Spring 2025

12 Mobility-as-a-service & Co-modality

CIVIL-324 Urban public transport systems

École polytechnique fédérale de Lausanne

Single vs inter-modal transport

Single-modal

Mass transit

Flexible transit

Personal mobility service

Inter-modal

Park & ride

First/last-mile

Mobility-as-a-service

Co-modality

Single vs inter-modal transport

Single-modal

Mass transit

Flexible transit

Personal mobility service

Inter-modal

Park & [illegible]

Topic of last week

[illegible] last-mile

Mobility-as-a-service

Co-modality

What is MaaS?

- The integration of various forms of transport services into a single on-demand mobility service[1]

Multi-modal travel via public transport

Single booking and payment channel

Tailor to user preferences

[1] ERTICO – ITS Europe. Mobility as a Service (MaaS) and Sustainable Urban Mobility Planning

Stakeholders and incentives to join MaaS

- Travelers
  - A convenient and flexible mobility option

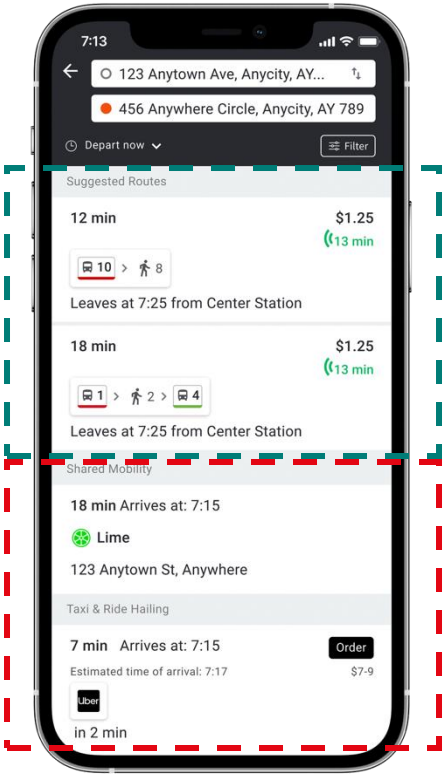
- Cities
  - Reduce private driving and traffic congestion
  - Consolidate local transport services and infrastructures

- Service providers
  - Increase ridership and capacity utilization

- MaaS platform
  - Novel mobility service
  - Data sharing and integration

Current practice

- Trip planning

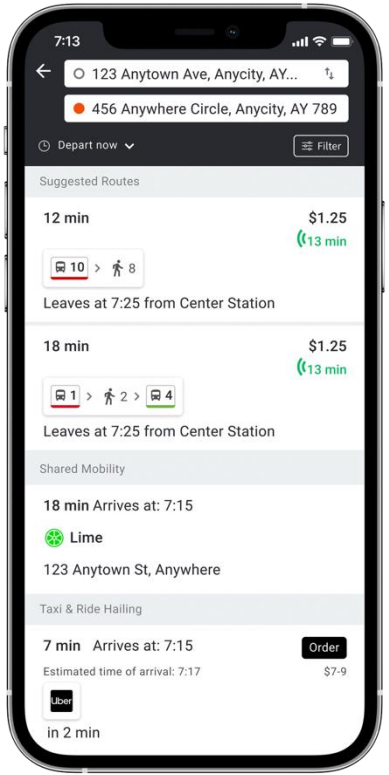


Public transit (e.g., bus, train, metro)

Shared mobility (e.g., bike-sharing, ride-hailing)

