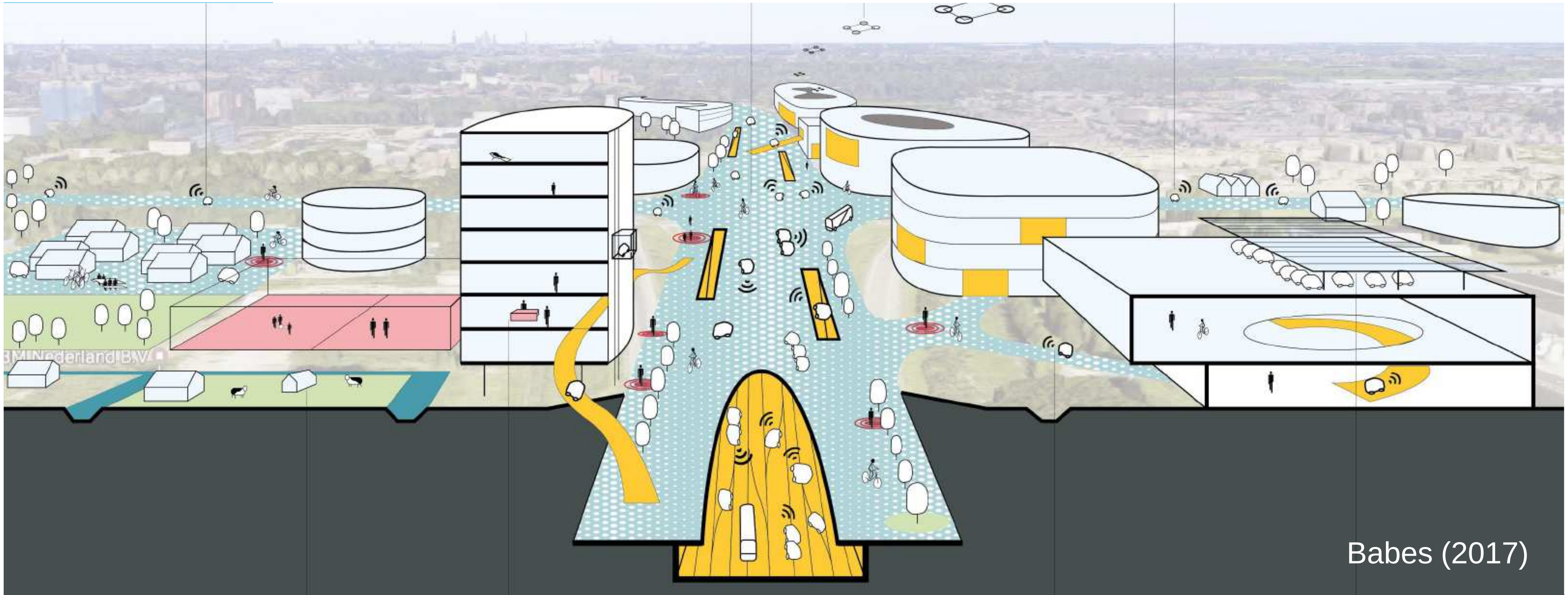

Babes (2017)

Self-Driving Cities: Will we have them? Do we need them? Do we want them?

Bart van Arem, Delft University of Technology, The Netherlands

Joint CoEXist/MAVEN/TRANSAID workshop, POLIS, Brussels, 10th October 2017

Spatial and Transport Impacts of Automated Driving

2016-2020 M€ 2,4

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RESEARCHLAB AUTOMATED DRIVING DELFT

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METROPOOLREGIO ROTTERDAM DEN HAAG

