
DTU

Prof. Jeppe Rich

Some thoughts on the “smart city” and the role of first- and last mile transport in public transport networks

Agenda

- **Part 1: Some thoughts on the ”smart city”**
  - Is there a **side-track of transport research?**
  - The **Transport Demand** and **Transport Research Pyramide**
  - Is there a **mismatch** between smart-city concepts and our peferences?

- **Part 2: The role of first- and last mile transport in public transport networks**
  - Intro to Rich 2024 and Rich et al. 2023
  - Methodology
  - Experimental setup
  - Assumptions and limitations
  - Results

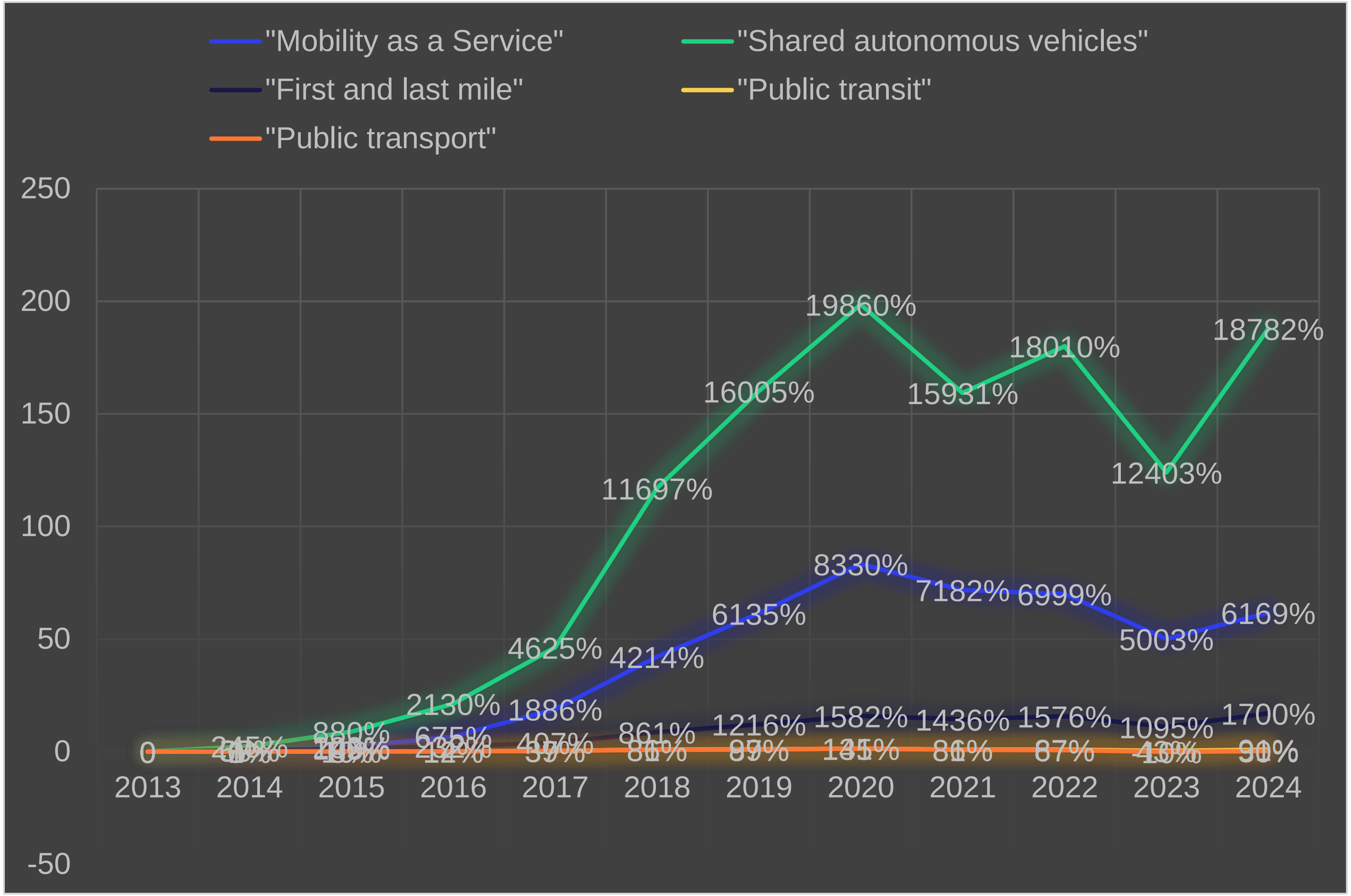
- **Part 3:**
- Discussion, conclusion and some recommendations

Part1: The “smart city”

Literature

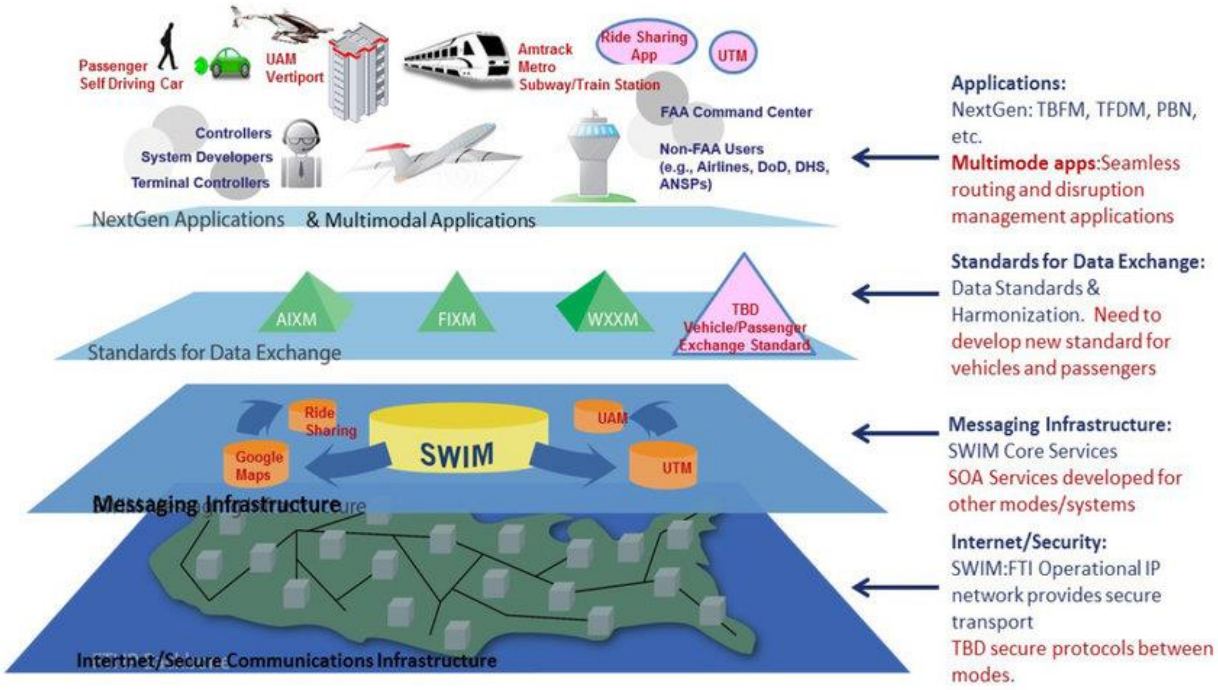
- A disproportional obsession with smart-city concepts
  - “**Mobility as a Service**”
  - **”First and last mile”**
  - **”Shared autonomous vehicles”**
  - **”Multimodality”**
  - **“Seamless transport”**

  % growth since 2013 relative to base growth in google scholar



Topic	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
"Mobility as a Service"	67%	209%	675%	1886%	4214%	6135%	8330%	7182%	6999%	5003%	6169%
"Shared autonomous vehicles"	245%	880%	2130%	4625%	11697%	16005%	19860%	15931%	18010%	12403%	18782%
"First and last mile"	59%	145%	232%	407%	861%	1216%	1582%	1436%	1576%	1095%	1700%
"Public transit"	1%	10%	12%	37%	86%	99%	135%	86%	87%	43%	91%
"Public transport"	0%	8%	14%	39%	81%	87%	141%	81%	67%	-10%	30%

Illustrations of the ”smart city”

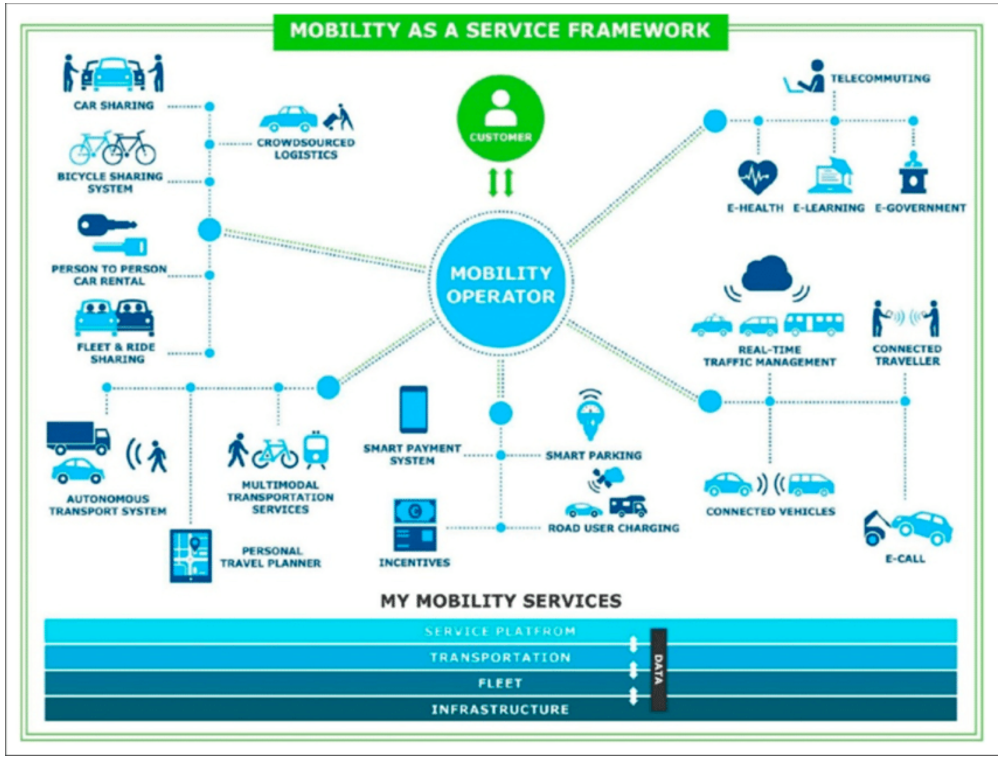


Applications:
NextGen: TBFM, TFDM, PBN, etc.
Multimode apps:Seamless routing and disruption management applications

Standards for Data Exchange:
Data Standards & Harmonization. Need to develop new standard for vehicles and passengers

Messaging Infrastructure:
SWIM Core Services
SOA Services developed for other modes/systems

Internet/Security:
SWIM:FTI Operational IP network provides secure transport
TBD secure protocols between modes.



