XCARCITY INFUZE Workshop 3rd April 2025

Agenda

09:00-09:45	*Walk-about Rotterdam*
09:45-10:00	*Walk in and Coffee*
10:00-10:30	*Introduction to the programmes INFUZE- XCARCITY - HYBRID*
10:30-11:00	*Design Methodology Across the programmes - HYBRID*
11:00-12:00	*Interactive session 1: Citizen engagements (hosted by INFUZE)*
12:00-13:00	*LUNCH*
13:00-14:00	*XCARCITY Researchers presentations - HYBRID - 8 presentations*
14:00-14:15	*Introduction to Models and Digital Twins - HYBRID*
14:15-15:15	*Interactive Session 2: Co design session for Use Case + Digital Twin (hosted by XCARCITY)*
15:15-15:30	*TEA*
15:30-16:15	*Interactive Session 3: Reading Group - HYBRID*
16:15-16:30	*Feedback/Reflections + Close out*

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Introductions

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Toward sustainable urban mobility using digital twins

Bart van Arem

NWO

TU Delft

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Urbanisation increasing

1 Million new houses planned by 2030

Mostly densification within existing cities

Population … world-wide;
… increasing

… limited population growth;
population in cities increasing,
population in rural areas
decreasing

https://www.un.org/development/desa/pd/
https://urban.jrc.ec.europa.eu/thefutureofcities/

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The Netherlands

17,5 Million
population
41.850 km²

Randstad area
(Amsterdam, Rotterdam, The Hague, Utrecht)
8,5 Million population
11.370 km²

Population large cities growing
(Amsterdam, Rotterdam, The Hague, Utrecht)

1 Million new houses planned by 2030

Mostly densification within existing cities

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1 Million new houses? What about accessibility and liveability ?

.

- The road transport system has reached the limits of what is:
  - usage of space
  - externalities
- Public transport system has also reached capacity limits.

Can we imagine a city without private cars?

Scarcity of space
eX Car City
---------- +
XCARCITY?

XCARCITY facts and figures

- Duration: 1st June 2023 -1st June 2029
- Budget: 4 M€ by NWO, 2 M€ by partners
- 9 PhD candidates, 2 postdocs, 1 programmer, TNO researchers (60 person years)
- 33 partners from academia, public and private sector
- Lead by TU Delft: Bart van Arem (PI), Maaike Snelder (co-PI)

Perspectief programme of NWO (Dutch Research Council)

New, challenging research projects within the application-oriented and technical sciences that generate economic and social impact in thematic areas relevant to the Netherlands.

https://www.nwo.nl/en/researchprogrammes/perspectief/previous-awards

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Smart mobility – promising solutions

Flexible combinations of:

- walking and cycling
- shared electric vehicles
- transport hubs
- traffic management

Building on service orientation and electrification of mobility.

Will this work?

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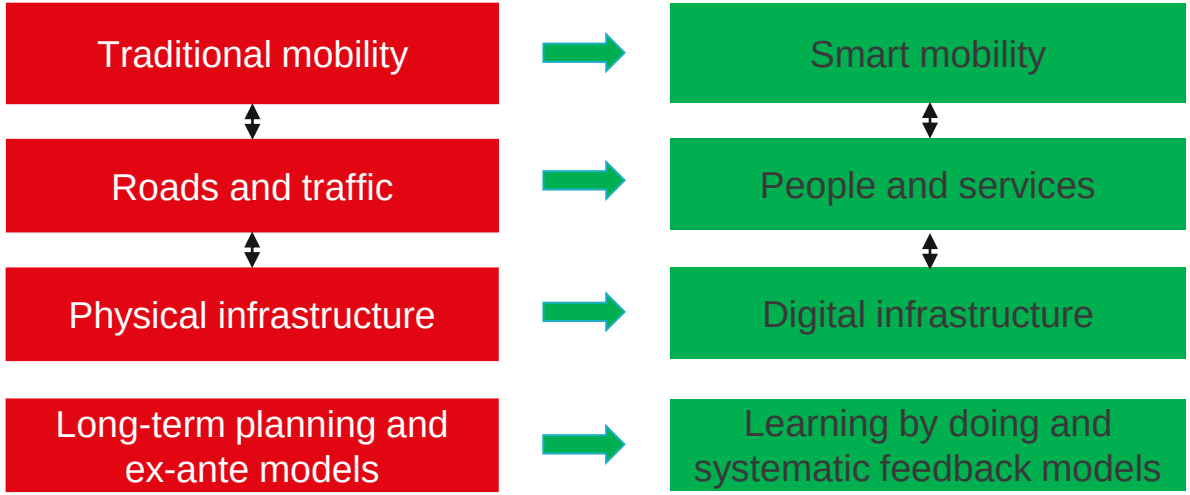
Traditional theories and methods are out dated



We need new theories and methods to start collecting evidence what works (and what doesn't).

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Proposition XCARCITY

Digital twin federation

Real-time management & Strategic planning

Model-based scenario development

Implementation of interventions

Real-life and virtual reality data

Monitoring and analyses

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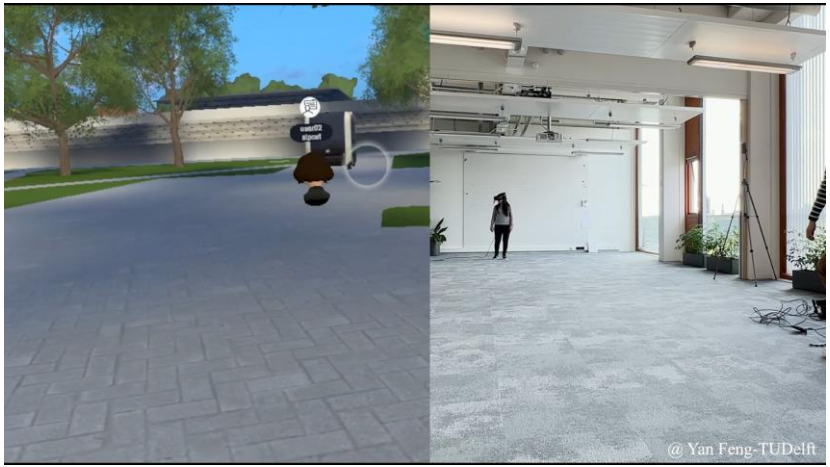

Interactive urban planning digital twin

Real-time mobility digital twin

Immersive, multi-user VR digital twin

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Scientific challenges

Measuring the behaviour of individuals and flows while respecting privacy and security

Developing smart mobility services that meet travel demands

Assessing the contribution of smart mobility to sustainable and inclusive accessibility.

In a context characterized by:

Multiple stakeholders

Highly dynamic interaction and feedback

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Towards content-rich digital twins

SP1 Framework, method and guidelines for optimal **sensor network design** and predictions

SP2 Insights in **behavioral responses**

SP3 Algorithms for and insights in the design of **smart mobility applications**

SP 6 Digital twin

SP4 Algorithms for and insights in the design of integrated transport networks

SP5 Algorithms for large-scale collection of mobility data for **traffic management**

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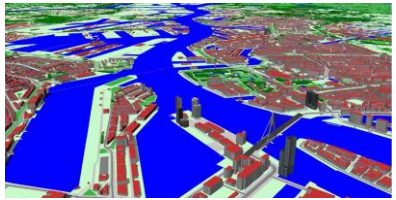
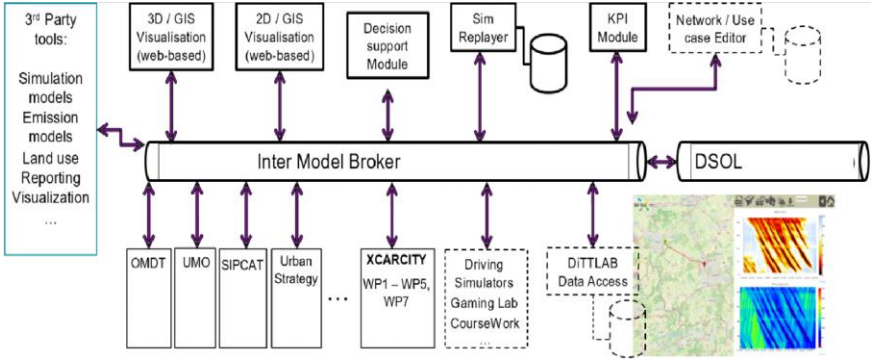
Digital twin federation





- 3D models of the cities selected for the use cases
- Open source model architecture of XCARCITY DT and communication protocol
- Visualisation dashboard and user interface
- Scenarios for selected use cases, with interactive options, visualisations and KPIs

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Impact Plan

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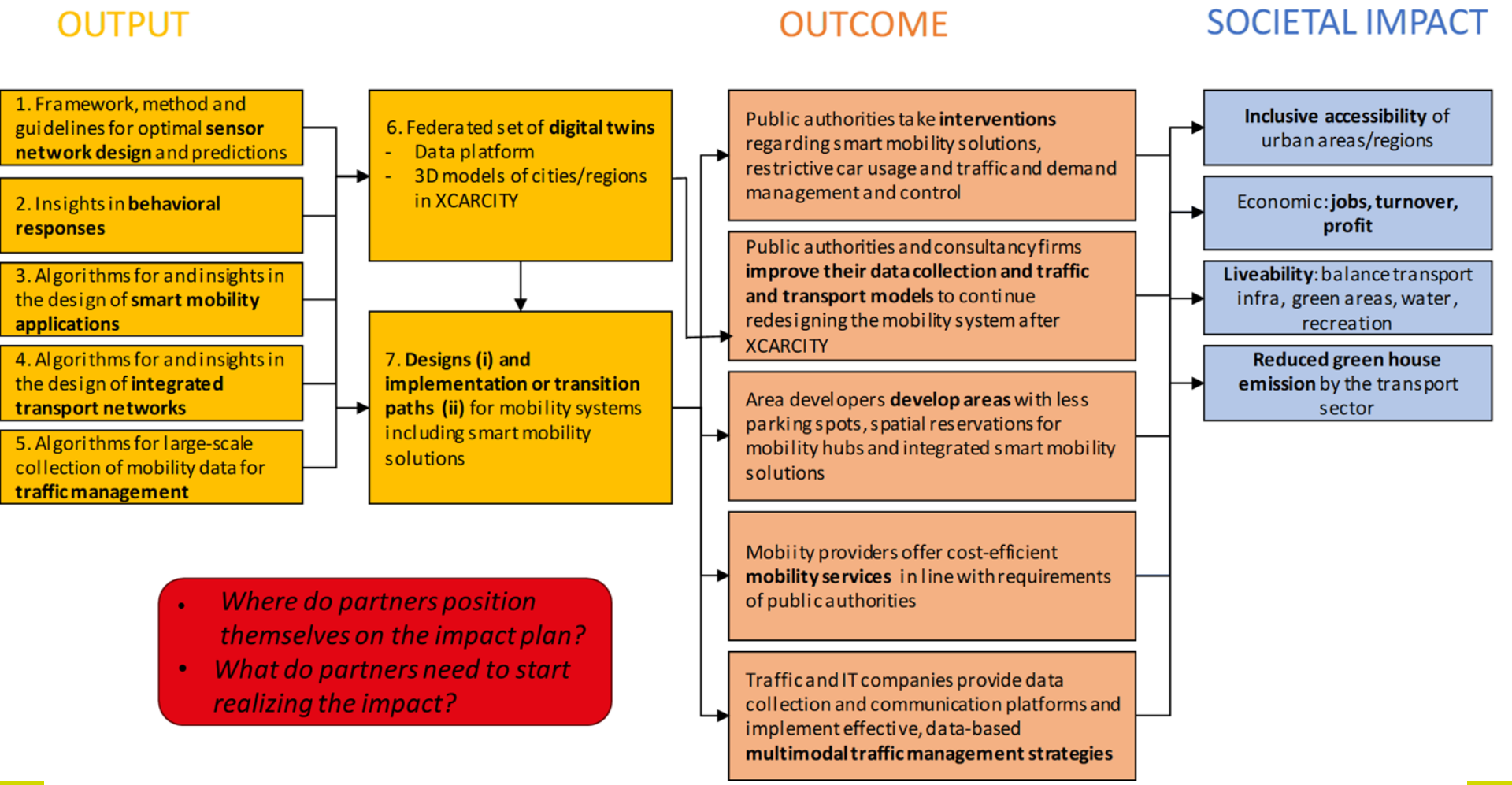
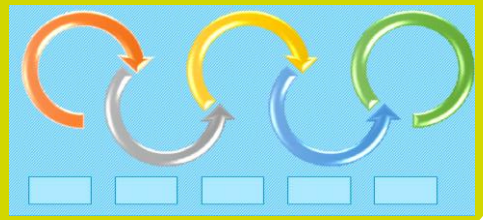

OUTPUT
OUTCOME
SOCIETAL IMPACT
1. Framework, method and guidelines for optimal **sensor network design** and predictions
2. Insights in **behavioral responses**
3. Algorithms for and insights in the design of **smart mobility applications**
4. Algorithms for and insights in the design of **integrated transport networks**
5. Algorithms for large-scale collection of mobility data for **traffic management**
6. Federated set of **digital twins**
- Data platform
- 3D models of cities/regions in XCARCITY
7. **Designs (i) and implementation or transition paths (ii)** for mobility systems including smart mobility solutions
Public authorities take **interventions** regarding smart mobility solutions, restrictive car usage and traffic and demand management and control
Public authorities and consultancy firms **improve their data collection and traffic and transport models** to continue redesigning the mobility system after XCARCITY
Area developers **develop areas** with less parking spots, spatial reservations for mobility hubs and integrated smart mobility solutions
Mobility providers offer cost-efficient **mobility services** in line with requirements of public authorities
Traffic and IT companies provide data collection and communication platforms and implement effective, data-based **multimodal traffic management strategies**
Inclusive accessibility of urban areas/regions
Economic: **jobs, turnover, profit**
Liveability: balance transport infra, green areas, water, recreation
Reduced green house emission by the transport sector
- *Where do partners position themselves on the impact plan?*
- *What do partners need to start realizing the impact?*

Utilisation approach

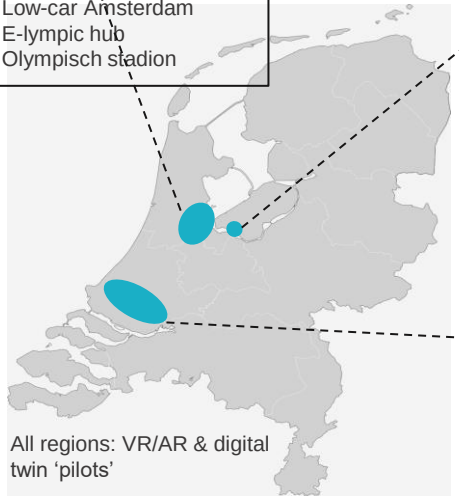
Pilots and applications, research by design, stakeholder interaction



Amsterdam and surroundings: centralized trip patterns

Pilots, e.g.
- Low-car Amsterdam
- E-lympic hub
- Olympisch stadion

Almere Pampus: a new city district



All regions: VR/AR & digital twin ‘pilots’

Metropolitan region Rotterdam-The Hague: decentralized trip patterns

Pilots, e.g.
- BMW shared mobility
- MaaS pilots
- Dynamic road spaces

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CONSORTIUM MEETING June 2024

City of Amsterdam

Climate change effects

Sacha Stolp, department of engineering

May 30, 2024

ZUIDASDOK

IMPACT PLAN

POSITIONING

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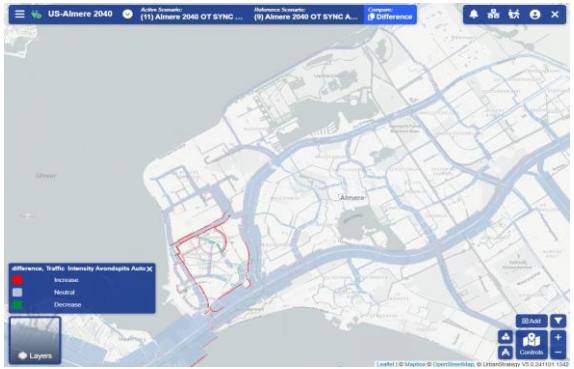
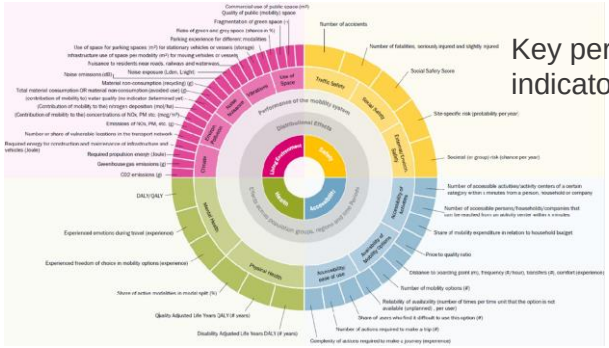
DESIGN SESSION November 2024

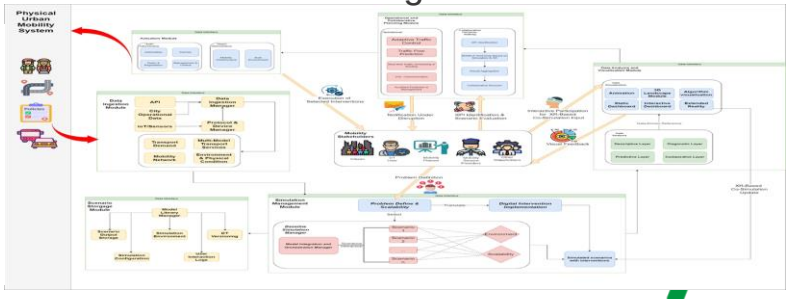


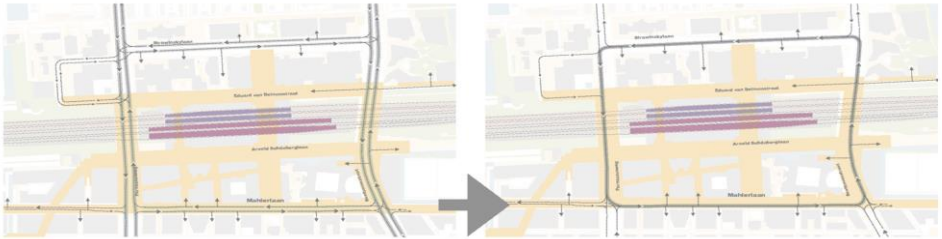
Digital twin assessment Almere Pampus



Key performance indicators

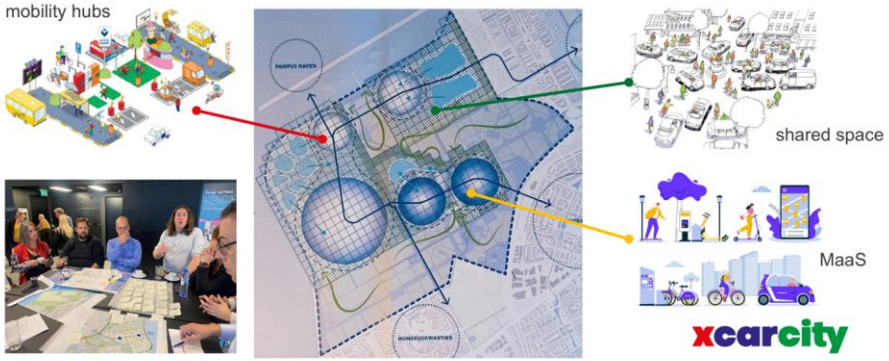
Digital twin federation





Redesign Parnassusweg

Almere Pampus



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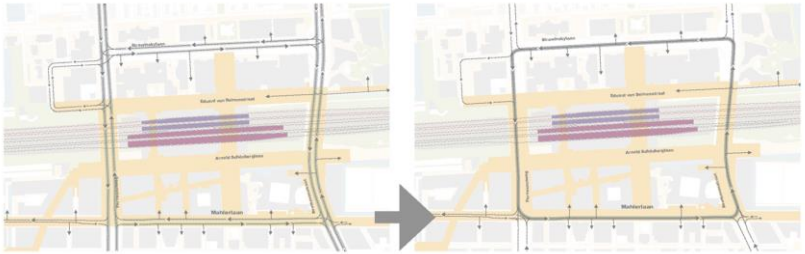
Amsterdam Zuidasdok



Redesign Parnassusweg around Zuidas train station

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Rotterdam Merwe4Haven

Immersive VR research by design Urban Community Vehicle (with BMW)

Integration of Rotterdam Open Urban Platform, Digital Twin Federation, Vehicle data (with BMW)

Modeling and optimisation of sustainable mobilty

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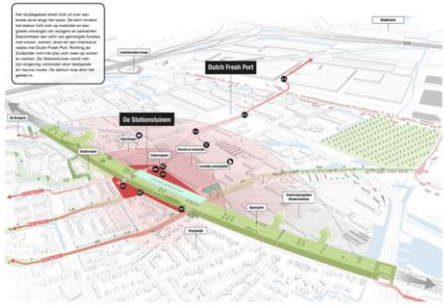
Barendrecht Stationstuinen



Uit: Koersdocument Barendrecht – de Stationstuinen (2019)

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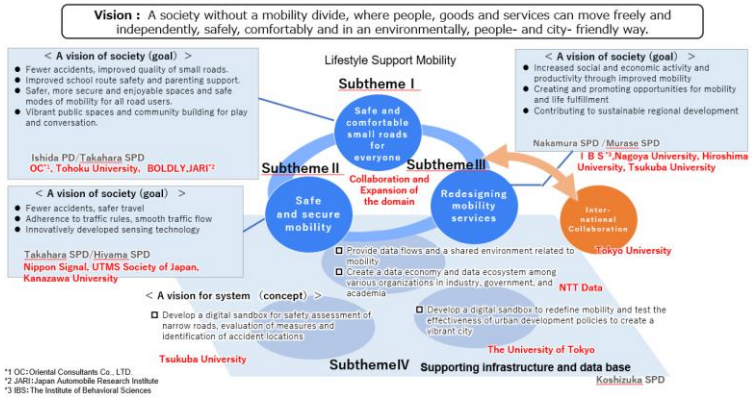
International collaboration



Japan SIP Development of Smart Mobility Platform

2nd joint workshop in Japan November 2025

Inspiring Futures for Zero Carbon Mobility (INFUZE)

Common workshop 3rd April 2025 in Delft

https://in-fuze.org.uk/

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Toward sustainable urban mobility using digital twins

From transportation infrastructure to smart mobility service orientation.

Digital twin federation integrating data-driven and model-based approaches.

Collaborative what-if analyses of new smart mobility approaches to ensure sustainable and inclusive accessibility.

THANK YOU!

Future work:

Automated Vehicles in Shared Space
XCARCITY and climate change

SUM Lab
Sustainable Urban Multimodal Mobility

xcarcity.nl

https://www.linkedin.com/groups/12822203/

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Help us imagine and codesign your city so you don't need to own a car

Professor Greg Marsden, University of Leeds

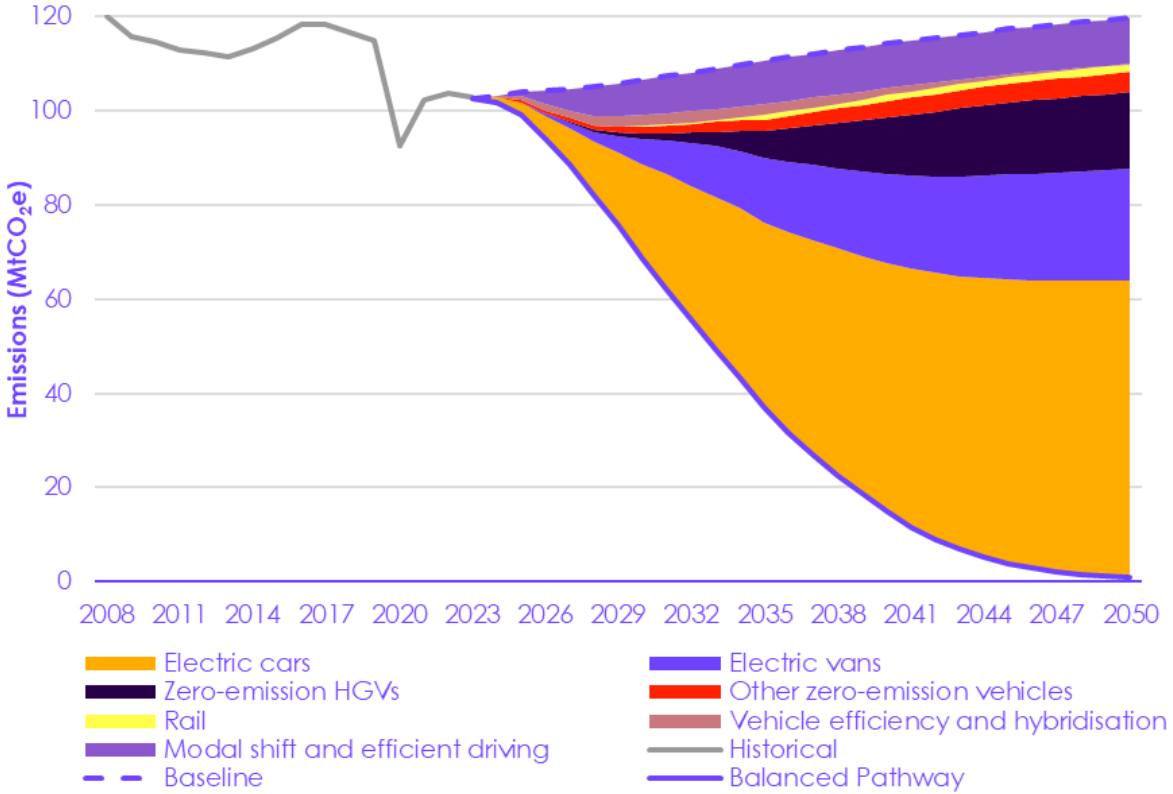
Engineering and Physical Sciences Research Council

Royal College of Art

Lancaster University

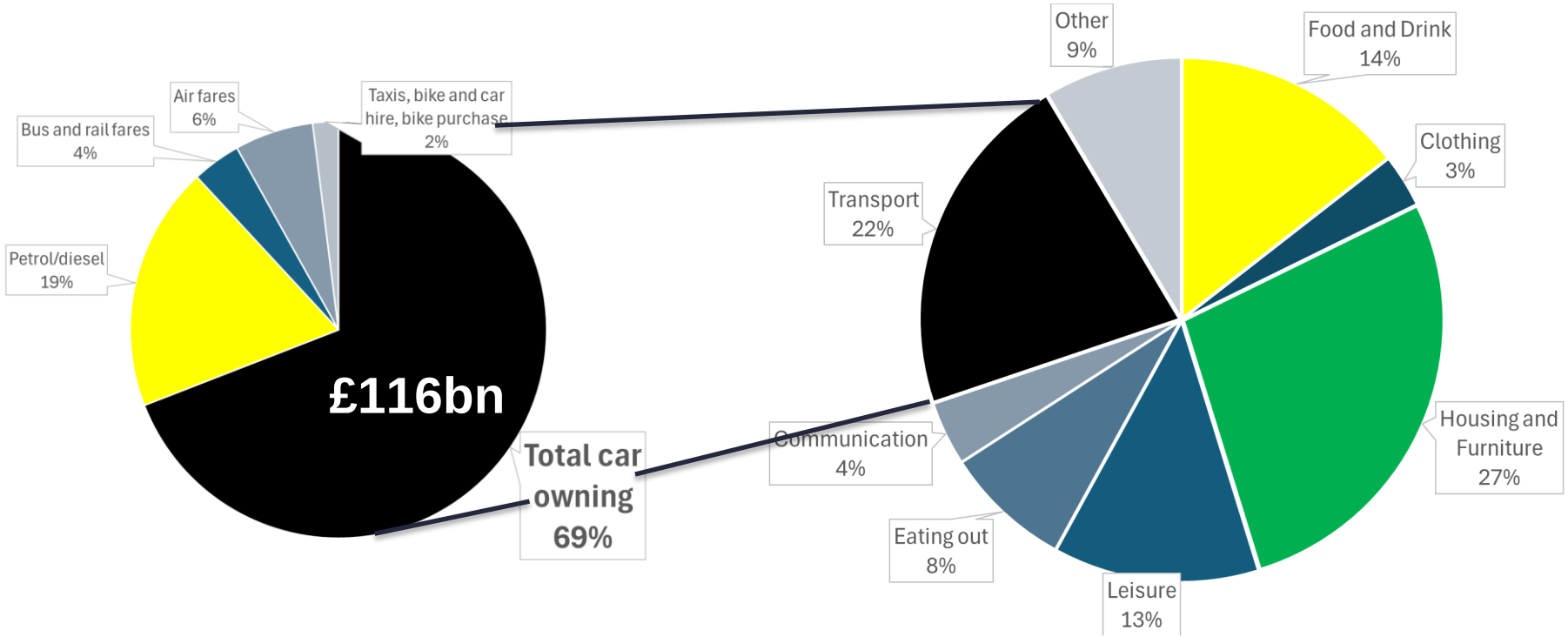
UNIVERSITY OF LEEDS

A pathway to Net Zero?



