases and when soot oxidation is initiated, the pressure drop and the O_2 outlet concentration quickly begin to drop. At this point, the engine is switched to idle, with very low flow rate and high O2 concentration. Due to the high soot loading and the conditions that favor soot oxidation, very high temperatures are observed (up to 1400°C).



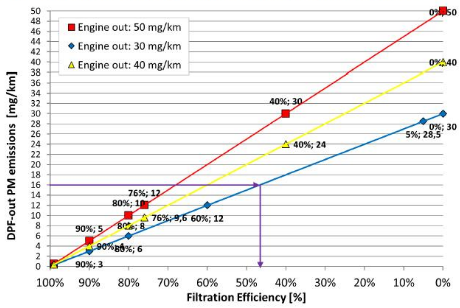
Despite of the apparent ring-off cracks, filtration efficiency of the DPF remained high.

Achieved failure:



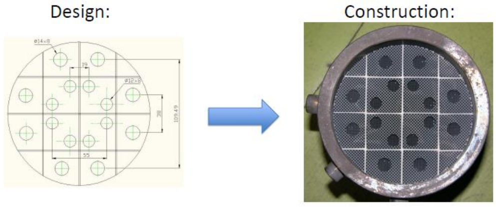
Plug removal DPF failure technique

The DPF is drilled in order to remove plus and create free channels. Drilling is designed based on calculations to achieve specific filtration efficiency based on the desired average filtration efficiency over the type-approval driving cycle and the response curve developed using past test. In addition, a certain algorithm is followed to allow uniform distribution of plugs removed that will ensure an almost linear response of Filtration Efficiency as a function of plugs removed.



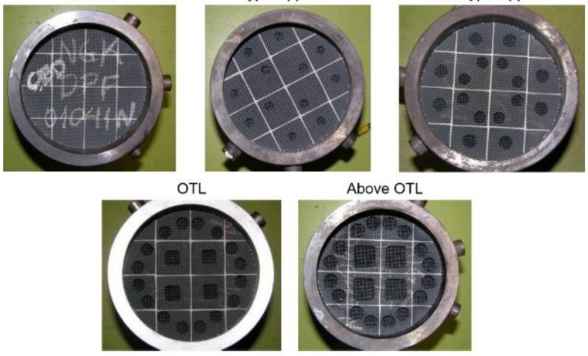
Results

Design: Construction:

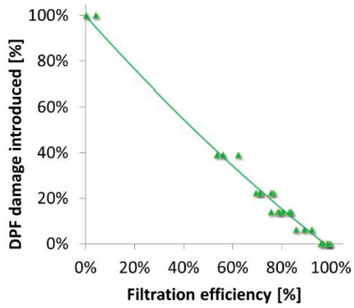


DPFs at various failure levels:

Full DPF Type-Approval 1.5 x Type-Approval



Results from actual tests verify the linear response of emissions as a function of plug removal:



Conclusions

Drop-to-idle technique:

- Can achieve DPF failure up to a limited level, not able to reach the required failure level for Euro 6 OBD type-approval
- Although method is close to what may happen in real world, extreme conditions as regards soot loading and temperatures reached need to be applied to achieve measurable filtration efficiency loss which are far from what is expected to happen in a vehicle.
- Repeatability of the method is very low and the resulting DPF filtration efficiency is difficult to be predicted

Plug removal technique

- Can achieve DPF failure to very high levels to create a qualified deteriorated component for OBD type-approval
- Repeatability of the method is very high and DPF failure level can be known while designing the removal of plugs

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3.9 New sensors and techniques

This section includes posters presented in the context of the “New sensors and techniques” session of the TAP conference. Table 21 provides an overview of these posters, as they are listed in the following sub-sections.

Table 21. Titles and authors of ““New sensors and techniques” posters

	Title	**Authors**
3.9.1	Real world transient emissions from cars and buses: a high resolution measurement technique to identify causes and locations	M.S. Peckham, F. Leach, J. Parnell and M. Hammond
3.9.2	A Counter Flow Denuder for Engine Exhaust Conditioning: First Laboratory Experiments	M. Bainschab, S. Martikainen, P. Karjalainen, J. Keskinen and A. Bergmann
3.9.3	Investigation of low cost sensors for particulate matter and gases for the application in measuring the ambient air quality	A. Samad, U. Vogt, B. Laquai, A. Surgaylo and G.C. Solis Castillo
3.9.4	PN measurements of automotive exhaust particles using charging-based techniques	M.A. Schriefl, M. Longin and A. Bergmann
3.9.5	"Smart Emission Measurement System (SEMS) for real-world driving emissions	N.E. Ligterink, F.J.M. van den Putte, F. Heepen, R.N. van Gijlswijk, E.G. Buskermolen, M. Elstgeest , G.Kadijk and E. Voogd

3.9.1 Real world transient emissions from cars and buses: a high resolution measurement technique to identify causes and locations

Real World Transient Emissions from Cars and Buses

A High Resolution Measurement Technique to Identify Causes and Locations

Mark Peckham[1]*, Felix Leach[2]*, Jamie Parnell[1], Matthew Hammond[1]

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[2]University of Oxford, Department of Mechanical Engineering *contact: felix.leach@eng.ox.ac.uk

ABSTRACT

Fast response emissions analysers have been adapted for on-board use to study the transient emissions of passenger cars and in-service buses during real world driving. The analysers have response times of a few milliseconds and, when combined with ECU and GPS data, can provide accurate, time-aligned data showing not only the engine-control-related reasons why such short-duration but significant "spikes" of emissions occur, but also the accurate location of such emissions. This, then, allows the accurate mapping of pollution "hot spots" – especially in urban environments which are often caused by traffic signals, speed bumps and congestion. Significant NOx emissions were noted from both Euro V and Euro VI buses, their locations correlating closely with bus stops. It is assumed that sub-optimal calibration or aged components contributed to the tailpipe transient emissions and was further exacerbated by the generally low speed and low load engine operation in those vehicles' urban routes.

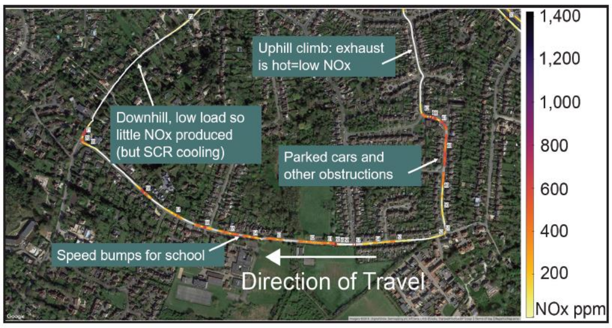
METHODOLOGY

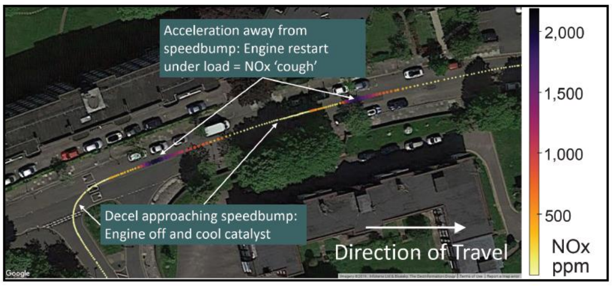
The routes followed by all the vehicles featured many different road features. The buses followed Oxford city routes and the EU VI PHEV a route supplied by TFL. Prior to the test, the analyzer was warmed up on AC grid power before switching to a 12V battery pack. Throughout the test, the exhaust NOx concentration was logged via the analogue output on the analyser. The buses were measured in-service giving realistic data in events such as bus stop approach and exit, speed bumps and traffic lights. No dashboard faults were present on either vehicle. Throughout the test, the PHEV's battery charge state was monitored. The test began with battery charge at 13.7%, believed to be an 'equilibrium point' between power supplied to the electric motor and recovered from regenerative braking. The vehicle operated as a standard parallel hybrid using internal combustion engine power where necessary, supplementing battery power to achieve the torque demand.