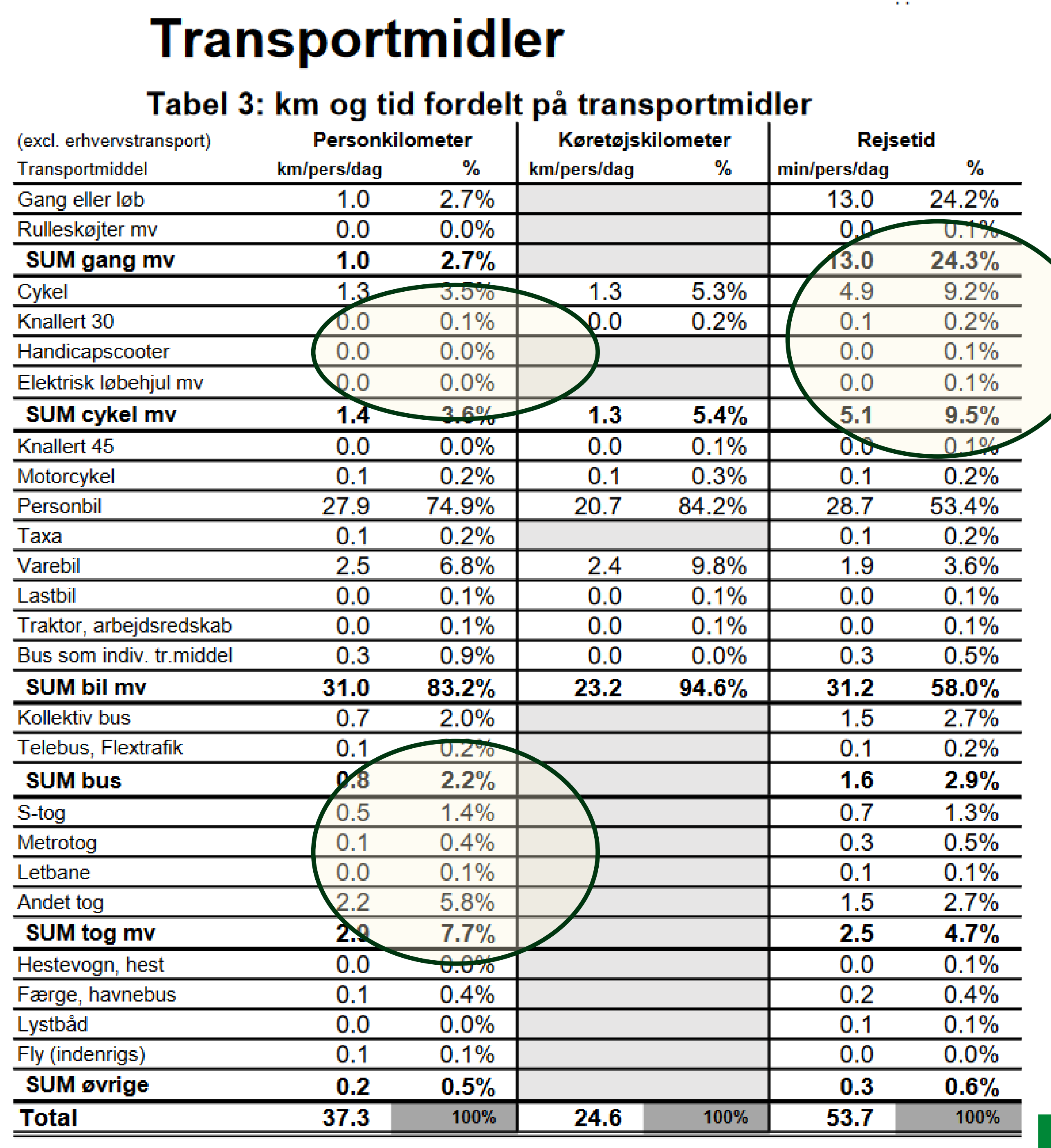
Reality is often different

Included in title of papers in google scholar…

Year	E-scooters/Electric scooters	Bike and Bicycle sharing	Bike and bicycles	Micromobility	Active modes	Public transit	Public transport
2015	0.25%	5.60%	48.53%	0.00%	1.73%	7.98%	35.92%
2016	0.30%	5.99%	49.92%	0.03%	1.35%	8.72%	33.68%
2017	0.33%	9.02%	49.24%	0.03%	1.80%	7.45%	32.13%
2018	1.92%	11.19%	45.51%	0.25%	1.27%	7.65%	32.21%
2019	3.91%	11.76%	44.11%	1.54%	1.57%	6.90%	30.21%
2020	3.29%	10.64%	40.73%	2.06%	1.36%	8.78%	33.13%
2021	3.66%	9.45%	40.25%	3.34%	1.03%	7.70%	34.57%
2022	3.97%	9.90%	40.80%	3.30%	1.56%	7.71%	32.76%
2023	4.05%	8.77%	41.22%	4.46%	1.65%	7.63%	32.23%
2024	4.15%	9.09%	38.65%	6.36%	2.15%	8.74%	30.86%

2023 data in DK

- Hyped modes with zero impact
  - E-scooters = 0.0%
  - Telebus = 0.2%
  - Sharing so small not worth mentioning….
- Walk and bike with high impact
  - Low KM/Day (6.6%)
  - High Travel time share (**35%**)
- Still for JCMR
  - E-scooter papers account for 10% of submissions!
  - Shared bicycle papers is around 13%

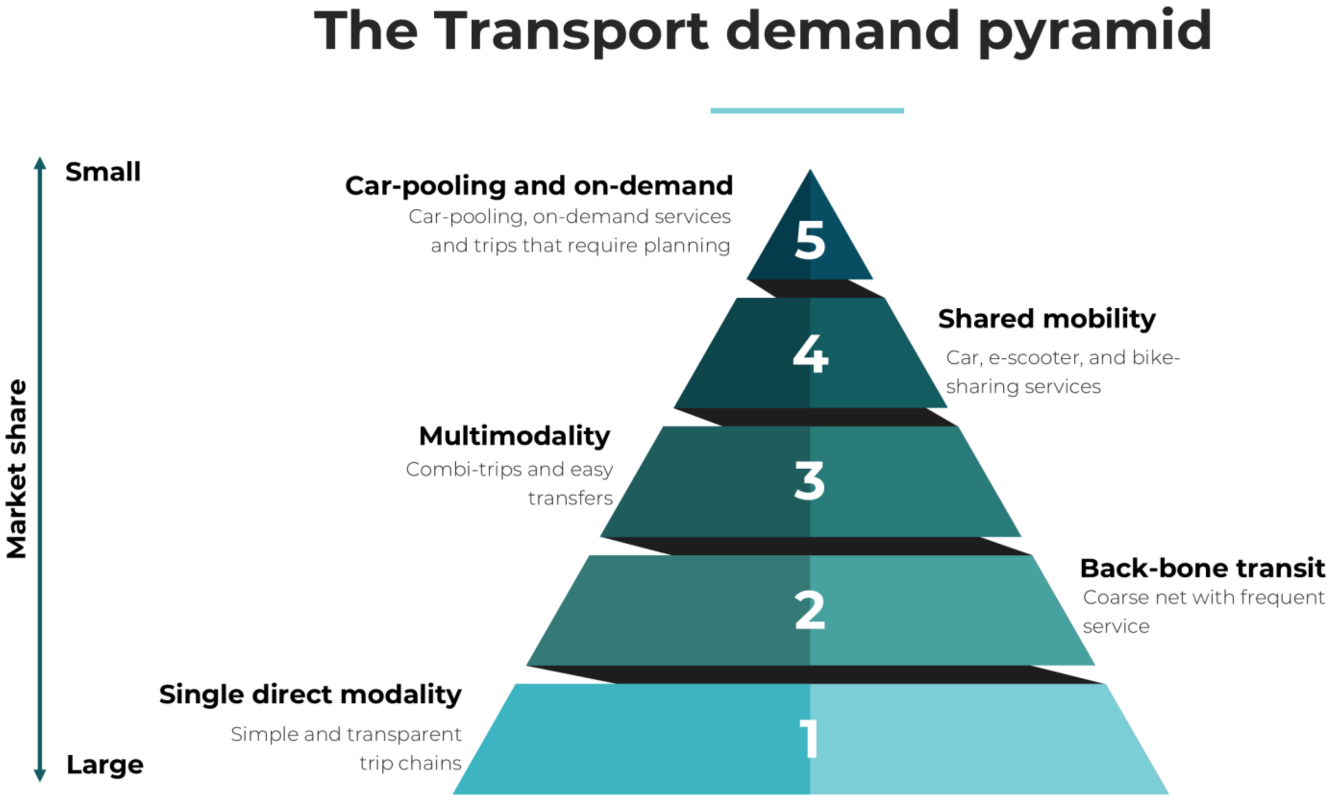


Transportmidler

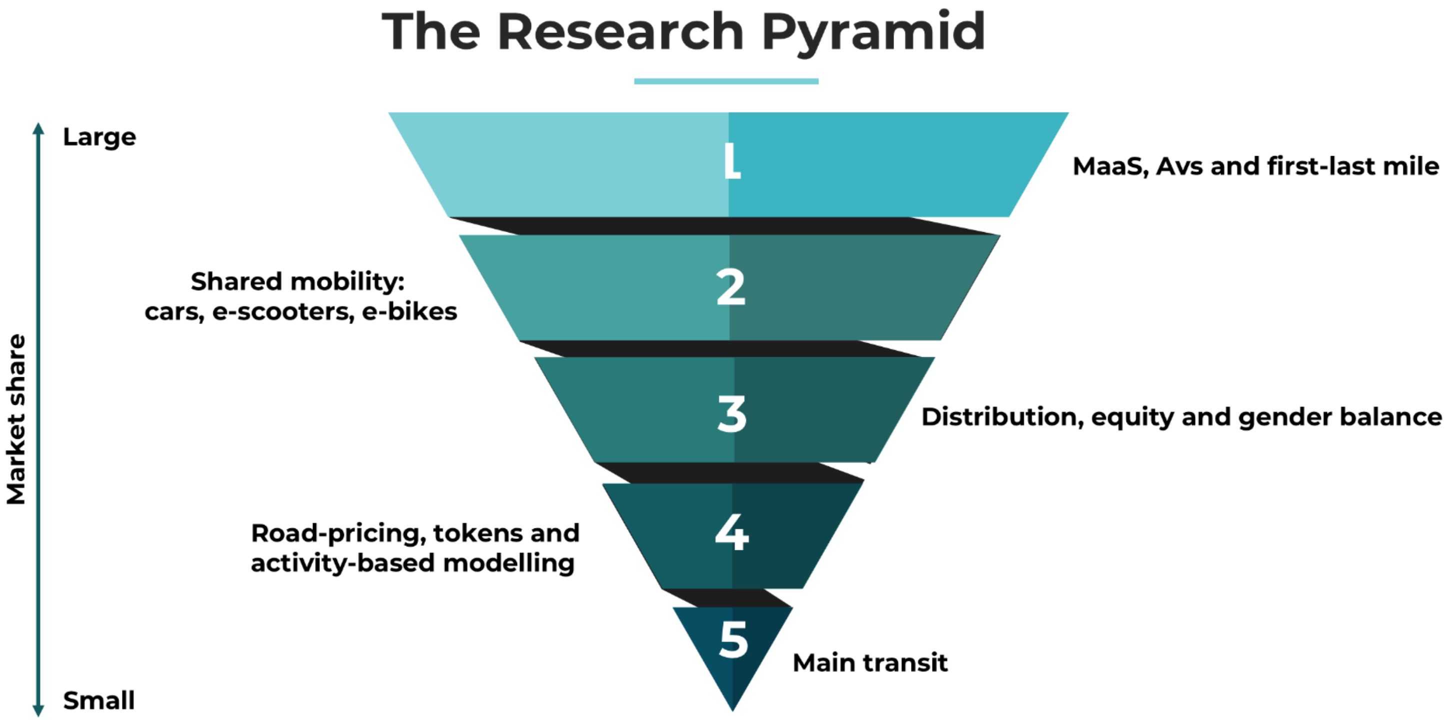
Tabel 3: km og tid fordelt på transportmidler

(excl. erhvervstransport)	**Personkilometer**		**Køretøjskilometer**		**Rejsetid**	
Transportmiddel	**km/pers/dag**	**%**	**km/pers/dag**	**%**	**min/pers/dag**	**%**
Gang eller løb	1.0	2.7%			13.0	24.2%
Rulleskøjter mv	0.0	0.0%			0.0	0.1%
SUM gang mv	**1.0**	**2.7%**			**13.0**	**24.3%**
Cykel	1.3	3.5%	1.3	5.3%	4.9	9.2%
Knallert 30	0.0	0.1%	0.0	0.2%	0.1	0.2%
Handicapscooter	0.0	0.0%			0.0	0.1%
Elektrisk løbehjul mv	0.0	0.0%			0.0	0.1%
SUM cykel mv	**1.4**	**3.6%**	**1.3**	**5.4%**	**5.1**	**9.5%**
Knallert 45	0.0	0.0%	0.0	0.1%	0.0	0.1%
Motorcykel	0.1	0.2%	0.1	0.3%	0.1	0.2%
Personbil	27.9	74.9%	20.7	84.2%	28.7	53.4%
Taxa	0.1	0.2%			0.1	0.2%
Varebil	2.5	6.8%	2.4	9.8%	1.9	3.6%
Lastbil	0.0	0.1%	0.0	0.1%	0.0	0.1%
Traktor, arbejdsredskab	0.0	0.1%	0.0	0.1%	0.0	0.1%
Bus som indiv. tr.middel	0.3	0.9%	0.0	0.0%	0.3	0.5%
SUM bil mv	**31.0**	**83.2%**	**23.2**	**94.6%**	**31.2**	**58.0%**
Kollektiv bus	0.7	2.0%			1.5	2.7%
Telebus, Flextrafik	0.1	0.2%			0.1	0.2%
SUM bus	**0.8**	**2.2%**			**1.6**	**2.9%**
S-tog	0.5	1.4%			0.7	1.3%
Metrotog	0.1	0.4%			0.3	0.5%
Letbane	0.0	0.1%			0.1	0.1%
Andet tog	2.2	5.8%			1.5	2.7%
SUM tog mv	**2.9**	**7.7%**			**2.5**	**4.7%**
Hestevogn, hest	0.0	0.0%			0.0	0.1%
Færge, havnebus	0.1	0.4%			0.2	0.4%
Lystbåd	0.0	0.0%			0.1	0.1%
Fly (indenrigs)	0.1	0.1%			0.0	0.0%
SUM øvrige	**0.2**	**0.5%**			**0.3**	**0.6%**
Total	**37.3**	100%	**24.6**	100%	**53.7**	100%

- Like with a food pyramid!
  - We need **most from the bottom**
  - Focus should be on the main **back-bone** transit network
  - We should focus less on the fruit in the top of the tree!

