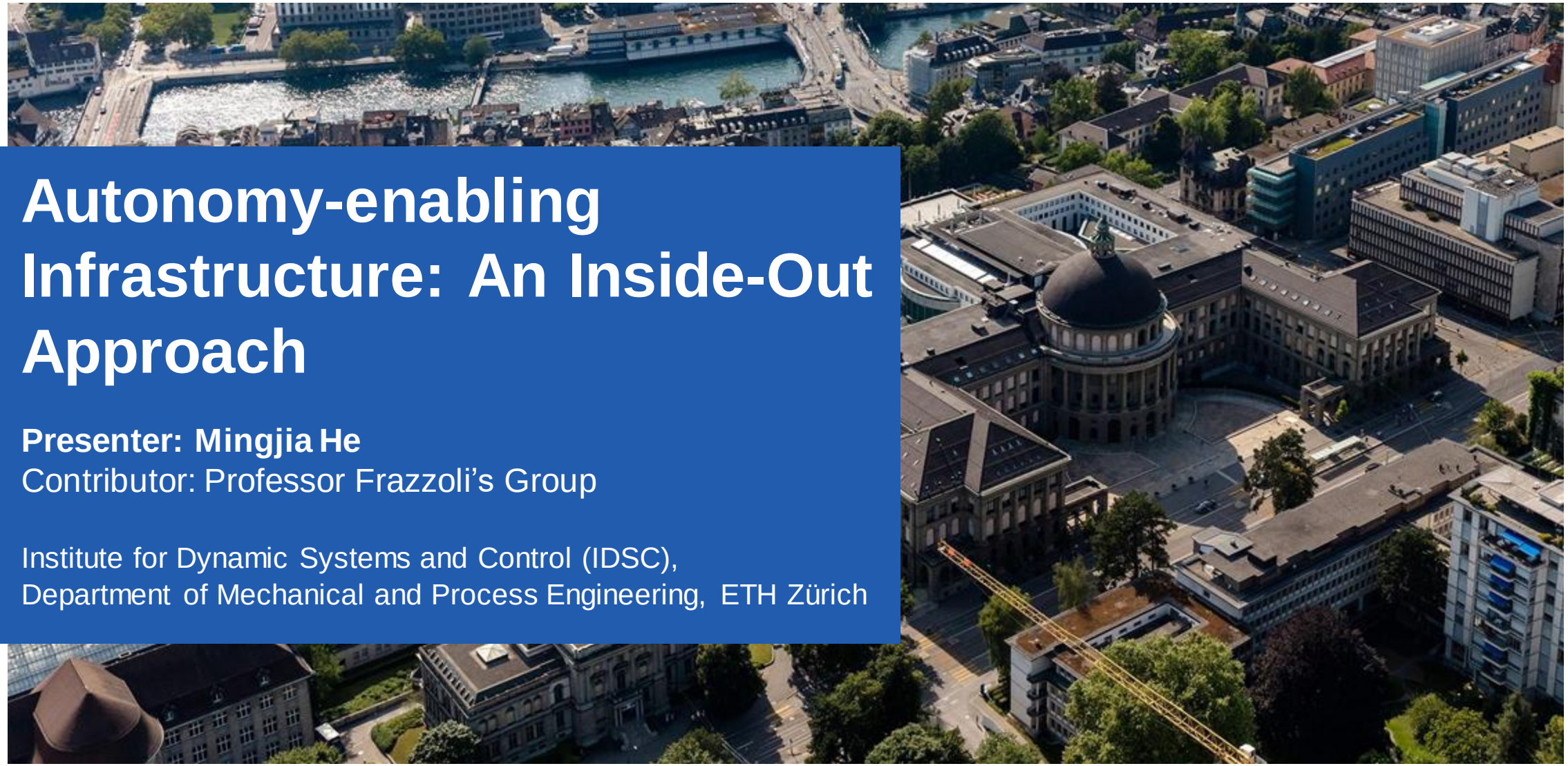

Autonomy-enabling Infrastructure: An Inside-Out Approach

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Autonomy-Enabling Infrastructure