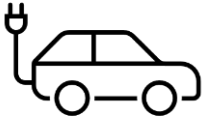

WHY, SOMETIMES
I'VE BELIEVED AS MANY AS
SIX IMPOSSIBLE
THINGS BEFORE BREAKFAST
~ ALICE IN WONDERLAND

The High Cost of Car Ownership



15p per mile

£1.35/litre



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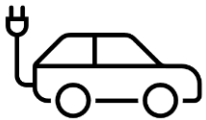
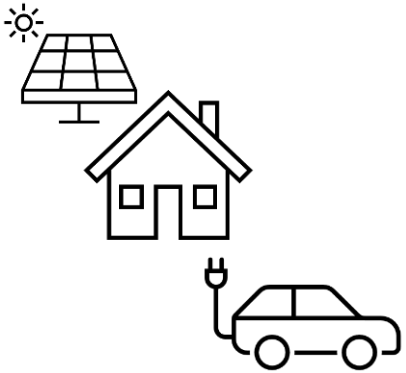
11p per mile

25p kWhr price cap



17p per mile or more

52p kWhr Slow/fast 80p/kWhr Rapid



7p per mile or less

https://www.zap-map.com/ev-stats/charging-price-index

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Better alternative fallacy

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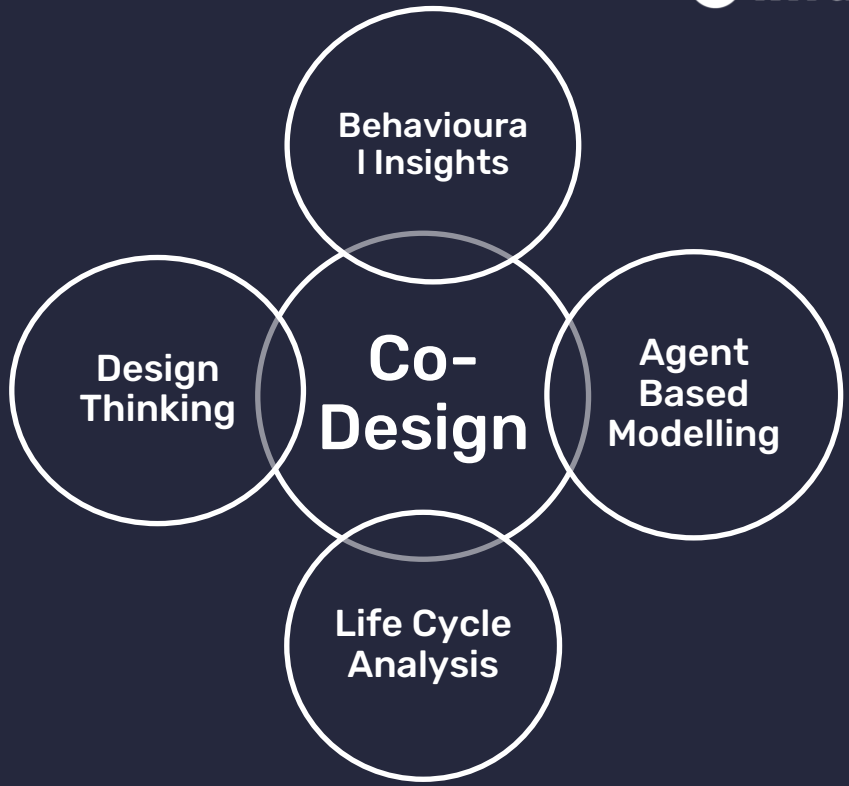
Does it have to be like this?

Cars

- 96% time stationary
- 33% don’t move on any given day
- average occupancy 1.6 (1.2 in peak)
- 14% is max % of cars on the move in peak

The INFUZE way

The question is not ‘can you live without your car?’ but ‘**what would a world where people did not need to own their own cars look like?**’



Call to Action

NATURE CONNECTEDNESS

SENSE OF COMMUNITY

SOCIAL JUSTICE

What follows?

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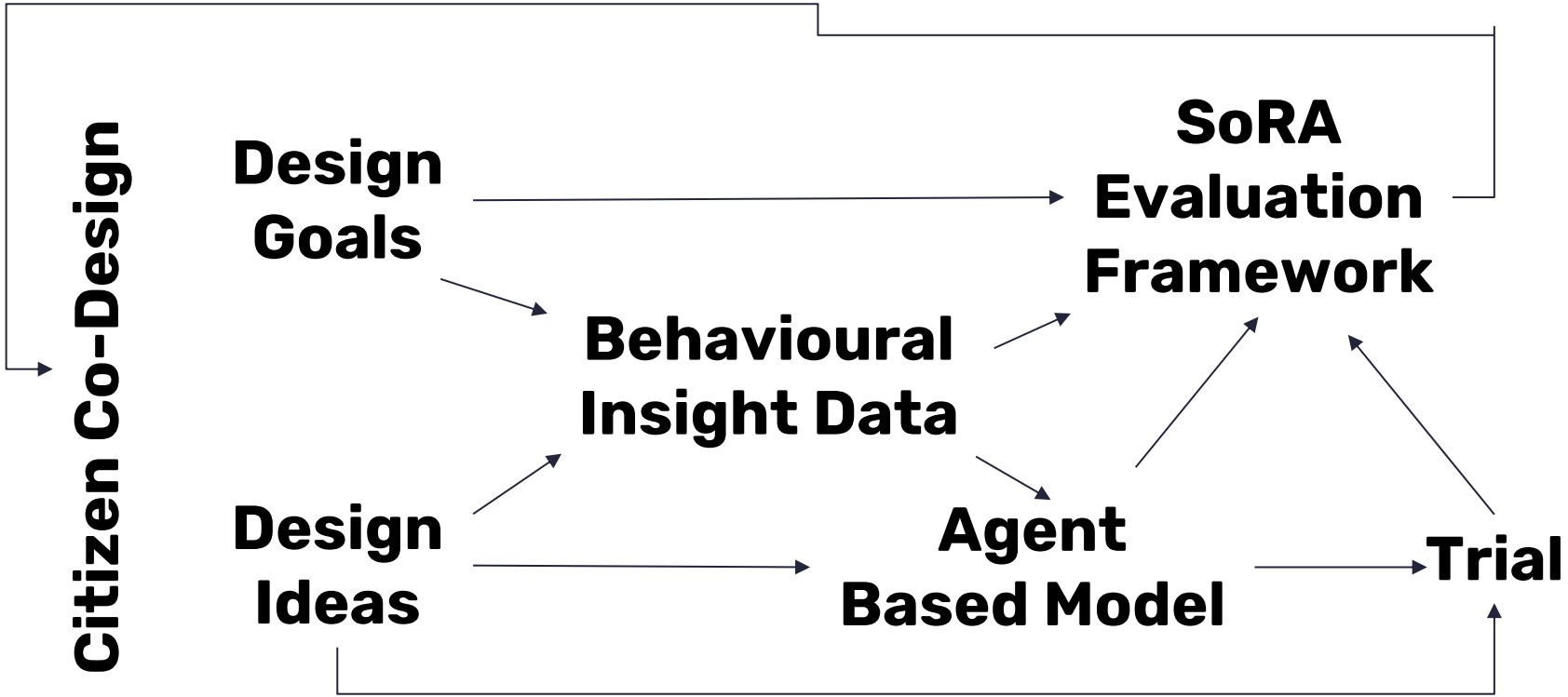

Experimentation

- 2025 – designing, learning, mini trials
- 2026 – implementing pilot alongside LCC
- 2027 – small area or household trials
- 2028 – 400 household demonstrator

Working in Partnership

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Main Test Site

- Leeds City Council, West Yorkshire Combined Authority

Key Transferability Sites

- Transport for West Midlands, Calderdale District Council

Other Government Partners

- Department for Transport, Transport for the North

Community Partners

- Third Sector Leeds, Ahead Partnership, Climate Action Leeds ACTS! CoMoUK

Consultant Partners

- Arup, Steer, Atkins Réalis, WSP, Connected Places Catapult

Service Providers and Aggregators

- Beryl Bikes, BetterPoints, First Bus, Flock Mobility, EnterpriseCarClub, HiyaCar, Mobilityways, Padam Mobility, RideTandem


Reimagine our streets?


Choose the vehicle you need for your journey?

infuze

Get in Touch

infuze@leeds.ac.uk

Find Out More

in-fuze.org.uk

UKRI Engineering and Physical Sciences Research Council
Royal College of Art
Lancaster University
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Design Methodologies

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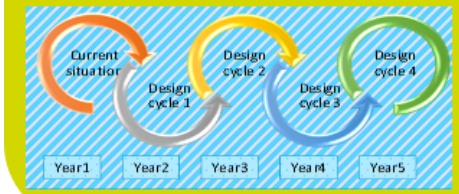
Purpose of Design Sessions

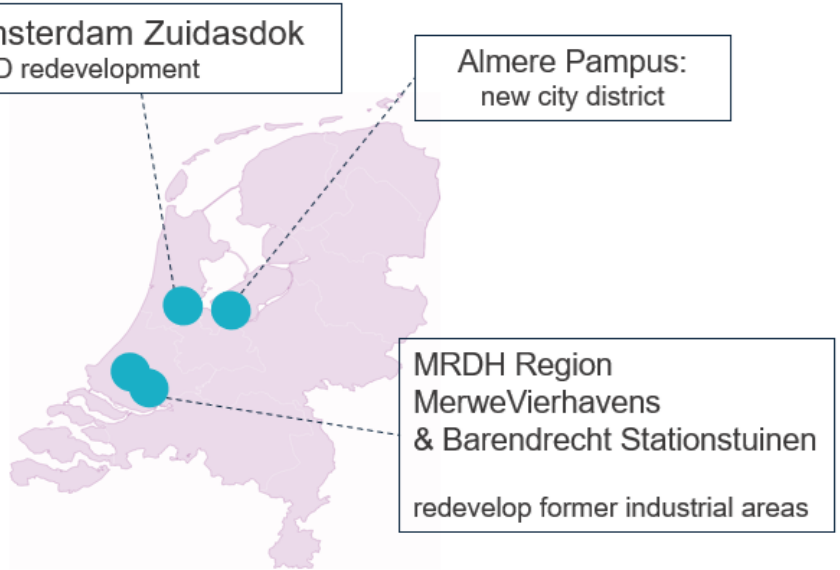
Pilots and applications, Research by Design, Stakeholder Interaction



research-by-design approach

annual design sessions

parallel development digital twins



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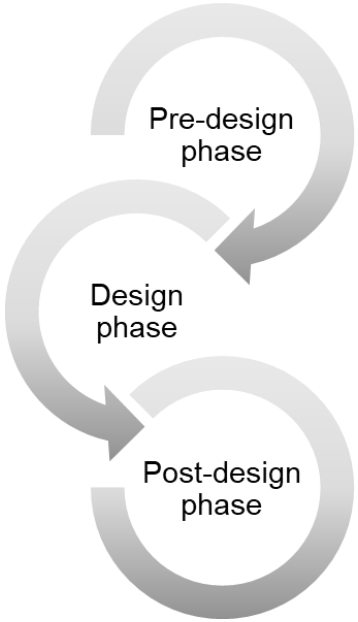
Annual process



- Research + findings
- Co-design mobility system use cases
- Yearly reports safety & spatial impacts
- Post design sessions governments, area developers, mobility service providers, IT & traffic companies
- Update research plans & digital twin developments

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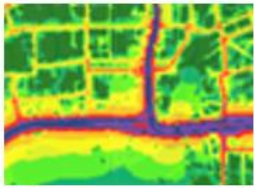

(modal-supported)
design

implement

monitor & evaluate

XCARITY innovations:

- Closes the loop between data-driven and model-based approaches
- Develops integrated, smart, safe and sustainable mobility services in/with the spatial context
- Supports collaborative decision-making by stakeholders

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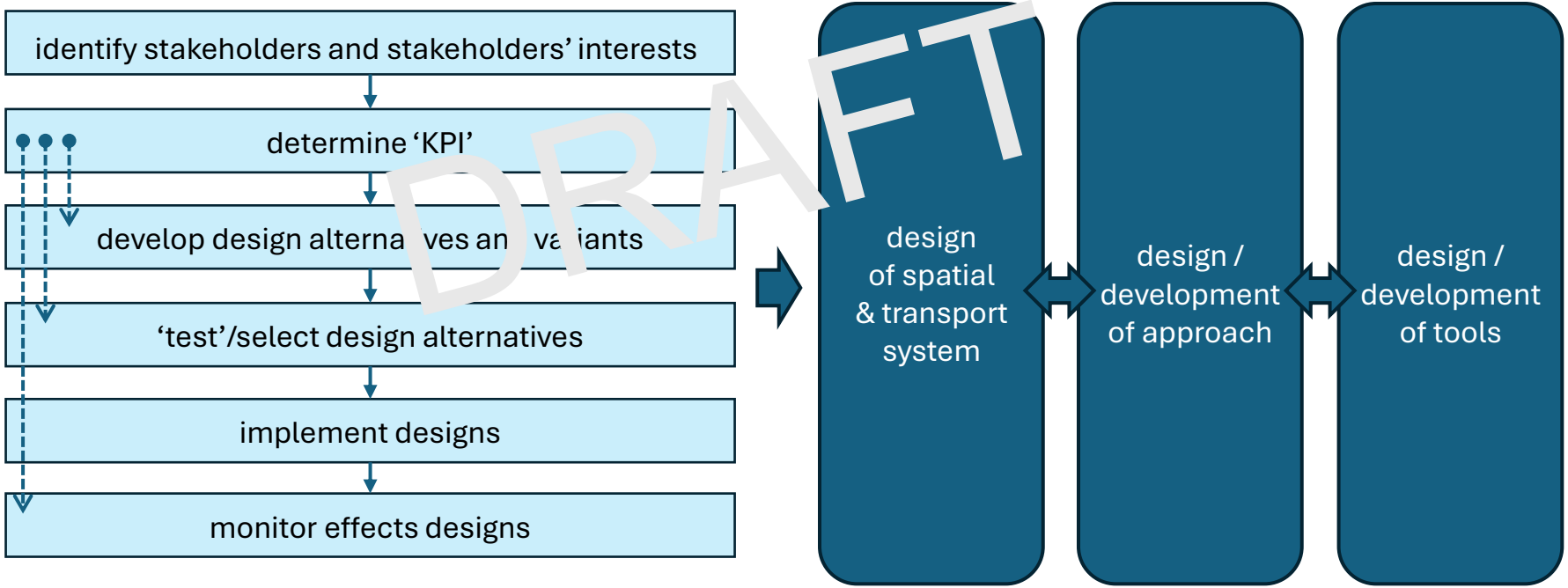
design and research side – by - side

simplified design process

to be designed/developed artefacts



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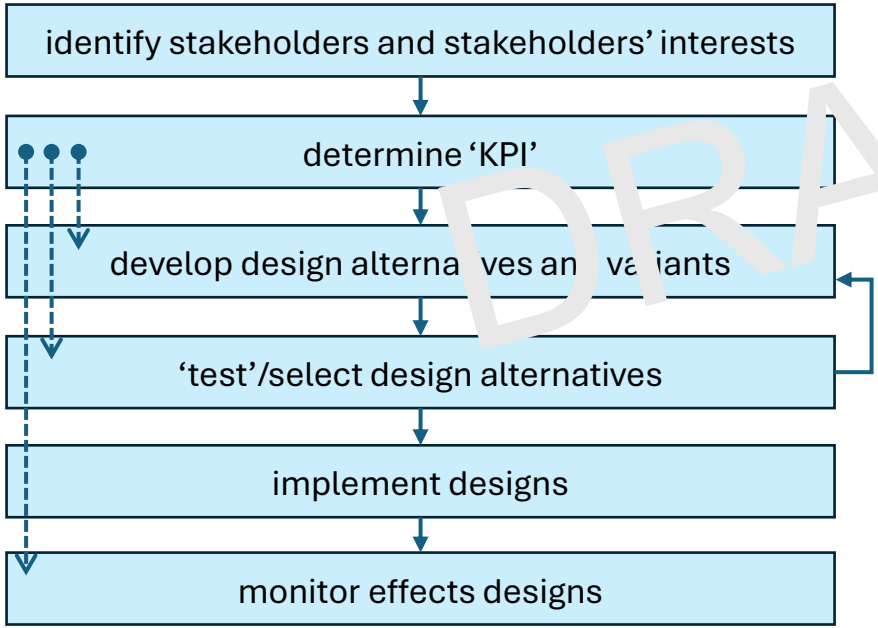
simplified design process



related knowledge questions for the design of a spatial & transport system

who are stakeholders,
who to involve, how and when?

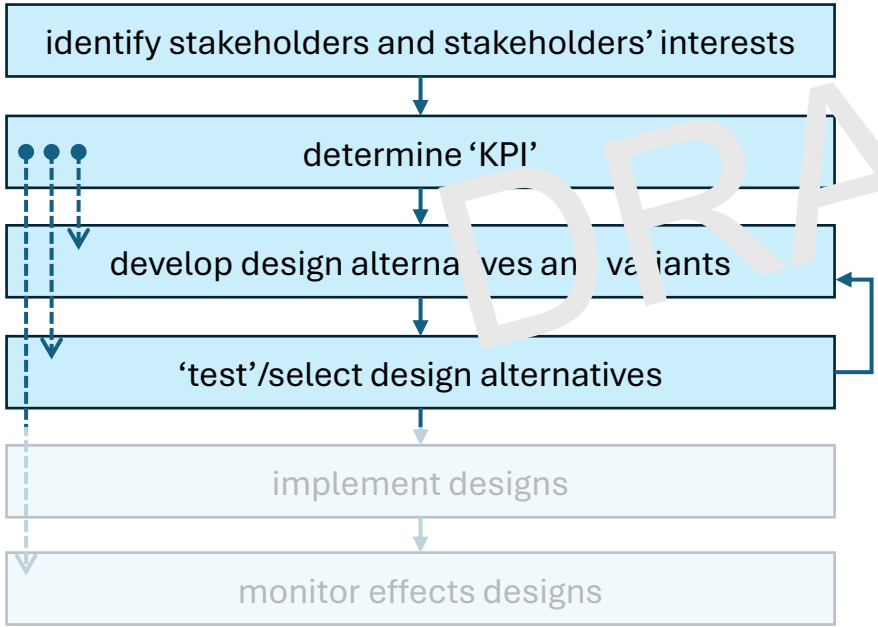
how to classify and prioritize criteria?

what are the degrees of freedom?
what (DT) tools are useful in designing?
how to ex-ante estimate effects? (KPI)

what additional design challenges result from the implementation phase?

design and research side – by – side (Almere)

simplified design process



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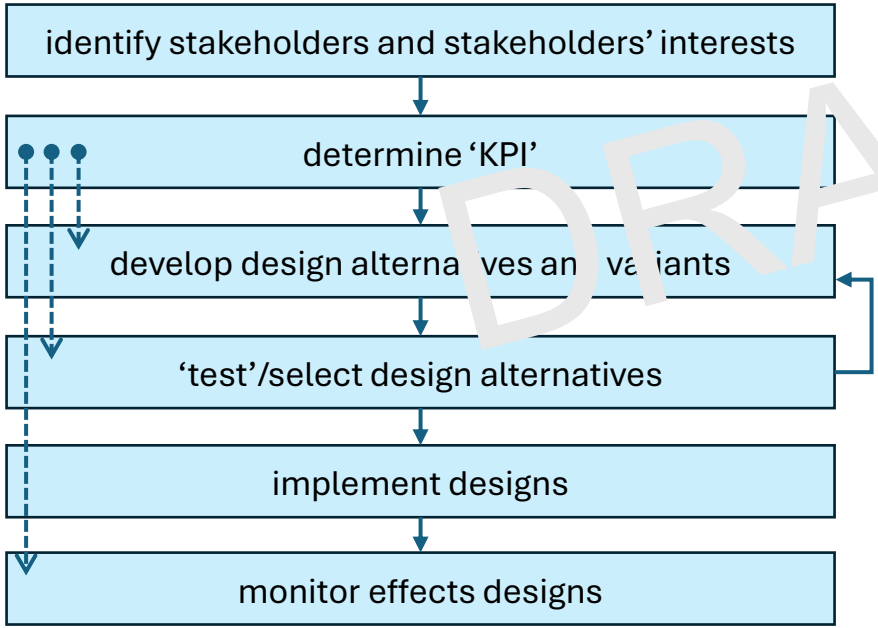
how to measure/monitor effects in real life?

design and research side – by – side (A'dam)

simplified design process



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design and research side – by - side

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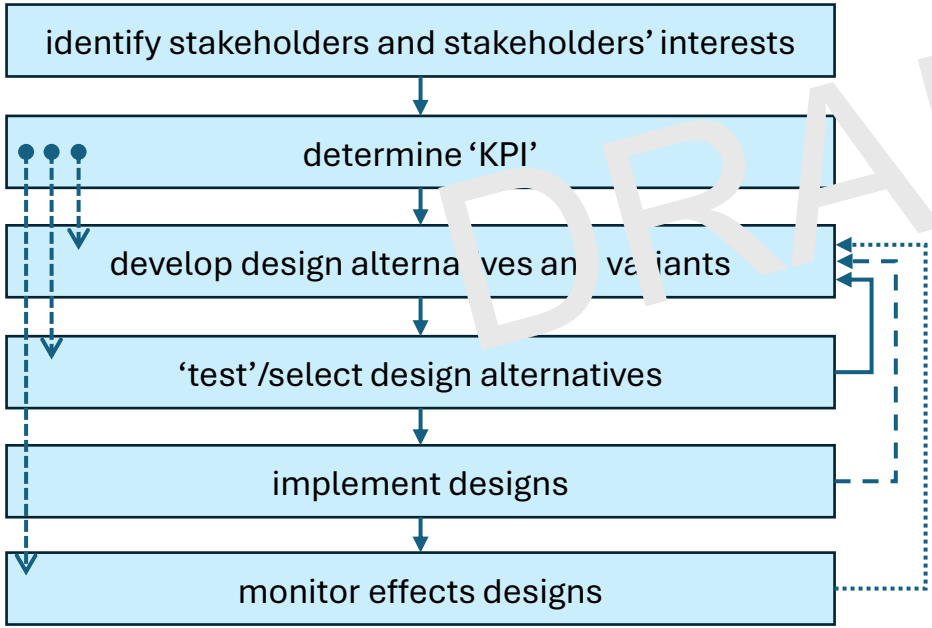


related knowledge questions for the design of a spatial & transport system

do we need more/other degrees of freedom?

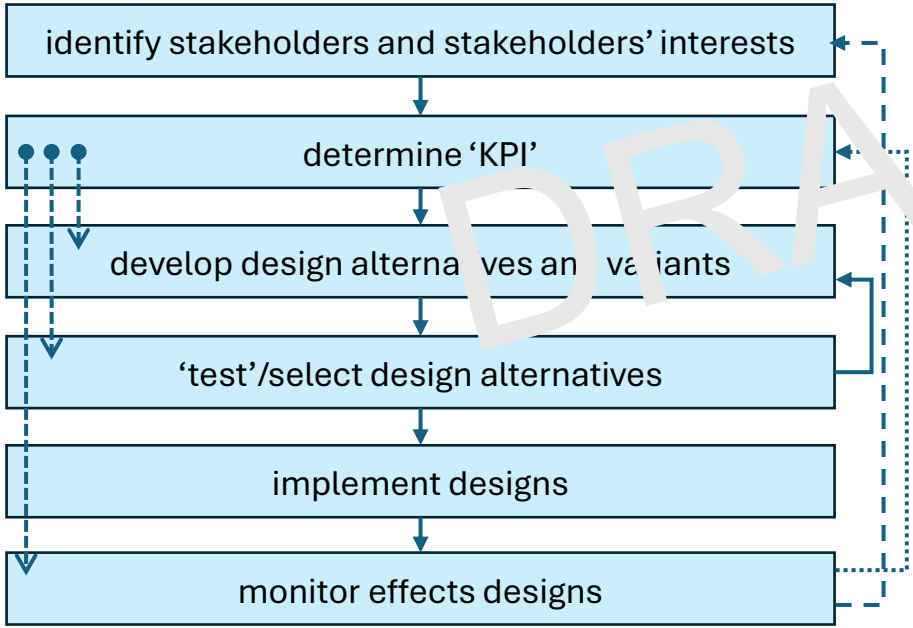
do we need other design alternatives?

feed-back loops

to strengthen *design*

design and research side – by - side

simplified design process



related knowledge questions for the design of a spatial, transport system & process

did we include the relevant stakeholders, in the right way and at the right time?

did we define meaningful criteria? do we need other/more criteria?

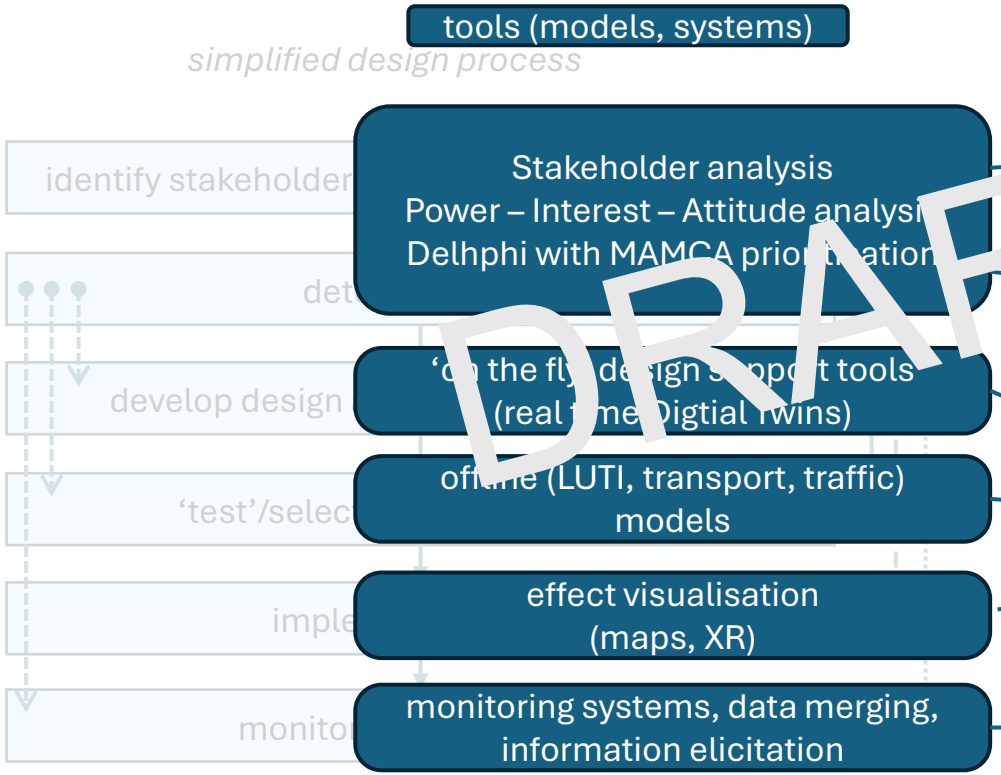
do we need updated or other (DT) tools?

were the estimations relevant? (KPI)

feed-back loops

to strengthen *process*

design and research side – by - side

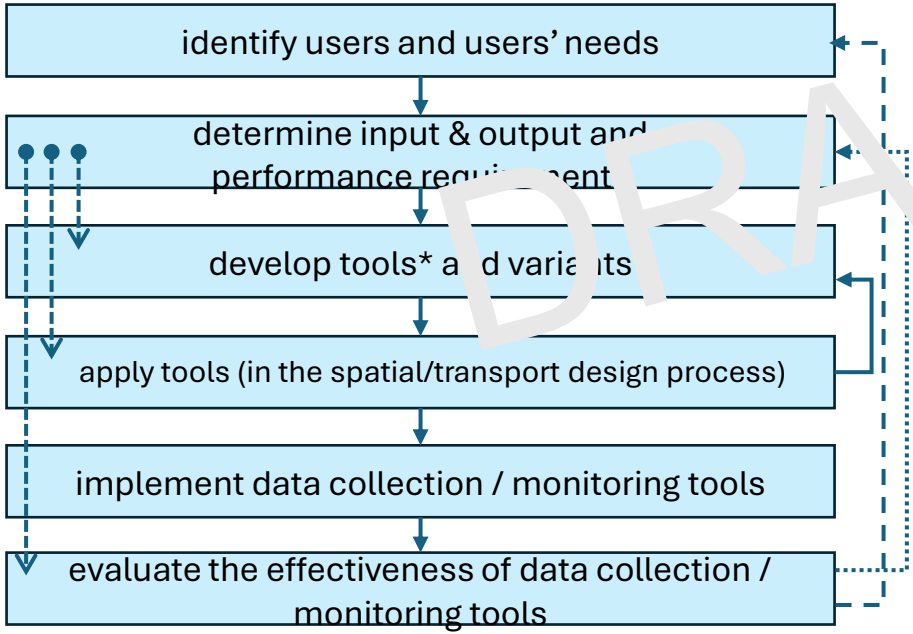


related knowledge questions for the design of the design process

- ho are stakeholders, who to involve how and when?
- ow to classify and prioritize criteria?
- what are the degrees of freedom?
- what (DT) tools are useful in designing?
- how to ex-ante estimate effects? (KPI)
- how to display and estimate effects, experiences and impacts? (KPI)
- how to measure/monitor effects in real life?