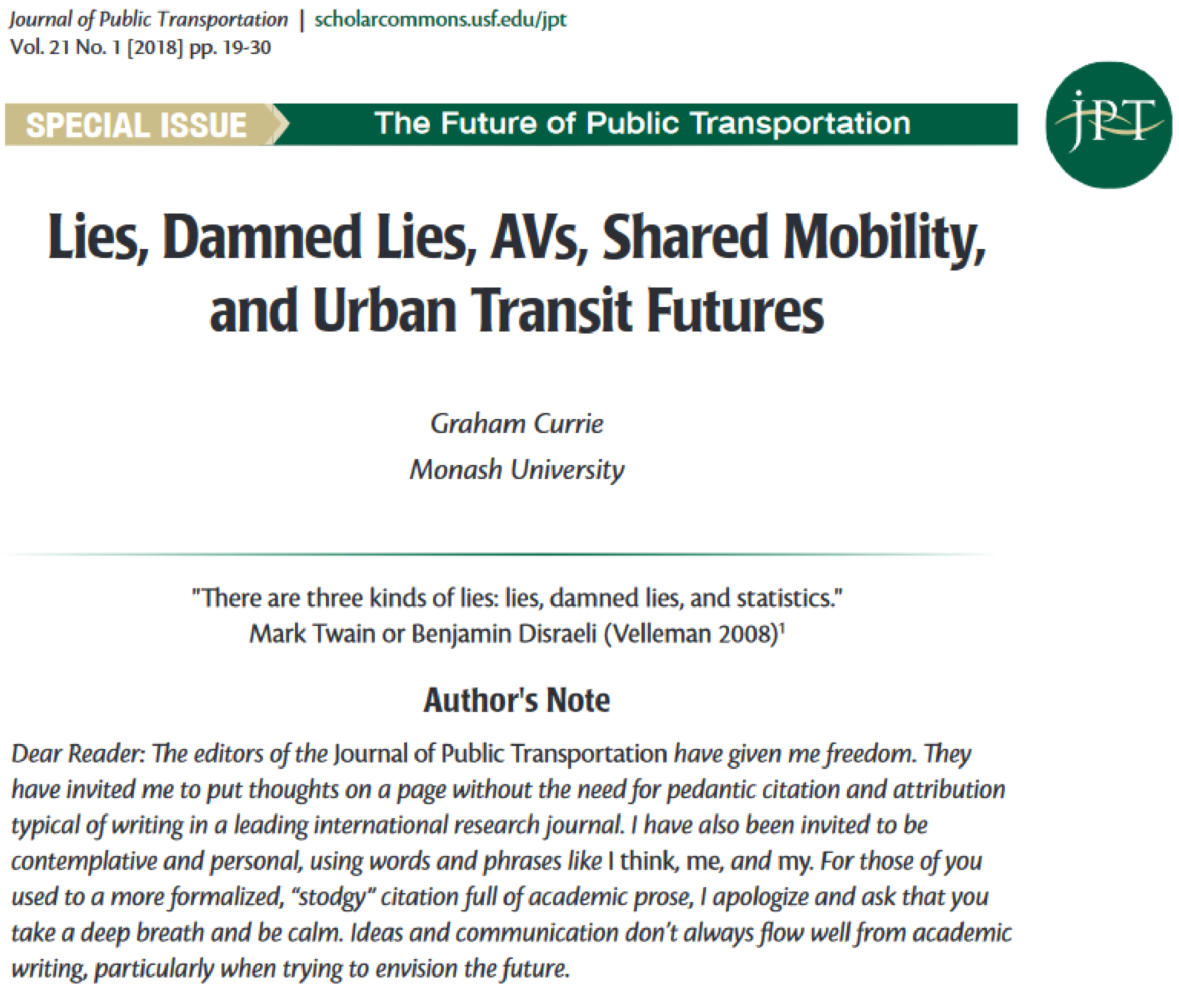


- In research **the pyramid is turned!**
  - Focus is on things that are academically interesting
  - But **matters little** in practise
  - We are picking the fruits in the top of the tree
- While this is clearly an exaggeration, it is nonetheless relevant to consider the balance of topics
- Large responsibility for this happening is research programs, e.g. **Horizon 2020**



Acknowledged by few…but Curri

- Challenge the idea that ”’**road-based AV technology will take over public transport**…”
- The phrase ”**shared mobility**” used as a buzz-word
- Disproportinal (little) focus on mass transit in the research literature
- Often research is focused on transport that benefit the few and not the waste majority



Journal of Public Transportation | scholarcommons.usf.edu/jpt
Vol. 21 No. 1 [2018] pp. 19-30

SPECIAL ISSUE The Future of Public Transportation

Lies, Damned Lies, AVs, Shared Mobility, and Urban Transit Futures

Graham Currie
Monash University

"There are three kinds of lies: lies, damned lies, and statistics."
Mark Twain or Benjamin Disraeli (Velleman 2008)[1]

Author's Note

Dear Reader: The editors of the Journal of Public Transportation *have given me freedom. They have invited me to put thoughts on a page without the need for pedantic citation and attribution typical of writing in a leading international research journal. I have also been invited to be contemplative and personal, using words and phrases like* I think, me, *and* my. *For those of you used to a more formalized, "stodgy" citation full of academic prose, I apologize and ask that you take a deep breath and be calm. Ideas and communication don't always flow well from academic writing, particularly when trying to envision the future.*

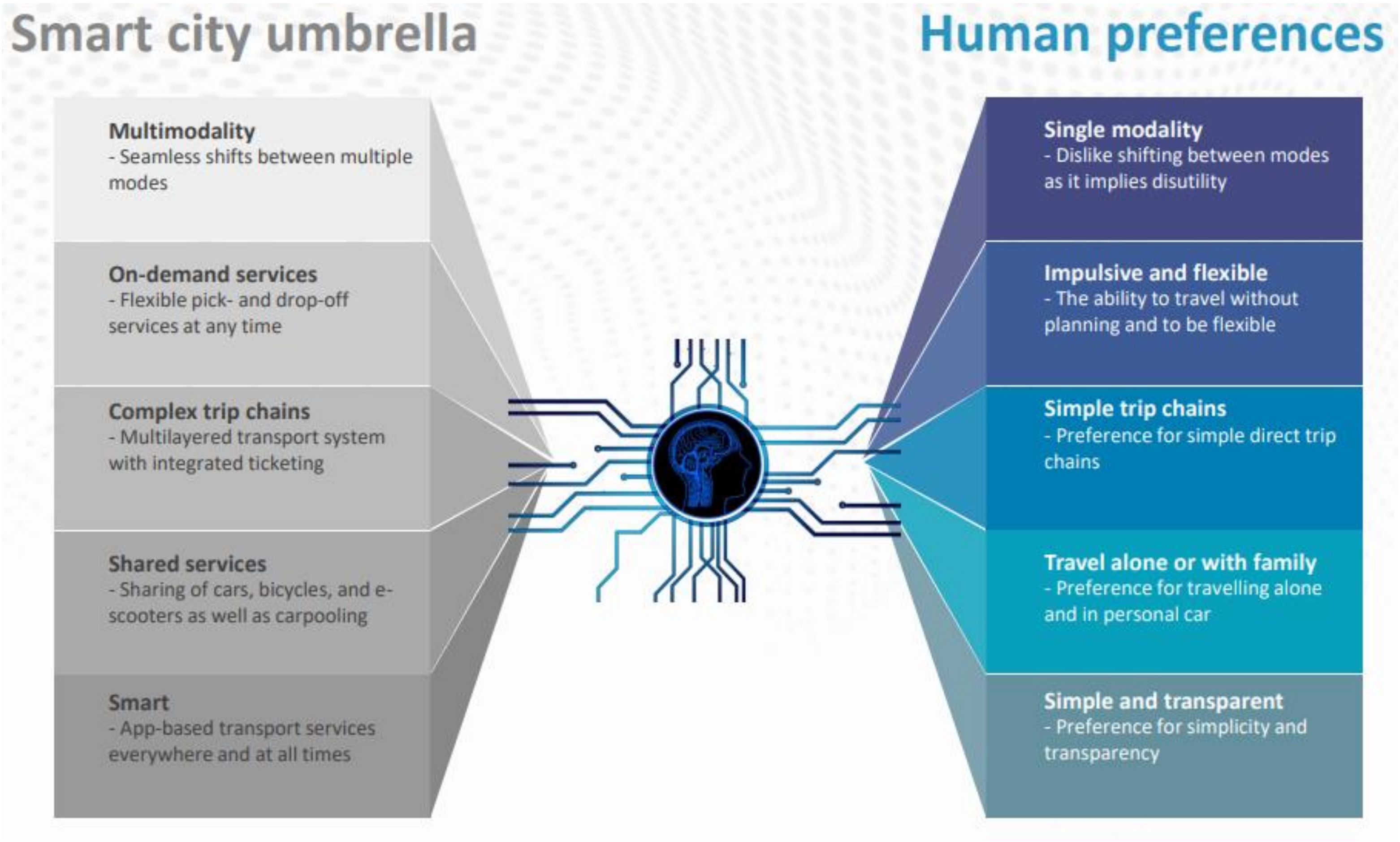
Mohring et al. 1987; Ceder and Marguier (1985) ; Nielsen et al. (2021); Hoogendoorn-Lanser and Bovy (2007)

The smart city and our actual preferences

- Largely speaking, the direction of the two are opposite
- Shifting and waiting is disliked

⇒ We don’t like **multimodality**

⇒ We don’t like **complex** trips



Smart city umbrella

Multimodality
- Seamless shifts between multiple modes

On-demand services
- Flexible pick- and drop-off services at any time

Complex trip chains
- Multilayered transport system with integrated ticketing

Shared services
- Sharing of cars, bicycles, and e-scooters as well as carpooling

Smart
- App-based transport services everywhere and at all times

Human preferences

Single modality
- Dislike shifting between modes as it implies disutility

Impulsive and flexible
- The ability to travel without planning and to be flexible

Simple trip chains
- Preference for simple direct trip chains

Travel alone or with family
- Preference for travelling alone and in personal car