INSTRUMENTATION

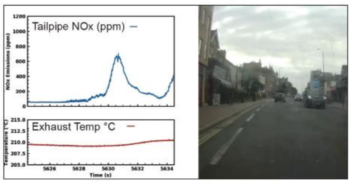
The vehicles were instrumented with an ultra-fast, on-board chemiluminescence analyzer (Reavell et al., 1997), which provides **exhaust gas NOx concentrations with a rise time of less than 10 ms**. The single channel system had the heated sample probe installed **after the aftertreatment systems** of all the sample vehicles. Dedicated software was written to obtain and simultaneously log ECU data from the OBD port alongside analyzer emissions data and **location data from a high precision GPS (0.1cm)**. ECU and GPS data was logged at 10 Hz, whilst fast emissions were logged at 100 Hz. In addition, the Euro VI bus was equipped with a **thermocouple to measure exhaust temperature**.

EMISSIONS MAPS

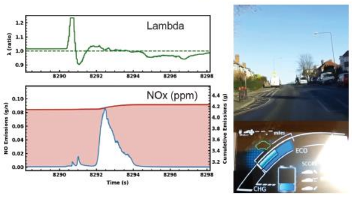




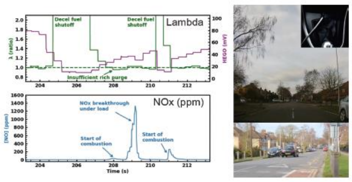
TYPICAL EVENTS



EU VI Bus stop: Pull-away spike of NOx due to preceding deceleration cooling.



EU VI PHEV Engine Restart: Heavy acceleraton leads to engine restart at high load. NOx 'cough' due to cool catalyst and insufficient rich purge.



EU IV Speedbump: Insufficient rich purge following decel fuel shut-off causing NOx breakthrough.

CONCLUSIONS

- Urban bus driving is highly transient and short-duration spikes of NOx are emitted
- Urban driving can also be low speed/load with associated low SCR temperatures
- Frequent, high concentration spikes of tailpipe NOx were produced by both Euro V & VI buses aggravated by the cool exhaust system
- Decelerations and significant engine off periods adversely affect the exhaust aftertreatment temperature and effectiveness

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Acknowledgements to **Oxford University** and **Oxford Bus Company** for their buses and route.

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Andrew J. Kotz, David B. Kittelson, and William F. Northrop. "Lagrangian Hotspots of In-Use NOX Emissions from Transit Buses". Environmental Science & Technology 2016 50 (11), 5750-5756. DOI: 10.1021/acs.est.6b00550

C Lambert, Douglas & Vojtisek-Lom, Michal & Joshua Wilson, P. (2002). "Evaluation of on road emissions from transit buses during revenue service" Clean Air Technologies Inc.

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3.9.2 A Counter Flow Denuder for Engine Exhaust Conditioning: First Laboratory Experiments

A Counter Flow Denuder for Engine Exhaust Conditioning: First Laboratory Experiments

M. Bainschab[1], S. Martikainen[2], P. Karjalainen[2], J. Keskinen[2] and A. Bergmann[1]

[1] Institute of Electronic Sensor Systems, Graz University of Technology
[2] Aerosol Physics, Tampere University

Introduction

The European emission standards limit the number of solid particles per kilometer emitted by vehicles. In order to measure this regulated quantity correctly it is necessary to:

- Remove volatile particles
- Inhibit the growth of sub-cut size particles
- Prevent nucleation
- Limit particle losses

There are three established methods to fulfill these requirements[2,3]:

- Evaporation tube
- Thermodenuder
- Catalytic stripper

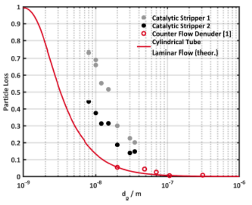

Figure 1: Diffusional particle loss comparison between two different catalytic strippers, the counter flow denuder [1] and the theoretical behavior of a cylindrical pipe

We present a counter flow denuder (CoFD) as an alternative approach to the existing methods. This device can tackle many downsides of the established devices. Figure 1 shows the relative particle loss as a function of particle diameter for different methods.

Working Principle

The counter flow denuder consists of a porous glass tube surrounded by a stainless steel tube. The sample gases inside the glass tube are Exchanged with the gases in the outer purge gas channel by diffusion. Antiparallel flow directions of the inner sample flow and the outer purge gas flow ensure a high concentration gradient over the whole length of the device. Figure 2 schematically illustrates the working principle of the counter flow denuder.

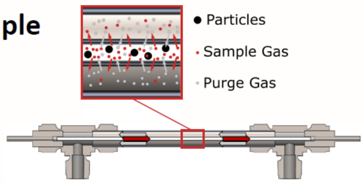

Figure 2: Drawing and schematic of the working principle of the counter flow denuder

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Swanson, J., & Kittelson, D. (2010). *Journal of Aerosol Science*, **41(12)**, 1113-1122.
[3] Amanatidis, S., Ntziachristos, L., Karjalainen, P., Saukko, E., Simonen, P., Kuittinen, N., ... & Keskinen, J. (2018). *Aerosol Science and Technology*, 1-13.

Experiment and Results

Laboratory based experiments were performed to test the potential of the counter flow denuder for engine exhaust conditioning. The formation of a nucleation mode after conditioning an aerosol containing soot and gaseous sulphuric acid, was monitored. The CoFD was compared with an evaporation tube and a catalytic stripper. Figure 3 shows a schematic of the experimental setup.

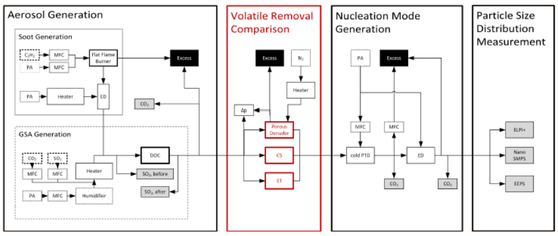


Figure 3: Schematic drawing of the experimental setup used to compare the counter flow denuder with an evaporation tube and a catalytic stripper.

The results in Figure 4 show that the CoFD prevents the formation of a nucleation mode at moderate SO_2 feeds and lowers the particle size and number concentration at high SO_2 feeds, taking the evaporation tube as a reference. The catalytic stripper prevents the formation of a nucleation mode entirely.

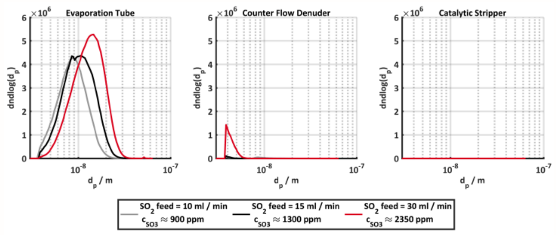


Figure 4: Nucleation particle size distribution for the evaporation tube, the CoFD and the catalytic stripper for different SO_2 feeds

Conclusion

We demonstrated that the use of a counter flow denuder can prevent the formation nucleation mode particles in a laboratory generated aerosol similar to engine exhaust. Further experiments will be conducted to test the removal efficiencies of other substances and to determine the long-term stability of the device.