design and research side – by - side

simplified design process



*related knowledge questions for the design of (DT) tools**

were the tools useful for identified users, both in design & monitoring?

did we define appropriate input, output and performance requirements?

do we need updated or other (DT) tools*?

could the KPI reliably be determined and shared with users?

feed-back loops

to strengthen *process*

**note:* different types of tools will be developed, some dedicated to the design phase, others to the monitoring phase

Interactive Session 1: Citizen engagements

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LUNCH

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Researchers Presentations

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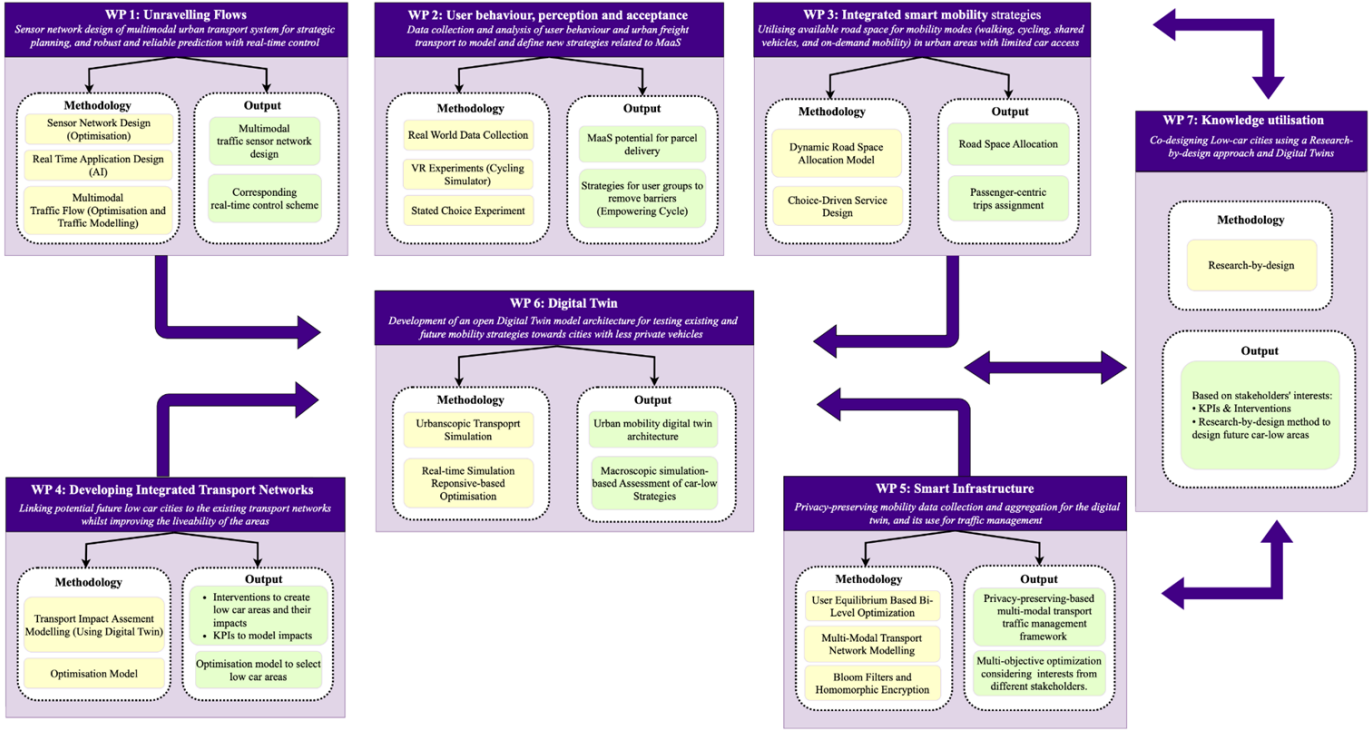
Introduce the Research Topics



Presenters

- Presenter 1 - Mohammed (WP 1)
- Presenter 2 - Yuxing (WP 1/5)
- Presenter 3 - Dennis (WP 2)
- Presenter 4 - Andrea (WP 2)
- Presenter 5 - Nourhan (WP 3)
- Presenter 6 - Jyotsna (WP 4)
- Presenter 7- Dingshan (WP 5)

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TOPIC: **Sensor Network Design for Strategic Multi-modal Transportation Service Planning**

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Idea

KPIs for Low-Car Areas

Sensor Network Design Optimization

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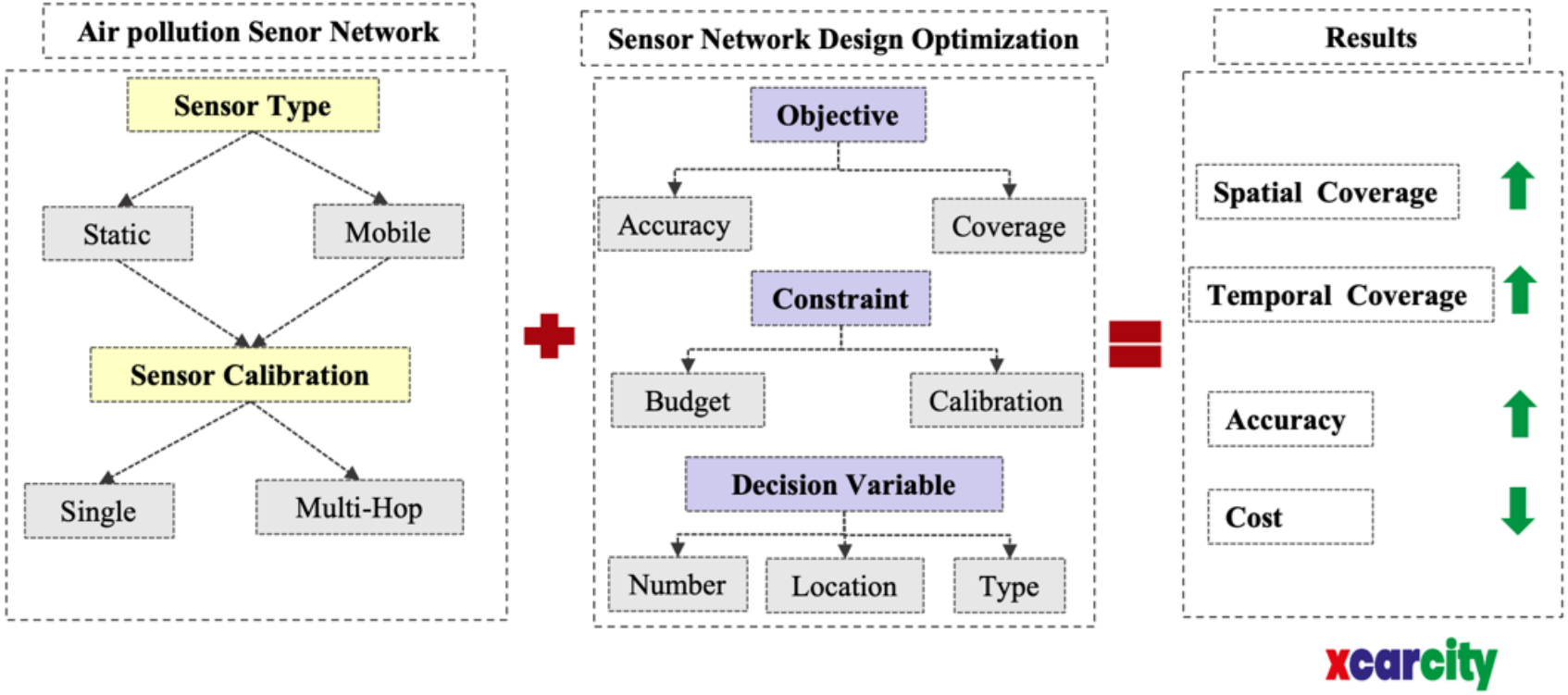
KPI (Air Pollution)



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Sensor

Air pollution Monitoring

Fix sensor

High quality ☺
High cost ☹
low spatial coverage ☹

Mobile sensor

Low cost ☺
High spatial coverage ☺
Low quality ☹
Need for calibration ☹

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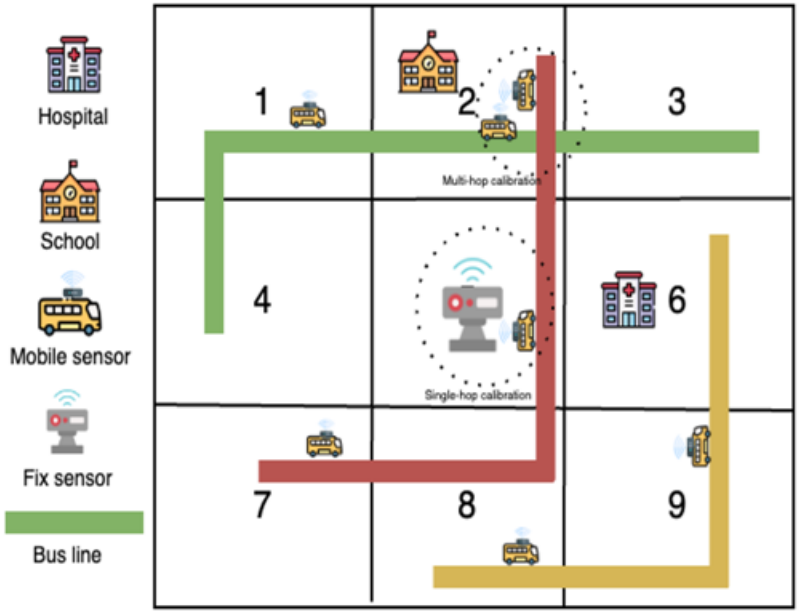
Network



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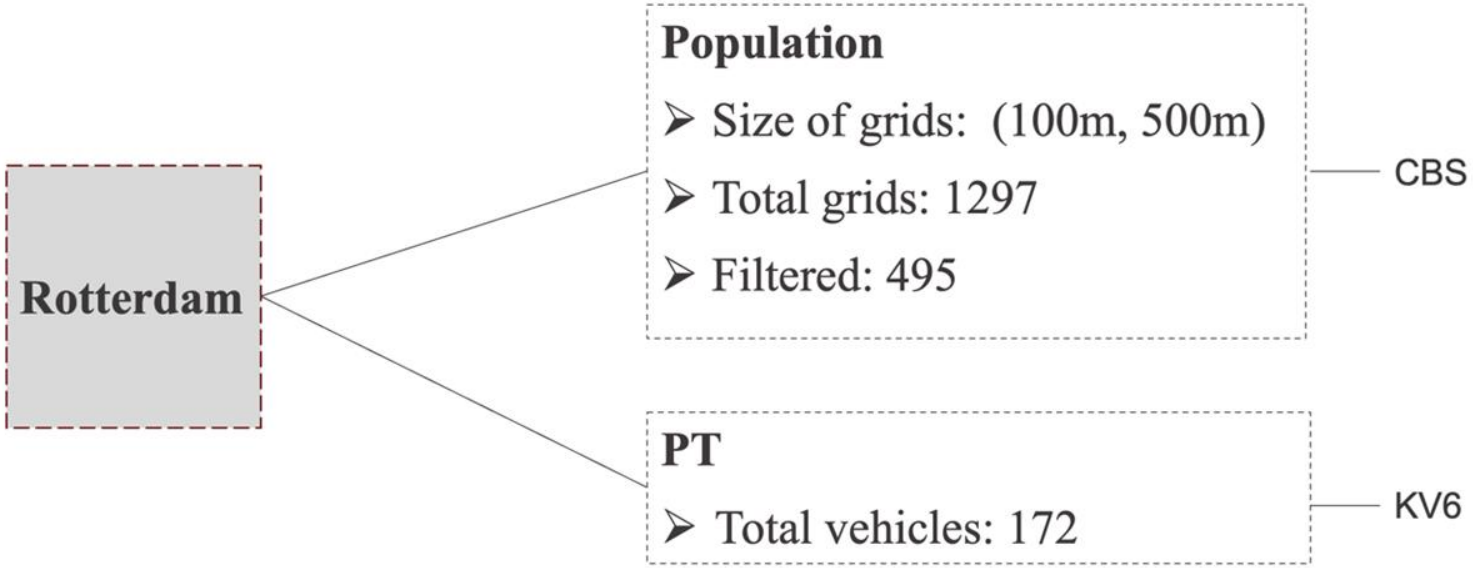
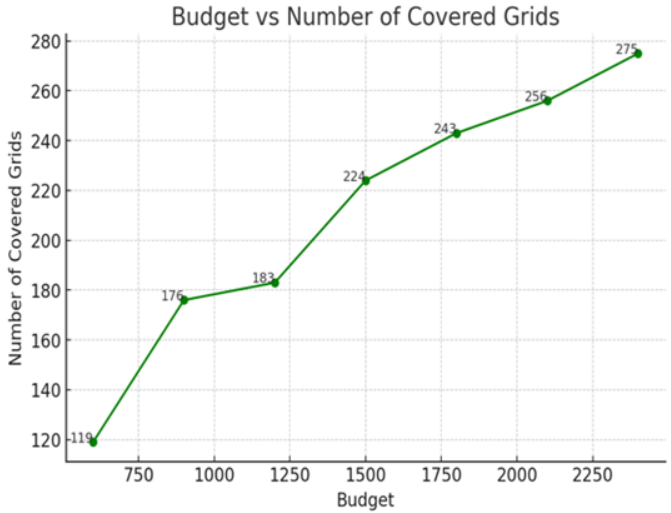
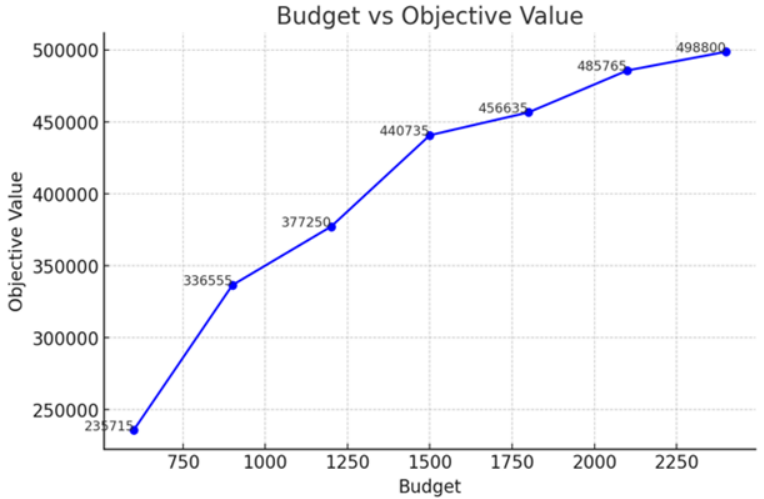
Case study

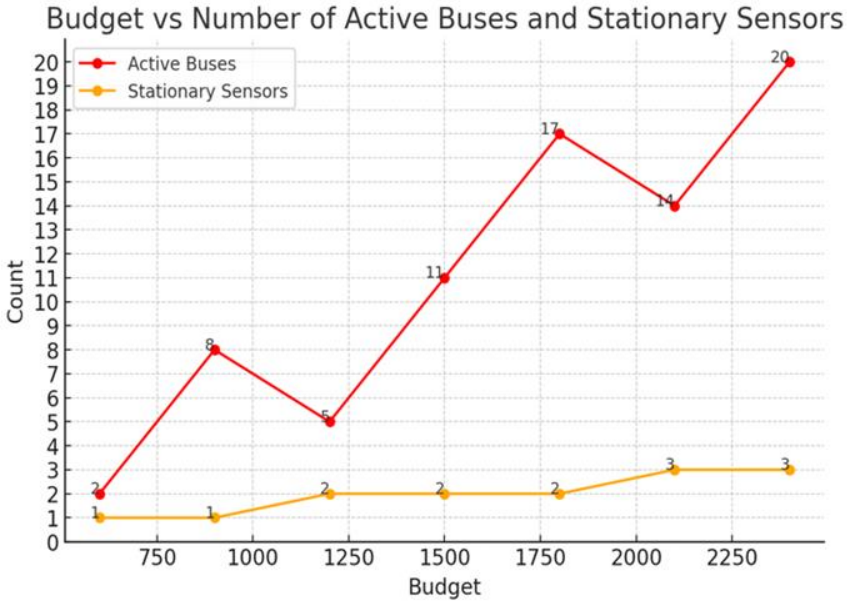

Rotterdam
Population
Size of grids: (100m, 500m)
Total grids: 1297
Filtered: 495
CBS
PT
Total vehicles: 172
KV6

Result


Budget vs Number of Covered Grids
Number of Covered Grids
Budget
280
260
240
220
200
180
160
140
120
750
1000
1250
1500
1750
2000
2250
119
176
183
224
243
256
275

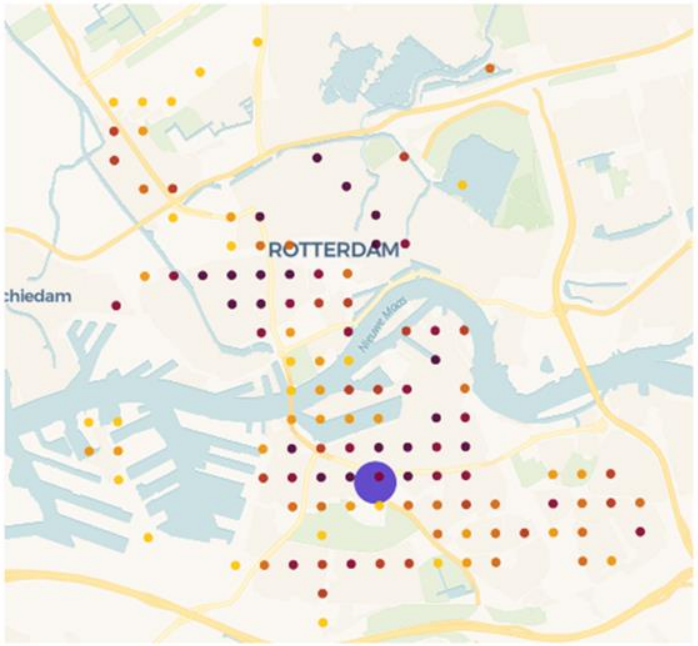

Budget vs Objective Value
Objective Value
Budget
500000
450000
400000
350000
300000
250000
750
1000
1250
1500
1750
2000
2250
235715
336555
377250
440735
456635
485765
498800

Result

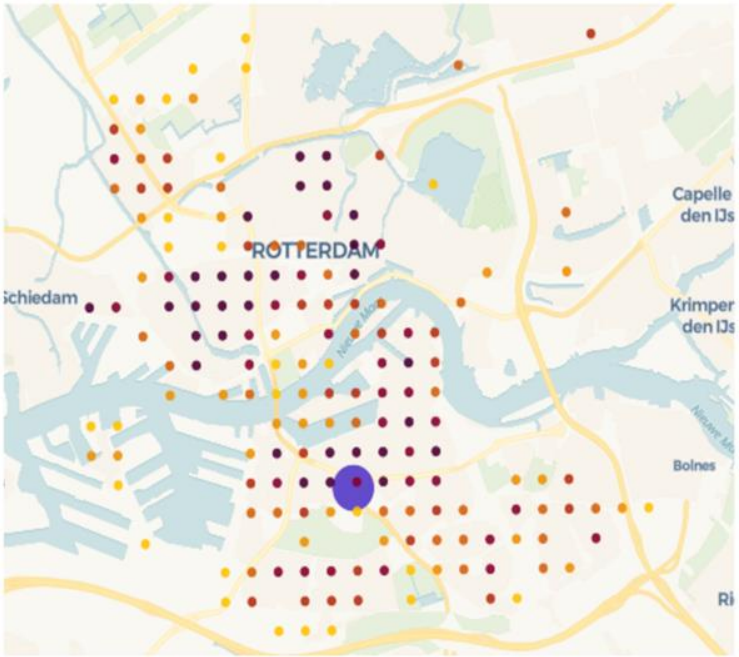

Budget vs Number of Active Buses and Stationary Sensors
Active Buses
Stationary Sensors
Count
Budget
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
750
1000
1250
1500
1750
2000
2250
2
8
5
11
17
14
20
1
1
2
2
2
3
3

Result

600

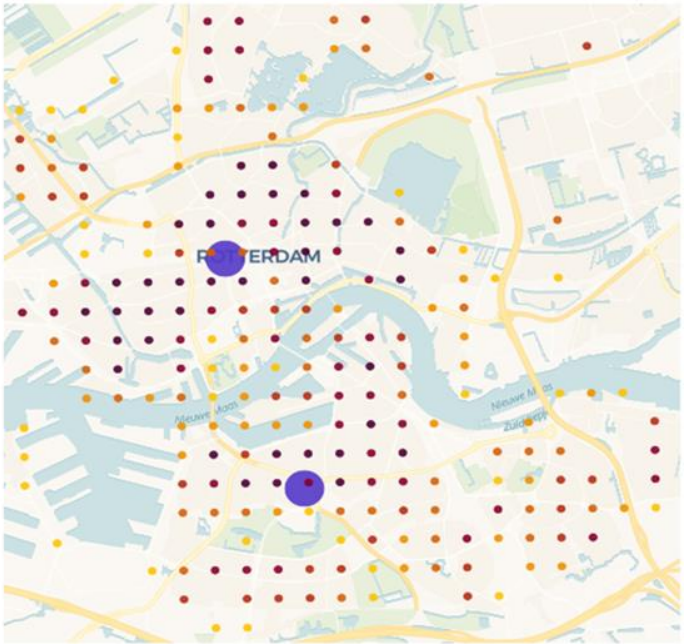


900

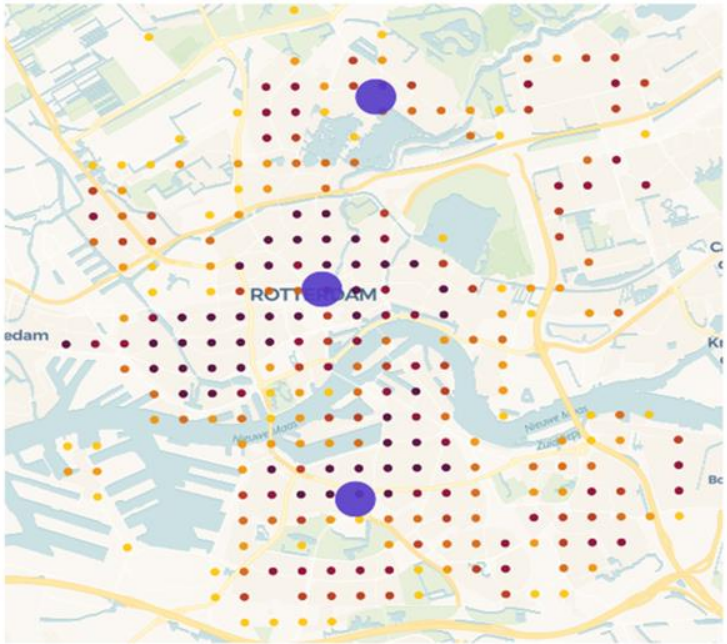


Result

1500



2400



Sensor network design for real-time traffic management

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Sensor network design for real-time traffic management

Sensor network design for real-time traffic management

(Ir. Yuxing Cheng, TU Delft)

- ***Provide methodology, tools, guidelines for sensing network design*** *to support multimodal traffic management*
- *Quantify the "**value of information**" for low-car area management applications*
- *Focus on using **Explainable, robust and efficient AI***

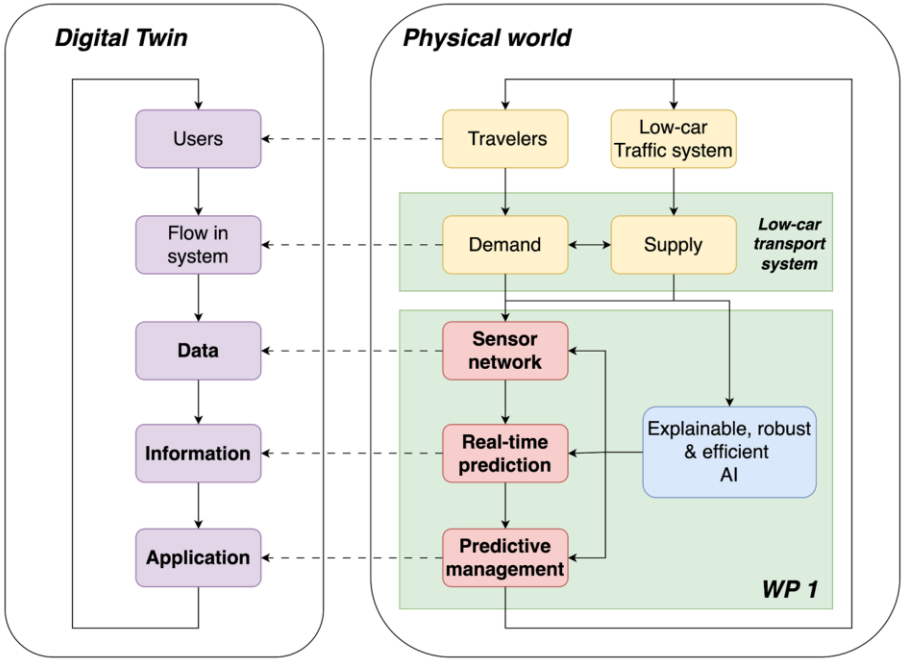

Figure: Correlation between the framework of physical transport system and digital twin

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Sensor network design for real-time traffic management

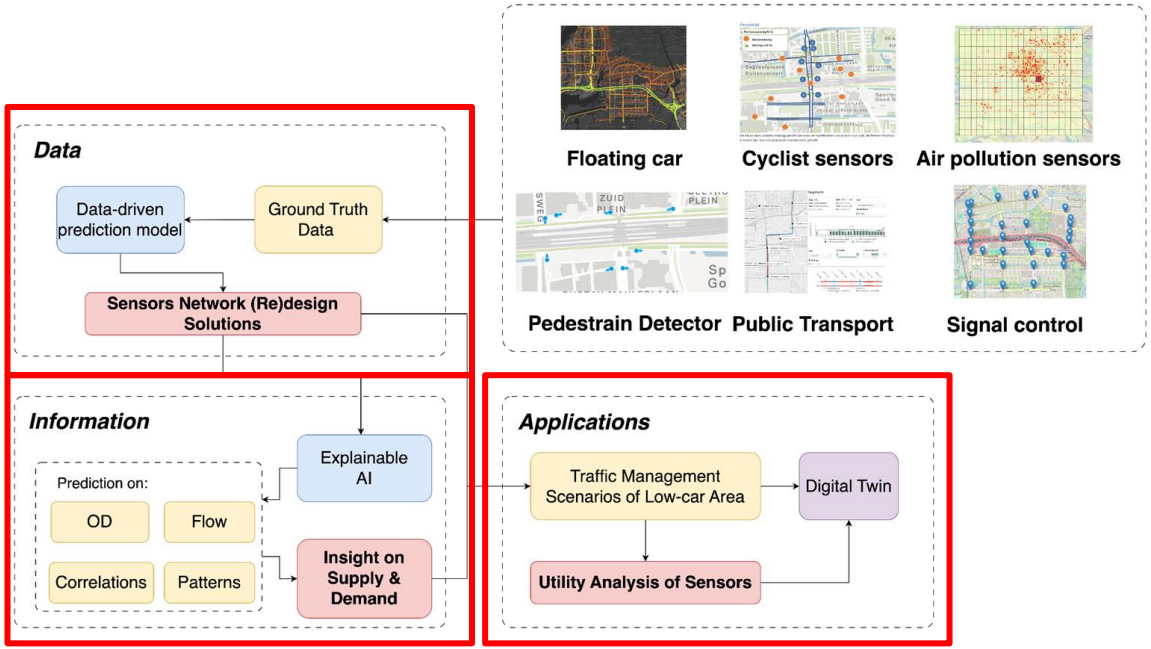

Figure: Framework of WP 1- Chain of Data, Information, and Application

Research modules

1. Sensor network design for **data-driven prediction model under budget constraints**

1. Sensor network optimization for **real-time Low-car area's KPIs prediction**

1. The **impact of sensor network design** for real-time Low-car area's management

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Effects of urban streetscapes on the perceived safety of cyclists

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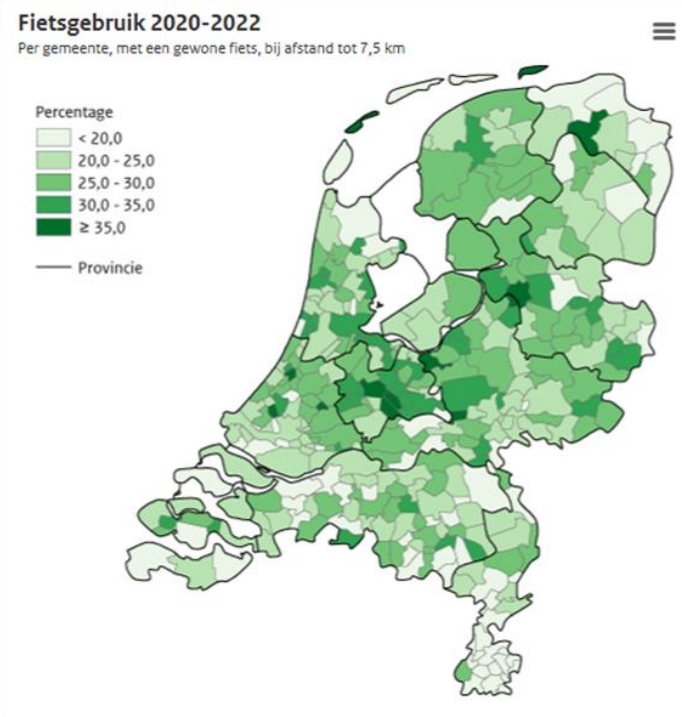
Effects of urban streetscapes on the perceived safety of cyclists

Context

Cycling is an integral part of the Dutch urban mobility system, and its share is growing.

