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On Discovering Optimal Trade-Offs when Introducing New Routes in Existing Multi-Modal Public Transport Systems

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Interreg North Sea Region ART-Forum European Regional Development Fund

EUROPEAN UNION

A.R.T.Forum Automated Road Transport

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Outline

1. Motivation and Introduction
   - The ART-Forum Project
   - General Objectives
   - Research Lines
2. Research Focus and Approaches
   - Present Research Focus
   - Macro-Level Mobility Simulations
   - Modelling KPIs & Optimisation Strategy
3. Tests and Results
   - Case Study
   - Results
   - Conclusions & Future Work

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The ART-Forum Project

ART-Forum is an Interreg North Sea Region Project with **14 partners** from **6 countries**

Aims to address **risks** and **opportunities** and help guide **policy development** regarding the impact of **automated road transport** on life in cities and regions.

More details at: **art-forum.eu**

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Automated Road Transport

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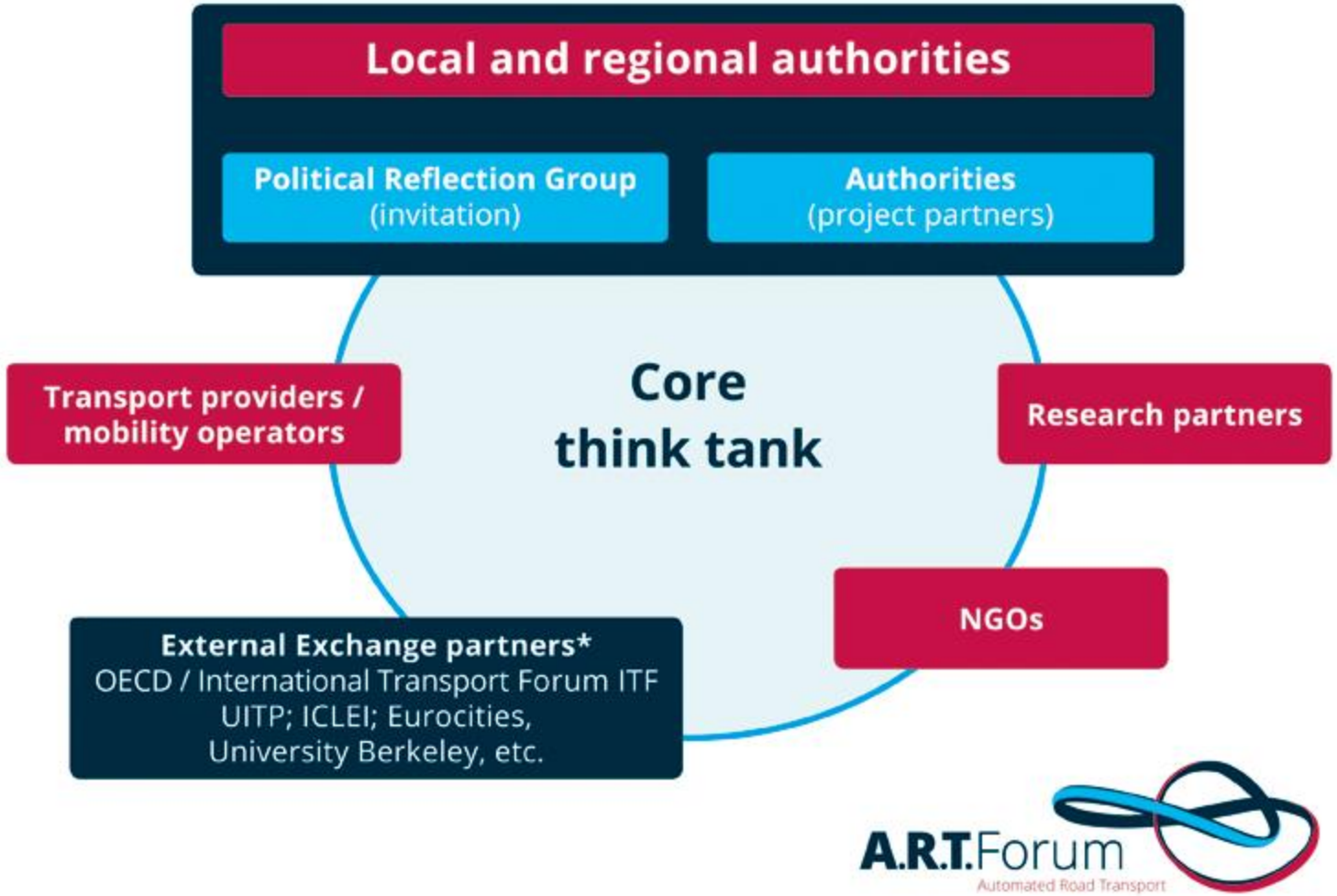
Reflection and Capacity Building



