Dynamic modelling of transient emissions and concentrations from traffic in street canyons

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Vlaamse
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Outline

1) Introduction
2) Methodology
3) Results and discussion
4) Conclusions

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EU-Project

DECADE

DECADE is a research project supported by the European Commission under the Fifth Framework Programme and contributing to the implementation of the Sub Programme **Energy** and Key Actions 6
'Economic and Efficient Energy for a Competitive Europe"
... within the Energy, Environment and Sustainable Development.

DECADE ist ein durch die Europäische Kommission unter dem fünften FTE-Rahmenprogramm unterstütztes Forschungsprojekt, für die Umsetzung des Unterprogrammes **ENERGIE** Aktions-Schlüssel 6
"Ökonomische und leistungsfähige Energie für ein konkurrenzfähiges Europa"
... innerhalb der Energie, der Umwelt und der nachhaltigen Entwicklung.

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TITLE: Development and validation of a highly accurate emissions simulation tool capable of comparatively assessing vehicles operating under dynamic conditions.

PARTNERS: MIRA, CLE, IDIADA Automotive Technology, Vito, University of Lund, Stadt Salzgitter, De Post

PROJECT DURATION: April 2000 to September 2003

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OBJECTIVE: detailed calculation of emissions and ambient air concentrations in street canyons based on the engine power required to drive a given vehicle over any particular route.

RESULT: a valuable tool for detailed assessments of the ambient air quality impact of e.g. street design (traffic lights, road bumps, busy crossings), driving patterns, driving behaviour and fleet composition.

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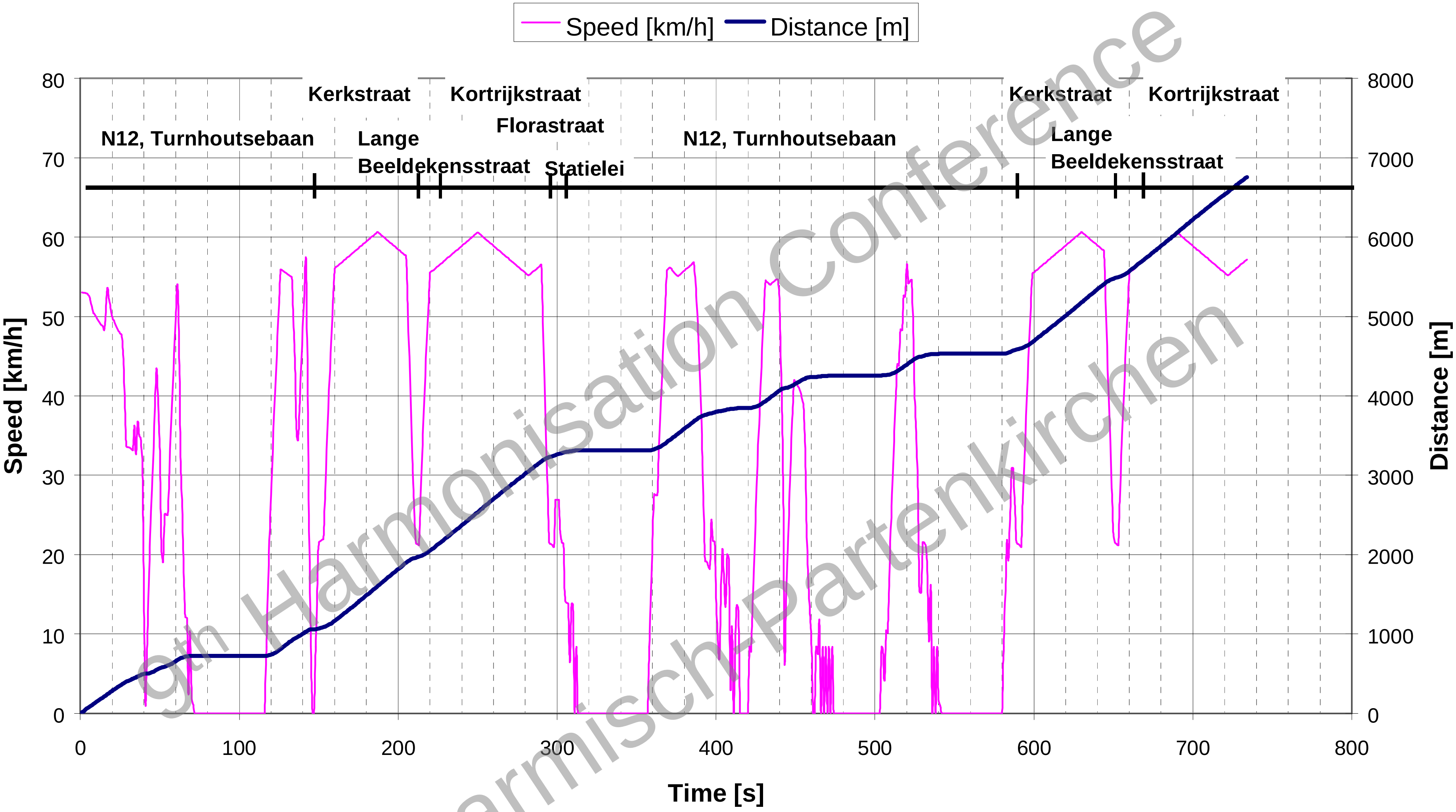
Recording of speed profiles and position tracking

- The speed (km/h), and position (lat-lon coordinates) are recorded using one or two GPS receivers and an optical speed meter.
- Together with the actual power demand of the vehicle, the speed profiles are used as input for the emission model (VeTESS)
- From the registered positions, the distance travelled (m) from the starting point is calculated

Speed and Distance



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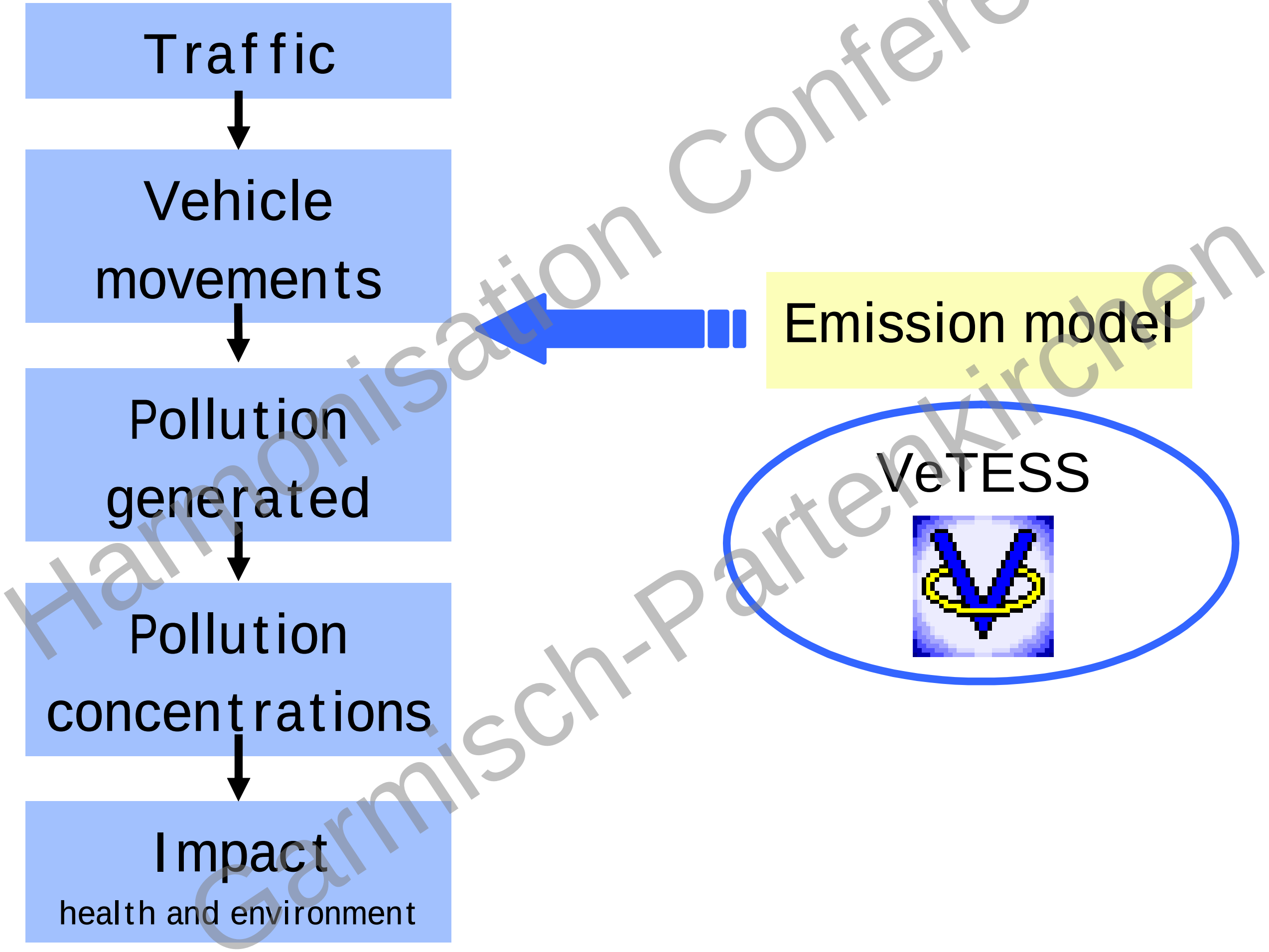
Emission calculation



