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CITYNEXUS

A Digital Twin Application Linking Mobility and Air Quality for Sustainability Transition

The Challenge: transforming Amager Vest

- The **City of Copenhagen** and the **Local Council of Amager Vest (LCAV)** aim to reduce traffic congestion and promote urban quality of life.
- A key proposal involves **transforming high-speed roads in Ørestad** (Amager Vest), a diverse area near the city center with about 25,000 residents, **to reduce traffic, improve air quality, and enhance living spaces.**
- Inspire other districts and municipalities to match mobility and economic needs with climate action and environmental health.

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CITYNEXUS: Aims and Scope

- DestinE Digital Twin Use-case for **sustainable urban interventions**;
- Interactive system for generating **policy-relevant user-defined '*what-if*' scenario** simulations
- Possibility to assess the impact **of decisions relating to traffic, infrastructure, land use** and **population on mobility** and **air quality**
- Collaborative platform to **experiment strategies** and **test solutions** to facilitate **evidence-based decision-making** at municipality level

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'What if' scenario capabilities

- **Road tunnelling:** simulate the tunnelling of any existing road segment
- **Change Points of Interest (POIs) and Population**: adding new POIs and increasing population.
- **E-vehicle and active mobility:** customize the proportion of e-vehicles, bicycles and pedestrians.
- **Low Emission Zones (LEZ) Creation:** identify roads where motorized circulation is prohibited to vehicles.
- **Adjusting Speed Limits: change speed limits of specific road segments.**
- **Traffic Fleet Composition:** Alter the proportion different vehicle types (electric vehicles, bicycles, cars)

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Scenario simulation parameters

Pollutants selection

Up to 5 different pollutants (CO_2, CO, HC, NO_2, PMx)

Time-window selection

Up to 8 selectable time-windows, each representing a 3-hour block

Day-type selection

Option to choose between a weekday or weekend.

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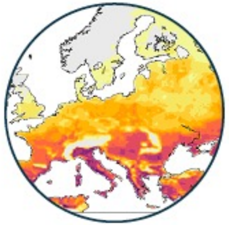
Key input datasets

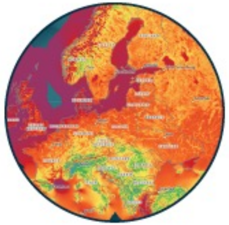
High Frequency Location Based mobility data

Sentinel-5P TROPOMI L2
(NO2, SO2, CO, O3 and clouds)



ECMWF ERA5 hourly estimates

CORINE Land Cover
at 100m resolution



Global Wind Atlas

Google Environmental Insight Explorer

EEA Airbase
ground monitoring stations

OpenStreetMap

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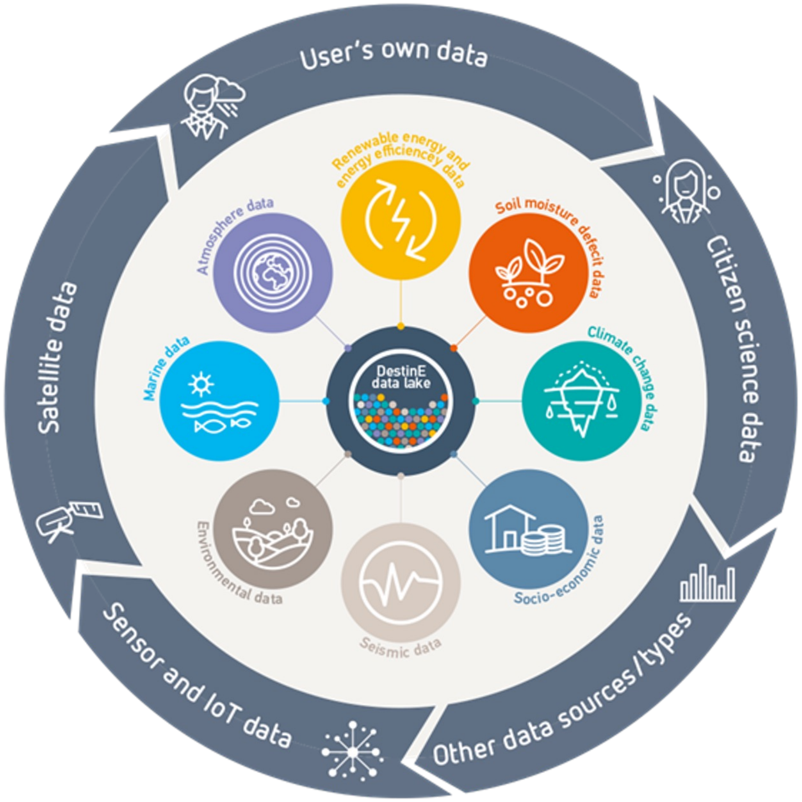
Input Data from DestinE Data Portfolio