Simple and transparent
- Preference for simplicity and transparency

We can just look at the empirical data on the load factor for cars

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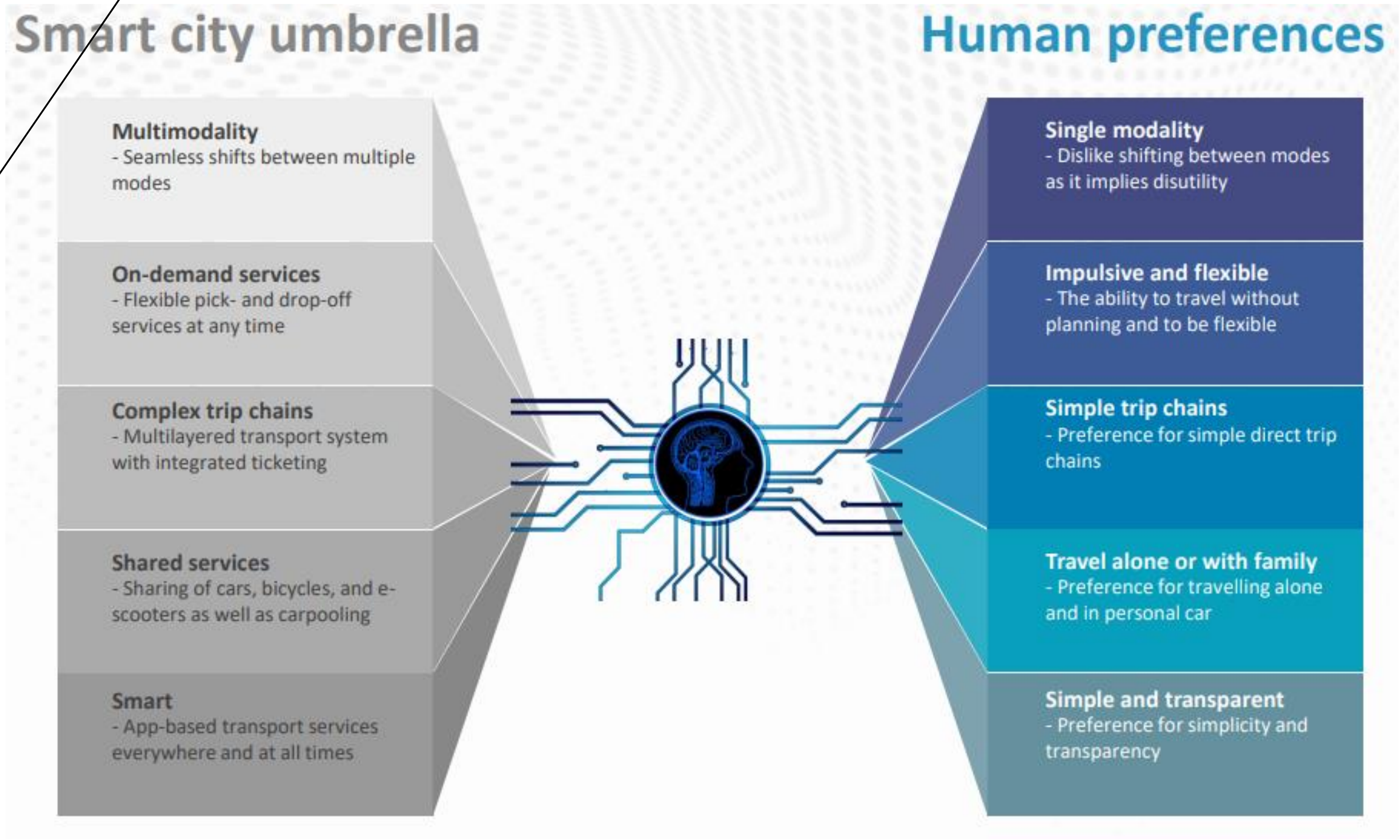
- We don't like **shared** services

⇒ **Car/bike sharing** limited potential

⇒ **Carpooling** is (very) limited



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Sharing of cars is going down!

- Increasing number of personal cars
- Fewer number of people in the cars
- Suggest little evidence for increased willingness to share…

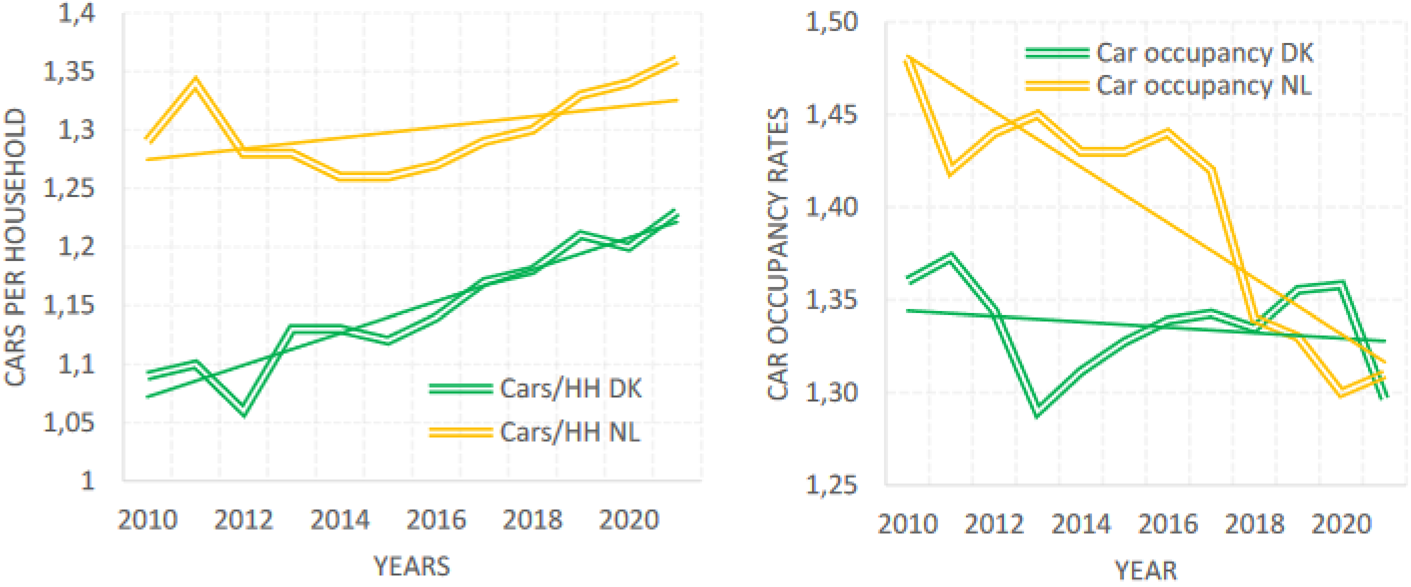
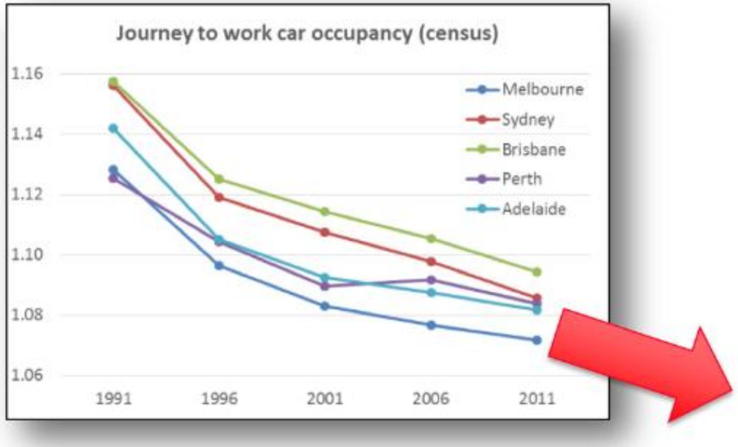
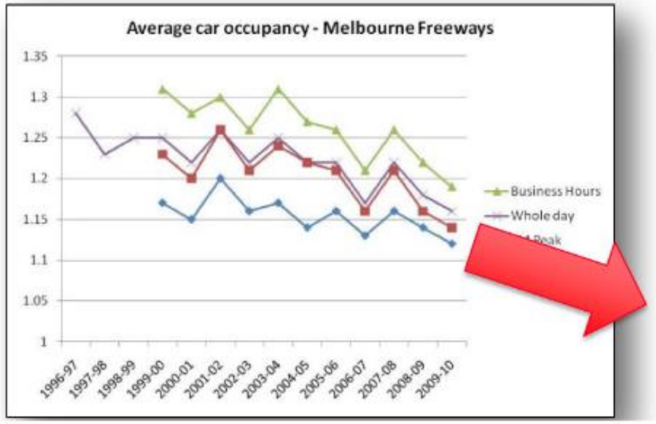


Figure 3: Car ownership and car occupancy rates in Denmark and the Netherlands.





Source: Charting Transport https://chartingtransport.com/tag/car-occupancy/ (last accessed September 2017)

This is more like a hypoteses, but with backing from other areas; Wouter et al. (2018) ; Bettman et al. (1998); Learner et al. (2015)

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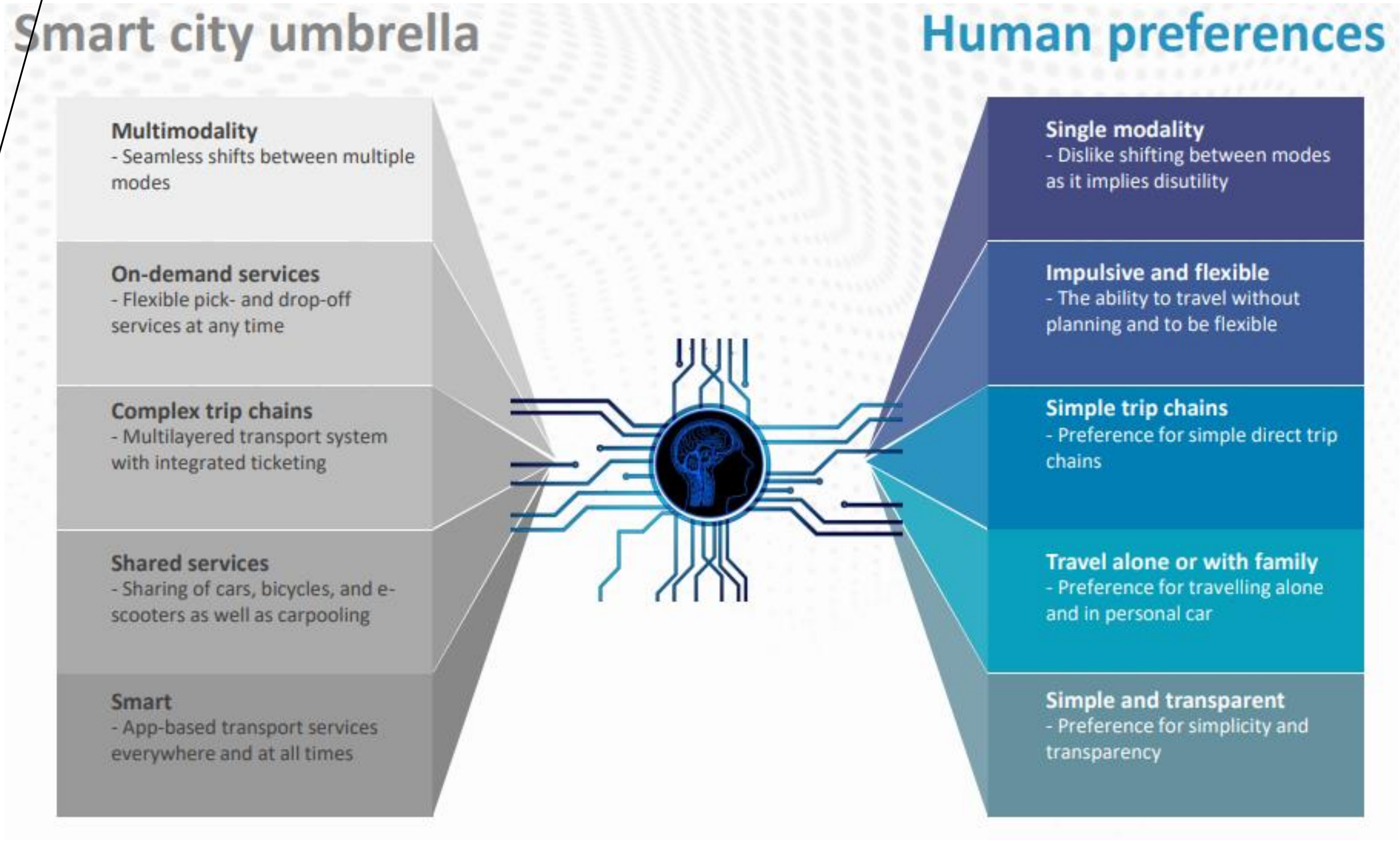
⇒ **Carpooling** is (very) limited