Traffic

Vehicle movements

Pollution generated

Pollution concentrations

Impact

health and environment

Emission model

VeTESS

Emission calculation

- Calculation of transient emissions for a specific vehicle or engine: it includes the rapidly changing demands placed on the engine, an area that has proved an obstacle to accurate simulations in the past.
- The VeTESS model calculates the emissions per second for CO_2, CO, NO_x, THC and PM for specific traffic situations, using the speed profiles and associated accelerations as input.
- In this way VeTESS looks at the actual fuel consumption and pollution generated on a specific duty cycle.

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Emission calculation

VeTESS simulation results for specific driving patterns

	Fuel l/100km		CO_2 g/km		NO_x g/km		PM g/km	
City calm	10,00	± 0,63	261,8	± 16,4	1,18	± 0,15	0,25	± 0,03
City aggressive	12,11	± 0,54	317,0	± 14,3	1,23	± 0,12	0,32	± 0,04
Rural calm	5,63	± 0,17	147,2	± 4,4	0,46	± 0,03	0,18	± 0,03
Rural aggressive	7,54	± 0,34	197,4	± 9,0	0,59	± 0,03	0,24	± 0,03
Motorway calm	6,55	± 0,39	171,5	± 10,3	0,60	± 0,05	0,10	± 0,02
Motorway aggressive	7,04	± 0,22	184,2	± 5,7	0,65	± 0,03	0,10	± 0,01

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Emission allocation

- The emissions calculated per second are allocated to the selected route. The GPS data are converted from lat-lon coordinates to Lambert coordinates (km).

- GPS reading accuracy varies between 0.5 to 20 m (due to wall reflections) and the accuracy of the speed meter is 1%, thus a corrective filtering is needed in order to represent the distance travelled correctly on the routing map.

- The digital routing map is derived from high quality land register maps. By dividing the emissions per second through the actual speed, the emissions per meter can be obtained.

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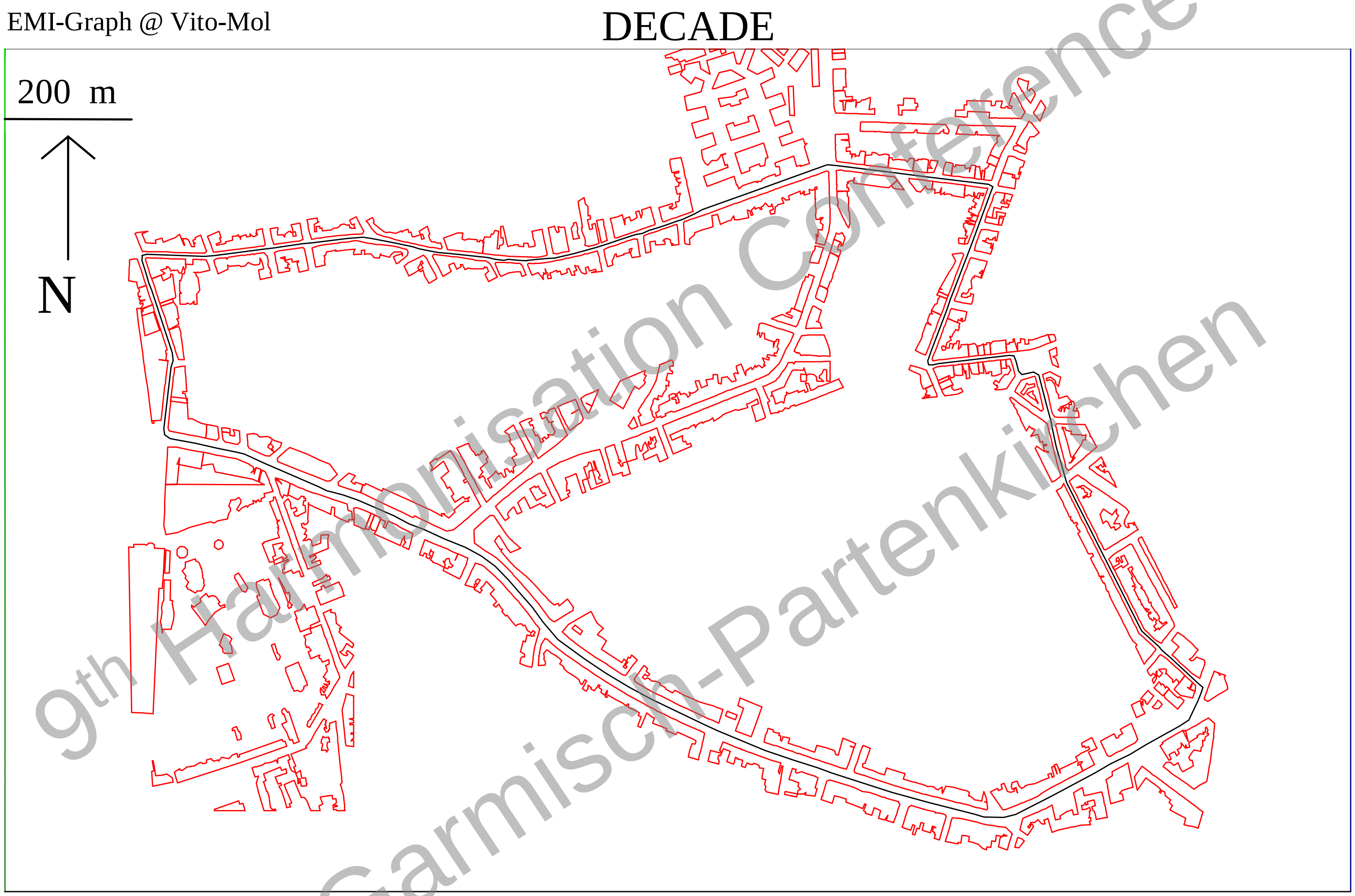
The Antwerp track (black) with house fronts from land register



