



# Simulating Traffic Networks

Driving SUMO towards digital twins

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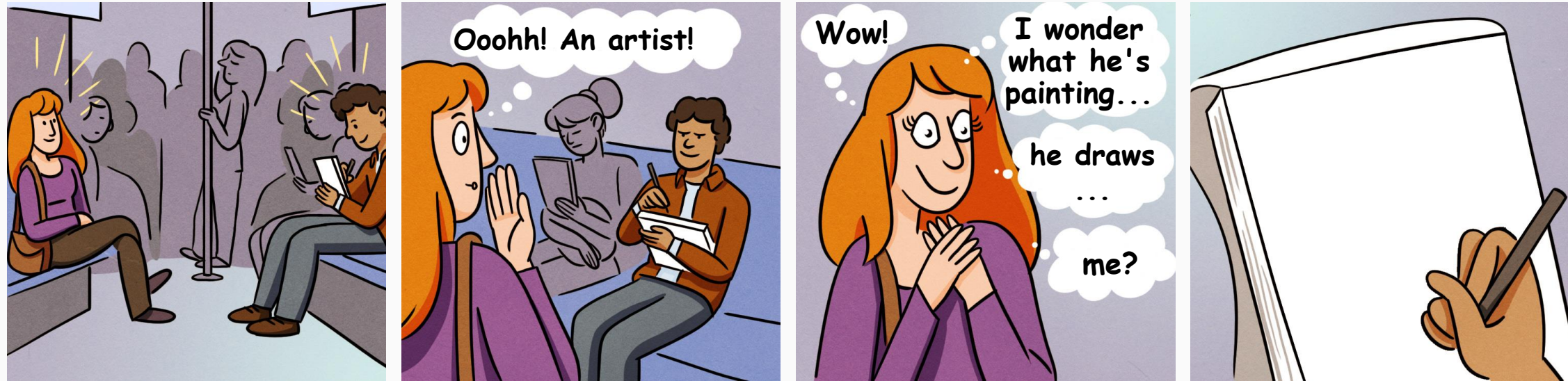
Hochschule Osnabrück – Fakultät Ingenieurwiss. und Informatik

# Completely without personal reference

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The modern way of drawing

# The modern way of drawing - Prompt Engineers: The new artists?



# The modern way of drawing - Prompt Engineers: The new artists?



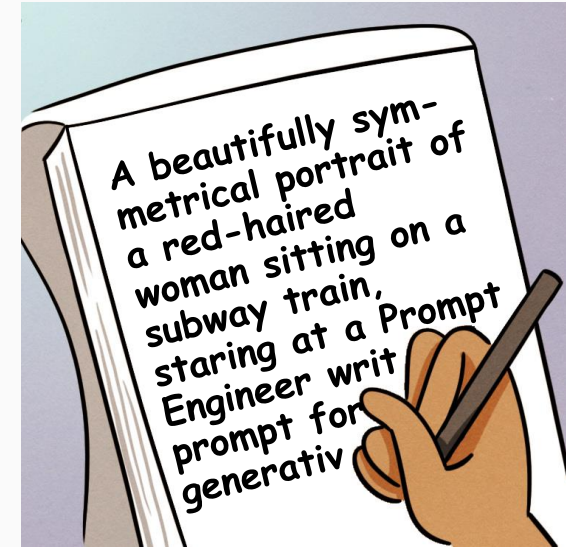
two  
years  
ago



# The modern way of drawing - Prompt Engineers: The new artists?



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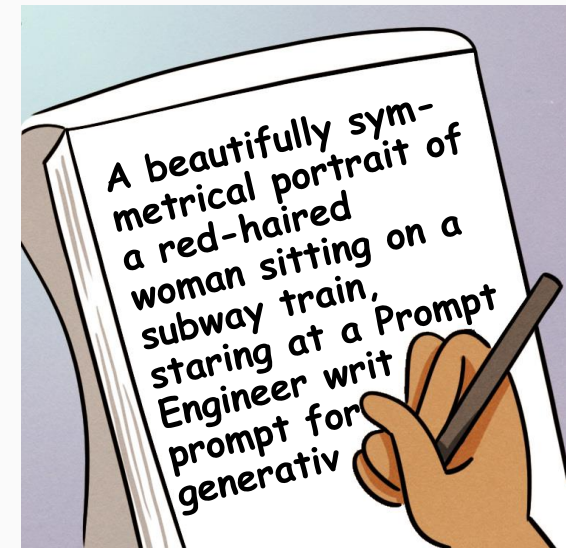
today



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two  
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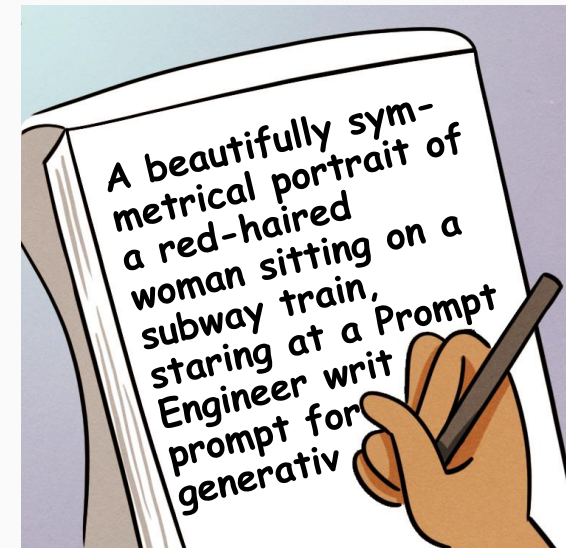


today

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with personal reference



without personal reference



# Intelligent Intermodal Commuter Traffic

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The research project and its aim

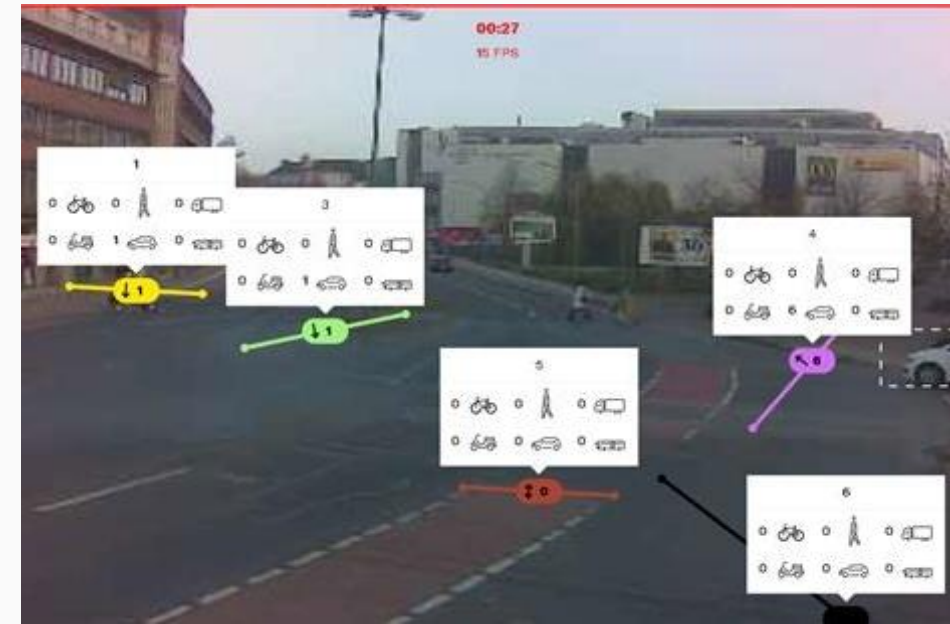
# Intelligent Intermodal Commuter Traffic

Motivation: Increase in individual and commuter traffic in

- Osnabrück (pop. 165,000 / 128,700 commuters)
- Münster (pop. 317,700 / 219,400 commuters)

Solution approach:

- Merging official and publicly available traffic data with sensor technology, crowdsourcing and citizen participation
- Protection of privacy through anonymized data collection
- Development and testing of business models oriented towards the common good with a focus on the intelligent use of different means of transport
- Cooperation partners: SWO Netz GmbH, Stadt Osnabrück, Hochschule Osnabrück, Universität Münster, items GmbH & Co. KG, iotec GmbH, Lambus GmbH, cybob communication GmbH



# Simulating Traffic Networks

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## Data of a crossing



# Data of a crossing

## Environmental sensors:

- temperature
- precipitation
- wind
- pollutant concentrations

## Intersection:

- # right turners
- # left turners
- # trucks / min
- # cars / min

## Pedestrian lights:

- # pedestrians

## Bus:

- # passengers
- delay in min
- position
- route

## Parking lots:

- occupancy status
- type

## Bike lane:

- # bicycles
- direction
- lane quality

## Bus Stop:

- # passengers
- delays in min
- position
- routes

Source: City of Osnabrück







# Data of a crossing



Source: City of Osnabrück



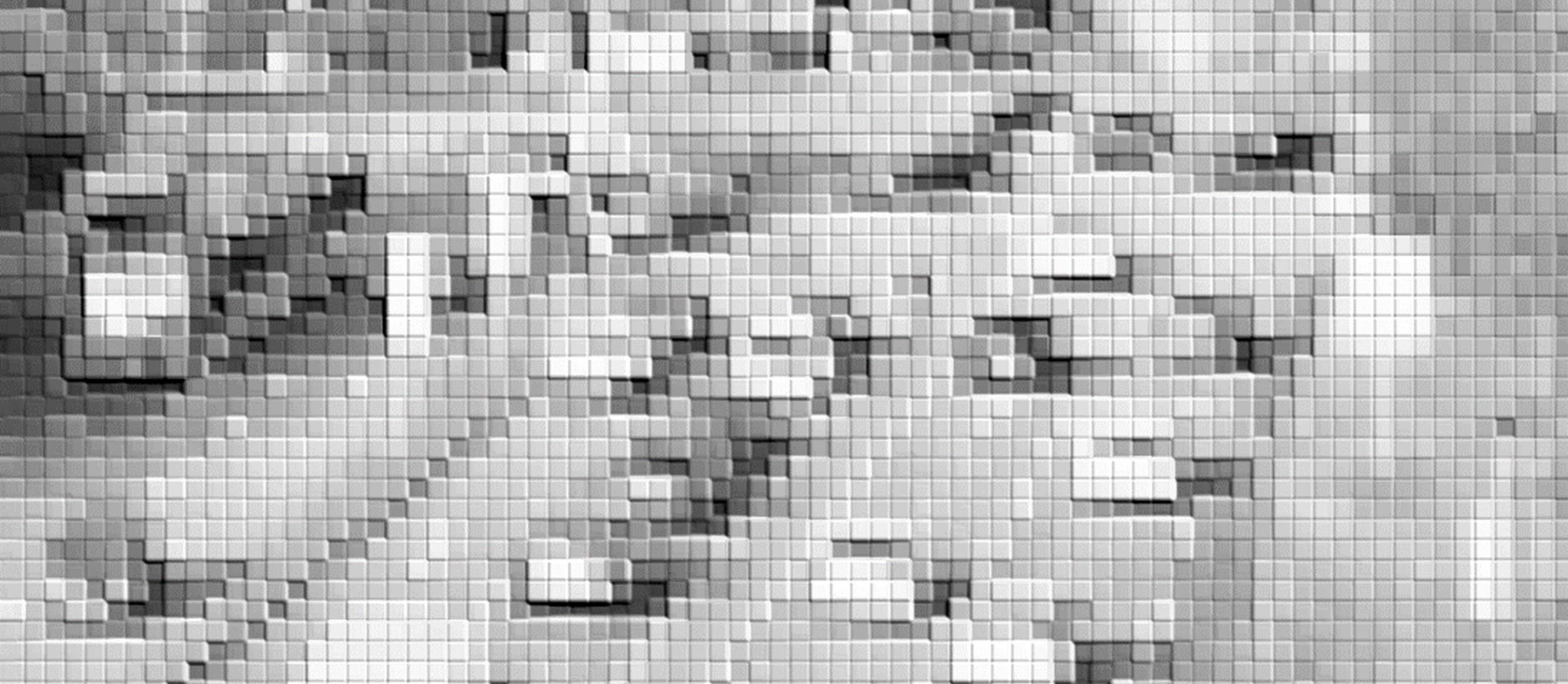
# Data of a crossing



Source: City of Osnabrück



# Data of a crossing



Source: City of Osnabrück

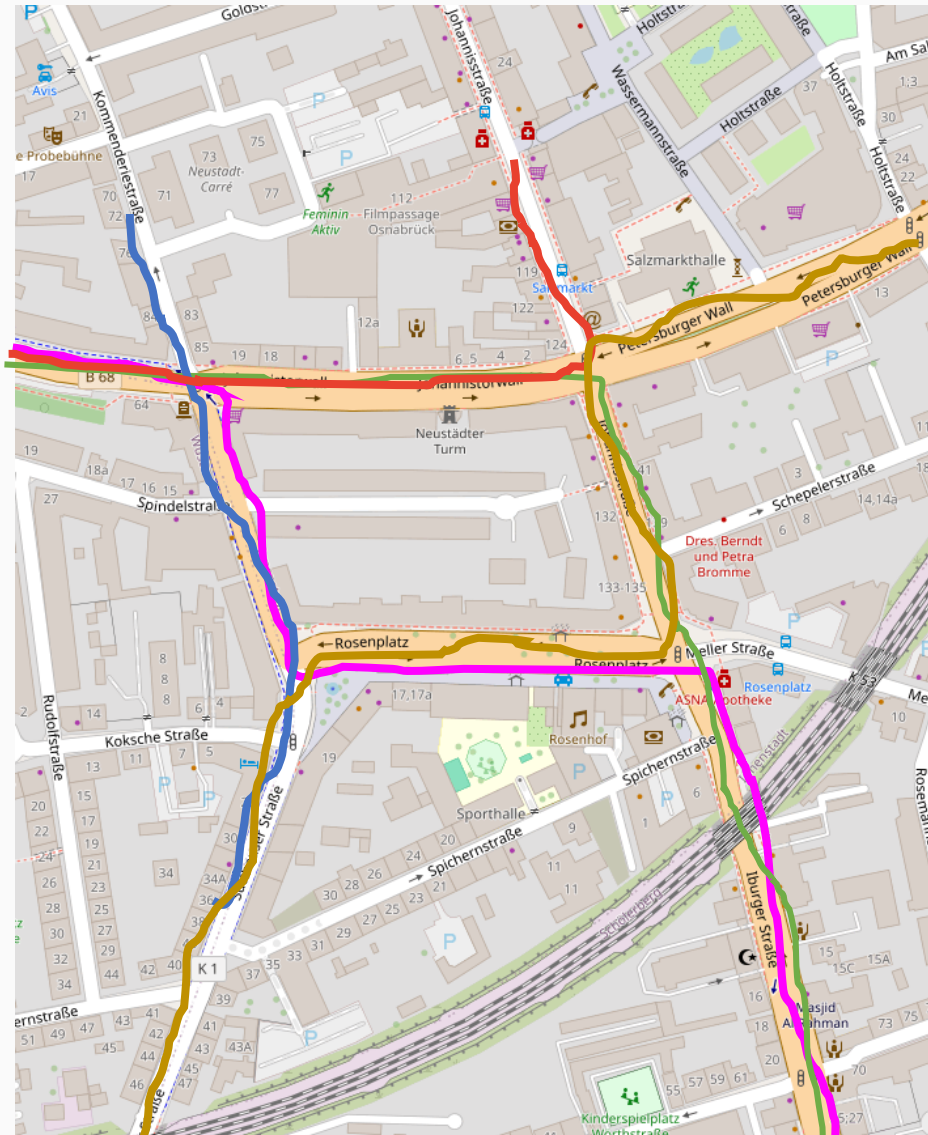
# Simulating Traffic Networks

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## Sensor-based traffic simulation



# Motivation: Sensor-based traffic simulation



- improving public transportation
- reduction of environmental pollution
- human-centered urban planning
- traffic flow optimization
- improving the quality of life
- accident prevention
- real-time traffic management
- ...