- **Sentinel-5P TROPOMI Level2** daily tropospheric NO2, SO2, CO, O3 vertical column densities;
- **Copernicus Digital Elevation Model** of Europe at 10m resolution;
- **ECMWF ERA5 hourly estimates** for different meteorological variables;
- **CORINE Land Cover** from the Copernicus Land Monitoring Service at 100m.

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HFLB Mobility data

CityNexus relies on **High-Frequency Location Based (HFLB)** mobility data, that is data precisely tracking the location of GPS-enabled logging devices over time.

This is used to provide **key insights** into commuting patterns, traffic flows, congestion rates and overall mobility dynamics

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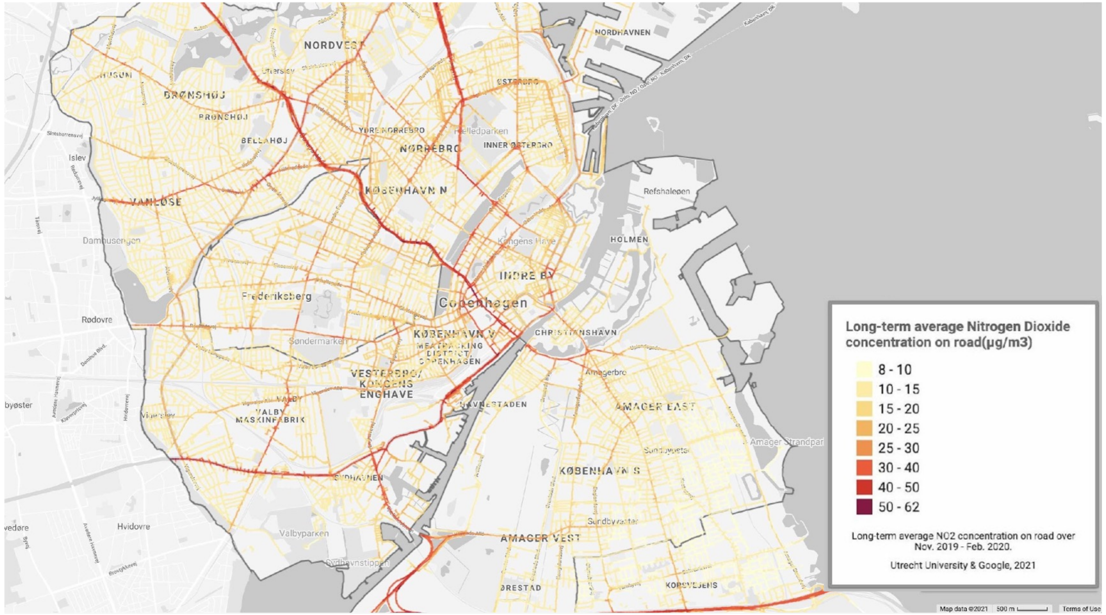
GEIE - Air Quality Labs data

Data gathered from mobile mapping campaigns (Google Environmental Insight Explorer - Air Quality Labs data).