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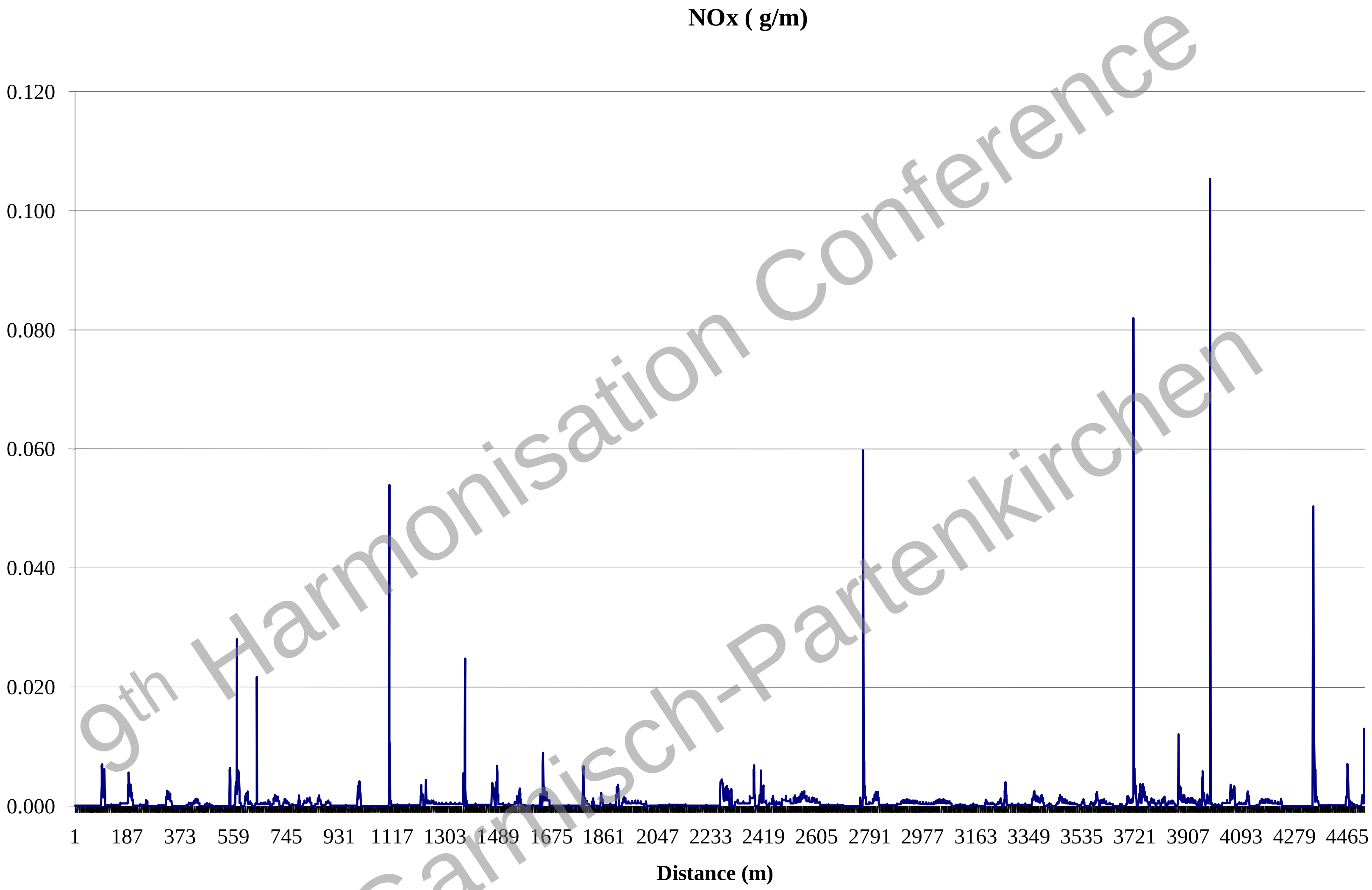
Emission integration

- Up to now, we have been working with the emissions of a single car for a single speed profile.
- The emissions per meter calculated by VeTESS are averaged for a number of speed tracks in order to obtain a more general driving pattern for the selected track. In this way the effect of arbitrary stand stills (e.g. due to traffic lights) is smoothened.
- The emissions per meter are then integrated over a distance of 75 meter to obtain a sliding average, revealing the density of emission peaks from the original recordings and making the input more suitable for air pollution calculations in a street canyon.



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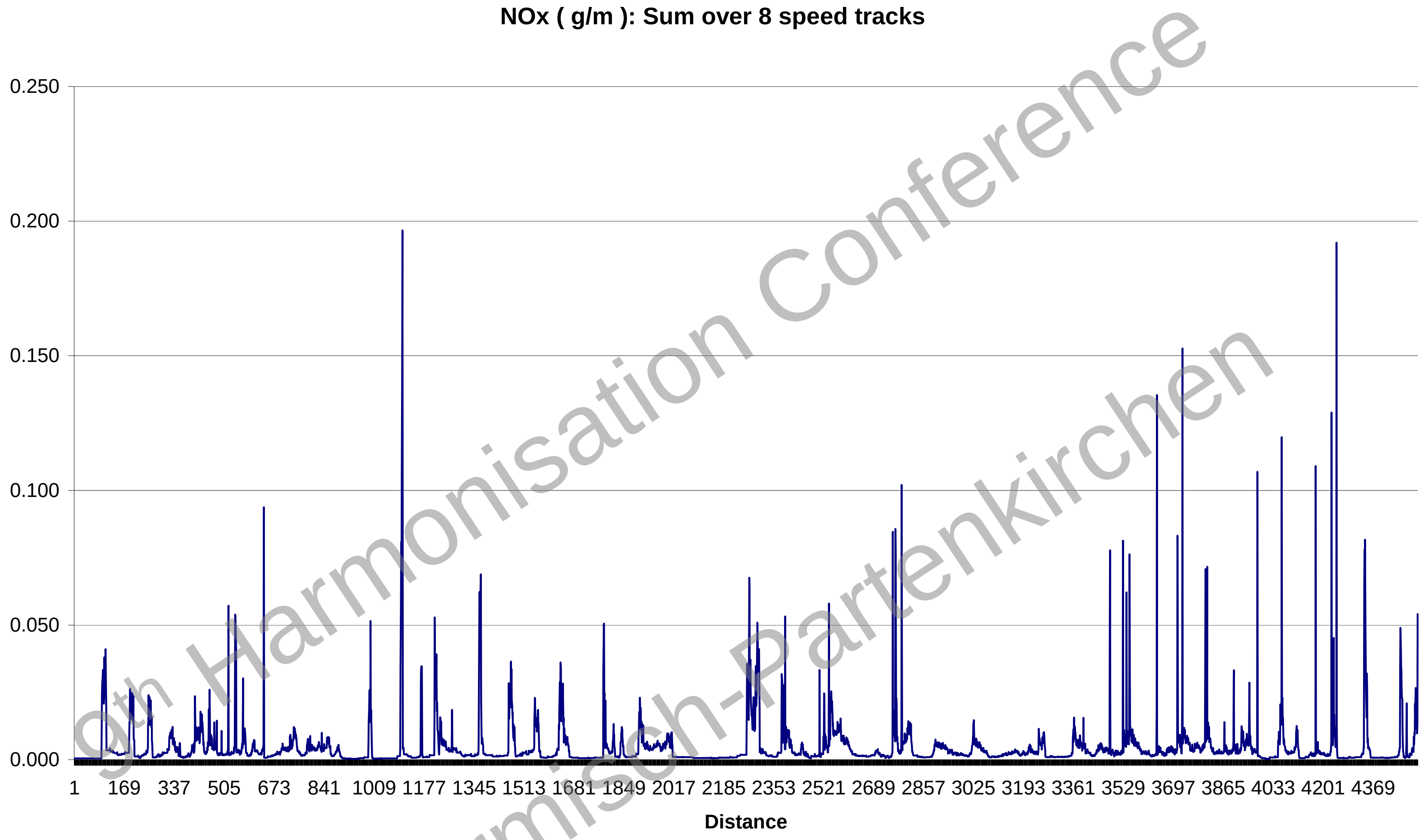