Inside approach: Autonomy fully on the vehicle

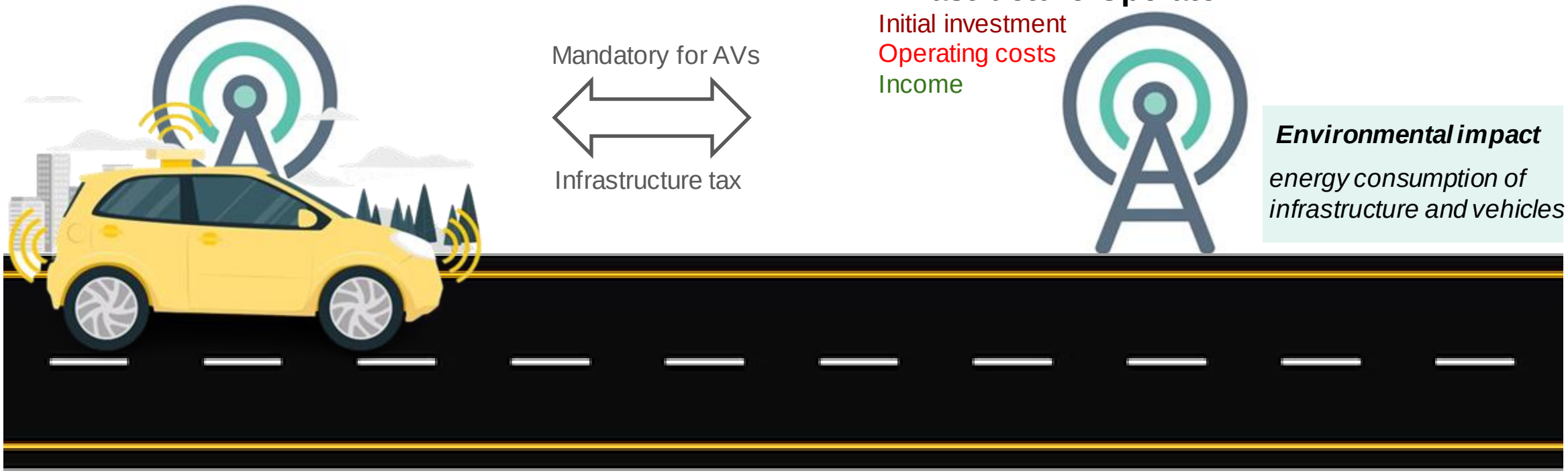
VS

Inside-out approach: Autonomy-enabling infrastructure to assist autonomous vehicles

- **Stakeholder Interaction Outcomes**
- **Customer Benefits Analysis**
- **Environmental Impact Assessment**
- **Optimal Location for AEI Installation**
- **Infrastructure Usage Charges**
- **Pricing Strategies for AV Operators**

Three perspectives: Municipalities, AV Operators, Customers

Municipalities / Infrastructure Operator:
Initial investment
Operating costs
Income



Mandatory for AVs

Infrastructure tax

Environmental impact

energy consumption of infrastructure and vehicles

AV / AMoD Operator:
Initial investment
Operating costs
Income

Transport Service within infrastructure zone

Service price

Customers:
Availability of services
Cost vs Benefit

Scenario Overview for Bern 2040

Models for case studies - Canton of Bern in 2040

Figure: Study area: the Canton of Bern
[source:OpenStreetMap]

Dataset:

Default scenario provided by SBB:

- *1.062.272 links*
- *584.752 agents*
- *2.508.577 total trips*

Simulation

Construct multiple scenarios

Enable / Disable streets for autonomous taxis

Simulation tool: MATSim Multi-Agent Transport Simulation

Which **streets** to select for the autonomy-enabling infrastructure?

