Flexible Urban Mobility
A public transport perspective

Jishnu S. Narayan

María Alonso González
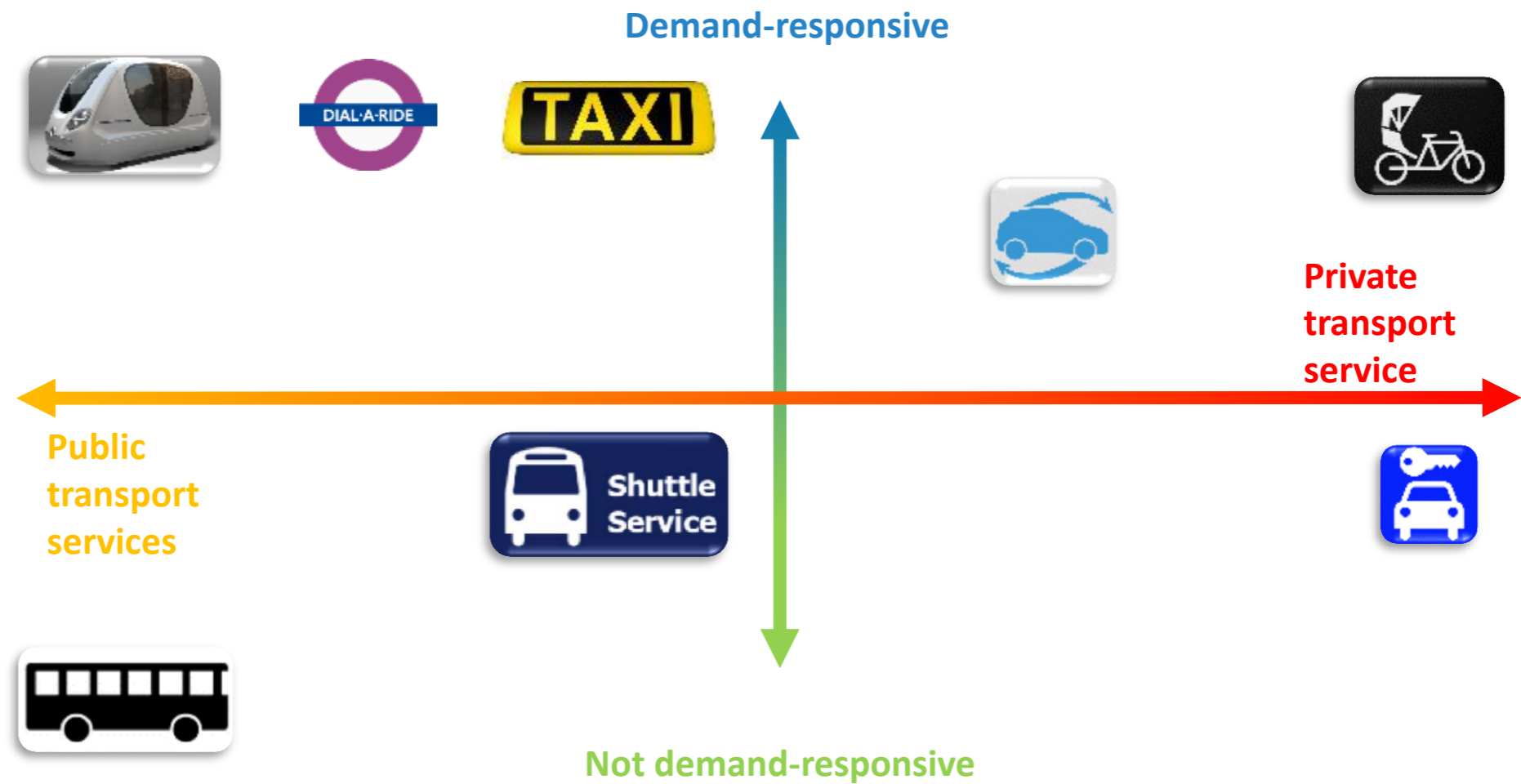
Niels van Oort

Oded Cats

Serge Hoogendoorn

Department of Transport & Planning
Delft University of Technology

TUDelft

Service Spectrum

Demand-responsive

Public transport services

Private transport service

Shuttle Service

Not demand-responsive

T U Delft

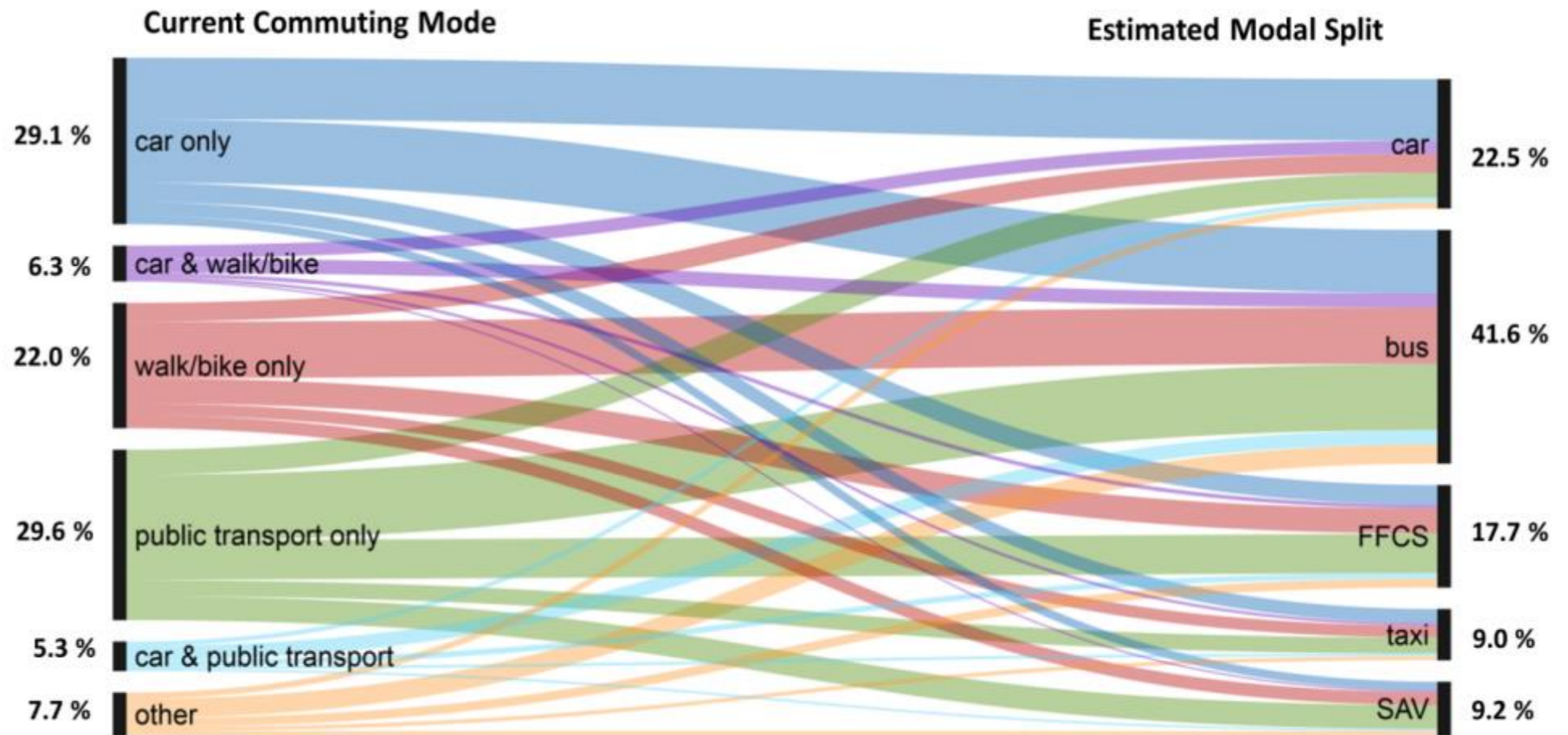➢ Increasing role for integrated (MaaS) platforms

Key research questions

- What is the market potential of shared mobility?
- How can fixed and flexible services co-exist?
- How does service design influence system efficiency and equity?
- How should the service be managed and controlled?
- How do travellers' perceive on-demand services?
- When does flexible become unpredictable?

Requires diverse expertise:
- Transport modelling
- Travel behaviour
- Operations research
- Vehicle routing
- Traffic management and control
- Transport economics

TUDelft

Potential market migration

Current Commuting Mode

Estimated Modal Split

- car only — 29.1 %
- car & walk/bike — 6.3 %
- walk/bike only — 22.0 %
- public transport only — 29.6 %
- car & public transport — 5.3 %
- other — 7.7 %

- car — 22.5 %
- bus — 41.6 %
- FFCS — 17.7 %
- taxi — 9.0 %
- SAV — 9.2 %

- High acceptance rate as a potential last-mile solution
- DRT perceived more positively by 1st class passengers than by 2nd class passengers as compared with PT and bike
- Pull factors: Parking search and cost
- Push factors: Sharing and predictability
- Automation: provokes strong (diverse) opinions

- Operations are critical – anticipatory capabilities, rebalancing

TUDelft

Research step and progress

Stage	User choice	Evolution		
		Demand	Supply	
			Fixed	Flexible
R1	Fixed or Flexible		-	-
R2	Fixed and Flexible	Users alter their travel strategy	-	-
R3	Fixed and Flexible		-	Evolve
R4	Fixed and Flexible		Evolve	Evolve

Publication

- *'Performance assessment of fixed and flexible public transport in a multi agent simulation framework'*
- Transportation Research Procedia
- Presented in EWGT conference 2017