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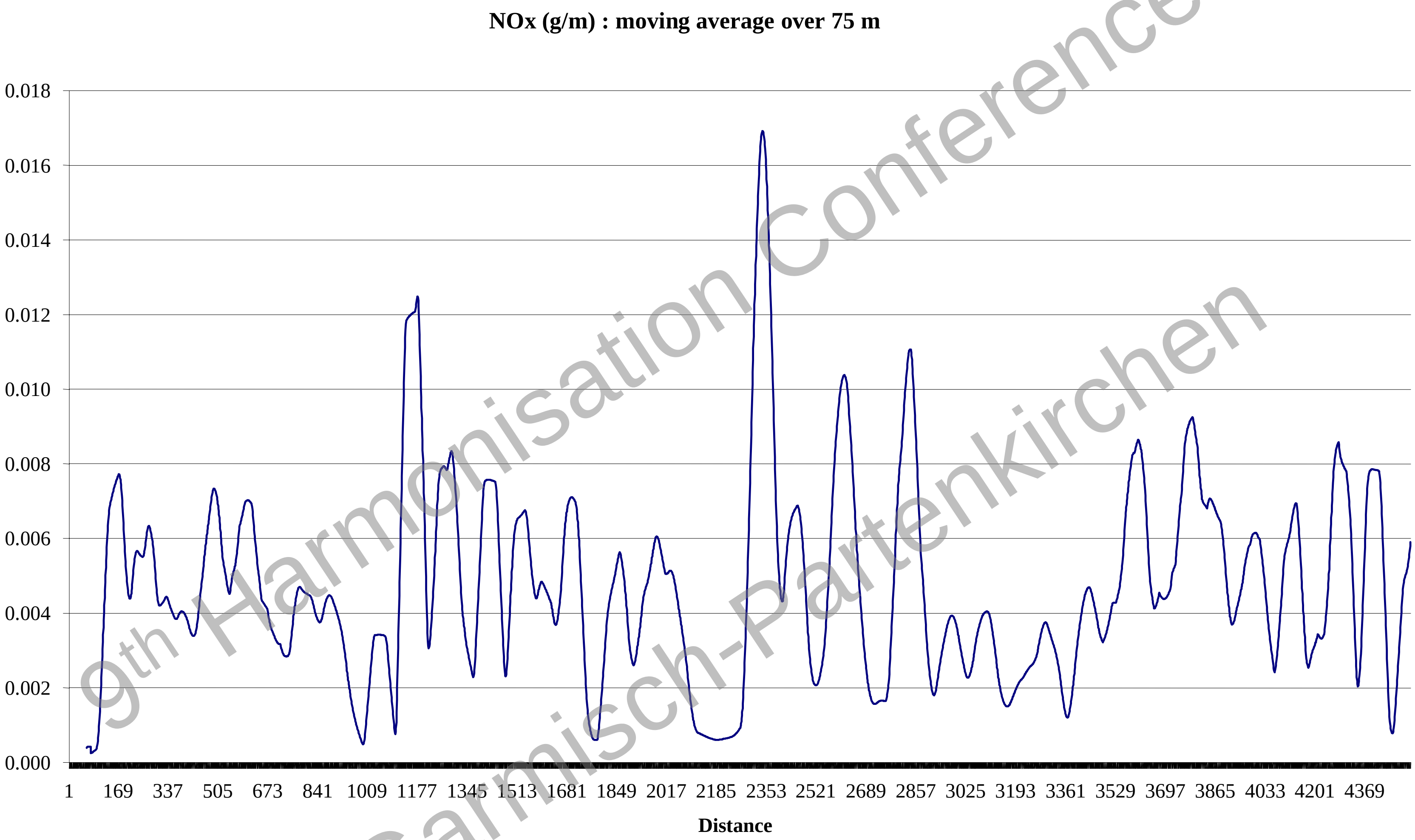
NOx (g/m) : moving average over 75 m
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
1
169
337
505
673
841
1009
1177
1345
1513
1681
1849
2017
2185
2353
2521
2689
2857
3025
3193
3361
3529
3697
3865
4033
4201
4369
Distance

Emission integration

- A next integration step is the extension of the emissions from a specific vehicle to emissions from a representative fleet by combining the emission from a number of representative cars.
- A final integration step relates the actual measured emissions with emissions at any particular time of the day. This can be obtained by measuring or modelling the hourly variations in traffic flow or traffic intensity at various locations on the selected track for the selected period of time (e.g. one year).

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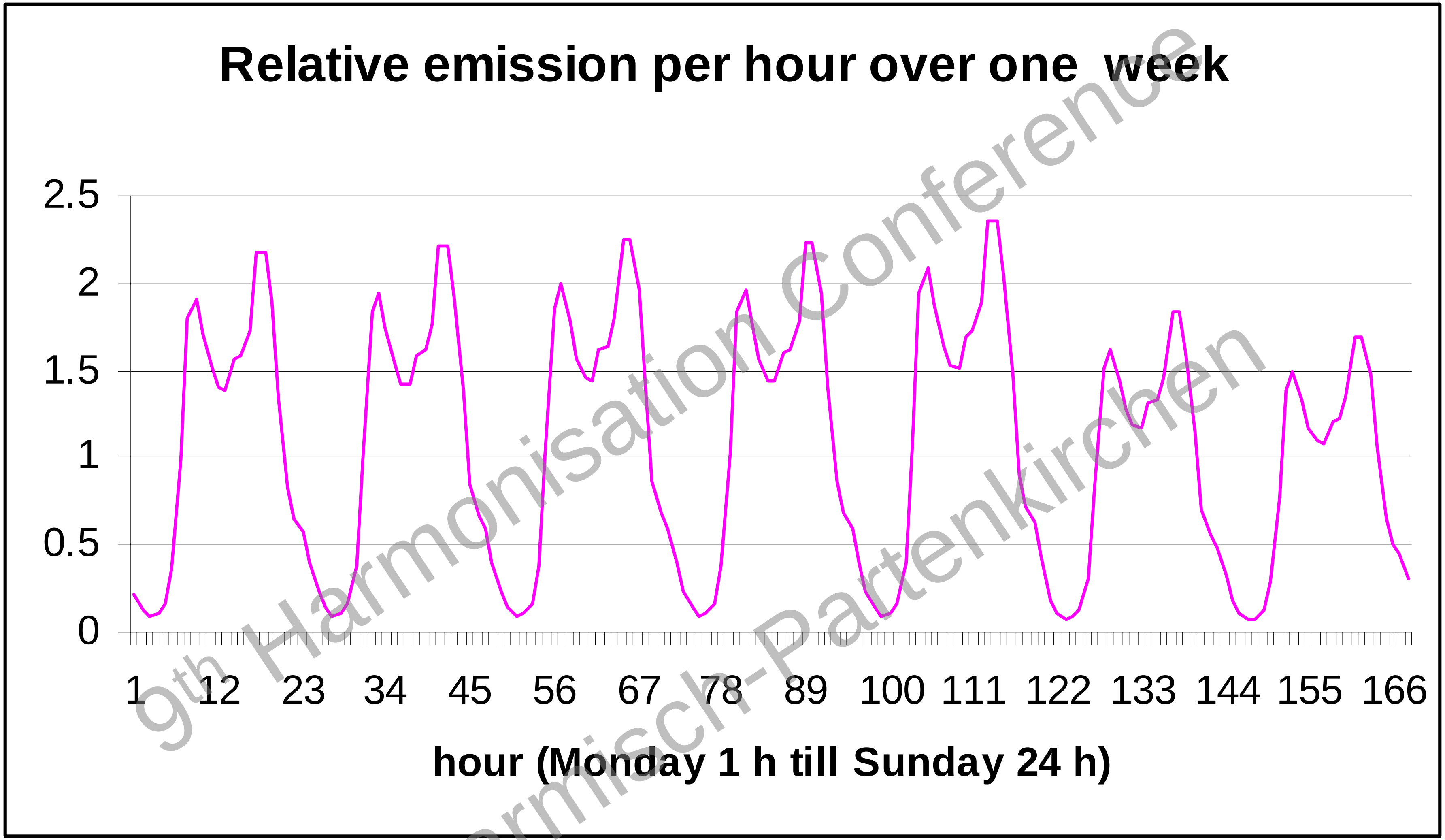
Relative emission per hour over one week
2.5
2
1.5
1
0.5
0
1
12
23
34
45
56
67
78
89
100
111
122
133
144
155
166
hour (Monday 1 h till Sunday 24 h)

