Conference about the status and future of the educational and R&D services for the vehicle industry

Computational simulation of air pollution dispersion induced by urban traffic

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„Smarter Transport" – IT for co-operative transport system section

Hungarian Academy of Science
Budapest, 31 January 2014

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RESEARCH CENTER OF VEHICLE INDUSTRY

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Collaborators – multidisciplinary research team

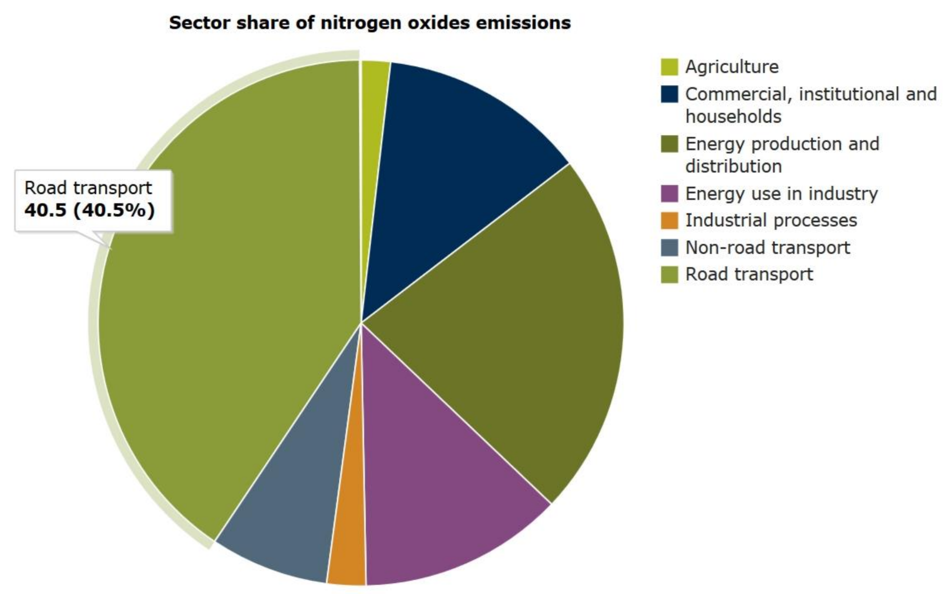
1. Challange
   1. Objectives, research management: Rozália Varga
2. Modeling and Simulation tools
   1. Measurements (traffic, NOx): Éva Rácz Pestiné, Ingrid Sándor, Anett Bedő, Péter Lautner, István Harmati
   2. Traffic flow simulation: Bertalan Gaál
   3. NOx emission simulation: Alfréd Csikós (BME)
   4. Geometry modeling: Bence Liszkai, Gábor Diósi, Péter Zsebők
   5. NOx dispersion simulation: Péter Zsebők, Bence Liszkai

Partners:

Győr City, Jel-Köz Kft, FŐMTERV Zrt, OMSZ, IBM

1. Challange

- WHO Air quality guidelines (2005)
- 2008/50/EC on ambient air quality and cleaner air for Europe - Emissions of harmful air pollutants should be avoided, prevented or reduced → Monitoring & Critical levels
- Clean Air Policy (IP/13/1274 18/12/2013)
  - http://ec.europa.eu/environment/air/clean_air_policy.htm



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1. Objectives (cont.): Projects, partnerships in EU

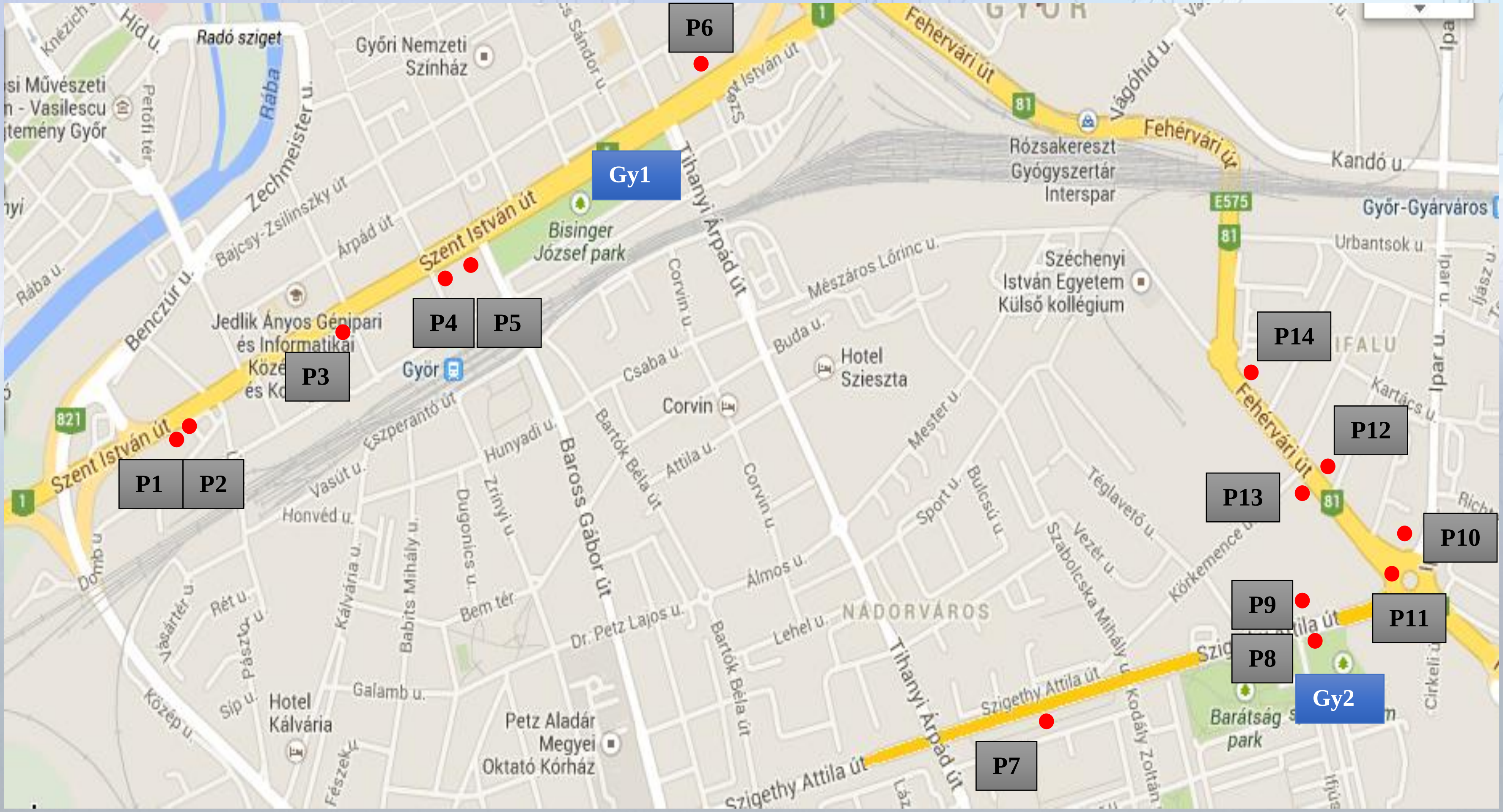
- Niches+ Action: Using Environmental Pollution Data in Traffic Management Centres (FP7) Smart Cities and Communities
  - "Strategic Implementation Plan" of the Smart Cities and Communities Partnership (2013)
- H2020 – Societal Challanges
  - (e.g. Smart Cities and Communities) – already several calls in H2020!
- In our TÁMOP 422C project: ”Research of computer simulation and optimization which supports the SmartCity-SmartTransport concept” subproject

2. Modeling and Simulation Tools

- Aims: model, simulate and then optimize and control traffic emitted NOx in cities, in particular in Győr
- Need of simulation of
  1. Traffic flow
  2. NOx emission
  3. NOx dispersion in real 3D geometry
- Preprocessing:
  1. Geometry modeling
  2. Measurements (for validation)
  3. Data compatibility
  4. Data from diverse sources (e.g. meteorology, etc.)
- Automated simulation, optimization and control

2.1 Modeling and Simulation Tools (cont.)- Measurements

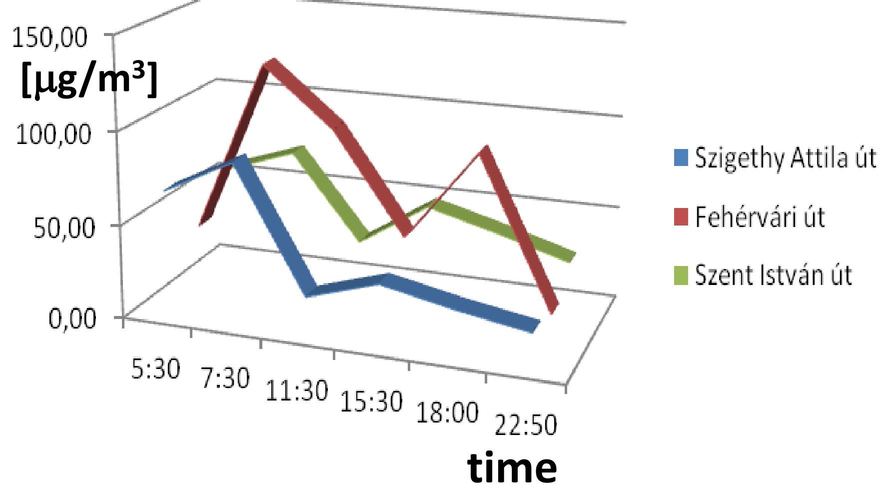
- Measurements in Győr at 2 different districts