Environmental Insights Explorer

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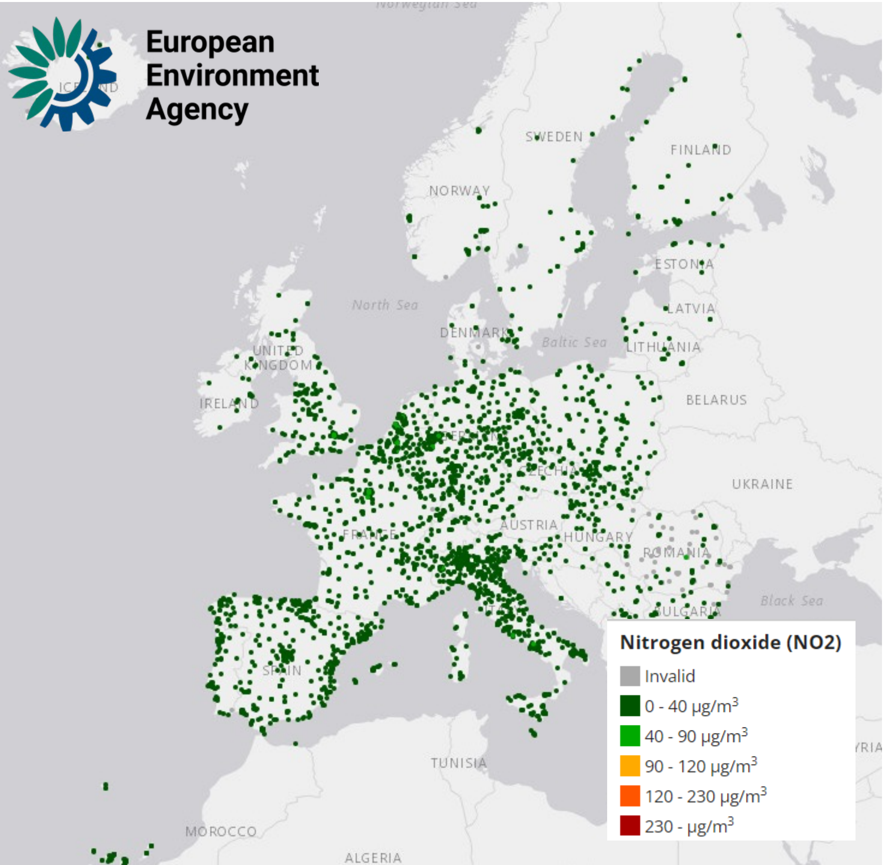
EEA AirBase Air Quality data



- **AirBase multi-annual time series** of air quality measurement data different **air pollutants (NO2)**
- To overcome the limtied number of air quality stations in **Denmark** (12-15 stations), **Germany** (>300 stations) and **Poland** (120-150 stations) were also included.

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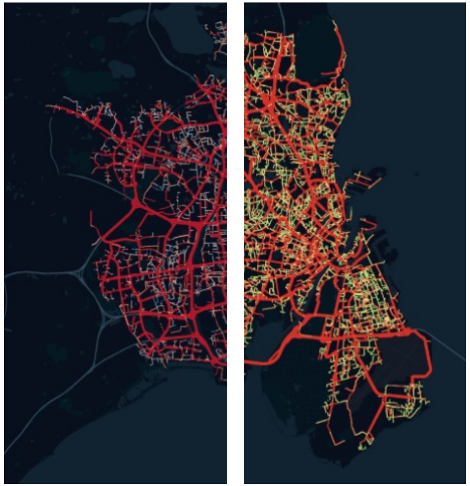
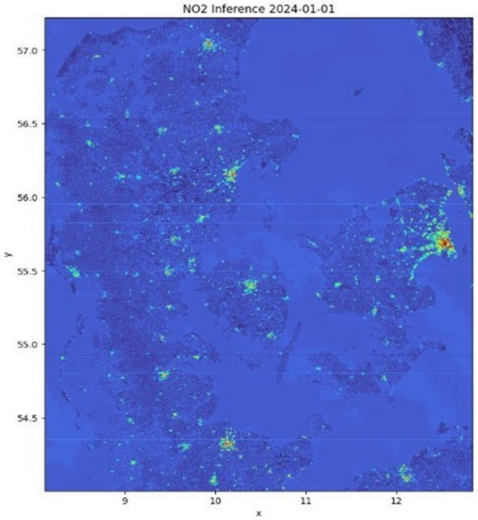
CityNexus Models





Local Mobility & Pollutant Concentration Model

To account for pollutants primarily generated by vehicular traffic

Regional Air Quality Model

To account for pollutants generated as result of all human activities

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Local Mobility & Pollutant Concentration Model