Working paper

- *'Combined fixed and flexible passenger route choice and assignment model'*

Jan 2018-June 2020

TUDelft

# Multi-agent simulation of fixed and flexible services
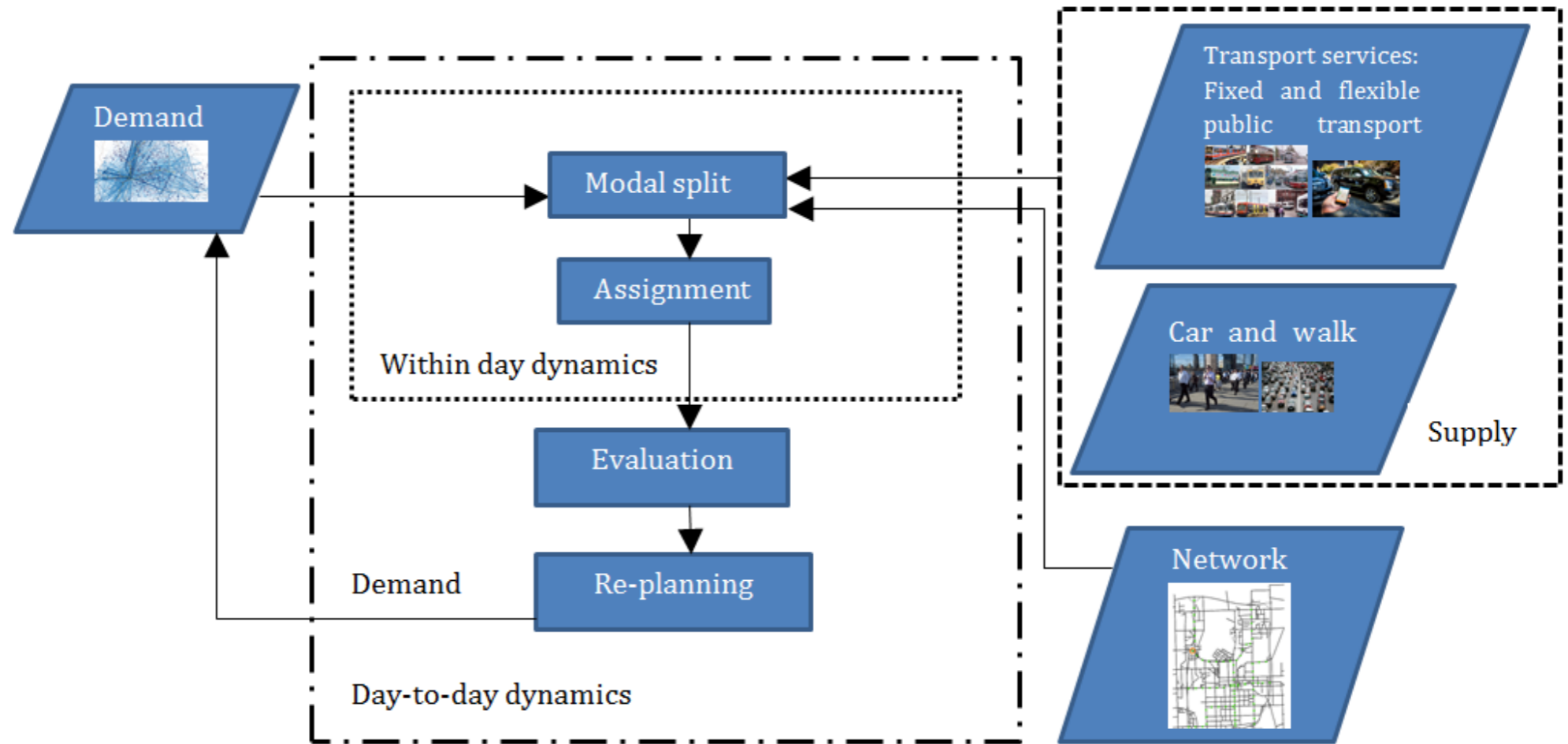
Simulation setup

Test network	Sioux Falls
Modes	Car
	Walk
	Fixed pt
	Flexible pt

Scenarios

Scenario	User mode choice
Base case	Car, Fixed PT, walk
Flexible as private	Car, Fixed PT, Flexible PT (private), walk
Flexible as shared	Car, Fixed PT, Flexible PT (shared),walk

Application

- **Test network:** Sioux Falls (Horl 2016)
- **Demand:** 84110 agents
- **Supply:** Fixed and flexible public transport service
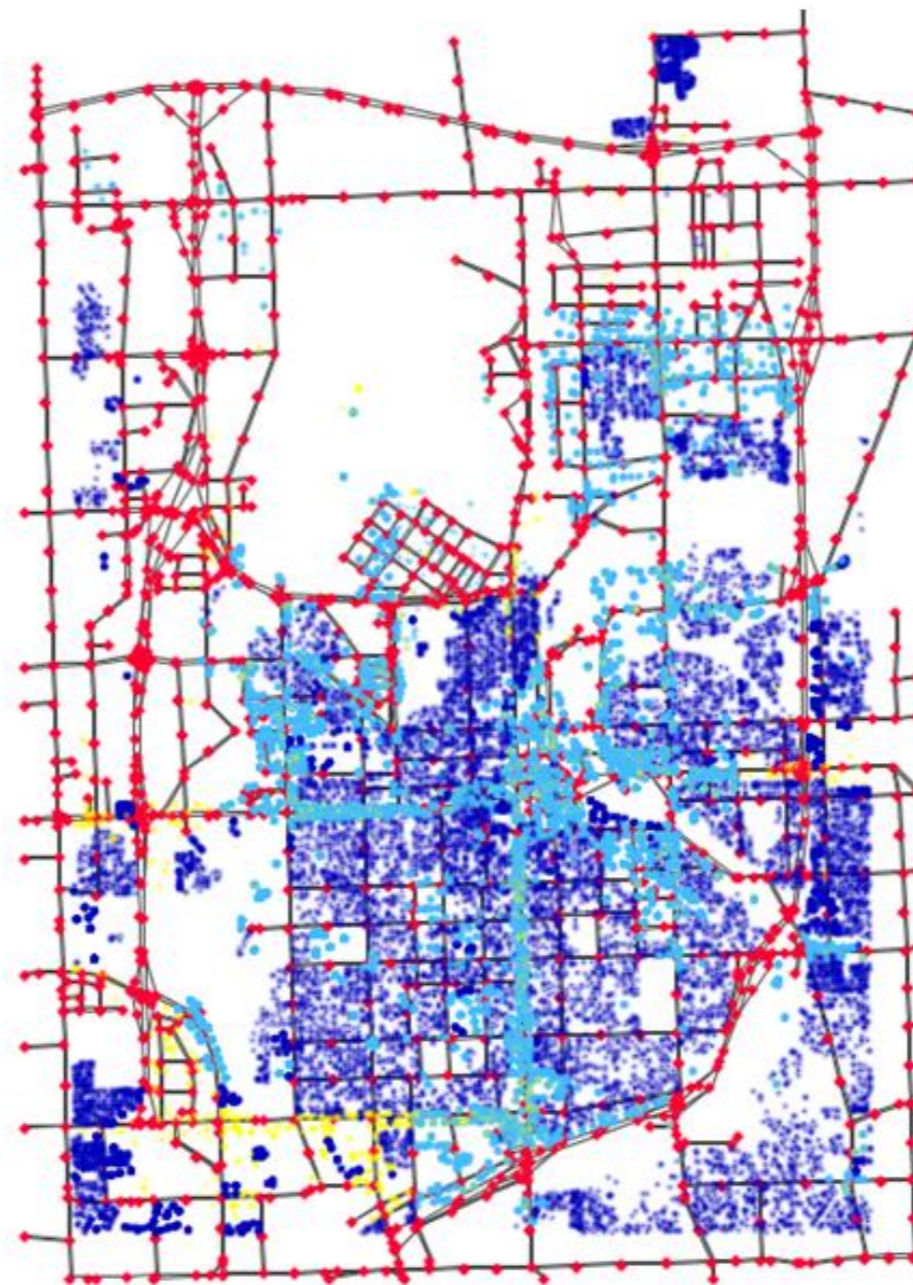
Stop locations of fixed pt
Home locations
Work locations
Secondary locations

