Development of an Open-Source Framework for Modeling Traffic-Related Emission Concentrations in Urban Areas

Master‘s Thesis of Seyed Mohammadsadegh Saghaeiannejad Esfahani

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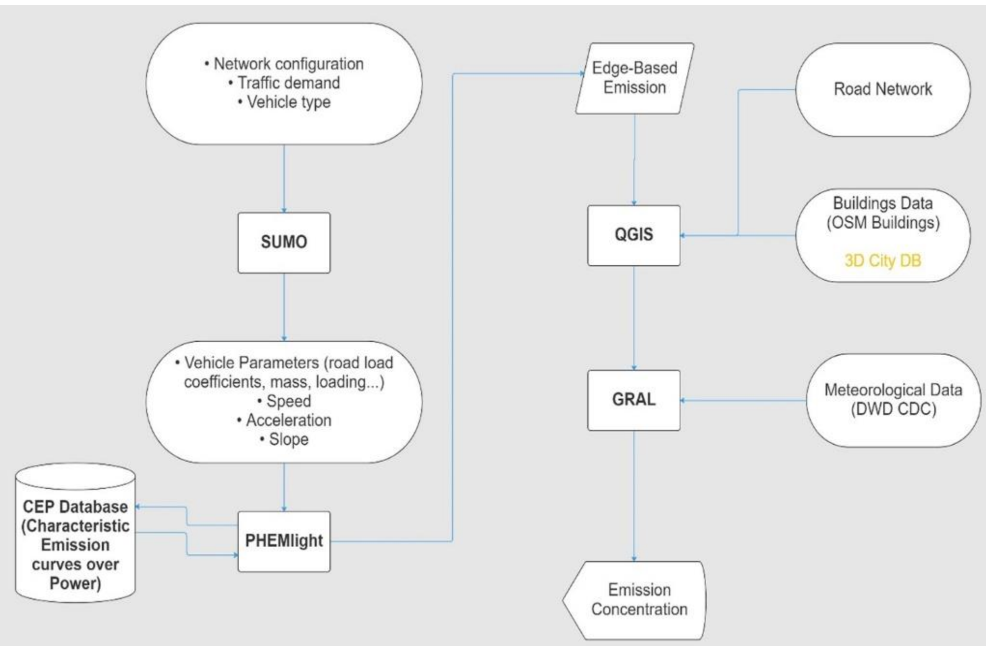

Fig.1 Structure of the developed open-source framework for pollutant concentration estimation.

In traffic engineering, traffic emissions are usually estimated by coupling traffic simulations and emission models, resulting in an absolute amount of emitted greenhouse gases and air pollutants within a given spatial area. Subsequently, this absolute emission quantity can be used as input to dispersion models that estimate the atmospheric concentration of air pollutants from traffic, taking into account various meteorological parameters that affect the formation of atmospheric concentrations of air pollutants. For this purpose, a variety of modeling tool chains containing a traffic simulator, a vehicle emission estimator, and a dispersion model have been already developed and validated. Among these frameworks, microscopic simulations typically offer high-resolution estimation; however, these models are computationally and economically expensive to make their application to local scale scenarios. Consequently, this research successfully presented an open-source microscopic modeling chain tool for the high-resolution estimation of pollutant concentration within urban areas. Furthermore, the functionality of the proposed framework has been validated through its implementation in an urban district of Munich city for simulation of NOx concentration at the pedestrian level during the morning peak hour.

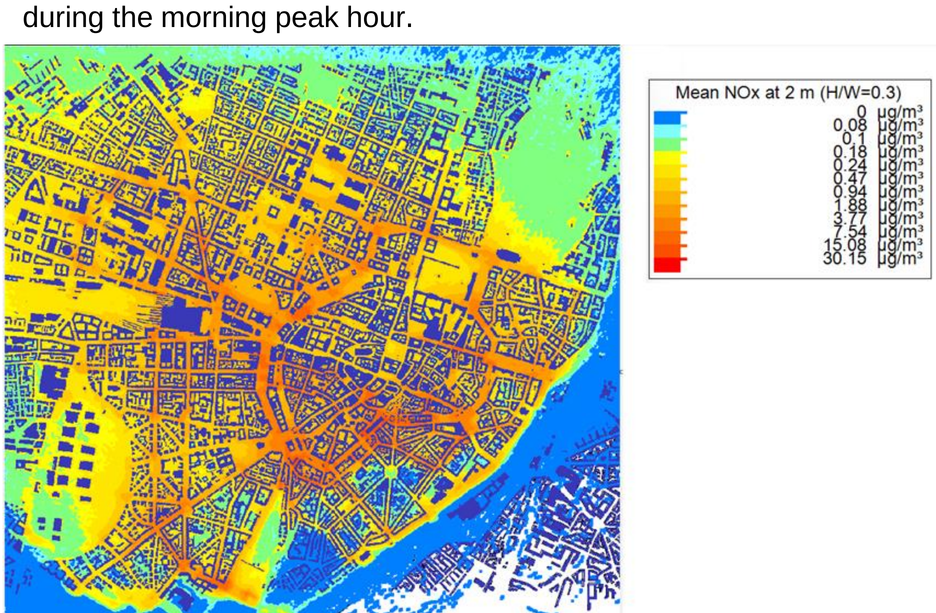

Fig.2 NOx concentration at two meters above ground (µg/m3).