2.1 Modeling and Simulation Tools (cont.)- Measurements

- „Street Canyon" – Szent István út – Jókai út, Győr
  - 2*8 sampling site (1.5 m & 3m)
  - 6 air samples during the day
  - 18 hours manual traffic counting
  - 3 lecturers and 40+ students involved

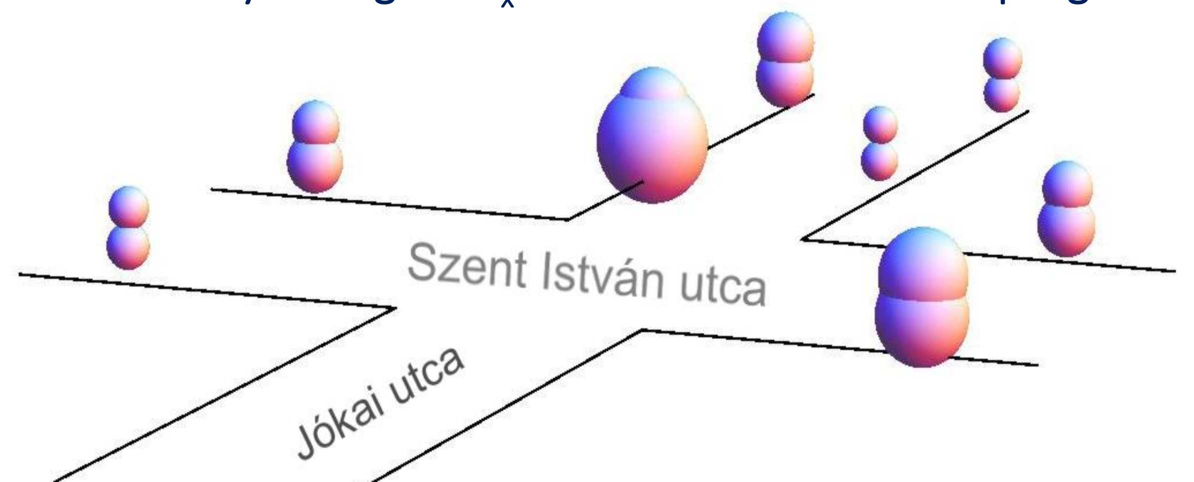
2.1 Modeling and Simulation Tools (cont.): Measurements



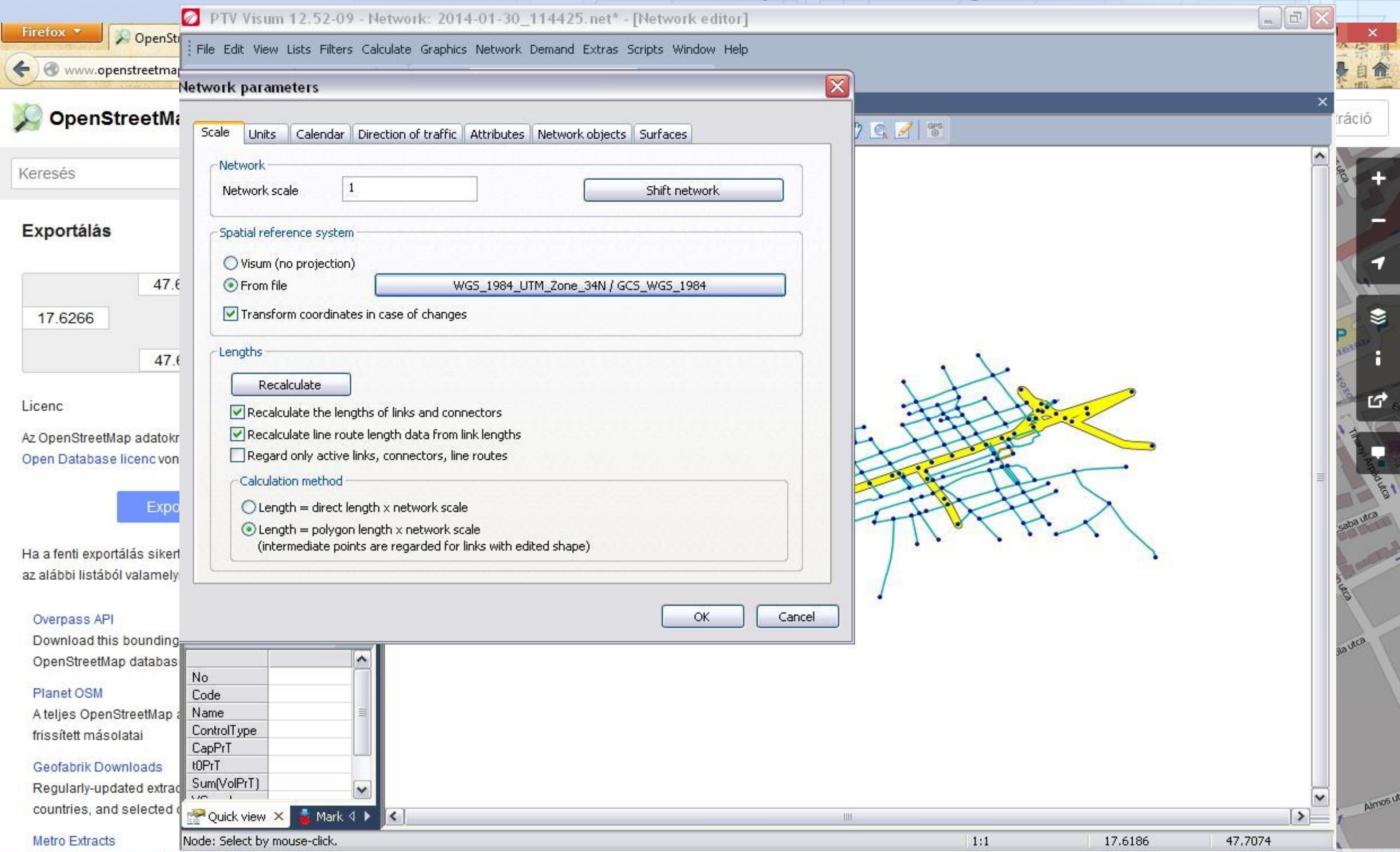
Results

1. Models for NOx , conspicuous differences in daily rhythm
2. canyon effect detected
3. no significant difference at heights
4. turbulence at corners

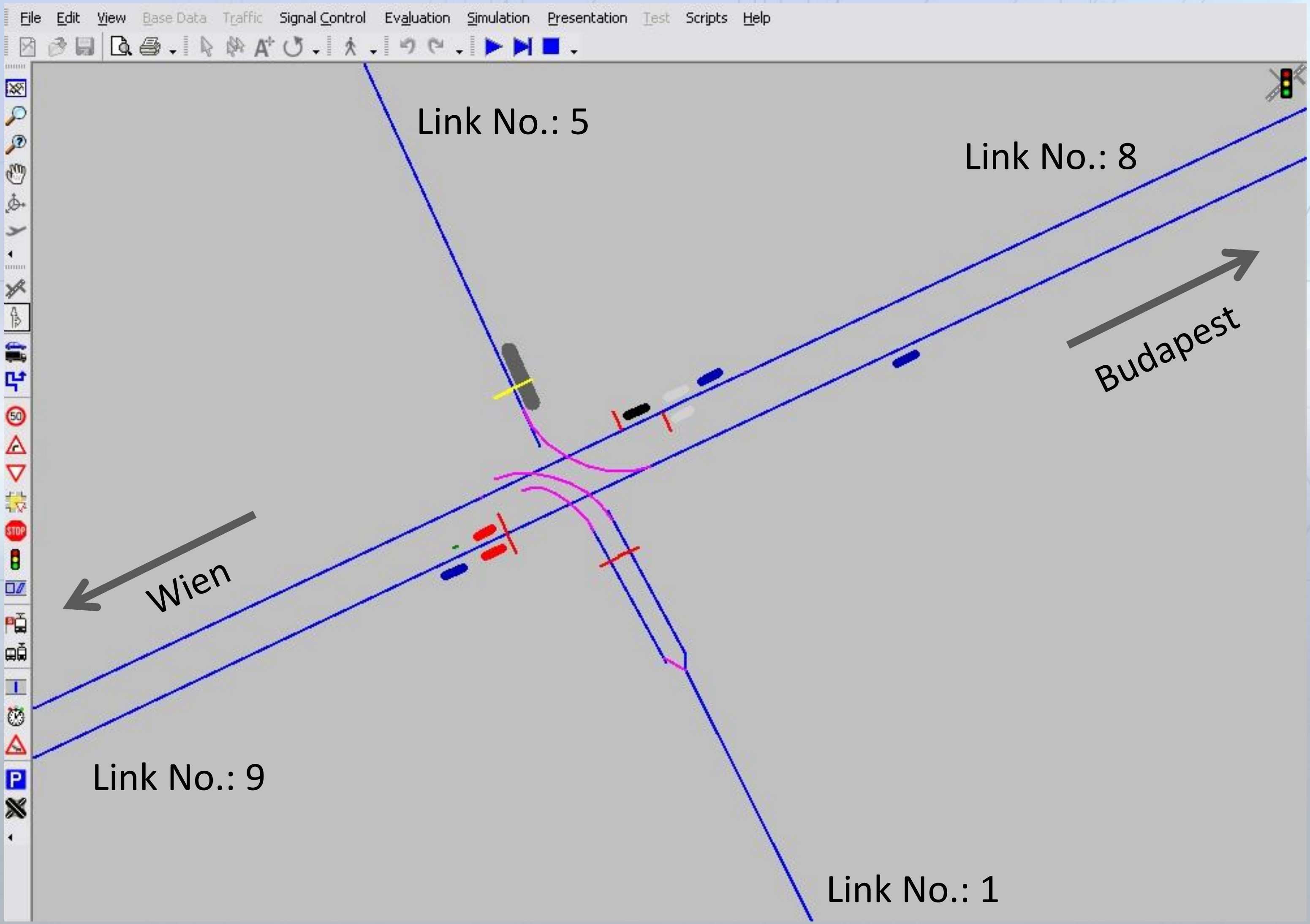
Daily average NO_x concentration at the sampling sites