TUDelft

Key findings

- This study analyzed the performance of a system when fixed and flexible public transport systems co-exist while offering competing services

- The analysis showed that the increase in fleet size caused an overall increase in mode share for flexible PT

- The effect on waiting times of passengers by increasing fleet size is more pronounced when an individual taxi-like door-to-door service is offered

- The variation of relative cost ratios showed a steady decline of mode share for flexible PT with increasing cost

- The results also showed that at higher relative cost ratios, the flexible PT that operate without sharing becomes less attractive than the one with sharing

TUDelft

Combined route choice and assignment
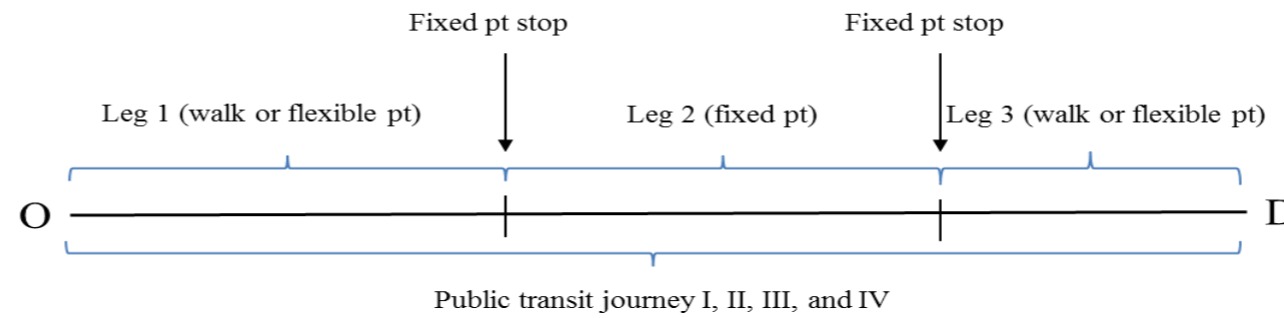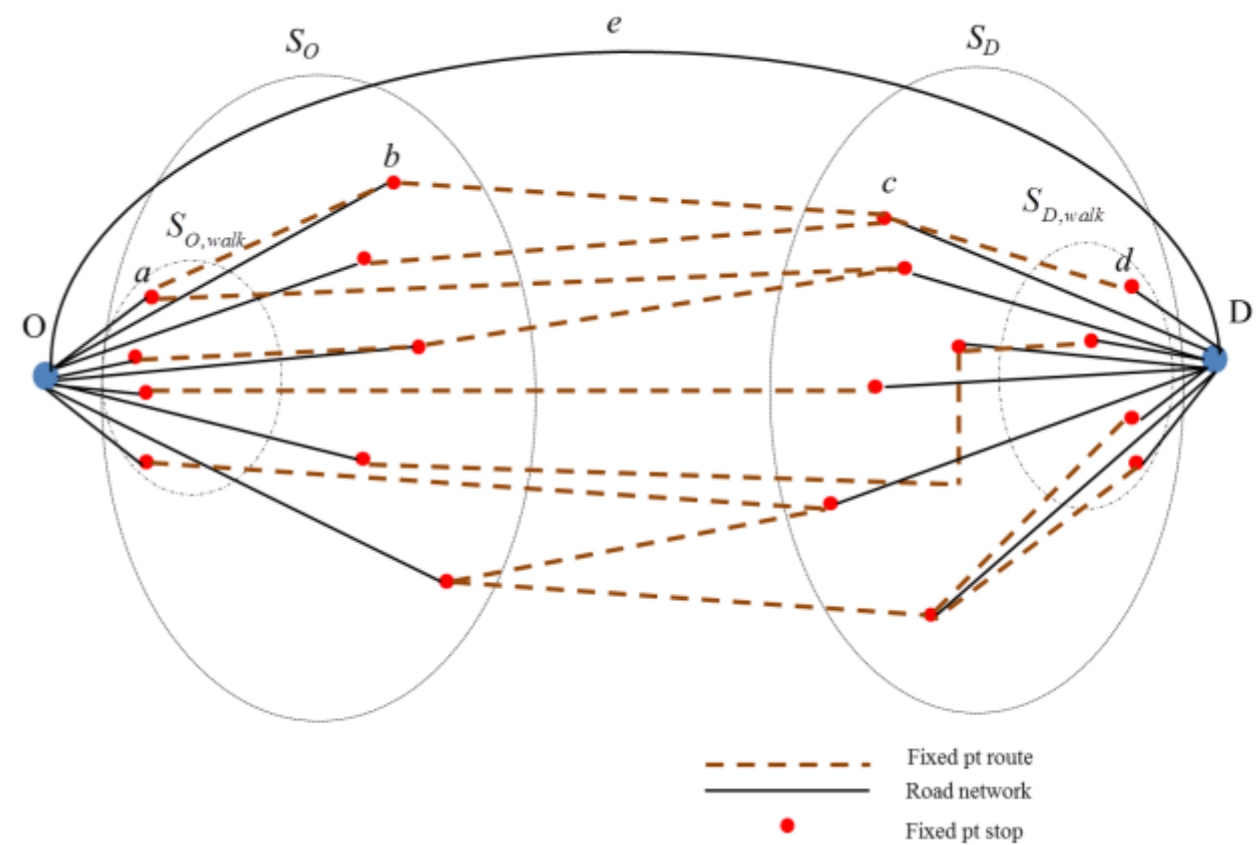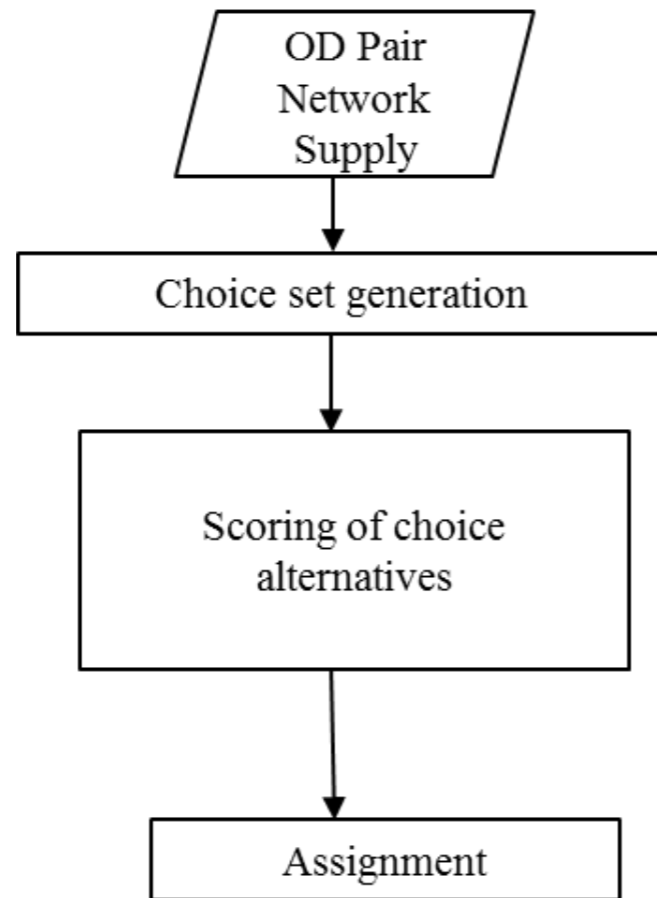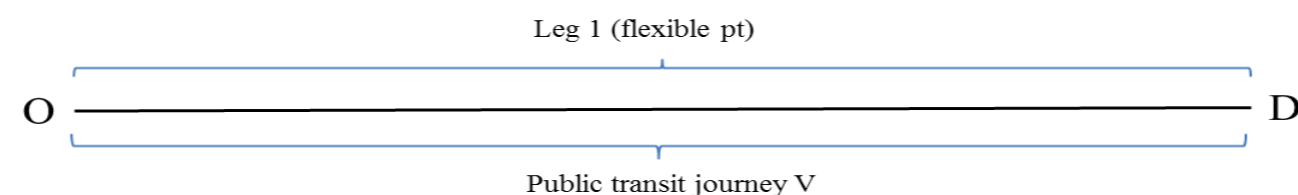
Simulation scenario: Amsterdam

