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Open-Source Framework for Modeling Emission Concentrations in Urban Areas

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Motivation / Background

- Air pollution poses one of the greatest environmental risks to health imposing risks of stroke, heart disease, lung cancer and both chronic and acute respiratory disease, including asthma.
- In 2019, ambient (outdoor) air pollution is estimated to have caused 4.2 million premature deaths worldwide. [1]
- More than 80% of people living in urban areas (that monitor air pollution) are exposed to air quality levels that exceed the air quality guidelines proposed by the world health organization [2].
- In urban areas, motorized traffic is the main source for air pollution.
- Urban areas lack a dense measurement network for assessing the ambient air pollution (e.g. three official air quality measurement stations within the City of Munich, see Figure 1), making it necessary to model (traffic-related) air pollution in urban areas to obtain a precise overview of the spatial extent of traffic-related emission concentrations.

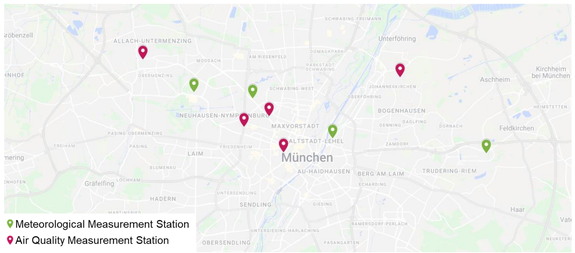

Figure 1: Meteorological & air quality measurement stations within the City of Munich

Advantages of emission concentration modeling:

- Provides information over a larger spatial area than measurement stations (punctual information).
- Enables air pollution hot-spot identification.
- Prediction capability enables support in political decision and policy making.
- Modeling and predicting large-scale (traffic-related) emission concentrations is one of the prerequisites for an adequate environmentally sensitive traffic management.

General Approach

- Modeling emission concentrations in urban areas requires a **toolchain** where each module covers a specific aspect of the physical and chemical properties of the generation and atmospheric dispersion of emissions (see Figure 2).

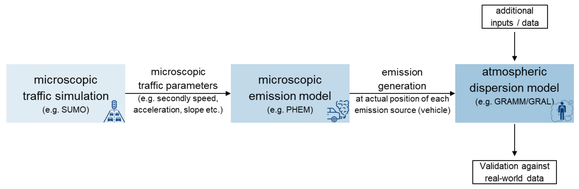

Figure 2: General approach (modeling framework) for traffic-related air pollution modeling

Data necessary for emission concentration modeling:

- Transportation network (incl. traffic light logics, detector locations, etc.).
- Traffic demand (fleet composition representing fuel types and Euro classes, etc.).
- Topological data (building sizes, building heights, etc.).
- Meteorological data (wind direction, wind speed, precipitation, etc.).
- Air quality measurements for model calibration and validation.

SUMO-Enabled Open-Source Framework (see Figure 3)

- SUMO incorporates a simplified version of the instantaneous **vehicle emission model** PHEM ("Passenger Car and Heavy Duty Emission Model") developed and constantly improved since 1999 by TU Graz, so-called **PHEMlight** [3].
- PHEMlight, embedded into SUMO, can be activated by defining an **edge-based emission output** within an additional file [4]:

```
<additional>
  <edgeData id="SUMO-UC_23> type="emissions" freq="3600"
   file="out/edgeData_emissions" />
</additional>
```

Activate edge-based outputs & assign an id

Activate edge-based emission outputs

Define an output path

Define an aggregation period

- SUMO-integrated tools (like plot_net_dump.py) can be used to **visualize the edge-based emission output** generated by SUMO-embedded PHEMlight [5].
- The use of the open-source micro-scale Langragian particle model **GRAL** ("Graz Langragian Model") developed and constantly improved since 1999 enables the **atmospheric dispersion modeling** of the previously modeled traffic-related emission generation [6].

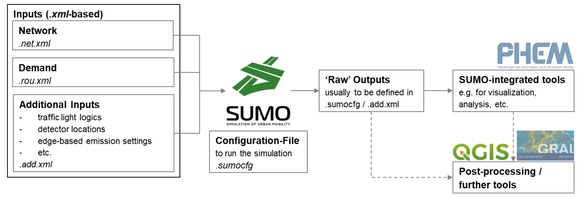

Figure 3: SUMO-enabled workflow for traffic-related air pollution modeling

Results

- Depending on the scope of investigation, the proposed open-source framework enables different visualizations and analyzes:
  1) Emission generation map (see Figure 4)
  2) Emission dispersion map (see Figure 5)

Emission Generation Map:

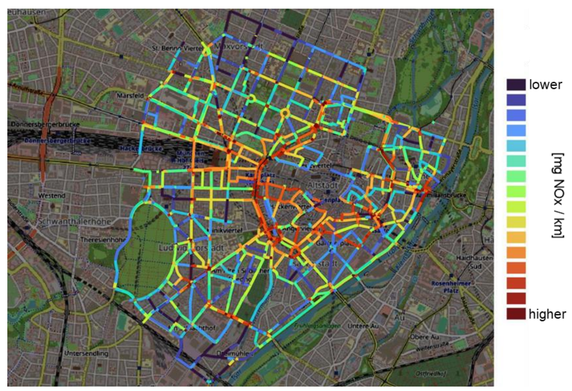

Figure 4: Emission Generation Map (City of Munich) - absolute amount of emissions

Emission Dispersion Map:

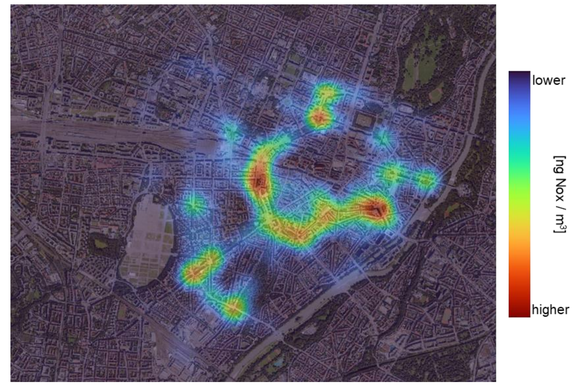

Figure 5: Emission Dispersion Map (City of Munich) - emission concentrations

References

[1] https://www.who.int/news-room/fact-sheets/detail/ambient (outdoor)-air-quality-and-health

[2] https://www.un.org/sustainabledevelopment/blog/2016/05/un health-agency-warns-of-rise-in-urban-air-pollution-with poorest-cities-most-at-risk/

[3] https://sumo.dlr.de/docs/Models/Emissions/PHEMlight.html

[4] https://sumo.dlr.de/docs/Simulation/Output/Lane-_or_Edge based_Emissions_Measures.html

[5] https://sumo.dlr.de/docs/Tools/Visualization.html#plot_net_ dumpy

[6] https://gral.tugraz.at/

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