Second Generation of Pollutant Emission Models for SUMO

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DLR

Emission Models
Why?

Does traffic cause emissions? Sure…

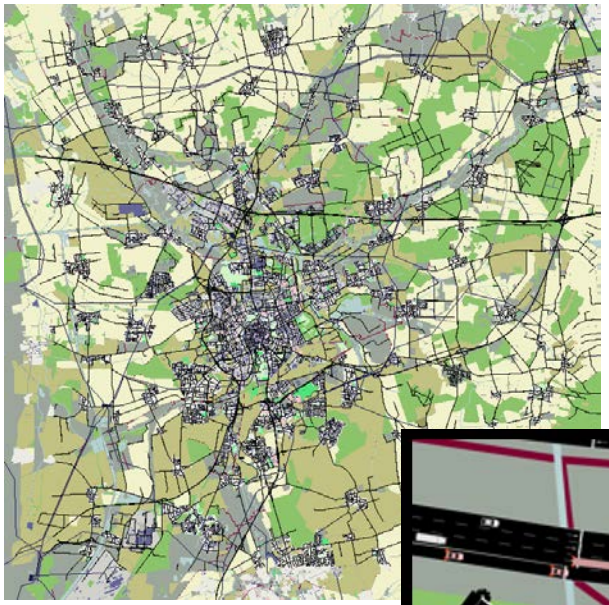
Some regulations already exist …
- reduce emissions of current vehicle fleets (car manufacturer)
- thresholds for NO_x and PM_x concentrations (local administration)

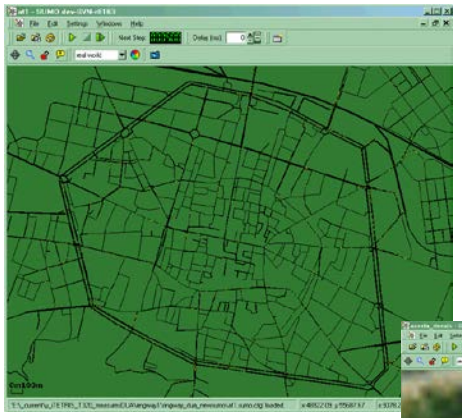
… as well as different approaches to reduce them:
- fleet management
- regulative actions (environmental zones, …)
- infrastructure-based solutions (traffic lights, …)
- in-vehicle solutions (GLOSA, …)

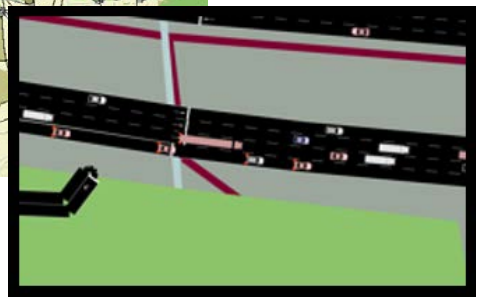
Answering whether they work is a traffic simulation task.