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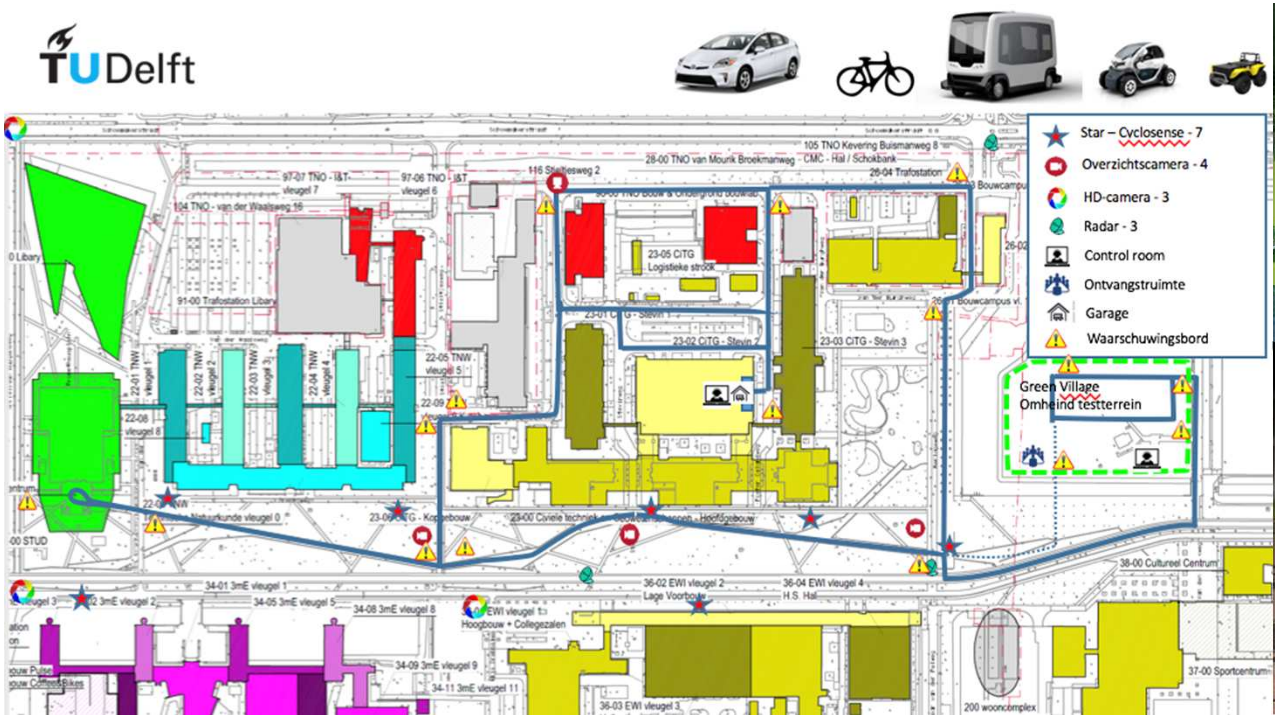
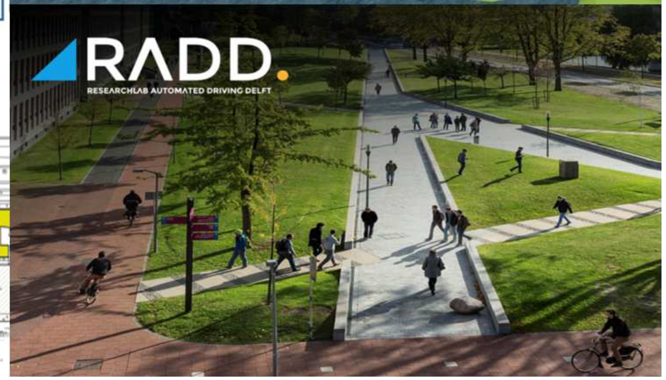
provincie Zuid Holland





Will we have them?

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Spatial and Transport Impacts of Automated Driving

Will we have them?

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Spatial and Transport Impacts of Automated Driving

Automated driving

Driver assistance/
Partial automation

Driver needs to be able to intervene at all times

Automated parking, autocruise

Conditional/ High automation

Vehicle in control in special conditions

Taxibots, platooning, automated highways

Comfort, efficiency, safety, costs

Mode choice, location choice, urban and transport planning

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Many questions …

When fully automated vehicles will hit the market?

Will we travel safer?

Are we going to own or share cars?

Will we need more or less road infrastructures?

Will we still need buses?

Will there be more or less congestion?

Will we drive longer or shorter distances?

How much on-street and off-street parking spaces will still be needed?

How will cities evolve?

Will we consume more or less energy to travel?

