MANTRA

Making full use of Automation for National Transport and Road Authorities

Risto Kulmala

6 November 2020

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Objectives & CEDR interaction

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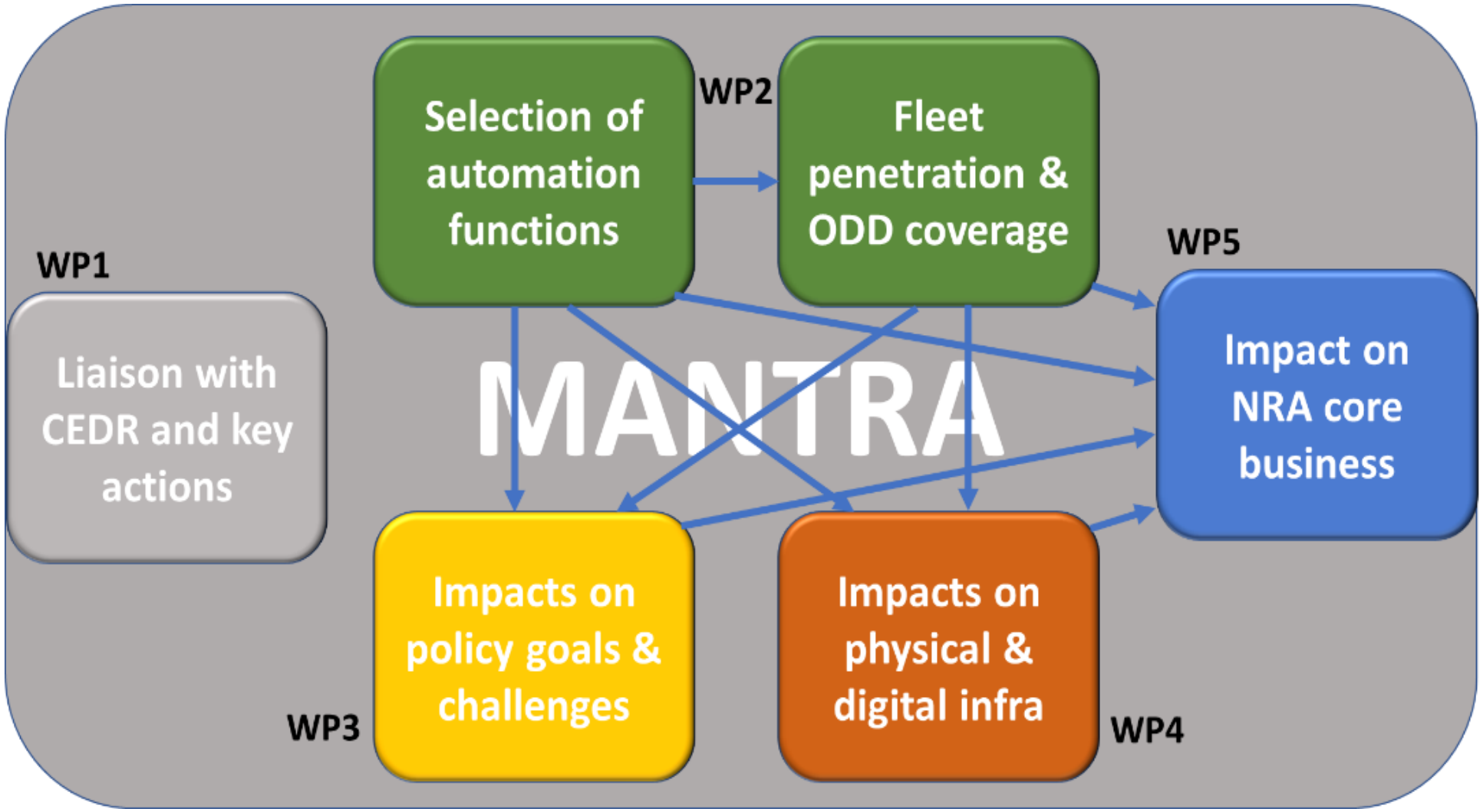
- Question posed in CEDR Automation Call 2017 Topic A: How will automation change the core business of NRA's
- Objective is to answer the following questions:
  - What are the **influences of automation on the core business** in relation to road safety, traffic efficiency, the environment, customer service, maintenance and construction processes?
  - **How will the current core business** on operations & services, planning & building and ICT **change** in the future?
- Valuable CEDR CAD WG & PEB interaction
  - Important workshops and liaison
  - PEB contacts: Eetu Pilli-Sihvola (Alina Koskela), Torsten Geissler, Anton Svigelj

Project structure & use cases



Close liaison with CEDR CAD WG and PEB

- Workshops
- Monthly Steering Group Meetings involving PEB contacts
- Deliverables sent to all CADWG members for comment before final submission

Also liaison with other related projects

Selected Use Cases*

Selected use cases
(mainly based on ERTRAC classification)

1

Highway autopilot including highway convoy (L4)

Highly Automated Driving up to 130 km/h on motorways from entrance to exit, on all lanes, including overtaking and lane change.