2.2 Traffic flow simulation: Preprocessing

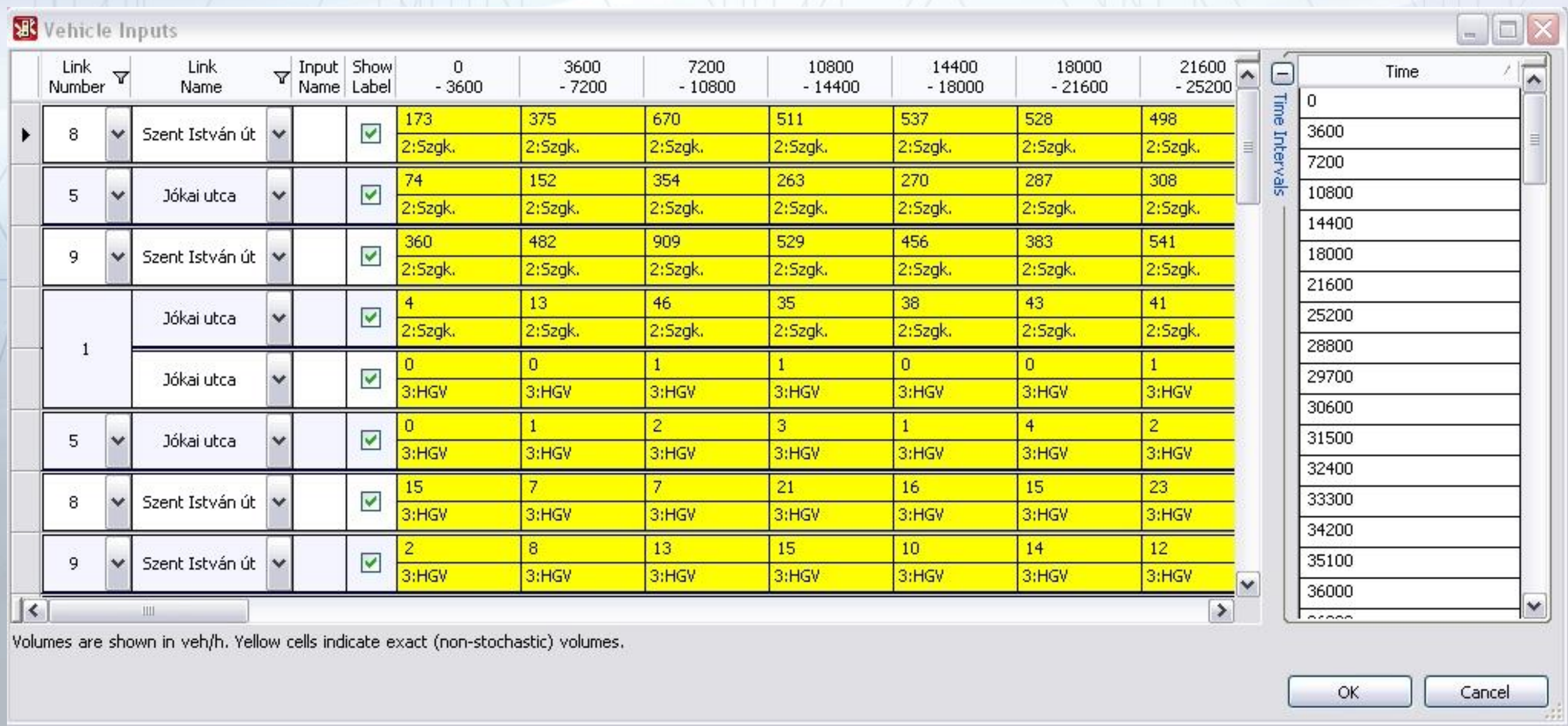


2.2 Traffic flow simulation: microscopic simulation in VISSIM



2.2 Traffic flow simulation with PTV VISSIM 5.40

- Cross-section counting with vehicle categories
    - Car
    - HGV (Heavy Goods Vehicle)
    - Bus
    - Motorbike


Vehicle Inputs

Link Number	Link Name	Input Name	Show Label	0 - 3600	3600 - 7200	7200 - 10800	10800 - 14400	14400 - 18000	18000 - 21600	21600 - 25200
8	Szent István út		☑	173 2:Szgk.	375 2:Szgk.	670 2:Szgk.	511 2:Szgk.	537 2:Szgk.	528 2:Szgk.	498 2:Szgk.
5	Jókai utca		☑	74 2:Szgk.	152 2:Szgk.	354 2:Szgk.	263 2:Szgk.	270 2:Szgk.	287 2:Szgk.	308 2:Szgk.
9	Szent István út		☑	360 2:Szgk.	482 2:Szgk.	909 2:Szgk.	529 2:Szgk.	456 2:Szgk.	383 2:Szgk.	541 2:Szgk.
1	Jókai utca		☑	4 2:Szgk.	13 2:Szgk.	46 2:Szgk.	35 2:Szgk.	38 2:Szgk.	43 2:Szgk.	41 2:Szgk.
	Jókai utca		☑	0 3:HGV	0 3:HGV	1 3:HGV	1 3:HGV	0 3:HGV	0 3:HGV	1 3:HGV
5	Jókai utca		☑	0 3:HGV	1 3:HGV	2 3:HGV	3 3:HGV	1 3:HGV	4 3:HGV	2 3:HGV
8	Szent István út		☑	15 3:HGV	7 3:HGV	7 3:HGV	21 3:HGV	16 3:HGV	15 3:HGV	23 3:HGV
9	Szent István út		☑	2 3:HGV	8 3:HGV	13 3:HGV	15 3:HGV	10 3:HGV	14 3:HGV	12 3:HGV