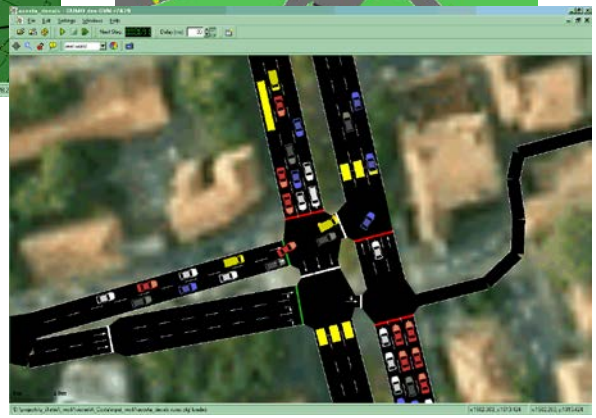
Emission Models
Requirements #1

What do we need?
Let’s take a look at typical scenarios…





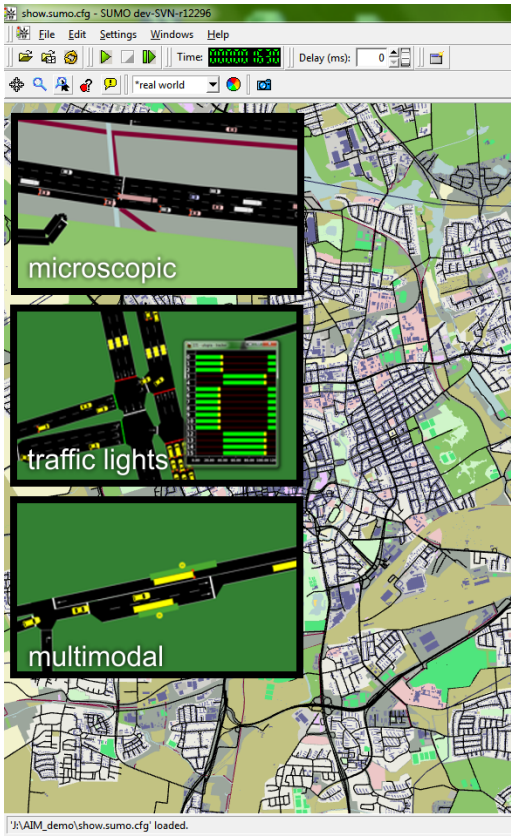




Emission Models
Requirements #2

How should an emission model look like to fit into SUMO? It should:

- cover the complete vehicle population;
- offer a classification into EURO-norms;
- compute CO, CO_2, NO_x, PM_x, HC, and fuel consumption;
- sensible to microscopic parameters available in the simulation;
- require only information that is available in the simulation;
- compute emissions in simulated time steps;
- easy to parameterize;
- portable, fast in execution;
- licensed under a GPL-compatible license.



Emission Models

Emission Models Survey – 2008, freely available only

	factors	vehicle model/class	fuel type	macroscopic average velocity	velocity	acceleration	engine temperature (cold/hot)	time line of velocities	time line of accelerations	vehicle mass	rolling resistance coefficient	road grade	engine displacement	air drag resistance	fuel-to-air equivalence ratio	engine parameters (1)	speed correction rolling coefficient	total tractive power	idle rate	rotational inertia coefficient	vehicle curb weight	VSP	engine stress	drive-train efficiency	accessoirs' consumption
#a09: DAT-Table																									
#a10: HBEFA																									
#a04: COPERT III																									
#a14: CT-EMFAC																									
#a15: Bai																									
#a01: Eissfeldt																									
#a02: MOBILE6																									
#a06: VT-M																									
#a03: INTEGRATION																									
#a05: EMIT																									
#a07: CMEM																									
#a08: AskPablo																									
#a11: Biggs/Akcelik																									
#a12: EcoGest																									
#a13: Kebin He																									

legend:

- already included in SUMO
- easy to implement
- rather complicated to be determined for a vehicle population
- complicated to be determined for a vehicle population
- impossible to be determined for a vehicle population / not given (factors)
- part of the model

	consumption	HC	NOx	CO	VOC	PM	NMVOC	CH4	CO2	further
#a09: DAT-Table										
#a10: HBEFA										several others
#a04: COPERT III										
#a14: CT-EMFAC										SOx
#a15: Bai										
#a01: Eissfeldt										
#a02: MOBILE6										
#a06: VT-M										
#a03: INTEGRATION										
#a05: EMIT										
#a07: CMEM										
#a08: AskPablo										
#a11: Biggs/Akcelik										
#a12: EcoGest										green house gas
#a13: Kebin He										

(1) such as engine speed, engine indicated efficiency, idle engine friction factor

Emission Models

HBEFA Implementation from iTETRIS

In the end, we have

-chosen an inventory model (HBEFA v2.1)

-extracted the data

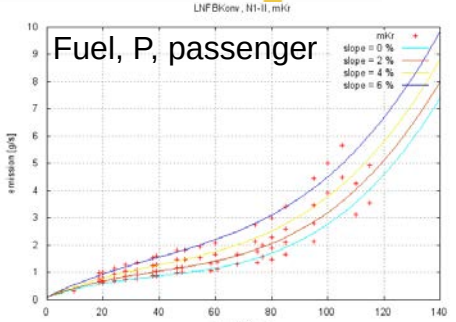
-fitted them to a function

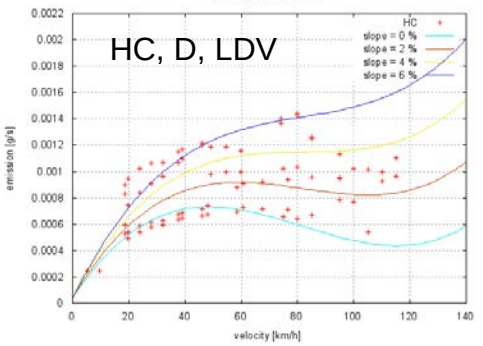
$$EF_p(v,\alpha) = \frac{c_0 + c_{va_1}\, v\, a + c_{va_2}\, v\, a^2 + c_1\, v + c_2\, v^2 + c_3\, v^3}{3600}$$