Mobility Data Cleaning and Filtering	Remove low-accuracy entries and identifying “stops”
Street Network & Spatial Features	Pre-process OSM network, link H3 cells with land use and POI data
Origin-Destination Matrix	Map O/D pairs into H3 cells, compute in/out flows.
Detection of Transport Modes	Identify trips by pedestrian, cyclist, vehicle based on mean speed and standard deviation
Deep Gravity Model	Models mobility patterns from O/D matrices and predicts changes under different simulation conditions.
Traffic & Emissions Simulation	Simulates traffic flows and emission estimates by vehicle type.
Pollutant Concentration Model	A regression model combines Google EIE data with emissions to estimate pollutant concentrations.

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Local Mobility & Pollutant Concentration Model: Key steps

Road occupancy

NO2 concentration

congestion

- 3.00 to 18.00
- 18.00 to 41.00
- 41.00 to 86.00
- 86.00 to 190.00
- 190.00 to 531.00
- 531.00 to 4501.00

model_no2

- 4.58 to 9.88
- 9.88 to 10.41
- 10.41 to 11.12
- 11.12 to 11.76
- 11.76 to 12.49
- 12.49 to 13.33
- 13.33 to 14.56
- 14.56 to 16.53
- 16.53 to 20.62
- 20.62 to 68.60

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Regional Air Quality Model (NO2)

- Gradient boosting methodology to generate 100m-resolution maps of near-surface NO2 concentration;
- Spatial covariates (i.e. DEM, land use data, population density, road density, traffic volume, industrial emissions...) employed as independent variables;
- NO2 measurements from in-situ stations employed as dependent variables.

Training:
using data from air quality stations Germany and Poland to exploit climatic similarities.

Validation
using in-situ air quality measurements and AirBase data from Denmark.

Fine-Tuning
iterative refinement and additional training to improve model accuracy.

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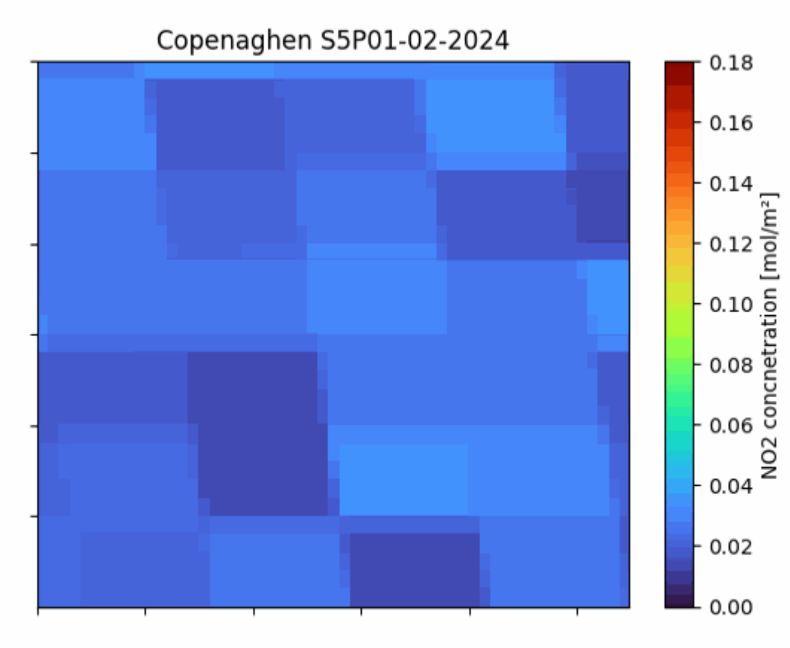
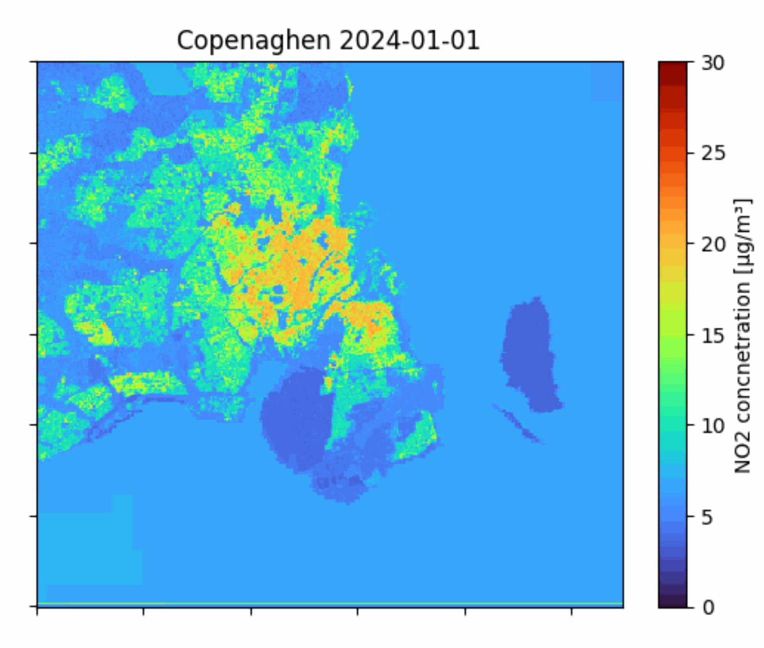
Regional Air Quality Model