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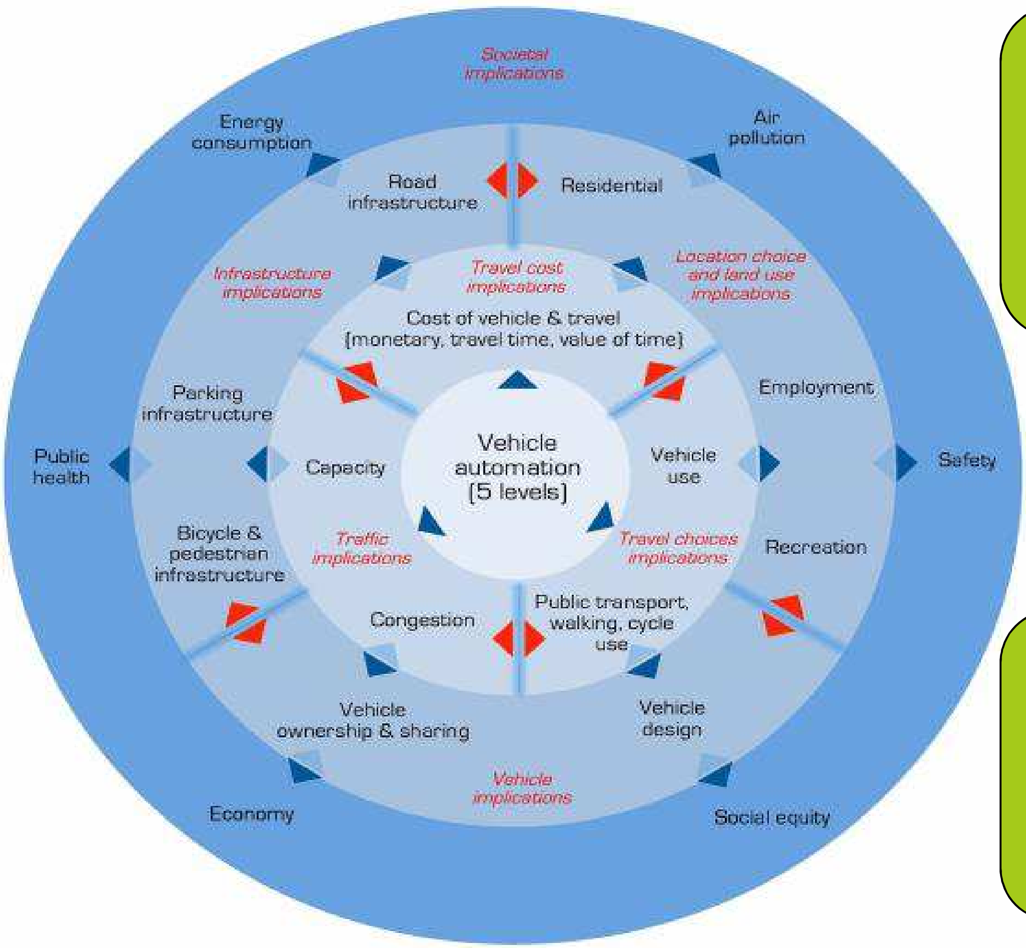

Much progress short term and small scale impacts on driver behaviour and traffic flow.

Research on longer term, indirect, wider scale impacts on mobility, logistics, residential patterns and spatial-economic structure in its infancy.

Milakis et al (2017), Policy and society related implications of automated driving, Journal of ITS.