PROJECT PARTNERS

LAT, AVL, CRF Centro Ricerche FIAT, RICARDO, TU Graz Graz University of Technology, TUM, Tampere University of Technology, JRC European Commission

In collaboration with:
The University of California at Riverside — UCR
National Traffic Safety and Environmental Lab (Japan) — 交通安全環境研究所
National Metrology Institute (Japan) — NMIJ National Metrology Institute of Japan

HORIZON 2020
Call: H2020-GV-2016-2017
Technologies for low emission light duty powertrains
Action:
"Measuring automotive exhaust particles down to 10 nanometres – DownToTen"

3.9.3 Investigation of low cost sensors for particulate matter and gases for the application in measuring the ambient air quality

University of Stuttgart
Germany

Institute of Combustion and Power Plant Technology

Prof. Dr. techn. G. Scheffknecht

INVESTIGATION OF LOW COST SENSORS FOR PARTICULATE MATTER AND GASES FOR THE APPLICATION IN MEASURING THE AMBIENT AIR QUALITY

A. Samad, U. Vogt, B. Laquai, A. Surgaylo, G.C. Solis Castillo
Department of Air Quality Control, University of Stuttgart, Germany

Introduction

Particulate Matter (PM) and gas measuring low-cost sensors

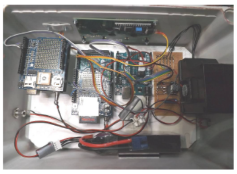
PM low cost sensor SDS011
Company Nova Fitness
Laser light scattering principle
PM_{10} and $PM_{2.5}$ output
0.3 to 10 µm
Response time: < 10 s
0.0 to 999.9 µg/m^3
-10 to +50 °C
0 to 95 % RH
Cost: ~ 25 €

PM low cost sensor OPC-N2
Company Alphasense
Laser light scattering principle
PM_{10}, $PM_{2.5}$, PM_1 output
16 channels for particle/volume
0.37 to 17 µm
Weight: < 105 g
-10 to +50 °C
0 to 99 % RH
Cost: ~ 300 €

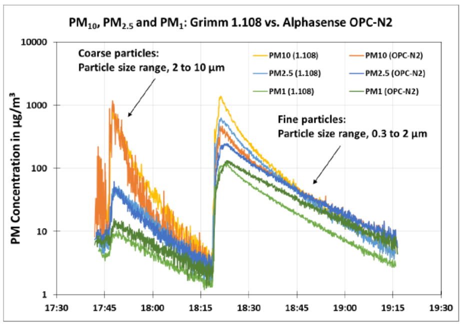
Gas sensors
Company Alphasense
Company Membrapor
Electrochemical sensors
NO_2, NO, O_3, CO
Response time: < 60 s
-30 to +40 °C
15 to 85 % RH
Cost: ~ 50 € per sensor

Results

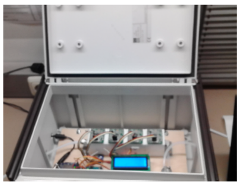
Testing of the low cost PM sensors in order to perform air quality measurements

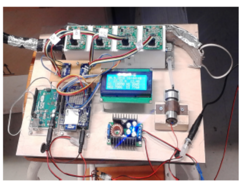


- Investigation and comparison of different low cost PM sensors that were available on the market with aerosol spectrometers was done
- Experiments were performed in the laboratory in order to identify the sensor with the best properties
- Low cost sensor OPC-N2 showed same temporal course as shown in the example but needs to be corrected by comparing to aerosol spectrometer
- It is a well known fact that humidity has an enormous influence on the results, therefore a low cost heater was built and tested together with low cost PM sensors
- The PM sensors box equipped with OPC-N2 was also tested for mobile measurements

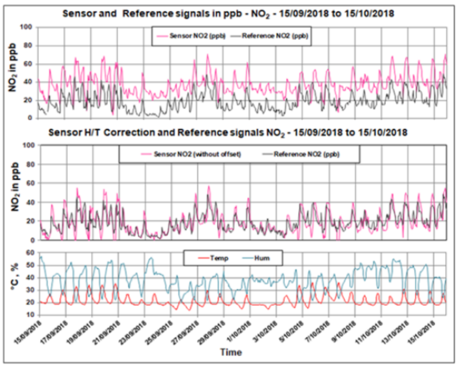


Testing of the low cost gas sensors in order to perform air quality measurements





- The low cost gas sensors were tested in the laboratory as well as in the field and the results obtained were compared to the reference devices for each parameter
- The factors influencing the quality of the data obtained by the low cost gas sensors were mainly meteorological parameters such as humidity and temperature
- Cross sensitivities of the low cost gas sensors against other gases was also investigated
- The possibility to use statistical analysis and laboratory experiments in order to correct the data taken by measurements in the field to enhance the accuracy of the low cost gas sensor results was analyzed
- Good agreement was seen after applying the algorithm developed to compensate humidity and temperature as shown in the example



Conclusions / Further work

PM sensors: The low cost dryer seems to be a good solution to solve the problem of the influence of moisture on particle concentration
Gas sensors: The quality of data can be improved by quantifying the effect of the parameters affecting the reliability of results obtained by the low cost gas sensors and applying the correction to the raw data

Acknowledgements

These investigations are done within the research initative Urban Climate Under Change [UC]² under the module: Three-dimensional Observation of Atmospheric Processes in Cities (3DO). The initative is sponsored by the Federal Ministry of Education and Research (BMBF), Germany.

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3.9.4 PN measurements of automotive exhaust particles using charging-based techniques

PN measurements of automotive exhaust particles using charging-based techniques

Mario Anton Schriefl[1,2], Matthias Longin[2] and Alexander Bergmann[1]
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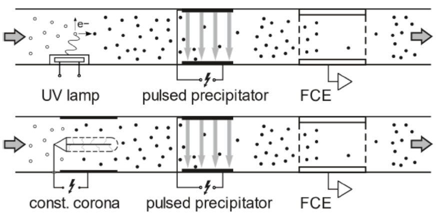
Backgrounds

- New emission legislation requires measurement of particle number concentration (PN) apart from laboratory environment[1]
- Charging-based sensors can be used to determine PN for automotive exhaust gas, providing a range of advantages compared to condensation particle counters (CPC): no toxic working fluid, no warm-up, low dilution, robust, compact, low-cost.

Sensor Principle

- Conventional charging-based methods consist of two stages:
  i. charging of aerosol particles using diffusion charging (DC) or photoelectric charging (PC)
  ii. measurement of electrical current caused by charged particles ($i = -\frac{dQ}{dt}$)
- Charging processes depend on particle size, so does the current amplitude: $I \propto N \cdot d^x \; (1 < x < 2)$
- Size dependency can be reduced by modulated precipitation[2]:

$$I \propto (1-T) \propto d^{-1} \Rightarrow \boldsymbol{I \,\tilde{\propto}\, N}$$



Own-built PN Sensor

Particle Charging Stage

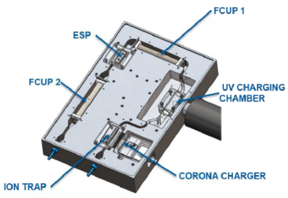
- Either DC (using Corona discharge) or PC (based on direct photoelectric effect, xenon flash lamp with λ down to 190 nm)
- DC is almost independent of the particle material
- PC depends strongly on the materials work function. Carbonaceous particles like soot can be charged, while NaCl particles cannot

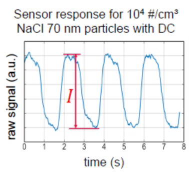
Electrostatic Precipitation Stage

- Periodically removes particles depending on electrical mobility
- Smaller ones are removed more effectively
- Pulsing (≈ 1 Hz) produces clouds of few and all particles

Faraday-Cage Electrometer Measurement Stage

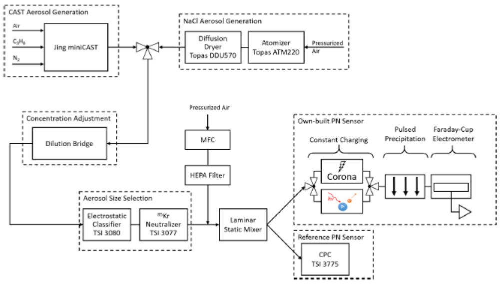
- Charged clouds enter a grounded Faraday cup, producing image charges at the surface
- The change in charge produces an alternating current
- An electrometer amplifier performs current to voltage conversion





Experimental Study

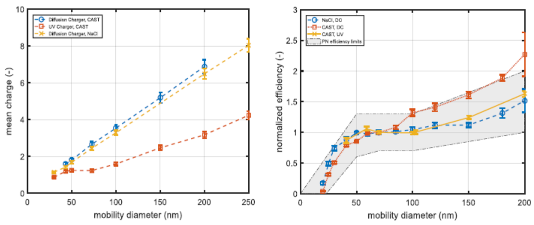
- We aim to fulfill efficiency limits[4] for onboard PN sensors
- Efficiency (compared to 70 nm) was measured using DC or PC
- Charging processes were characterized by mean number of elementary charges per particle