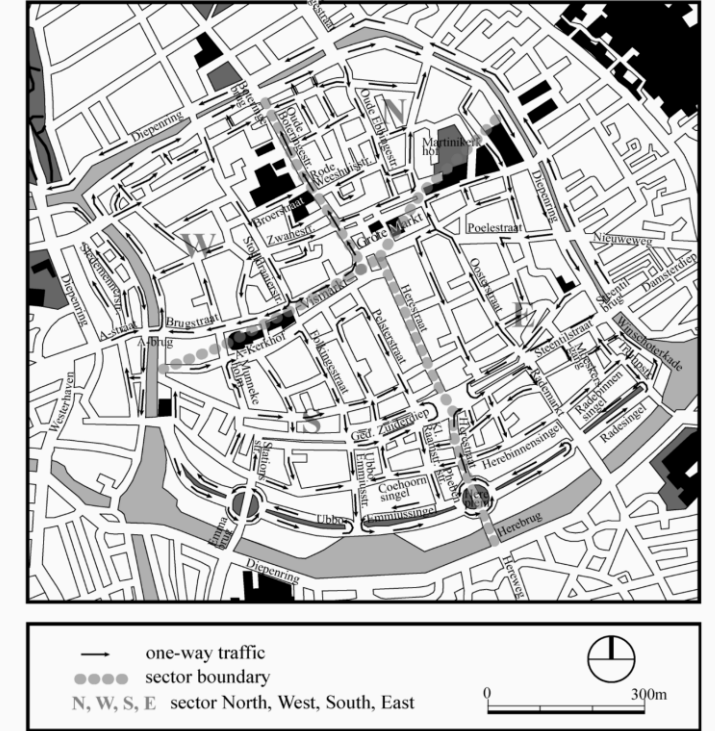
- pedestrian
- cyclist
- bus R42
- truck (40 tons)
- car (3 passengers)
- - ...