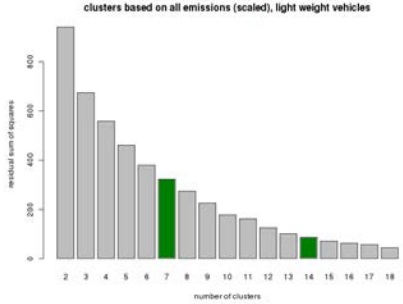
-clustered the so obtained curves

-embedded this in SUMO

(that all was already described, in fact)







Emission Models

HBEFA Implementation from iTETRIS – Issues

Great?! So why do we need new models?

- Modern vehicles (EURO-5, EURO-6) were not covered by HBEFA 2.1 properly
- The obtained fits to the data do not always fulfil basic constraints
  - emission at idling >0
  - no emissions < 0
- Joining emission classes into clusters is a bad idea – one looses the control over the vehicle fleet

So both had to be done:

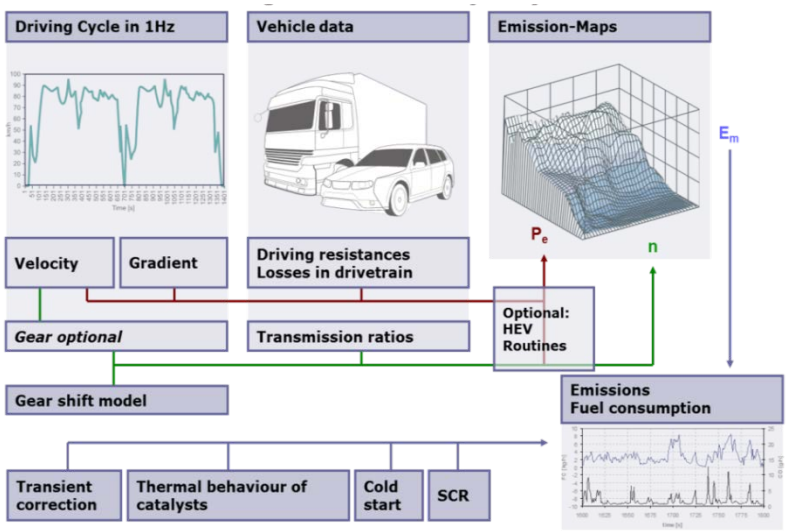
- Updating the database
- Improving the data processing

Emission Models

PHEMlight #1

Based on PHEM („Passenger Car and Heavy Duty Emission Model")

- Product of TU Graz
- An instantaneous emission model
- Consists of several sub-models
- Calibrated to real-world measures
- Feeds HBEFA and COPERT
- Commercial license



Joint work between TU Graz and DLR within the COLOMBO project

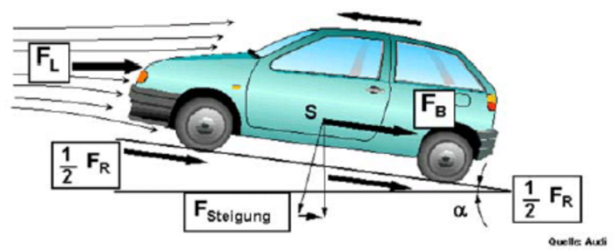
Besides implementing PHEMlight, TU Graz also extended PHEM by models for start/stop systems, hybrid electrical and fully electrical vehicles, vehicles running on compressed natural gas