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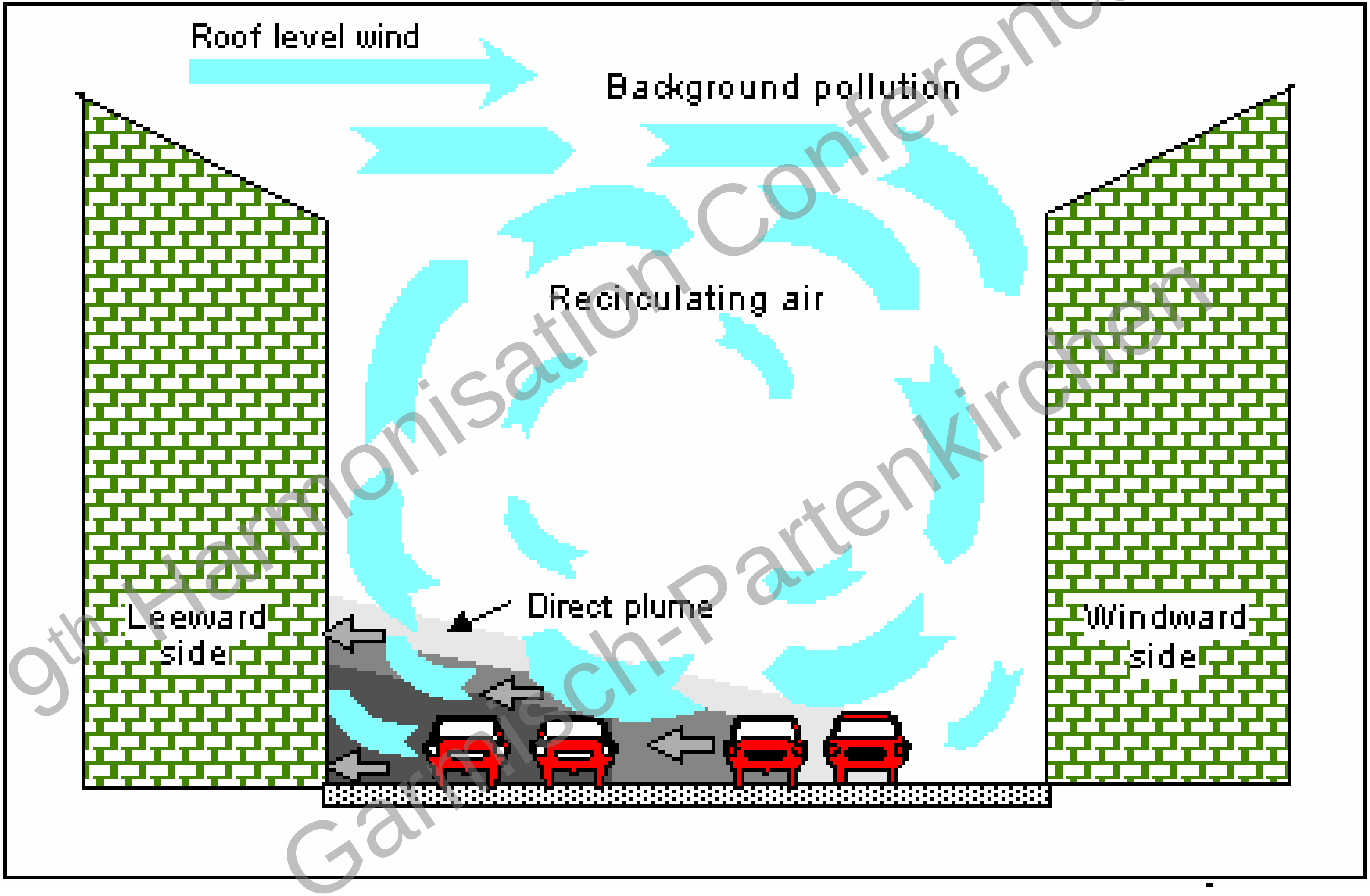
OSPM model


Roof level wind
Background pollution
Recirculating air
Direct plume
Leeward side
Windward side

Concentration calculations

- For assessment purposes (EU directive 96/62/EC), we need calculate a time series of (half)hourly concentrations over a period of one year at a height of 1.5 m to 4 m above the ground.
- OSPM needs a time series of the emissions that influence the receptor and a time series of the relevant hourly meteorological data during one year.
- OSPM produces a time series of calculated pollutant concentrations. From this time series, relevant statistical parameters can be calculated to compare their values with the limits imposed by the air quality standard.

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Scenario calculations

Due to the powerful combination of transient micro-scale emission calculations and air quality impact modelling, a wide range of scenario’s can be defined:

- driving behaviour and driving patterns or cycles (gear shifting)
- optimal vehicle use
- engine composition and scaling (engine rating, power, torque, gear ratio’s)
- load impacts (mass or number of passengers)
- impact of traffic measures (e.g. speed limiting)
- impact of street design (traffic lights, road bumps, roundabouts)
- impact of fleet composition
- use of (alternative) fuels (electric, hybrid, fuel cells)
- impact of auxiliaries (e.g. air conditioning equipment)

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Results

- The use of the methodology is demonstrated for a selected route in the city of Antwerp. The total length of one circuit was 4.5 km.

- As an example of the outcome of the methodology we show NOx concentrations for 6 different fleet composition scenario's.

- These fleets are composed of combinations of 5 vehicle types for which speed profiles have been measured and emissions have been calculated using VeTESS.