Ensuring that cycling is an accessible mobility option is crucial.

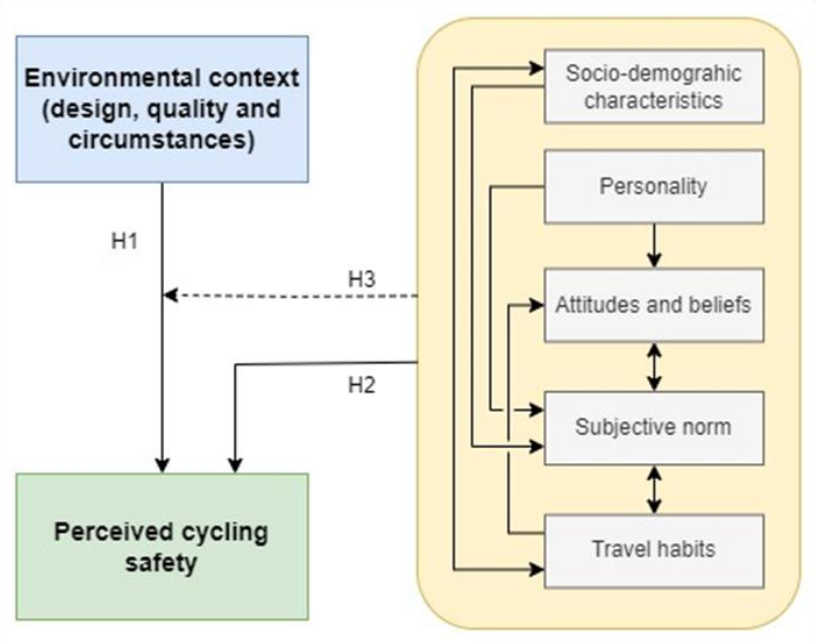
To date, research on cycling safety has primarily been conducted from a traditional traffic safety perspective.



Statistics Netherlands, 2022

Effects of urban streetscapes on the perceived safety of cyclists

Research framework



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Effects of urban streetscapes on the perceived safety of cyclists

Methods

1. **Survey-based experiment**

2. Cycling simulator-based experiment
3. Real world experiment

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Effects of urban streetscapes on the perceived safety of cyclists

Methods

1. Survey-based experiment
2. **Cycling simulator-based experiment**

Berge et al., 2024

3. Real world experiment

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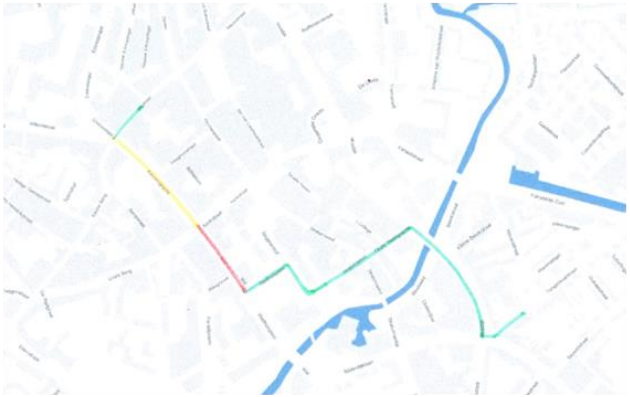
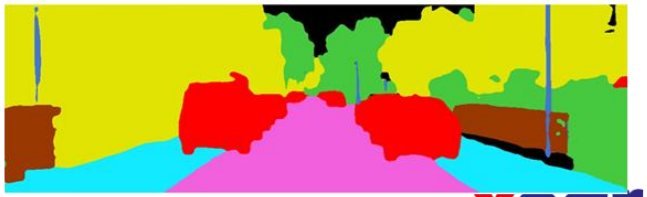
Effects of urban streetscapes on the perceived safety of cyclists

Methods

1. Survey-based experiment
2. Cycling simulator-based experiment
3. **Real world experiment**





TowardsAI.net, 2021

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Crowdsourced parcel Delivery (CSD)

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Parcel delivery challenges

Market

E-commerce

- Increasing demand with a purchasing rate in the Europe (Eurostat, 2024).
- Same day delivery.

Couriers' challenges

- Last mile costs can be up to 41% of the total supply chain (Statista, 2023).
- Short delivery time windows requests.
- Sustainable solutions needed.

Society

Urban planning

- Low space efficiency and short delivery time in city logistics. (topsector Logistiek & TNO, 2020).
- Design of zero emission zones and car-low areas.

Customer

- Parcel delays
- High cost of delivery

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How to tackle the challenges?

Define a feasible way to implement

Crowd sourced parcel Delivery

that:

- Complements the market challenges and
- Incorporates well in efficient and sustainable urban planning

Interviews with key stake holders

- Identify the best business model for the Netherlands

Agent based simulations

- To evaluate CSD performance in urban context.

CSD Pilots

- Evaluating a real-world pilot based on an ex-post analysis.

Future outlook

- Defining a comprehensive framework for the effective implementation of Crowd-Sourced Delivery (CSD)

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Interviews

To understand motivators, opportunities and barriers in implementing last mile Crowd-Sourced Delivery in urban areas of the Netherlands.

- Couriers
- MaaS/TNC
- Producers (e-commerce companies/ retail sector)
- Government

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Implementation barriers

Based on 13 interviews with key stakeholders we found:

Market dynamics	Business sustainability	Technical Feasibility	Policy and regulation
• Resistance towards new mobility (MaaS) • Demand unpredictability • Willingness to pay from the customer	• Unclear profitability for mobility providers • Strong competition • Parcel security and liability concerns	• Integration challenges for mobility and logistics. • Lack of standardized APIs hinders interoperability.	• Regulations made in a local level can vary. • Lack of policy enforcement.

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Topic: Integrated smart mobility strategies

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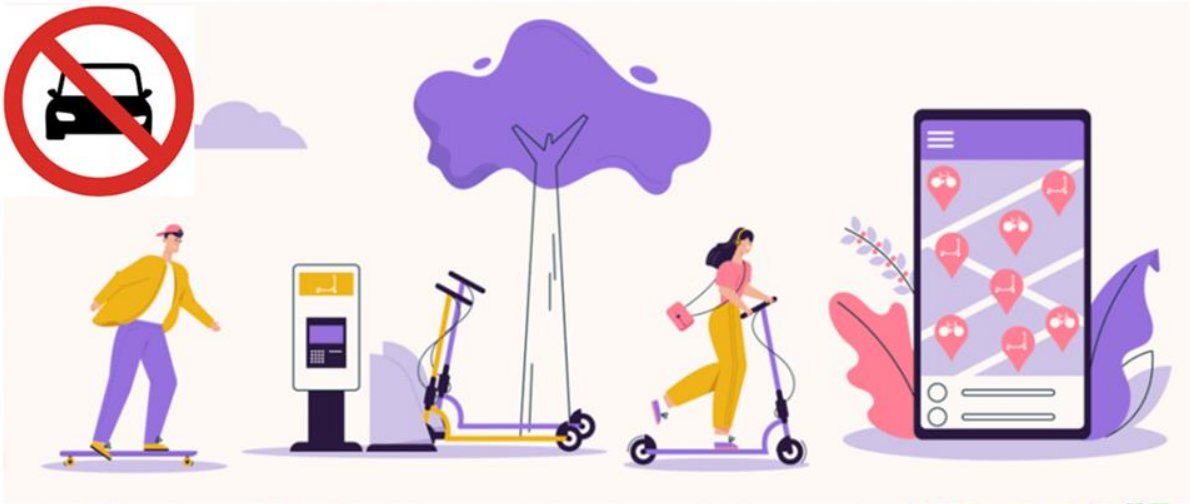
WP3: Integrated smart mobility strategies

- The objective of WP3 to investigate the possibility of multi-purpose usage of the available road space for different mobility modes (walking, cycling, shared vehicles and on-demand mobility) at different times in car-low or car-free urban areas



Working on better cities with less cars

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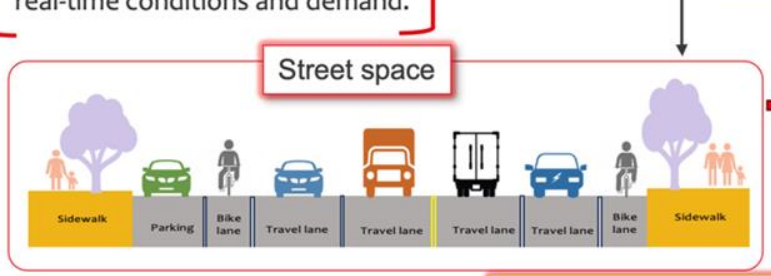
Research Objectives

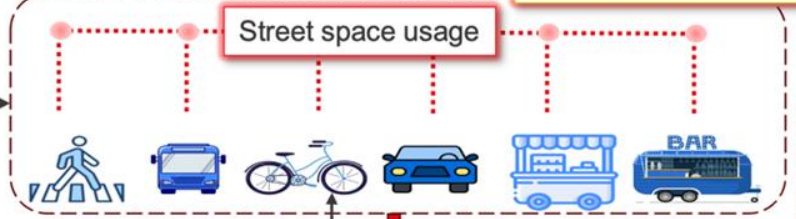
1. The practice of dynamically allocating road space to different modes of transportation based on real-time conditions and demand.



Dynamic Road Space Allocation Model

Optimization

Choice-Driven Service Design Model

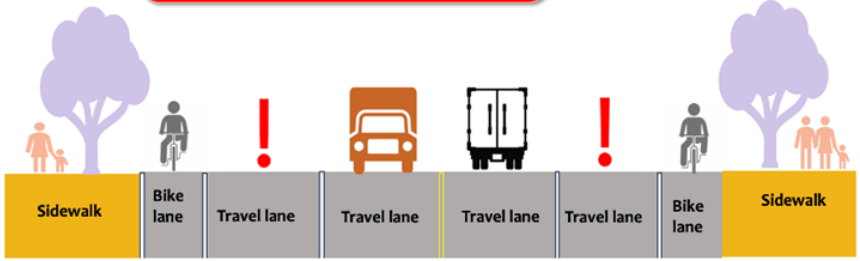


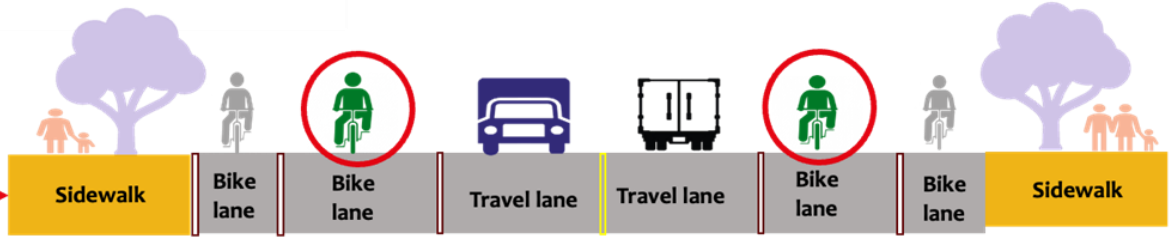
2. Focuses on providing customers with a range of options and empowering them to make choices that best suit their needs and preferences.

WP3: Static Road Space Allocation

Low Space Utilization

- Car-focused infrastructure has worsened traffic and made cycling and walking harder to adopt.
- This framework optimizes road space allocation to better integrate bikes into the existing road network.





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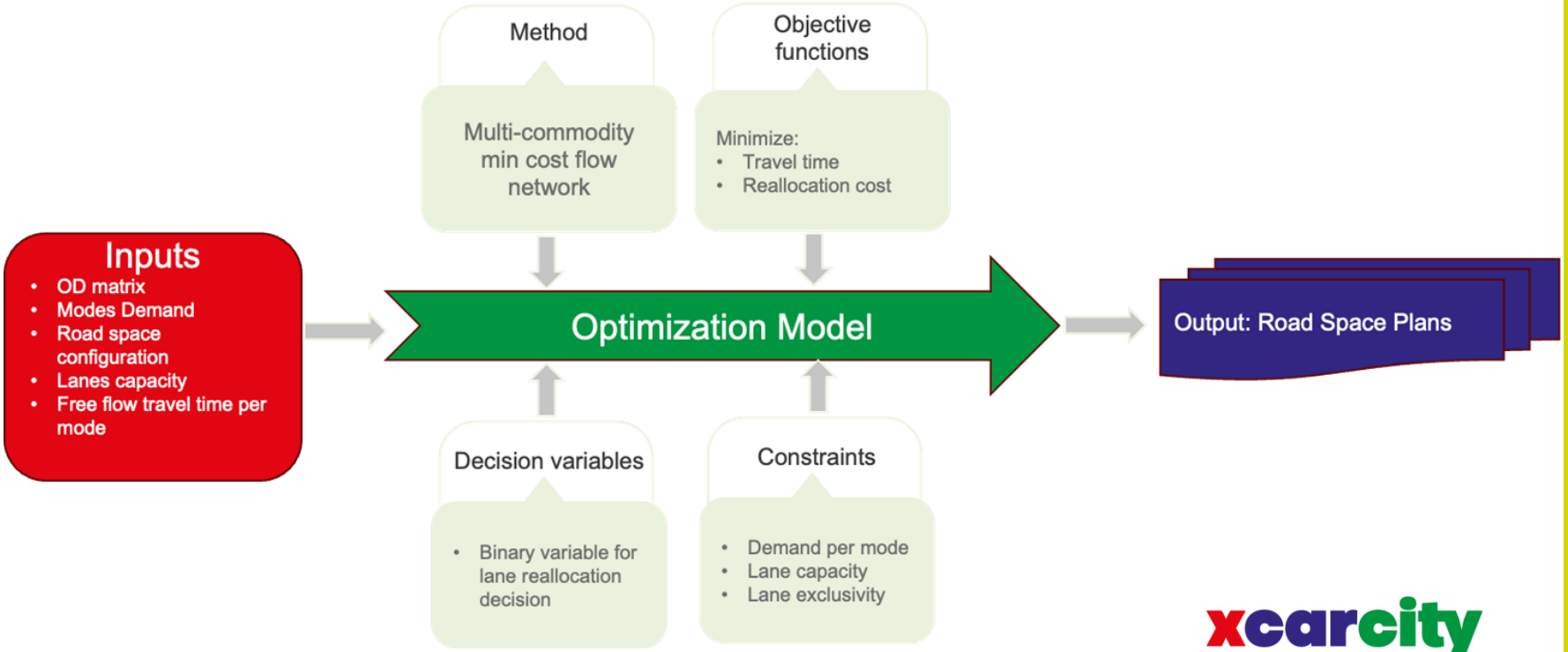
WP3: Static Road Space Allocation



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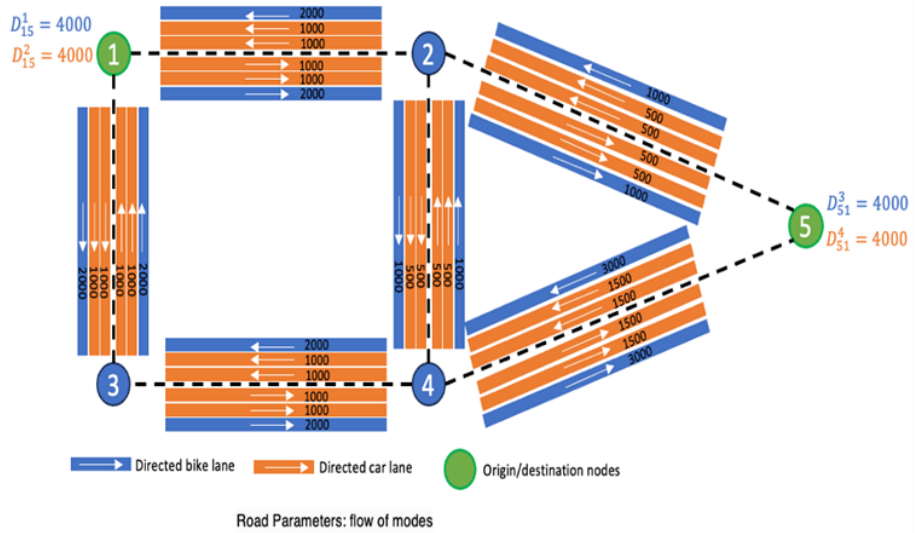
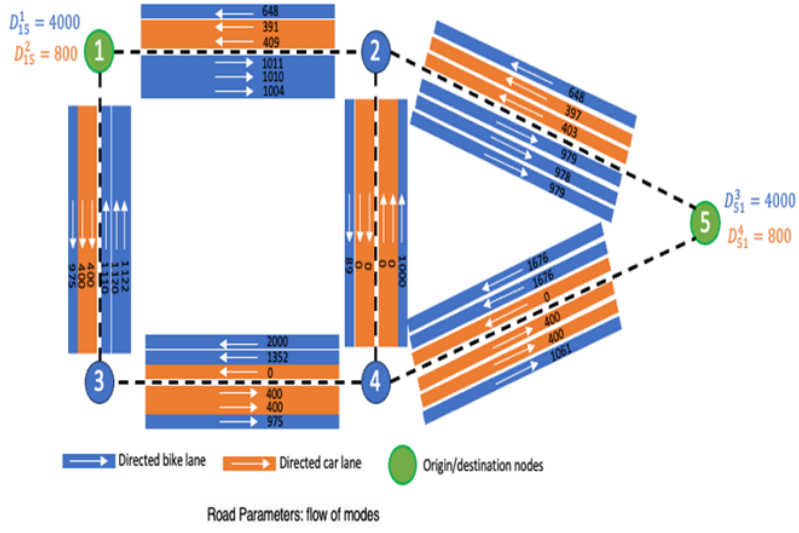
WP3: Static Road Space Allocation

The model is validated using a simplified test scenario.



Base case scenario where demands for both modes are equal



Low car demand with unchanged bike demand

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WP3: Case Study

The model is applied to the Zuidas case study under three scenarios:

- **Base Case:** Both bike and car demand are at full capacity.
- **Low Car Scenario:** Car demand is reduced by 50%, while bike demand remains unchanged.
- **No Car Scenario:** Car demand is entirely removed, with bike demand remaining the same.

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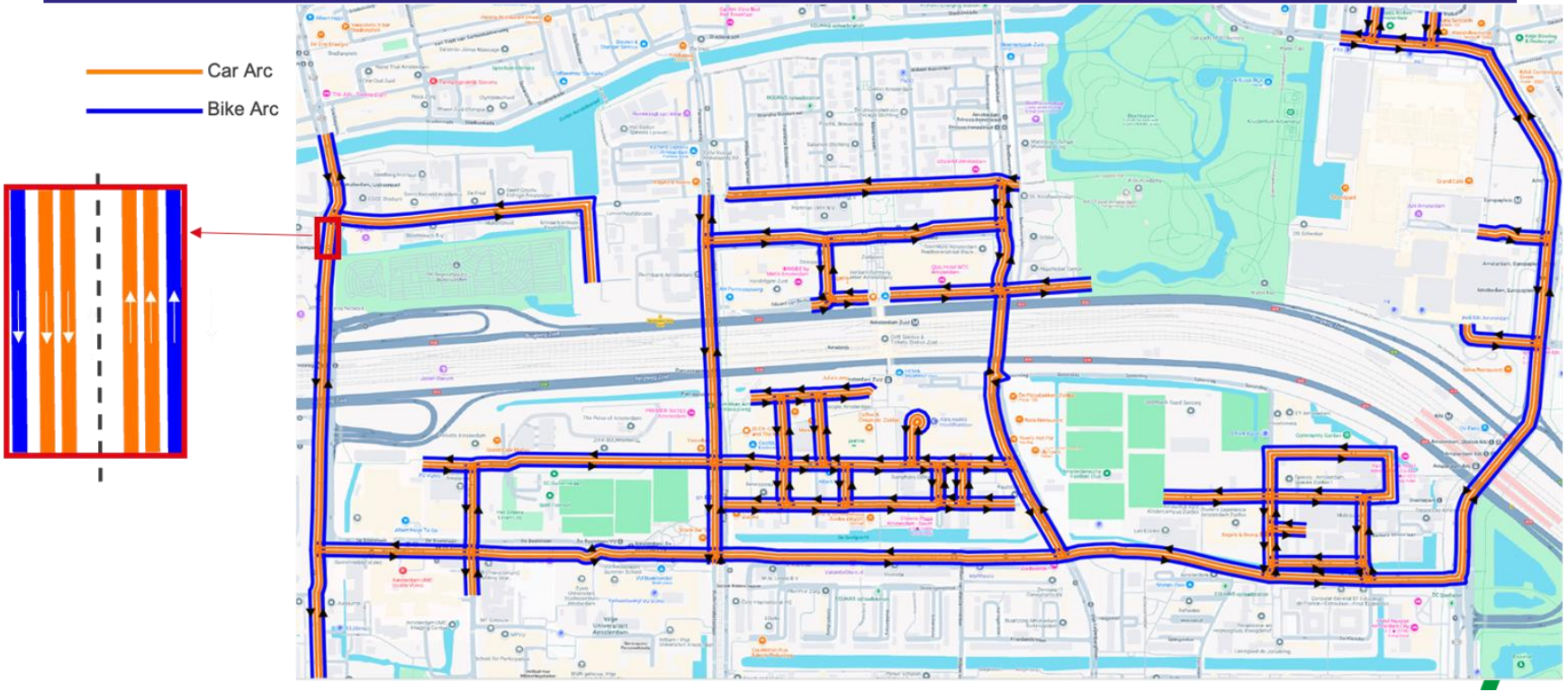
WP3: Current Topology