- Aerosol Generation and Size Selection
  - NaCl particles generated by atomizer and diffusion dryer
  - Soot particles generated by a Jing MiniCAST
  - Aerosol Size selection by Differential Mobility Analyzer
- Efficiency Measurements
  - Response measurements against a reference CPC
  - Efficiency given by ratio of sensor reading and CPC reading
- Mean Charge Measurements
  - Characterization of DC and PC charging using CPC and Aerosol Electrometer in parallel

Results

- With DC efficiency limits are fulfilled for NaCl particles, while the limits are exceeded for CAST particles
- The reason may be different particle morphology, however, mean charge is just slightly enhanced for soot compared to NaCl
- The Photoelectric charging curve is much more flat indicating lower charging efficiency but also lower size dependency
- Therefore, for PC also the efficiency curves stays within the limits



Conclusions

- PN can be measured using charging-based sensors operated in modulated precipitation configuration
- With DC the efficiency significantly depends on particle morphology → soot has bigger size dependency than NaCl
- With PC the charging process is less size dependent, the efficiency requirements can be fulfilled for soot

Literature

[1] Änderung der Richtlinie für die Durchführung der Untersuchung der Abgase von Kraftfahrzeugen nach Nummer 6.8.2 der Anlage VIIIa Straßenverkehrs-Zulassungs-Ordnung (StVZO) (AU- Richtlinie).
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3.9.5 Smart Emission Measurement System (SEMS) for real-world driving emissions monitoring

Smart Emission Measurement System (SEMS) for real-world driving emissions monitoring

N.E. Ligterink[1], F.J.M. van den Putte[2], F. Heepen[3], R.N. van Gijlswijk[1], E.G. Buskermolen[1], M. Elstgeest[1], G. Kadijk[1] and E. Voogd[1]

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TNO innovation for life

INTRODUCTION

During the last decade the gap between real-world driving emissions and test-bench tests became increasingly clear. Meanwhile, all modern passenger cars and trucks in Europe must undergo an on-road driving emission test with portable emissions measurement systems (PEMS). However, to cover real-world driving conditions, a simple and easy-to-use system is required that allows for longer term monitoring.

SEMS

Smart Emission Measurement System (SEMS) consists of both measuring devices/sensors and a data platform. SEMS includes GPS, temperature, NO_x, CO_2, Lambda and NH_3 sensors, a connection with the vehicle's OBD system (e.g. for Mass Air Flow) as well as a wireless link towards the SEMS data platform. The latter one consists of a database, automated data processing and analyses and a user interface. SEMS outputs fuel consumption, NO_x and CO_2 in g/kg, and NO_x, NH_3, and CO_2 in g/km or g/kWh based on the real time sensor data

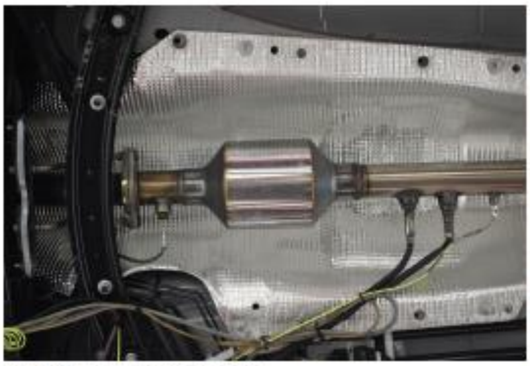

Fig 1. SEMS sensors installed in exhaust system.

VALIDATED SCREENING TOOL

Procedures have been developed and validated to calibrate the sensors and to perform signal processing. Together with the large amount of data already available (more than 11.000 hours of heavy duty vehicles (HDV), 2250 hours of light duty vehicles (LDV), 1875 hours of non-road mobile machinery (NRMM)), SEMS can be positioned as a validated screening tool for real driving emissions and is able to show anomalies or abnormalities in vehicle emission data.

Fig 2. Visualization of calculated results in the SEMS user interface, in this example CO_2 emissions.

FURTHER DEVELOPMENT

At this moment, SEMS can be used for diesel engines on vehicles, NRMM, locomotives and ships. Further short term developments include:

- Adaptations for use with petrol powered engines.
- Measurement of Particulate Matter and Particle Number concentration.
- Applications for (hybrid) electrical vehicles.

For future application of the system, consumers and end users are targeted as well. The system can provide information based on real driving emissions for the comparison of fuel economy and true environmental performance, to help end-users choose vehicles that suit their requirements best.

To guarantee successful market introduction, TNO and HORIBA collaborate on the industrialization and large-scale deployment of SEMS.

CONCLUSION

SEMS is a screening tool capable of generating large amounts of real driving emission data, calibrated and validated, that can be used as input for:

- Emission models,
- Environmental policy making,
- Fleet testing over long periods,
- Characterizing emission behavior,
- Development and analysis toolboxes for aftertreatment calibration and validation by OEMs,
- Emission and fuel consumption performance comparability purposes for end users.

3.10 Planning & projections

This section includes posters presented in the context of the "Planning & projections" session of the TAP conference. Table 22 provides an overview of these posters, as they are listed in the following sub-sections.

Table 22. Titles and authors of ""New sensors and techniques" posters

	Title	**Authors**
3.10.1	Scrapping or not scrapping: About effectivity of grants for car scrapping and electromobility	J. Horváth, J. Mačala, J. Szemesová and L. Zetochová
3.10.2	Present situation and scenarios of greenhouse gases and pollutants reduction from road transport	K. Georgiou
3.10.3	Environmental aspects of the passenger cars fleet renewal in Montenegro	R.V.Vujadinovic, M. Z. Damjanovic and S.S.Simovic
3.10.4	Influence of various approaches to the structuring of vehicle fleet on the inventory of black carbon and greenhouse gas emissions in Russia	V. Ginzburg ,Yu. Trofimenko, V. Komkov and V. Lytov
3.10.5	How EU providers of Forest Carbon Offsets calculate carbon emissions, resulting from Transport, and cost accounting projections for Greece	A. Zikouli and Z. Andreopoulou

3.10.1 Scrapping or not scrapping: About effectivity of grants for car scrapping and electromobility

SCRAPPING OR NOT SCRAPPING: About Effectivity of Grants for Car Scrapping and Electromobility

Ján Horváth[1,2], Janka Szemesová[1], Lenka Zetochová[1] and Jozef Mačala[3]

[1]Slovak Hydrometeorological Institute, [2]Faculty of Ecology and Environmental Sciences TUZVO, [3]Faculty of Natural Sciences UCM

One of the most important areas with a great need to reduce emissions (especially GHGs, NO_x and PMs) is road transport. **The National Air Pollution Control Programme** (NAPCP) and the **Integrated National Energy and Climate Plan** (NECP) require several measures that can be analysed and evaluated. One of the measures, that have been introduced in the past, is the so-called "Scrapping subsidy programme" and the Electromobility Project, which will be also part of the updated Low-Carbon Strategy.