2

Highly automated (freight) vehicles on open roads with platooning (L4)

Automated freight transport carriers on public high level roads, platooning as an option.

3

Commercial vehicles as taxi services (L4)

Highly Automated Driving up to limitation speed, in urban and suburban areas. The system can be activated by the driver on defined road segments, in all traffic conditions.

4

Driverless maintenance and road works vehicles on highways (L4)

4a Safety trailer
Following trailer (L4) protecting moving work zones

4b Winter maintenance (L4)
Highly automated winter maintenance truck

* Together with PEB & CEDR CAD WG as part of the mini-workshop in Vienna (31.08.2018) and in more detail in Oslo (05.11.2018)

Deliverables

D2.1	Vehicle fleet penetrations and ODD coverage of NRA-relevant automation functions up to 2040
D3.1	Intermediate report of the state of the art on the impact of automated and connected vehicles
D4.1	Intermediate report on infrastructural consequences
D3.2	Impacts of automation functions on NRA policy targets
D4.2	Infrastructural consequences of connectivity and automation, and recommendations for their implementation
D5.1	Draft road map - road operator core business affected by connectivity and automation
D5.2	Road map for developing road operator core business utilising connectivity and automation

Project web site: www.mantra-research.eu

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Predicted vehicle and network coverage 2030 and 2040

Walter Aigner

6 November 2020

TASKS IN WP2
Deployment of automated functions up to 2040

1: identifying the automated functions most relevant to road operator core business by 2040, together with CEDR CAD WG.

2: predictions of vehicle fleet coverage by vehicle type

3: provide similar coverage forecasts for the Operational Design Domain (ODD) coverage of each function to determine the spatial and temporal coverage of each function.

D2.1 (2/2019)

plus explicit section: Relevance to road authorities and operators

Instruments for preparing CAD issues and this transition phase within NRAs' **management layers**:

- Operational Design Domains (**ODDs)** for the use cases, including the road operator attempts to categorise their physical and digital infrastructures in support to them
  - » Highway autopilot including highway convoy (L4)
  - » Highly automated (freight) vehicles on open roads (L4)
  - » Commercial driverless vehicles (L4) as taxi services
  - » Driverless maintenance and road works vehicles (L4)
- estimated ODD coverages up to 2040
- a set of **fleet penetration rates** for these priority use cases and
- a first discussion on limitations of this approach to discussing an open future

Vehicle km (flow) penetrations (D2.1)

MANTRA Use case	Fleet	Vehicle km penetration (%)			
		2030		2040	
		Low	High	Low	High
Highway chauffeur and autopilot	Cars	1.3	6.6	11.1	47.2
Automated freight vehicles	HGVs	0.8	5.1	12.4	59.5
Robot taxis	Taxis	0.0	8.6	5.7	72.6
Automated winter maintenance vehicles	Maintenance HGVs	0.0	1.3	6.9	24.0
Automated roadworks safety trailers	Safety trailers	3.9	8.9	14.7	39.7

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Impacts of highly automated driving on mobility, behaviour, safety, efficiency, environment

WP 3

Marieke van der Tuin, Oliver Carsten

Simulation of use cases

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Automated freight transport carriers on public high level roads, platooning as an option.

3 Commercial vehicles as taxi services (L4)

Highly Automated Driving up to limitation speed, in urban and suburban areas. The system can be activated by the driver on defined road segments, in all traffic conditions.