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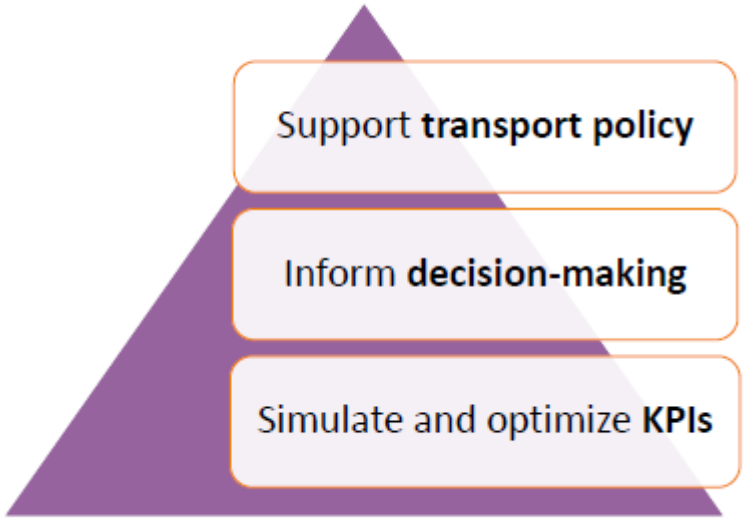
Our role:



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General Objectives

Explore	the **policy decision space** on real transport networks
Identify	how **user preferences** interact with network and policy design
Analyse	the influence of introducing **Connected and Autonomous Vehicles** (CAVs) into existing transport networks

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Connected and Autonomous Vehicles

Source: https://www.intelligenttransport.com/transport-news/96887/autonomous-bus-serviceinaugurated-in-danish-suburb/

Source: https://www.thelocal.se/20190221/self-driving-buses-to-hit-swedish-public-roads-next-year

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Research Lines

Explore	the **policy decision space** on real transport networks
Identify	how **user preferences** interact with network and policy design
Analyse	the influence of introducing **Connected and Autonomous Vehicles** (CAVs) into existing transport networks

A. **Simulate** the **accessibility** provided by real-life multi-modal **Public Transport (PT)** networks

B. **Model demand dynamics** across the PT network

C. **Discover optimal improvements of the PT network** supported by CAVs

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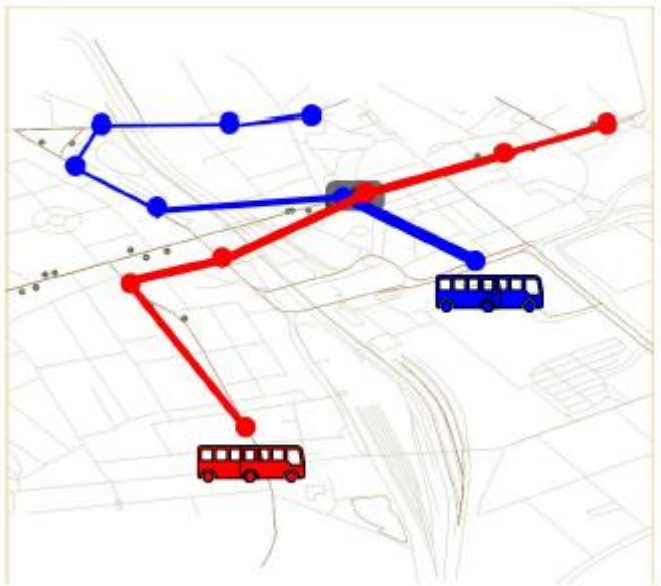
Expectation: A.+B.