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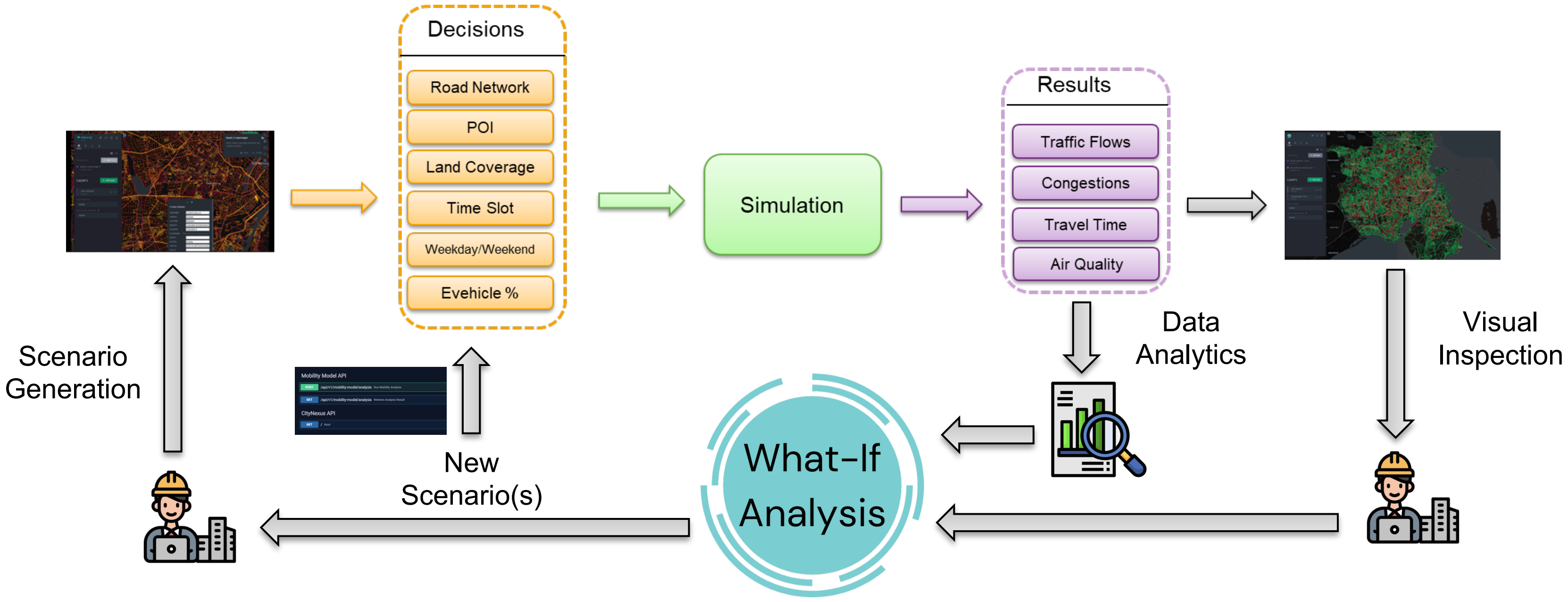
User Workflow