Current practice

- Trip planning



- North America

umo

moovit

- Asia

moovit

Baidu map

Gaode map

- Europe

Trafi

UbiGo

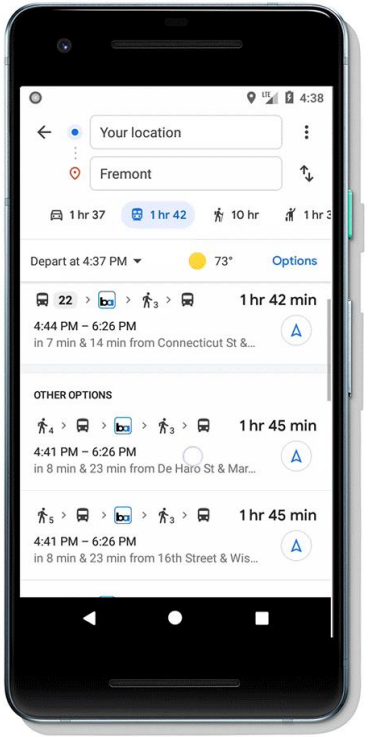
- Switzerland

SBB CFF

Public transit
Shared mobility

Current practice

- Trip planning



- Global

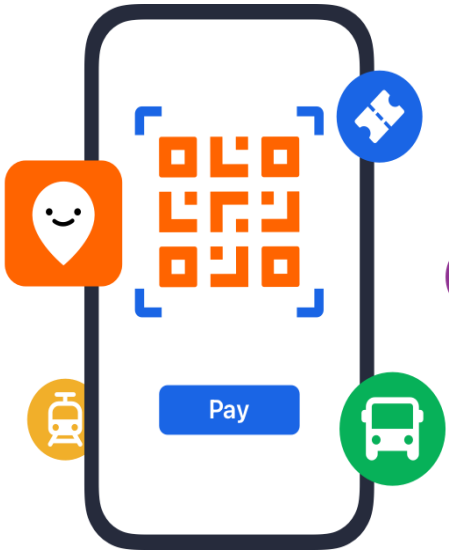
Google Maps

https://blog.google/products/maps/travel-your-first-and-last-mile-google-maps/

Public transit
Shared mobility

Current practice

- Single payment channel
  - Separate ticketing
- Integrated ticketing
  - e.g., OD-based, bundle, subscription



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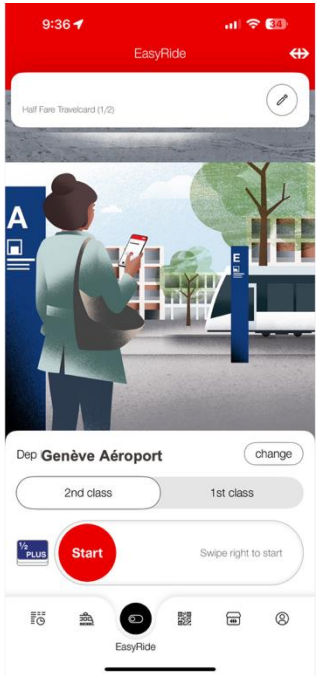
Trafi



umo

ÜbiGo

Business model

- Role of MaaS platform
  - Trip planner
    - Multi-modal trip planning
  - Broker
    - + take a share of multi-modal trip revenue
  - Integrator
    - ++ set price of multi-modal trips
  - Intermediary
    - +++ buy service capacity at a wholesale price, and retail multi-modal trips

Google Maps

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UbiGo

integration level

Business model

- Data provision and sharing schemes
  - Private platforms

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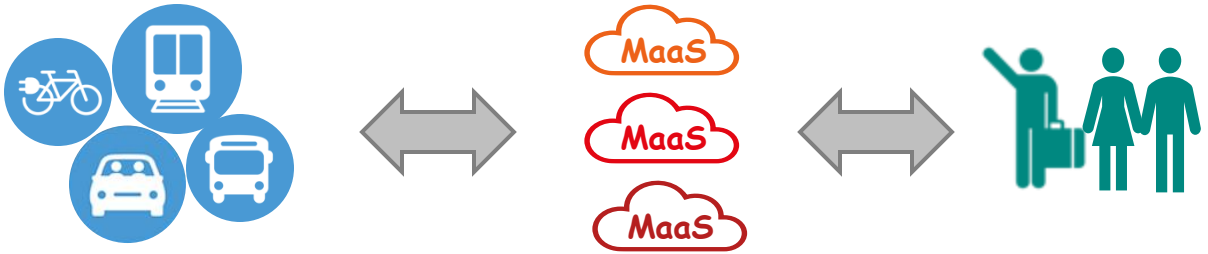

Business model

- Data provision and sharing schemes
  - Private platforms

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  - Public data provider + private platforms

Google Maps

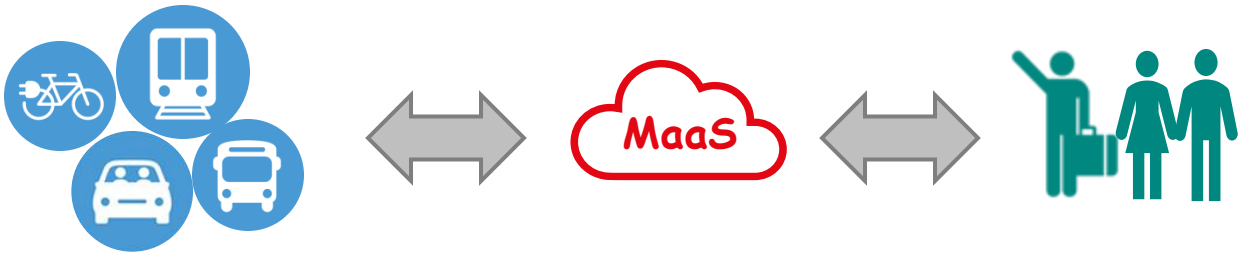
Business model

- Data provision and sharing schemes
  - Private platforms

    moovit umo
  - Public data provider + private platforms

    Google Maps du
  - Public integrator

    UbiGo



Opportunities

- Policy
  - Sustainable urban mobility plans (SUMPs) and Urban Mobility Package
  - European strategy for low-emission mobility
  - EU Regulation on the provision of multimodal travel information services

- Industry
  - MaaS Alliance
  - European Metropolitan Transport Authorities (EMTA)
  - Urban Mobility Partnership (UMP)

