Spatial and Transport Impacts of Automated Driving

Webinar 2 Infrastructure

Design and optimization of road networks for automated vehicles

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PhD candidate, TU Delft

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Spatial and Transport Impacts of Automated Driving

Automated Vehicles (AVs) & the transition period

https://www.[illegible].com/features/futuristic-technologies-improving-roadways-now.html

Source: https://oppmax.com/blog/state-self-driving-car-mid-2017-report/

Source: https://www.mercedes-benz.com/en/mercedes-benz/innovation/research-vehicle-f-015-luxury-in-motion/

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Automated Vehicles (AVs) & the transition period

	Human Driver Monitors Environment			System Monitors Environment		
	0 No Automation: The absence of any assistive features such as adaptive cruise control.	**1** Driver Assistance: Systems that help drivers maintain speed or stay in lane but leave the driver in control.	**2** Partial Automation: The combination of automatic speed and steering control—for example, cruise control and lane keeping.	**3** Conditional Automation: Automated systems that drive and monitor the environment but rely on a human driver for backup.	**4** High Automation: Automated systems that do everything—no human backup required—but only in limited circumstances.	**5** Full Automation: The true electronic chauffeur: retains full vehicle control, needs no human backup and drives in all conditions.
Who steers, accelerates and decelerates	Human driver	Human driver and system	System	System	System	System
Who monitors the driving environment	Human driver	Human driver	Human driver	System	System	System
Who takes control when something goes wrong	Human driver	Human driver	Human driver	Human driver	System	System
How much driving, overall, is assisted or automated	None	Some driving modes	Some driving modes	Some driving modes	Some driving modes	All driving modes

Source: Shladover et al. (2016)

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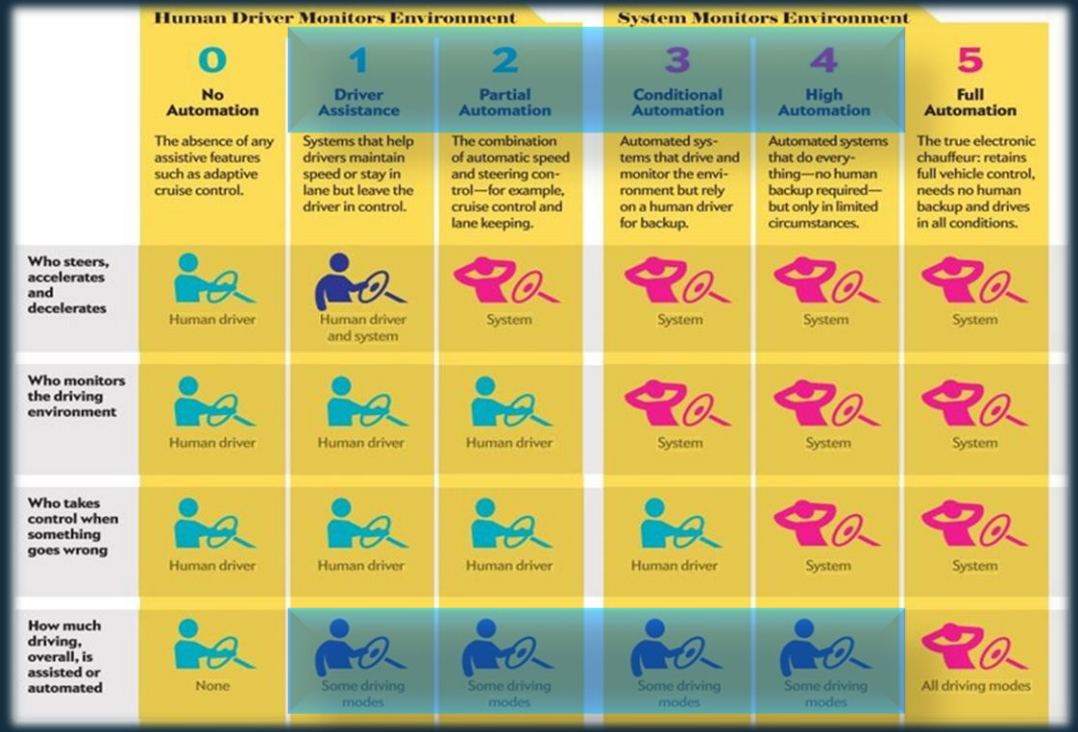

Source: Shladover et al. (2016)

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How and where can we accommodate AVs on road networks during the transition period?