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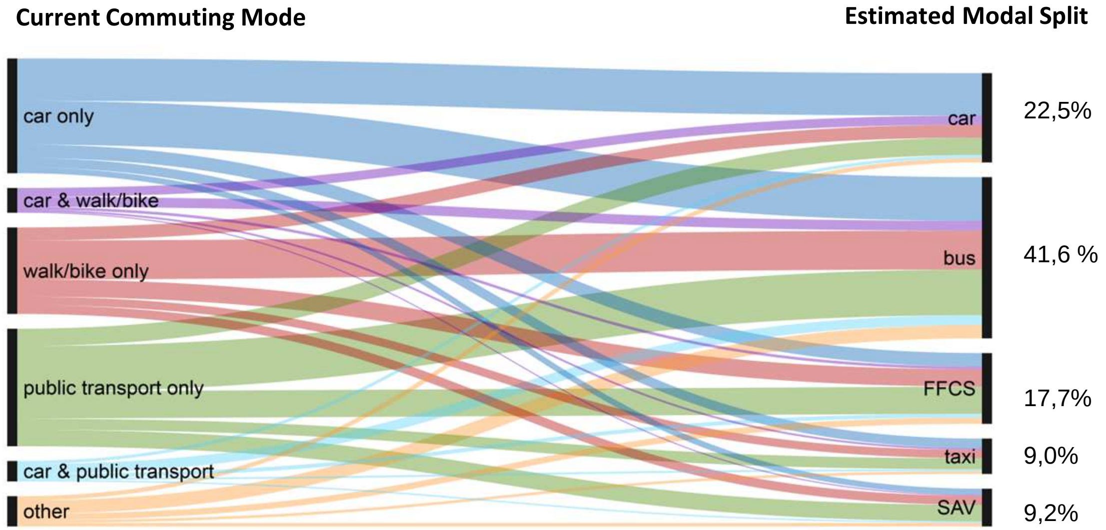
Spatial and Transport Impacts of Automated Driving

Which of the following options would you choose for going from your home to your fictive work / educational institution?

1	auto-to-go	own vehicle	taxi	bus	self-riding vehicles
Cost for the trip	€ 3,60	€ 2,40	€ 3,60	€ 3,60	€ 3,60
Cost for parking	--	€ 5,00	--	--	--
Time to walk to and from vehicle or bus stop	2 minutes	6 minutes	--	6 minutes	--
Waiting time	--	--	4 minutes	7 minutes	4 minutes
Travel time in vehicle	15 minutes	15 minutes	15 minutes	20 minutes	15 minutes
Time to find a parking spot	4 minutes	4 minutes	--	--	--
	auto-to-go	own vehicle	taxi	bus	self-riding vehicle
I choose:	○	○	○	○	○



840 respondents
Amsterdam, Utrecht, The Hague Rotterdam

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Winter et al (2017), Mode Preferences in Times of Free-Floating Carsharing and Shared Automated Vehicles - a Stated Choice Experiment, submitted.

Spatial and Transport Impacts of Automated Driving

Value of travel time in private vehicles

VOTT

The amount a traveller is willing to pay for 1 minute travel time reduction.

VOTT ↑

Trip is less useful or comfortable, traveller is willing to spend more for a shorter trip

VOTT ↓

Trip is useful and comfortable, traveller is willing to spend less for a shorter trip

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Spatial and Transport Impacts of Automated Driving

Value of time in private vehicles: a stated preference experiment

Assume your next trip is from home to work,
which option would you choose?

A. Conventional car	B. AV – office interior	C. AV – leisure interior
Travel time: 15 Min	Travel time: 45 Min	Travel time: 30 Min
Travel costs: € 4.50	Travel costs: € 4.50	Travel costs: € 7.50
Walking time: 6 Min	Walking time: 0 Min	Walking time: 0 Min
AV activity: driving	AV activity: working extra time	AV activity: do whatever you want
Travel companions: friends and/or family	Travel companions: friends or family	Travel companions: alone
○	○	○

De Looff et al (2017), Value of travel time changes as a results of vehicle automation – a case study in the Netherlands (forthcoming)

242 respondents;
results excluding 96 non traders

	Mean value of travel time
Conventional car	7,91
AV Office interior	4,97
AV Leisure interior	10,47