# Motivation: Sensor-based traffic simulation



Supermanzana Barcelona

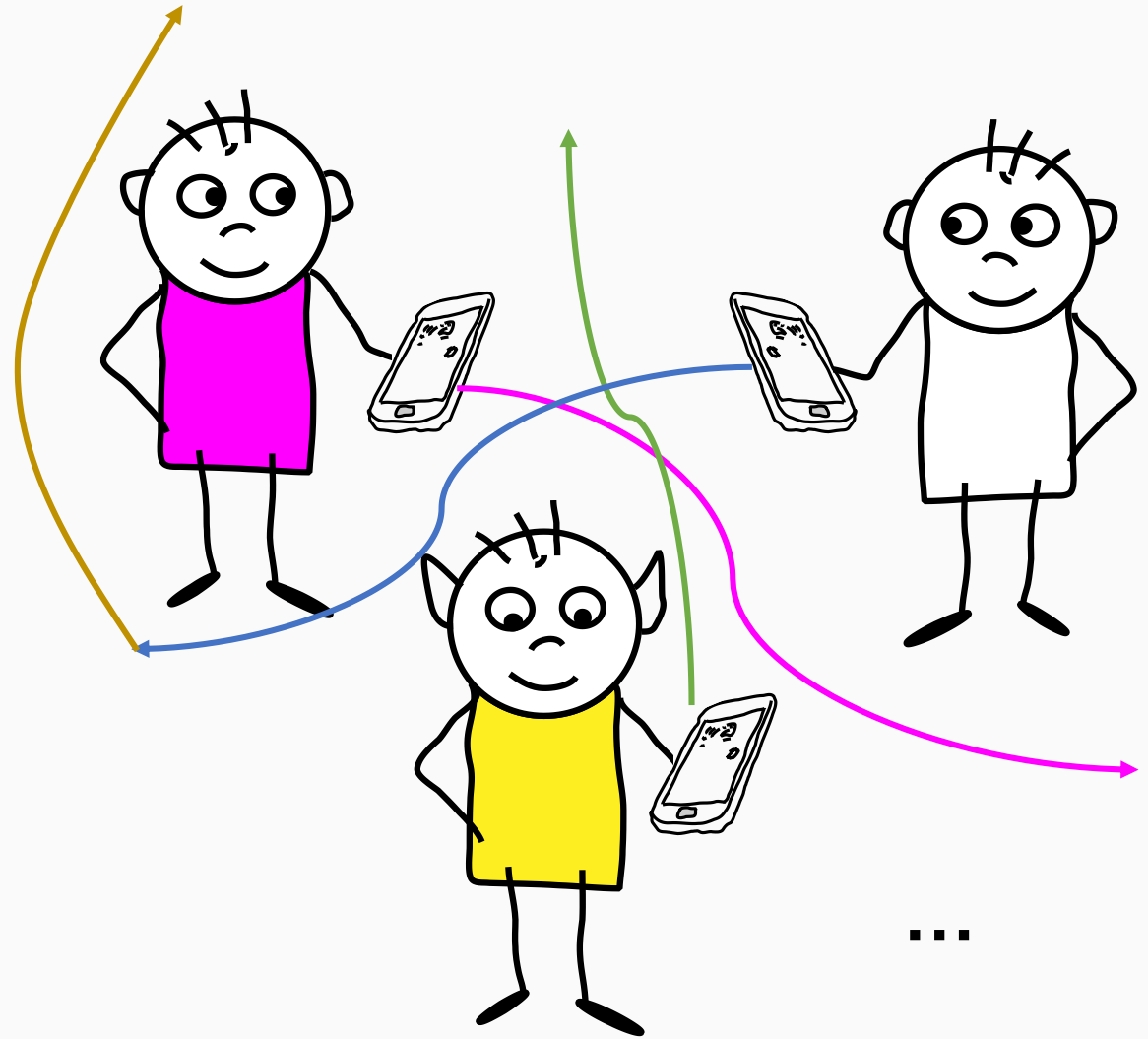
Leezenflow Münster



Traffic Circulation Plan Groningen

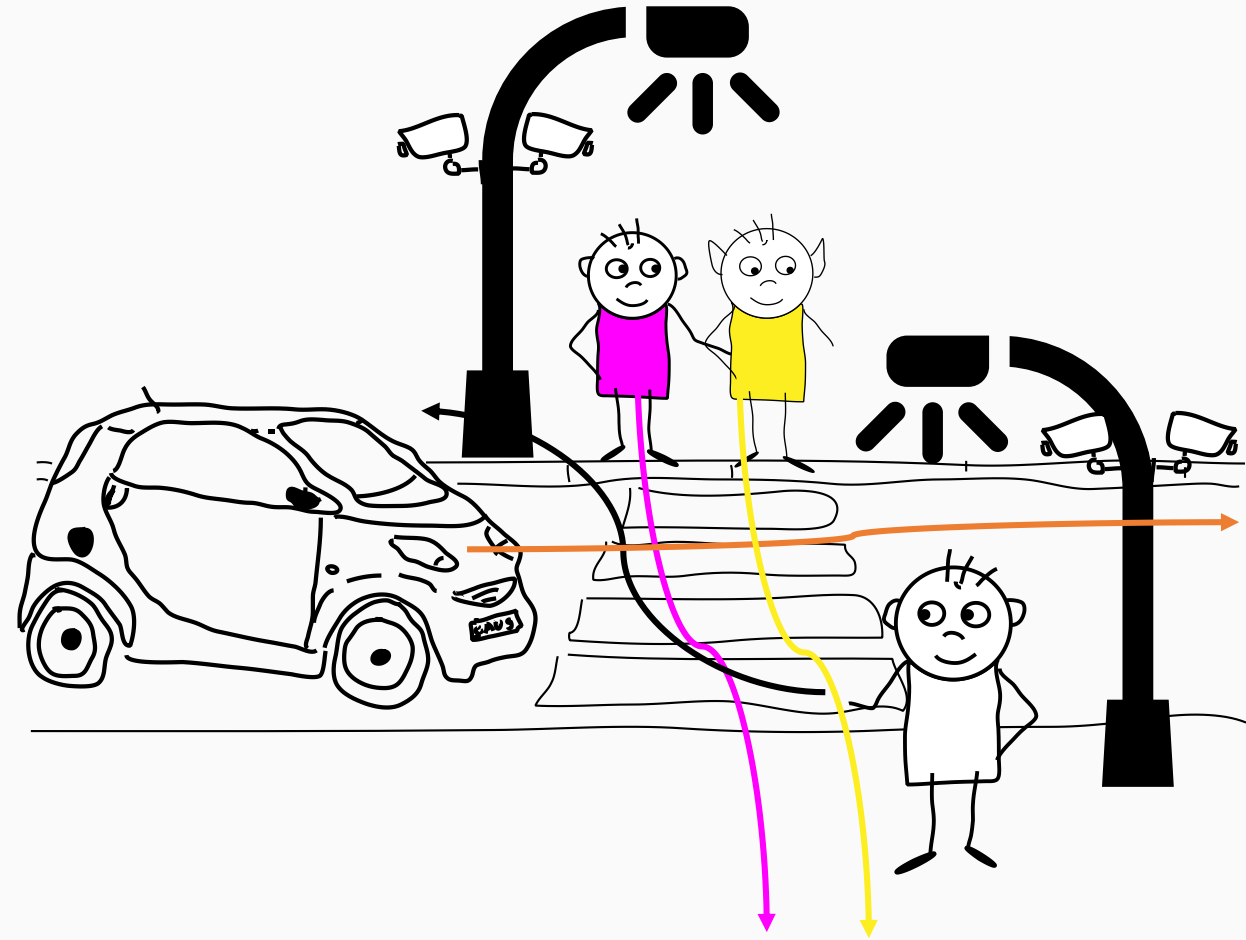
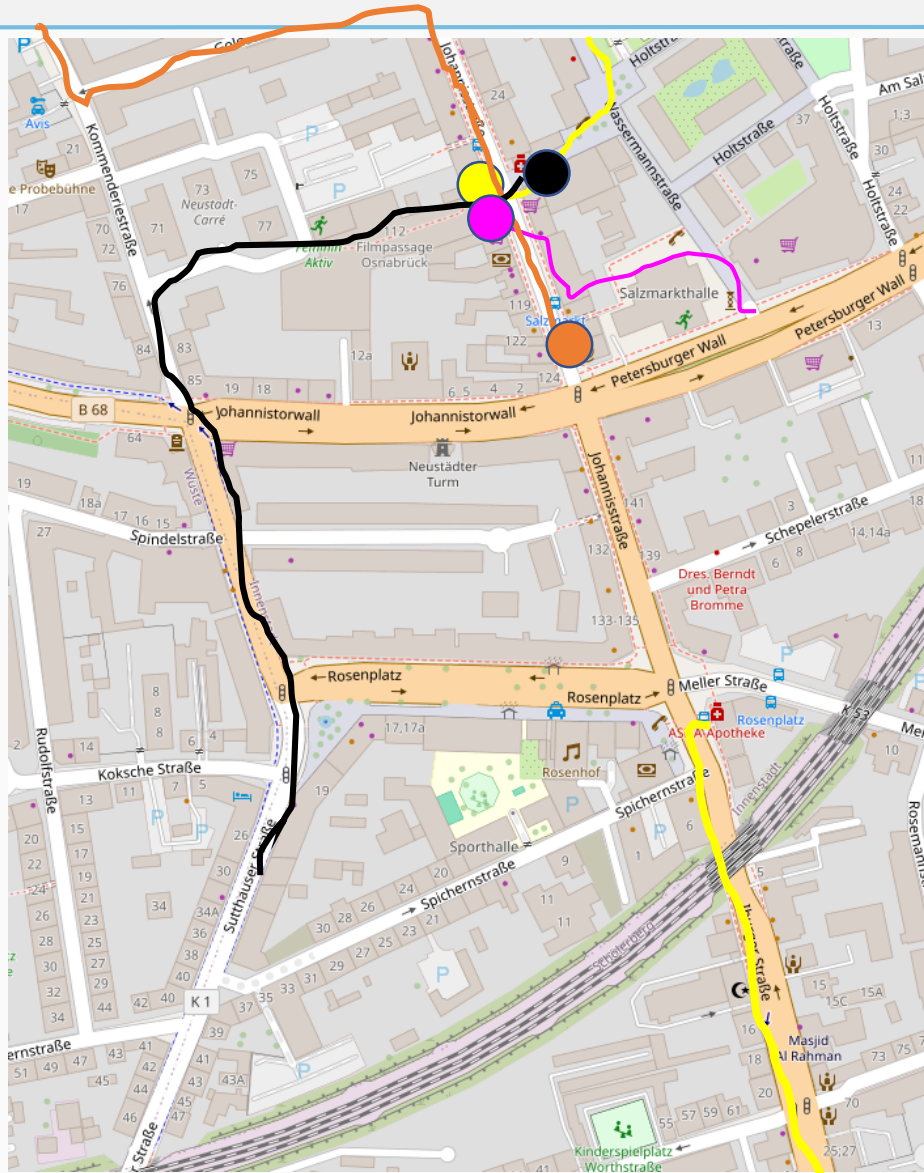