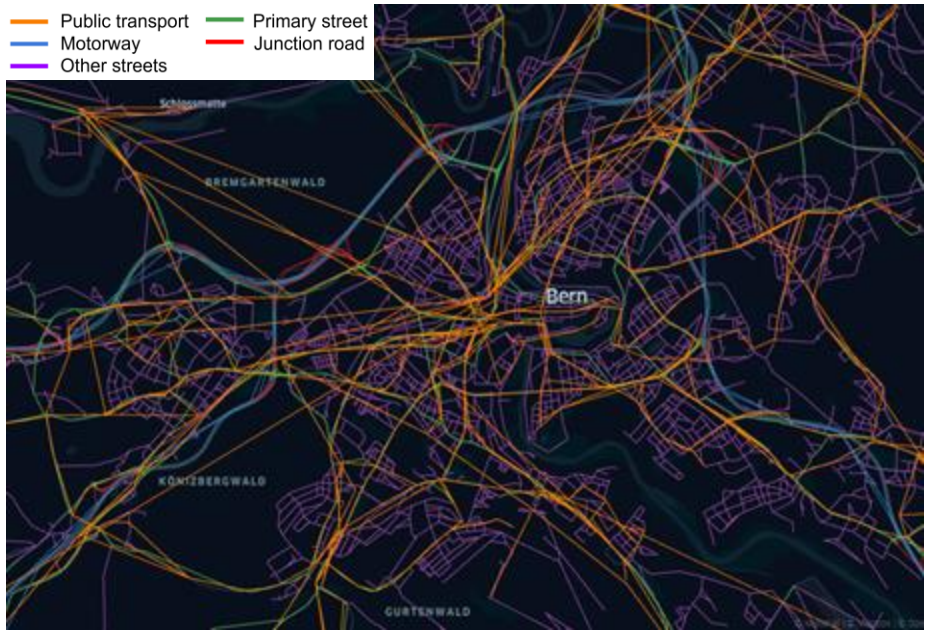


Figure: Map of Bern

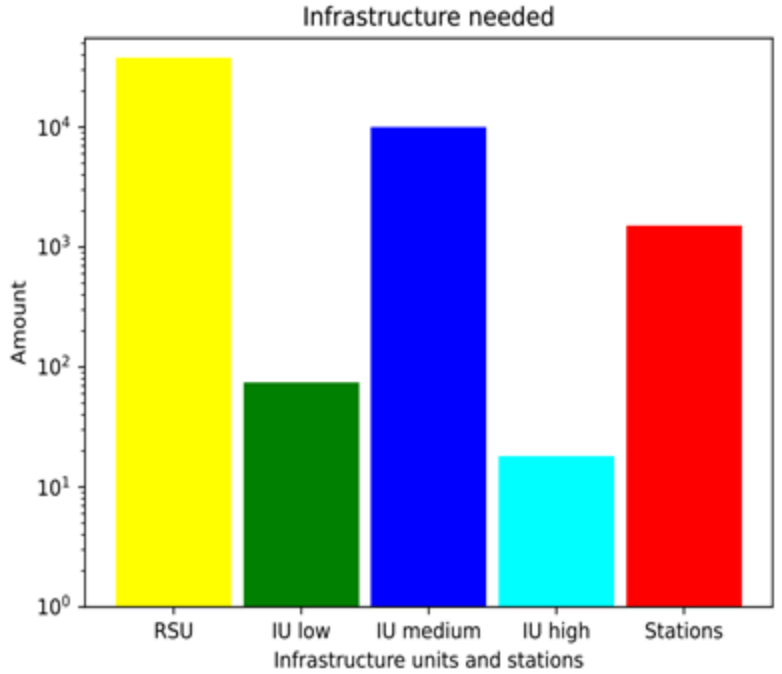


Figure: Autonomy-enabling infrastructure

Influential factors:

- Street usage/link volume
- Overall location
- Type of street
- Length of street

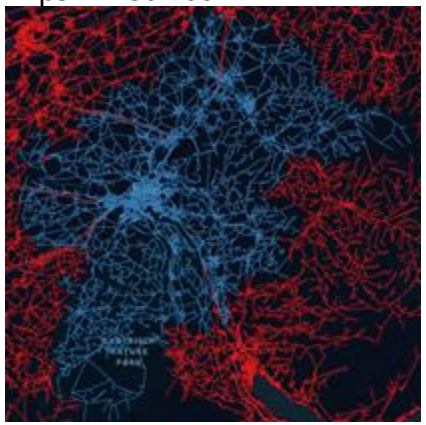
Scenarios:

All streets, Primary streets, non-motorway streets, **rural, urban** areas, streets with speed limits, optimization-based selection, etc.

Infrastructure Scenarios

Streets where infrastructure will be installed
Streets that do not meet the criteria