Dedicated AV infrastructure

- Dedicated AV lanes
- Dedicated AV links
- Dedicated AV zones

Mixed traffic

- Regular infrastructure
- Enhanced infrastructure

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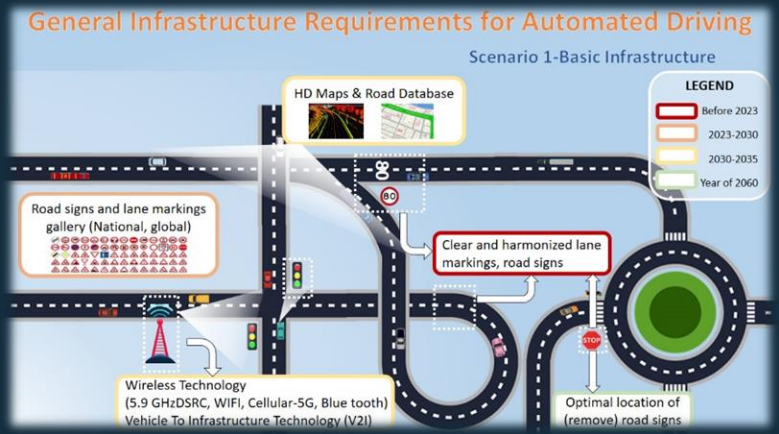
Enhanced infrastructure (Lu et al. 2019)

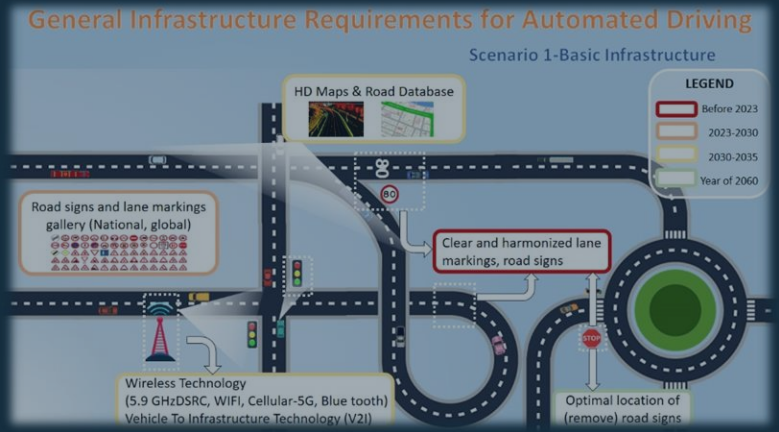
Basic



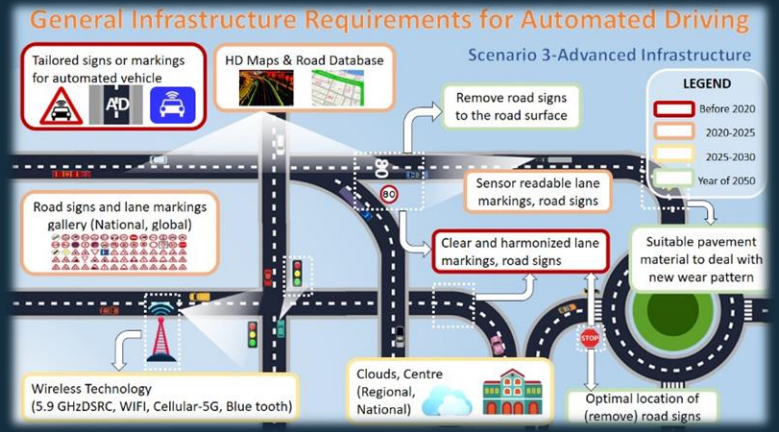
Advanced

Enhanced infrastructure (Lu et al. 2019)