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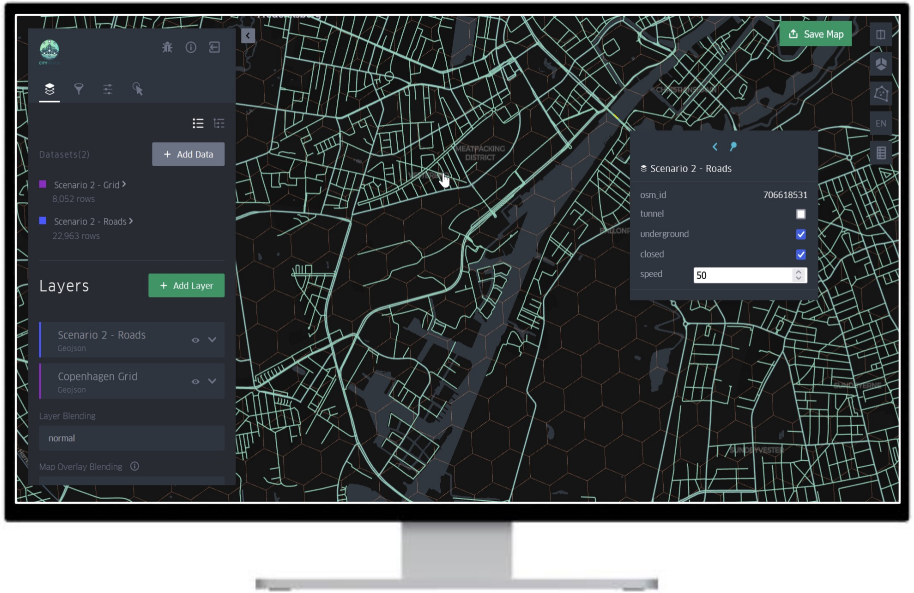
User Interface



- Interactive user interface build on Kepler.gl and OPENAPI
- Visualise a scenario, make modifications, start a simulation and explore results

kepler.gl OPENAPI

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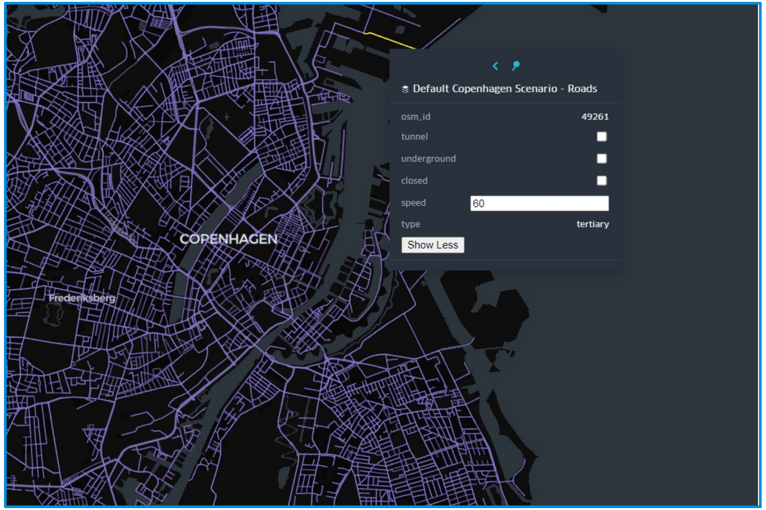
User Interface