# Solutions: Sensor-based traffic simulation - GPS tracker

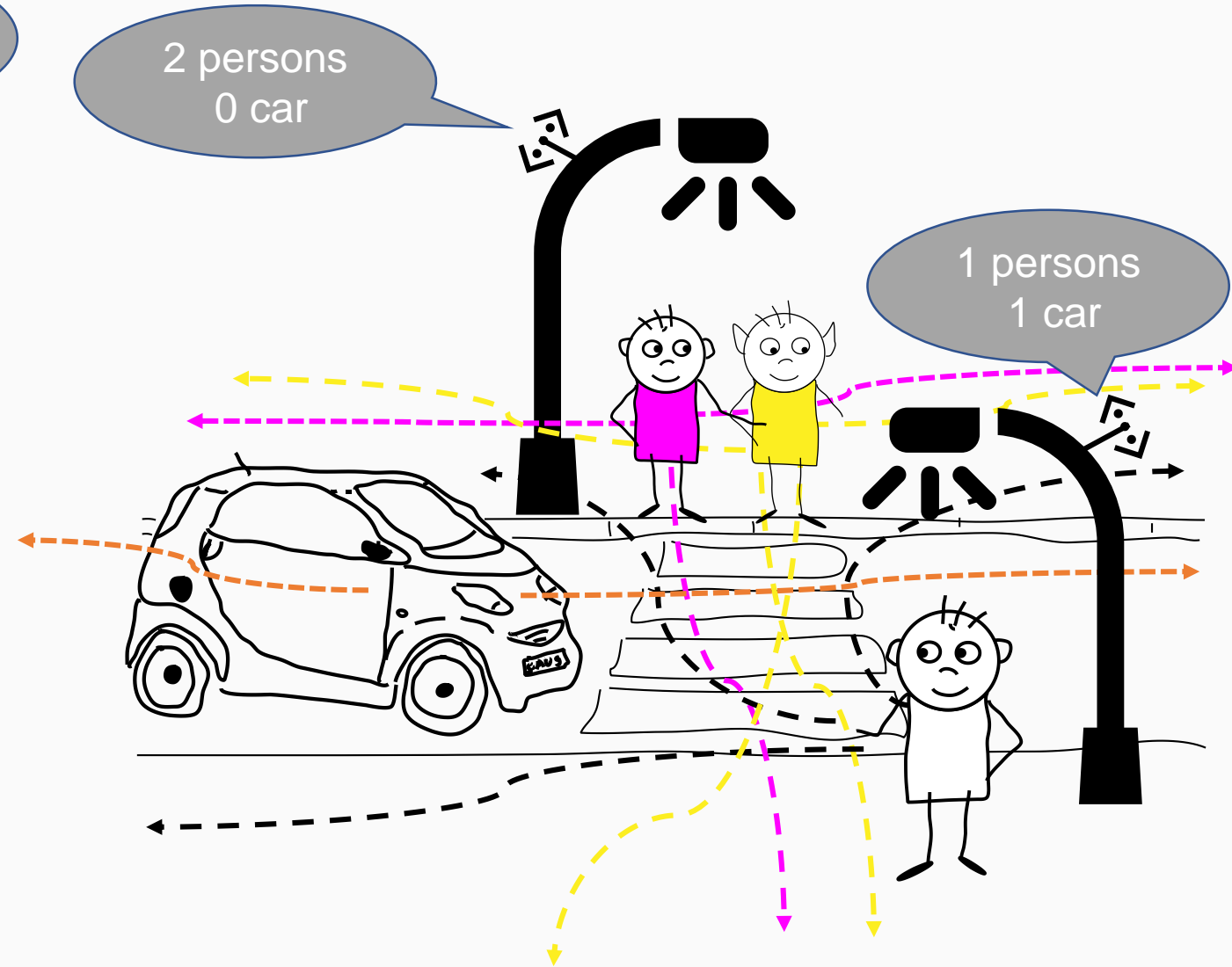
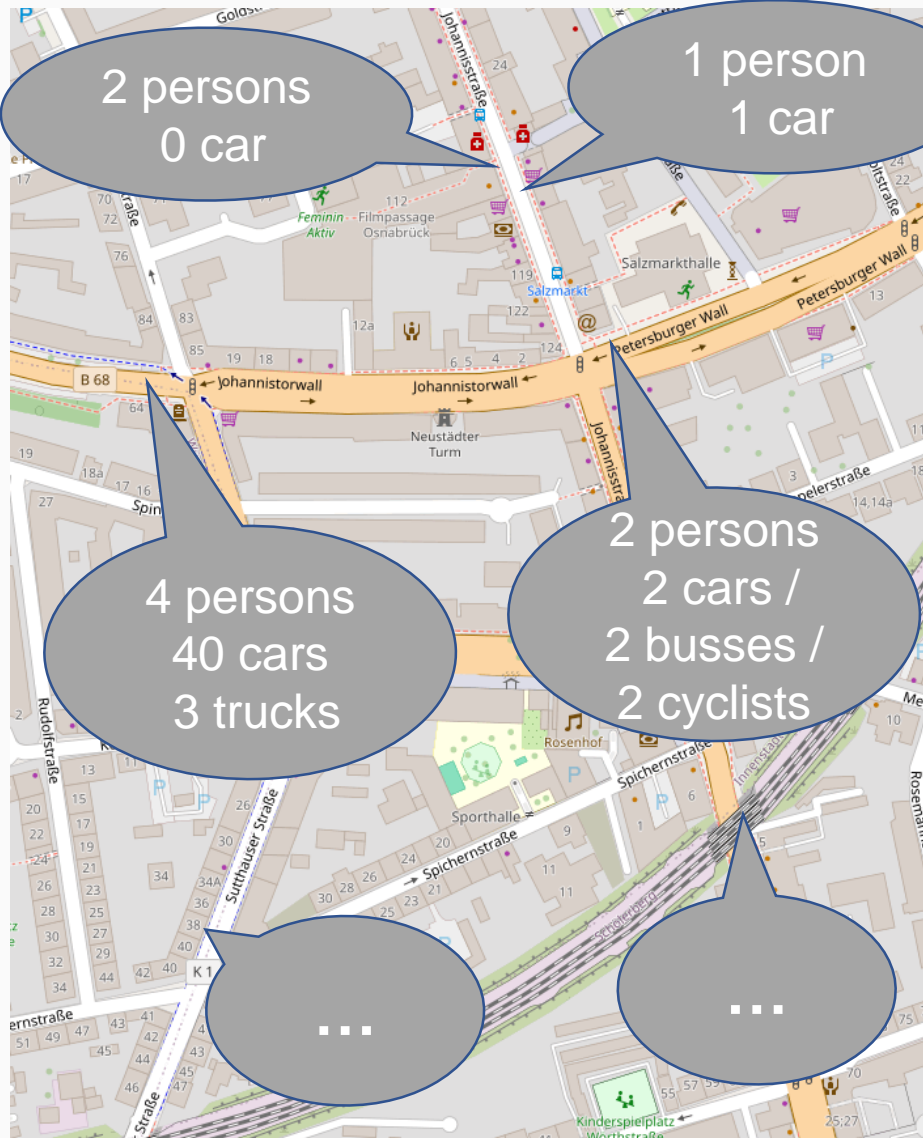