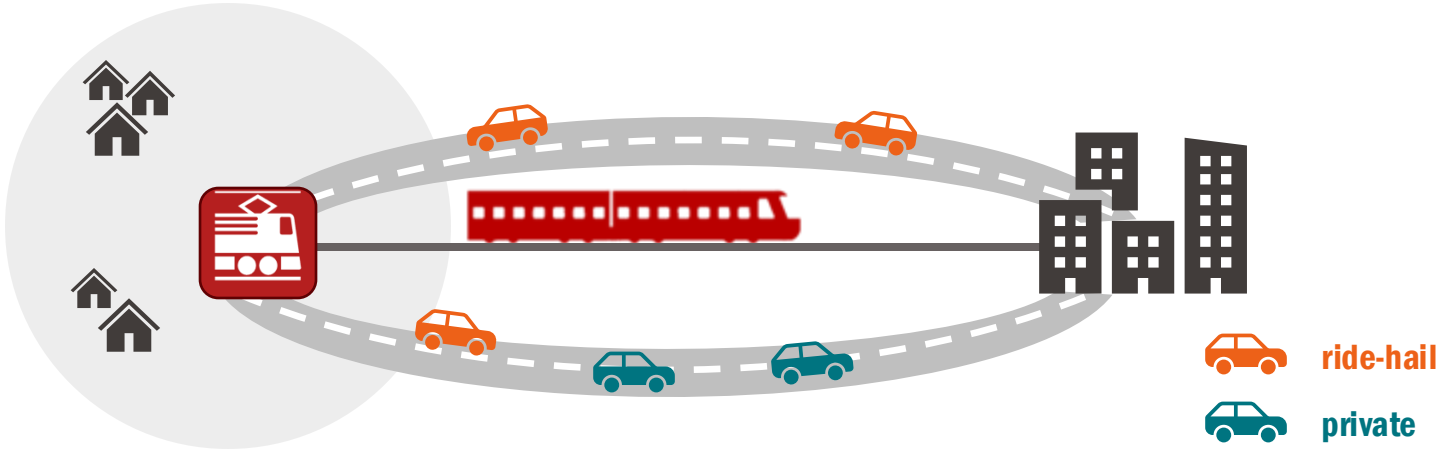
- Research
  - MaaS4EU
  - HOMES

Challenges

- Prerequisites to build a MaaS system
  - Well-developed public transport system
  - Ubiquitous mobile computing
- Operations of MaaS platforms
  - Coordinate and optimize of multimodal trips
  - Participation of both travelers and service providers
- Regulations on mobility data
  - Sharing and standardization
  - Privacy and security

Benefit of MaaS

- Stylized model with single origin-destination
  - Travel demand from the residential area to the city center at rate λ_0 (pax/hr)
    - Driving through highway at cost c_{drv} (CHF)
    - Ride-hailing trip through highway at price c_{hail} (CHF)
    - Multimodal trip (self-planned or MaaS) at cost c_{inte} (CHF)
  - Ride-hailing service with fleet size M (veh)



Benefit of MaaS

- Total travel time per trip
  - Driving

    $t = t_a + t_{\text{hwy}}$

    - t_a driving time to highway
    - t_{hwy} travel time on highway

  - Ride-hailing

    $t = w + t_a + t_{\text{hwy}}$

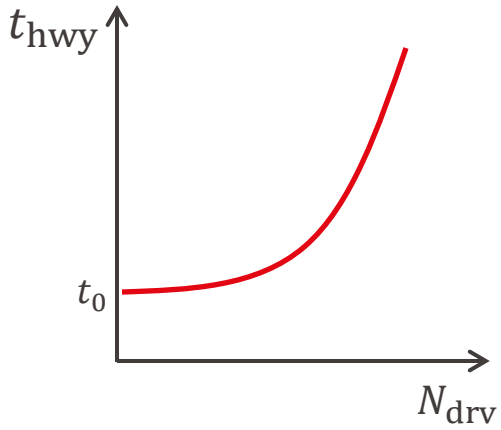
    - w waiting time

  - First-mile + Rail

    $t = w + t_a + \tau + t_{\text{rail}}$

    - τ transfer & planning time
    - t_{rail} riding time of train

*** Self-planned vs MaaS trip**



$$t_{\text{hwy}} = t_0 \left[1 + \gamma \left(\frac{\lambda_{\text{drv}} + \lambda_{\text{hail}}}{\kappa} \right)^{\alpha} \right]$$