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EMI-Graph @ Vito-Mol

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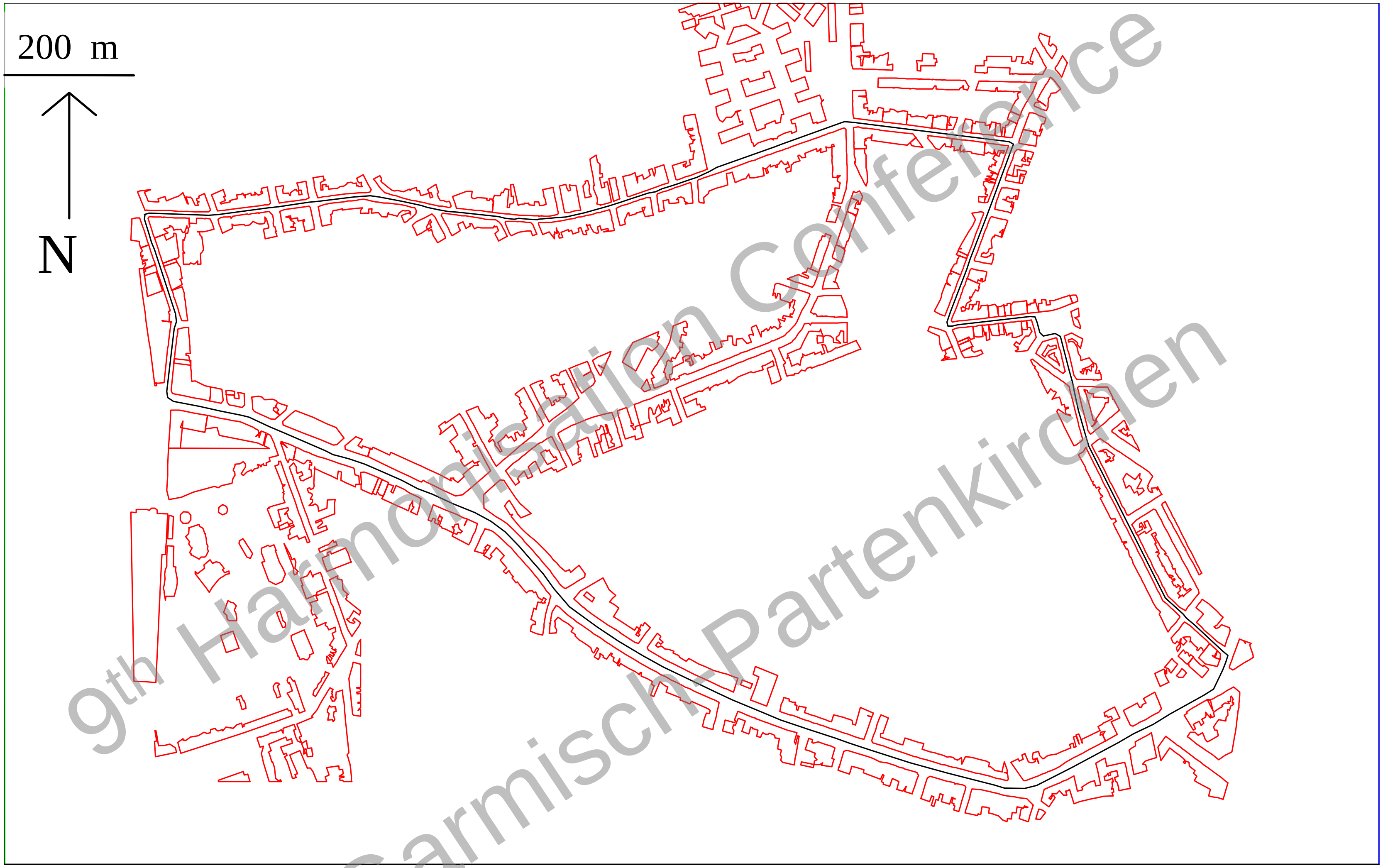

Scenario	**Passenger car 1** *Polo 1.4 16V* *Petrol/Gasoline*	**Passenger car 2** *Golf 1.9TDi* *Diesel*	**Bus 15 passengers** *MAN_A12_City bus* *(Euro 2 Diesel Engine)*	**Van (Load 500 kg)** *Citroen Jumper*	**City Truck (Load 3000 kg)** *IVECO Eurocargo*
1	2000				
2		2000			
3	1000	1000			
4	500	500	67		
5	475	475	67	100	
6	475	475	67		17

Scenario 1: all petrol cars

Scenario 2: all diesel cars

Scenario 3: petrol and diesel cars with equal frequency

Scenario 4: 50 % transported by buses, 15 cars replaced by 1 bus

Scenario 5: 5 % of cars are vans, with a transport load of 500 kg each

Scenario 6: the total van load is transported by City Trucks

Calculation assumptions

- No background concentrations were taken into account in this demonstration case.
- Receptors were placed every 25 meters along the Antwerp track, at a height of 1.5 m above the ground. This gives 180 receptors.
- For each receptor, a street canyon description (street geometry, orientation, traffic density, building height, emissions) is generated as required by OSPM.
- Hourly meteorological data of the year 1998 measured along the Zwijndrecht meteorological tower were used
- Traffic data from the Antwerp traffic flow model provide the number of cars during peak hour.

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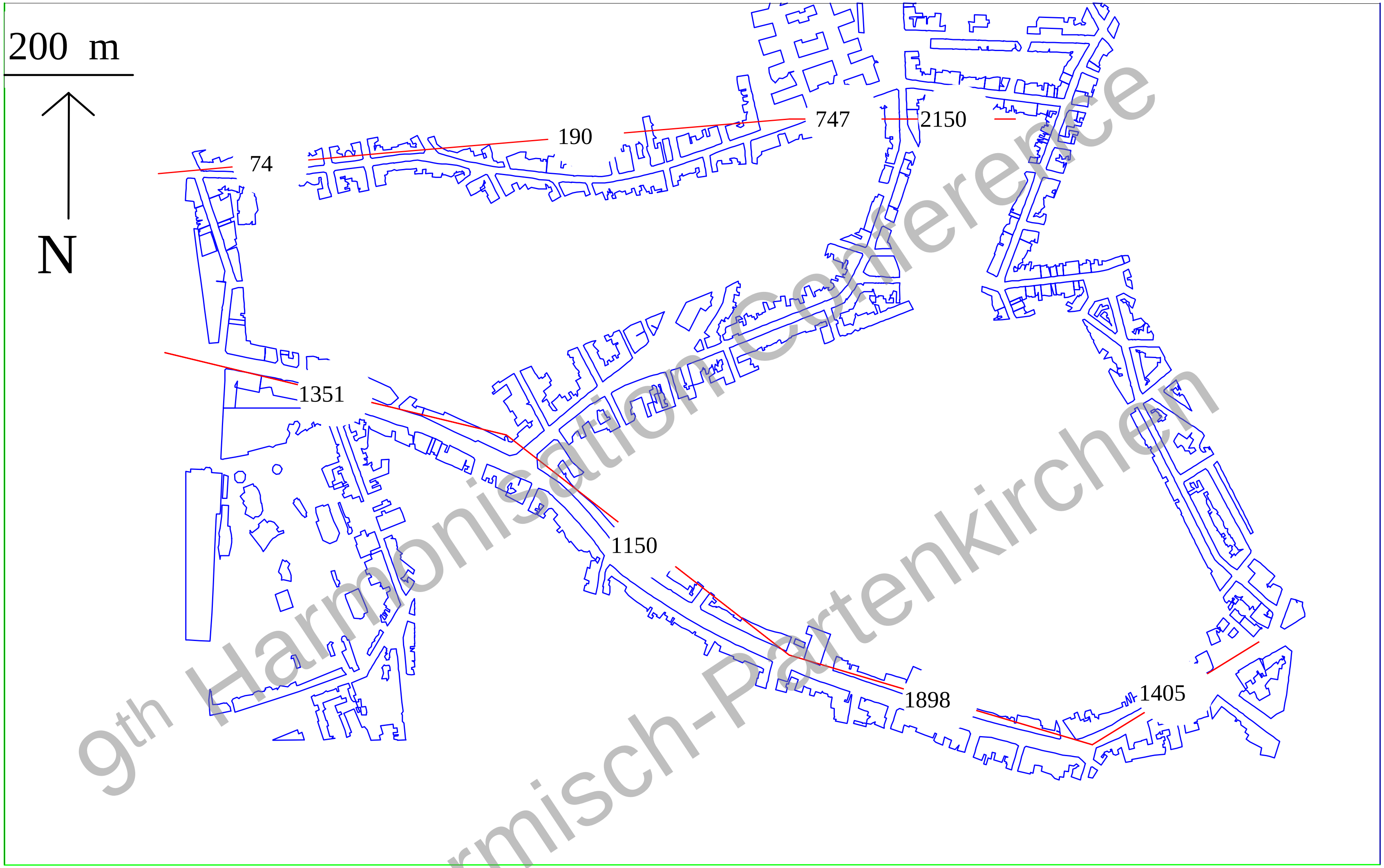

Traffic Flow Model Antwerp: number of vehicles during peak hour.