- We don’t like to plan

⇒ **On-demand** is tiny

⇒ **Flexibility** is preferred



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Some final thoughts

- Perhaps the idea of **seamlessly transitioning between different modes** of transport is unrealistic?
- Given that only a few daily trips are complex, perhaps we should focus more on the **main journey and facilitate active modes for access and egress**?
  - This approach will maintain **flexibility**, **reduce dependency and waiting time**, and promote **health benefits**
- If people don’t like to share, forcing them to share should incur a significant **consumer surplus loss**
  - Maybe it is better to focus on policies that are aligned with preferences

Part2: First- and last mile solutions

Rest of talk is based on two recent papers…

Transportation
https://doi.org/10.1007/s11116-024-10505-5

Check for updates

Let's walk! The fallacy of urban first- and last-mile public transport

Jeppe Rich[1]

Accepted: 11 June 2024
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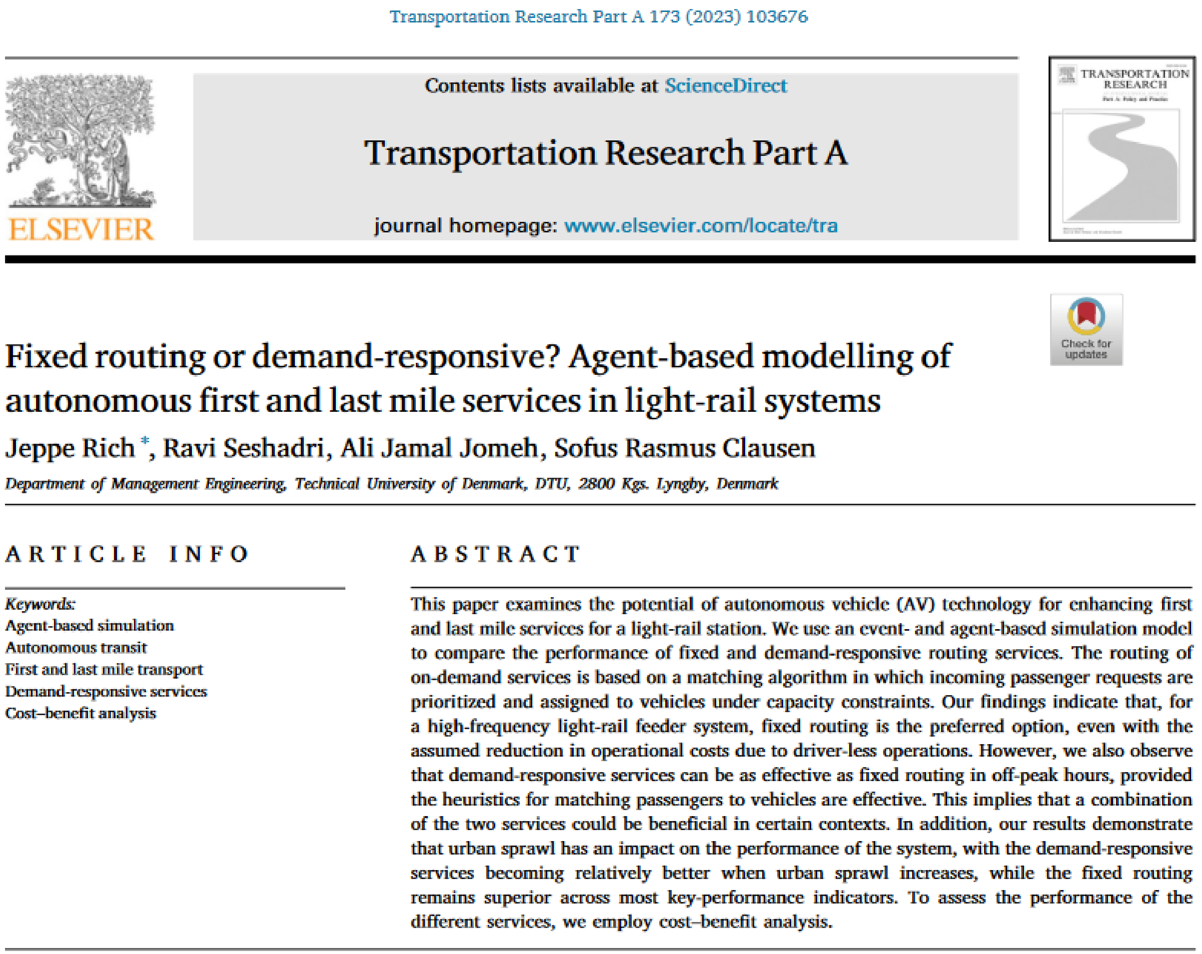
Abstract
In recent years, there has been an upsurge in intelligent mobility solutions that provide door-to-door services. Although these services offer convenience to certain individuals, it is frequently overlooked that they can lead to welfare losses when accounting for the reduced health benefits that result from reduced physical activity. In this paper, we derive a welfare function of introducing first- and last-mile public transport services. By comparing possible health gains from walking with corresponding accessibility losses, we identify the distance boundaries under which the service fails to be socially beneficial. The results are based on a simulation study and draw on further insights from a recent agent-based model from Copenhagen focusing on first- and last-mile public transport. Although the model is intentionally stylized and may not apply universally to all scenarios featuring diverse population densities, demographic profiles, or transport network layouts, the fundamental conclusion presented in the paper is that first-mile services have minimal welfare impact for average trip distances below 1 km, appears robust even under conservative assumptions. In this case, the probability of failure is almost 100% for any realistic parametrization. This finding implies that planners and researchers should focus on the design of main transit networks and the access and egress of active modes to and from the stations. In particular, door-to-door services covering shorter distances should not be the priority of public funding unless in particular situations or contexts.

Keywords First- and last-mile transport · Demand-responsive services · Cost-benefit analysis · External costs · Transport economics · Scenario discovery



Transportation Research Part A 173 (2023) 103676

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TRANSPORTATION RESEARCH

Check for updates

Fixed routing or demand-responsive? Agent-based modelling of autonomous first and last mile services in light-rail systems

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Department of Management Engineering, Technical University of Denmark, DTU, 2800 Kgs. Lyngby, Denmark

ARTICLE INFO

Keywords:
Agent-based simulation
Autonomous transit
First and last mile transport
Demand-responsive services
Cost–benefit analysis

ABSTRACT

This paper examines the potential of autonomous vehicle (AV) technology for enhancing first and last mile services for a light-rail station. We use an event- and agent-based simulation model to compare the performance of fixed and demand-responsive routing services. The routing of on-demand services is based on a matching algorithm in which incoming passenger requests are prioritized and assigned to vehicles under capacity constraints. Our findings indicate that, for a high-frequency light-rail feeder system, fixed routing is the preferred option, even with the assumed reduction in operational costs due to driver-less operations. However, we also observe that demand-responsive services can be as effective as fixed routing in off-peak hours, provided the heuristics for matching passengers to vehicles are effective. This implies that a combination of the two services could be beneficial in certain contexts. In addition, our results demonstrate that urban sprawl has an impact on the performance of the system, with the demand-responsive services becoming relatively better when urban sprawl increases, while the fixed routing remains superior across most key-performance indicators. To assess the performance of the different services, we employ cost–benefit analysis.

Background

- There is an **increasing awareness of the public health effects** of active modes
  - HEAT model (https://www.who.int/tools/heat-for-walking-and-cycling)
    - Breda et al. (2018) https://doi.org/10.1016/j.healthpol.2018.01.015
    - Foley, L., Dumuid, D., Atkin, A., et al.: Patterns of health behaviour associated with active travel: a compositional data analysis. Int. J. Behav. Nutr. Phys. **15**, 1–2 (2018)
  - Also part of national recommendations in DK, SE, NO and other places
- The **health-effects ~ 1 Euro / KM**
  - With a walking distance of 6 KM/H, this correspond to a **VoT ~ 6 Euro/H**
  - With a bicycling distance of 15 KM/H, this correspond to a **VoT ~ 15 Euro/H**
- These values, even if slightly inflated, is **not neglectable**!
- If first-and-last mile services captures active trips, **we need to assess their welfare performance by also accounting the loss in health**

The fallacy paper: Aim and Methodology

- **Hypothesis**
  - There must be a distance threshold under which FML services are irrelevant
- Objective is to look at the **societal welfare performance** of a FML service
  - By accounting for **health-benefit** losses
  - Use favourable conditions for the FML
  - Study **”failure” and ” succes” regions** for FML
- Hopefully draw useful conclusions

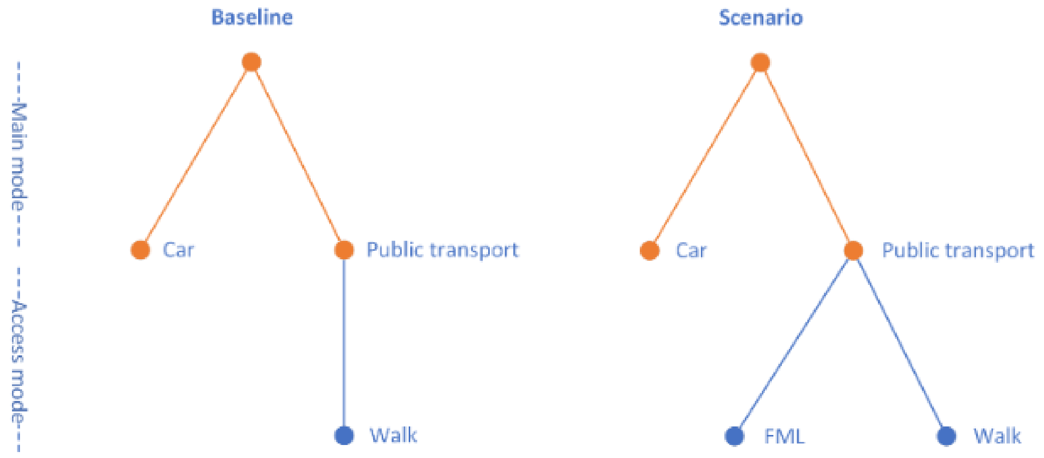
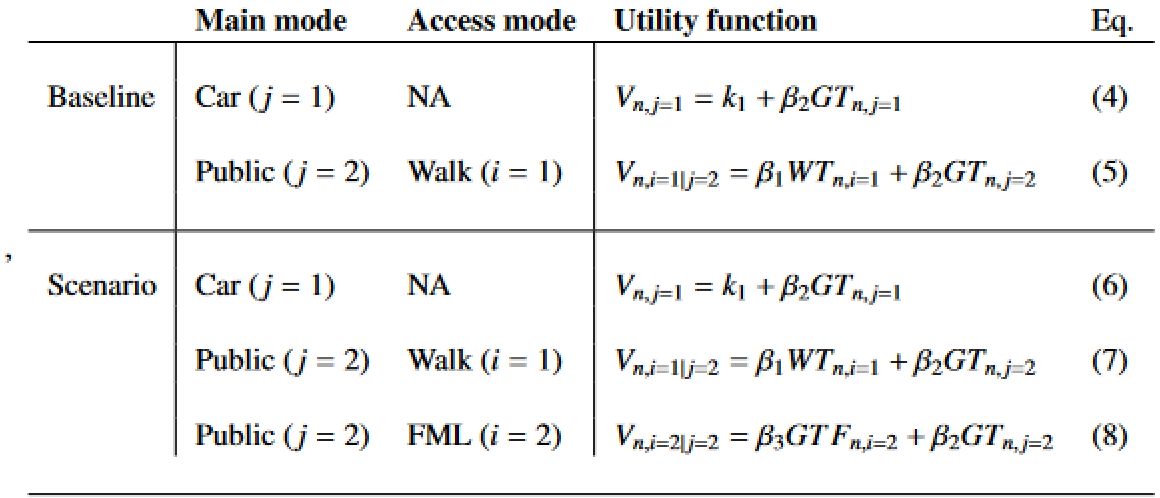


Figure 1: A mode choice model for first- and last-mile transport, segmented into primary and feeder modes. The feeder mode in the baseline is represented by walk, while in the scenario, the feeder modes are represented by walk and FML.