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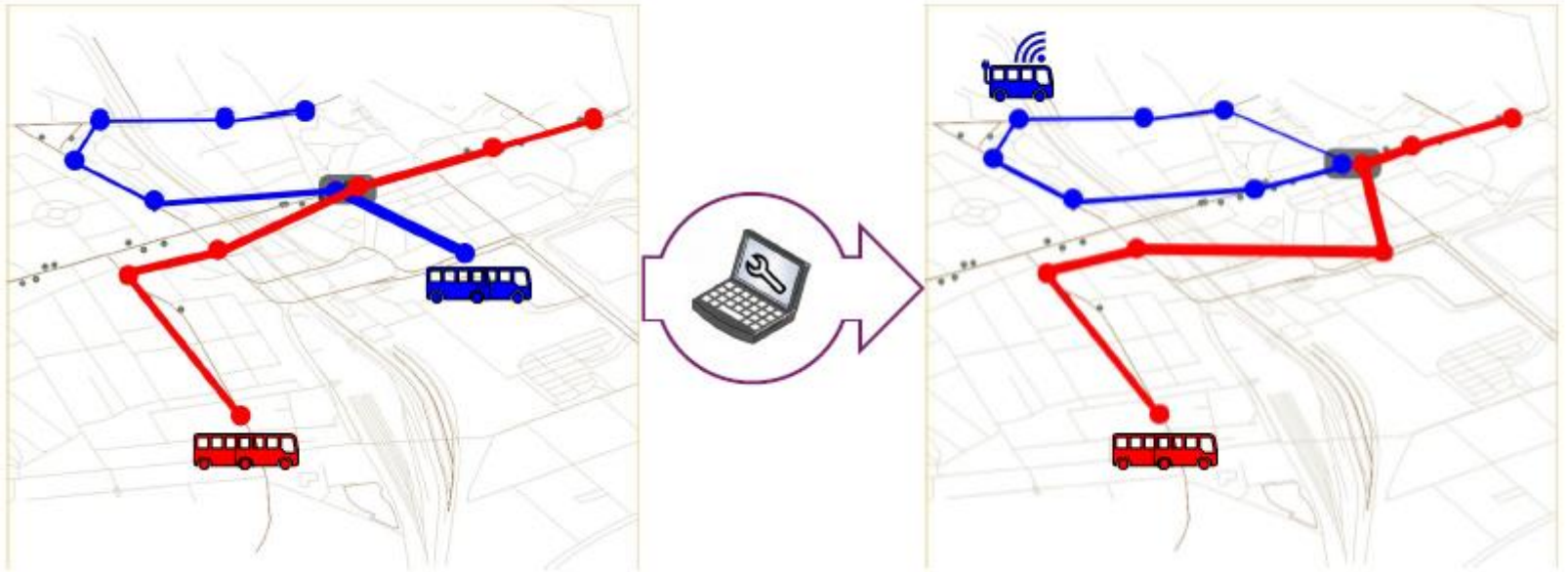
Expectation: A.+B.+C.=



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Present Research Focus

Discover realistic **optimal trade-offs** when wishing to **complement** an **existing multi-modal public transport system with a new CAV route** when considering:

1. **improvement of geographic accessibility** across the wider area
2. investments required by the new route (**capex**)
3. costs of day-to-day route operation (**opex**)

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Macro-Level Mobility Simulations

Based on:

- OpenStreeMap (**OSM**) datasets for information on **roads and footpaths**
- General Transit Feed Specification (**GTFS**) files for information on **PT timetables**
- programmatic **corrective links**
- a modified version of **Dijkstra's algorithm** for computing **multi-modal accessibility**

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Macro-Level Mobility Simulations

Key features:

- enable the **spatial-temporal modelling** of the PT network
- use a reversible graph structure → inbound and outbound isochrones
- **lightweight design** → quantifying geographic accessibility