Office interior aligns with work activities

Leisure interior does not align with work activities

Convenience, safety and trust

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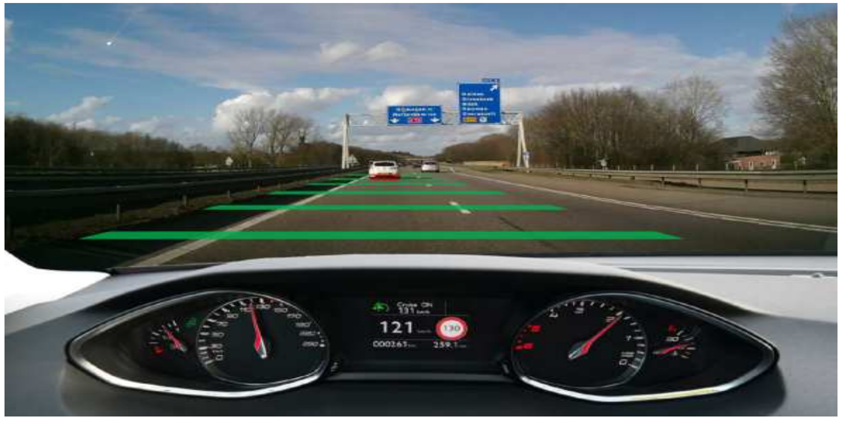

Driving with ACC

Field study 8 ACC vehicles at RHDHV
Questionnaire in cooperation with RDW

Current ACC systems maintain longer headways than human drivers

Drivers reduce lane changing when using ACC –staying in left or right most lane

ACC users rate pleasureness at 8 on a 1-10 scale
- Full range ACC scores higher
- Clumsy technology decreases pleasure

ACC more likely to be bought by high-income males

Winter, et al (2017) , Pleasure in using adaptive cruise control, Traffic Injury Prevention
Schakel et al (2017), Driving Characteristics and Adaptive Cruise Control, IEEE ITS Magazine

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	Reactietijd [s]	Gemiddelde volgtijd [s]	Gemiddelde maximale versnelling [m/s²]	Gemiddelde normale vertraging [m/s²]	Gemiddelde maximale vertraging [m/s²]
Auto	0.8	- (≈ 1.0)	2.8	-3.5	-7
ACC	0.8	1.6	2.5	-2.5	-6
Nieuwere ACC	0.4	1.6	2.5	-2.5	-6
Verbeterde ACC	0.4	1.2	2.5	-2.5	-6
CACC	0.2	0.8	2.5	-2.5	-6

- Current ACC increases congestion
- New/improved ACC start reducing congestion at 10% penetration rate
- CACC strongly reduces congestion

Note: (C)ACC modelled as ‘special’ drivers

Huisman (2016)
Repository.tudelft.nl

Spatial and Transport Impacts of Automated Driving

General findings on motorway capacity

"CACC can double roadway capacity"

- on motorways without on/off ramps -

Many microsimulations
Different reference cases
ACC and CACC
Hardly any bottlenecks

Arnaout & Bowling, 2011; Arnaout & Arnaout, 2014; Delis, Nikolos, & Papageorgiou, 2015; Fernandes, Nunes, & Member, 2015; Grumert, Ma, & Tapani, 2015; Hoogendoorn, van Arem, & Hoogendoorn, 2014; Huang, Ren, & Chan, 2000; Michael, Godbole, Lygeros, & Sengupta, 1998; Monteil, Nantes, Billot, Sau, & El Faouzi, 2014; Ngoduy, 2013; Rajamani & Shladover, 2001; Shladover, Su, & Lu, 2012; van Arem, van Driel, & Visser, 2006; Yang, Liu, Sun, & Li, 2013; Carbaugh et al., 1998; Hall et al., 2001; Le Vine et al., 2015; Michael et al., 1998; Talebpour & Mahmassani, 2016; Wang et al., 2016a, b; Xie et al., 2016; Zhou et al., 2016)

ACC changes motorway capacity between -5% and +10%
At bottlenecks change is less than +10%
Additional benefits: improving stability (CACC) and reducing capacity drop
CACC increase capacity further at penetration rates beyond 40%

Hoogendoorn et al (2014), Automated driving, traffic flow efficiency and human factors: literature review, Transportation Research Record
Milakis et al (2017), Policy and society related implications of automated driving, Journal of ITS.