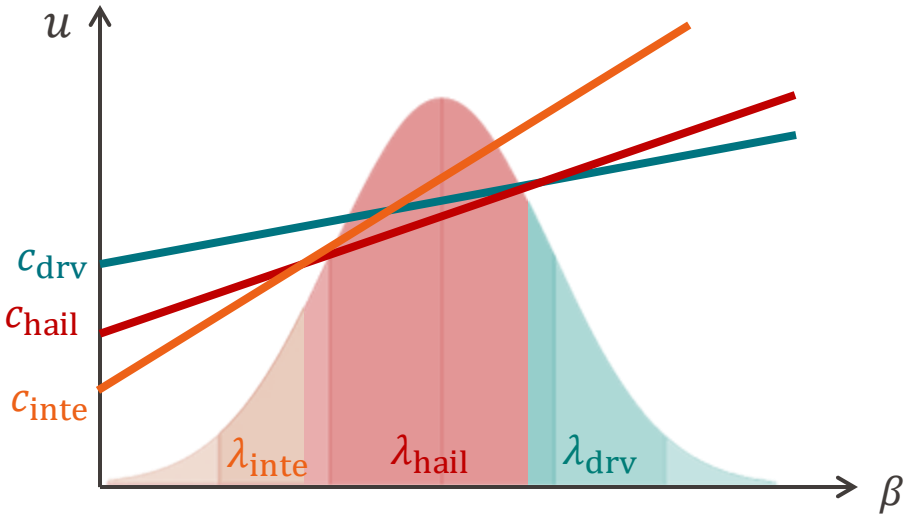
- t_0 free-flow travel time on highway
- $\lambda_{\text{drv}}, \lambda_{\text{hail}}$ driving and ride-hailing demand
- κ highway capacity
- α, γ parameters in highway travel time function

Benefit of first-mile service

- Mode choice of commuters

$$u = c + \beta t$$

- u generalized cost
- c, t monetary cost and total travel time
- β value of time with probability density function $f(\beta)$

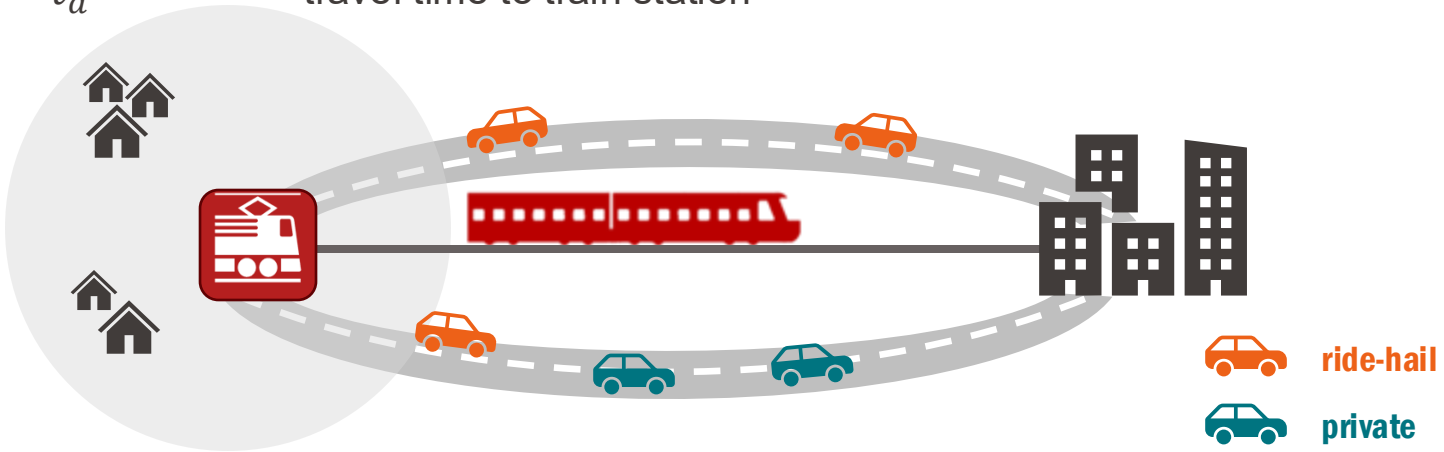


Benefit of MaaS

- Ride-hailing vehicle conservation

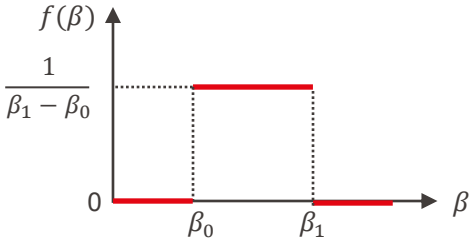
$$M = V + (\lambda_{\text{inte}} + \lambda_{\text{hail}})(w + t_a) + \lambda_{\text{hail}}(t_0 + t_{\text{hwy}})$$

- V vacant vehicle time in residential area
- $\lambda_{\text{inte}}/\lambda_{\text{hail}}$ demand for multi-modal and regular trips
- t_0 relocation travel time
- w waiting/pickup time
- t_a travel time to train station



Benefit of MaaS

- Case study
  - Uniform distribution of value of time
    - $\beta_0 = 25$ (CHF/hr); $\beta_1 = 50$ (CHF/hr)
  - Demand rate $\lambda_0 = 1000$ (pax/hr)