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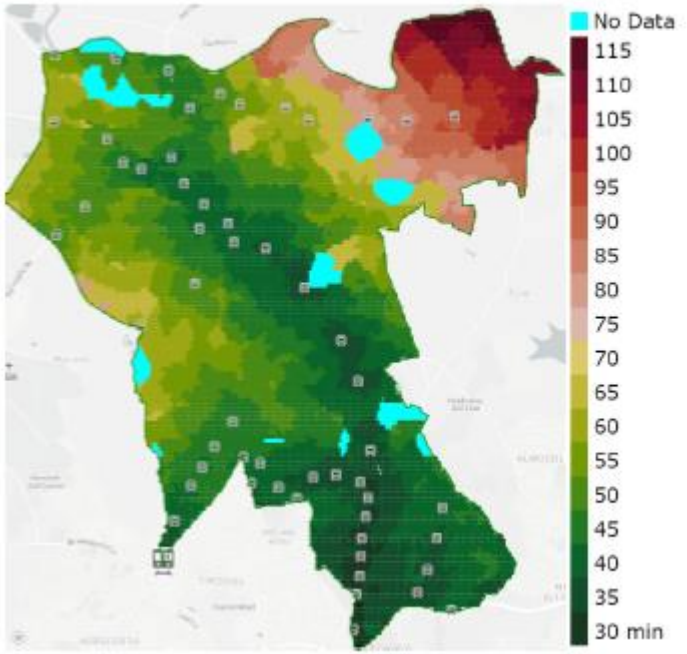
Modelling KPIs

1. **geographic accessibility score**
   - define a **grid *G*** of equidistant points
   - compute the distance from each grid point *A* to the desired destination *B*:

   - **average** results across all grid points



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Modelling KPIs

1. **geographic accessibility score**
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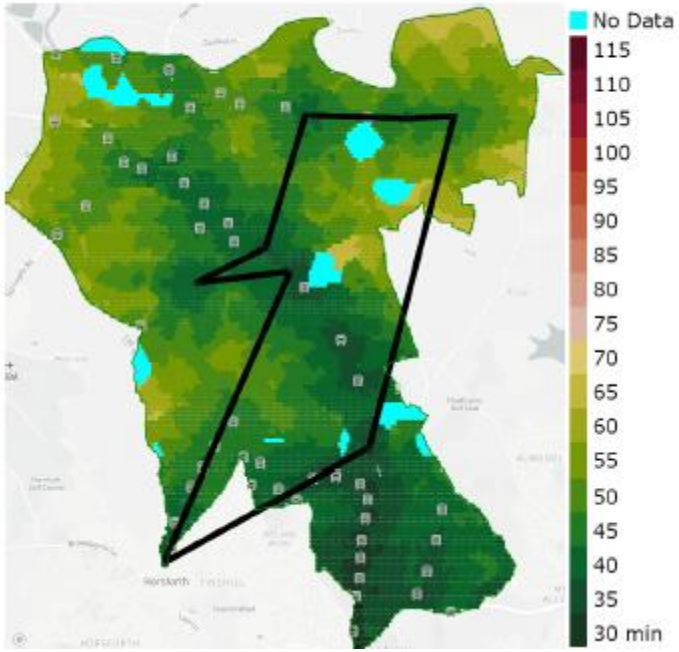
   - compute the distance from each grid point *A* to the desired destination *B*:

   - **average** results across all grid points
2. **capex** – use **no. of CAVs** as proxy
3. **opex** – use **route length** as proxy



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Optimisation Strategy

Encoding:

- uni-dimensional array of size *L* = the total number of usable PT stops in the study area
- real values in [0,1]
- **clock-wise ordering** of selected stops within route based on **fixed start point**

Solver:

- **NSGA-II** – well-known multi-objective evolutionary algorithm
- standard genetic operators and parameterisation: **SBX** (0.9, 20) & **polynomial mutation** (1/*L*, *20*)
- population/archive size = 200
- budget = 50,000 fitness evaluations
- random initialisation with **95% 0-bias**