Table 1: Outcomes of the three basic scenarios considered in the SSP 2009

	CO_2 (Gg)		
SCENARIO	PETROL	DIESEL	MIX
Scrapped	58.70	39.81	52.98
New registrations	66.07	43.96	53.11
Difference	7.38	4.14	0.13
Impact on 2009* level	0.44%	0.50%	0.01%
	CH_4 (t)		
SCENARIO	PETROL	DIESEL	MIX
Scrapped	26.30	2.66	19.65
New registrations	4.34	0.09	1.85
Difference	-21.96	-2.57	-17.8
Impact on 2009* level	-5.97%	-12.97%	-4.60%
	N_2O (t)		
SCENARIO	PETROL	DIESEL	MIX
Scrapped	2.28	0.18	1.66
New registrations	0.46	1.76	1.22
Difference	-1.82	1.58	-0.44
Impact on 2009* level	-2.50%	7.02%	-0.47%
	CO_2 eq. (Gg)		
SCENARIO	PETROL	DIESEL	MIX
Scrapped	60.03	39.94	53.97
New registrations	66.32	44.48	53.52
Difference	6.29	4.55	-447.82
Impact on 2009* level	0.37%	0.55%	-0.02%

* according to the GHG emissions inventory of PCs submitted in 2018

	NO_x (t)		
SCENARIO	PETROL	DIESEL	MIX
Scrapped	397.12	138.31	326.11
New registrations	18.29	142.05	90.82
Difference	-378.80	3.74	-235.20
Impact on 2009* level	-8.46%	0.12%	-3.11%
	$PM_{2.5}$ (t)		
SCENARIO	PETROL	DIESEL	MIX
Scrapped	3.03	47.20	15.40
New registrations	2.95	11.68	8.07
Difference	-0.08	-35.51	-7.33
Impact on 2009* level	-0.09%	-8.73%	-1.50%
	NMVOC (t)		
SCENARIO	PETROL	DIESEL	MIX
Scrapped	768.71	42.01	559.20
New registrations	63.5	5.07	29.25
Difference	-705.2	-36.95	-529.90
Impact on 2009* level	-7.10%	-11.50%	-5.20%

* according to the air pollutants inventory of PCs submitted in 2018

Scrapping subsidy programme (SSP) 2009

During the SSP 2009, 44 200 passenger cars (PCs) were scrapped and replaced by 39 275 new PCs. The evaluation of the effect on GHGs emissions and air pollutants was conducted by comparison of potential emissions balance without and with the SSP 2009. This approach was applied in three basic scenarios:

1. Comparison of petrol PCs emissions only (PETROL scenario);
2. Comparison of diesel PCs emissions only (DIESEL scenario);
3. Comparison of combined gasoline and diesel PCs emissions (MIX scenario).

The SSP 2009 helped reduce the national total of GHGs emissions of PCs according to scenario MIX by 0.02% in 2009 in comparison with the emissions level without SSP 2009 (*Table 1*).

The SSP 2009 helped reduce the air pollutants of PCs according to all scenarios except of NO_x in DIESEL scenario in 2009 in comparison with the emissions level without SSP 2009. This increase can be caused by the fact that the new PCs fall into the "dieselgate" period (*Table 1*).

Scrapping subsidy programme (SSP) 2019

Results and knowledge about the SPP 2009 effect on emissions are important for the future parameters of scrapping measure. New round of the SSP 2019 will be a part of the NAPCP. According to the national circumstance in Slovakia, scrapping older PCs with lower annual mileages and substituted it with the EURO 6 PCs would have no reduction effect on GHG emissions. The best scenario with the highest potential on emissions reduction would be substitution of any old car by the new diesel car (EURO 6 and higher). The SSP 2019 would have be aimed to middle class and economically active younger people who are using cars frequently. Proper and balanced conditions of the future scrapping programs would be essential for maximising the effect of this measure.

Electromobility programme (EMP)

In Slovakia, by the end of 2016, 578 electric cars (EV) were registered. The projected GHG savings in terms of energy consumption are about 0.004% of the total energy consumption of passenger cars. Estimated GHG savings in the view of identical annual mileage are at the level of 0.03% on total GHG emissions in passenger transport. In both cases, there is also a negligible reduction in air pollutant emissions (considering only petrol and diesel). These emissions range 0.0001‰ – 0.02% (*Table 2*).

According to these results, can be concluded, that the EMP is not an effective measure to decrease air pollution. The EMP has the potential to save GHG emissions but it will need more support and attention from the Government. Other possible EMP-like measures could be PCs consuming hydrogen or alternative fuel.

Table 2: Emission savings according to the same energy consumption in the three basic scenarios compared with EURO 6b - PCs

EMISSIONS	GHGs			NO_x			$PM_{2.5}$			NMVOC		
UNITS	t of CO_2 eq.			kg			kg			kg		
SCENARIO	PETROL	DIESEL	MIX	PETROL	DIESEL	MIX	PETROL	DIESEL	MIX	PETROL	DIESEL	MIX
Tesla	6.76	193.58	120.67	3.67	55.93	27.82	0.901	1.134	1.009	6.100	0.177	3.363
Nissan Leaf	398.19	1 328.39	828.07	25.17	383.82	190.92	6.183	7.783	6.922	41.860	1.213	23.075
Nissan ENV 200	192.41	641.90	400.14	12.16	185.47	92.25	2.988	3.761	3.345	20.227	0.586	11.150
KIA Soul	167.26	557.98	347.83	10.57	161.22	80.19	2.597	3.269	2.908	17.583	0.509	9.693
Smart Electric drive	64.97	216.73	135.10	4.11	62.62	31.15	1.009	1.270	1.129	6.830	0.198	3.765
VW UP!	56.26	187.70	117.00	3.56	54.23	26.98	0.874	1.100	0.978	5.915	0.171	3.260
Hyundai IoniQ	44.32	147.84	92.16	2.80	42.72	21.25	0.688	0.866	0.770	4.659	0.135	2.568
Renault Zoe	22.57	75.31	46.94	1.43	21.76	10.82	0.351	0.441	0.392	2.373	0.069	1.308
Mercedes B250e	17.22	57.44	35.81	1.09	16.60	8.26	0.267	0.337	0.299	1.810	0.052	0.998
Peugeot ION	1.39	4.62	2.88	0.09	1.34	0.66	0.022	0.027	0.024	0.146	0.004	0.080
BMW i3	65.40	218.18	136.01	4.13	63.04	31.36	1.015	1.278	1.137	6.875	0.199	3.790
TOTAL SAVING	1 036.73	3 629.68	2 262.61	68.77	1 048.74	521.66	16.894	21.265	18.914	114.376	3.314	63.050

Calculated and disaggregated results show that the new subsidy scheme has to be more robust than its predecessors and cover all alternative fuels (CNG, LPG, H_2 and electricity). Moreover, the calculations show that all PCs older than EURO 3 and most of the EURO 4 standards have to be replaced in near future. Slovakia is obliged to meet its goals in transport emissions reduction and therefore scrapping programs and support for alternative fuels in PCs has to be more robust, effective and focused.

A similar conclusion is relevant in the promotion of electromobility to the extent that it has been introduced so far. Subsequent evaluation of environmental measures and subsidy schemes are also challenging. Where such analyses are missing, planning is inefficient and positive results are negligible or missing. Modelling in different scenarios shows, that Slovakia need to increase the share of electric cars to total energy consumption to at least 22%, potentially helping to reduce GHG emissions by more than 60% and between 1.5% and 8% of air pollutants emissions. In order to achieve these goals, it is necessary to increase the share of electric vehicles in Slovakia to about 500 000 vehicles what means at least 25% of all PCs.

3.10.2 Present situation and scenarios of greenhouse gases and pollutants reduction from road transport

Present situation and scenarios of greenhouse gases and pollutants reduction from road transport

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ARISTOTLE UNIVERSITY OF THESSALONIKI

INTRODUCTION

Transport related air pollution is one of the current major environmental issues. In 2015, in Europe, the transport sector made up approximately one third of the final energy consumption.

Road transport amounted to 82% of the energy consumption in transport (European Commission, 2017), leading to high rates of pollutant emissions. This is also shown by the fact that in 2015, 49% of the European freight transport and 81% of the passenger transport were carried out by road (European Commission, 2017). The main pollutants emitted are NO_x and PM, while greenhouse gas emissions are also significant.

The transport sector is an indicator of a country's economic development since it affects and is affected by the economic situation prevailing (Ntziachristos, 2011).

From 1990 until 2007, the constant economic development was followed by a growth of goods and passengers transport. The financial crisis and the GDP drop in 2008 led to a shrinkage in the freight transport sector due to the decreased demand and the fuel price increase, while the need for passenger transport remained unchanged (European Commission, 2017).