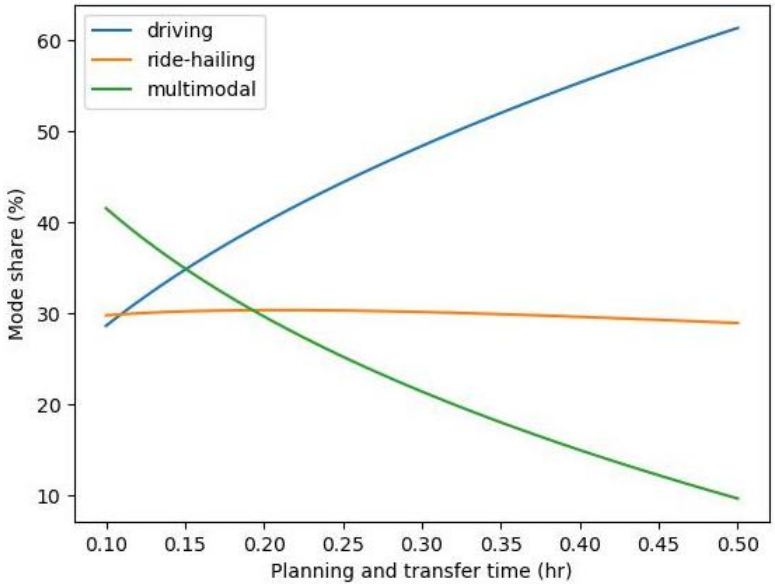
  - Costs of driving $c_{\text{drv}} = 25$ (CHF) and ride-hailing trip $c_{\text{hail}} = 20$ (CHF)
  - Driving time to highway/train station $t_a = 0.25$ (hr)
  - Riding time on train $t_{\text{rail}} = 0.75$ (hr)
  - Highway free-flow travel time $t_0 = 0.5$ (hr)
    - capacity $\kappa = 400$ (veh/hr)
    - other parameters $\alpha = 4, \gamma = 0.15$
  - Ride-hailing fleet size $M = 500$ (veh)
  - Ride-hailing waiting time

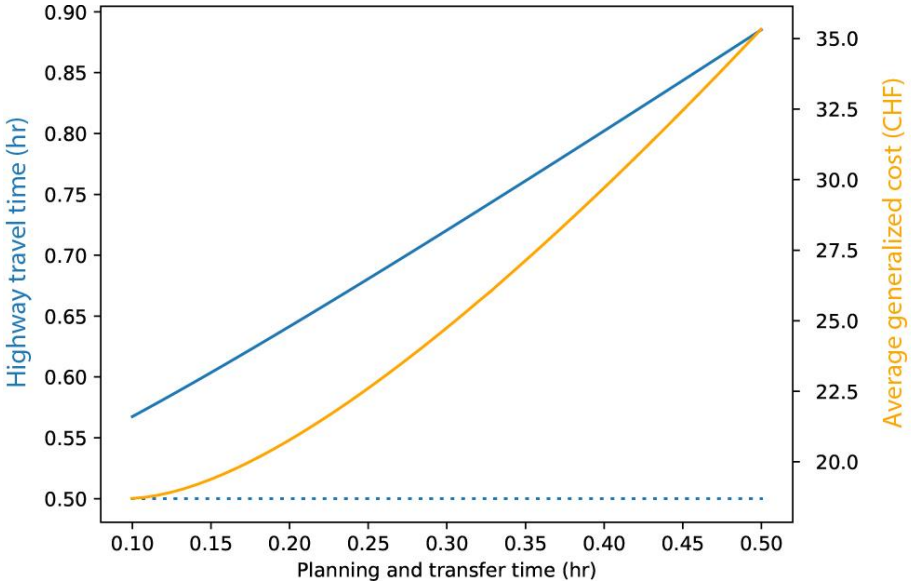
$$w = \frac{\delta}{2v}\sqrt{A/V}$$

    - residential area $A = 40$ (km^2)
    - cruising vehicle speed $v = 20$ (km/hr)
    - network detour ratio $\delta = 1.4$

Benefit of MaaS

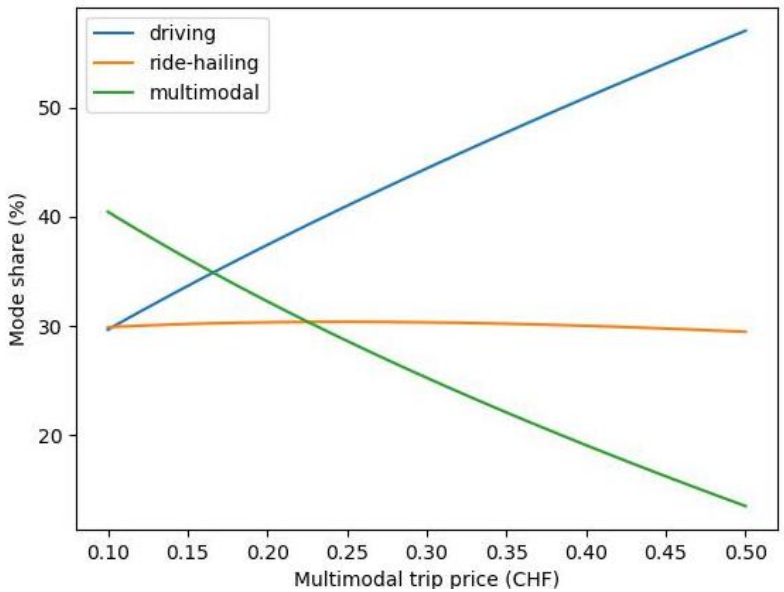
- Self-planned vs MaaS multimodal trip
  - Fixed trip price $c_{\text{inte}} = 10$ (CHF)
  - Impact of transfer & planning time τ