# Solutions: Sensor-based traffic simulation - Video cameras



# Solutions: Sensor-based traffic simulation - Sensors

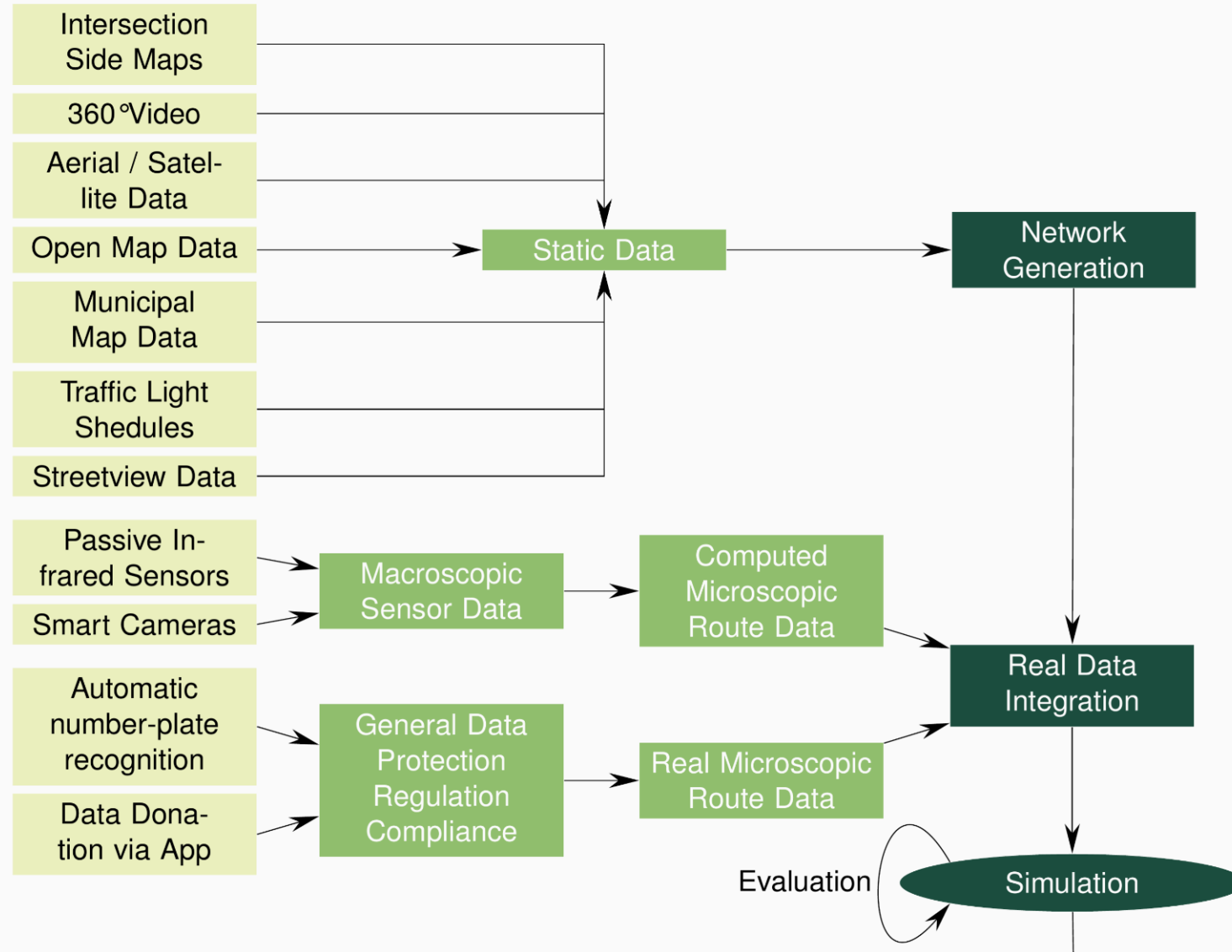


# Simulating Traffic Networks

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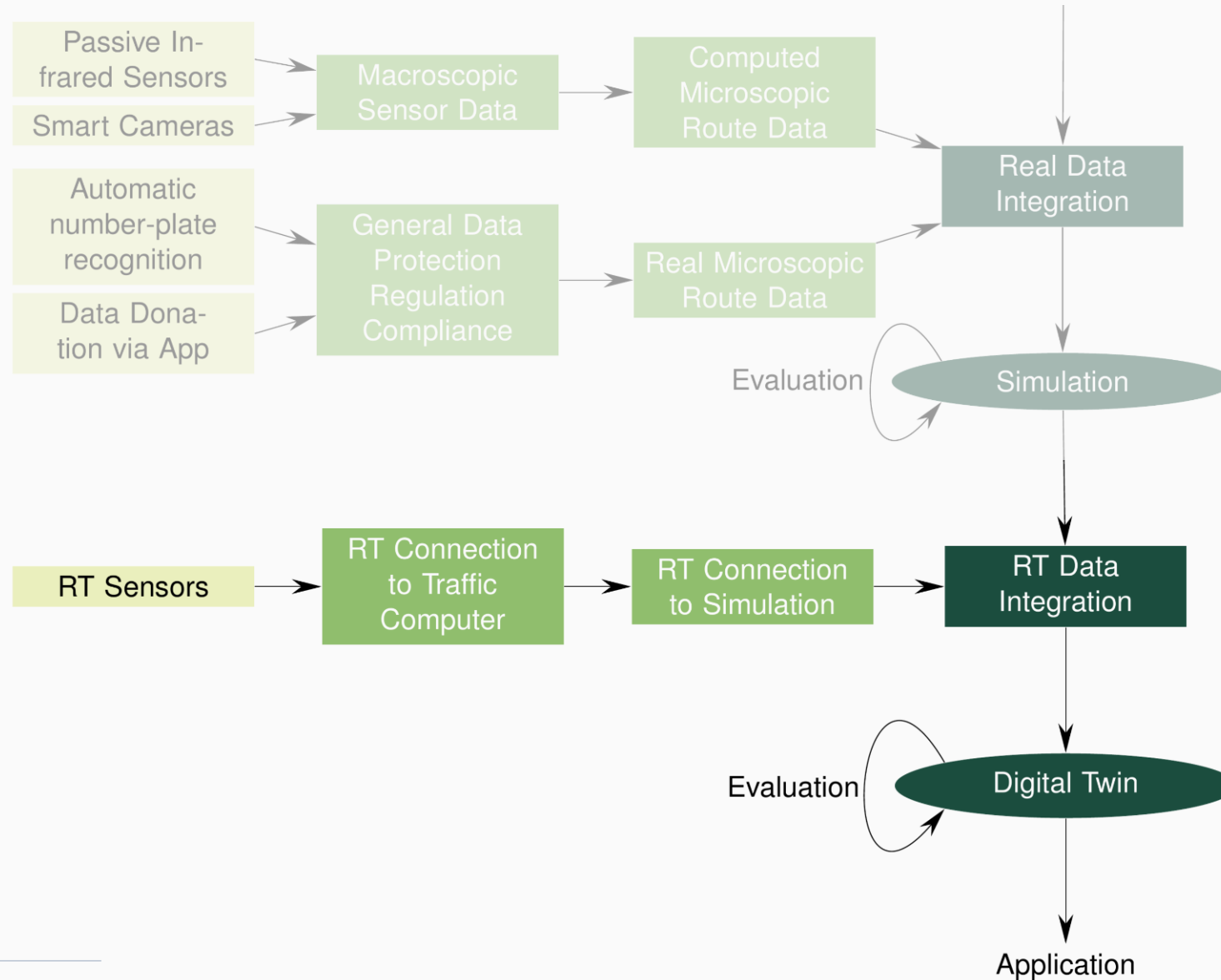
## Driving SUMO towards digital twins

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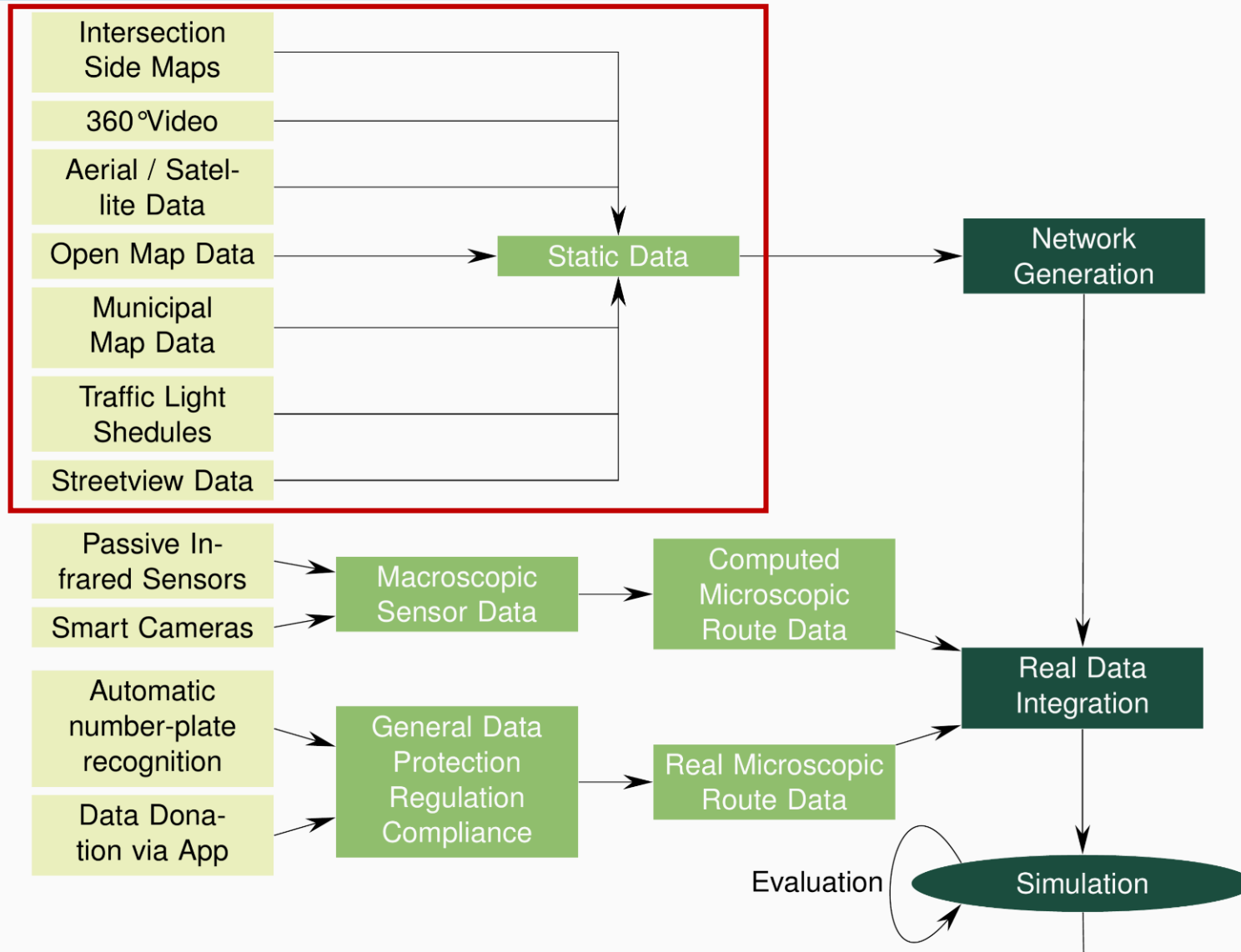