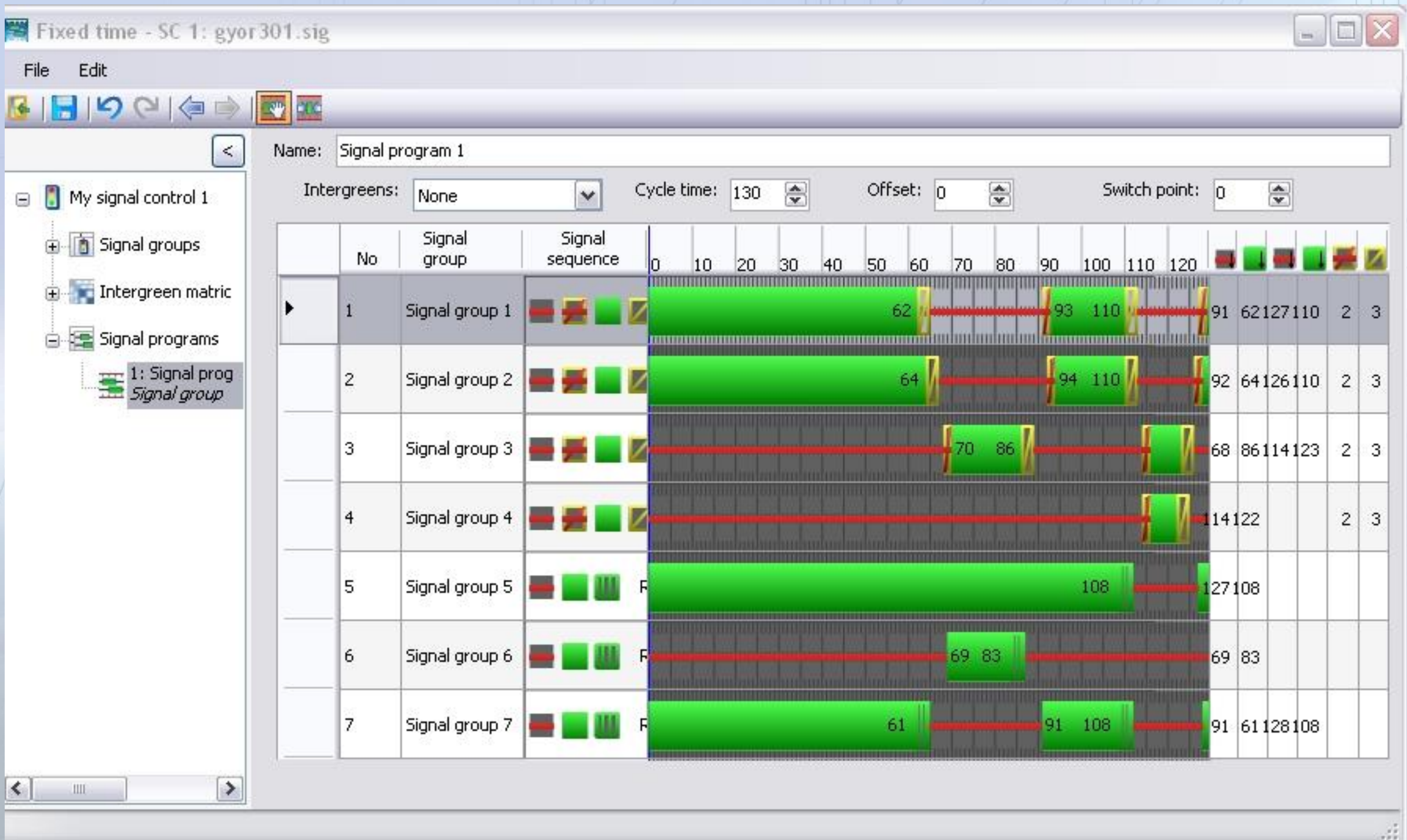
Time Intervals

Time
0
3600
7200
10800
14400
18000
21600
25200
28800
29700
30600
31500
32400
33300
34200
35100
36000

Volumes are shown in veh/h. Yellow cells indicate exact (non-stochastic) volumes.