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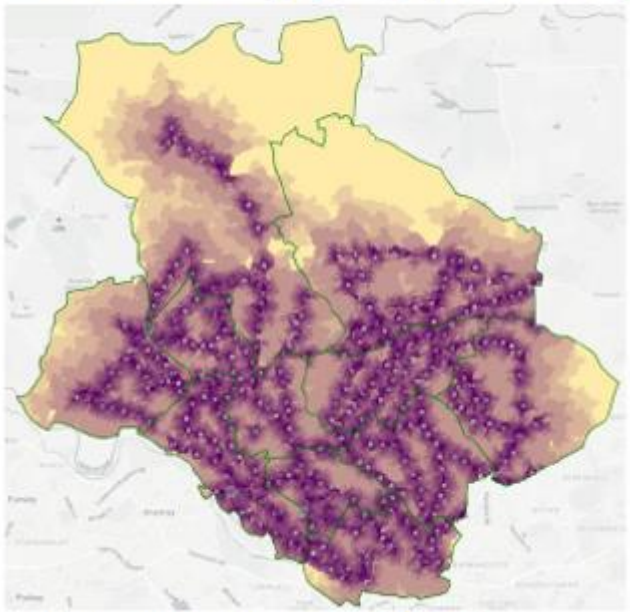
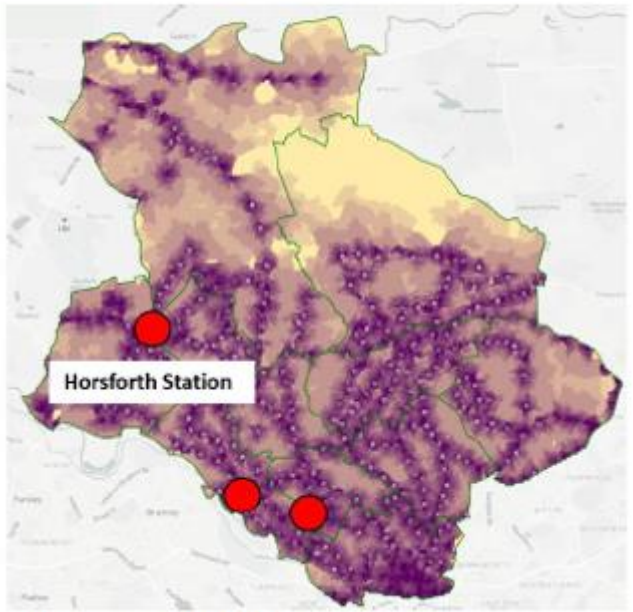
Case study (big picture)





High-frequency PT stops in NW Leeds

All PT stops in NW Leeds

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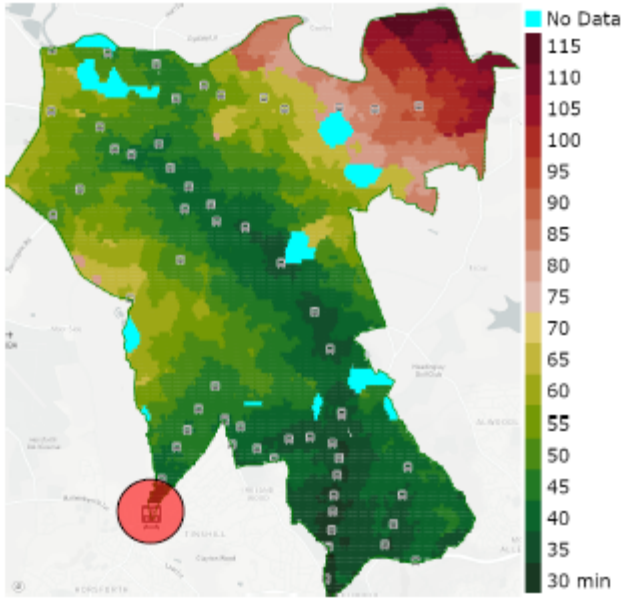
Case study (focus)

Discover CAV-based routes that minimises commuting time to Leeds (Central) Station by 10 AM on a workday .

Constraints / assumptions:

- **Horsforth station must be included**
- Bi-directional circular service
- 10 min frequency and 30s waiting time at each PT stop
- Average travel speeds (32km/h for CAVs and 5km/h for walking)