# Simulating Traffic Networks

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## Static data

# Static data: Sources





# Static data: Fusion

- embedding all data sources in the GIS
- utilization:
  - creation of the traffic network
  - definition of new sensor positions
  - assignment of sensor position, masts, locations
  - ...
- publication as WMS / WFS for integration into other GIS systems
- publication as a website for direct use in the browser

# Static data: Fusion

The screenshot displays the QGIS desktop environment. The main map area shows a network of green dashed lines connecting several red circular nodes. The nodes are labeled with IDs: OSN0600, OSN059W, OSN061W, OSN064S, OSN063N, and OSN064Z. The map is overlaid on a street map of a city area. Four inset maps provide zoomed-in views of specific nodes, showing their location relative to surrounding streets and buildings. The left sidebar contains two panels: 'Browser' and 'Layers'. The 'Browser' panel shows a tree view of data sources, including 'WCS / OGC API - Features' and 'iip'. The 'Layers' panel shows a list of layers, with 'wms\_os' selected. The bottom status bar displays the following information: Coordinate: 895429.4, 6848431.5; Scale: 1:4090; Magnifier: 100%; Rotation: 0.0°; Render: EPSG:3857.

# Static data: Network generation

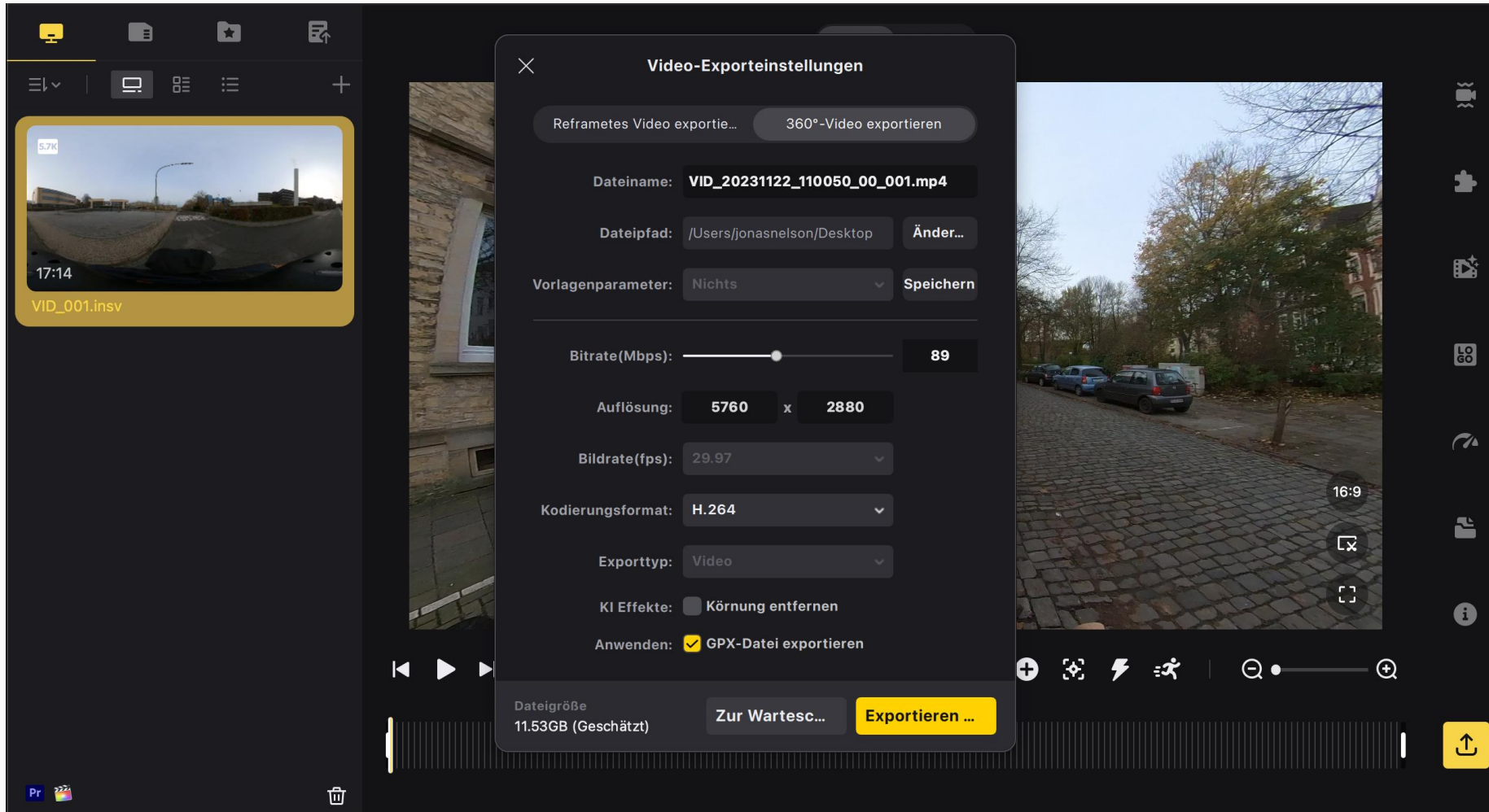
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- recording your own 360° videos
- update and correction of OpenStreetMap data
- conversion of OpenStreetMap data to SUMO mesh
- renewed correction of OpenStreetMap data
- conversion of OpenStreetMap data to SUMO mesh again
- final adjustments to the SUMO network
- assignment of the signal programs to the individual signal systems



# Static data: Network generation

## Creation of missing static data



# Static data: Signal systems

## Modeling of signaling systems and dependencies

The image displays four distinct components of traffic signal modeling software:

- Top Left:** A map view showing a street intersection with signal locations marked by colored dots. A red arrow points to a specific signal location. The map includes a scale bar and a date stamp '2021-01-27'.
- Top Right:** A signal timing diagram for a 'Signalgruppe'. It shows a horizontal axis from 0 to 90 seconds. Multiple horizontal bars represent different signal phases, color-coded as green, red, and yellow. A table on the right provides numerical data for these phases.
- Bottom Left:** A 'Edit Traffic Light' configuration window. It contains various settings for a traffic light, including junction ID, type, and a list of phases with their respective durations and states.
- Bottom Right:** A code editor window showing XML code for a signal system. The code defines various elements like 'Signalgruppe', 'Phase', and 'Standard' with their respective attributes and values.