Basic



Advanced



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Enhanced infrastructure (Lu et al. 2019)

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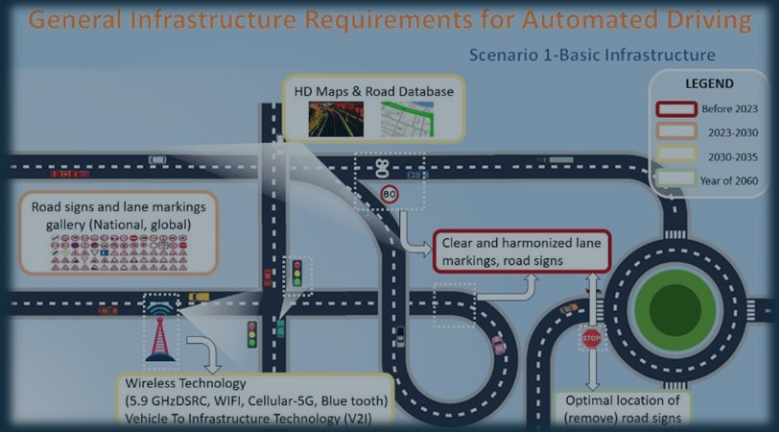

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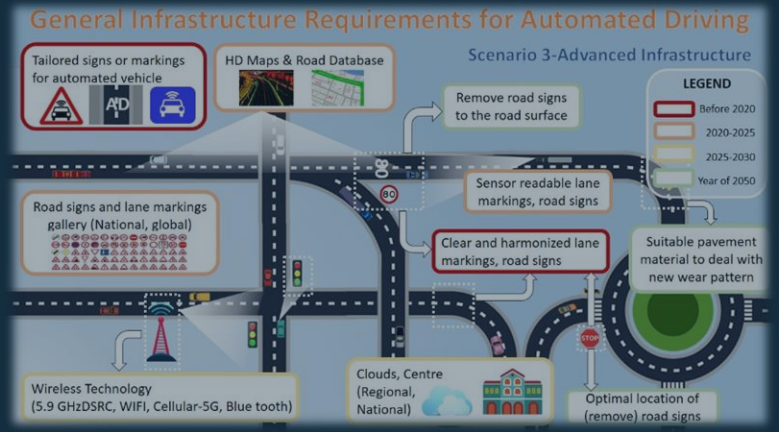

Do we need this on all roads?

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Mixed traffic on enhanced infrastructure

AV-ready subnetworks

(Madadi et al., 2019)

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Mixed traffic on enhanced infrastructure

AV-ready subnetworks

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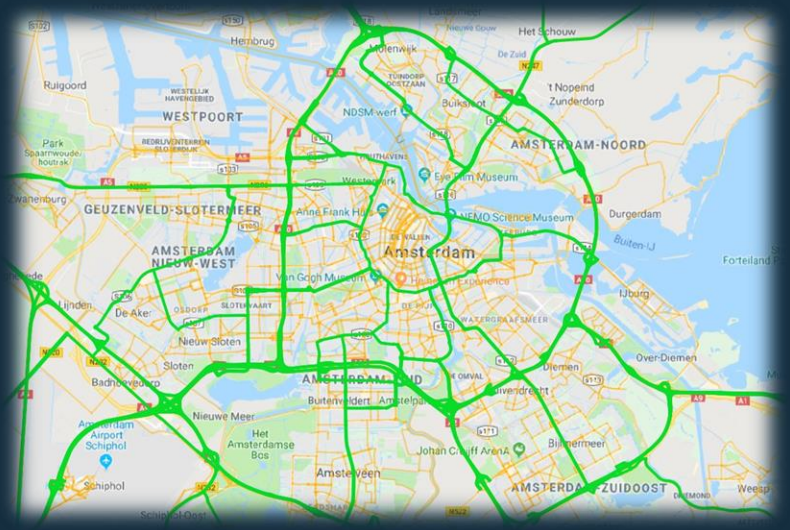