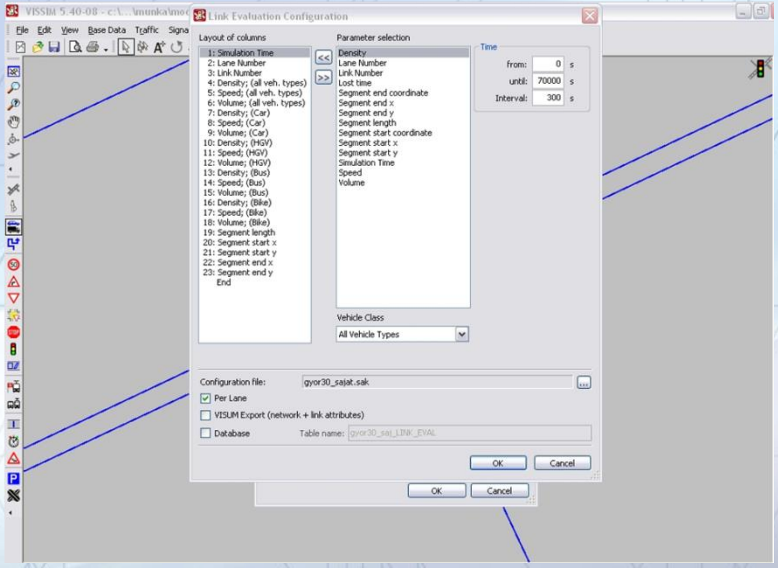
OK Cancel

2.2 Traffic flow simulation: signal program



2.3 Traffic flow simulation: Post processing and NOx emission computation

1. Link evaluation
2. Output for emission computation
3. MATLAB script (Copert model)




```
t: Simulation Time [s]
Lane: Lane Number
Link: Link Number
Density: Vehicle density [veh/km] (Vehicle Class 0)
v: Average speed [km/h] (Vehicle Class 0)
Volume: Volume [veh/h] (Vehicle Class 0)
Density: Vehicle density [veh/km] (Vehicle Class 10)
v: Average speed [km/h] (Vehicle Class 10)
Volume: Volume [veh/h] (Vehicle Class 10)
Density: Vehicle density [veh/km] (Vehicle Class 20)
v: Average speed [km/h] (Vehicle Class 20)
Volume: Volume [veh/h] (Vehicle Class 20)
Density: Vehicle density [veh/km] (Vehicle Class 30)
v: Average speed [km/h] (Vehicle Class 30)
Volume: Volume [veh/h] (Vehicle Class 30)
Density: Vehicle density [veh/km] (Vehicle Class 60)
v: Average speed [km/h] (Vehicle Class 60)
Volume: Volume [veh/h] (Vehicle Class 60)
SegLen: Segment length [m]
SegStX: Segment start (cartesian coordinate x)
SegStY: Segment start (cartesian coordinate y)
SegEndX: Segment end (cartesian coordinate x)
SegEndY: Segment end (cartesian coordinate y)

    t; Lane;  Link; Density(0);     v(0); Volume(0); Density(10);     v(10); Volume(10); Density(20);     v(20); Volume(20);
300.0;    1; 10001;       0.73;    31.70;    23.25;        0.73;    31.70;    23.25;        0.00;    0.00;    0.00;      0.00;
300.0;    1; 10001;       0.59;    44.85;    26.25;        0.59;    44.85;    26.25;        0.00;    0.00;    0.00;      0.00;