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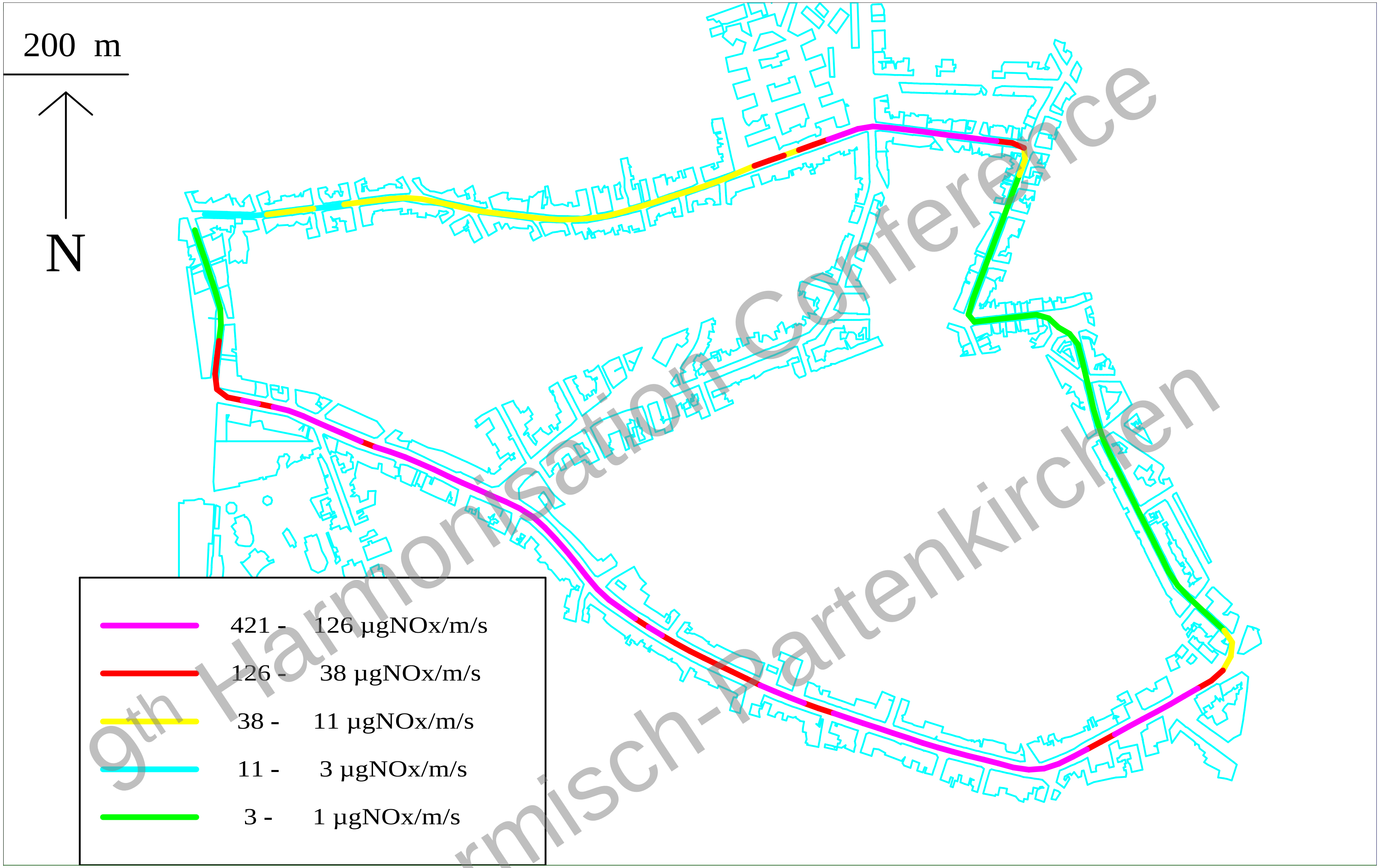

Emission averaged over 150 m around receptor (µg NOx/s/m) scenario.s6
Second line, file d:\decade\qpm\recepl.Qal

EMI-Graph @ Vito-Mol

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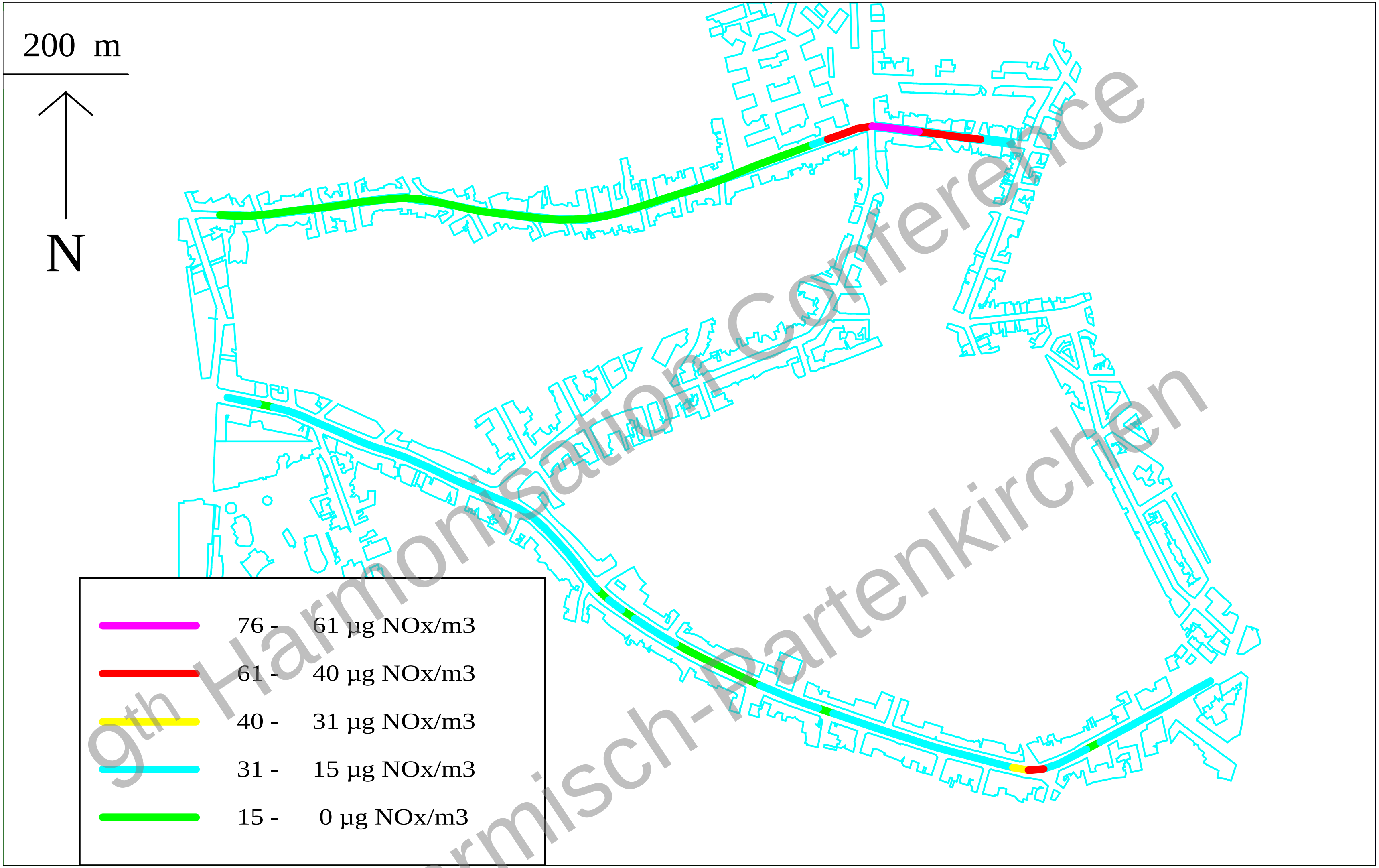

Year averaged NOx concentration (µg/m3)
Second line, file d:\decade\qpm\stat_av.txt