In addition, by assessing the performance of the PHEMlight emission model, as the most essential factor in an accurate emission concentration estimation, under different vehicle dynamics and road conditions, the sensitivity of the emission model to microscopic parameters has been evaluated. Using this analysis, users are enabled to comprehend model dynamics and establish the degree of precision required for both efficient and valid framework parameters. It has been observed, while the model was not able to replicate the impact of aerodynamic parameters on the generated emission rates, it could reasonably consider different affecting factors such as vehicle speed, acceleration, and road inclination on vehicle exhaust emission. Considering acceleration parameters, it has been observed in gasoline cars for the increasing trend in acceleration rates, PHEMlight might logically estimate PMx emission rates until 8.5 m⁄s^2, whereas other emissions can be modeled tangibly even at 9.5 m⁄s^2. Generally, as acceleration increased, the amount of increase in emission rates became smaller for each 1 m⁄s^2 increase in acceleration. Also, the percentage of emission increase was considerably higher at increases in lower acceleration ranges.

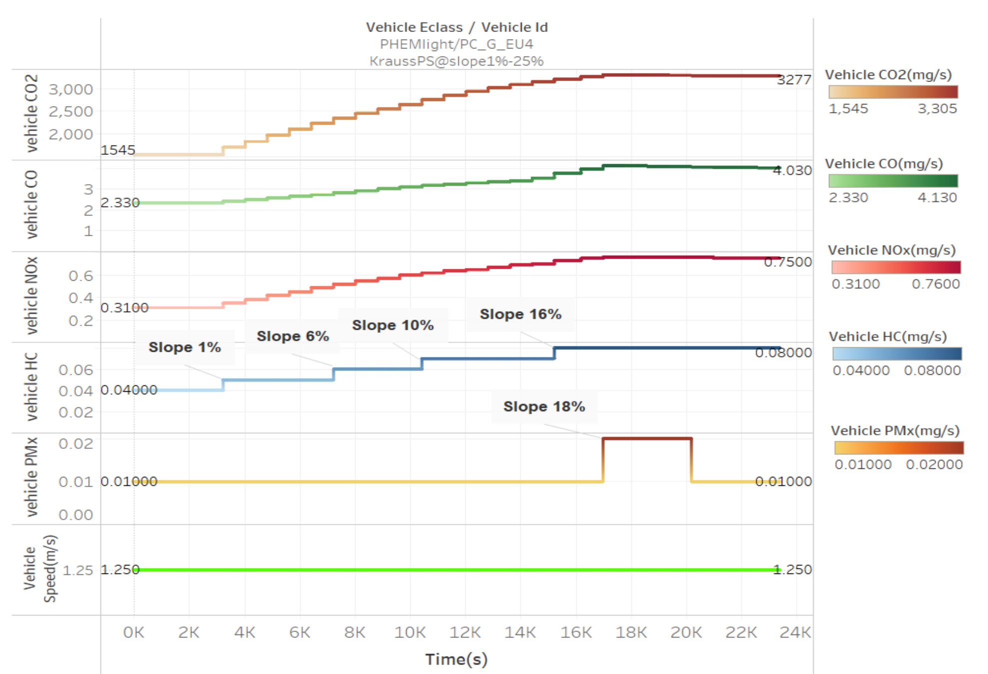

Fig. 3 Impact of road gradient on Euro 4 gasoline vehicle’s emission rates.

Considering the impact of speed and acceleration on the generated emission rates, in gasoline cars as the acceleration increased (until 4.5 m⁄s^2) the speed, at which maximum emission rates of most pollutants had been observed, failed from 24 m/s to 13.5 m/s. For PMx maximum emission was observed at speed of around 60 m/s. Likewise, in diesel passenger cars this speed rate decreased from 31 m/s to 9m/s. For CO, the maximum emission rate was mainly detected at speed of around 67 m/s. Regarding roadway gradient and its impact on gasoline engine emission rates, the most obvious observation refers to PMx, where this emission was only sensitive to an increase in road slope from 17% to 18% inclination. Furthermore, generally, NOx estimated values seem to be more sensitive among other emissions to the road gradient, whereas HC rates showed to be sensitive only at 1%, 6%, 10%, and 16% road gradient. In diesel vehicles, the sensitivity of CO rates to road slope was almost dominant until 4% road slope. Moreover, from 5% to 8% road gradient NOx rate was shown to be more affected by the change in road slope. Additionally, above the 11% gradient, the increase in road slope did not affect HC emission rates.