Demand data: Developed from Albatross; 168103 agents; 20% of the pop.

Modes available: Car, PT (bus, tram, ferry), Walk and Bike

TUDelft

Understanding of reliability-flexibility attributes and DRT

❑ Which is the potential of DRT?
❑ How much are the flexibility and reliability attributes valued?

Flexibility

Flexibility

Reliability

Reliability

TUDelft

3	OPENBAAR VERVOER	GEDEELDE VERVOERS-DIENSTEN	INDIVIDUELE VERVOERS-DIENSTEN	UW EIGEN AUTO
BOEKINGDETAILS				
Minimum boekingstijd vooraf	-	10 min	2 min	-
BESTAANDE VASTE RITTEN				
Frequentie	Elke 15 min	-	-	-
FLEXIBELE RITTEN: WAARSCHIJNLIJKHEID VAN AANGEBODEN OPHAALTIJD				
Aangeboden rit is gepland precies zoals u wilt	-	30%	30%	-
Aangeboden rit is 10 minuten later gepland dan u wilt	-	60%	65%	-
Aangeboden rit is 30 minuten later gepland dan u wilt	-	10%	5%	-
REISDETAILS				
Looptijd	3 min	3 min	-	2 min
Vertraging bij vertrek	3 min	6 min	4 min	-
Reistijd in voertuig	50 min	46 min	25 min	23 min
Reiskosten	3,30 €	4,40 €	13,80 €	3,20 €

Flexible Urban Mobility

Understanding of reliability-flexibility attributes and DRT

ASCs

SP attributes

SIGMAS in ASCs

Mobility characteristics

Parameter	Value	Robust t-test
ASC_PT	0	
ASC_car	1.13	2.60
ASC_DRT	-0.447	-1.25
ASC_taxi	-1.7	-2.59
β_departure delay_PT	-0.0169	-1.23
β_departure delay_taxi	-0.0814	-2.35
β_frequency_PT	-0.00687	-1.69
β_min booking time_DRT	-0.00561	-2.27
β_min booking time_taxi	-0.0488	-2.78
β_trip cost_PT	-0.237	-5.73
β_trip cost_car	-0.178	-4.56
β_trip cost_DRT	-0.231	-11.30
β_trip cost_taxi	-0.109	-8.48
β_prob. 30 min difference_taxi	-0.0253	-1.86
β_prob. on time_DRT	0.00483	1.08
β_prob. on time_taxi	0.0122	1.77
β_riding time_PT	-0.0238	-6.48
β_riding time_car	-0.0257	-5.00
β_riding time_DRT	-0.0145	-3.31
β_riding time_taxi	-0.0267	-1.89
β_walking time	-0.0341	-3.11
SIGMA_PT	1.64	19.30
SIGMA_car	-2.25	-16.43
SIGMA_DRT	0	
SIGMA_taxi	-1.94	-11.67
β_frequent app user_DRT	0.136	0.91
β_frequent app user_taxi	0.732	2.88
β_car availability_DRT	-0.544	-3.22
β_car availability_taxi	-0.294	-1.02
β_frequent PT user	0.304	1.66
β_frequent car user	0.058	0.22
β_frequent DRT user	2.49	5.71
β_frequent taxi user	2.73	3.80
β_PT card availability_car	-1.18	-4.51
β_PT card availability_DRT	-0.416	-2.40
β_PT card availability_taxi	-0.899	-3.17

TUDelft

Role of DRT in MaaS

❑ What is the potential usage of DRT in large-scale MaaS ecosystems?
❑ Which market segment may it penetrate into?