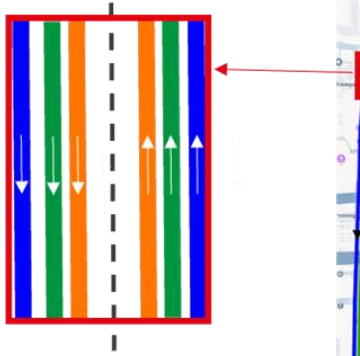


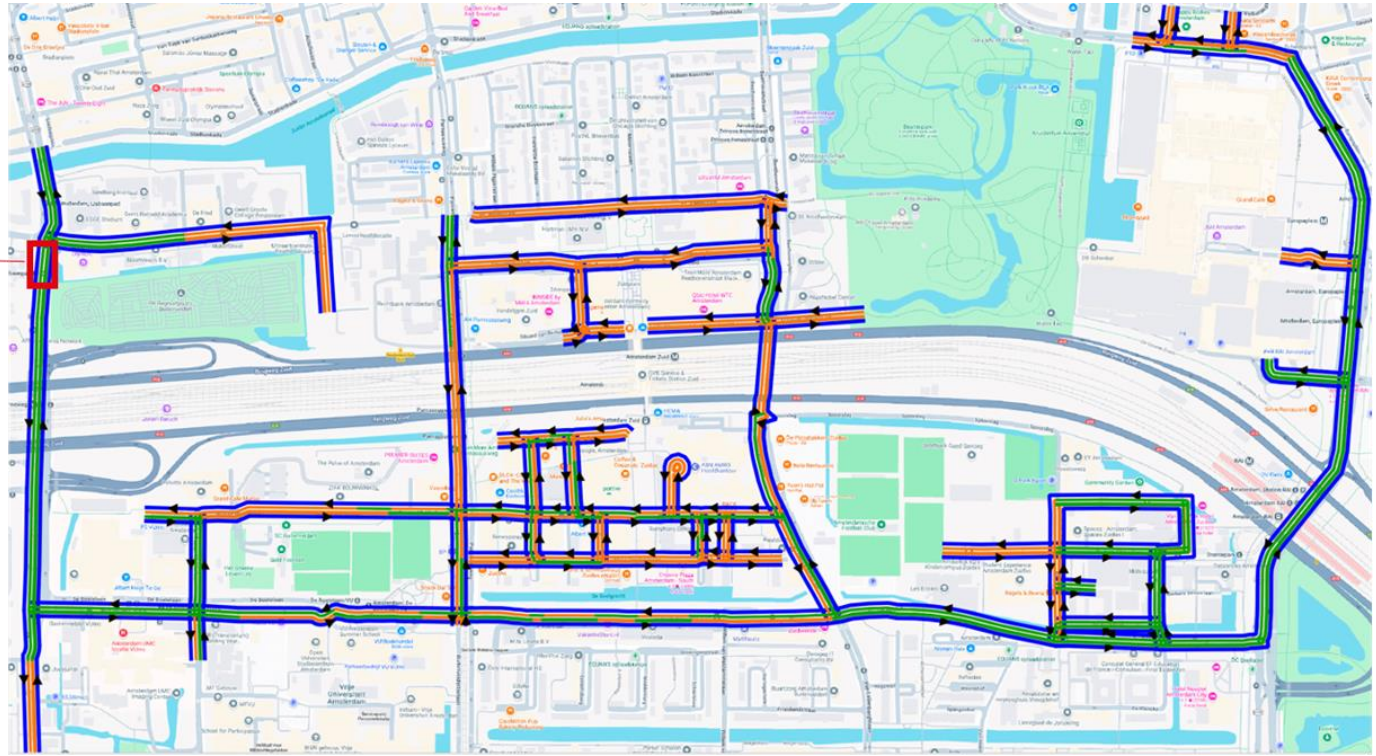
WP3:Low Car

Car Arc

Bike Arc

Car Arc where reallocation took place



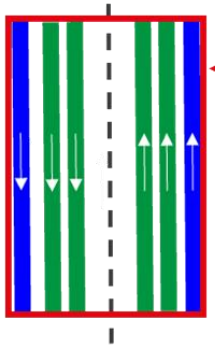


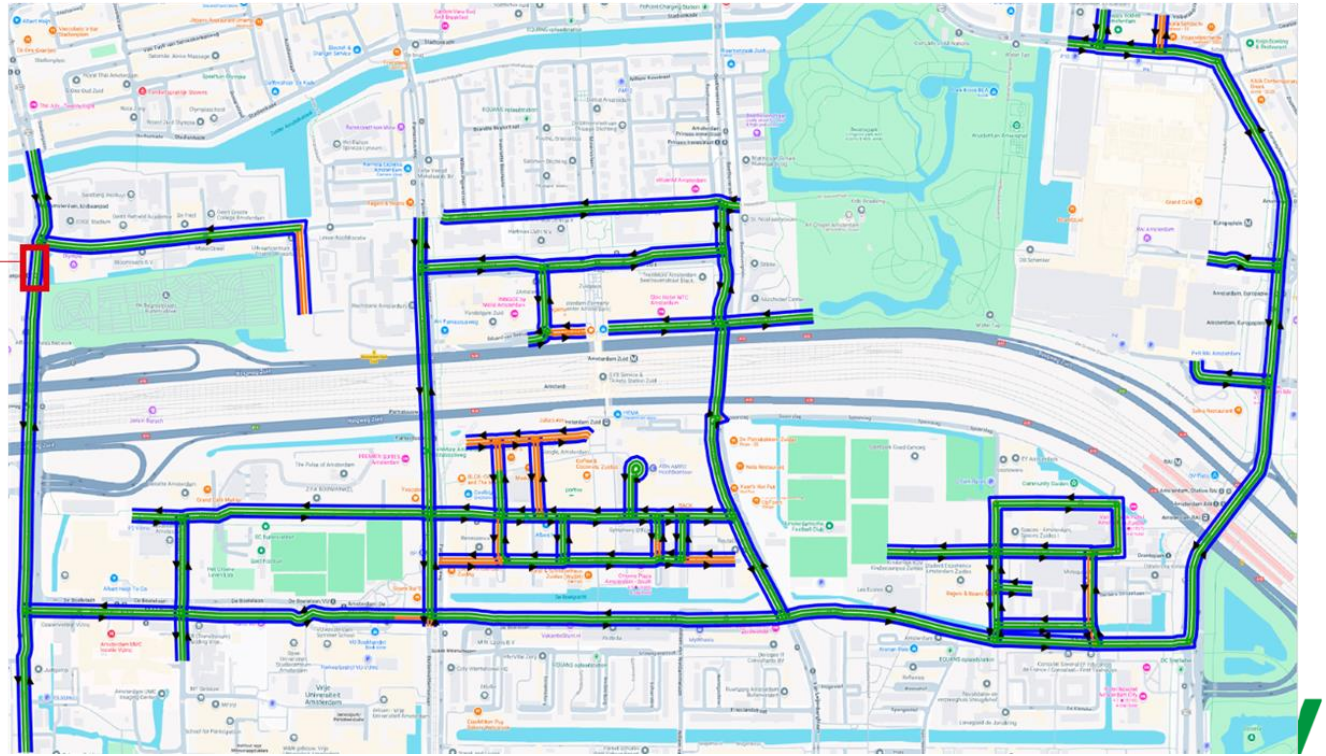
WP3: No Car

Car Arc

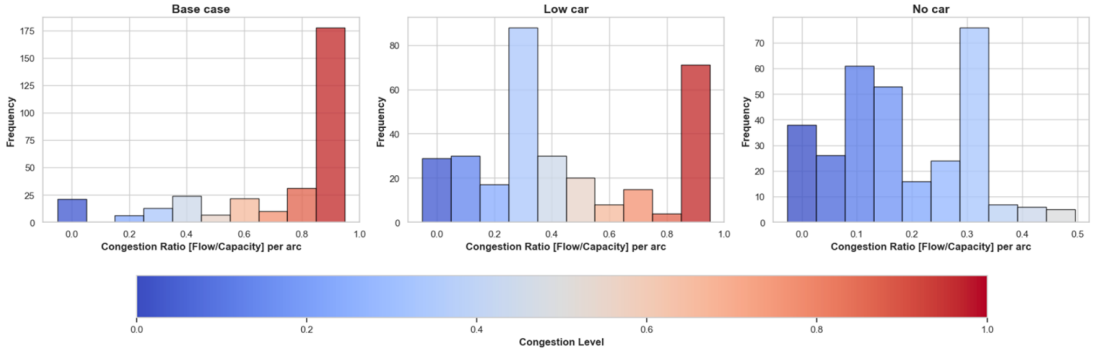
Bike Arc

Car Arc where reallocation took place

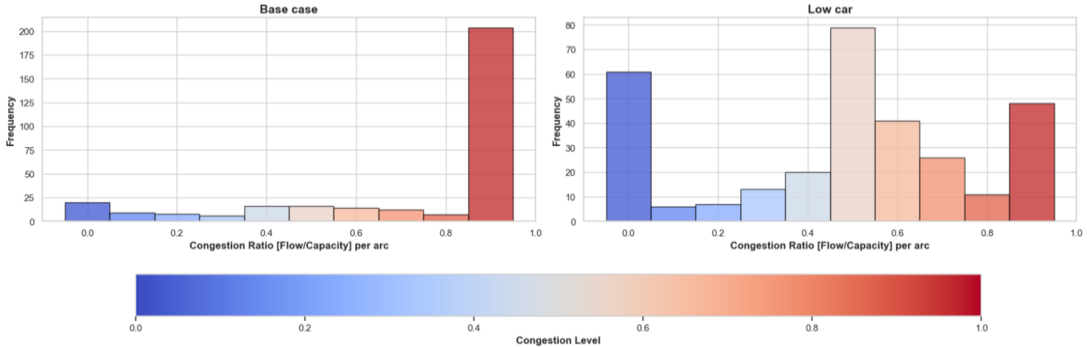




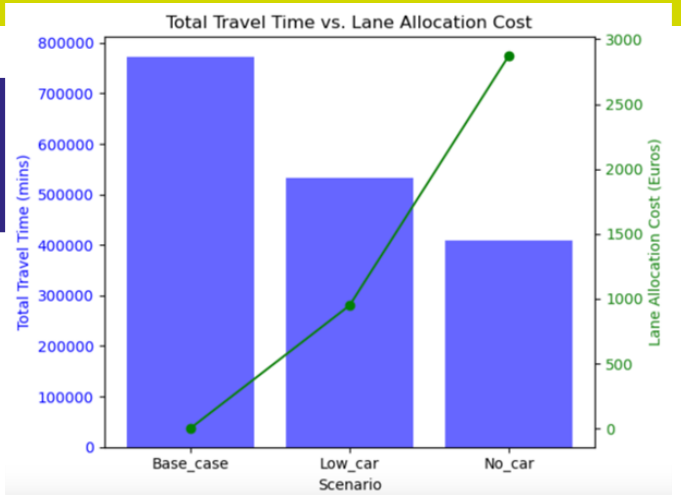
WP3:Results

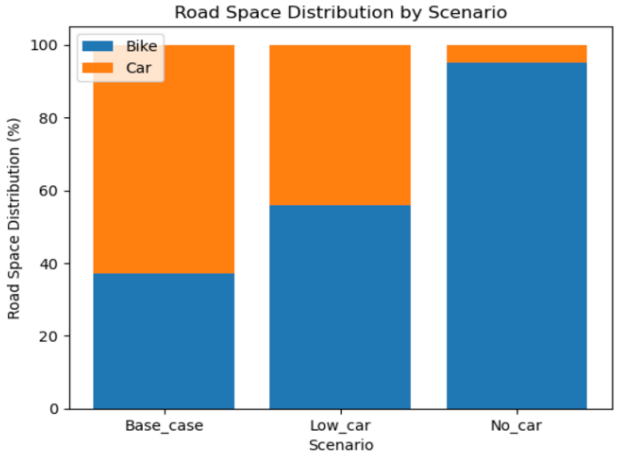


Bike congestion over the three scenarios



Car congestion over the three scenarios





WP4 : Developing Integrated Transport Network

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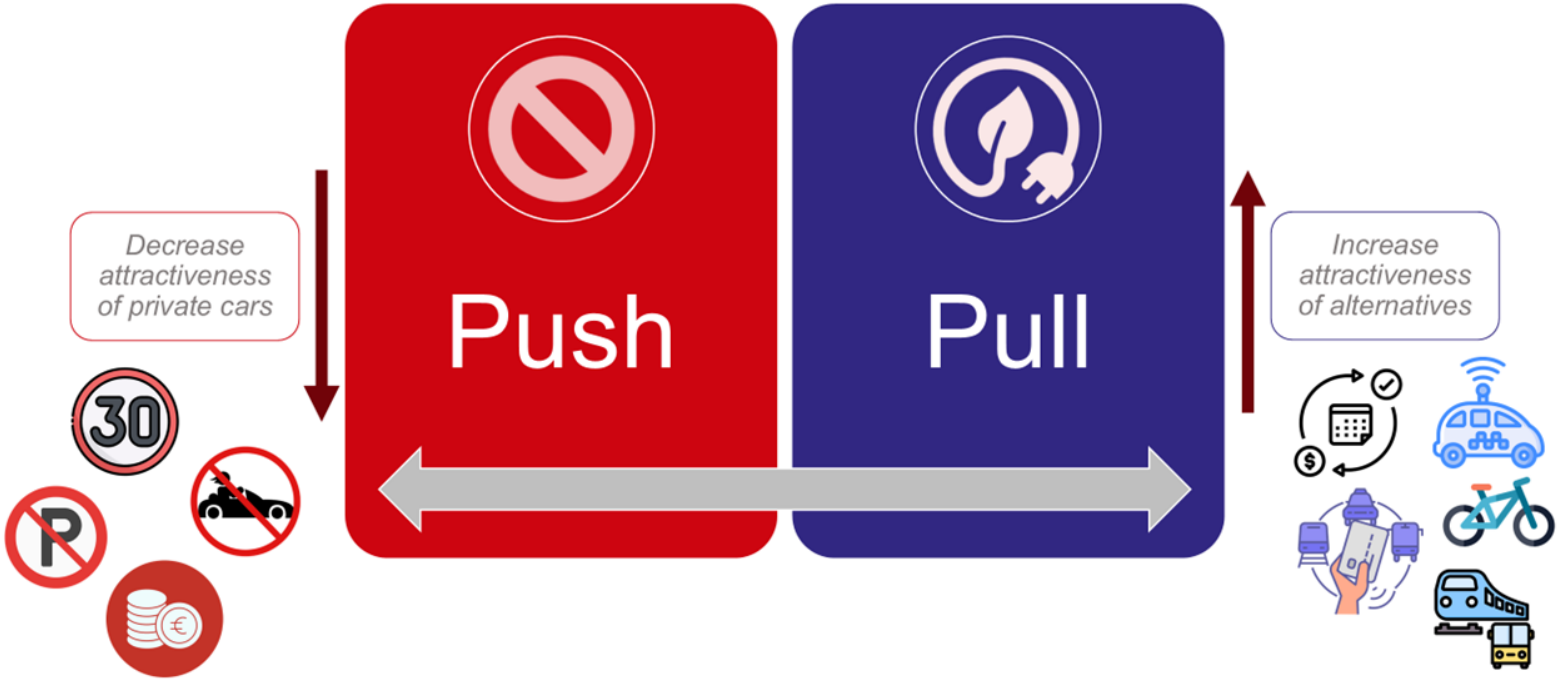
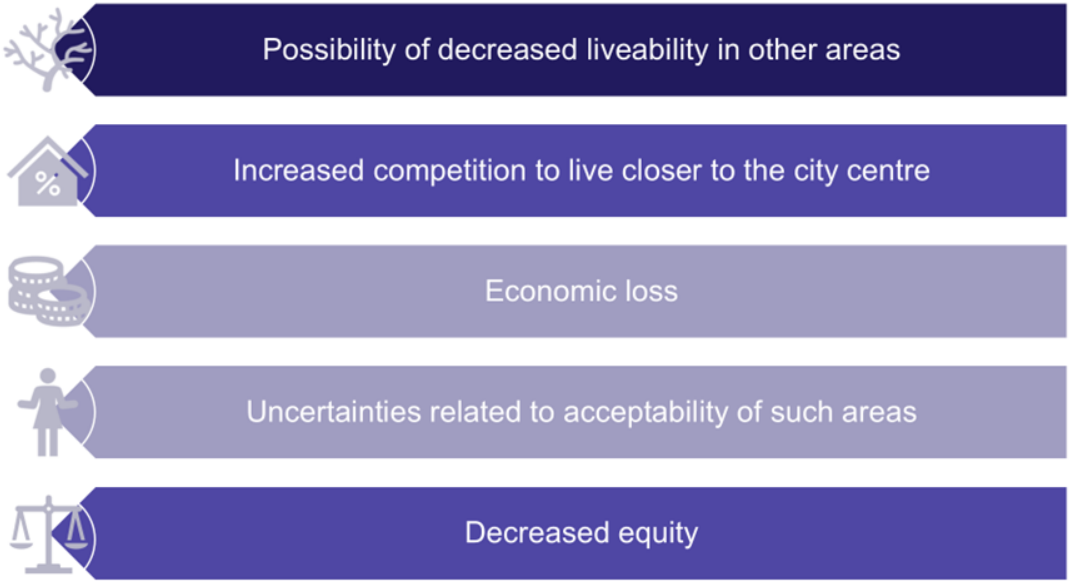
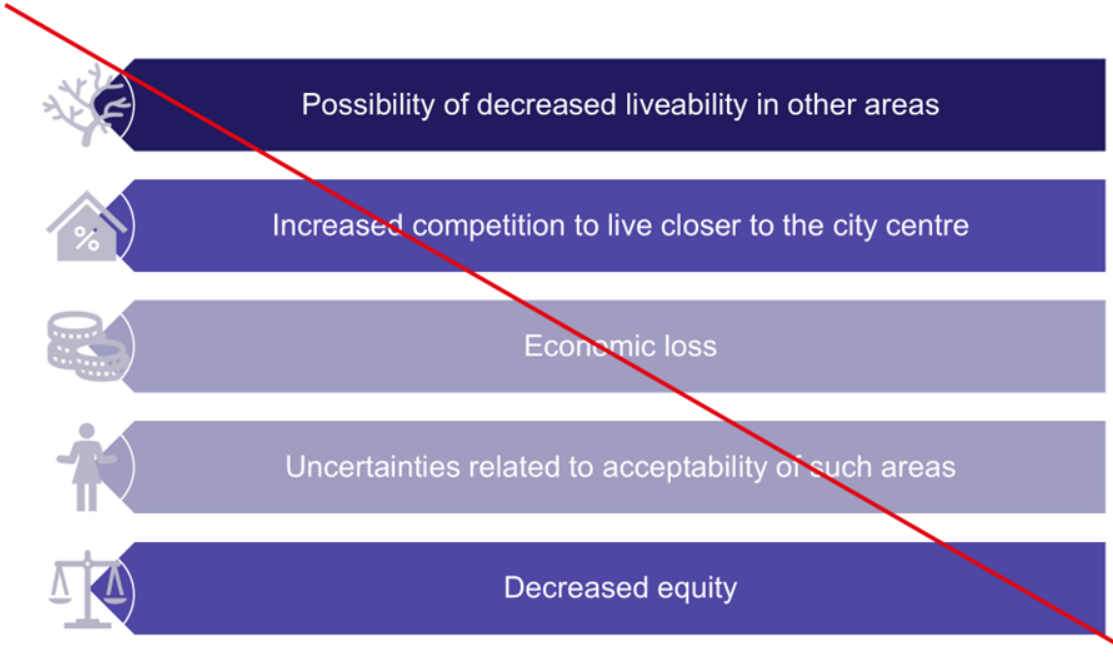
Push & Pull- Interventions



But if not planned properly..



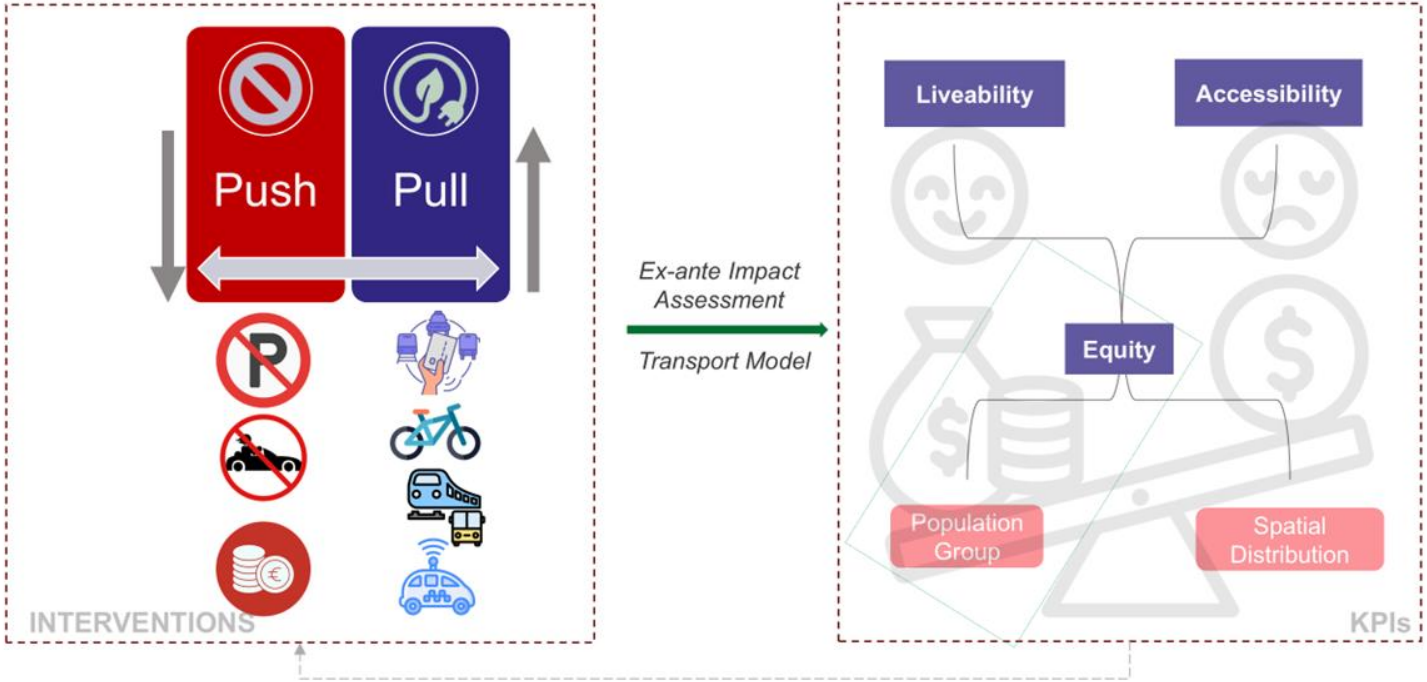
But if not planned properly..



Ex- Ante Detailed Quantitative Studies

Shift towards new set of indicators

Framework


Push
Pull
INTERVENTIONS
Ex-ante Impact Assessment
Transport Model
Liveability
Accessibility
Equity
Population Group
Spatial Distribution
KPIs

Measuring Equity

Gini's Coefficient

An indicator of social inequality

Value ranges between 0 & 1;

where 0 indicates a scenario of perfect equality and 1 indicates perfect inequality

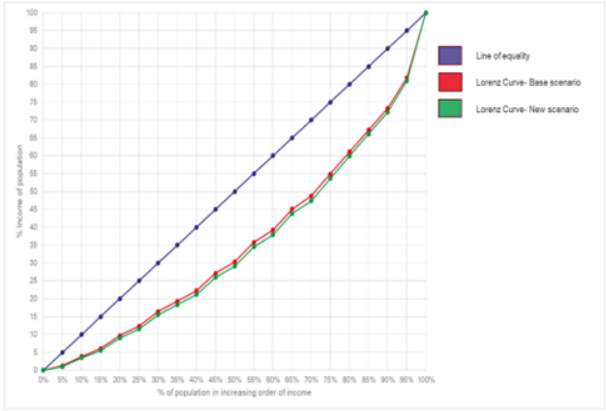
$$G = \frac{1}{2N^2\mu}\sum_i\sum_j |y_i - y_j|$$

G=Gini Coefficient
N= Population groups
i = [1,N]
j= [1,N]
y_i = Welfare of a user group 'i'
μ = Mean welfare value

Utilised in conjunction with Lorenz curve

Lorenz Curve

Lorenz Curve is used to visualize the distribution effects by plotting the cumulative distribution function of an attribute across the population



Palma's Ratio

Alternative/complimentary approach to Gini's

Measures the ratio of welfare distribution between the Richest 10% and Poorest 40% groups.

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Application

Economic Impact Analysis
Economic equity change across different income groups, as an effect of a new intervention

$$dCg_{kl} = dC_{kl} + v_m dT_{kl}$$

dCg = change in genarilsed cost of travel

dC = change in monetary cost (including parking price change)

v = value of time for a household 'm'

dT = change in travel time

Impact On Mode Shift
Change in car usage across different income groups as an effect of a new intervention

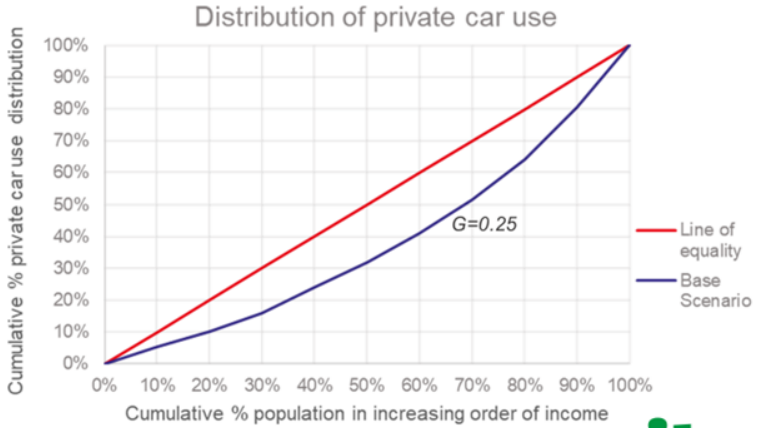
For the Netherlands

ODiN 2018

- Representative travel survey data of the Netherlands
- Age>18 Purpose: Work/Business
  N: 62791 Urbanization: High

Analysis

- Higher the household income, higher the private car usage
- Higher income households travel more distance than lower income households



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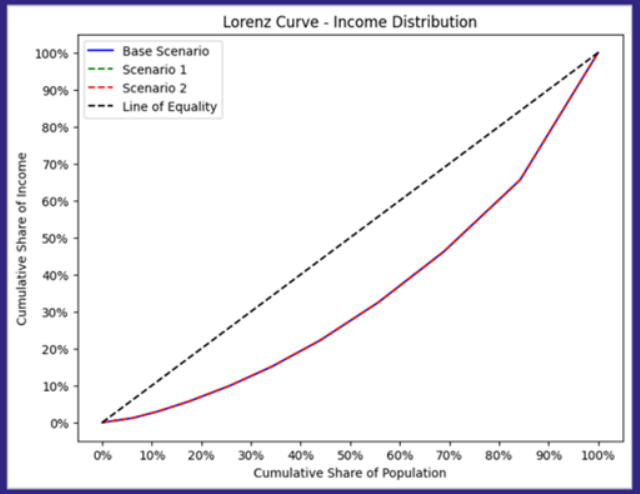
Mode Choice Model- MNL

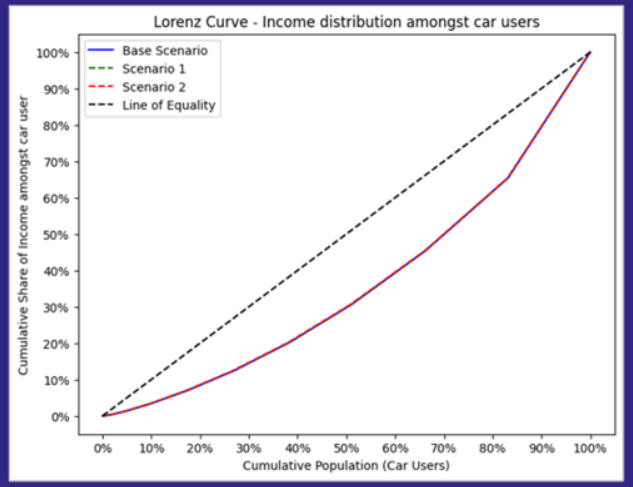
- Segmented model- 10 Income Groups; Based on ODiN 2018 data
- Test scenarios
  - Base Scenarios
  - Scenario 1: Trave Cost by car increased by 20%
  - Scenario 2: Travel Cost by car increased by 20% & Travel time by car increased by 10%

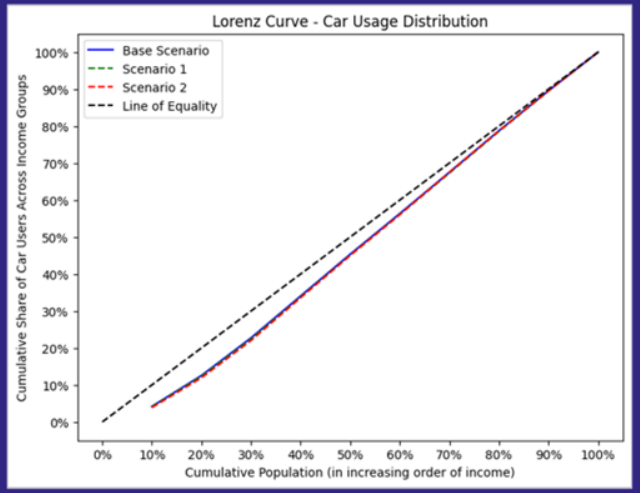
Modes	Attributes	Co-variates (to be added)
• Car-Driver • Car-Passenger • BTM • Train • Bicycle • Walk	• Travel Time • Travel Cost • Parking Cost • Employer Compensation • Discount subscription (PT)	• Income • Urbanization level • Purpose of travel • Age • Gender • Household Composition • Number of cars • Departure time

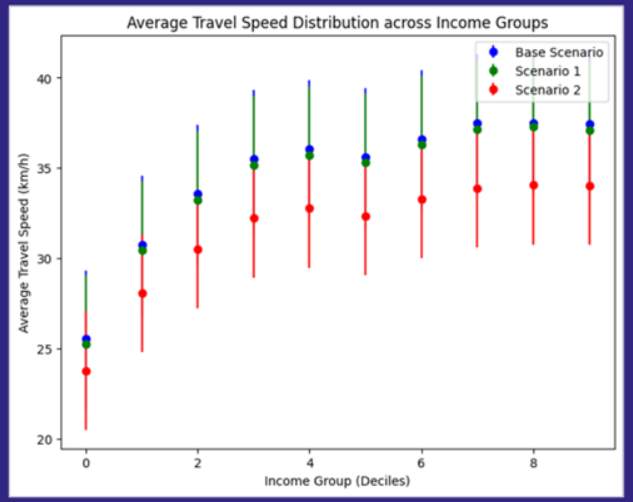
Test Run-Results

Scenario	Indicator	Income Inequity Across Population	Income Inequity Amongst Car Users	Car Usage Across Income Groups
Base Scenario	Gini's	0.3209	0.2873	0.0926
	Palma's	1.1329	0.9521	0.3417
Scenario 1	Gini's	0.3212	0.2869	0.0949
	Palma's	1.1347	0.9469	0.3452
Scenario 2	Gini's	0.3213	0.2852	0.1018
	Palma's	1.1354	0.9402	0.3559

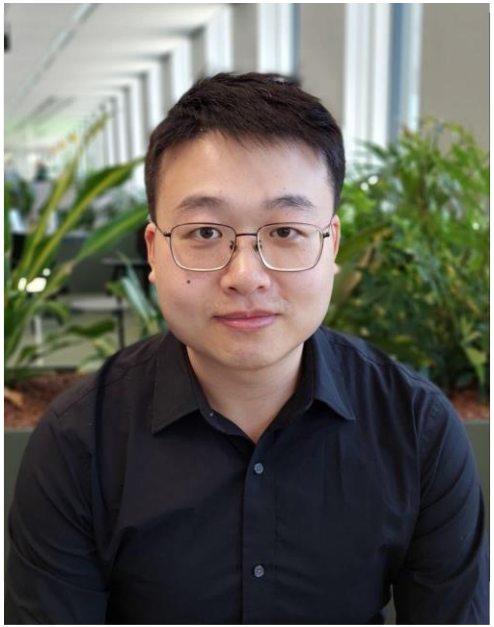

Lorenz Curve - Income Distribution
Base Scenario
Scenario 1
Scenario 2
Line of Equality
Cumulative Share of Income
Cumulative Share of Population
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%


Lorenz Curve - Income distribution amongst car users
Base Scenario
Scenario 1
Scenario 2
Line of Equality
Cumulative Share of Income amongst car user
Cumulative Population (Car Users)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%


Lorenz Curve - Car Usage Distribution
Base Scenario
Scenario 1
Scenario 2
Line of Equality
Cumulative Share of Car Users Across Income Groups
Cumulative Population (in increasing order of income)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%


Average Travel Speed Distribution across Income Groups
Base Scenario
Scenario 1
Scenario 2
Average Travel Speed (km/h)
Income Group (Deciles)
20
25
30
35
40
0
2
4
6
8

Multi-modal transport network management



Name: Dingshan Sun

PhD, Postdoctoral researcher

TU Delft

Email: d.sun-1@tudelft.nl

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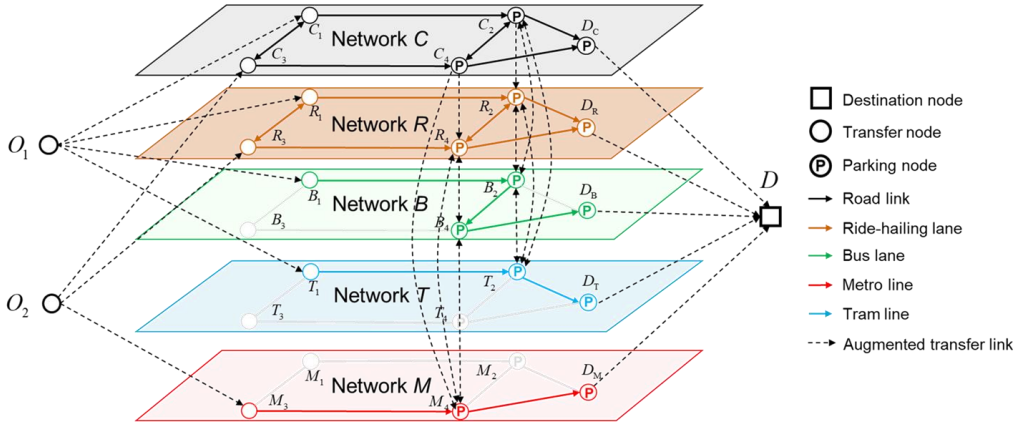
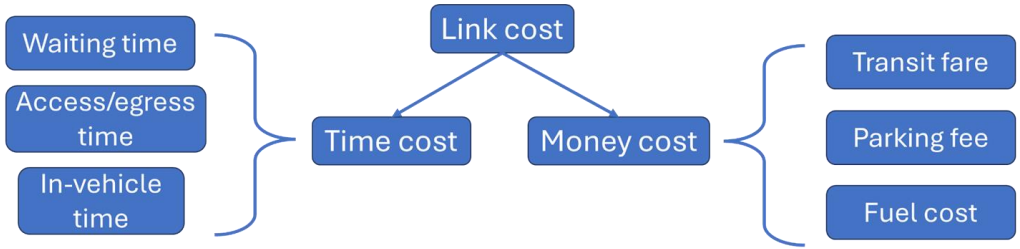
Multi-modal transport network management