Baseline accessibility score: **3379s** = 56m 19s

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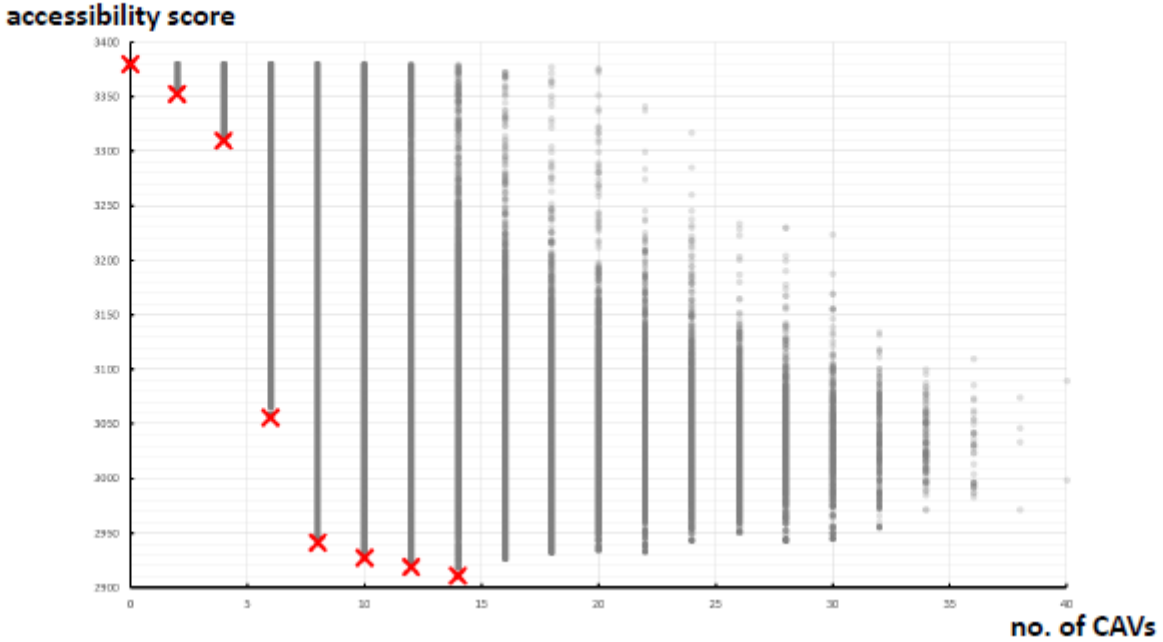
Results: accessibility score vs no. of CAVs



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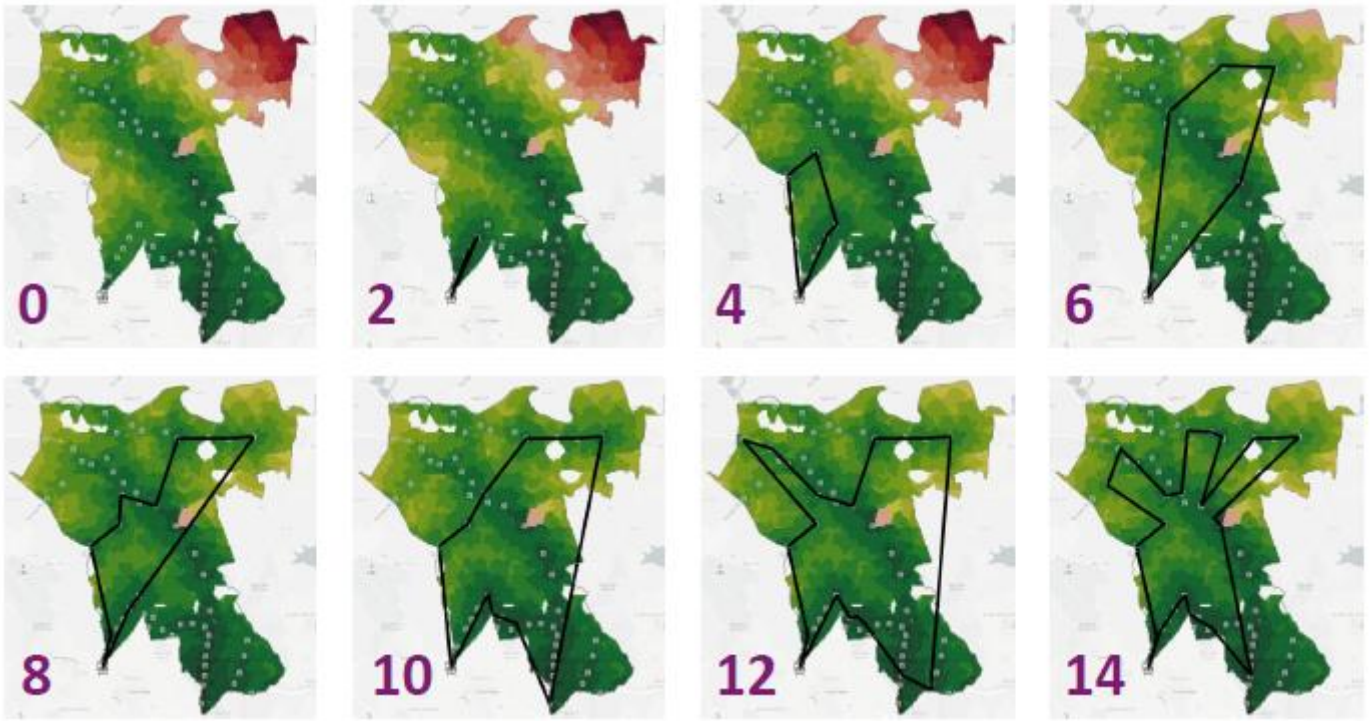