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Accommodating AVs on road networks during the transition period

A network of **dedicated AV lanes**

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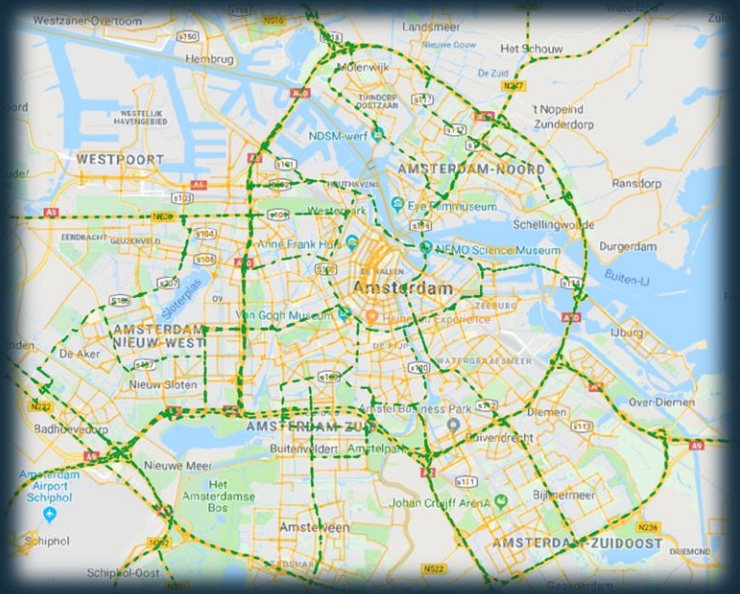

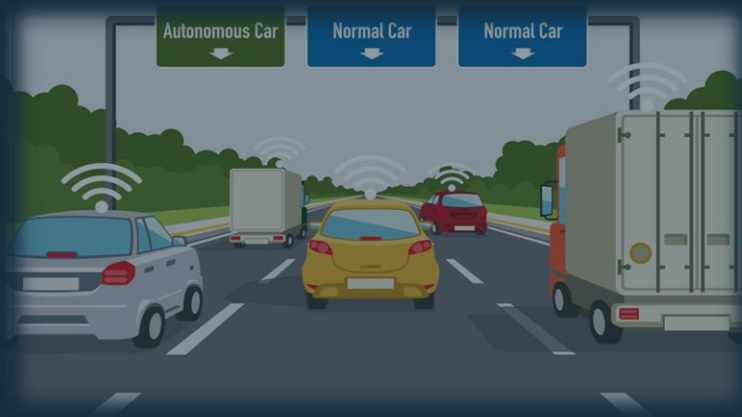

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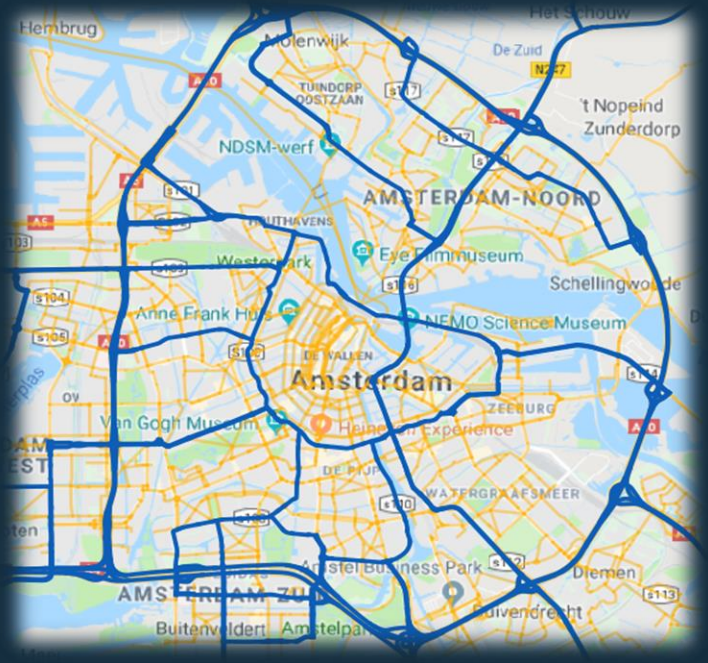