Network design and impacts of Automated Driving

High automation on designated roads

AV has 95% VOTT of regular vehicles

Passenger Car Equivalent AV:
95% penetration rate <= 40%
90% penetration >40%

Level 4 enabled network of Delft

Automated Vehicles may travel further to be on L4 roads

Automated Vehicles lead to shorter travel time on L4 roads

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Spatial and Transport Impacts of Automated Driving

User equilibrium static assignment

Penetration Rate	Total Travel Cost (€)	Total Travel Time (h)	Total Travel Distance (km)
0	71265	3451	211580
10%	70897	3448	211686
50%	67574	3438	212911
90%	64634	3429	213971
Max improvement	**- 9%**	**- 1%**	**+1%**

Madadi et al (2017) Automated Driving and infrastructure network design (TRB 2018, forthcoming)

Next steps
Dynamic assignment
Multi-user class
Optimal Network Design

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Spatial and Transport Impacts of Automated Driving

Automated Vehicles in National Market and Capacity Analysis (NMCA)

NMCA

Updated every 4 year to identify main transport problems

Used to support major transport infrastructure decisions

Typical horizon 20 years

Uses Dutch National Transport Model (LMS)

What if AVs could deliver substantial capacity improvement in 20 years?

I&M (2017), Nationale Markt- en Capaciteitsanalyse Hoofdrapport, 01-05-2017

Results* motorways

	AV Penetration rate cars	AV Penetration rate trucks	PCU car HWN	PCU truck HWN*	ΔVOT car	ΔVOT truck
Truck platooning	0%	40%	1	0,75	0%	-20%
Autonomous	30%	40%	1,15	0,75	-5%	-20%
Cooperative	30%	40%	0,7	0,75	-5%	-20%
Cooperative VOT	30%	40%	0,7	0,75	-20%	-20%

Capacity –4,5%

Capacity + 9%

KM driven	Morning peak	Evening peak	Other	Total
Truck platooning	100.9	100.8	100.9	**100.8** ↑
Autonomous	99.1	100.2	99.0	**99.8** ↓
Cooperative	105.3	103.2	105.4	**103.9** ↑
Cooperative VOT	106.4	105.0	106.7	**105.5** ↑

Vehicle loss hours	Morning peak	Evening peak	Other	Total
Truck platooning	97.6	95.9	99.6	**97.8** ↓
Autonomous	103.6	107.9	104.7	**105.3** ↑
Cooperative	91.0	80.0	91.9	**87.9** ↓
Cooperative VOT	94.0	83.9	95.1	**91.3** ↓

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* Results are indications. Functionality to assess impacts of AVs is still experimental.

Spatial and Transport Impacts of Automated Driving

Do we need them?