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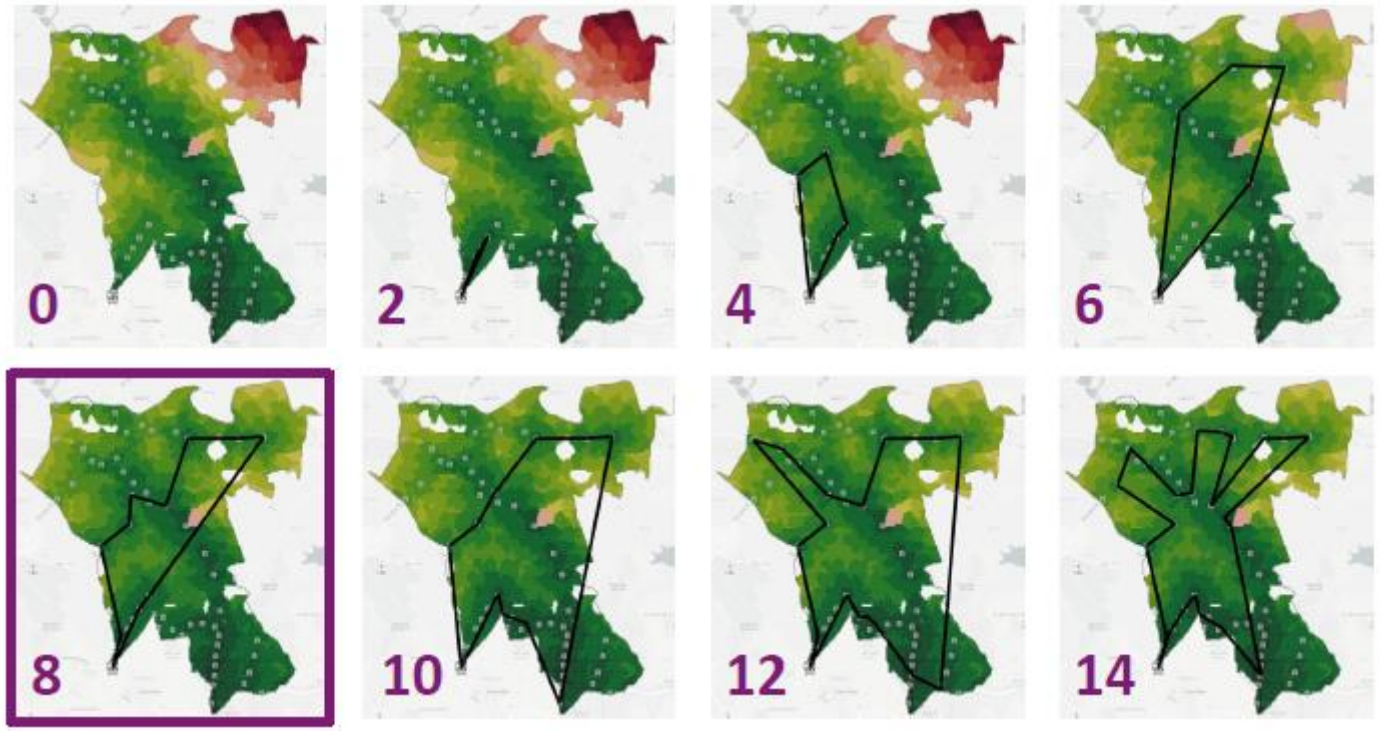