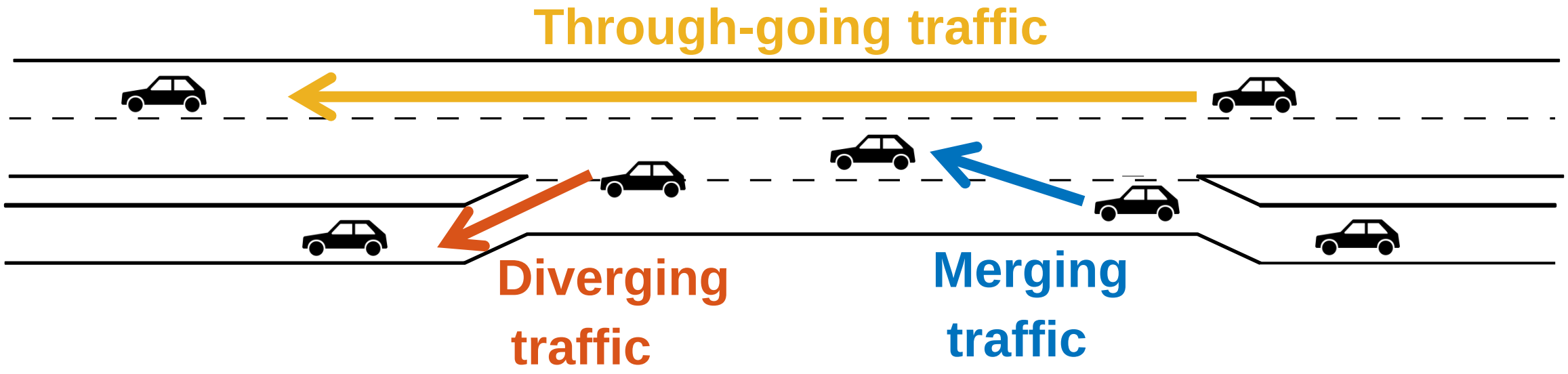
4 Driverless maintenance and road works vehicles on highways (L4)

4a Safety trailer
Following trailer (L5) protecting moving work zones

4b Winter maintenance (L4)
Highly automated winter maintenance truck

- Impact on traffic efficiency
- Impact on mobility

Highway autopilot – impact on traffic efficiency



- VISSIM Microsimulation software
- AV penetration rates from 0 to 100%
- Different AV behaviour (cautious, normal, all-knowing)
- Different human behaviour ("VISSIM default", "Dutch calibrated")