METHOD

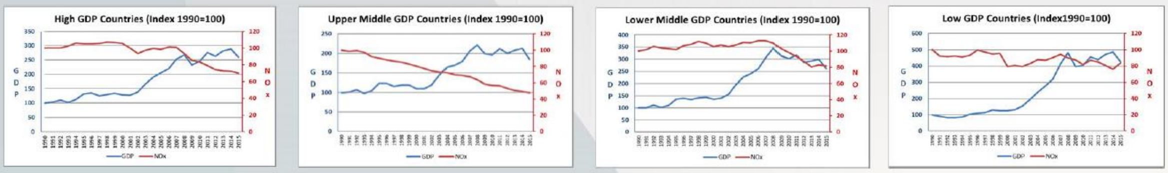
The aim of the study was, firstly, to investigate how road transport related pollutant emissions are linked to the economy (Figures1-4).

- The road transport data used were collected from the European Union emission inventory report under the UNECE Convention on Long-range Transboundary Air Pollution.
- The EU countries were classified according to their GDP per capita. For each group, the GDP per capita was compared to the development of the air pollutant emissions.

The second part of the study focused on drawing up scenarios to predict the course of greenhouse gases and pollutant emissions from road transport by the year 2030 (Figures 5-6). The scenarios were conducted using the SIBYL software, developed by EMISIA.

- Three scenarios were drawn up along with baseline scenario produced by the software: (a) growth of new conventional vehicles usage, (b) growth of electric and hybrid vehicles usage and (c) reduction in conventional passenger cars activity.

RESULTS



Figures 1-4. Evolution of NO_x emissions and GDP per capita, for each of the four country groups, 1990-2015.

It was found that countries with a higher GDP per capita have a greater NO_x emissions reduction compared to the ones with lower GDP. The decrease in NO_x emissions is more abrupt with the appearance of the recession in 2008 due to the level of activity drop. The economy of countries with higher GDP appeared to be decoupled from NO_x emissions since these two figures follow different trends, which is not the case in poorer countries.

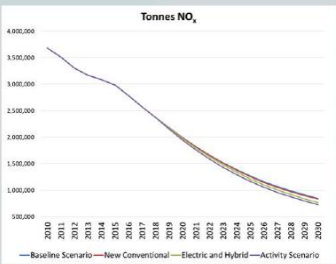


Figure 5. Evolution of NO_x emissions from the road transport sector, 2010-2030.

The baseline scenario predicted a constant reduction in NO_x emissions by 2030 due to the continuous improvement of vehicle technology. The greatest reductions were predicted with the assumption of less conventional passenger car usage.

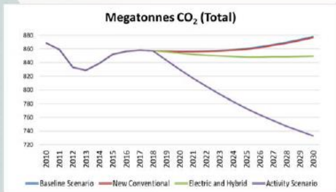


Figure 6. Evolution of total CO_2 emissions from the road transport sector, 2010-2030.

Current legislation regulates vehicle efficiency until 2021 thus, the baseline scenario predicted a small drop followed by a stabilisation in CO_2 emissions. An activity level rise led to an emission increase from 2012 and onwards. More significant drops were predicted by the electric and hybrid scenario though with a small increase after 2028. The reduction in conventional passenger cars activity scenario predicted the greatest CO_2 emissions decrease.

CONCLUSIONS

- Future legislation that will determine improved vehicle efficiencies can prompt more significant decrease in CO_2 emissions, regarding the growth of new conventional vehicles usage scenario.
- The electric and hybrid scenario's effectiveness can be improved with the assumption of a cleaner electrical energy production.
- Carbon budget calculations certified that the passenger car activity reduction scenario is the most effective with 967Mt of CO_2 in total. Therefore, incentives for less car usage will result in a decrease of air pollution that is caused by the road transport sector.

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Ntziachristos, L. (2011) *Pollution sources- Transport*, Aristotle University Press.

3.10.3 Environmental aspects of the passenger cars fleet renewal in Montenegro

TAP 2019

23rd International Transport and Air Pollution Conference

15-17 May 2019

Thessaloniki, Greece

Environmental aspects of the passenger cars fleet renewal in Montenegro

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1. Introduction

Due to the relatively low standard of citizens in developing countries, the logical consequences are high average ages of passenger car fleets, as the most numerous category of vehicles [1,2]. The high average age of the vehicle results in higher specific fuel consumption, and therefore a higher CO2 emission and all other toxic products of fuel combustion [3,4]. Thus, a vehicle's energy inefficiency is even more problematic for the improvement of citizens' living standard, and due to poor vehicle emission characteristics the citizens of these countries have more health problems. Because the benefits that new vehicles bring in terms of safety, comfort, design, energy and environmental parameters, the renewal of fleet with these vehicles is very important for the population of developing countries. The renewal of the car fleet in the WBC is carried out mostly by import of used vehicles from the countries of the European Union.

On the other hand, the developed countries of the European Union are characterized by high living standards of their citizens, and the consequence of it is that they have newer passenger car fleets, with better energy and environmental performances, as well as with less impact on citizens health. In a large number of EU countries there are car factories so that citizens of these countries have significantly better opportunities to buy new cars.

This paper presents a comparative analysis of some indicators of the passenger car fleet in Montenegro with those of the EU members, and an analysis of the dynamics of the Montenegro fleet renewal in previous years. In order to forecast the state of the passenger car fleet in Montenegro in 2025, several possible scenarios were developed, with a special review of the environmental performance of vehicles.

Given similar conditions of fleets in the Western Balkans Counties (WBC), this analysis, with certain corrections, can be applied to the operation of all other countries WBC.

2. Material and methods

Table 1. The average age of the fleet of passenger cars

Year of production	2011	2012	2013	2014	2015	2016	2017
The average age of the car	15.67	15.83	15.99	15.79	15.83	15.98	16.02

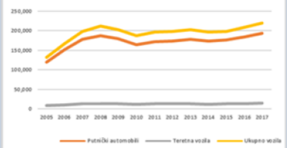

Figure 1. Number of PC in Montenegro

Figure 2. Motorization rate in Montenegro 2005-2017

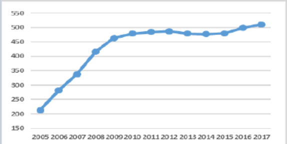

Figure 3. Net income in Montenegro from 2005 to 2017

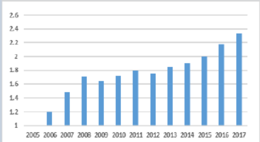

Figure 4. Relative net income rise from 2005-2017

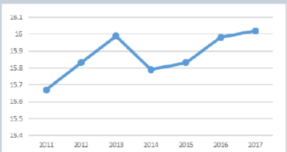

Figure 5. Average age of passenger cars in Montenegro

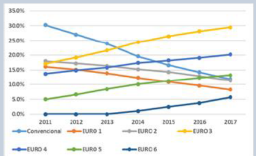

Figure 6. Ecological parameters of PC fleet

Figure 7. Number of new registered PC

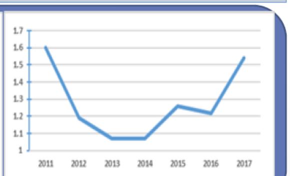

Figure 8. Percent of new vehicles in the fleet

2.2. Indicators of passenger car fleet in the countries from the EU

- The EU passenger car fleet has risen by 4.5% for the last five years; the number of vehicles on the road has jumped from 241 to 252 million,
- Cars in the EU are, on average, 10.7 years old. Poland, Latvia and Lithuania have the oldest fleets, while the youngest cars can be found in Luxembourg and Belgium,
- Despite an increase in registrations in recent years, alternatively-powered passenger cars make up only 3% of the total EU car fleet,
- The EU counts 494 cars per 1,000 inhabitants. The highest number of cars per inhabitant in the EU can be found in Luxembourg, while Romania has the lowest car density[13].