Signalgruppe	TFI1	TFE1	TFD1	RES
12	53	41	36	
63	76	13	8	
86	53	57	52	
63	76	13	8	
85	4	9	4	
62	74	12	7	
85	53	58	53	
62	74	12	7	
11	51	40	35	
4	59	55	50	
62	86	24	19	
85	60	65	60	
62	86	24	19	
11	62	51	46	

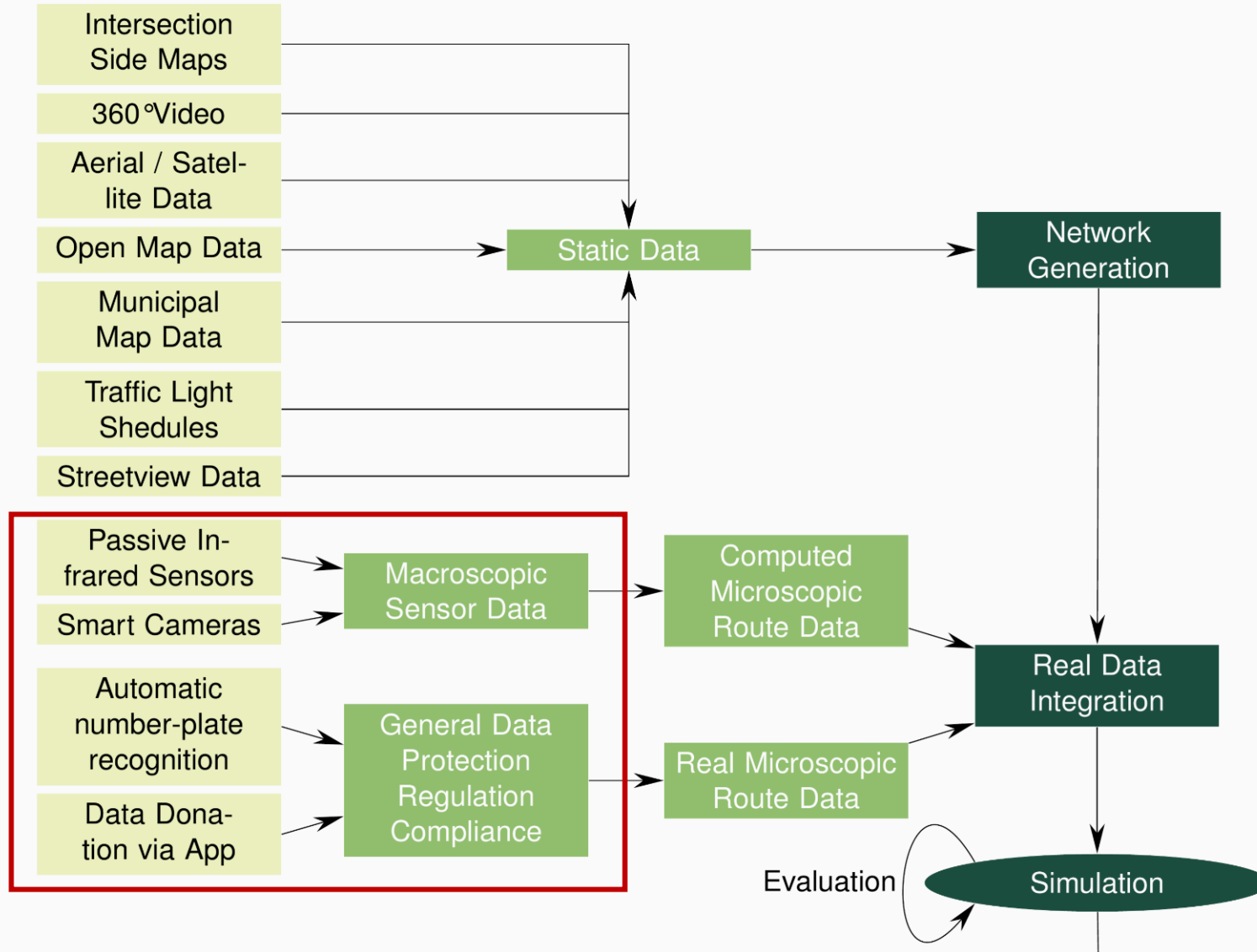
# Simulating Traffic Networks

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Dynamic data



# Static data: Sources



# Static data: Sources

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## Passive Infrared Sensors

- traffic volume measurement
- measurement of traffic speed
- differentiation of different road users by vehicle length

## Smart Cameras

- measurement of turning behavior at individual intersections
- AI-based differentiation of different road users

## Further sensor technology for

- public transport: capacity utilization, delay...
- shared mobility: positioning, availability...
- non-motorized individual transport: bicycles, pedestrian walkways...

# Dynamic data: Positioning of smart cameras

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Depends on requirements

- turning behavior at intersections
  - two cameras per intersection, each measuring two directions of travel
  - viewing direction diagonally across the intersection
  - traffic light pole
  
- speed, flow
  - measurement in free flowing traffic
  - viewing direction away from the intersection
  - traffic light pole or lamppost.



# Dynamic data: Data output

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- sensors send data to traffic computer
- data is copied to high-performance timeseries database
- SUMO and other applications access the database

# Dynamic data: Database

The screenshot displays the InfluxDB Data Explorer interface. On the left is a navigation sidebar with options: Load Data, Data Explorer, Notebooks, Dashboards, Tasks, Alerts, Settings, and Help & Support. The main area is titled "Data Explorer" and features a "Graph" view with a "CUSTOMIZE" button. A line graph shows data from 2022-01-01 to 2023-10-01, with values ranging from approximately 100 to 600. Below the graph is a query editor for "Query 1 (0.09s)". The query configuration includes:

- FROM:** A list of buckets with "teu\_data" selected.
- Filter 1:** "\_measurement" set to "teu\_measure".
- Filter 2:** "\_field" set to "count".
- Filter 3:** "id" with values "OSN0460", "OSN054W", and "OSN045W".
- Filter 4:** "vehicle" set to "car".
- WINDOW PERIOD:** Set to "AUTO".
- AGGREGATE FUNCTION:** Set to "mean".

Buttons for "View Raw Data", "SCRIPT EDITOR", and "SUBMIT" are visible at the bottom right of the query editor.

# Dynamic data: Routing and demand modeling

- sensors only measure macroscopic count data
- microscopic simulation means
  - simulation of all road users as individuals
  - individuals drive from origin-destination
  - all individuals follow fixed routes

⇒ How can routes be generated from count data?



# Dynamic data: Routing and Demand Modeling

## SUMO Demand Modeling Algorithms

- assignment of sensors to positions in the traffic network
- retrieving sensor data for the simulation period from the database
- data cleansing and conversion (routes to lanes, units)
- generation of routes for each vehicle so that
  - # vehicles measured at the measurement points matches the simulation
  - avg. simulated speeds with the avg measured speeds match the measured speeds
  - excess vehicles leave the network at other positions or missing vehicles start at other positions
- estimation or randomization of
  - individual routes and speeds
  - driving behavior: Overtaking, acceleration, safety distances
  - vehicle parameters: dimensions, consumption, environmental impact

# Simulating Traffic Networks

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## Outlook

# Outlook

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## Next Goals

- collection and fusion of traffic data
- analysis, simulation and forecasting

## Motivation

- identification of possibilities for promotion of alternative means of transport
- development of effective solutions to improve traffic flow and mobility in cities
- contributing to the creation of more pleasant and environmentally friendly urban traffic environments

## Challenges

- data situation, fusion, metadata
- macroscopic data vs. microscopic simulation



# Completely without personal reference

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The modern way of drawing

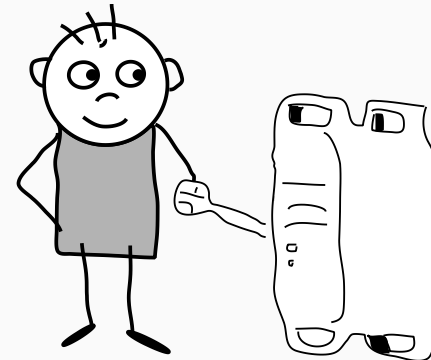
# The modern way of drawing - Prompt Engineers: The new artists?

Without any personal reference!

But close to reality!



today





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## Publications

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 [Research Gate](#)

 [Homepage](#)