Utility-functions

- A **generalised cost-perspective**
- Nested-logit (main mode and feeder-mode)
  - Even **induced demand** on main-mode is considered



	Main mode	Access mode	Utility function	Eq.
Baseline	Car ($j = 1$)	NA	$V_{n,j=1} = k_1 + \beta_2 GT_{n,j=1}$	(4)
	Public ($j = 2$)	Walk ($i = 1$)	$V_{n,i=1\|j=2} = \beta_1 WT_{n,i=1} + \beta_2 GT_{n,j=2}$	(5)
Scenario	Car ($j = 1$)	NA	$V_{n,j=1} = k_1 + \beta_2 GT_{n,j=1}$	(6)
	Public ($j = 2$)	Walk ($i = 1$)	$V_{n,i=1\|j=2} = \beta_1 WT_{n,i=1} + \beta_2 GT_{n,j=2}$	(7)
	Public ($j = 2$)	FML ($i = 2$)	$V_{n,i=2\|j=2} = \beta_3 GTF_{n,i=2} + \beta_2 GT_{n,j=2}$	(8)

Table 2: Overview of indirect utility functions for the baseline and the scenarios. Only two alternatives are available for the baseline, whereas three are available for the scenario. The notation is deliberately redundant because we specify the walking alternative $i = 1$ even for the baseline, where it is the only alternative. However, it makes it simpler to express the welfare function.

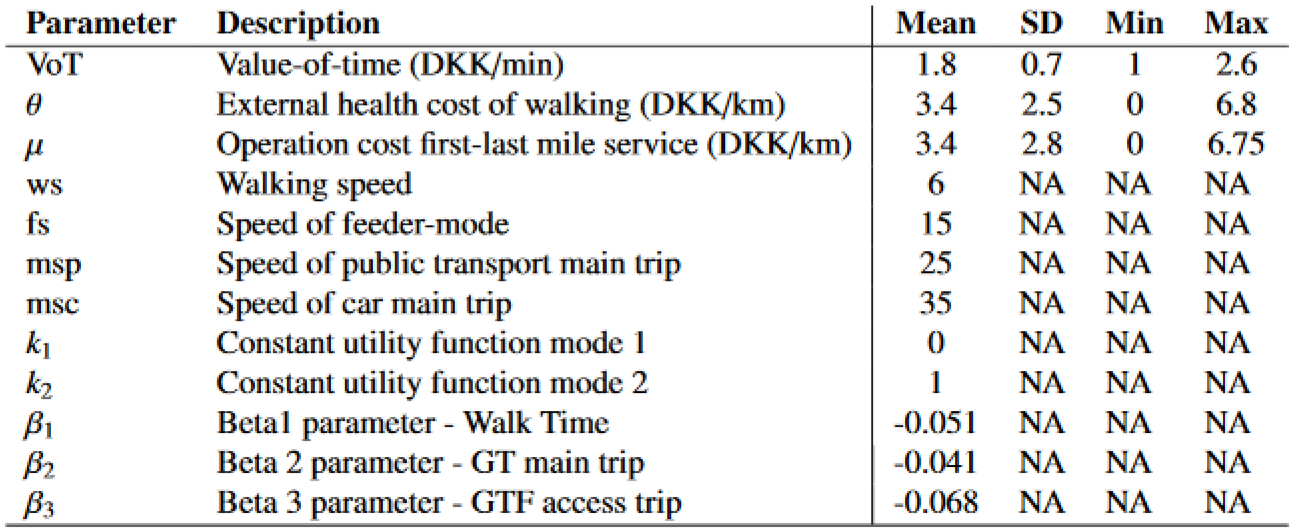
Welfare function

- **Welfare function** expressed for every trip
  - Based on a **rule-of-the-half** approximation (Kidokoro, 2004)
  - Reduces to **very simplistic first-order condition** as the only scenario is FML
- By **simulating** a varity of key input parameters we **study the failure regions**
  - μ: Health benefit by walking 1 km
  - θ: Operational km cost for FML
  - VoT_n: Value-of-time DKK/min
  - WTF_n: Waiting time for FML service
  - Distance

$$Z = \sum_{n} \sum_{i,j} (p^{0}_{n,i|j} - p^{1}_{n,i|j}) \cdot \frac{(d^{0}_{n,i|j} + d^{1}_{n,i|j})}{2}$$

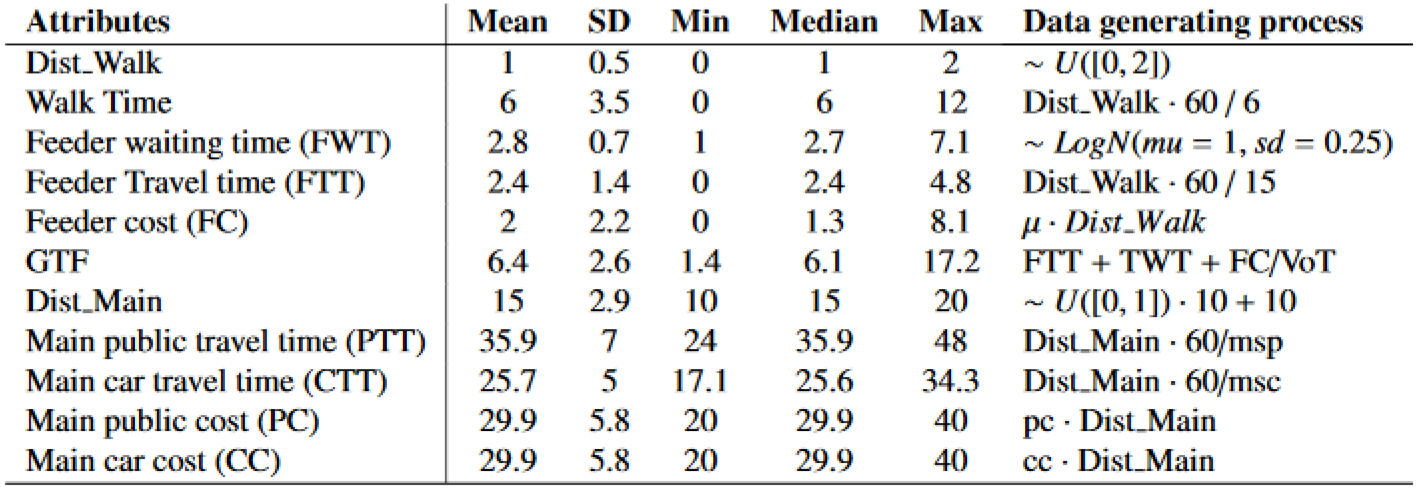
$$\theta Dist\_walk_{n,j=2} \leq Dist\_walk_{n,j=2} \left(\frac{60 \cdot VoT_n}{ws} - \frac{60 \cdot VoT_n}{fs} - \mu \right) - WTF_{n,i=2} \cdot VoT_n$$

- All very uncontroversial inputs
  - – Mostly in favour of FML
- **Only walk** (no bike)
- Cost-structure assume **autonomous operation**
- Neglecting **transfer penalty** between FML and Main transit
- Cognetive cost of **booking** neglected



Parameter	Description	Mean	SD	Min	Max
VoT	Value-of-time (DKK/min)	1.8	0.7	1	2.6
θ	External health cost of walking (DKK/km)	3.4	2.5	0	6.8
μ	Operation cost first-last mile service (DKK/km)	3.4	2.8	0	6.75
ws	Walking speed	6	NA	NA	NA
fs	Speed of feeder-mode	15	NA	NA	NA
msp	Speed of public transport main trip	25	NA	NA	NA
msc	Speed of car main trip	35	NA	NA	NA
k_1	Constant utility function mode 1	0	NA	NA	NA
k_2	Constant utility function mode 2	1	NA	NA	NA
β_1	Beta1 parameter - Walk Time	-0.051	NA	NA	NA
β_2	Beta 2 parameter - GT main trip	-0.041	NA	NA	NA
β_3	Beta 3 parameter - GTF access trip	-0.068	NA	NA	NA

Table A.5: Parameters used in simulations. The specific parameters for VoT, θ, and μ will appear in the respective Figure or Table. The beta parameters are taken from Hallberg et al. (2021), where linear generalized time functions were estimated for Copenhagen for walking, cycling, and motorized modes.



Attributes	Mean	SD	Min	Median	Max	Data generating process
Dist_Walk	1	0.5	0	1	2	$\sim U([0,2])$
Walk Time	6	3.5	0	6	12	Dist_Walk · 60 / 6
Feeder waiting time (FWT)	2.8	0.7	1	2.7	7.1	$\sim LogN(mu = 1, sd = 0.25)$
Feeder Travel time (FTT)	2.4	1.4	0	2.4	4.8	Dist_Walk · 60 / 15
Feeder cost (FC)	2	2.2	0	1.3	8.1	$\mu \cdot Dist\_Walk$
GTF	6.4	2.6	1.4	6.1	17.2	FTT + TWT + FC/VoT
Dist_Main	15	2.9	10	15	20	$\sim U([0,1]) \cdot 10 + 10$
Main public travel time (PTT)	35.9	7	24	35.9	48	Dist_Main · 60/msp
Main car travel time (CTT)	25.7	5	17.1	25.6	34.3	Dist_Main · 60/msc
Main public cost (PC)	29.9	5.8	20	29.9	40	pc · Dist_Main
Main car cost (CC)	29.9	5.8	20	29.9	40	cc · Dist_Main

Table A.6: Derived variables applied in the simulation.

Results!

The distance failure

- Generally **FML services operated under a certain KM threshold will fail**
  - The is because **walking** becomes more more compettetive the lower distance
  - **Waiting time** means more on shorter distances
- Everyting **under 0.7 KM fails** under almost every parametrisation
- Hence, if we make sure that the granularity of our public transport network is consistent with this, we should not worry about the rest!

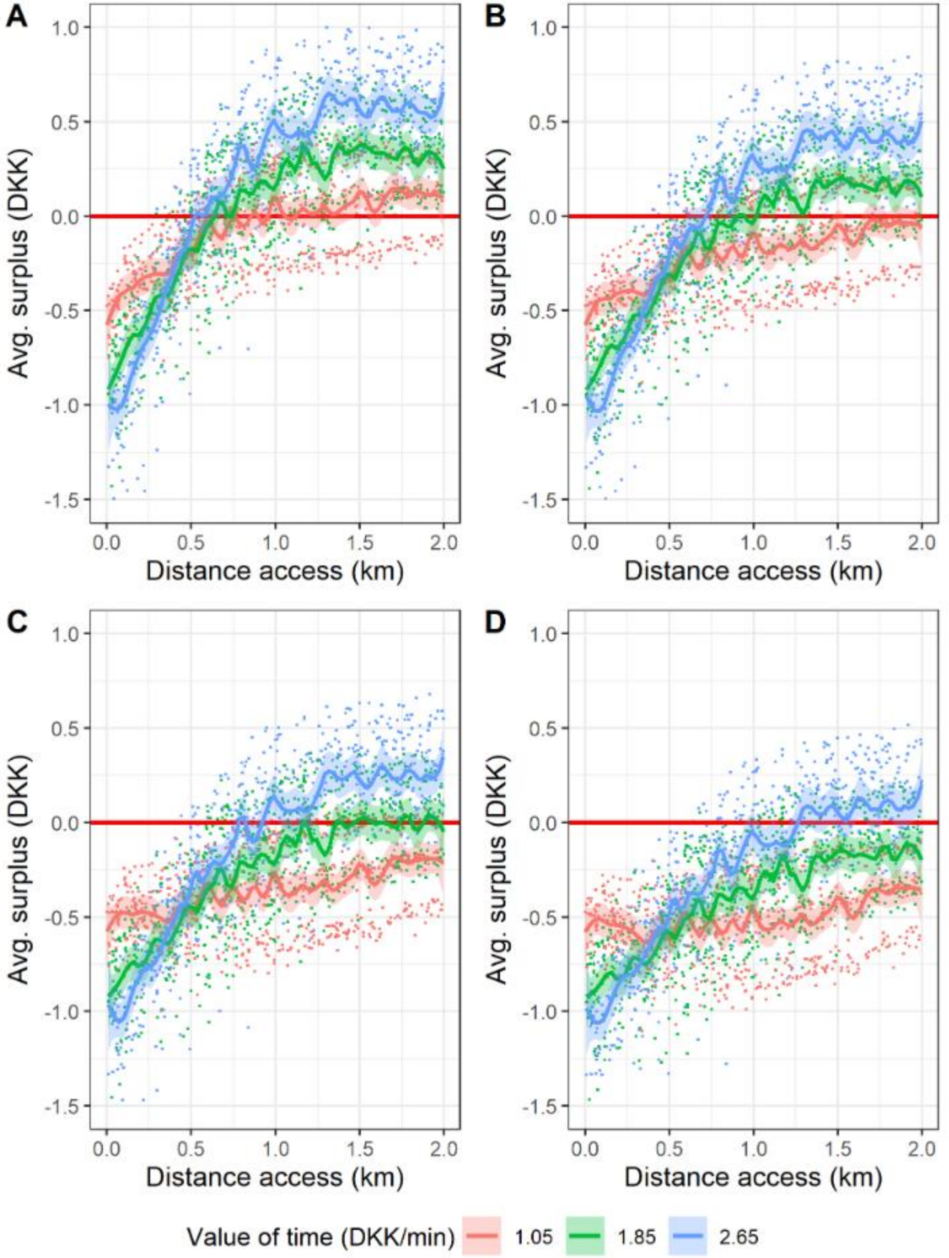
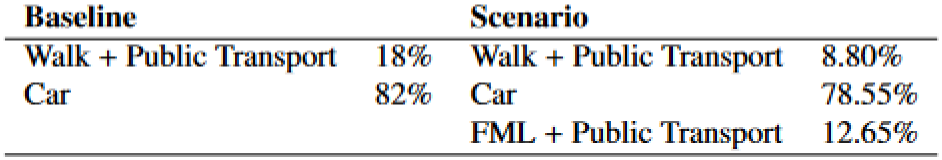