300.0;    2; 10001;       0.70;    34.56;    24.19;        0.70;    34.56;    24.19;        0.00;    0.00;    0.00;      0.00;
300.0;    2; 10001;       0.59;    46.79;    27.38;        0.59;    46.79;    27.38;        0.00;    0.00;    0.00;      0.00;
300.0;    1; 10013;       0.00;     0.00;     0.00;        0.00;     0.00;     0.00;        0.00;    0.00;    0.00;      0.00;
300.0;    1; 10013;       0.00;     0.00;     0.00;        0.00;     0.00;     0.00;        0.00;    0.00;    0.00;      0.00;
300.0;    1; 10014;       0.00;     0.00;     0.00;        0.00;     0.00;     0.00;        0.00;    0.00;    0.00;      0.00;
300.0;    1;     1;       0.00;     0.00;     0.00;        0.00;     0.00;     0.00;        0.00;    0.00;    0.00;      0.00;
300.0;    1;     1;       0.00;     0.00;     0.00;        0.00;     0.00;     0.00;        0.00;    0.00;    0.00;      0.00;
300.0;    1;     1;       0.00;     0.00;     0.00;        0.00;     0.00;     0.00;        0.00;    0.00;    0.00;      0.00;
300.0;    1;     1;       0.00;     0.00;     0.00;        0.00;     0.00;     0.00;        0.00;    0.00;    0.00;      0.00;
300.0;    1;     1;       0.00;     0.00;     0.00;        0.00;     0.00;     0.00;        0.00;    0.00;    0.00;      0.00;
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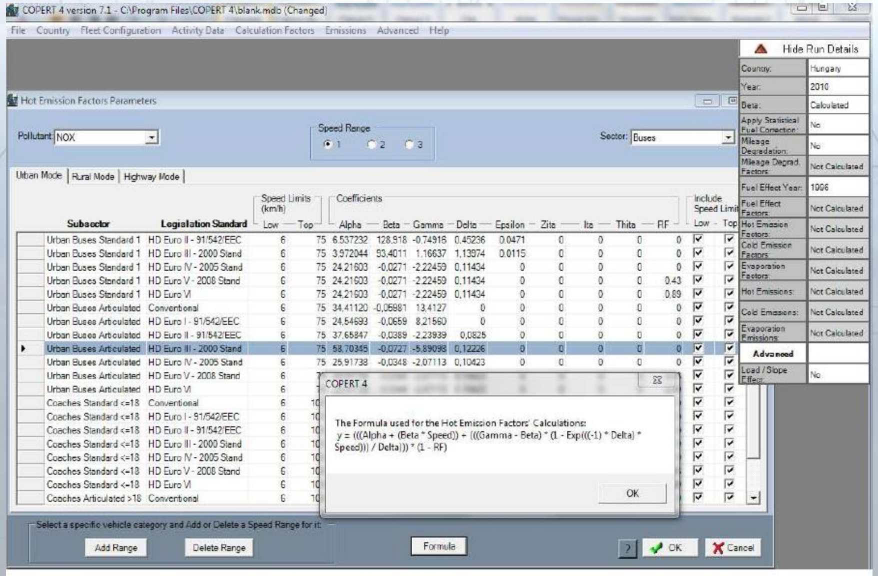


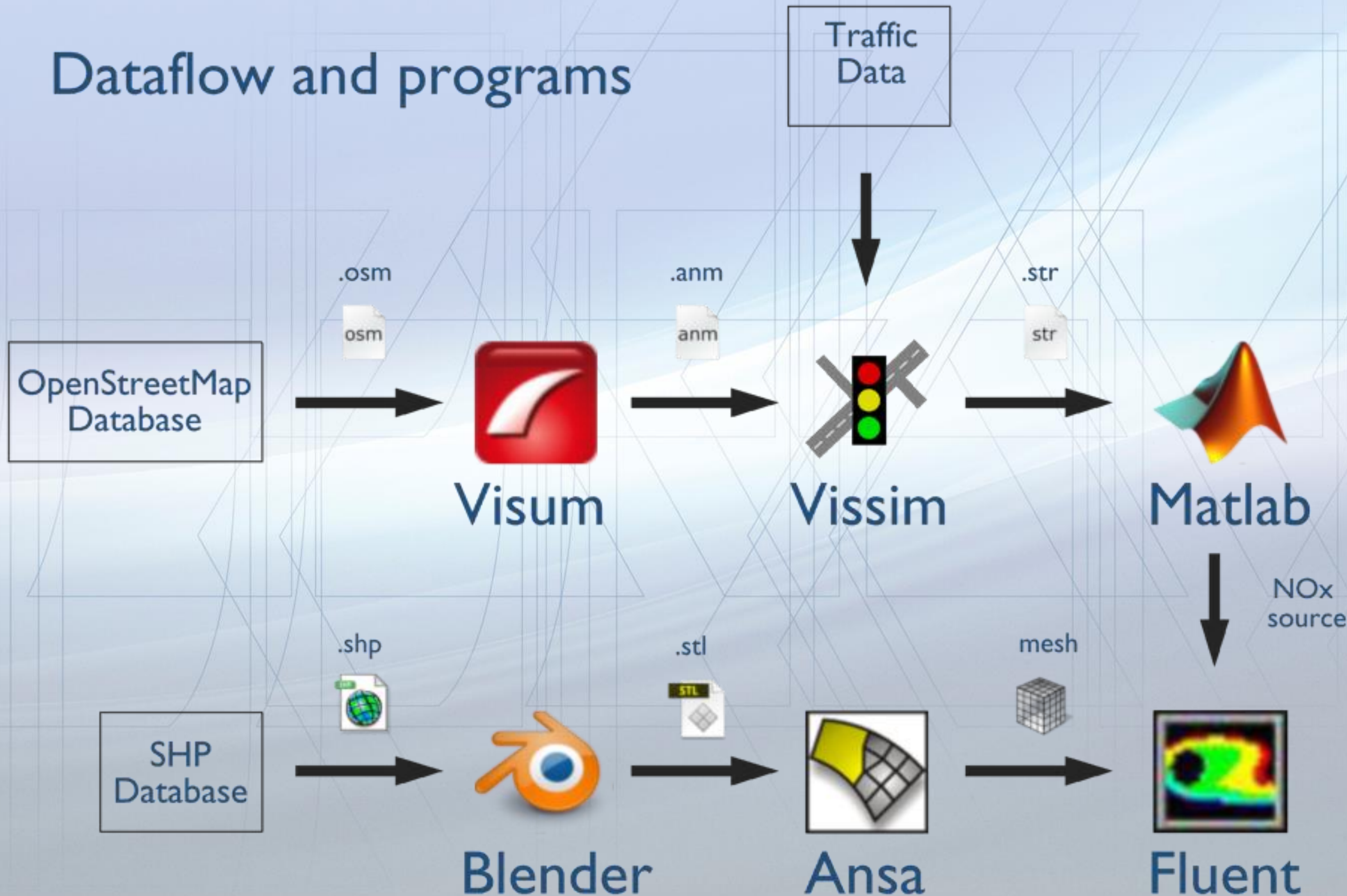
emisszió együtthatók kinyerése a Copert programból

2.4-5 Geometry modeling and NOx dispersion simulation

Software

- Fluent: CFD