All streets
Infrastructure cost: 398 mn CHF
Trips: 1.750.400

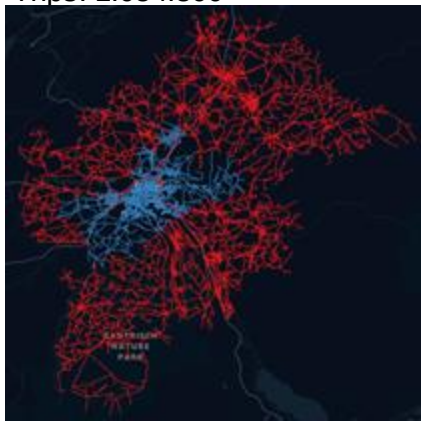


Non-motorway
Infrastructure cost: 393 mn CHF
Trips: 1.746.500

Primary
Infrastructure cost: 75 mn CHF
Trips: 64.500

60 km/h & 30 km/h
Infrastructure cost: 89 mn CHF
Trips: 1.001.100

Urban
Infrastructure cost: 112 mn CHF
Trips: 1.054.800



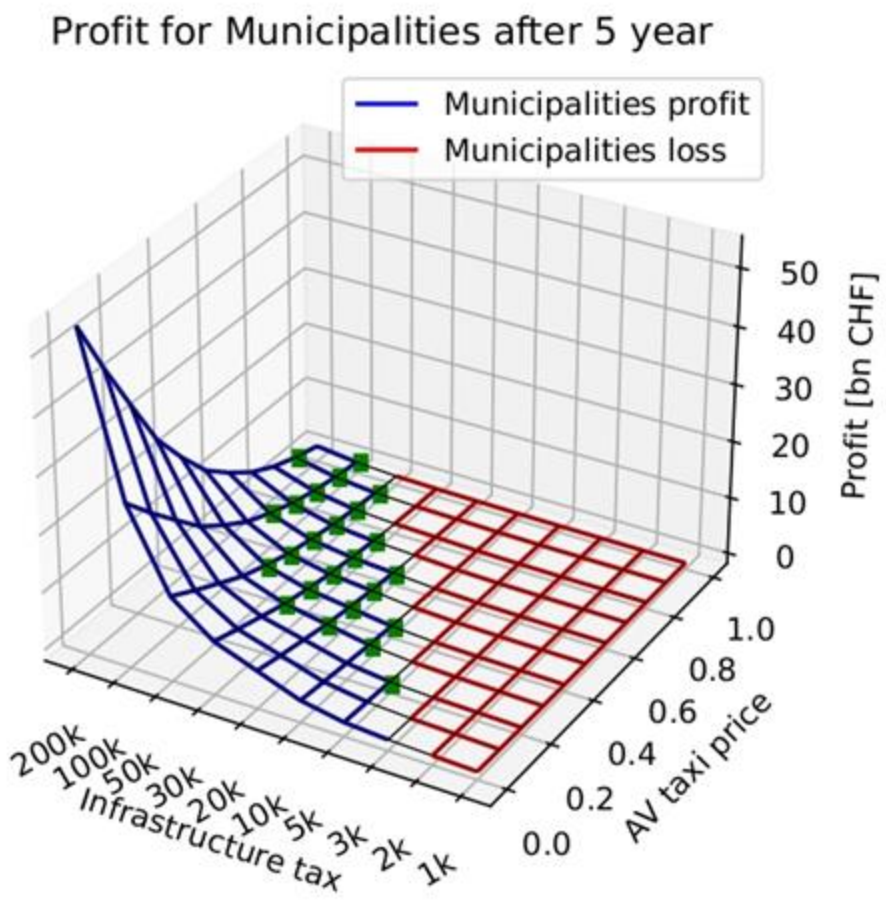
Rural
Infrastructure cost: 243 mn CHF
Trips: 282.000

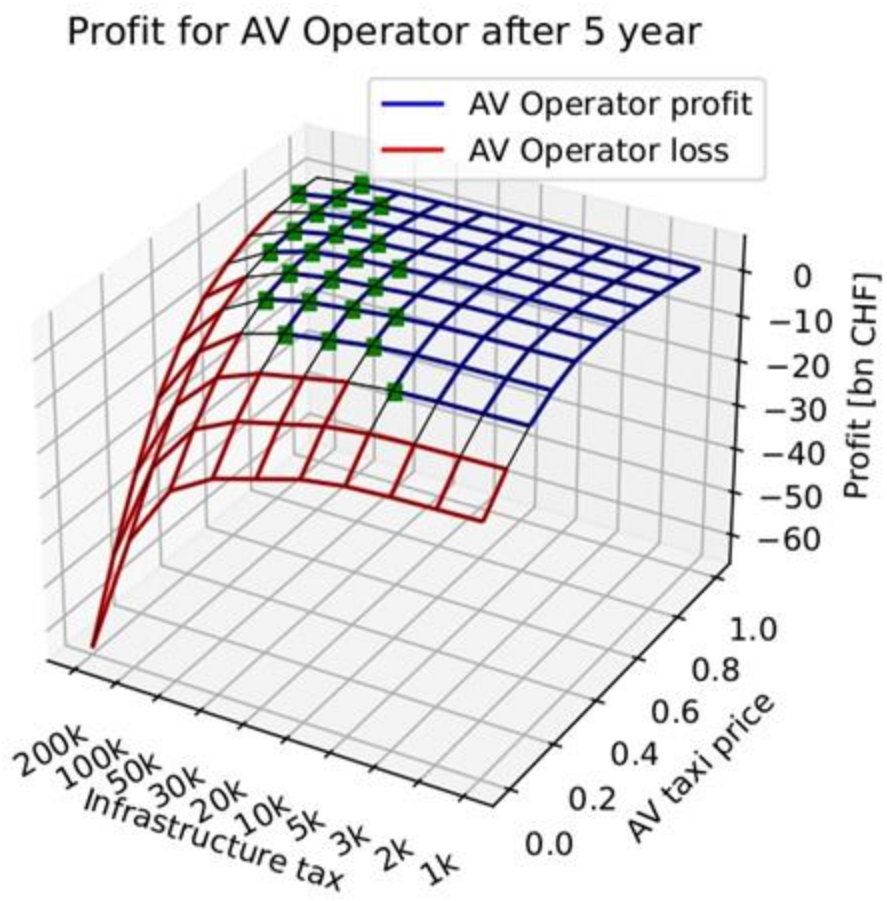
Highest link volumes
Infrastructure cost: 94 mn CHF
Trips: 171.100