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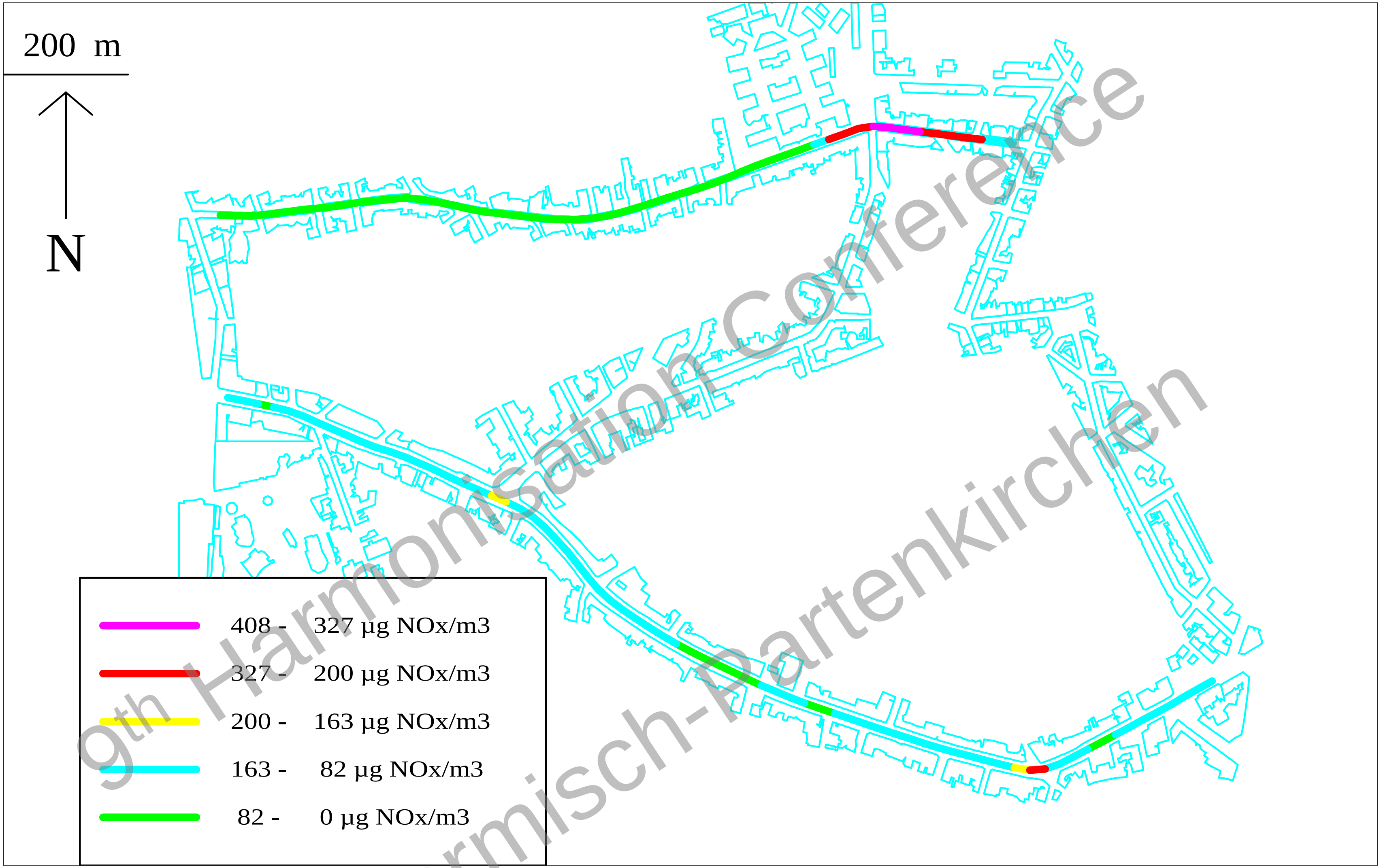

Half hourly NOx concentration (µg/m3) exceeded at most 18 times per year
Second line, file d:\decade\qpm\stat15b.txt

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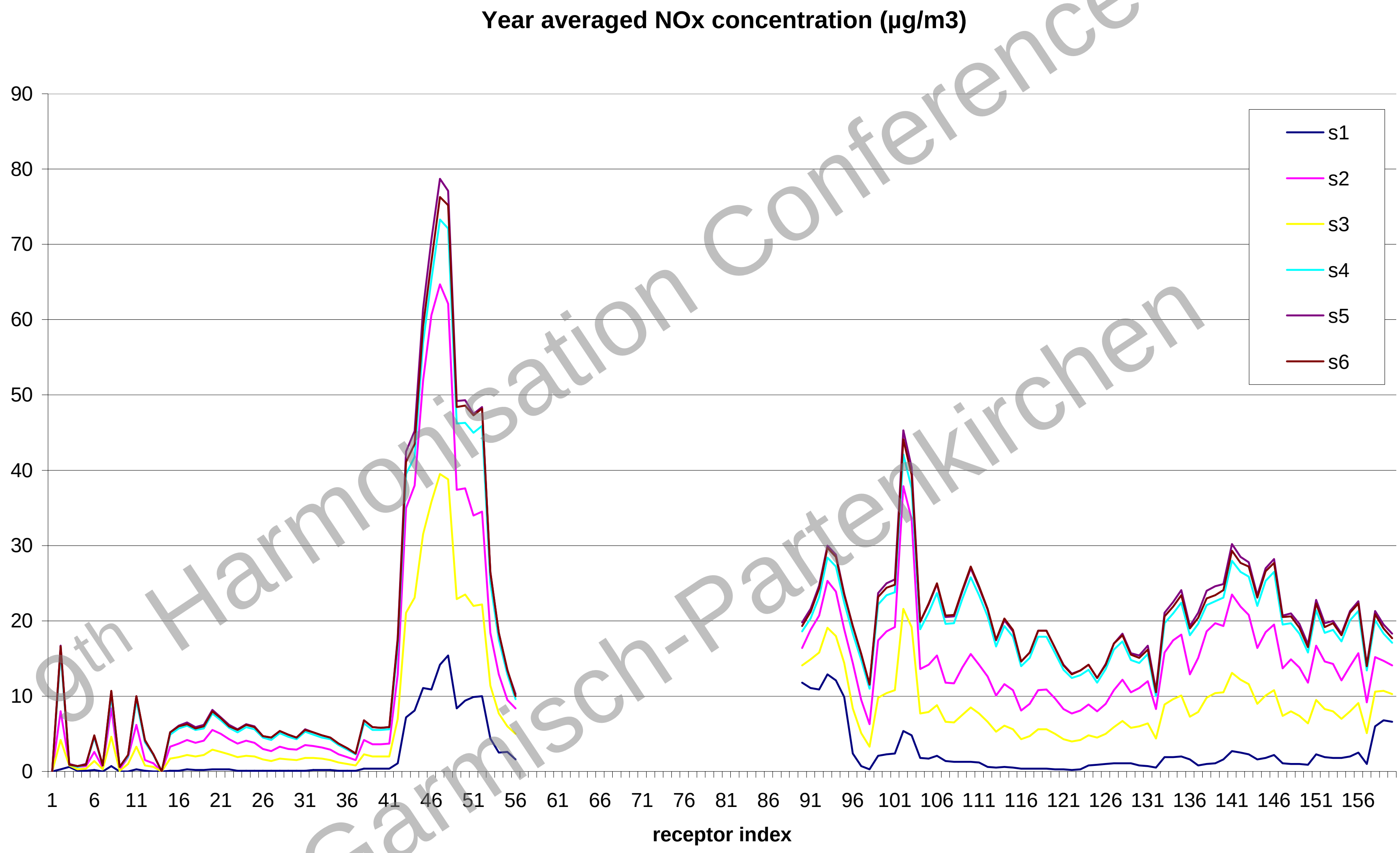

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Conclusions

- The VeTESS model calculates in detail traffic emissions for a specific vehicle as based on the engine power required to drive the vehicle over any particular route.
- This information can be used to built various scenario's in which traffic situations, driving patterns, technological measures and vehicle concepts can be evaluated.
- The emissions can then be used as input in air dispersion models, which result in pollution concentrations.
- Results show exactly where on the route the hot spots are located and where and when exceeding of the limit values (EU directive) can be expected.

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