- Ansa: Mesher
- Blender: Geometry from shp
- VisSim: traffic
- ViSum: traffic
- Matlab: NOx from traffic simulation

Dataflow and programs

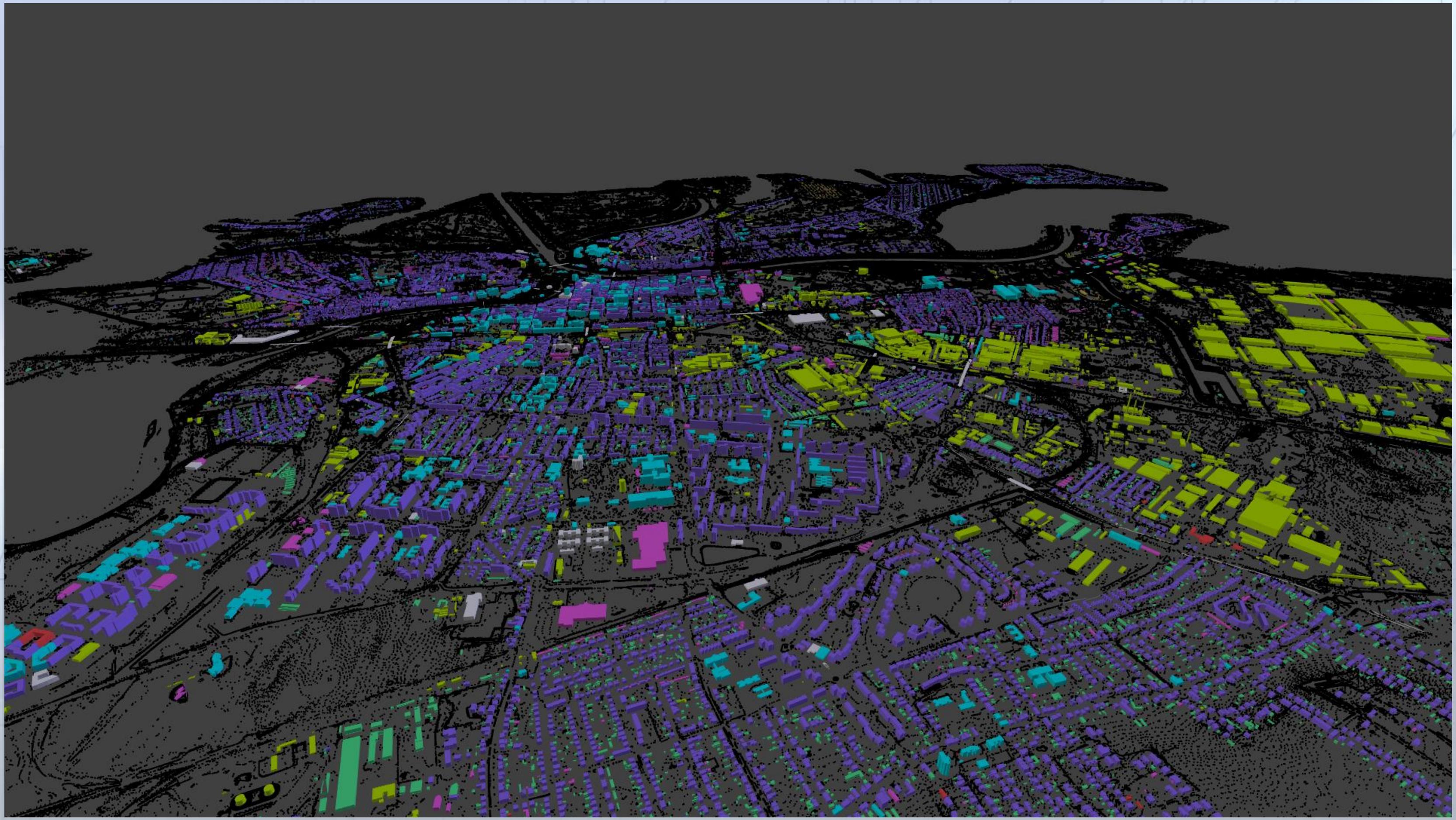


2.4 Geometry modeling: City geometry

Converted from SHP file with Blender python script

- Buildings
- Ground
- Noise barrier walls
- Bridges

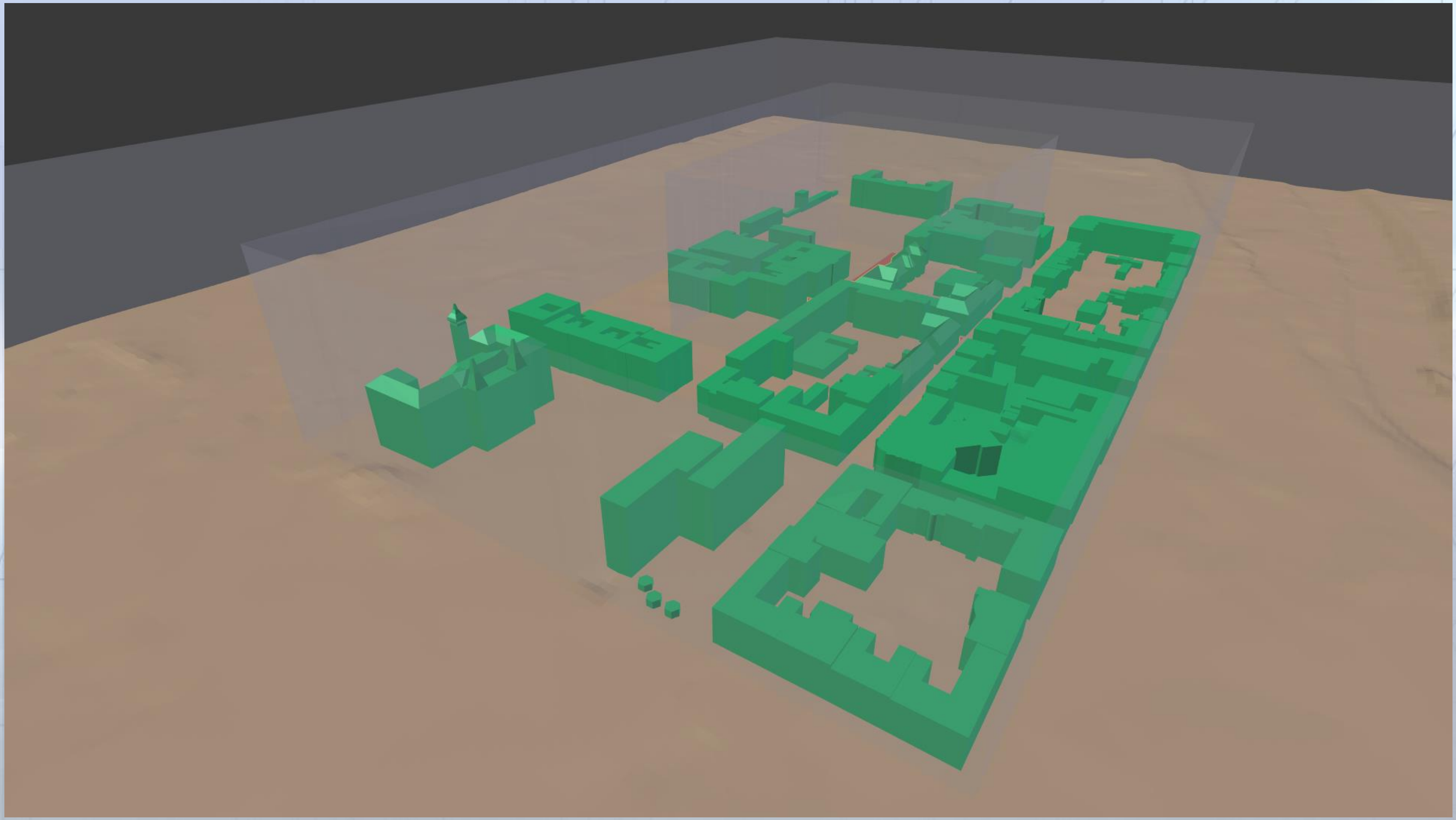
2.4 Geometry modeling: Full 3D model of Győr



2.4 Geometry modeling workflow

- Improved geometry
- Create ground surface from points
- Add the elements with mesh boolden operators
- Convert to STL format

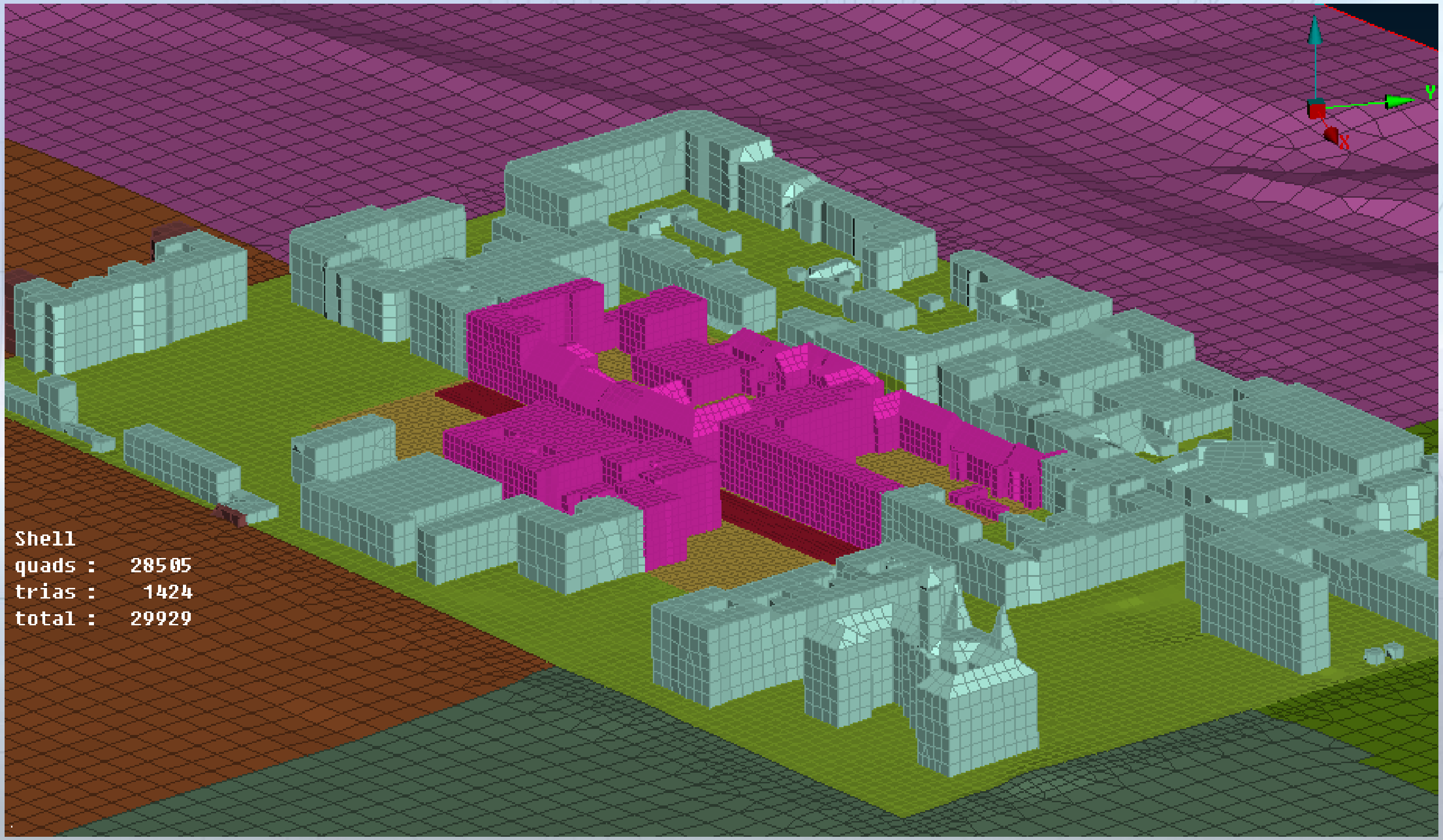
STL mesh in Blender



2.5 NOx dispersion simulation: Mesh specification

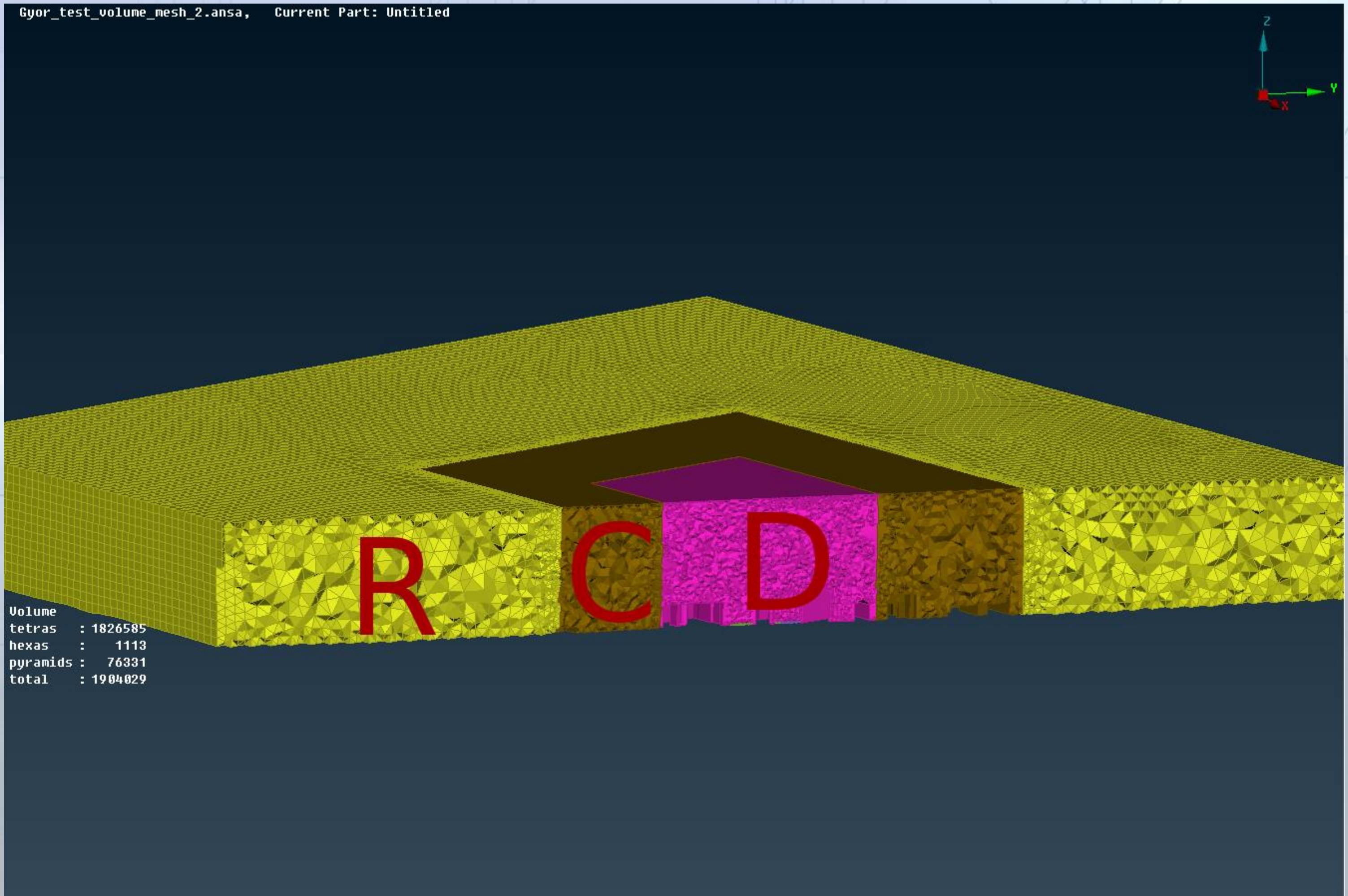
- Quad shell mesh (mostly)
- Three reginions of resolution
  - Detailed: buildings’s geometry+ high res. mesh
  - Coarse: buildings’s geometry + medium res. mesh
  - Rough: buildings as roughness + low res. Mesh
- Tetra volume mesh
- Prism layer mesh on the roads
- Two global resolution
  - Low res. mesh: 1.7 million volume elements
  - High res. mesh: 3,6 million volume elements

2.5 NOx dispersion simulation: After remesh in ANSA



2.5 NOx dispersion simulation: Volume meshing

Model: Rough, Coarse and Detailed regions



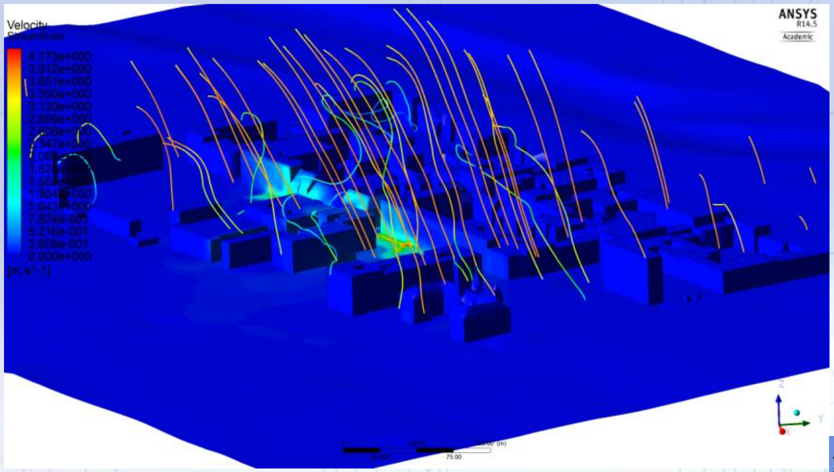
2.5 NOx dispersion simulation: Simulation setup

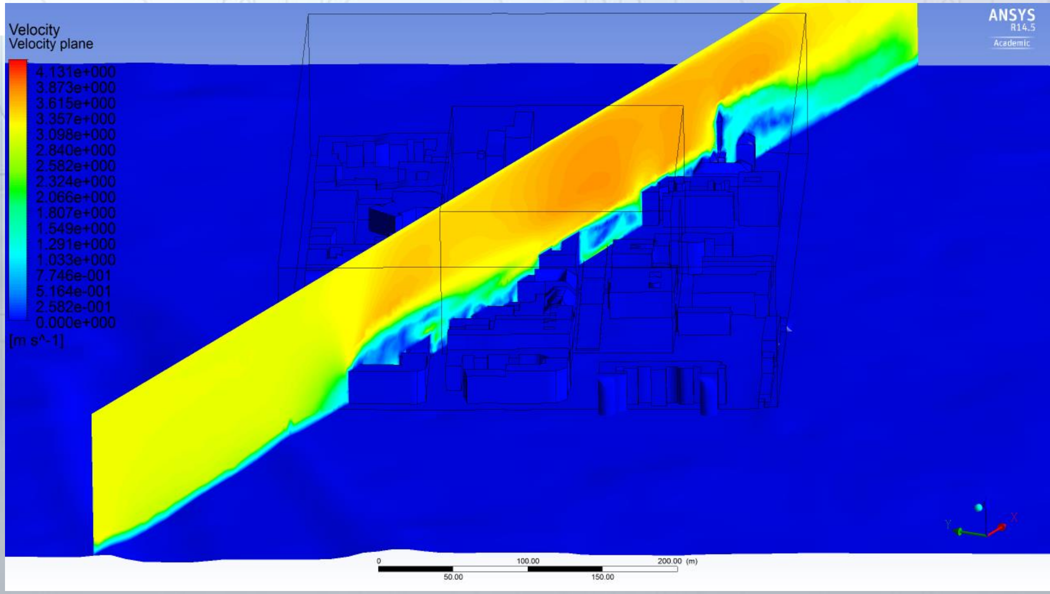
- Boundary conditions:
  - NOx source: road prism layer
  - Solar radiation
  - Constant 3 m/s N-W wind
- Species transport for the pollutant air