Emission Models
PHEMlight #2

Slightly different approach than HBEFA-derivations

-Compute the needed power, first

$$P_e = (P_{rolling\ resistance} + P_{air\ resistance} + P_{acceleration} + P_{road\ gradient}) \ / \ \eta_{gearbox}$$



$$P_R = (m_{Vehicle} + m_{Load}) \times g \times (\mathrm{Fr}_0 + \mathrm{Fr}_1 \times \mathrm{v} + \mathrm{Fr}_4 \times \mathrm{v}^4) \times \mathrm{v}$$

$$P_{Air} = (Cd \times A \times \frac{\rho}{2}) \times \mathrm{v}^3$$

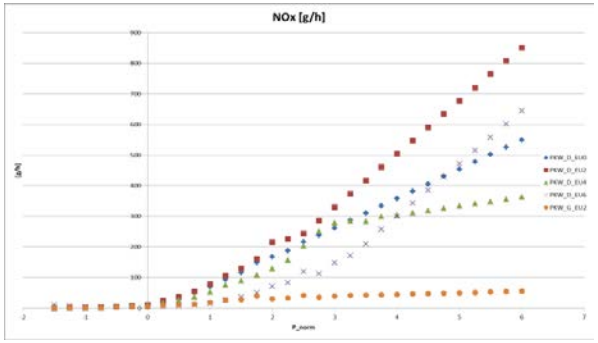
$$P_a = (m_{Vehicle} + m_{Rot} + m_{Load}) \times \mathrm{a} \times \mathrm{v}$$

$$P_{grad} = (m_{Vehicle} + m_{Load}) \times Gradient \times 0.01 \times \mathrm{v}$$

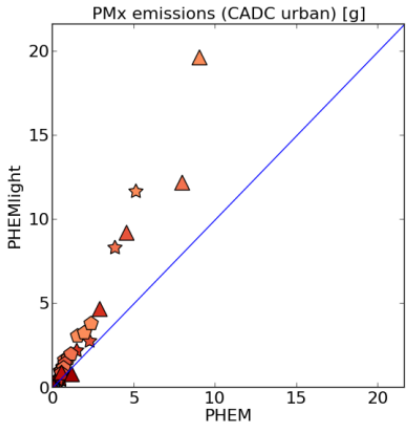
$$\eta_{gearbox} = 0.95 \quad \text{(average efficiency)}$$

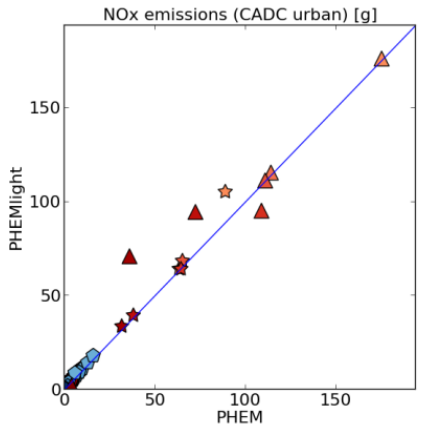
-Then look up in according “CEP” files
(CEP: Characteristic Emission curves over Power)

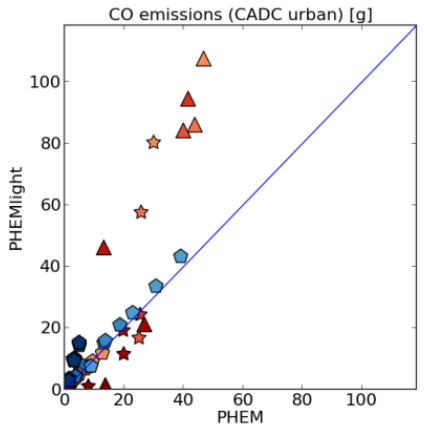
-CEP-files are obtained by sampling PHEM