Super-network model





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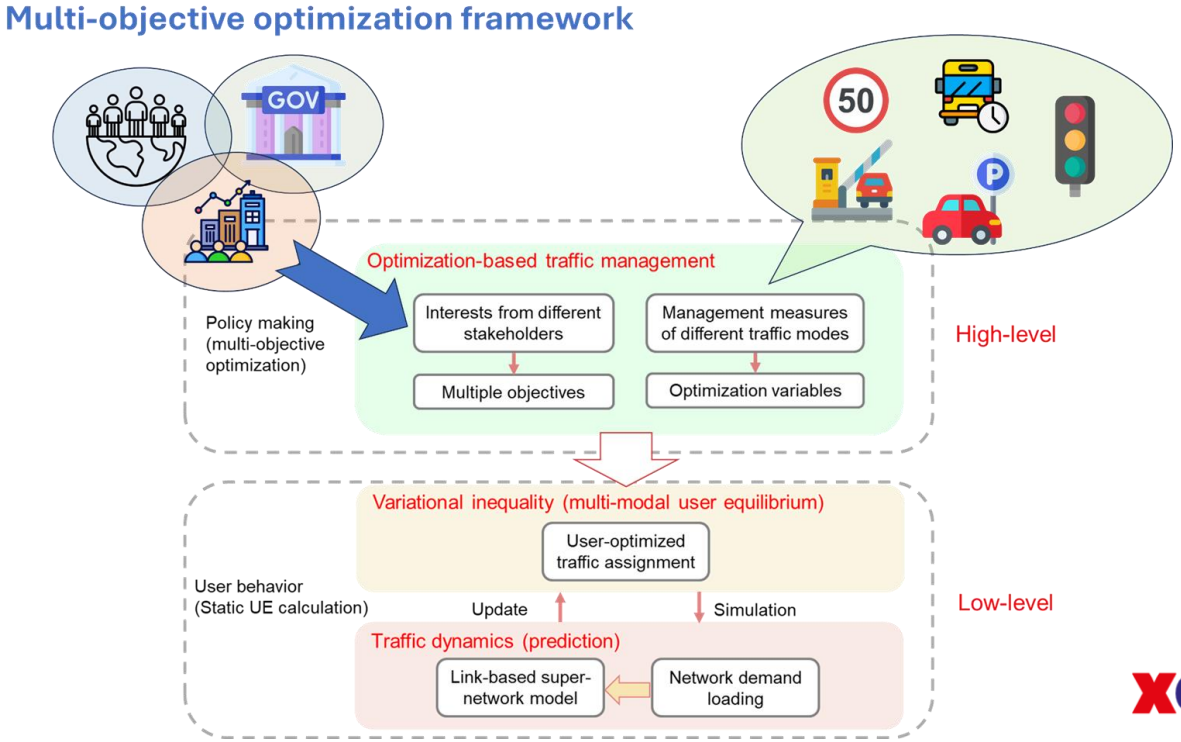
Bi-level multi-objective optimization framework



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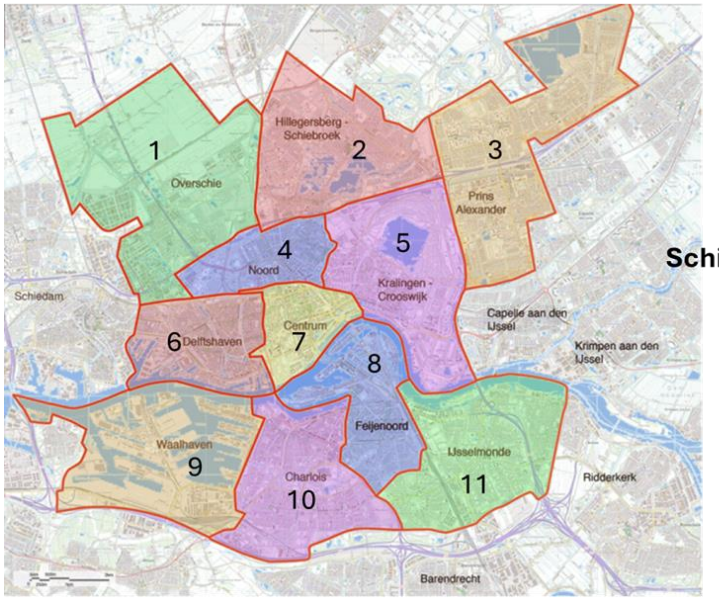
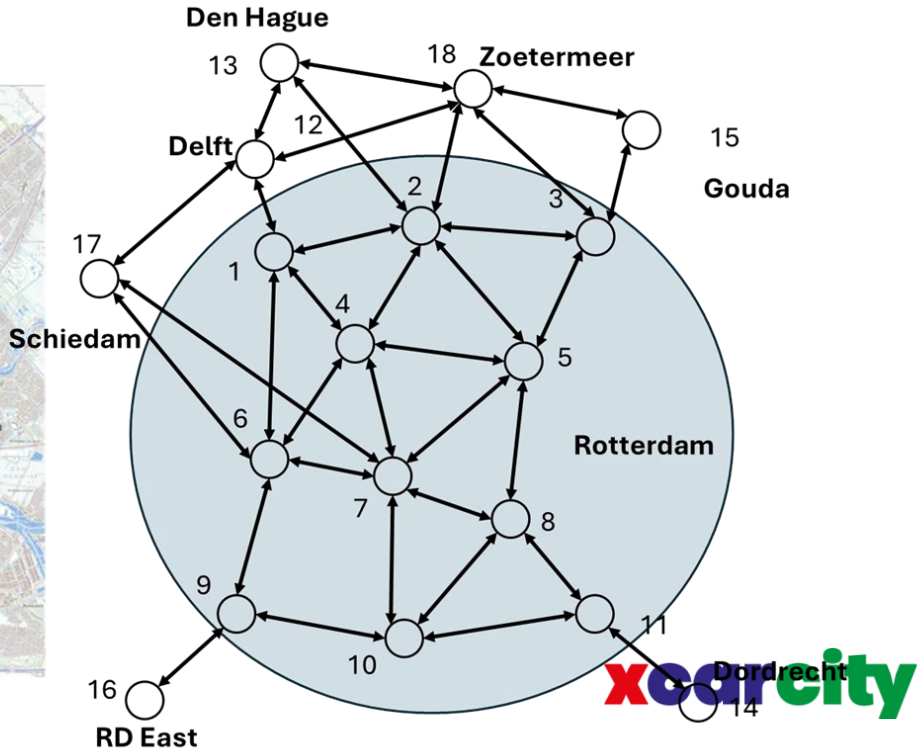
Rotterdam case study





Rotterdam case study

Morning Peak Rush Hour OD Pairs

Zone	1	2	3	4	5	6	7	8	9	10	11	Delft /12	DenHague/ 13	Dordrecht/ 14	Gouda/15	RDEast/16	Schiedam/ 17	Zoetermeer/18
1	511	348	171	780	189	534	797	151	37	109	63	444	438	72	25	85	423	101
2	260	2281	952	1247	697	459	1380	331	60	202	156	483	452	216	100	88	328	409
3	207	821	10507	754	2017	474	1796	552	84	281	500	419	525	846	691	126	309	617
4	417	843	682	3141	1167	1188	3518	636	154	331	272	508	512	308	96	147	537	241
5	154	444	1349	1322	3453	626	3397	722	103	305	395	238	258	556	109	104	284	176
6	529	394	545	2031	739	5281	4759	835	252	694	326	633	652	509	71	282	1251	196
7	290	450	779	1878	1419	1715	6632	1183	227	628	501	472	487	658	95	202	555	226
8	157	273	637	811	943	865	3330	5249	351	2208	1765	259	349	1229	87	247	348	133
9	10	9	24	45	34	42	130	69	173	199	46	29	45	95	3	150	86	6
10	131	231	435	586	488	848	2227	2454	765	4627	1152	224	281	1165	60	519	357	100
11	69	156	783	346	798	394	1399	1559	225	1034	4098	146	167	2807	96	216	150	124
Delft/12	516	543	632	820	350	647	1333	304	120	239	146							
DenHague/13	366	380	558	543	301	473	972	277	151	190	137							
Dordrecht/14	60	134	747	364	659	440	1349	1116	268	1057	2195							
Gouda/15	0	9	78	10	13	4	16	6	0	6	11							
RDEast/16	179	150	300	362	196	516	902	568	750	853	381							
Schiedam/17	672	468	501	1455	534	1903	2278	567	370	523	197							
Zoetermer/18	120	435	670	328	253	191	604	160	40	76	88							

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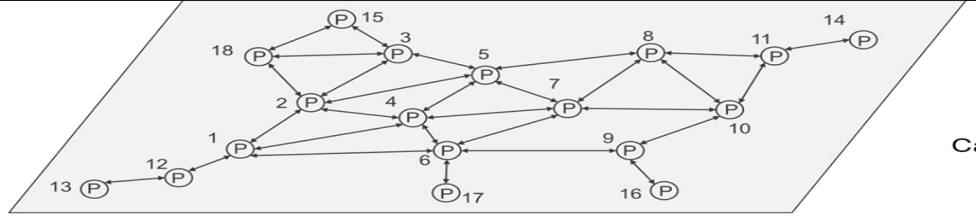
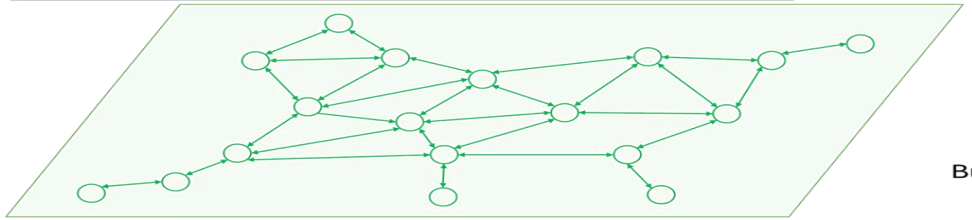
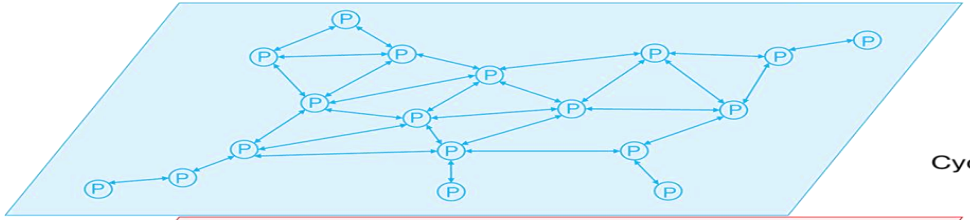


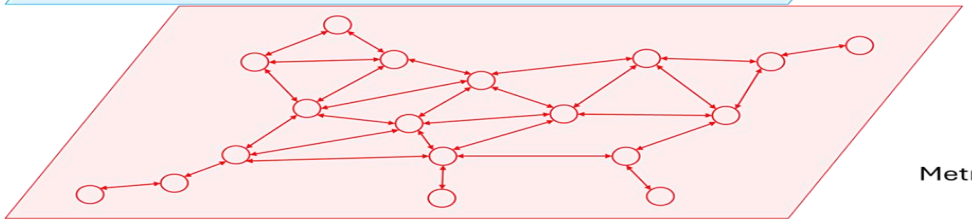
Car network



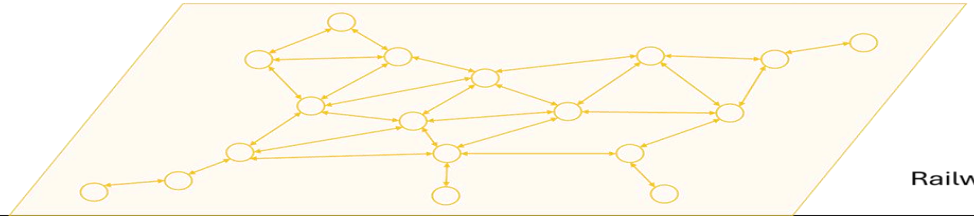
Bus/Tram network



Cycle network



Metro network



Railway network

Presentation Maaike & Jingjun

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Proposition XCARCITY

Digital twin federation
Real-time management & Strategic planning

Model-based scenario development

Implementation of interventions

Real-life and virtual reality data

Monitoring and analyses

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XCARCITY Digital Twin

What do we mean by “Digital Twin Federation”?

- **Classical DT Definition: physical system, digital system, information flows between two systems;**
- **Many toolkits / digital twin available in different aspects of mobility system, but none of them could provide comprehensive evaluations of mobility interventions;**
- **A digital twin federation is needed.**

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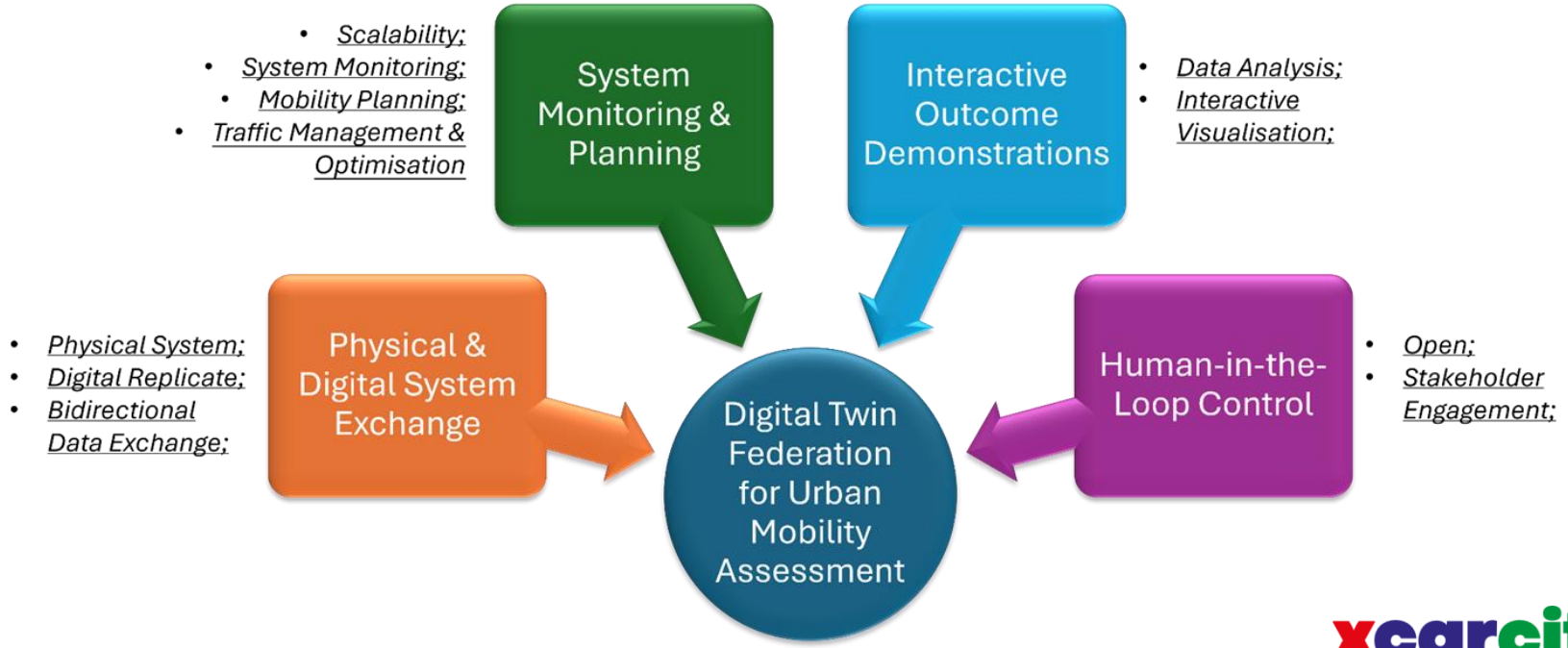
Features of Digital Twin Federation



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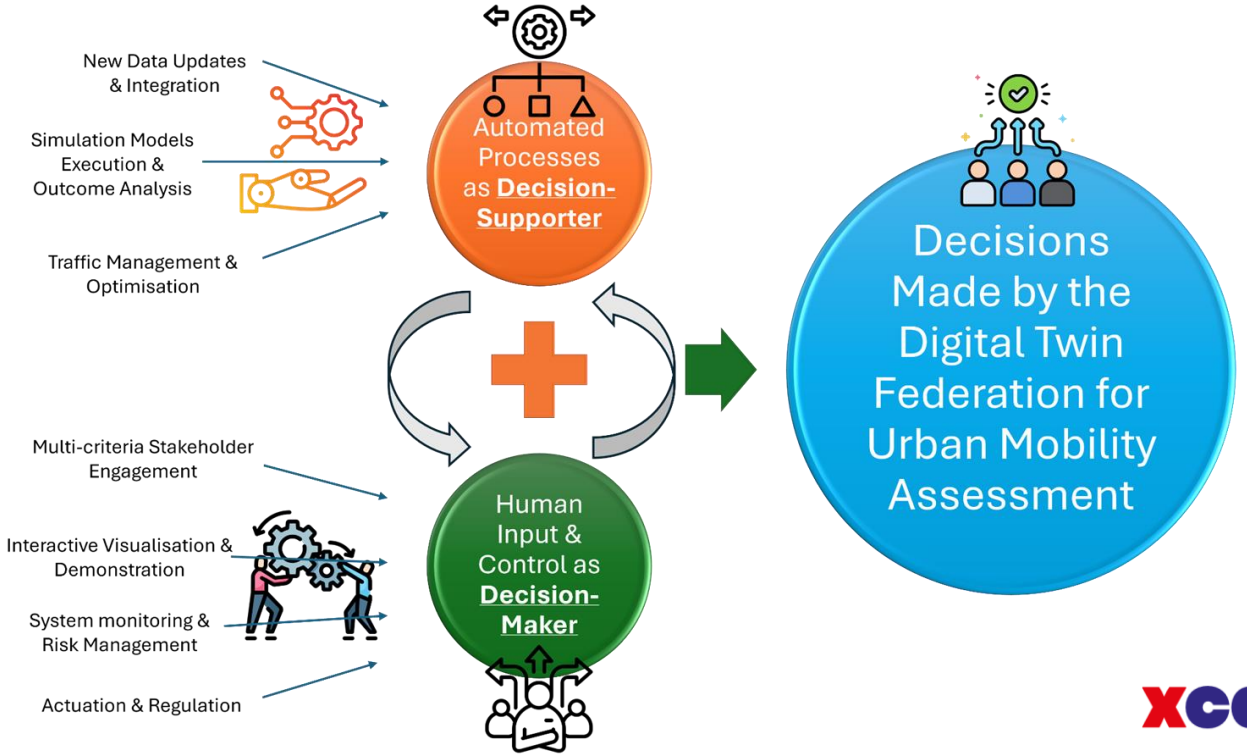
Meaningful Human Control in FedDT



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Urban Mobility Digital Twin

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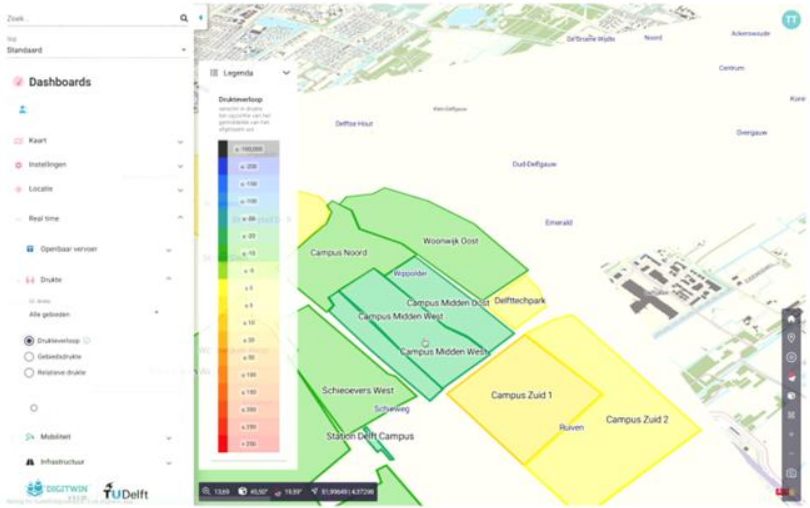
UMDT sensors and travel patterns

Video UMDT sensors



Video UMDT travel patterns

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Urban Strategy

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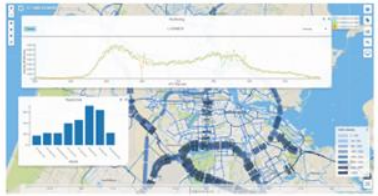
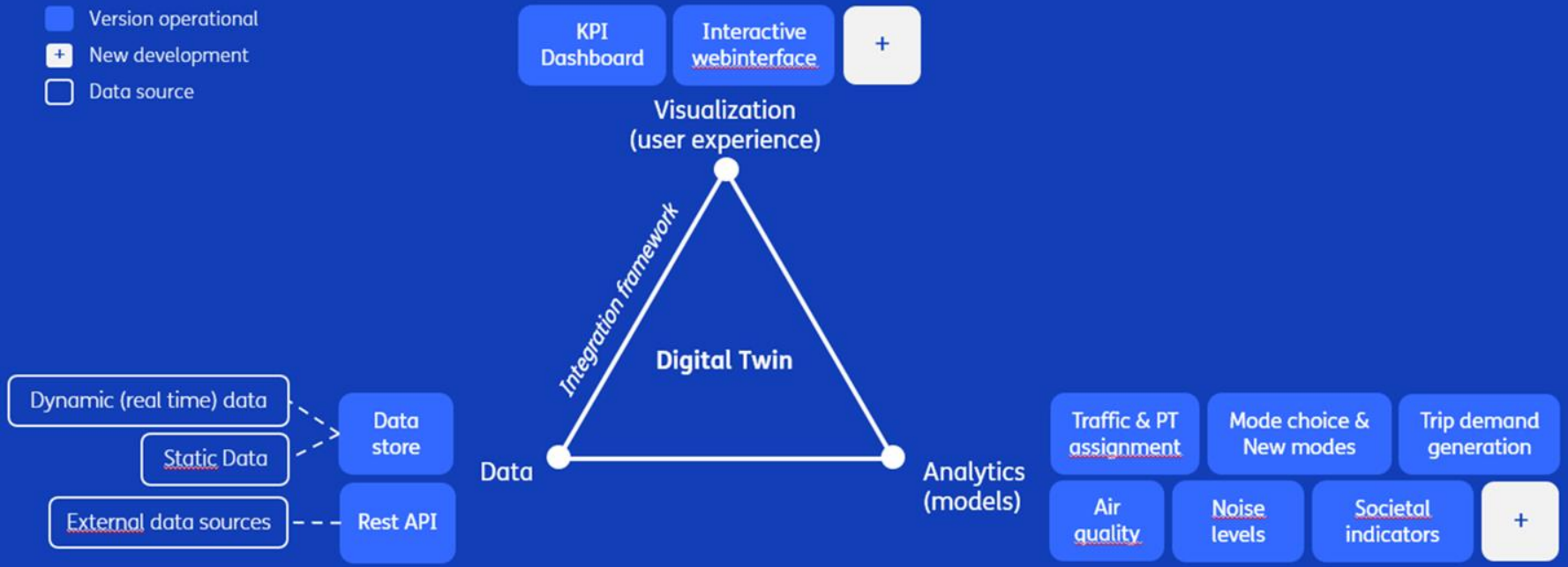
Digital Twins with Urban Strategy

Making Complexity Manageable



Digital Twins: making complexity manageable



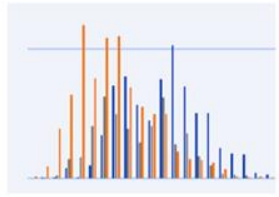
Walter Lohman, Hans Cornelissen, Jeroen Borst, Ralph Klerkx, Yashar Araghi, Erwin Walraven,
Building digital twins of cities using the Inter Model Broker framework, Future Generation Computer Systems, Volume 148, 2023, Pages 501-513, ISSN 0167-739X,
https://doi.org/10.1016/j.future.2023.06.024.

Urban Strategy simulation modules

Mobility
Demand

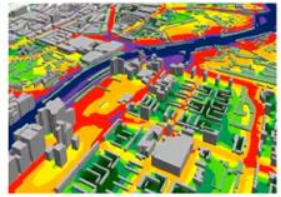
Multi-mode
network allocation

Active transport
cycling & walking



Distribution
of accessibility

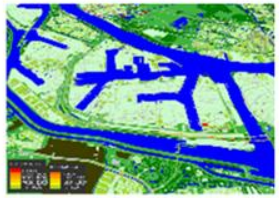
Air quality
(road & Industry)



Noise (Road, Rail
& Industry)