Figure 2: Simulation of average consumer surplus Z_n per access trip (DKK/trip) as a function of access distance (km) and value-of-time segments (DKK/min). A: $\theta = 0$, B: $\theta = 2.25$ DKK/km, C: $\theta = 4.5$ DKK/km, D: $\theta = 6.75$ DKK/km. For all figures $\mu = 5.9$ DKK/km.

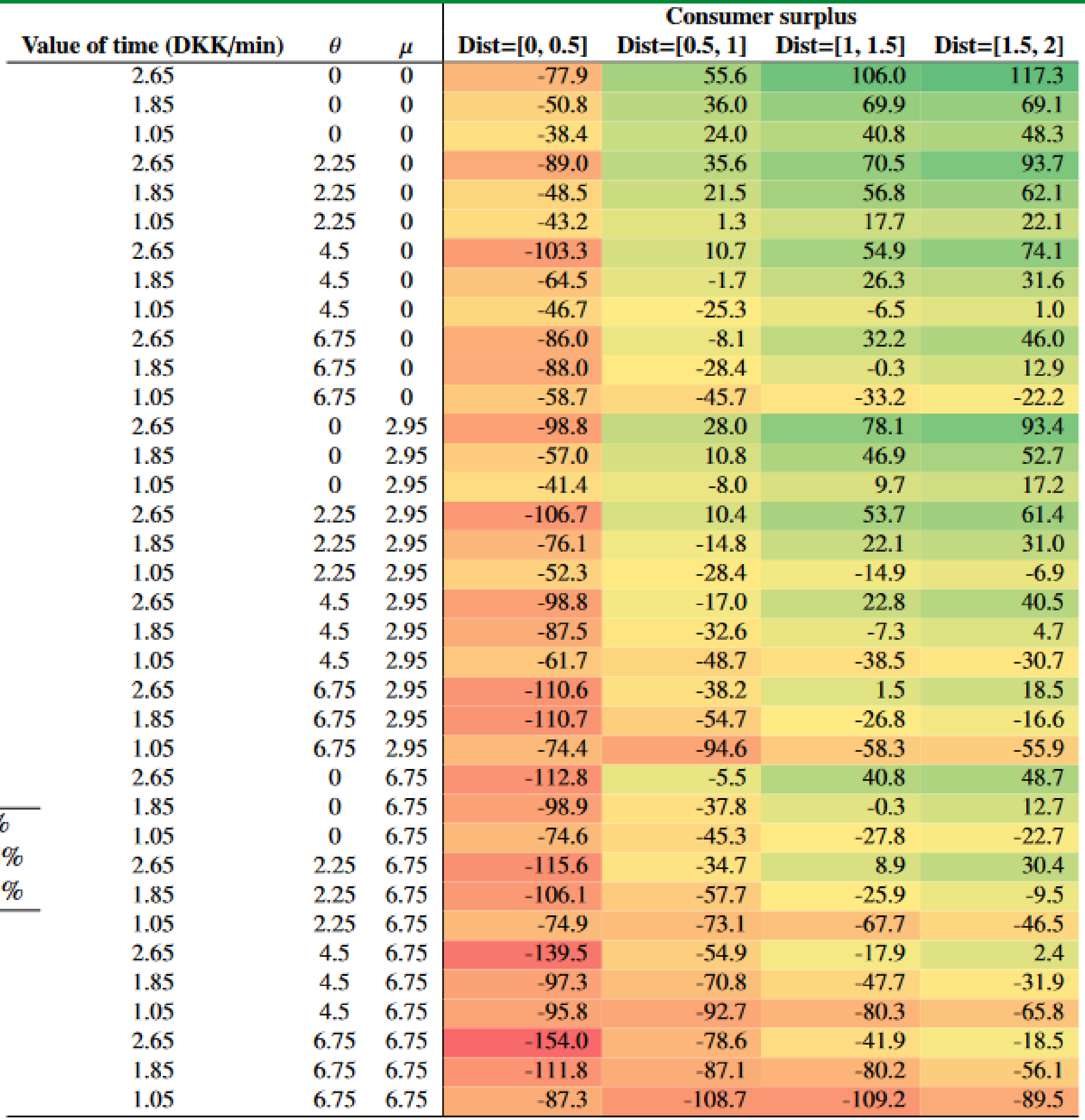
Input sensitivity

- It depends on;
- µ: Health benefit
- θ: Operational km cost
- VoT_n: Value-of-time
- Distance



Baseline		Scenario	
Walk + Public Transport	18%	Walk + Public Transport	8.80%
Car	82%	Car	78.55%
		FML + Public Transport	12.65%

Table 3: Inferred market shares in the simulation.

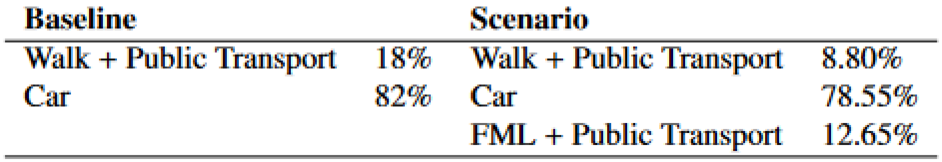


Value of time (DKK/min)	θ	μ	Consumer surplus Dist=[0, 0.5]	Dist=[0.5, 1]	Dist=[1, 1.5]	Dist=[1.5, 2]
2.65	0	0	-77.9	55.6	106.0	117.3
1.85	0	0	-50.8	36.0	69.9	69.1
1.05	0	0	-38.4	24.0	40.8	48.3
2.65	2.25	0	-89.0	35.6	70.5	93.7
1.85	2.25	0	-48.5	21.5	56.8	62.1
1.05	2.25	0	-43.2	1.3	17.7	22.1
2.65	4.5	0	-103.3	10.7	54.9	74.1
1.85	4.5	0	-64.5	-1.7	26.3	31.6
1.05	4.5	0	-46.7	-25.3	-6.5	1.0
2.65	6.75	0	-86.0	-8.1	32.2	46.0
1.85	6.75	0	-88.0	-28.4	-0.3	12.9
1.05	6.75	0	-58.7	-45.7	-33.2	-22.2
2.65	0	2.95	-98.8	28.0	78.1	93.4
1.85	0	2.95	-57.0	10.8	46.9	52.7
1.05	0	2.95	-41.4	-8.0	9.7	17.2
2.65	2.25	2.95	-106.7	10.4	53.7	61.4
1.85	2.25	2.95	-76.1	-14.8	22.1	31.0
1.05	2.25	2.95	-52.3	-28.4	-14.9	-6.9
2.65	4.5	2.95	-98.8	-17.0	22.8	40.5
1.85	4.5	2.95	-87.5	-32.6	-7.3	4.7
1.05	4.5	2.95	-61.7	-48.7	-38.5	-30.7
2.65	6.75	2.95	-110.6	-38.2	1.5	18.5
1.85	6.75	2.95	-110.7	-54.7	-26.8	-16.6
1.05	6.75	2.95	-74.4	-94.6	-58.3	-55.9
2.65	0	6.75	-112.8	-5.5	40.8	48.7
1.85	0	6.75	-98.9	-37.8	-0.3	12.7
1.05	0	6.75	-74.6	-45.3	-27.8	-22.7
2.65	2.25	6.75	-115.6	-34.7	8.9	30.4
1.85	2.25	6.75	-106.1	-57.7	-25.9	-9.5
1.05	2.25	6.75	-74.9	-73.1	-67.7	-46.5
2.65	4.5	6.75	-139.5	-54.9	-17.9	2.4
1.85	4.5	6.75	-97.3	-70.8	-47.7	-31.9
1.05	4.5	6.75	-95.8	-92.7	-80.3	-65.8
2.65	6.75	6.75	-154.0	-78.6	-41.9	-18.5
1.85	6.75	6.75	-111.8	-87.1	-80.2	-56.1
1.05	6.75	6.75	-87.3	-108.7	-109.2	-89.5

Table 4: Aggregated surplus Z for different parameter combinations and distance segments. Results are based on a simulation of 20.000 trips. Distance intervals are in km.

Input sensitivity

- It depends on;
- µ: Health benefit
- θ: Operational km cost
- VoT$_n$: Value-of-time
- Distance



Baseline		Scenario	
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Car	82%	Car	78.55%
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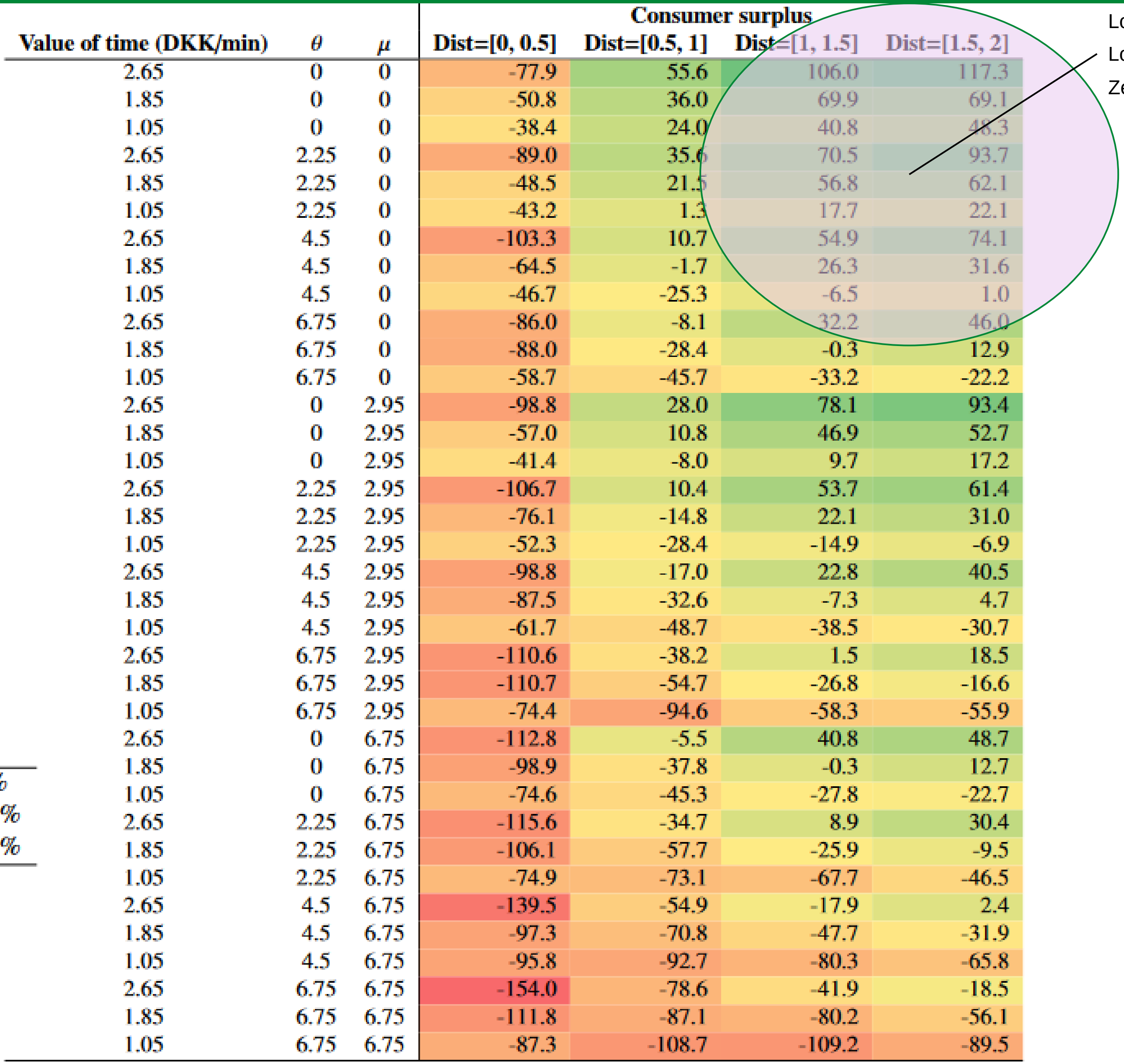
Table 3: Inferred market shares in the simulation.