➢ The 4 stages of the MaxSem Model:
Stage 1:   Pre-contemplative stage
Stage 2:   Contemplative stage
Stage 3:   Preparation/action change
Stage 4:   Maintenance stage

Total set

Awareness set

Consideration set

Choice set

TUDelft
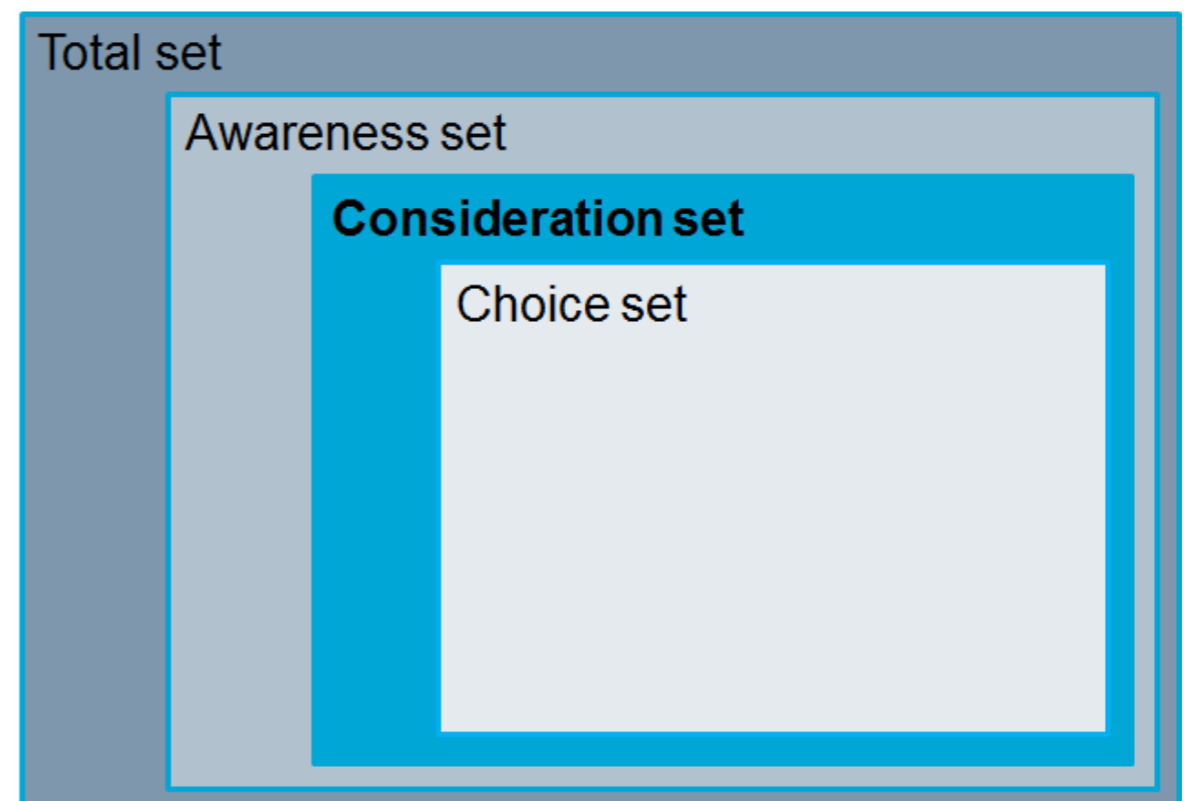
Role of DRT in MaaS

The "Multimodality Ladder"

➢ Socio-economic characteristics and current mobility patterns vary across people with different modal portfolios.

▪ Among car-holders, likeliness to include DRT
  - Decreases with age.
  - Increases with education
▪ Among non-car holders, likeliness to include DRT
  - Decreases with age