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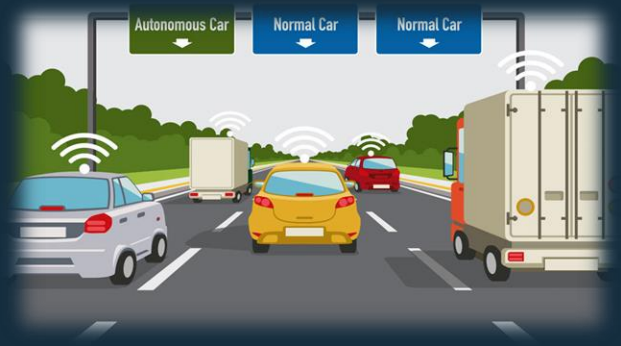
Which one is the right one?

AV-ready subnetworks (mixed traffic)

Dedicated AV lanes

Dedicated AV links



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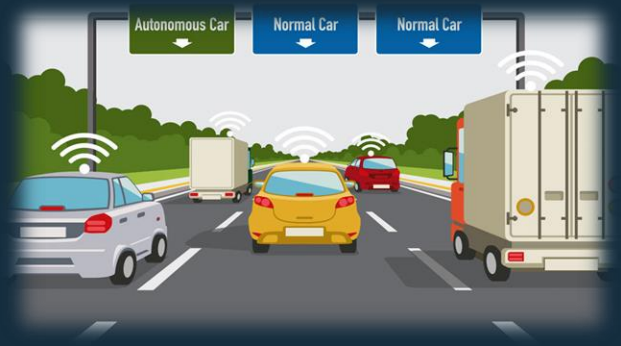

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Unified framework for optimizing road networks for AVs

- AV-ready subnetworks (mixed traffic)
- Dedicated AV lanes
- Dedicated AV links

Where and when to deploy?

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Where and when to deploy?

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A bi-level network design problem

Upper level:

Decide which link becomes

- AV-ready link
- Dedicated AV lane
- Dedicated AV link

To maximize total societal benefits

Lower level:

Network equilibrium with travelers' route choice

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Scenario-based approach

One optimal design for each AV market penetration rate:

10%

30%

50%

70%

90%

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Results

10% AV market penetration rate

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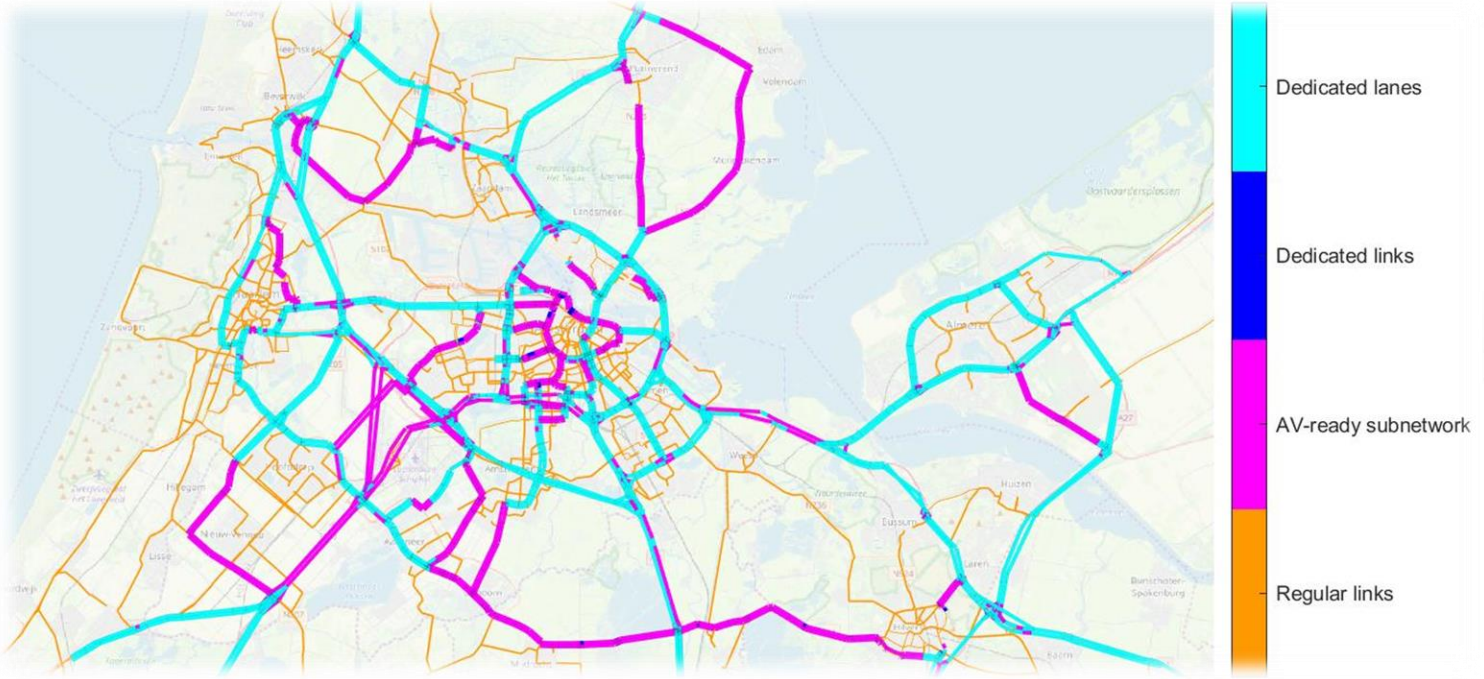
Results

50% AV market penetration rate



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ADS usage

10% MPR					
	AV-ready subnetwork	Dedicated AV links	Dedicated AV lanes	Autopilot (AD mode)	AV class
TTC (€)	44.83%	0.06%	4.59%	49.47%	100.00%
TTT (h)	38.21%	0.06%	3.31%	41.55%	100.00%
TTD (km)	62.57%	0.08%	7.07%	69.72%	100.00%

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25% upgraded roads

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Share of each network design concept

	10% MPR			
Road type	**AV-ready subnetwork**	**Dedicated AV links**	**Dedicated AV lanes**	**All subnetworks**
Motorways	46.43%	0.09%	12.03%	58.55%
Regional roads	25.09%	0.28%	2.35%	27.82%
Urban roads	10.90%	0.19%	2.63%	13.63%
All roads	82.42%	0.66%	17.01%	1,064 (100%)

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Share of each network design concept

50% MPR				
Road type	**AV-ready subnetwork**	**Dedicated AV links**	**Dedicated AV lanes**	**All subnetworks**
Motorways	14.18%	0.08%	36.81%	51.07%
Regional roads	18.52%	0.30%	10.98%	29.80%
Urban roads	9.91%	0.38%	8.77%	19.13%
All roads	42.61%	0.76%	56.55%	1,312 (100%)

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Share of each network design concept

50% MPR				
Road type	**AV-ready subnetwork**	**Dedicated AV links**	**Dedicated AV lanes**	**All subnetworks**
Motorways	14.18%	0.08%	36.81%	51.07%
Regional roads	18.52%	0.30%	10.98%	29.80%
Urban roads	9.91%	0.38%	8.77%	19.13%
All roads	42.61%	0.76%	56.55%	1,312 (100%)

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Main lessons learned

- **Large benefits by enhancing a proportion of links**
- **Mixed traffic first**
- **Gradually adding dedicated lanes**

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THANK YOU!

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