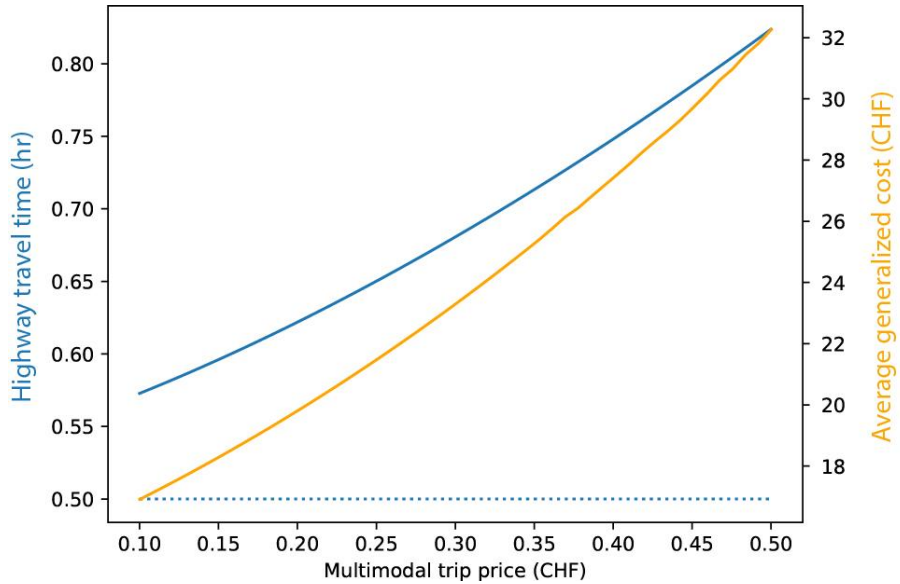




Benefit of MaaS

- Self-planned vs MaaS multimodal trip
  - Fixed transfer & planning time $\tau = 0.25$ (hr)
  - Impact of multi-modal trip fare c_{inte}





Questions?

What is co-modality?

- Integrate freight transportation and mobility services
  - Move goods using public transport vehicles
    - e.g., last-mile logistics by transit
  - Combine urban logistics and mobility services
    - e.g., ride-hailing + crowd-shipping
  - Move passengers using logistics vehicles

Cargo tram in Zurich

- Already widely applied in long-haul transport
  - e.g., air and rail transport

Freight transport by passenger plane

Incentives to join co-modality

- Mobility service providers
  - Increase capacity utilization
  - Extra revenue channel
  - Consolidate services (e.g., Uber + UberEat)

- Logistics operators
  - Save costs of last-mile deliveries

- Cities
  - Reduce congestion and relive parking issue in urban areas

Classification by integration level

- Shared infrastructure
  - passenger and freight vehicles use the same infrastructure
- Shared fleet
  - each vehicle is used for one service at a time
- Shared vehicle
  - passengers and freight may be delivered using the same vehicle

Shared ride-hailing fleet (DiDi, China)

Shared bus (Yamato, Japan)

Existing practices

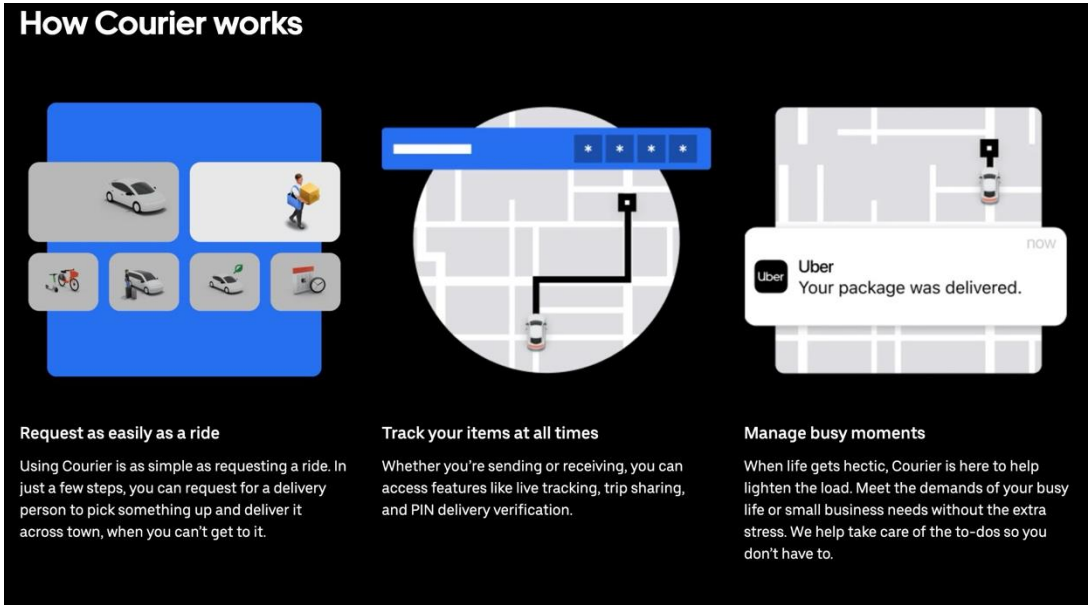
- Cargo tram
  - Use tram to move freight from city center to outskirt during off-peak periods
  - High capital and operational costs
    - often more expensive than truck delivery
    - main services were ended after several years
  - The most successful project is in Zurich for waste collection
    - thanks to stable demand and local government support