Taxi & TNCs

DRT

PT

Car

TUDelft
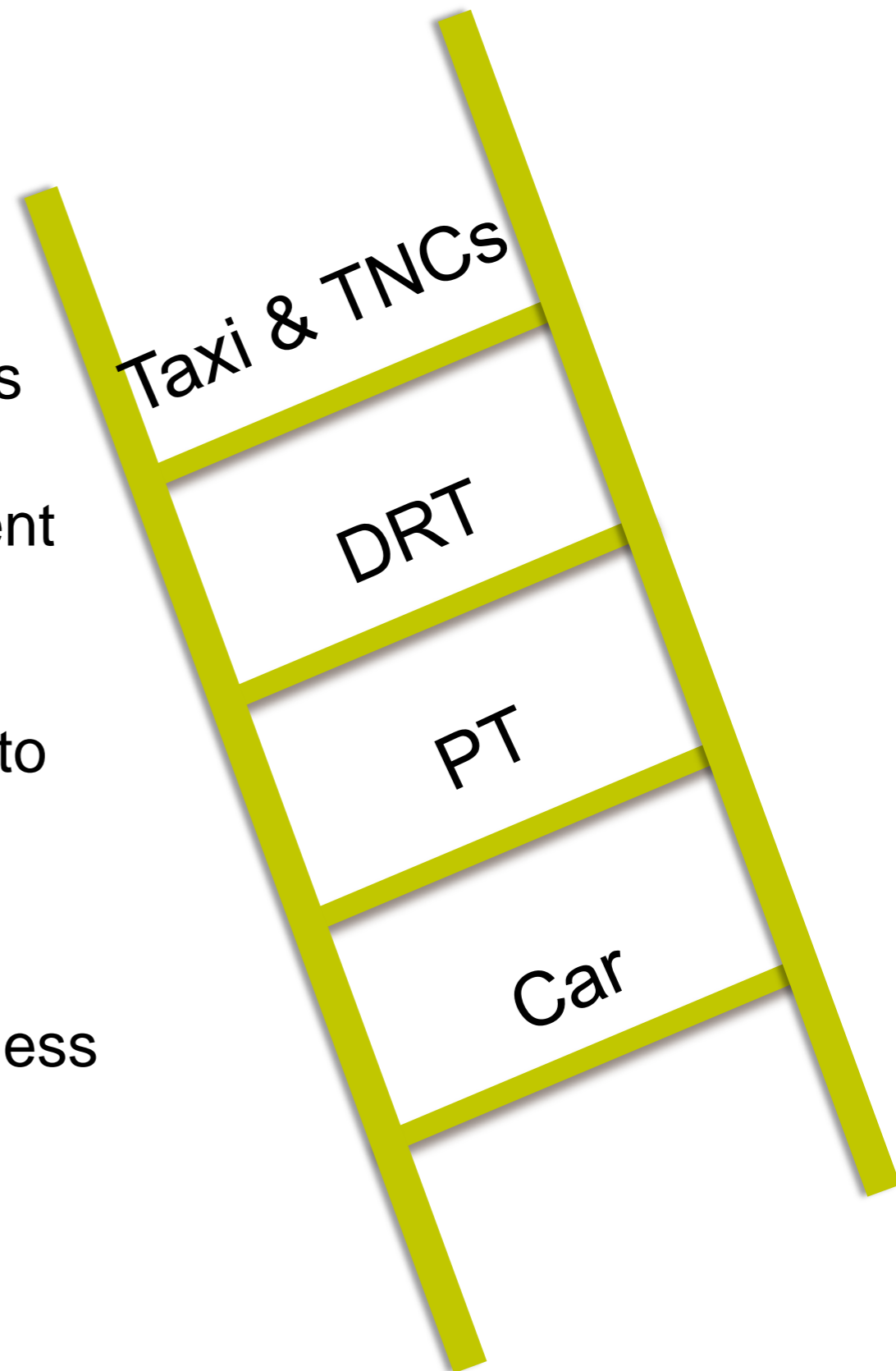
DRT accessibility framework

❑ How are real DRT services being used?
❑ Is DRT being used mostly as a competitor or as a complement of PT?
❑ How much is accessibility being increased by DRT usage?

➢ Application: Breng flex Nijmegen

TUDelft
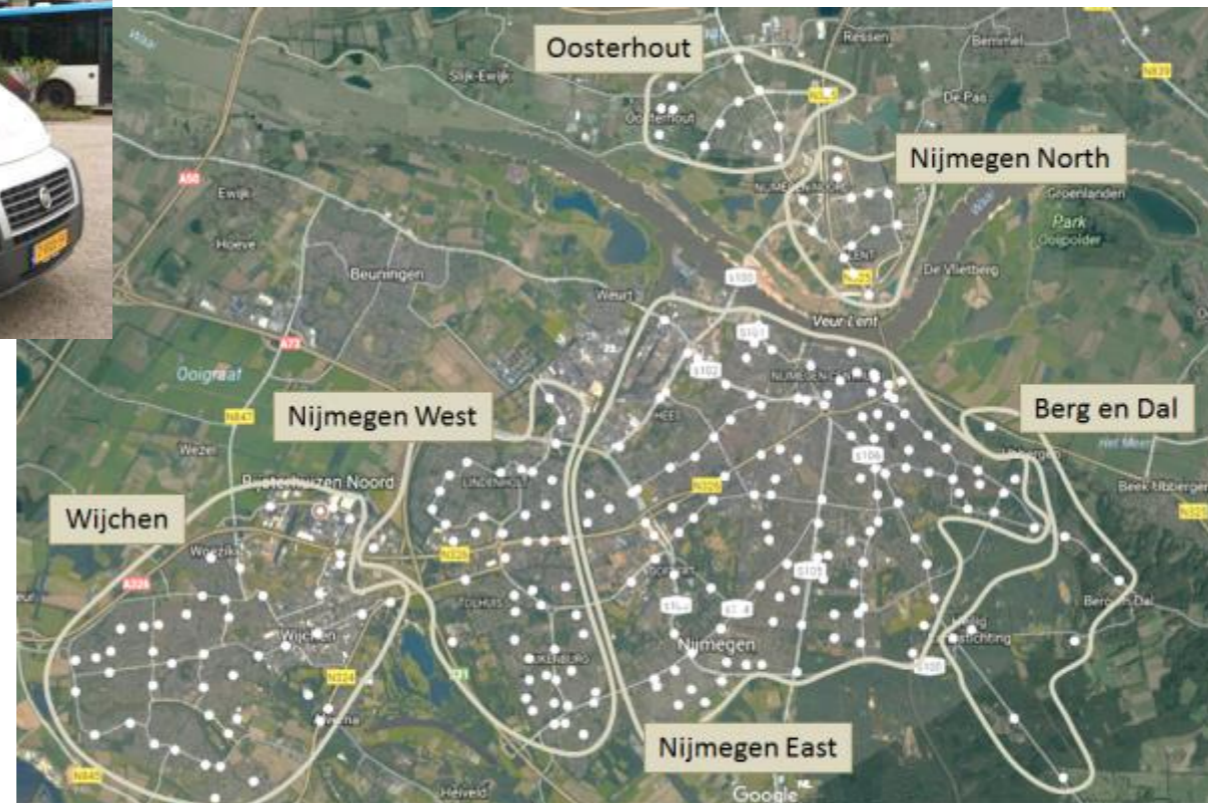
DRT accessibility framework

16.5 % < 3.6 km

0.1 % < 1.2 km

12.3 %

8.3 %

A → B

A → B

Histogram

(GC DRT) / (GC FT)