			Consumer surplus			
Value of time (DKK/min)	θ	μ	Dist=[0, 0.5]	Dist=[0.5, 1]	Dist=[1, 1.5]	Dist=[1.5, 2]
2.65	0	0	-77.9	55.6	106.0	117.3
1.85	0	0	-50.8	36.0	69.9	69.1
1.05	0	0	-38.4	24.0	40.8	48.3
2.65	2.25	0	-89.0	35.6	70.5	93.7
1.85	2.25	0	-48.5	21.5	56.8	62.1
1.05	2.25	0	-43.2	1.3	17.7	22.1
2.65	4.5	0	-103.3	10.7	54.9	74.1
1.85	4.5	0	-64.5	-1.7	26.3	31.6
1.05	4.5	0	-46.7	-25.3	-6.5	1.0
2.65	6.75	0	-86.0	-8.1	32.2	46.0
1.85	6.75	0	-88.0	-28.4	-0.3	12.9
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Long distance
Low operating cost
Zero health benefits

Table 4: Aggregated surplus Z for different parameter combinations and distance segments. Results are based on a simulation of 20.000 trips. Distance intervals are in km.

Input sensitivity

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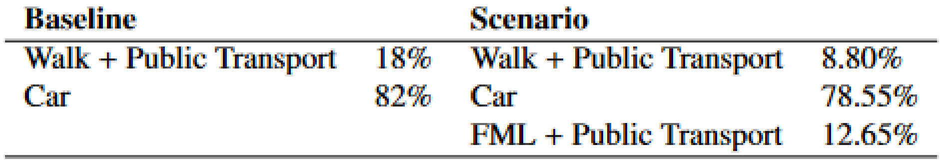

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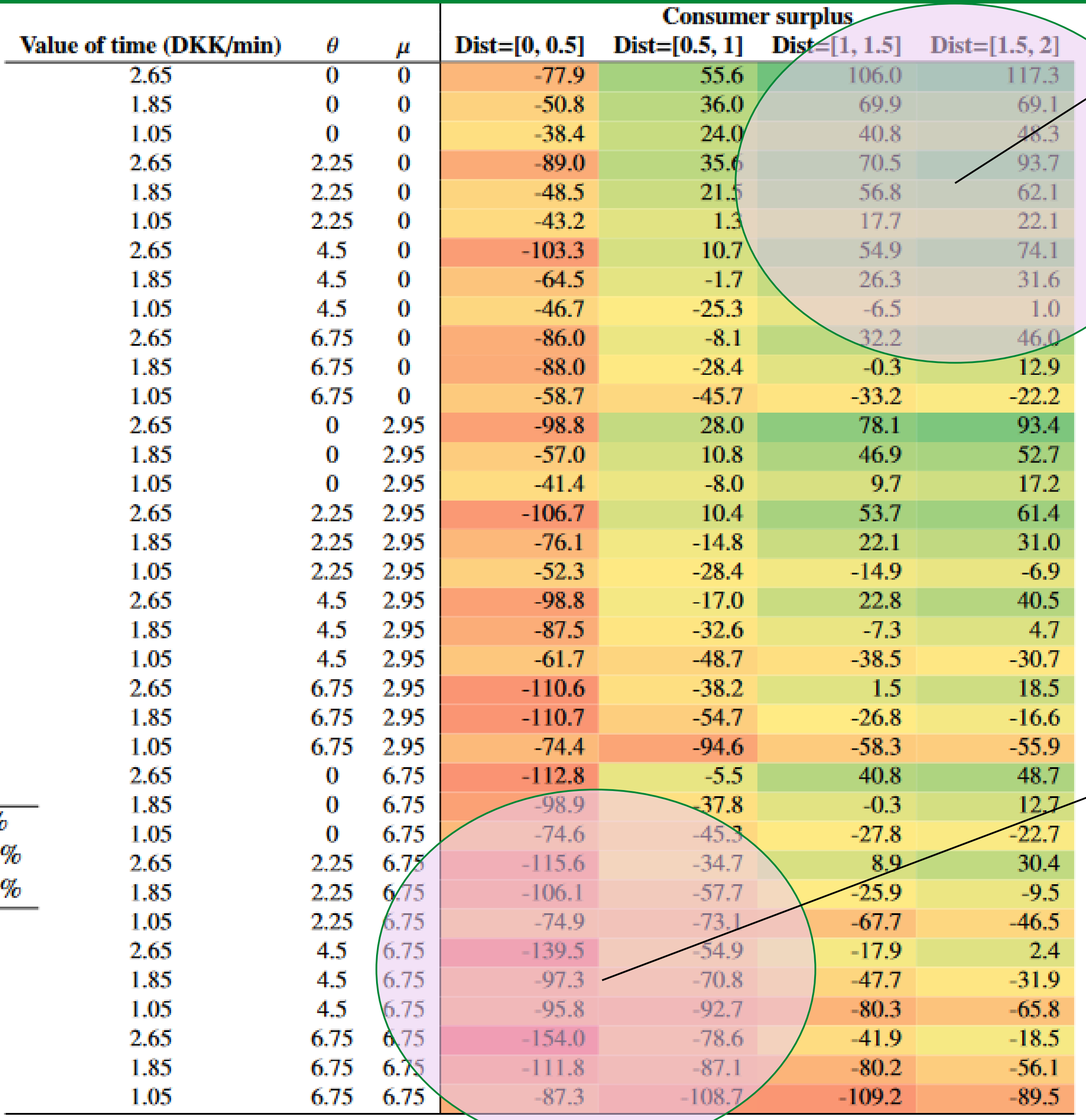

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1.05	6.75	6.75	-87.3	-108.7	-109.2	-89.5

Long distance

Low operating cost

Zero health benefits

Short distance

Normal operating costs

Normal health benefits

Table 4: Aggregated surplus Z for different parameter combinations and distance segments. Results are based on a simulation of 20.000 trips. Distance intervals are in km.

ABM model for Hersted Industrial Park

- Here we actually **developed a dedicated ABM model**
- With optimised **routing pattern**
- Comparison with **flexible and on-demand**
- But, again, **if accounting for health-effects, FML turned negative!**

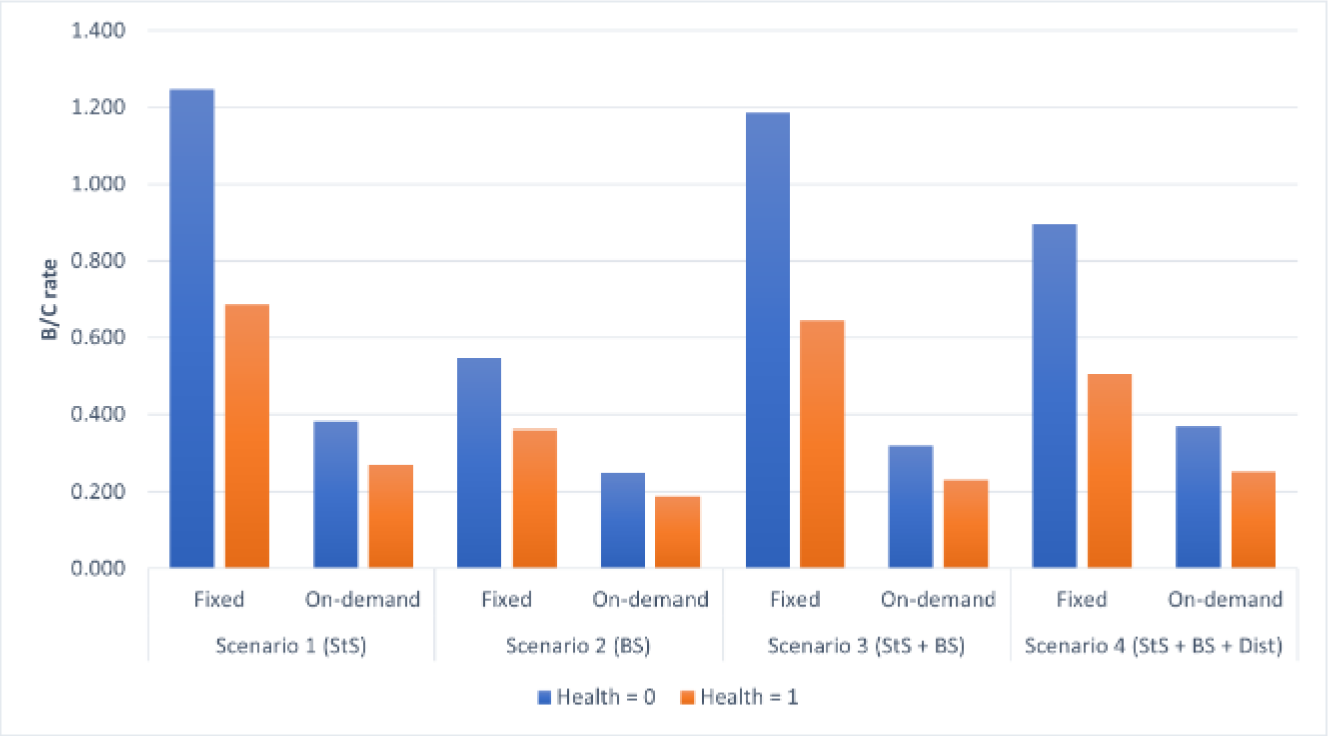

Figure 3: Simulation of cost-benefit performance for Scenario 1 - 4 for fixed routing and a station-to-door service. Blue bars represent B/C rates for the service when health costs are not included, while orange bars represent the B/C rates when health costs are included (refer to Table A.5 for the specific value.

Part3: Summary

We need to think about active modes as enablers

Discussion and conclusion

- If we do the ”math” it is clear that **FML services have a large failure region**
  - While they target ”first- and last mile trips” they are **not beneficial under 0.7 km** and most likely up to 1 km
  - So there is a **inherited fallacy** in these services
- This is an **important design criteria** when designing the granulatity of our public transport net

Recommendations

- Public transport operators should focus on:
  - Developing an **efficient back-bone network grid structure with a minimum of 1 km between stops** (correspond to 0.5 km in access and egress on average)
  - Make it **easy and safe to get to and from stations** and stops by walk and bike
  - **Direct fast lines**

- Consider **bicycle parking** and **bicycles in bus**
- **Make stations nice and pleasant to wait at** (fewer but better stations and stops)
- **Higher frequency? Rather than many stations/stops**

- **Improve** bus-operations **where micro-mobility options are few**
- **Reduce** bus-operations **where micro-mobility options are plenty**