Electric fleet
simulation

EV – power grid
Interaction

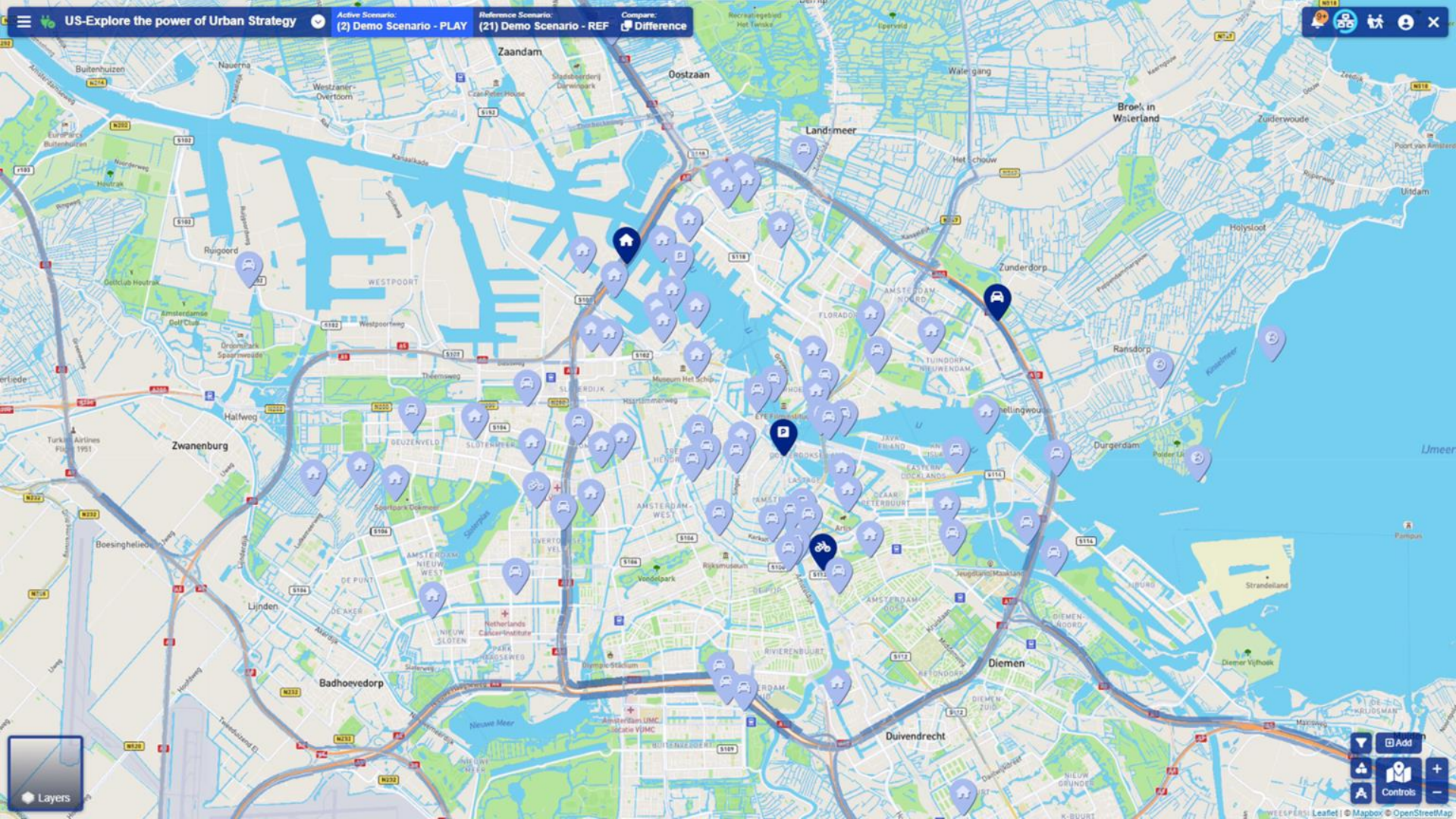


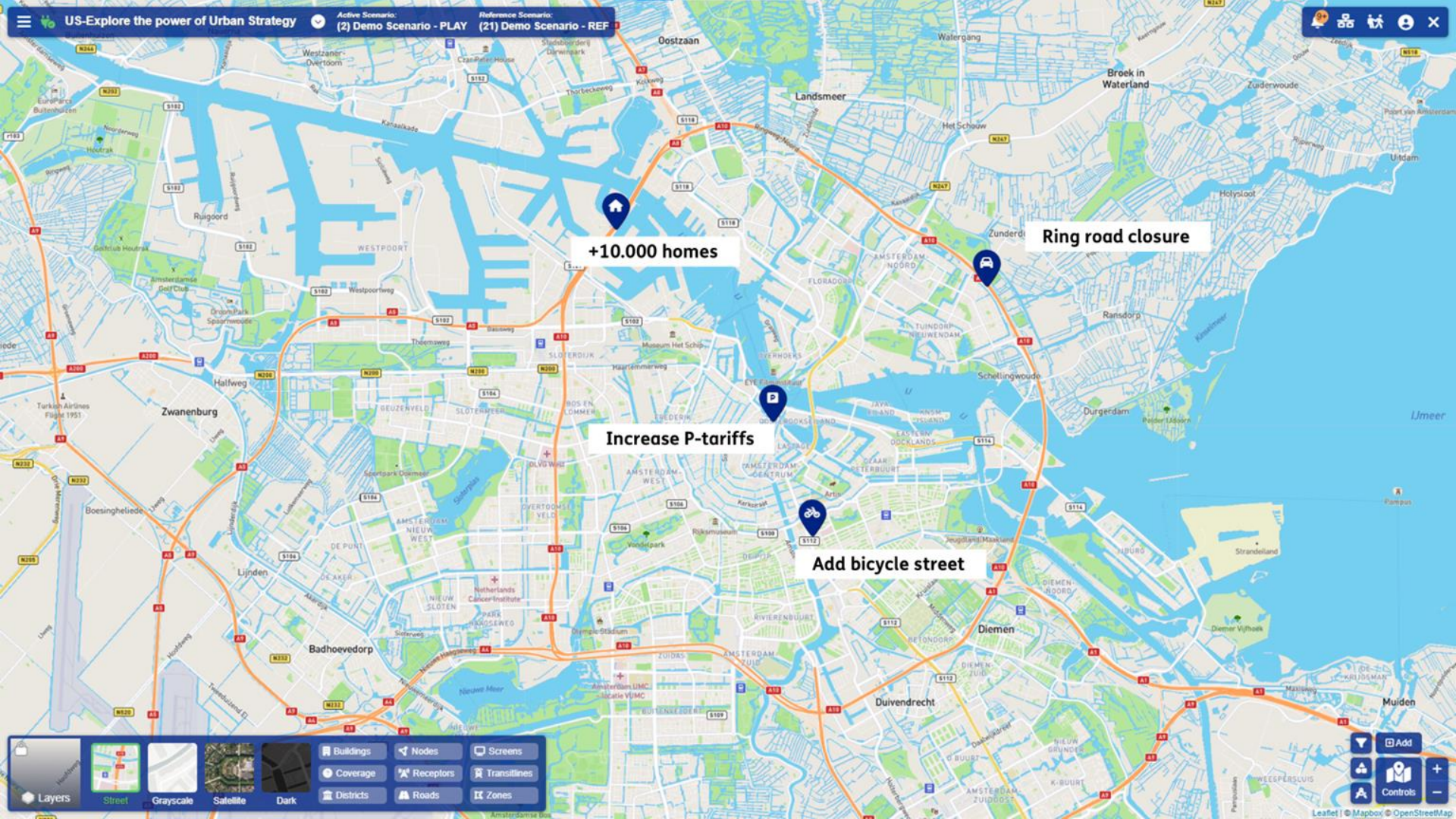
Greenhouse gas
emissions

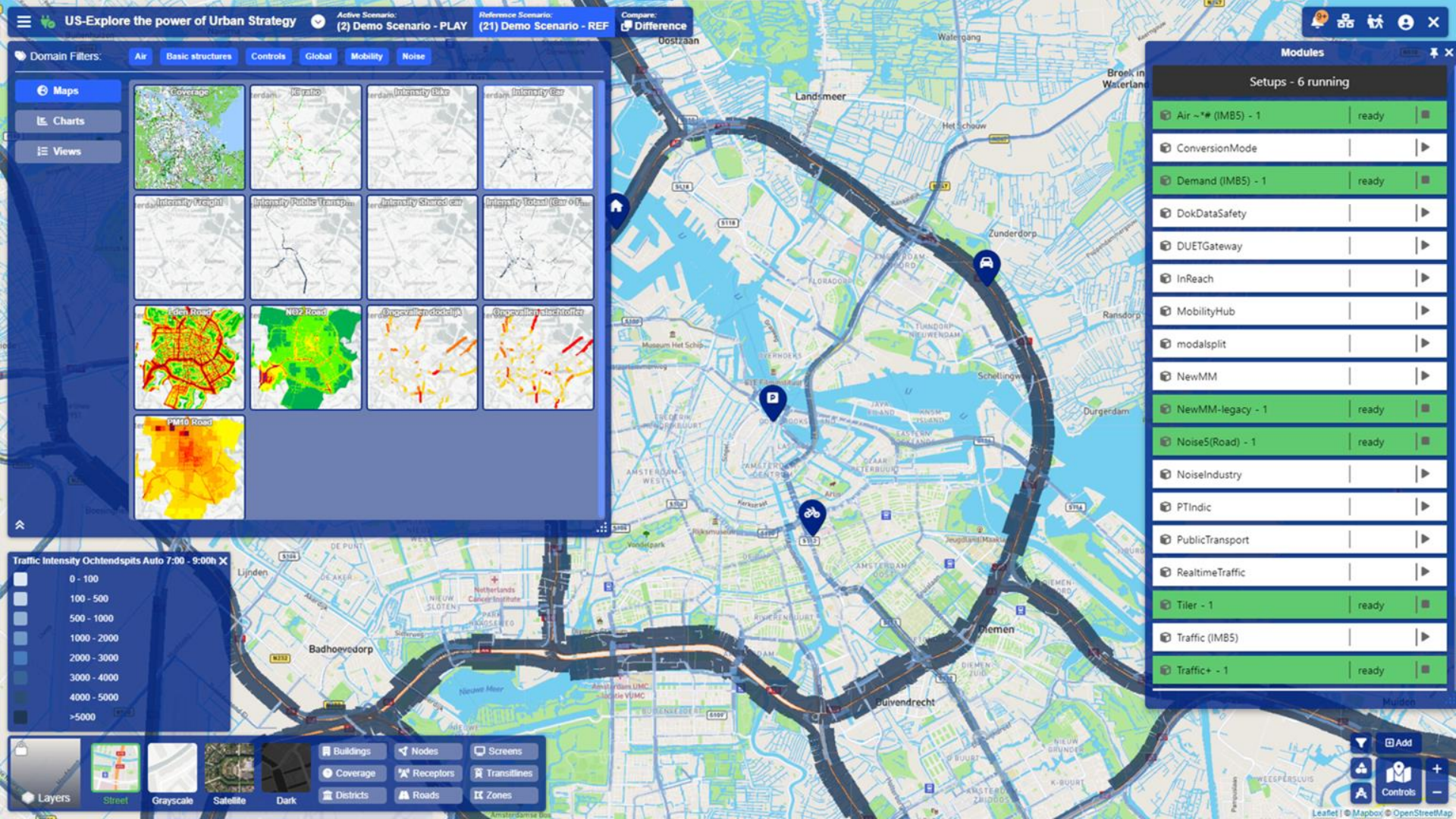
Infrastructure
Resilience

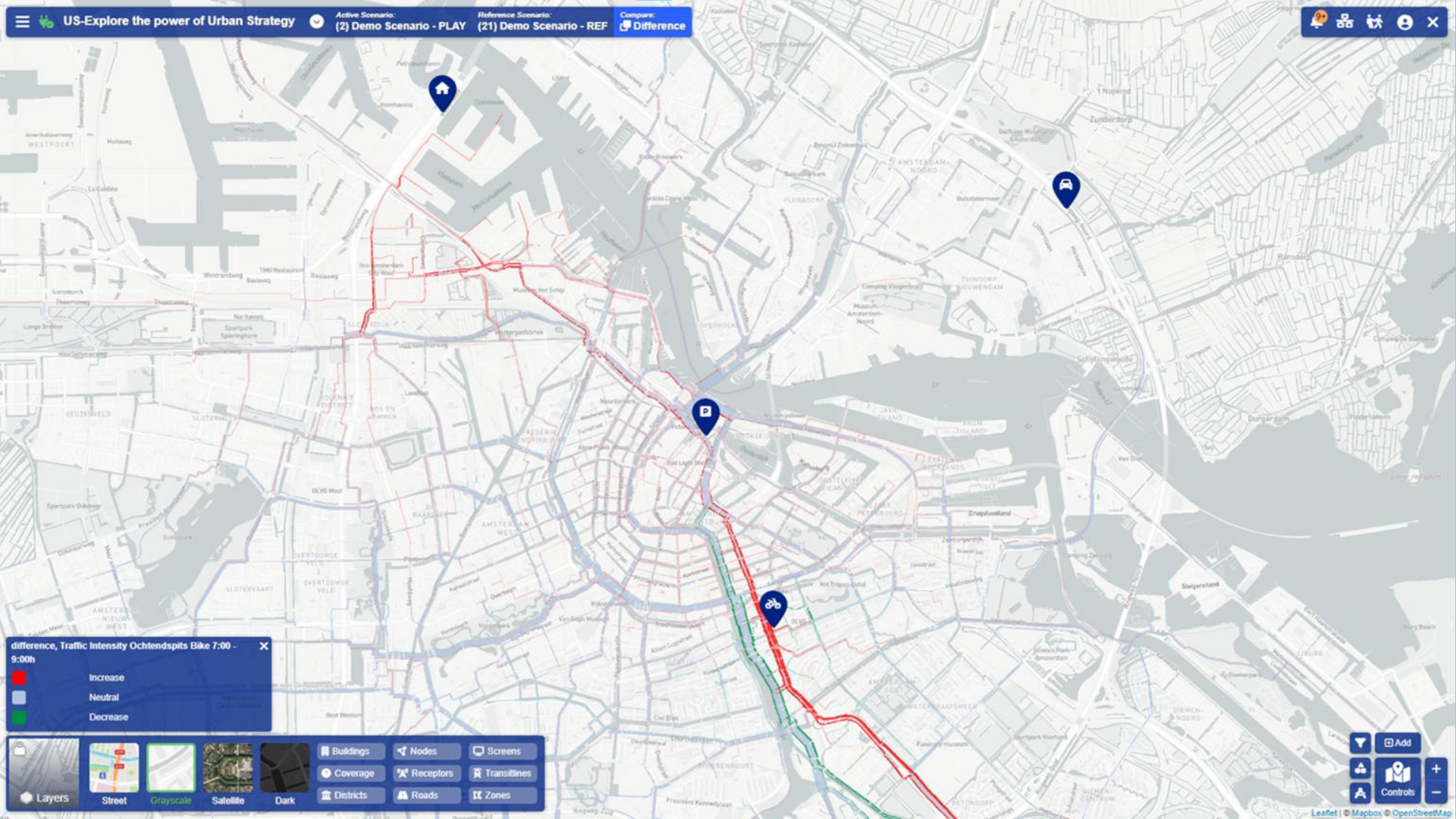
Spatial
impacts

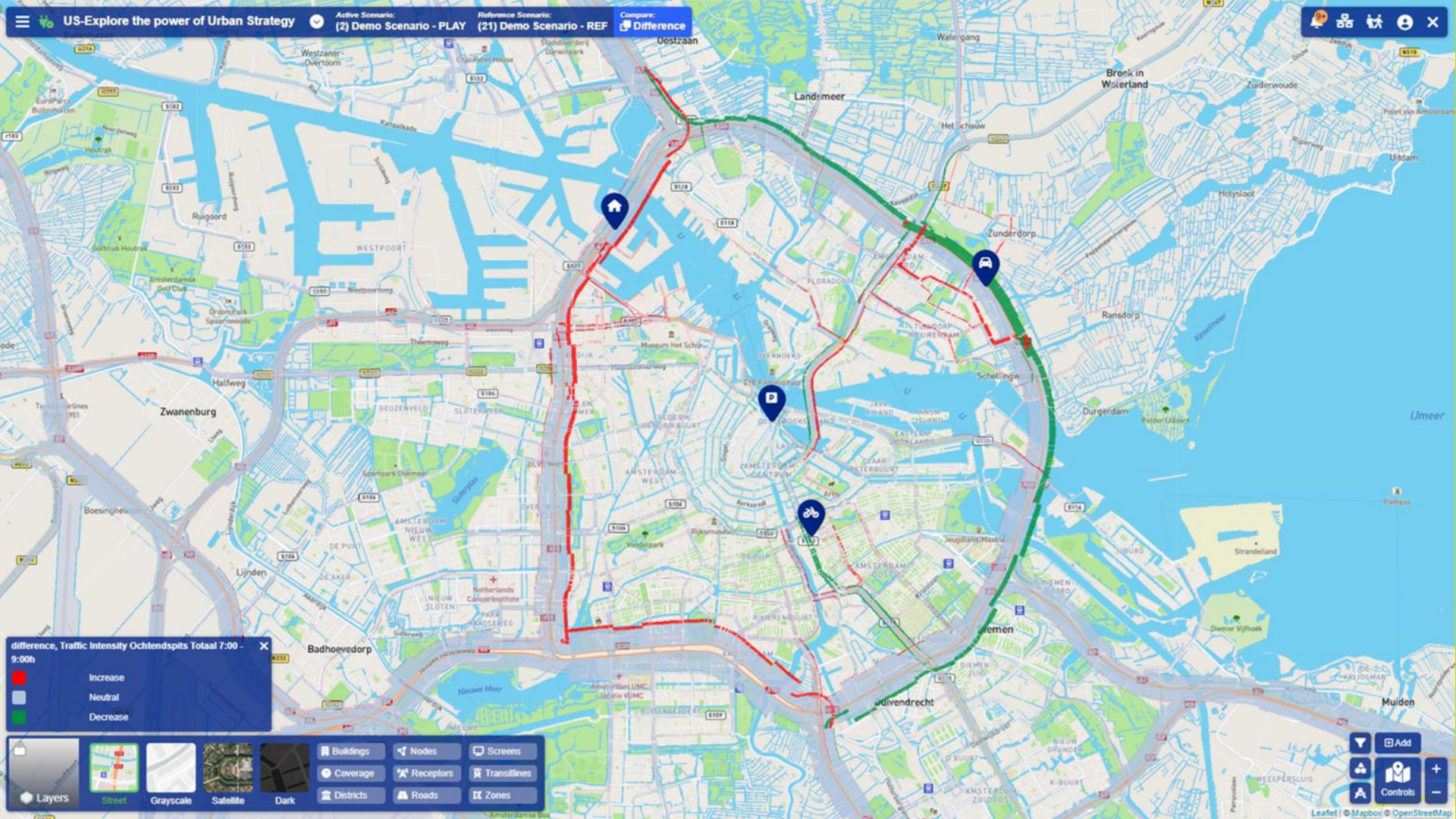
Well-being
indicators

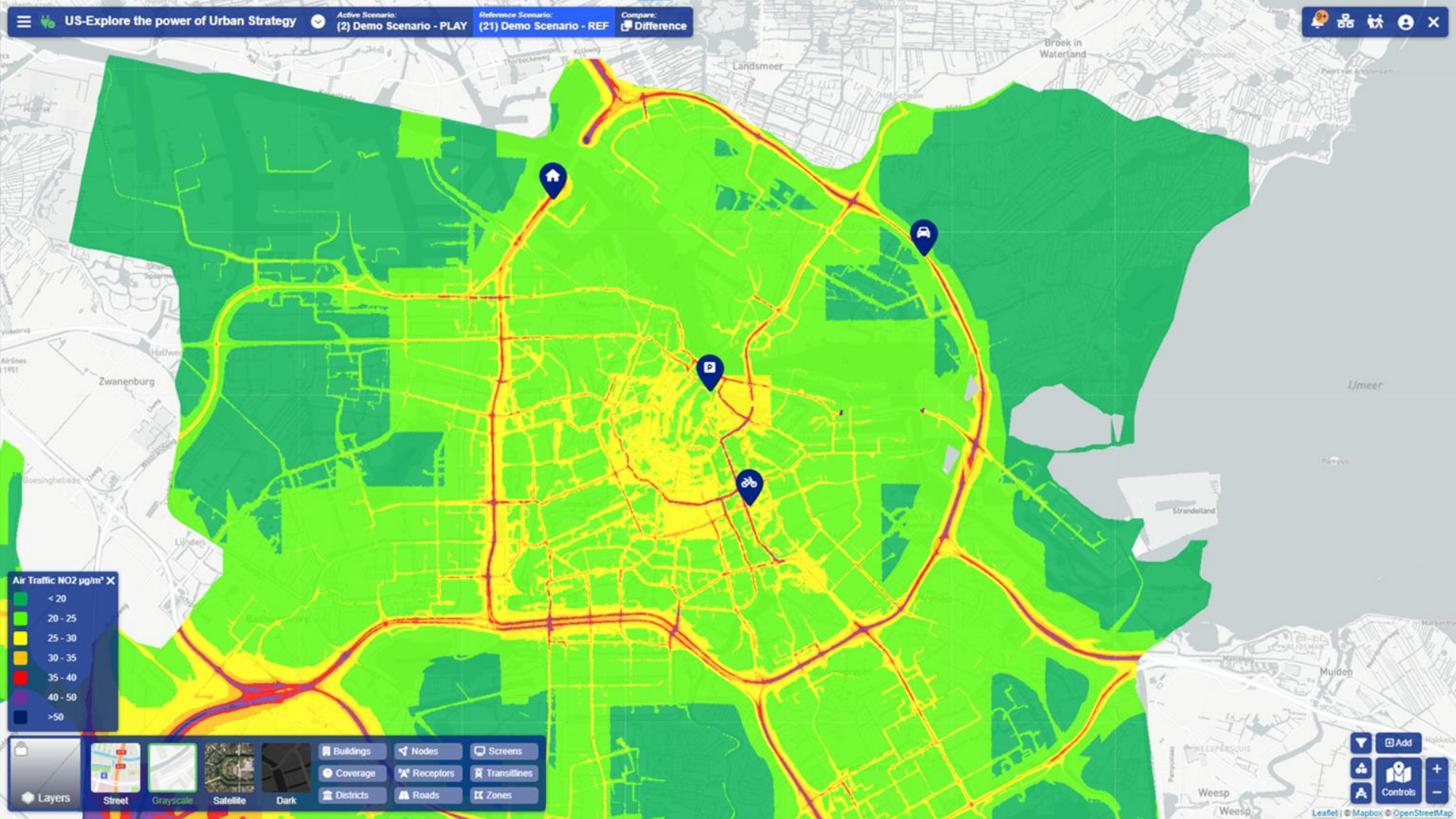

US-Explore the power of Urban Strategy
Active Scenario:
(2) Demo Scenario - PLAY
Reference Scenario:
(21) Demo Scenario - REF
Compare:
Difference
Zaandam
Oostzaan
Landsmeer
Broek in Waterland
Zunderdorp
Ransdorp
Durgerdam
Uitdam
Holysloot
Halfweg
Zwanenburg
Westpoort
Amsterdam-West
Amsterdam-Noord
Diemen
Duivendrecht
Badhoevedorp
Lijnden
Boesingheliede
Buitenhuizen
Nauerna
Ruigoord
Layers
Add
Controls
Leaflet | © Mapbox © OpenStreetMap

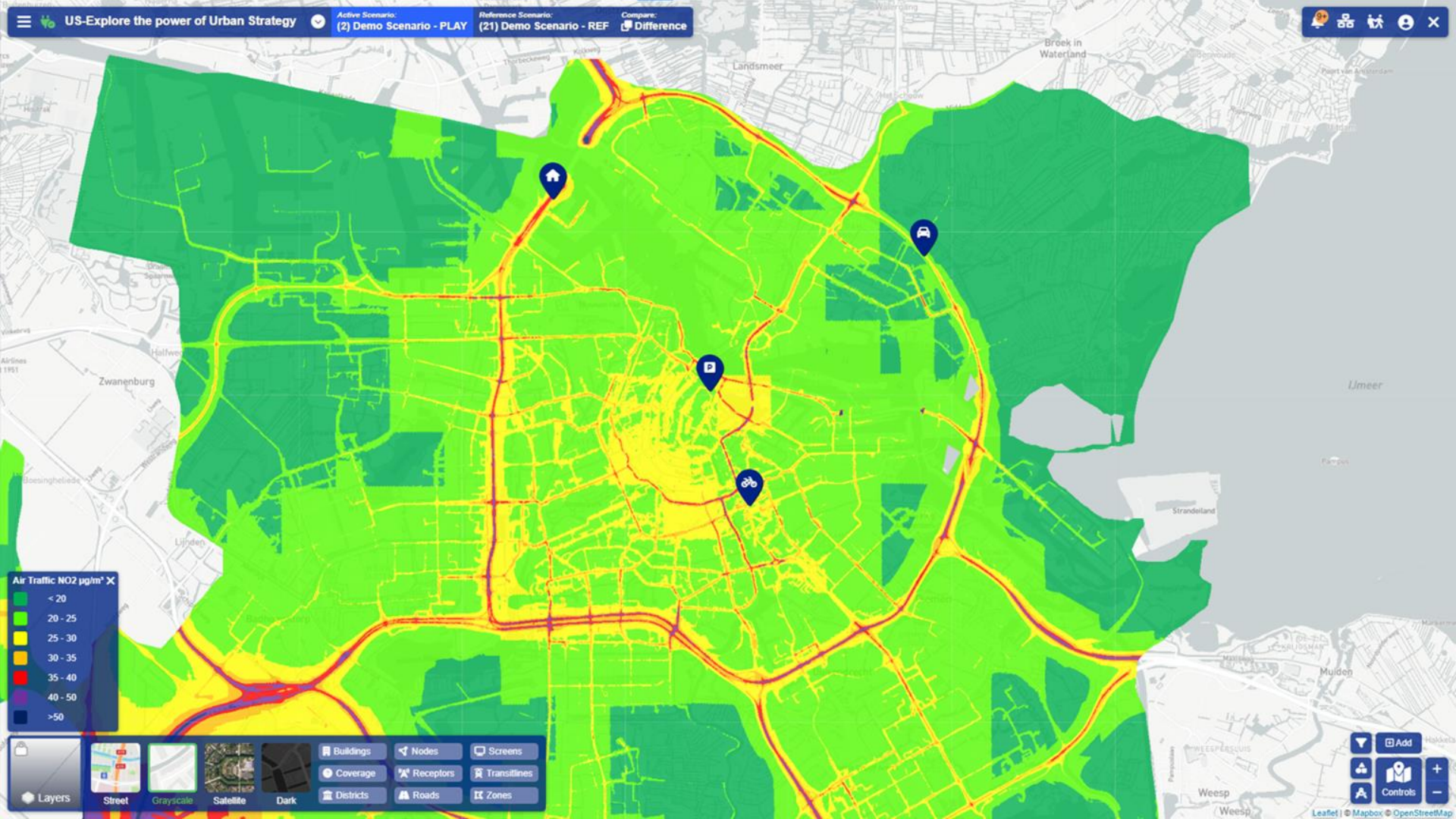

US-Explore the power of Urban Strategy
Active Scenario:
(2) Demo Scenario - PLAY
Reference Scenario:
(21) Demo Scenario - REF
+10.000 homes
Ring road closure
Increase P-tariffs
Add bicycle street
Oostzaan
Landsmeer
Broek in Waterland
Zwanenburg
Halfweg
Diemen
Duivendrecht
Muiden
Badhoevedorp
Lijnden
Ransdorp
Schellingwoude
Durgerdam
IJmeer
Layers
Street
Grayscale
Satellite
Dark
Buildings
Nodes
Screens
Coverage
Receptors
Transitlines
Districts
Roads
Zones
Add
Controls
Leaflet | © Mapbox © OpenStreetMap

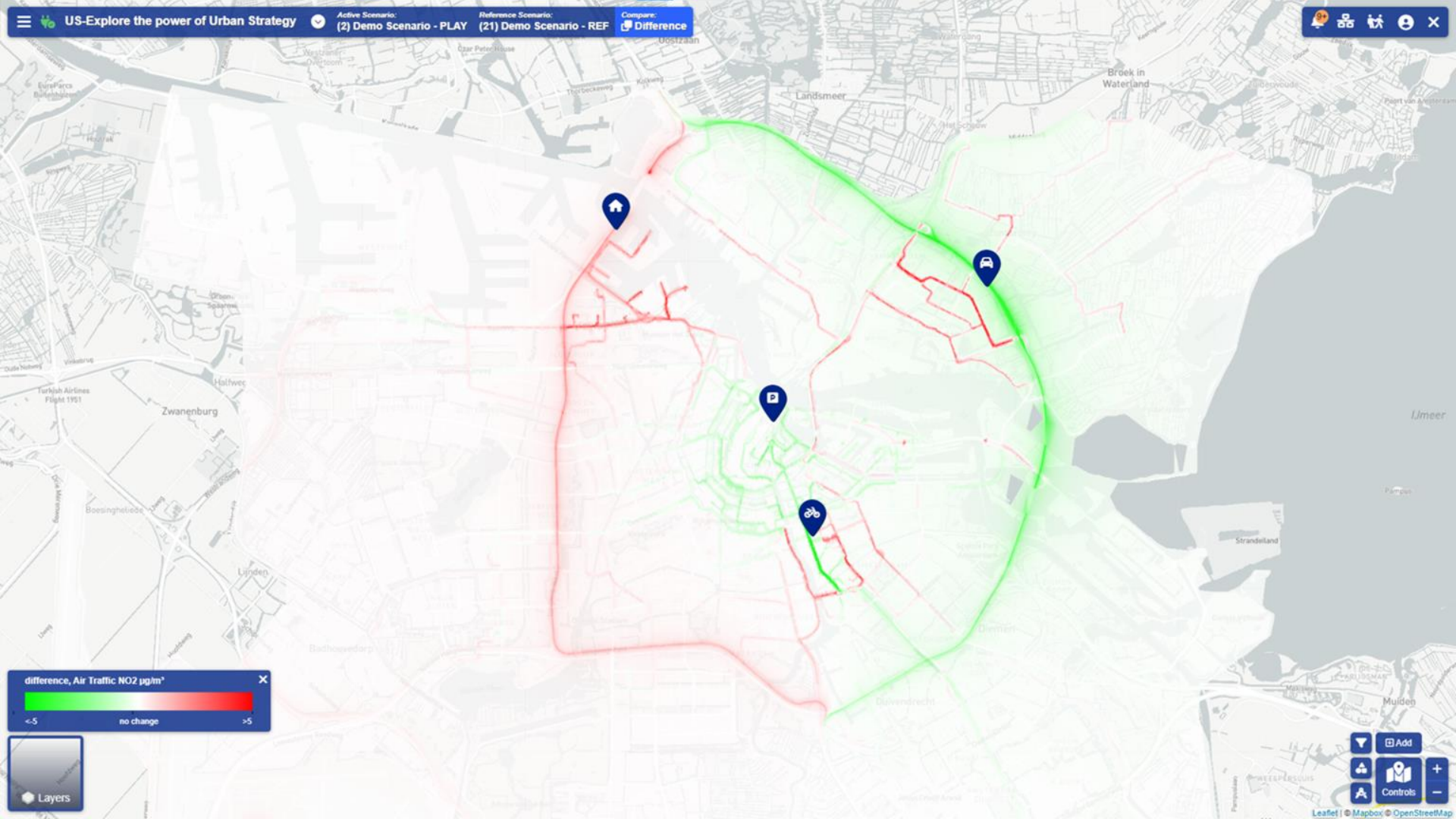

US-Explore the power of Urban Strategy
Active Scenario:
(2) Demo Scenario - PLAY
Reference Scenario:
(21) Demo Scenario - REF
Compare:
Difference
Domain Filters:
Air
Basic structures
Controls
Global
Mobility
Noise
Maps
Charts
Views
Coverage
IC ratio
Intensity Bike
Intensity Car
Intensity Freight
Intensity Public Transp...
Intensity Shared car
Intensity Total (Car + F...
Iden Road
NO2 Road
Ongevallen dodelijk
Ongevallen slachtoffer
PM10 Road
Modules
Setups - 6 running
Air ~*# (IMB5) - 1
ready
ConversionMode
Demand (IMB5) - 1
ready
DokDataSafety
DUETGateway
InReach
MobilityHub
modalsplit
NewMM
NewMM-legacy - 1
ready
Noise5(Road) - 1
ready
NoiseIndustry
PTIndic
PublicTransport
RealtimeTraffic
Tiler - 1
ready
Traffic (IMB5)
Traffic+ - 1
ready
Traffic Intensity Ochtendspits Auto 7:00 - 9:00h
0 - 100
100 - 500
500 - 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 5000
>5000
Layers
Street
Grayscale
Satellite
Dark
Buildings
Nodes
Screens
Coverage
Receptors
Transitlines
Districts
Roads
Zones
Add
Controls
Leaflet | © Mapbox © OpenStreetMap