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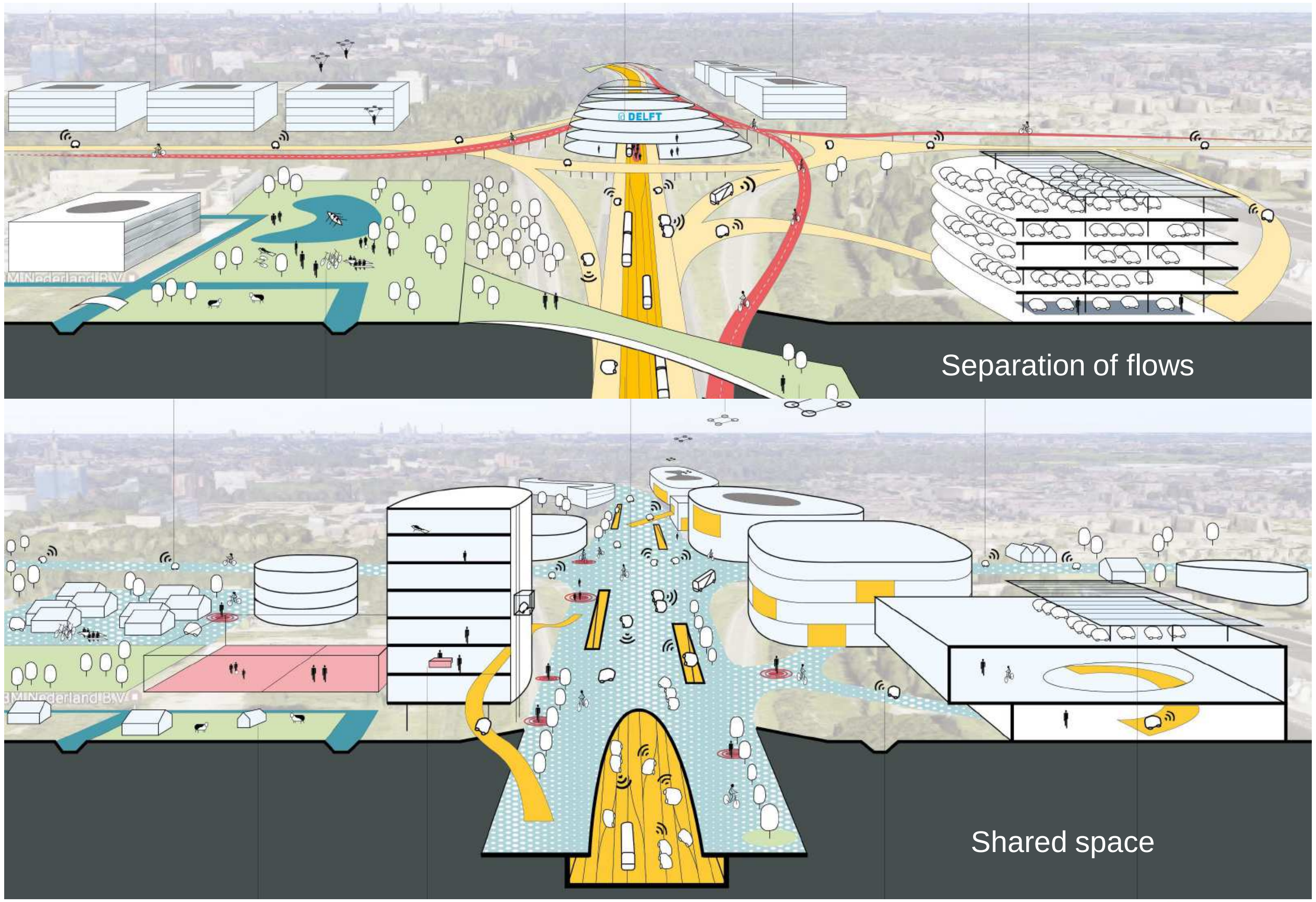
Reclaim infrastructure and parking space

Improve environmental quality

Improve social quality

Improve economic conditions

AVs: shared and electric



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Babes (2017), A Method to Assess the Impact of Automated Vehicles on Urban Liveability in the Rotterdam The Hague Metropolitan Region, European Post-Master in Urbanism (EMU), P5 report, repository.tudelft.nl

Spatial and Transport Impacts of Automated Driving

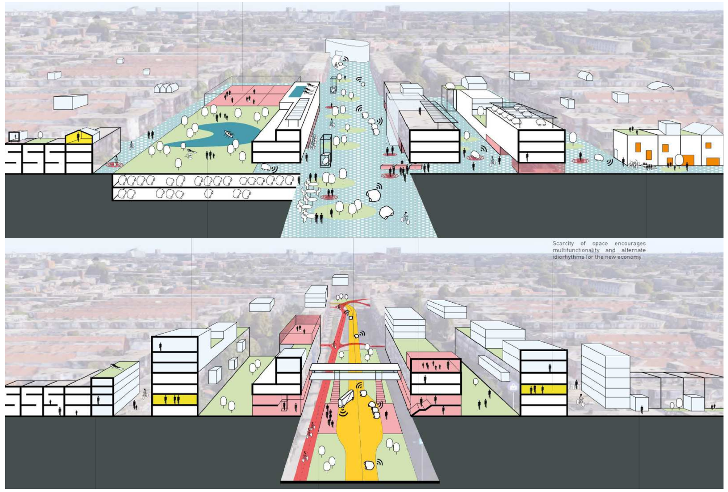
Self-driving cities

AV slowly building market penetration in specific groups

Traffic efficiency only improves when AVs are cooperative

Transport system level impacts moderate



AV friendly roads
C-ITS
EVs, sharing
Parking, accessibility and land use policies
Learning by doing (but safe!)

Spatial and Transport Impacts of Automated Driving

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Thank you!

http://www.citg.tudelft.nl/BvanArem

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