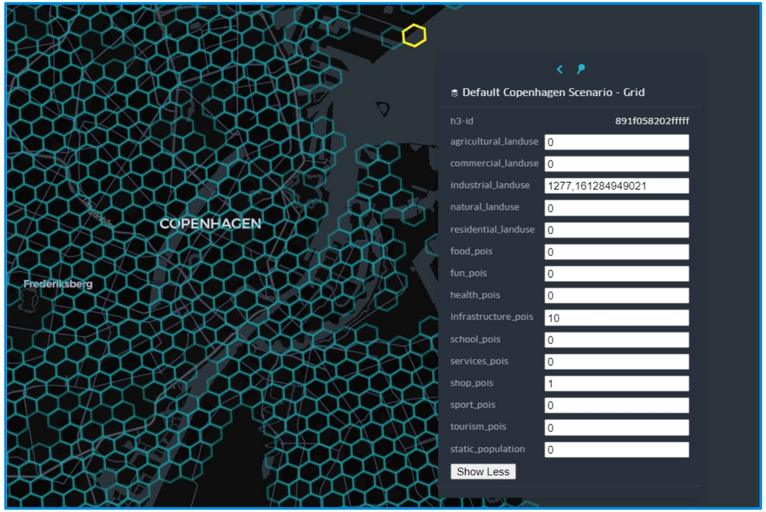
Road Segment Properties

Road Segment Conversion
Average Speed Adjustment
Road Segment Accessibility



Map Zone Properties

Land use classes change
Points of Interest management
Population dynamics adjustment



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Explainable AI

XAI for ***validation and increased trustworthiness*** for operational deployment	"*validating the system*" mostly on algorithm transparency and global interpretability, to understand how a model was generated and how the system makes predictions.
XAI as support for decision-making and ***intelligent assistance***	"*improving the system*" global interpretability, to justify the decisional process, local interpretability, to provide explanations on specific suggestions generated
XAI for ***root cause analysis*** and explanation	"*learning from the system*" global interpretability, to understand how causes/anomalies are found, local interpretability, to provide explanation on specific findings

Thank You

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Local Mobility & Pollutant Concentration Model

SUMO (Simulation of Urban MObility):

- Open source, highly traffic simulation package developed by the Institute of Transportation Systems at DLR.
- Designed for microscopic and continuous traffic modeling in large networks.
- Supports intermodal simulation, including pedestrians, with a comprehensive toolkit for scenario creation.
- Facilitates detailed analysis of traffic flows, including vehicular and pedestrian traffic in complex urban environments.

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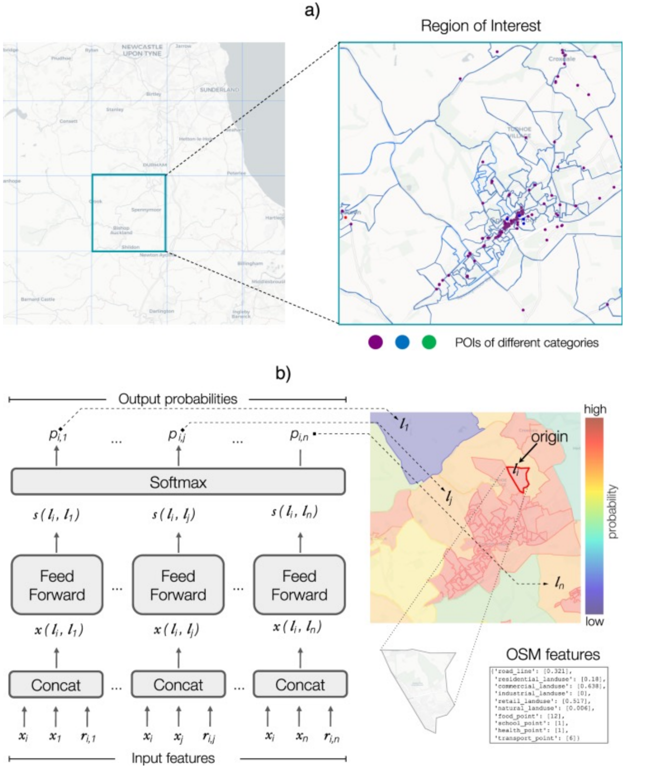
Local Mobility & Pollutant Concentration Model

Deep Gravity Model:

- Utilizes deep neural networks to predict mobility flows within a city or region;
- Generates new scenarios based on different parameters;
- Integrates mobility-related variables such as POIs, road infrastructure, population, and land use;
- Able to transfer knowledge to metropolitan areas not previously analysed;
- Offers more accurate predictions than traditional gravity models, especially in areas with scarce data;
- Helps to better understand the motivations behind movements



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