CarGoTram in Germany

DHL cargo tram in Germany

Emerging ideas

- Ride-hailing + parcel delivery
  - use empty ride-hailing vehicles to deliver parcels

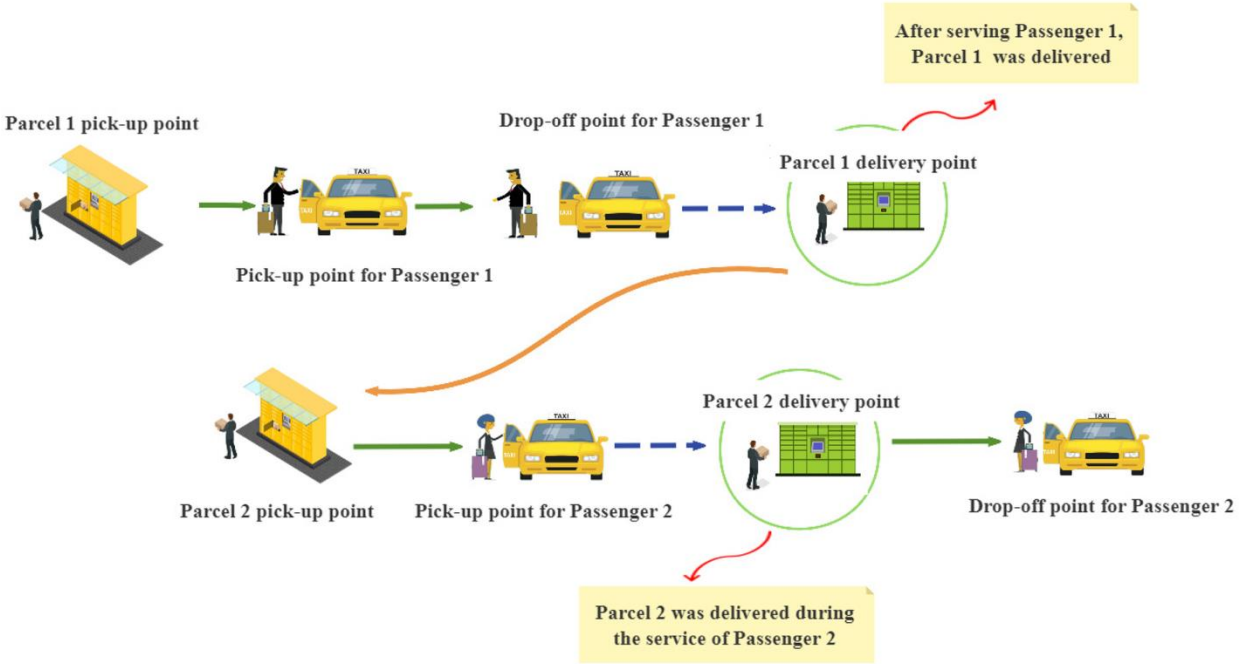


Uber Courier

https://www.uber.com/us/en/item-delivery/

Emerging ideas

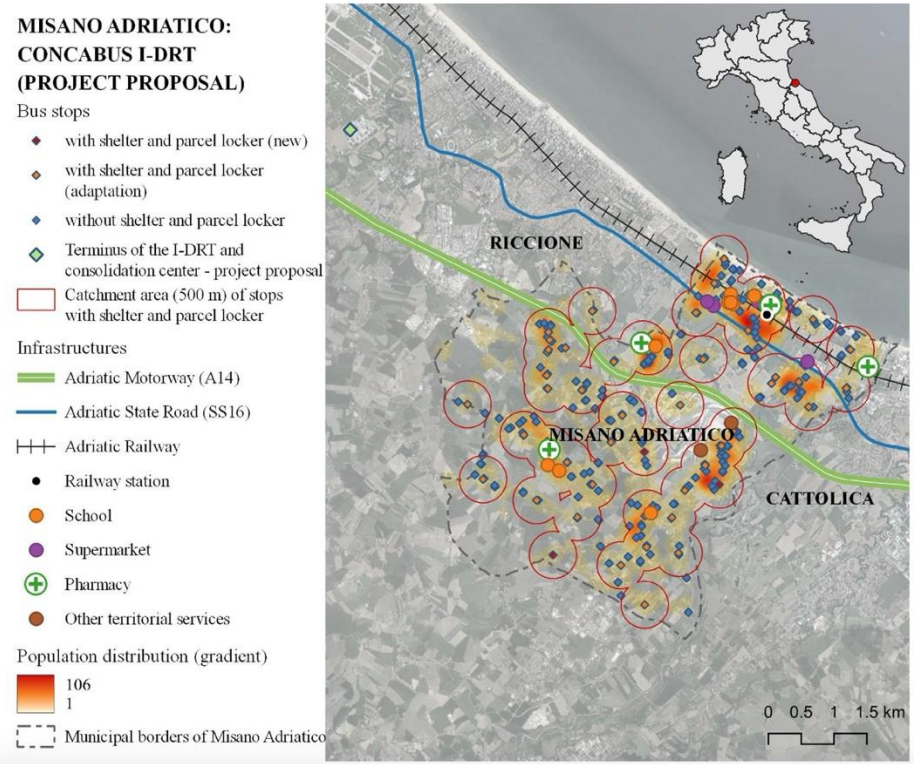
- Ride-hailing + parcel delivery
  - use empty ride-hailing vehicles to deliver parcels
  - serve ride-hailing trips en route to deliver parcels



Xue, Zhang, & Shiwakoti (2024)

Emerging ideas

- DRT + parcel delivery