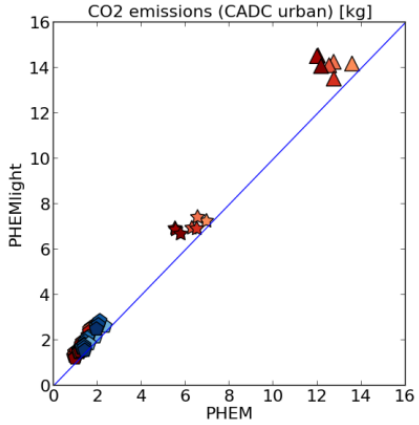


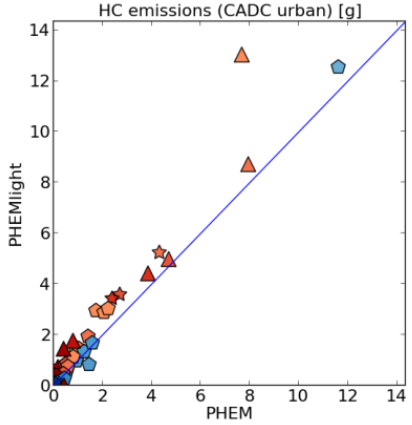
Emission Models
PHEM against PHEMlight











Emission Models
New HBEFA implementation

Almost as done in iTETRIS, but
- Using up-to-date HBEFA version 3.1
- More emission classes covered
- New, improved fitting procedure
- No clustering
- Free and included in SUMO

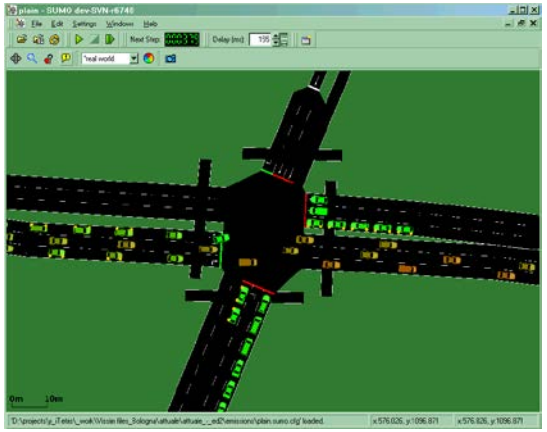
Some drawbacks
- Only some major classes were selected, but the model is easily extensible
- The dependency on acceleration had to be determined from the dependency on the slope of the road, given in HBEFA
- Not all pollutants‘ curves can be fit well to the used function

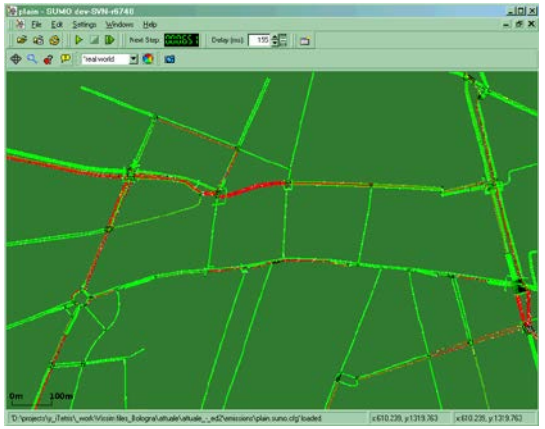
Emission Models
Generated Data

Several data types can be generated

- aggregation of emissions per lane with variable interval time spans
- aggregation of emissions per edge with variable interval time spans
- aggregation of emissions for each simulated vehicle
- non-aggregated (step-wise) vehicle emissions
- a vehicular trajectory file as defined in AMITRAN

… but some other (mainly areal) seem to be additionally needed …





Emission Models
Comparison

PHEMlight is commercial
- The source code is GPL-licensed and included in SUMO
- Two vehicle classes are included
- The other data has to be licensed from TU Graz

HBEFA v3.1-derivation is included in SUMO
- Completely GPL-licensed

HBEFA v2.1-derivation will be probably removed at some time
- Already deprecated

Emission Models
Comparison

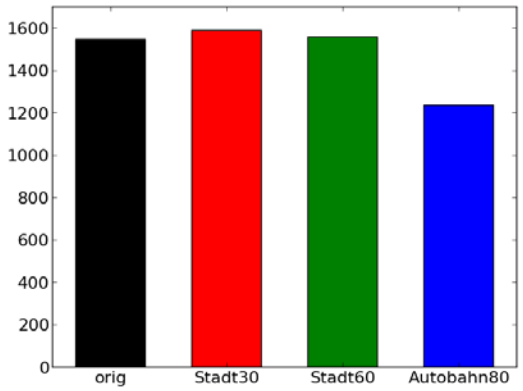
Requirement	HBEFA 2.1-based	HBEFA 3.1-based	PHEMlight
No. of emission classes	56*2(+1)	45(+1)	112(+1)
coverage	no modern (Euro 6) and seldom classes	Major passenger, heavy duty, and bus classes	almost complete, new engine types
Euro-Norms	-	x	x
Covers chosen polutants	x	x	x
Uses speed	x	x	x
Uses acceleration	x	x	x
Uses slope	-	-	x
Needs further attributes	-	-	x (are included)
Step-size resolution	x	x	x
Easy parameterization	x	x	x

Emission Models
Comparison

1.: Difficult! Compare against what?