BAU SCENARIO

- The level of motorization is growing 2.5% annually
- The percentage of new vehicles is 1.25%
- The renewal of the fleet is done by importing used vehicles from the EU - requirement for import is the EURO 3 standard
- The average age of the fleet grows slightly

YELLOW SCENARIO

- The level of motorization is growing 4% a year
- The percentage of new vehicles is 2.5%
- The renewal of the fleet is done by importing used vehicles from the EU requirement for the import of the EURO 4 standard
- The average age of the fleet is slowly decreasing

BLUE SCENARIO

- The level of motorization is growing 5.5% annually
- The percentage of new vehicles is 3.75%
- The renewal of the fleet is carried out by importing used vehicles from EU-EURO 4 borders from 2019 and EURO 5 from 2022
- Provide incentives for recycling vehicles older than 30 years
- The average age of the fleet is significantly reduced

GREEN SCENARIO

- The level of motorization is growing 7% annually
- The percentage of new vehicles is 5%
- The renewal of the fleet is done by importing used vehicles from the EU-EURO 4 borders from 2019 and EURO 5 from 2020
- Provide incentives for recycling vehicles older than 30 years
- Non-interest loans are provided for owners of vehicles over 30 years of age
- The fleet average age fleet is approaching the EU

Let us suppose that the number of population will stay on the level from 2017 in all the scenarios (622.387)

3. Results and discussion

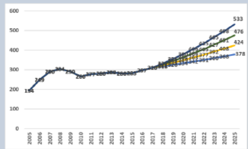

Figure 9. Motorization rate in Montenegro

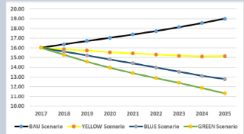

Figure 10. Average age of PC fleet in Montenegro

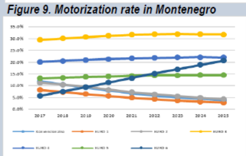

Figure 11. Results of BAU scenario

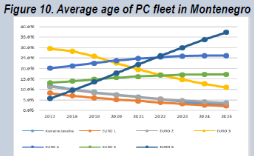

Figure 12. Results of YELLOW scenario

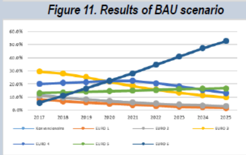

Figure 13. Results of BLUE scenario

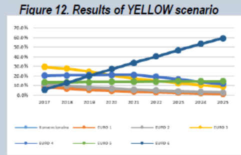

Figure 14. Results of GREEN scenario

4. Conslusion

The average age of the passenger car fleet in Montenegro has lately been about 16 years, what is more than 5 years bigger than the value of this indicator in the EU. A particularly worrying fact is that the average vehicle fleet age does not decrease, instead it has shown a trend of rise in last seven years.

This paper presents several scenarios for the renewal of the vehicle fleet in Montenegro up to 2025. BAU scenario indicates that, if more intensive measures by responsible ministries are not undertaken, this situation will further worsen in relation to the indicator for average age of the vehicle fleet, and it will bring negative ecologic impact on human health and on the environment. Other considered scenarios lead to decrease of the average age and other considered indicators, while GREEN scenario even succeeds to achieve the average of the EU for the considered indicators.

It depends on multitude of factors which scenario will be applied for the renewal of the vehicle fleet:

- rising of living standard of citizens,
- tightening of limits standards for exhaust emissions for import of used cars,
- tightening of control of cars during regular annual overhauls,
- subsidies for purchase of new cars,
- favourable conditions for financing of purchases of new cars,
- introduction of ecologic tariffs related to exhaust emissions

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3.10.4 Influence of various approaches to the structuring of vehicle fleet on the inventory of black carbon and greenhouse gas emissions in Russia

Influence of various approaches to the structuring of vehicle fleet on the inventory of black carbon and greenhouse gas emissions in Russia

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Introduction

Representative estimations of black carbon (BC) and greenhouse gases (CO_2, CH_4, N_2O) emissions from motor transport are crucially needed for understanding of transport contribution to national total emissions as well as its particular influence on climate change and local air pollutions. Creation of unified national system for black carbon and greenhouse gases inventory from road transport is currently constrained by the lack of the required detail and level of accuracy of data on road transport activities

The Russian statistical data (http://stat.gibdd.ru) do not contain information on the structure of vehicle fleet by environmental classes and the type of fuel consumed, as well as data on the annual mileage of various vehicles.

Disaggregation of statistical data is carried out on the basis of surveys of car owners and expert assessments. We have selected three expert assessments made for 2014 to conduct a comparative analysis of approaches to vehicle fleet structuring and their impact on the estimation of black carbon and greenhouse gas emissions from vehicles in Russia.

Methodology

The approach to estimate emissions from road transport implemented in this study corresponds to the IPCC level 2 for CO_2 and the IPCC level 3 for CH_4, N_2O and BC. GHGs and black carbon emissions were calculated using the COPERT-4 program, which complies with the IPCC methodology.

Emissions from vehicles in the COPERT-4 program are calculated taking into account the average annual mileage, average speed on urban, rural roads and highways, category, vehicle mass, engine volume of passenger cars, type of fuel and ecological class.

CO_2 emissions can be most accurately estimated based on data of the amount and type of fuel combusted and its carbon content (equation 1),

$$M_{CO2} = \sum_a [Fuel_a \cdot EF_a] \quad (1)$$

As initial data for estimating the values of gross emissions of CH4 and N2O, annual vehicle mileage and other factors are used according to the equation (2). At the same time, to calculate the emissions of black carbon, it is necessary to first calculate the emissions of solid particles (PM 2.5), using the equation (2), and then calculate the share of black carbon in solid particles.

$$M_{CH4,N2O,PM\,2.5} = \sum_{abcd} [Distance_{a,b,c,d} \cdot EF_{a,b,c,d}] + \sum_{abcd} C_{a,b,c,d} \quad (2)$$

The structure of vehicle fleet from different expert's assumptions

We have selected three expert assessments made for 2014:

1. THE JGCRI approach, USA (Kholod N. et all, 2016) (option 1)
2. THE MADI approach (NDK, 2015) (option 2)
3. The IGCE approach (NDK, 2018) (option 3)

Assumptions made in different expert options are summarized in Table 1 and Figure 1.

Table 1: The structure of the vehicle fleet by type of fuel, %

Type of vehicles	Option 1		Option 2		Option 3	
	Gasoline	Diesel oil	Gasoline	Diesel oil	Gasoline	Diesel oil
Passenger cars	95	5	95	5	96	4
LCV's	72	28	65	35	72	28
Heavy duty	38	62	9	91	25	75
Buses	55	45	37	63	46	54

Estimations were made by two methods:

1) with average annual mileage equal among vehicles of the same type. The average annual mileage for each vehicle class were taken to be the same for all modelling options (Figure 2);
2) with equal total annual mileage each modelling approach or "total conditional transport work" concept. It's mean that total annual millage should be the same for all considered modelling options. (see equation 3)

$$T_w = \sum_j (M1_j \cdot l_{M1j} + N1_j \cdot l_{N1j} + N2_j \cdot l_{N2j} + N3_j \cdot l_{N3j} + M2_j \cdot l_{M2j} + M3_j \cdot l_{M3j}) \quad (3)$$

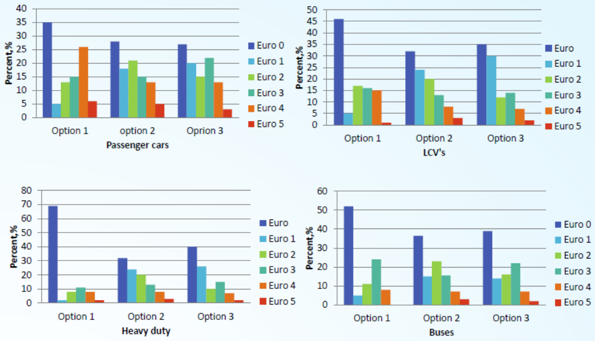

Figure 1: The structure of the vehicle fleet in Russia by ecological class in 2014 according to simulation options

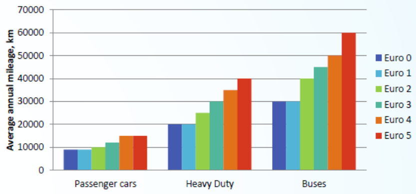

Figure 2: The average annual mileage

Results

The results of calculating emissions in Russia for 2014 using different options for the approach to fleet structuring by fuel type and environmental class are presented in Table 2.