  - integrate demand responsive transit (DRT) in rural areas with parcel delivery

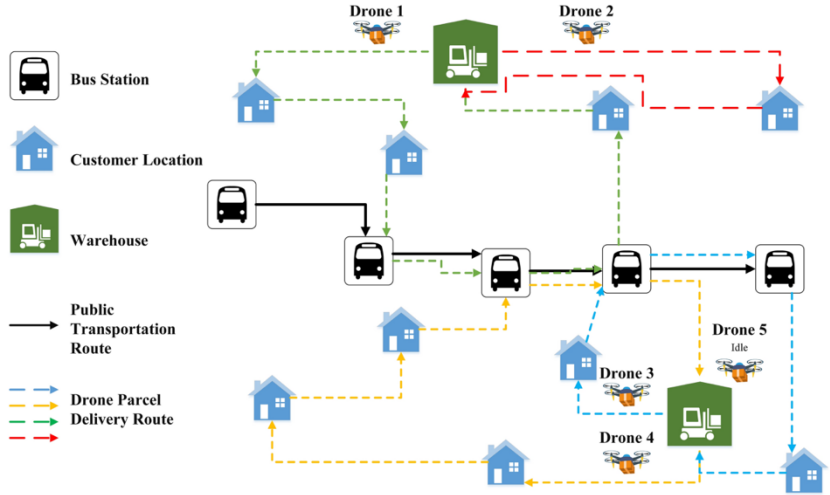


Cavallaro, & Nocera (2023)

Emerging ideas

- Public transit + drone parcel delivery
  - use public transit vehicles as moving parcel hub

Mercedes-Benz + Matternet

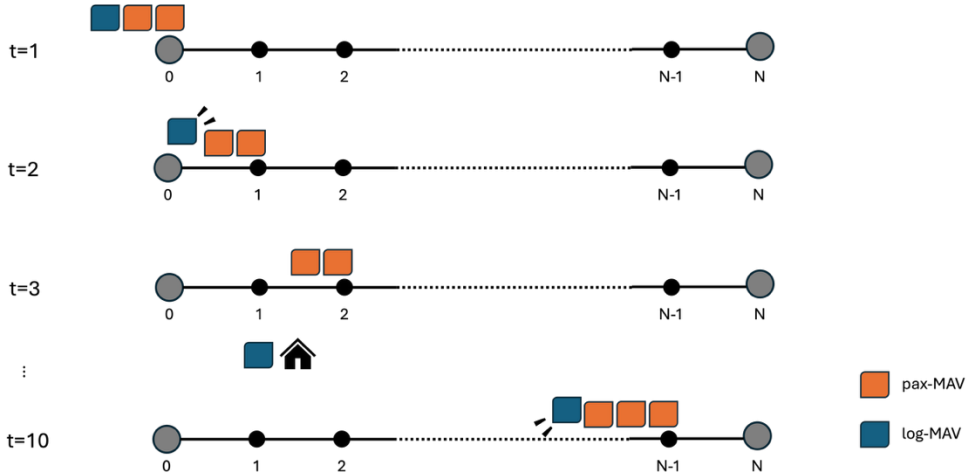


Moadab, Farajzadeh, & Fatahi Valilai (2022)

Emerging ideas

- Passenger and freight modular autonomous vehicles (MAV)
  - Decouple and recouple at bus stops

Next MAV



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