- Only possible for single vehicles – but is this what we need?

First check: emission values for Brunswick (old HBEFA)



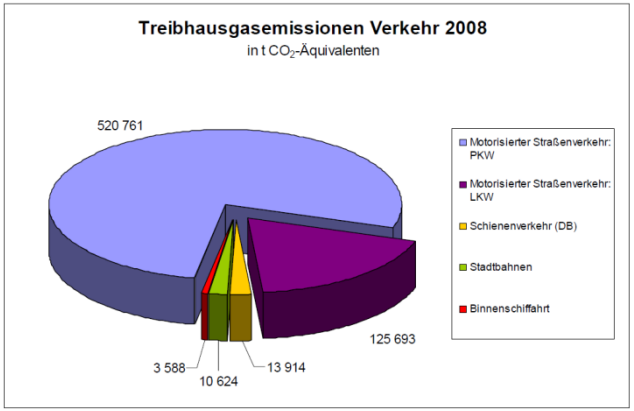


Abbildung 2.22: Treibhausgasemissionen des Gesamt-Verkehrs in 2008

521kt+126kt = 647kt p.a.; 647kt p.a./365 days ~= 1772 t

10 % error? Great, but: Same area? Same population? Who knows?

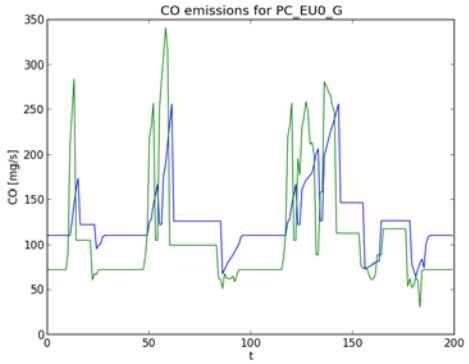
Emission Models
Additional Tools #1

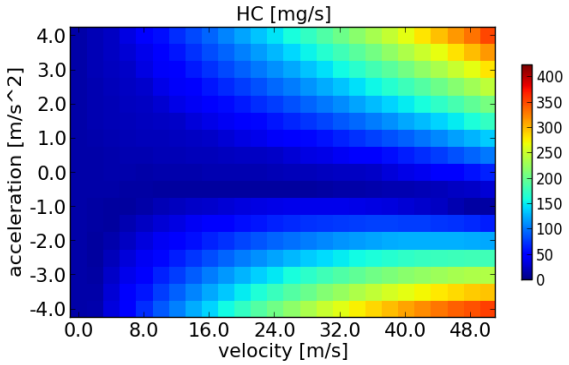
Well, three models
→Model Test Suite!

… needs some further tools, mainly for evaluation …

- Emissions map generator
- An emissions computing application that reads trajectories
- Some visualisation scripts

… already in use for other purposes (trajectory optimisation)