Flow optimization
Infrastructure cost: 67 mn CHF
Trips: 264.600

Performance Analysis of Autonomy-enabling Infrastructure

Profitability: Municipalities and AV operators - Highest volumes scenario

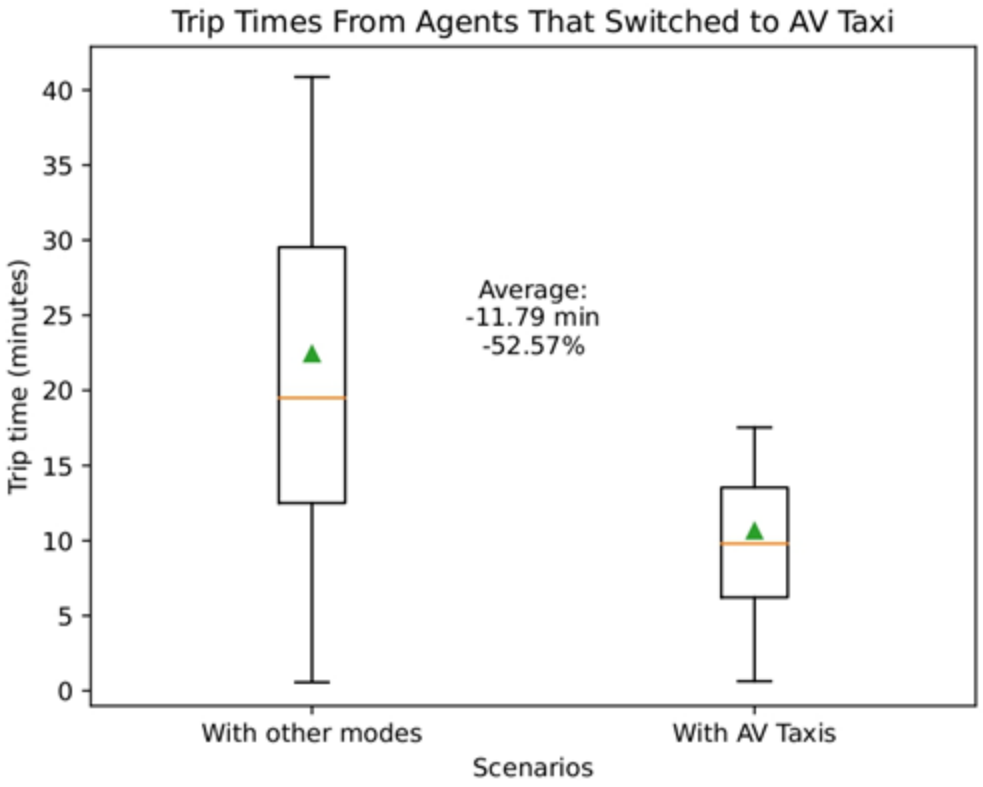




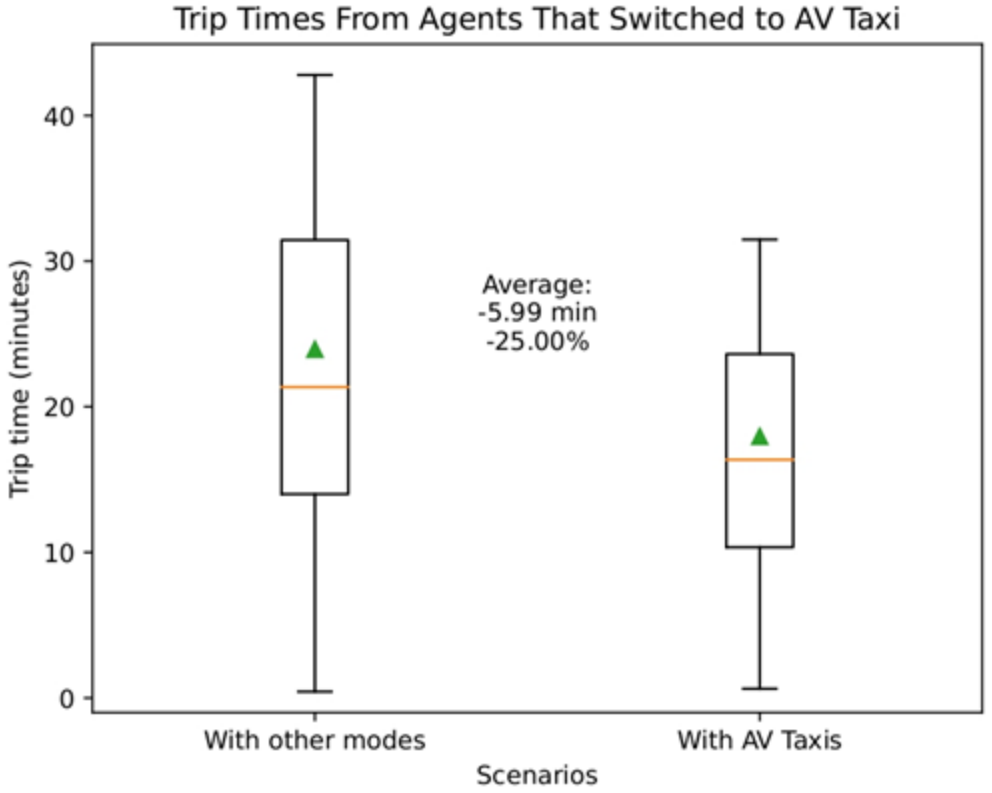
Only some combinations of infrastructure taxes and autonomous taxi prices lead to **profit for both stakeholders**