Table 2: Emissions GHG and BC from motor vehicles of Russia in 2014 calculated by method 1 and 2 (values in brackets), Gg

Vehicles Type	Option 1				Option n 2				Option 3			
	CO_2	CH_4	N_2O	BC	CO_2	CH_4	N_2O	BC	CO_2	CH_4	N_2O	BC
Passenger cars	97157 (77120)	17,2 (14)	2 (1,6)	1,75 (1,46)	89253	19,3	3	2,34	89130 (81028)	17,7 (16)	3 2,7)	1,79 (1,63)
LCV's	16146 (12658)	2,4 (1,8)	0,53 (0,41)	1,34 (1,14)	16284	2	0,73	6,66	16164 (14695)	2,2 (2)	0,78 (0,71)	1,5 (1,36)
Heavy duty	27555 (18789)	3,3 (2,2)	0,7 (0,48)	3,67 (2,68)	34900	3,9	0,94	2,18	34509 (31372)	4,5 (4,1)	0,84 (0,76)	6,05 ((5,5)
Buses	11426 (9053)	1,4 (1,2)	0,12 (0,12)	2,79 (1,11)	17609	2,2	0,27	2,99	15330 (12970)	2,9 (1,4)	0,2 (0,2)	2,3 (2,25)
Total	**152284 (117620)**	**24,3 (19,2)**	**3,35 (2,61)**	**9,58 (6,4)**	**158046**	**27,4**	**4,94**	**14,16**	**155133 (140065)**	**27,3 (24,58)**	**4,82 (4,37)**	**11,65 (10,75)**

Conclusion

The Russian statistical reporting form does not contain data on the distribution of vehicles by environmental classes and by type of fuel consumed, and there are no data on the average annual mileage of vehicles of various categories and various environmental classes.
The study showed that with the same total conditional transport work, the baseline data adopted by different options on the division of the vehicle fleet into environmental classes and fuel type does not significantly affect the final estimate of greenhouse gas emissions. However, for black carbon emissions, there is a discrepancy of 10% of the average estimate. If such an adjustment is not made, then the difference between the obtained calculated values of gross GHG emissions from different options reaches for GHGs emissions and 27% - for black carbon emissions.

3.10.5 How EU providers of Forest Carbon Offsets calculate carbon emissions, resulting from Transport, and cost accounting projections for Greece

TAP 2019 | THESSALONIKI, GREECE
23rd International Transport and Air Pollution Conference 15-17 May 2019

How EU providers of forest carbon offsets calculate carbon emissions, resulting from Transport, and cost accounting projections for Greece

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OBJECTIVES

Forests and forestlands take an active part in climate change through the sequestration of carbon dioxide (CO_2).[1] Worldwide, the Voluntary Carbon (C) Market (VCM) is a way to isolate their C footprint by investing in forestry activities to individuals and companies. The aim of this survey is to analyze the European forest developers that implement forest carbon projects and have online C calculator.

HYPOTHESES

1. Do the European forest developers' calculators give higher results than the chosen methodology?
2. Could any correlation be found between the CO_2 results, the necessary tree plantation and the offset's price?

PROCEDURE

According to ENDS Carbon Offsets, an independent guide that records who is activated in the VCM, thirty European companies and non-profit organizations carry out forest projects. Nine developers host C calculator for transport.

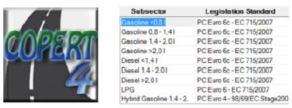
The study concerns:
A] Analyzing European forest developers' web content
B] Applying same data and comparing CO_2 results
C] Recording correlation among CO_2 results and tree planting
D] Evaluating forest C offsets' price

ENDS carbon offsets

EU forest developers:
1. C Level
2. C Offset Scotland
3. Climate Care
4. Climate Stewards
5. CO_2 Balance
6. Future Forests
7. Prima Klima
8. South Pole C
9. World Land Trust
C Balanced

METHODOLOGY & DATA

'Comparative content analysis' was applied to distinguish between CO_2 results and offset charge. The method chosen for the calculation of emissions, resulting from Transport used COPERT4 (Computer Programme to calculate Emissions from Road Transport), according to (Gkatzoflias et al., 2012)[2] this program is applied in EU widely. The calculations concerned the use of gasoline, diesel, liquefied petroleum gas (LPG), hybrid vehicle and conventional two-wheeled engine (motor).



Data:
1,000km in Greece; 60km/hour; urban environment and the CO_2 factors by COPERT4.

RESULTS

1. The developers have updated websites; three are non-profit organizations and the majority allocates in Great Britain. The implementation of forest programs mainly occurs in Mexico, Kenya and Uganda; five companies do not allow the investor to choose which forestry activity to assist; two companies exclusively develop forest programs in the United Kingdom.
2. All developers undertake forestation; eight have created programs for fighting deforestation in developing countries and two conduct forest adaptation programs.
3. With reference to the calculations of CO_2 resulting from transport; six developers measure emissions from the use of gasoline and diesel vehicle (small, medium and high cubism), four from the use of LPG vehicle, three from the use of motor and one from the use of hybrid vehicle.

CONCLUSION

- Two developers did not give information on the templates that is used on their C calculators.
- A majority applies higher CO_2 factors for the use of gasoline vehicles (figure 1). Offset price for gasoline: €1.99-4.76.

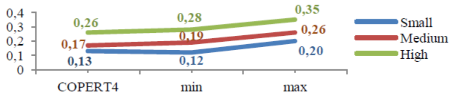


Figure 1. *Emissions from gasoline vehicle by COPERT4 and providers (min and max) in tCO_2*

- The use of diesel vehicles gives greater variation of emissions (figure 2). Offset price for diesel: €1.44-4.81.

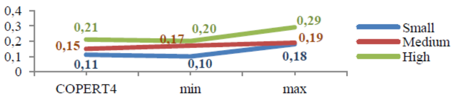


Figure 2. *Emissions from diesel vehicle by COPERT4 and providers (min and max) in tCO_2*

- Offset price for LPG (four providers) is €1.14-5.12, for hybrid vehicle (one provider) is worth €2.75 and for motor (three providers) ranges from €0.39 to €6.5. Figure 3 presents the CO_2 results for these categories.

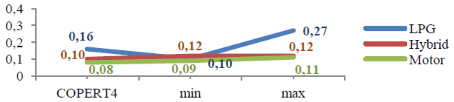


Figure 3. *Emissions from LPG, hybrid vehicle and motor by COPERT4 and providers (min and max) in tCO_2*

- Non-matching high carbon offsets with high pricing.
- Two forest developers: Fairly high charge-policy.

FURTHER RECOMMENDATIONS

1. Proposed $1tCO_2$ emissions by transport to be compensated with €10.3; offset charge €3.6 per 1,000km for each vehicle. Table 1 shows which are the proposed numbers for both CO_2 emissions and offset price for each vehicle category.

Table 1. *Proposed emissions and offset charge for each vehicle category per 1000km in Greece (in tCO_2)*

Vehicle category	CO_2 Emissions (in tones)			Offset price (in €)
	Small Cubism	Medium Cubism	High Cubism	
gasoline	0.15	0.18	0.25	3.40-4.75
diesel	0.13	0.17	0.21	2.40-4.07
LPG	0.10	0.14	0.19	2.40-3.66
hybrid		0.10		2.00-3.30
motor		0.10		2.27

2. Proposed saving of $1tCO_2$ could be achieved with the planting of two saplings; suitable for individuals, or planting of one hectare of new forest could in the initial stage, correspond to the absorption of roughly $10tCO_2$ per year; useful for high polluters and companies.

ACKNOWLEDGEMENTS

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