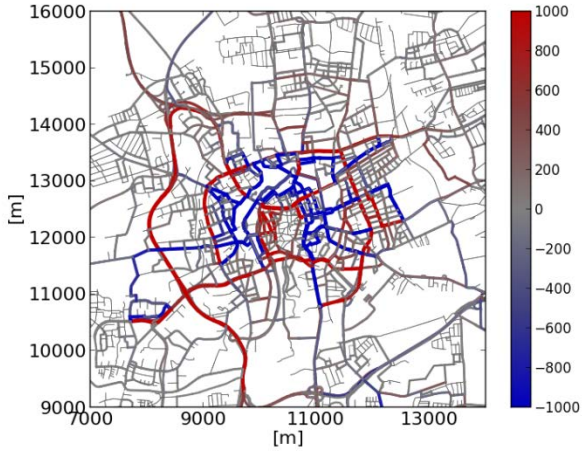


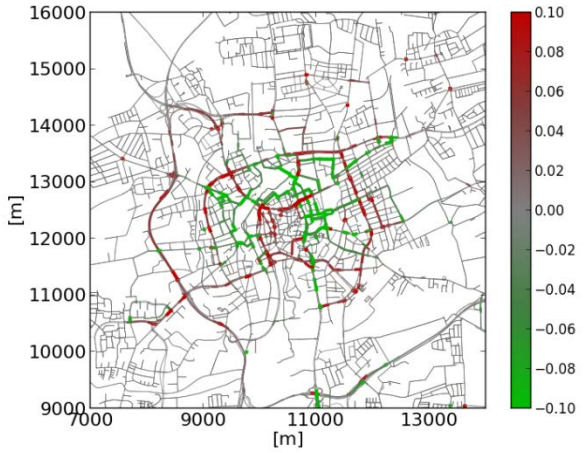


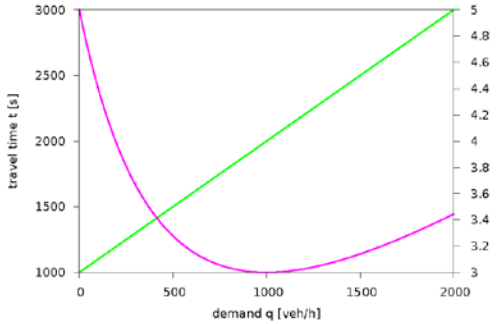
Emission Models
Applications #1

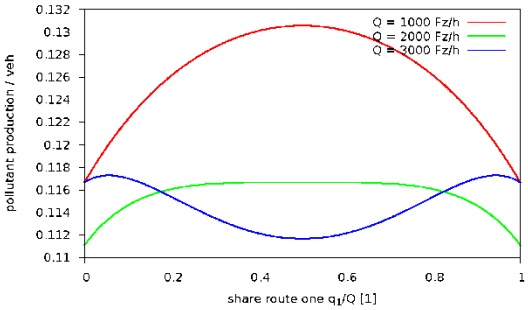
Large-scale investigations, mainly based on route choice

- abstract emission-based traffic assignment
- simulation of regulative traffic management actions (changes in speed limits, environmental zones)





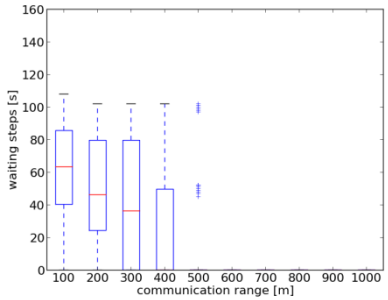


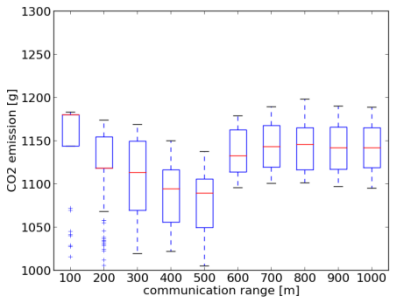


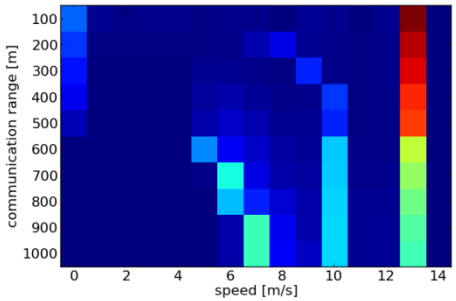
Emission Models
Applications #2

Benchmarking ITS-solutions

- usually boring, but sometimes surprising (trivial GLOSA may generate more emissions)







Current work topics in COLOMBO

- emission-optimal driving behaviour
- local emissions monitoring system
- Investigation of correlations between conventional and emission measurements

Emission Models
Next Steps

Missing at most:

- a dispersion / imission model
- some better ways to interpret the measures
- some tools to ease the definition of a vehicle population
- some more evaluations, also against available measures from single vehicles

SUMO

… in the end …

Institut für Verkehrssystemtechnik / DLR

Aktuelle Version:	Version 0.20.0
Webseite / Download:	http://sumo-sim.org/
Kontakt:	sumo-user@lists.sourceforge.net