TUDelft
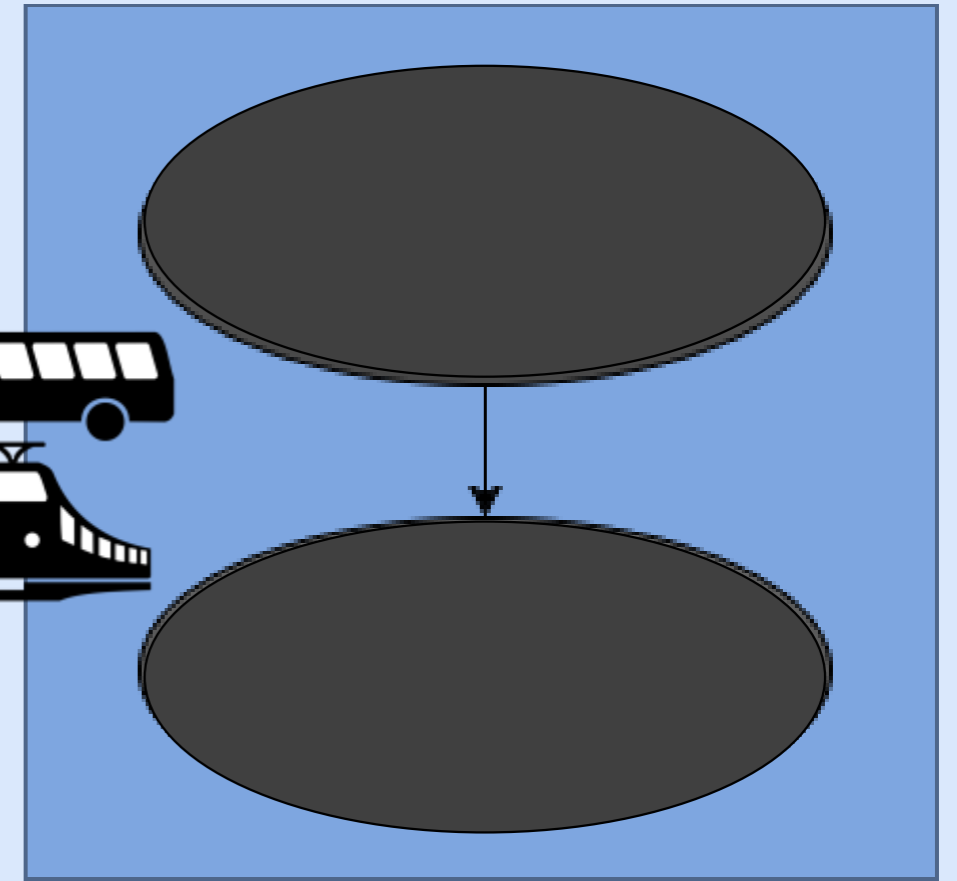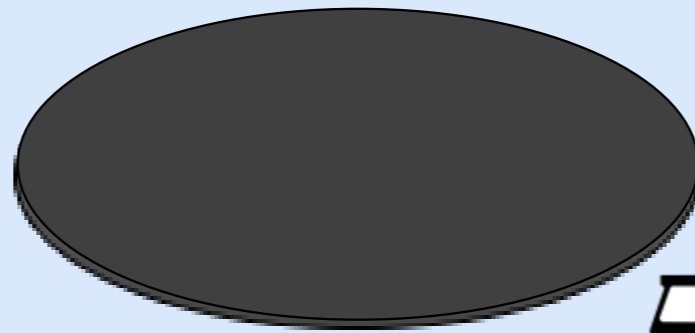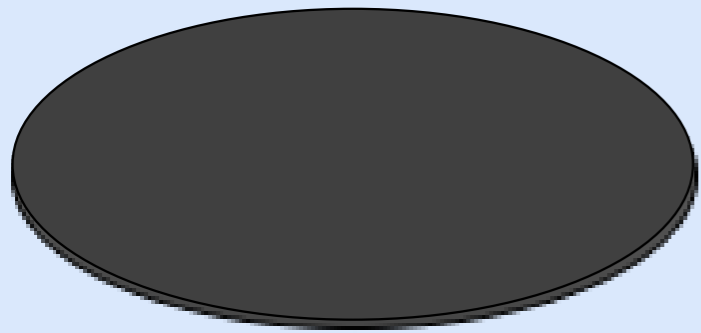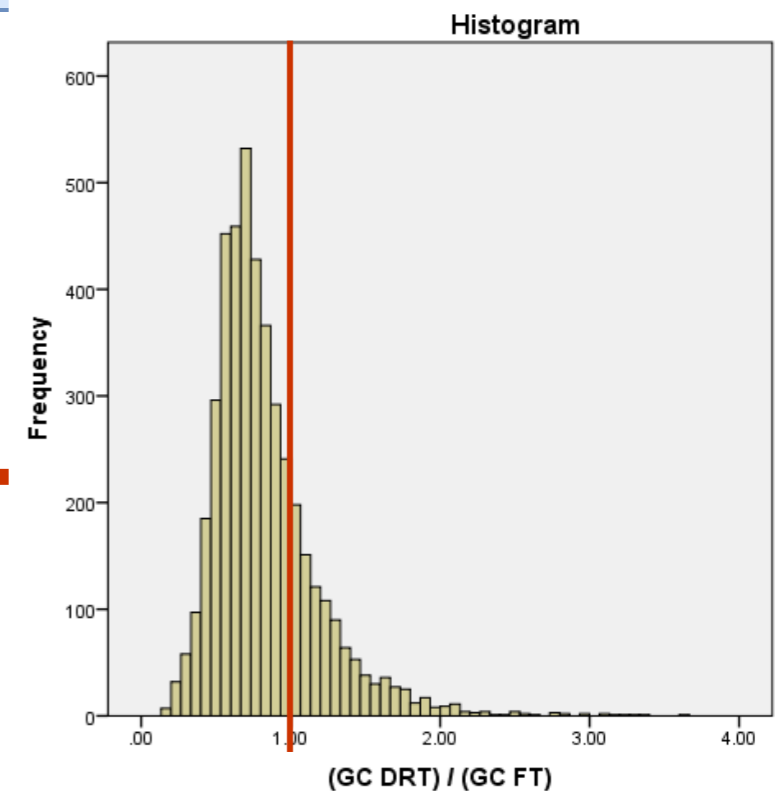
The road ahead

- Amsterdam case study application
- Market share of individual and shared mobility
- 'Lisbon-study' for Amsterdam, substitute mobility demand
- Supply-side dynamics

- SL!M evaluation
- Latent class modelling of DRT survey
- MPN survey extension
- Modelling flexible services in an assignment graph

TUDelft

Thank you for your attention