Time reduction: Customers

All Streets Scenario



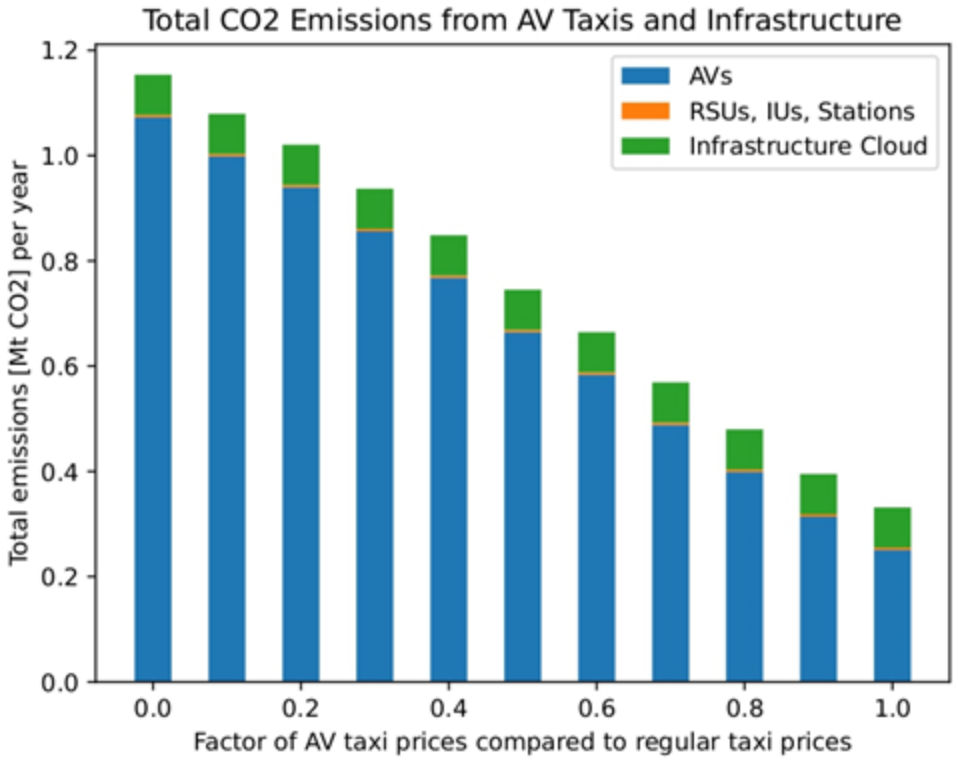
Highest Volumes Scenario



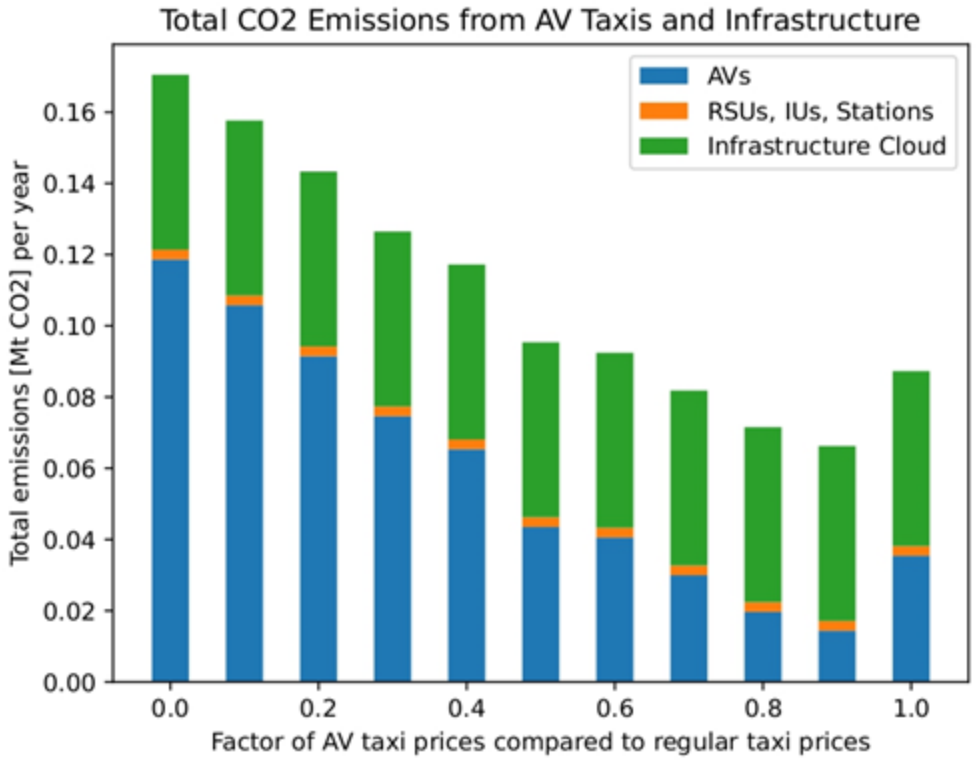
Autonomous vehicles can significantly **decrease the trip time** by up to 53%

Total CO_2 Emission

All Streets Scenario
(Much infrastructure and much AV usage)