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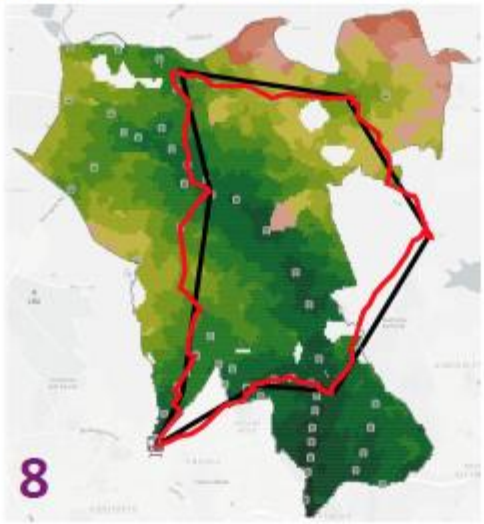
Results: validation

Proposed approach

Accessibility score: 2941s **(13% improvement)**

Human planner (best of 3 attempts)



Accessibility score: 3195s **(5.45% improvement)**

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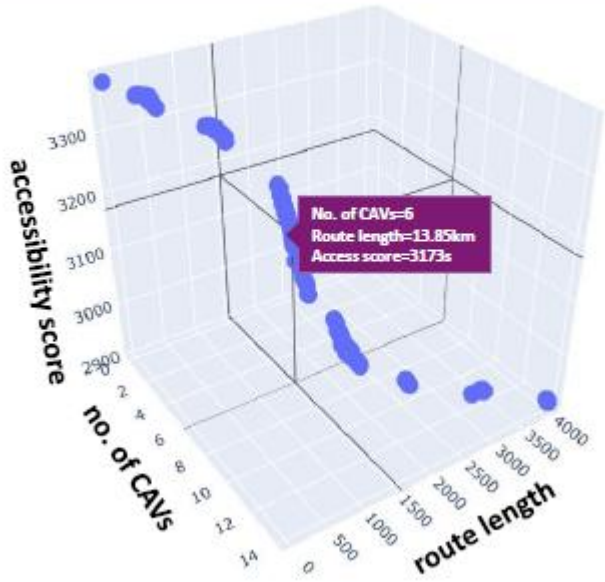
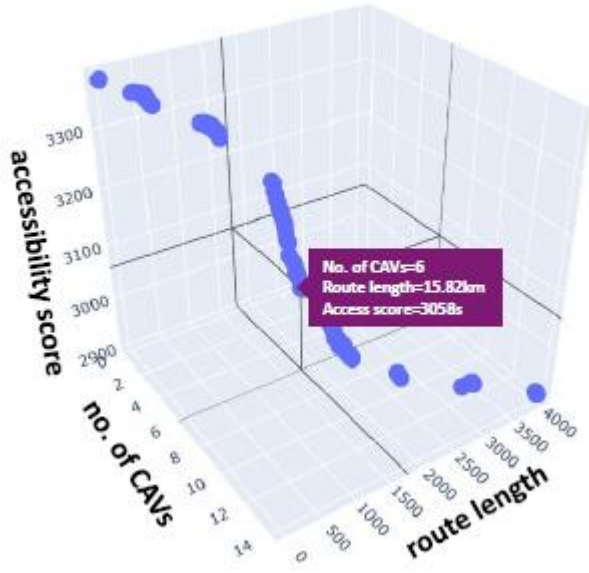
Results: accessibility score vs no. of CAVs vs route length





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Conclusions and Future Work

By **coupling macro-mobility simulations with standard MOEAs**, one can:

1. discover **highly insightful trade-offs in PT route planning**
2. produce **human-competitive PT route sketches**

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Conclusions and Future Work

By **coupling macro-level mobility simulations with standard MOEAs**, one can:

1. discover **highly insightful trade-offs in PT route planning**
2. produce **human-competitive PT route sketches**

Future work involves:

- Investigate **non-circular routes**
- Experiment with **different encoding / stop ordering strategies**
- **Improve simulation parameterisation/assumptions** based on micro-mobility simulation results (e.g. SUMO framework)

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Thank You Very Much!