- In that early case the pollutant load is a constant hourly average pollution of a normal day
- Rough region
  - Divided into four segment
  - Roughness setup depends on the average building height

2.5 NOx dispersion simulation: Simulation setup

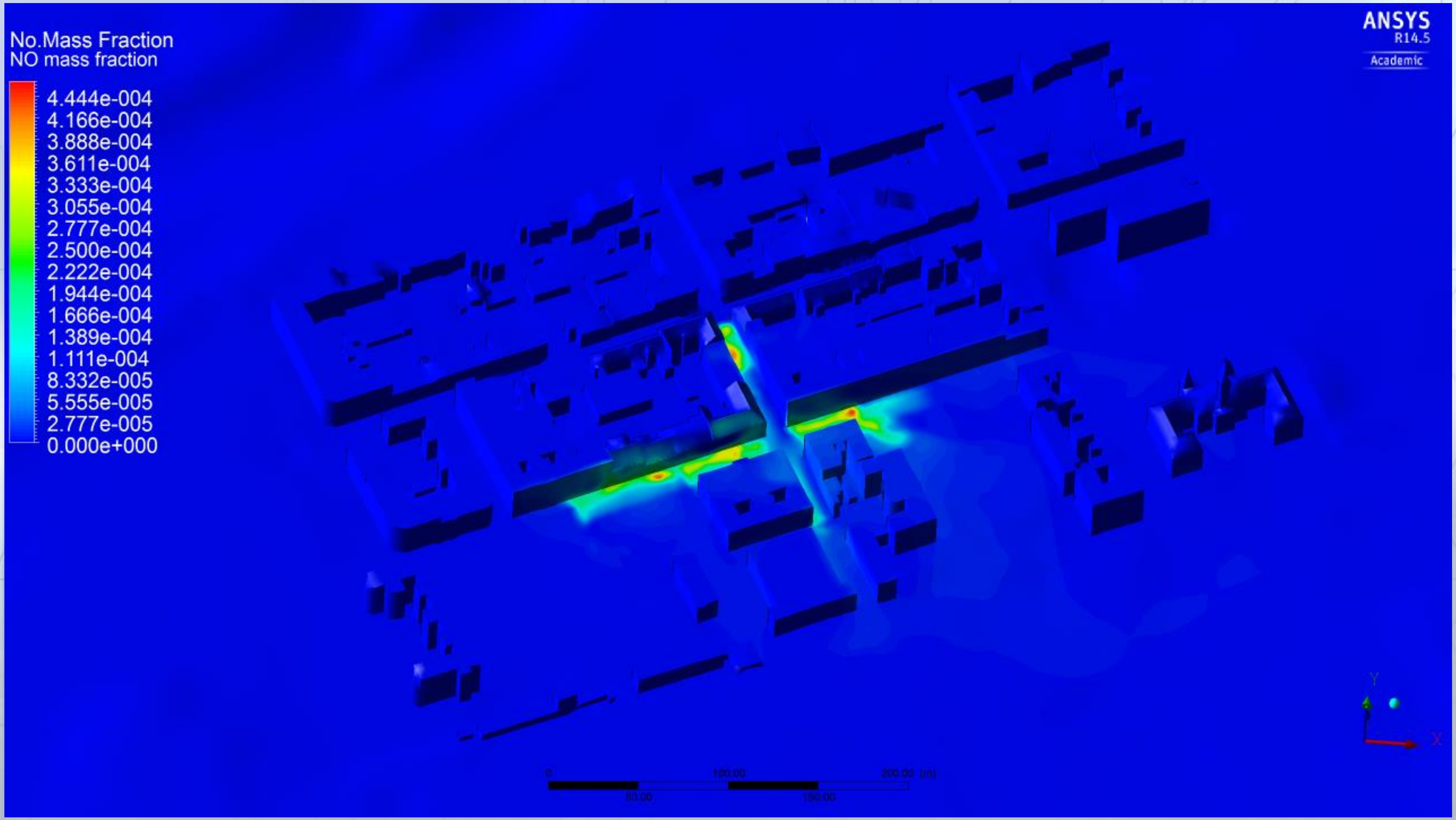
- Double precision transient solver
- k-ε model in the beginning while the flow unstable
- LES model for the stable flow
- Coupled second order implicit transient formulation
- Running time on 16 core was around 8 hour

2.5 NOx dispersion simulation results: effect of the wind

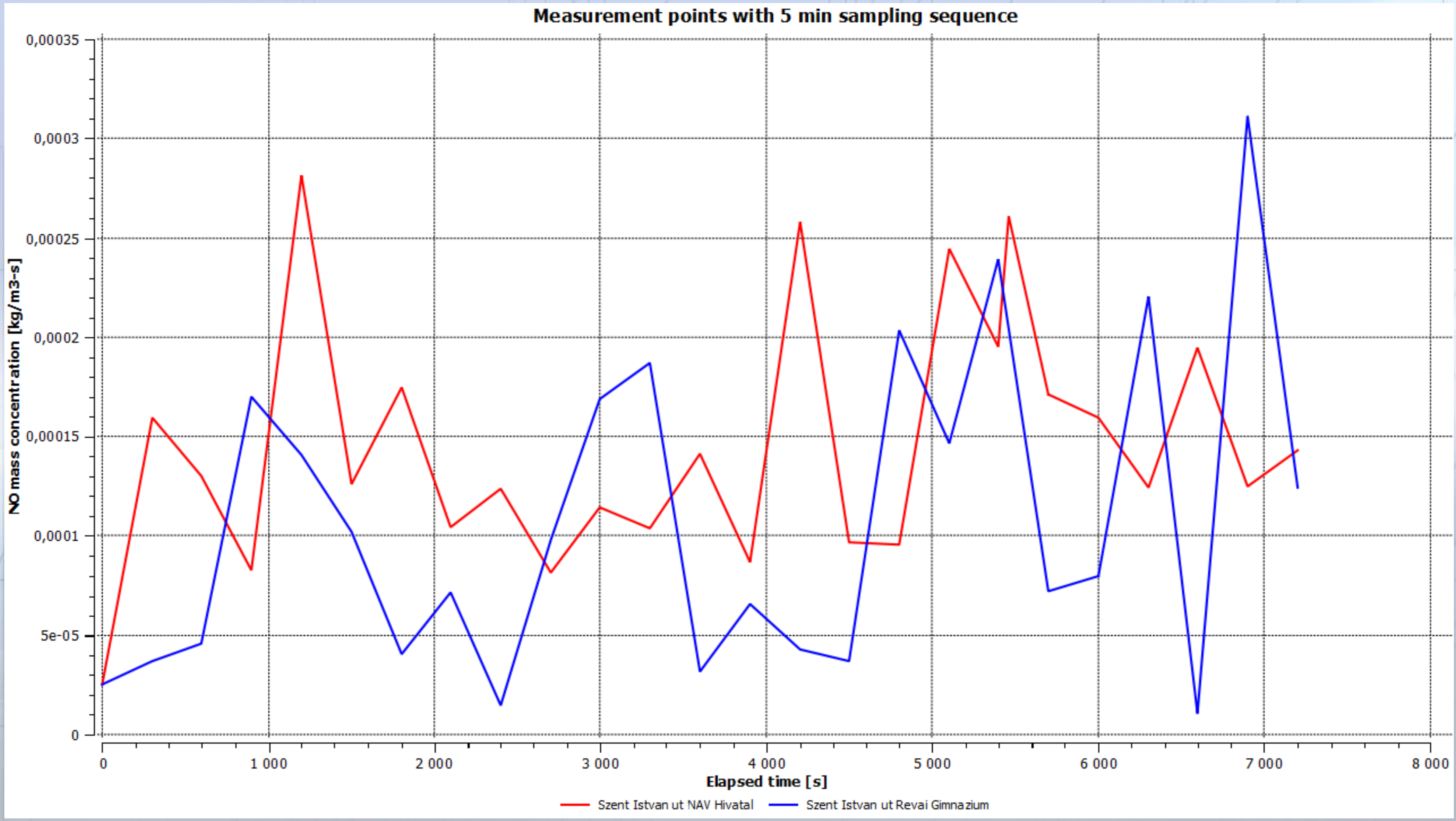




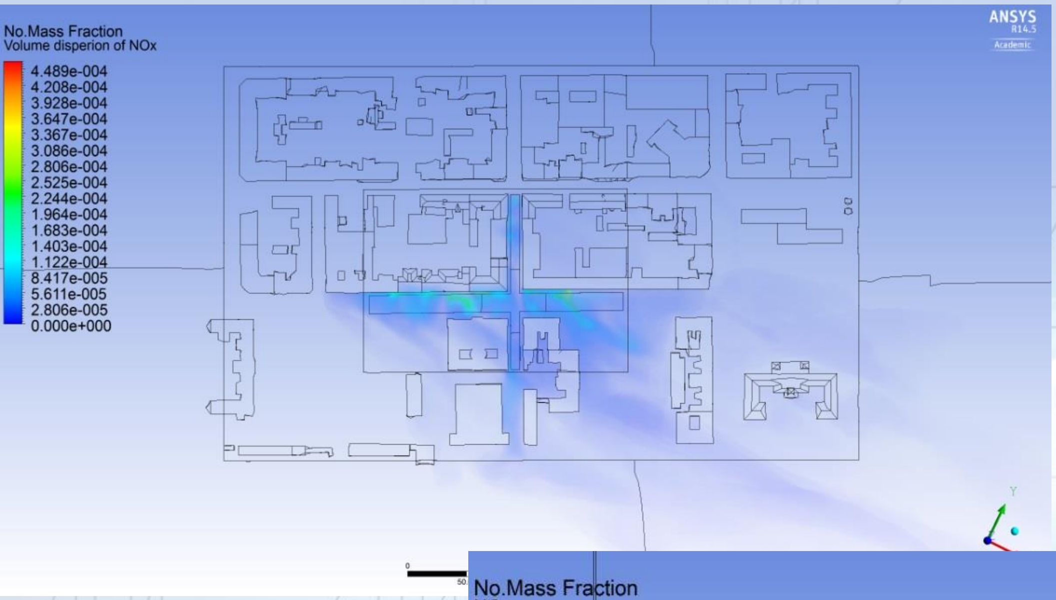
2.5 NOx dispersion simulation: Surface dispersion of NOx

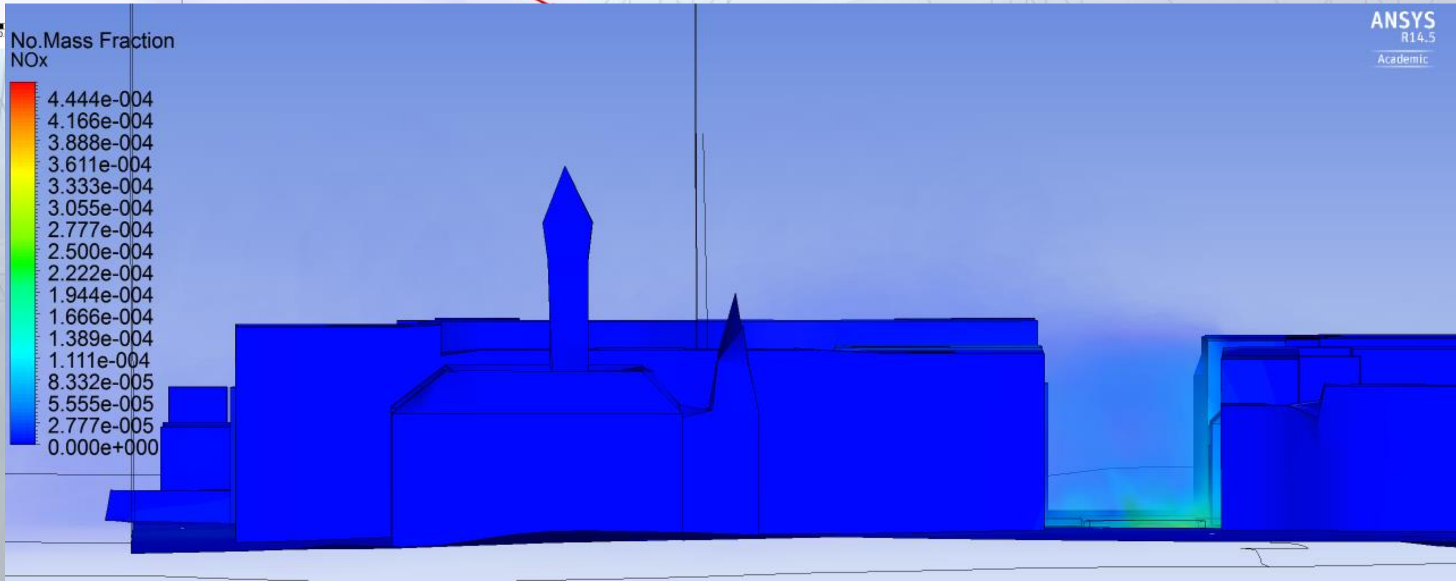


2.5 NOx dispersion simulation results: NOx mass concentration at measure points



2.5 NOx dispersion simulation results: NOx propagation





3. Future tasks

- New NOx measurements and traffic counting
- Traffic flow and emission simulation
  - VISSIM scripting for handling design and control variables
    - traffic volume
    - signal control program
  - Further simulation tool: Pannon Traffic
- Simulation of NOx dispersion on supercomputers with other software tools (Parmod, OpenFOAM)
- Automatization of data processing, optimization and control
- Embedding into IBM IOC (Intelligent Operations Center)
- Challange: Simulation of full Győr
- Implementing new projects – H2020 and more

THANK YOU FOR YOUR ATTENTION!

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HUNGARY'S RENEWAL

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