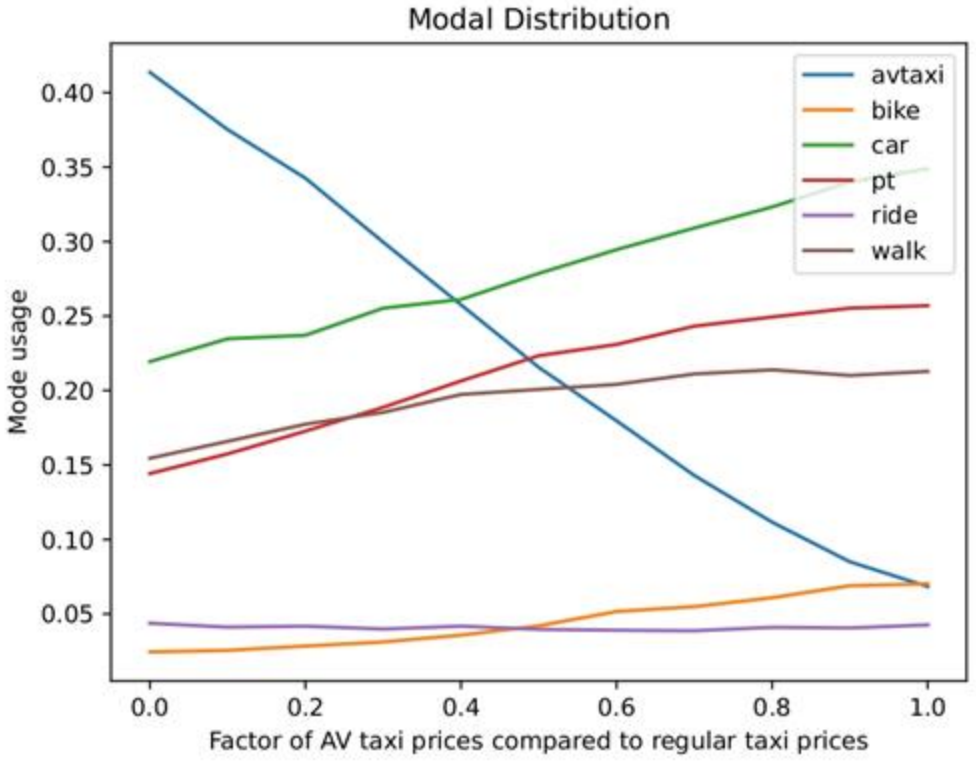


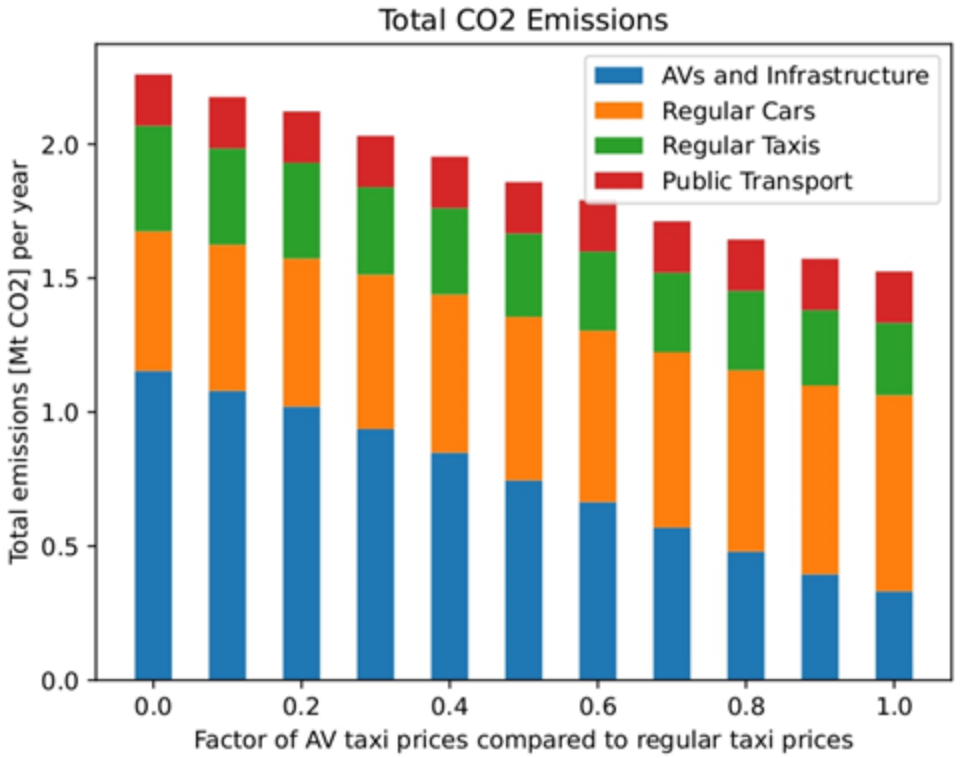
Rural Scenario
(Much infrastructure but little AV usage)



The Infrastructure Units and Cloud Computing account for a minor share of total emissions in the All Streets scenario, yet they represent a significant share in the Rural scenario.

Autonomy might increase CO2 emissions





A **higher usage of AMoD services** might lead to a **higher total of CO2 emissions** due to the additional energy needed for the autonomy technology

Scenario comparison at lowest profitable prices

Scenario			Infra. Operator	AV Operator	Societal Impact		
Name	AV Taxi Price [% of regular Taxi]	Infra. Tax [k CHF]	Profit p.a. [m CHF]	Profit p.a. [m CHF]	Travel Time Saving	CO2 Emissions [Mt]	Mode Share
All Streets	20%	10	329	398	-53%	2,20	46%
Non-Motorway	30%	10	148	1 027	-32%	1,83	43%
Urban	30%	5	28	207	-43%	1,53	29%
Rural	60%	100	37	-7	-4%	1,40	13%
60 km/h	30%	5	42	313	-47%	1,56	26%
30 km/h	40%	20	10	-6	-40%	1,40	5%
Primary Streets	20%	10	12	38	0%	1,48	17%
Primary & Secondary Streets	20%	10	246	509	-45%	2,13	42%
High Volume Streets	20%	5	48	372	-25%	1,65	29%
Flow Optimization	20%	3	7	295	-21%	1,64	23%

Summary

- **Exploring Autonomy-Enabling Infrastructure:**

Investigated the underlying reasons for adopting autonomy-enabling infrastructure, incorporating perspectives from municipalities, autonomous vehicle (AV) operators, and customers.

- **Performance Analysis Across Scenarios:**

Assessed the performance across different scenarios focusing on environmental impacts, economic effects, and quality of service over different planning horizons.

- **Advancing Simulation Models:**

Many critical factors and opportunities for further exploration, highlighting the importance of utilizing advanced optimization-based and learning-based algorithms to improve the simulation models.
The impact of new stakeholders; regulations and incentives; technological evolution (clean energy, autonomy cost)

Thanks for your attention