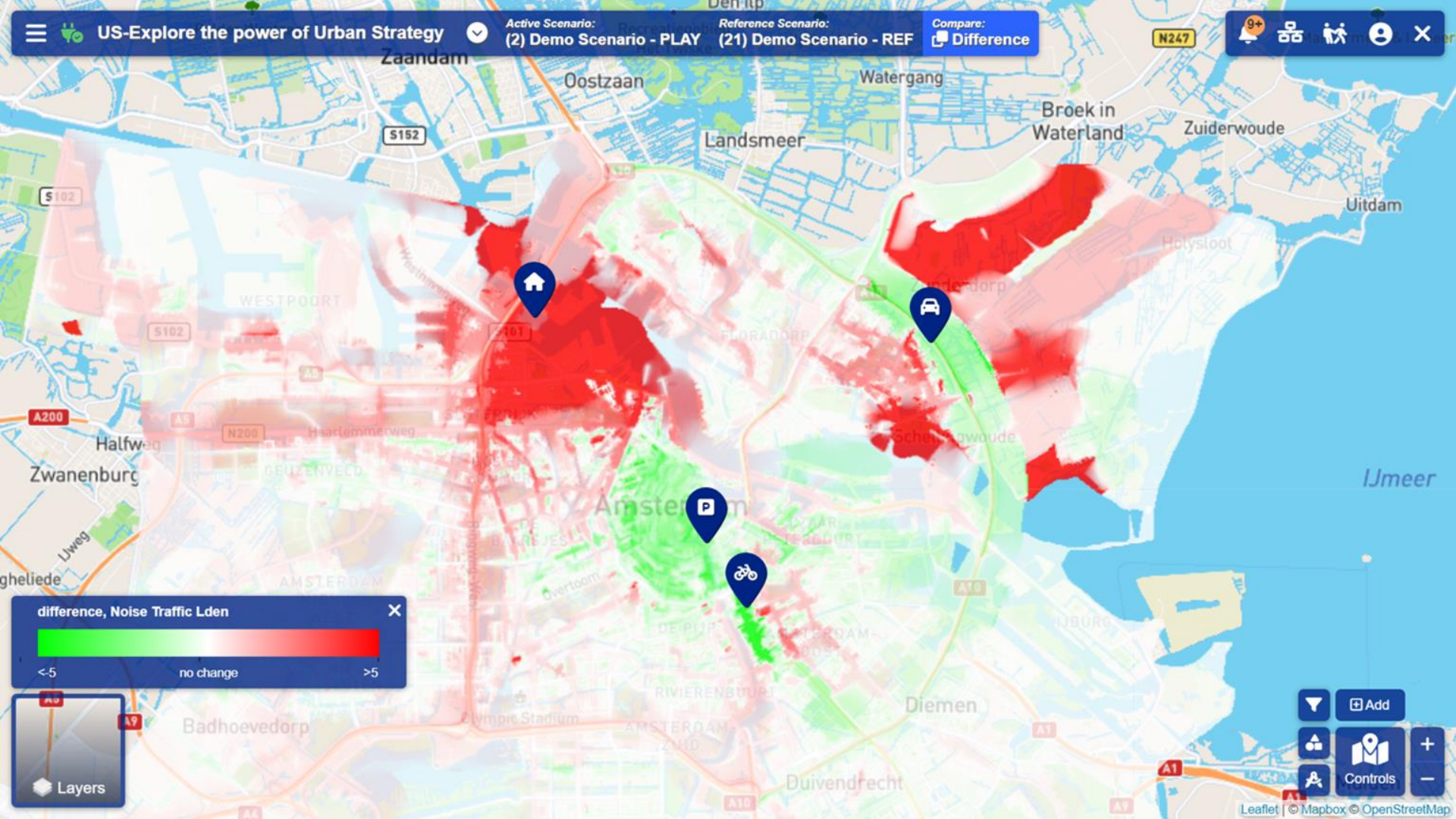

US-Explore the power of Urban Strategy
Active Scenario:
(2) Demo Scenario - PLAY
Reference Scenario:
(21) Demo Scenario - REF
Compare:
Difference
9+
difference, Traffic Intensity Ochtendspits Bike 7:00 - 9:00h
Increase
Neutral
Decrease
Layers
Street
Grayscale
Satellite
Dark
Buildings
Nodes
Screens
Coverage
Receptors
Transitlines
Districts
Roads
Zones
Add
Controls
Leaflet | © Mapbox © OpenStreetMap

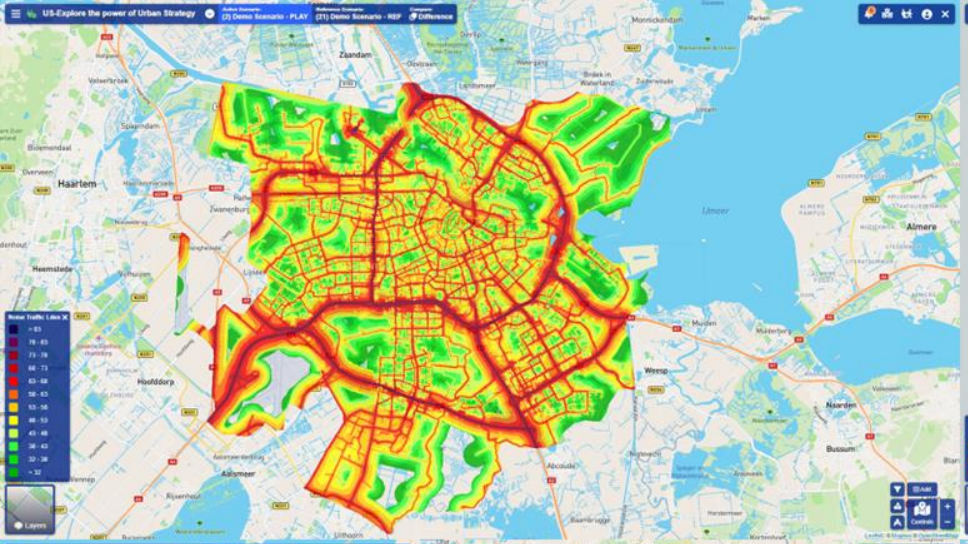

US-Explore the power of Urban Strategy
Active Scenario:
(2) Demo Scenario - PLAY
Reference Scenario:
(21) Demo Scenario - REF
Compare:
Difference
difference, Traffic Intensity Ochtendspits Totaal 7:00 - 9:00h
Increase
Neutral
Decrease
Layers
Street
Grayscale
Satellite
Dark
Buildings
Nodes
Screens
Coverage
Receptors
Transitlines
Districts
Roads
Zones
Add
Controls
Leaflet | © Mapbox © OpenStreetMap

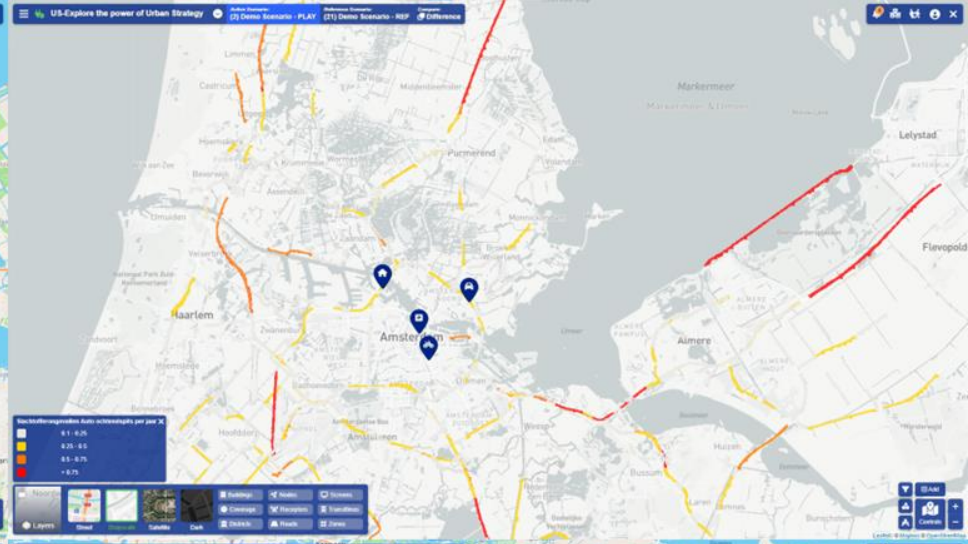

US-Explore the power of Urban Strategy
Active Scenario:
(2) Demo Scenario - PLAY
Reference Scenario:
(21) Demo Scenario - REF
Compare:
Difference
Air Traffic NO2 µg/m³
< 20
20 - 25
25 - 30
30 - 35
35 - 40
40 - 50
>50
Layers
Street
Grayscale
Satellite
Dark
Buildings
Nodes
Screens
Coverage
Receptors
Transitlines
Districts
Roads
Zones
Add
Controls
Leaflet | © Mapbox © OpenStreetMap


US-Explore the power of Urban Strategy
Active Scenario:
(2) Demo Scenario - PLAY
Reference Scenario:
(21) Demo Scenario - REF
Compare:
Difference
Air Traffic NO2 µg/m³
< 20
20 - 25
25 - 30
30 - 35
35 - 40
40 - 50
>50
Layers
Street
Grayscale
Satellite
Dark
Buildings
Nodes
Screens
Coverage
Receptors
Transitlines
Districts
Roads
Zones
Add
Controls
Leaflet | © Mapbox © OpenStreetMap
Landsmeer
Broek in Waterland
Zwanenburg
IJmeer
Strandeiland
Muiden
Weesp

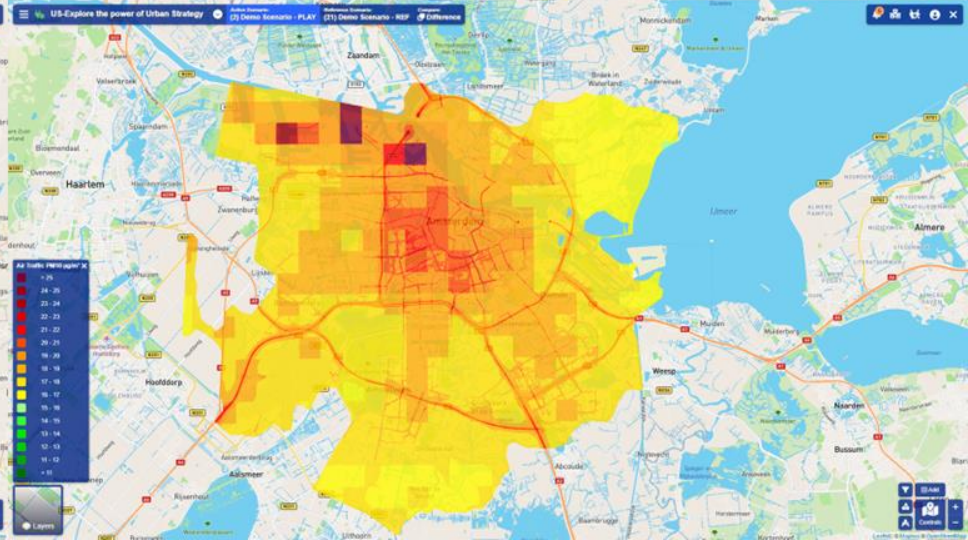

US-Explore the power of Urban Strategy
Active Scenario:
(2) Demo Scenario - PLAY
Reference Scenario:
(21) Demo Scenario - REF
Compare:
Difference
9+
Zwanenburg
Landsmeer
Broek in Waterland
Ijmeer
Muiden
Strandeiland
Boesingheliede
Linden
Badhoevedorp
Diemen
Ouderkerk
Turkish Airlines Flight 1951
difference, Air Traffic NO2 µg/m³
<-5
no change
>5
Layers
Add
Controls
Leaflet | © Mapbox © OpenStreetMap

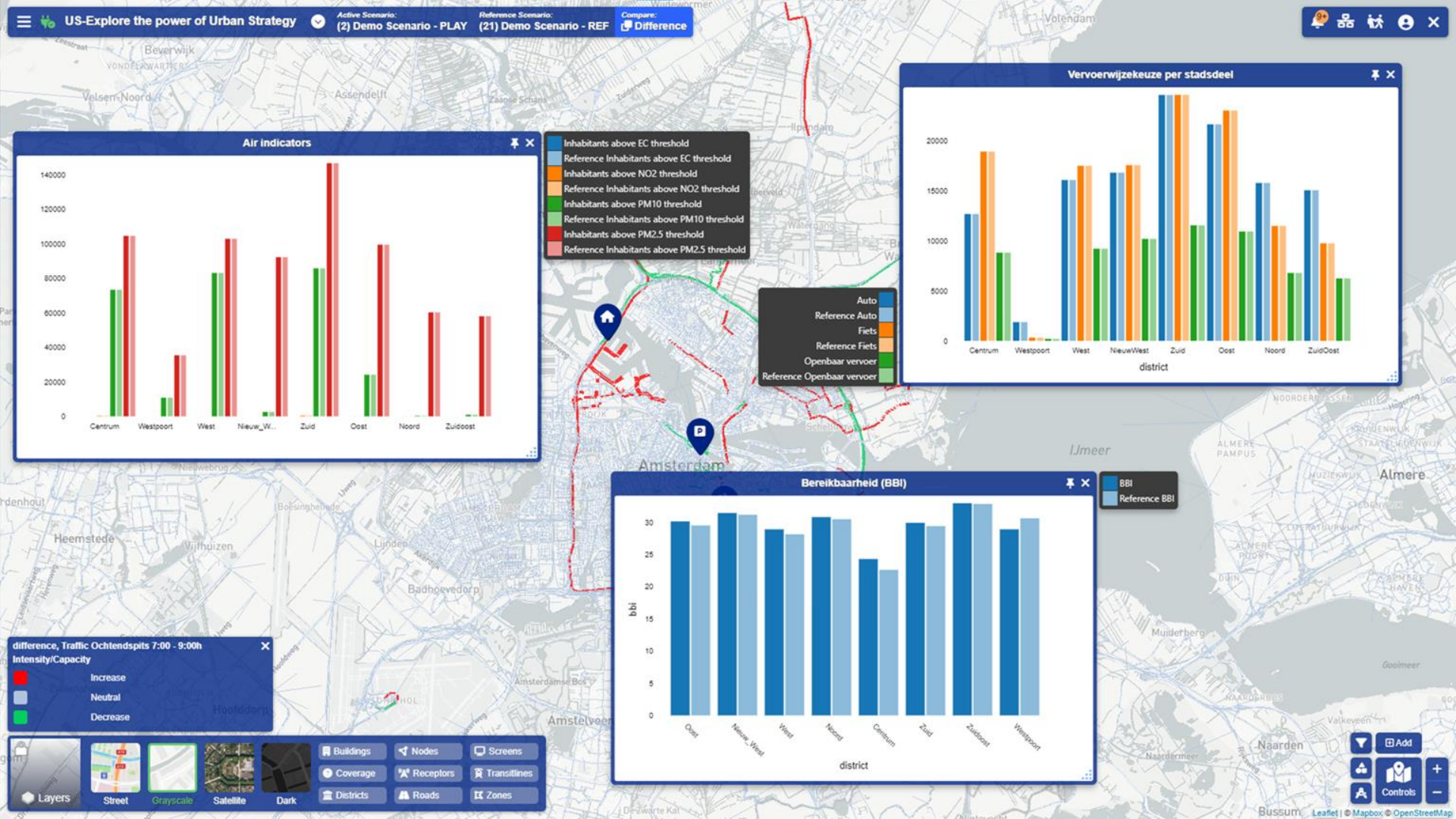

US-Explore the power of Urban Strategy
Active Scenario:
(2) Demo Scenario - PLAY
Reference Scenario:
(21) Demo Scenario - REF
Compare:
Difference
Zaandam
Oostzaan
Watergang
Landsmeer
Broek in Waterland
Zuiderwoude
Uitdam
Holysloot
IJmeer
Zwanenburg
Halfweg
Amsterdam
Diemen
Badhoevedorp
Duivendrecht
difference, Noise Traffic Lden
<-5
no change
>5
Layers
Add
Controls
Leaflet | © Mapbox © OpenStreetMap


US-Explore the power of Urban Strategy
Haarlem
Zaandam
Almere
Amsterdam
Hoofddorp
Weesp
Naarden
Bussum
Aalsmeer


US-Explore the power of Urban Strategy
Haarlem
Amsterdam
Almere
Lelystad
Flevopolder


US-Accessibility, Well-being and Equity
Haarlem
Amsterdam
Almere
Leiden
The Hague
Rotterdam
Utrecht
Hertogenbosch
Breda
Münster
Hamm
Dortmund
Gelsenkirchen
Assen


US-Explore the power of Urban Strategy
Haarlem
Zaandam
Almere
Amsterdam
Hoofddorp
Weesp
Naarden
Bussum
Aalsmeer


US-Explore the power of Urban Strategy
Active Scenario:
(2) Demo Scenario - PLAY
Reference Scenario:
(21) Demo Scenario - REF
Compare:
Difference
Air indicators
Inhabitants above EC threshold
Reference Inhabitants above EC threshold
Inhabitants above NO2 threshold
Reference Inhabitants above NO2 threshold
Inhabitants above PM10 threshold
Reference Inhabitants above PM10 threshold
Inhabitants above PM2.5 threshold
Reference Inhabitants above PM2.5 threshold
Centrum
Westpoort
West
Nieuw_W...
Zuid
Oost
Noord
Zuidoost
Vervoerwijzekeuze per stadsdeel
Auto
Reference Auto
Fiets
Reference Fiets
Openbaar vervoer
Reference Openbaar vervoer
district
Bereikbaarheid (BBI)
BBI
Reference BBI
bbi
district
difference, Traffic Ochtendspits 7:00 - 9:00h
Intensity/Capacity
Increase
Neutral
Decrease
Layers
Street
Grayscale
Satellite
Dark
Buildings
Nodes
Screens
Coverage
Receptors
Transitlines
Districts
Roads
Zones
Add
Controls
Leaflet | © Mapbox © OpenStreetMap

Introduction to Models and Digital Twins

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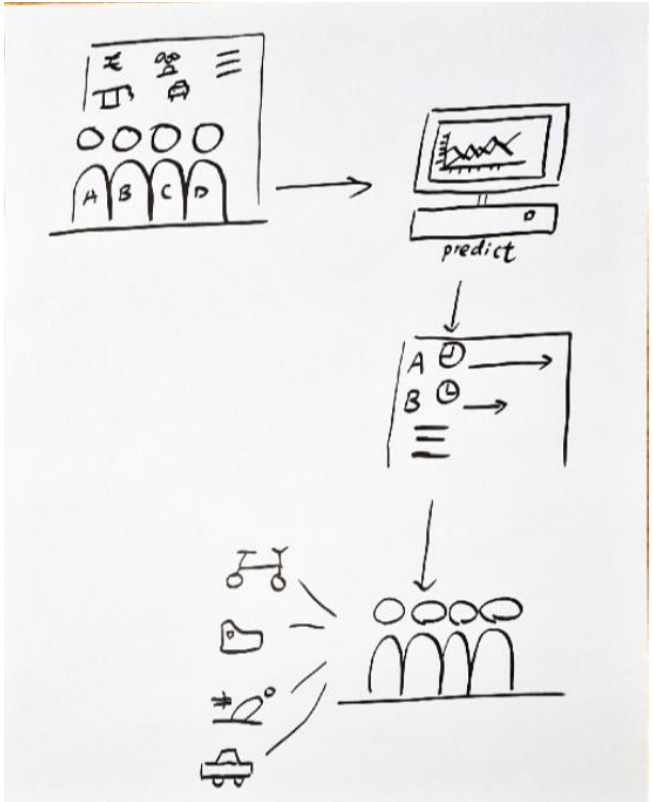
Activity-based travel demand modeling (ABM)

What is it?



- What
- Where
- When
- How long
- How

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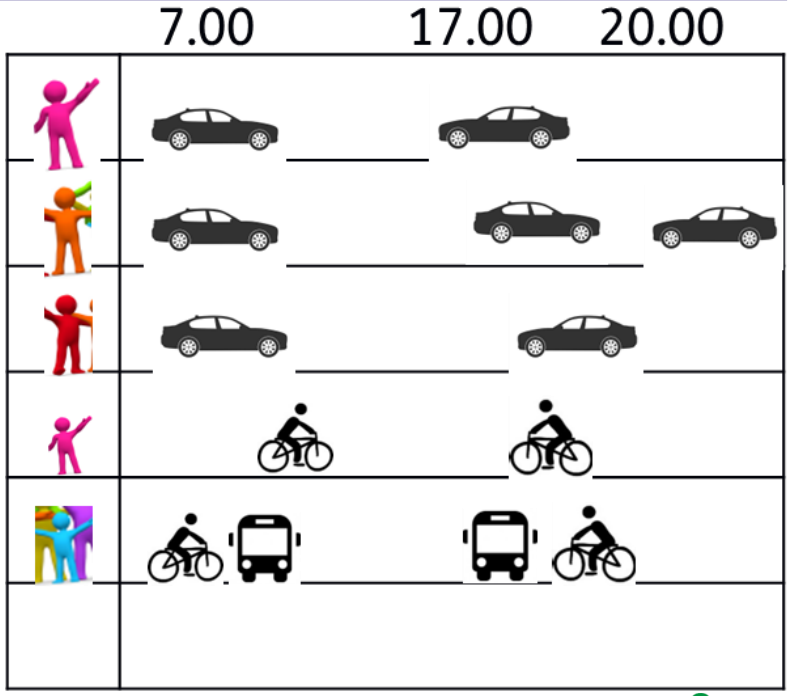
ABM



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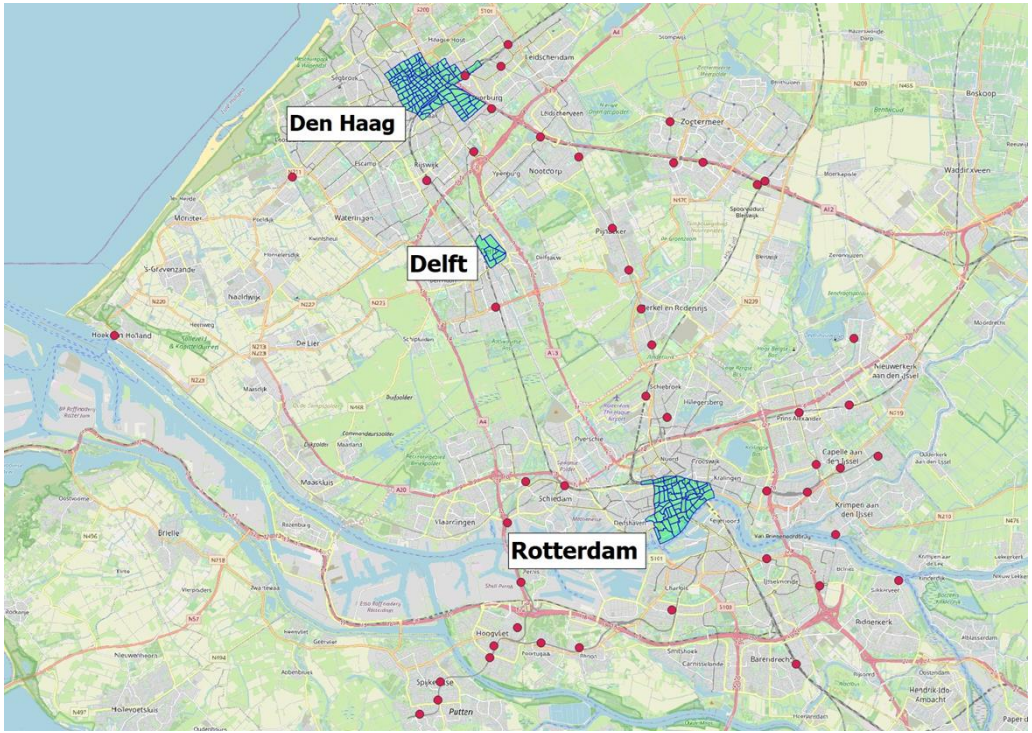
ABM: Case study in MRDH



- Population 2030: 2.56 M
- Level of Service: 7011 zones
- Land use
- 48 Hubs
- Parameters

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ABM: Case study in MRDH

Scenarios:

1. Hubs + Share Service
2. Hubs + Share Service + Reduced parking capacity

Results

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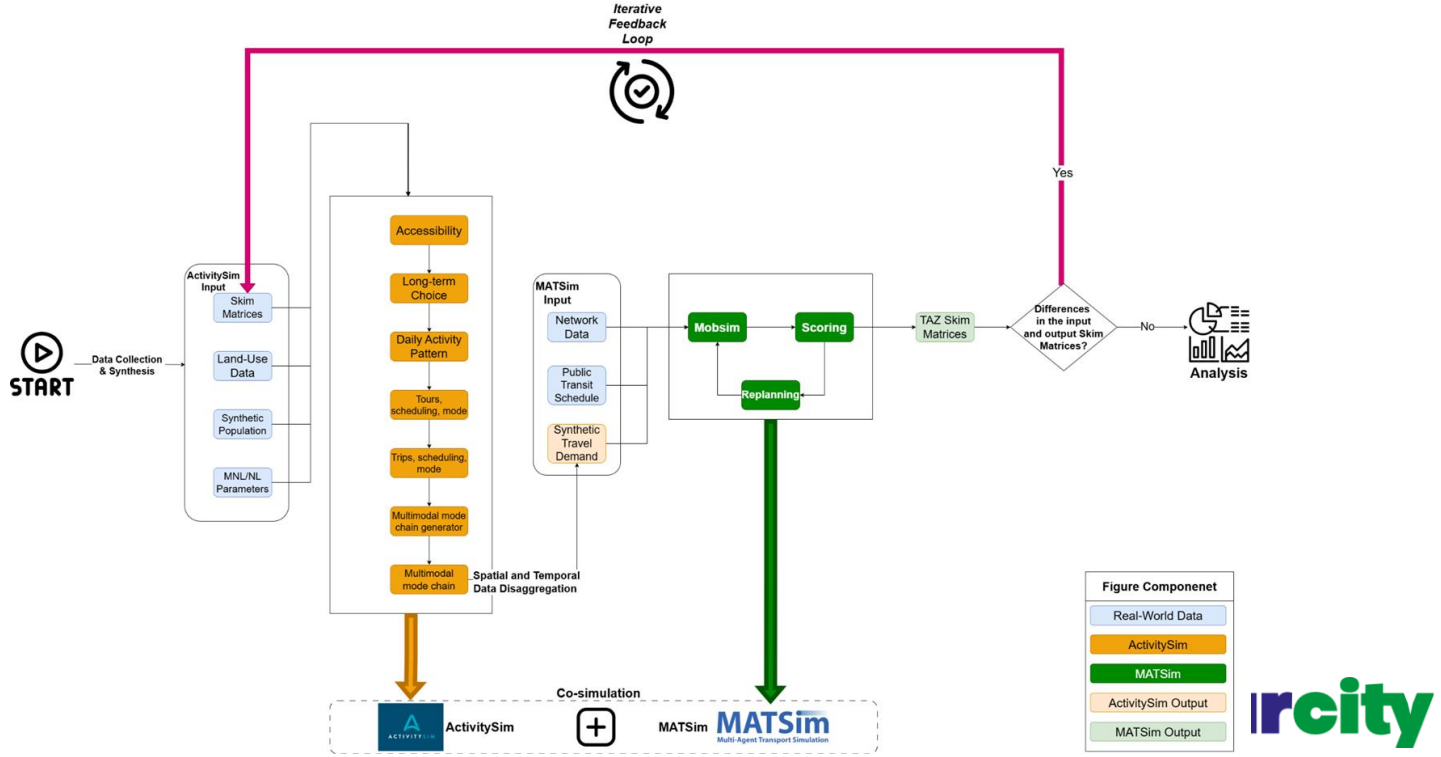
Activity- and Agent-based Co-Simulation



Agent based visualisation

Interactive Session 2: Co design session for Use Case + Digital Twin

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Session format

Merwe-vierhavens case (5 min)
Group discussion (20 min)

1. How can AcBM and AgBM help answer the questions about cities with fewer private vehicles?

2. In the research context of INFUZE, what are the advantages of AcBM + AgBM compared to existing tools?

3. Transferability? If we want to transfer these algorithms to other areas like Leeds, what data do we need and what data do you already have?

4. How can the research from INFUZE be integrated with the simulation platform we develop here at XCARCITY?

5. How can we calibrate and validate our results?

6. What is the future of AI in AcBM and AgBM?

Reflections (15 min)

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TEA BREAK

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Interactive Session 3: Reading Group

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Papers

P1: Stuck in the driver's seat: a conceptualisation for understanding car dependence and its determinants": Full article: Stuck in the driver's seat: a conceptualisation for understanding car dependence and its determinants

P2: Accessibility of urban regions on a low car diet – A research agenda for digital twins: Accessibility of urban regions on a low car diet – A research agenda for digital twins - ScienceDirect

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FEED BACK
+ REFLECTION

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