Highway autopilot – impact on traffic efficiency

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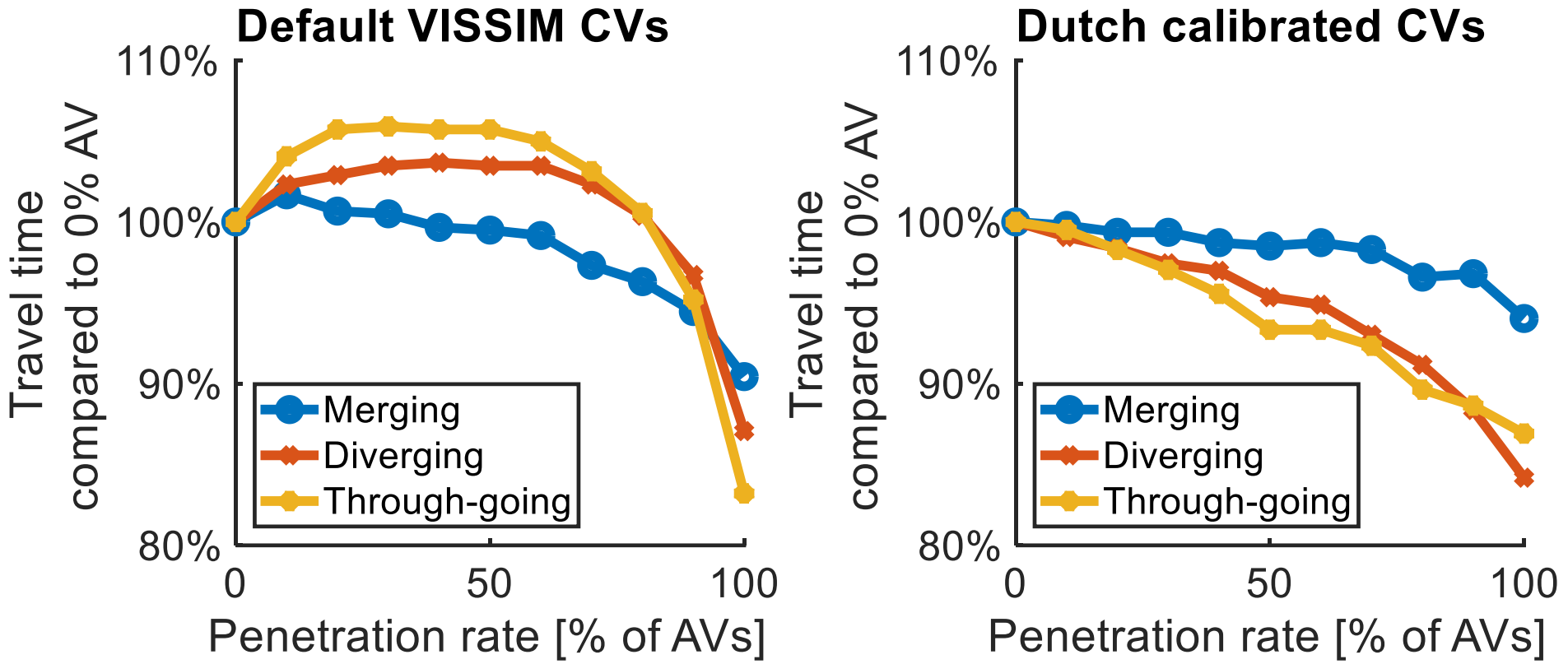
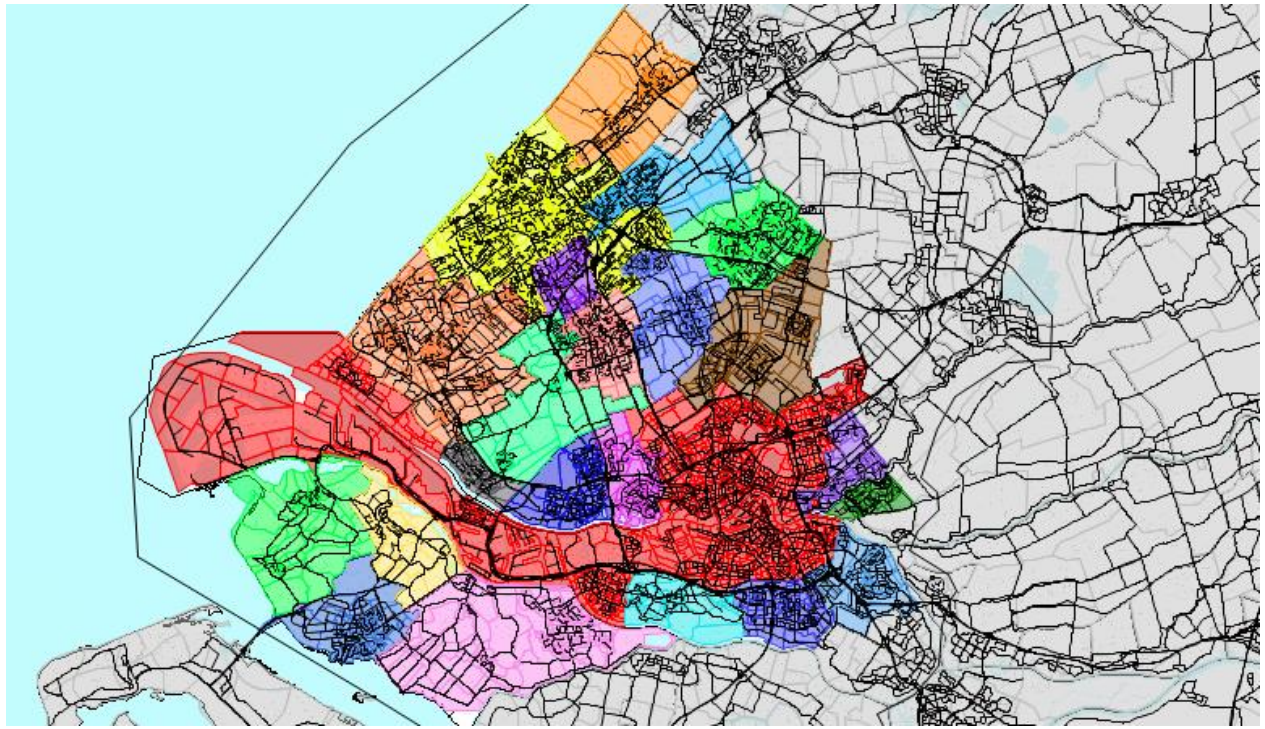
- **Cautious AVs**: increasing travel times as penetration rate increases
- **Normal or all-knowing AVs**:



- Conclusion: very different results depending on the behaviour of human drivers (e.g. 'aggressiveness')

Highway autopilot – impact on mobility



- What is the effect on the traffic system if 50% of the vehicles on the highway are a CAV?
- 2040-High scenario

- The Hague-Rotterdam Network
- DAT.Mobility, OmniTRANS 8.0.16

Highway autopilot – impact on mobility

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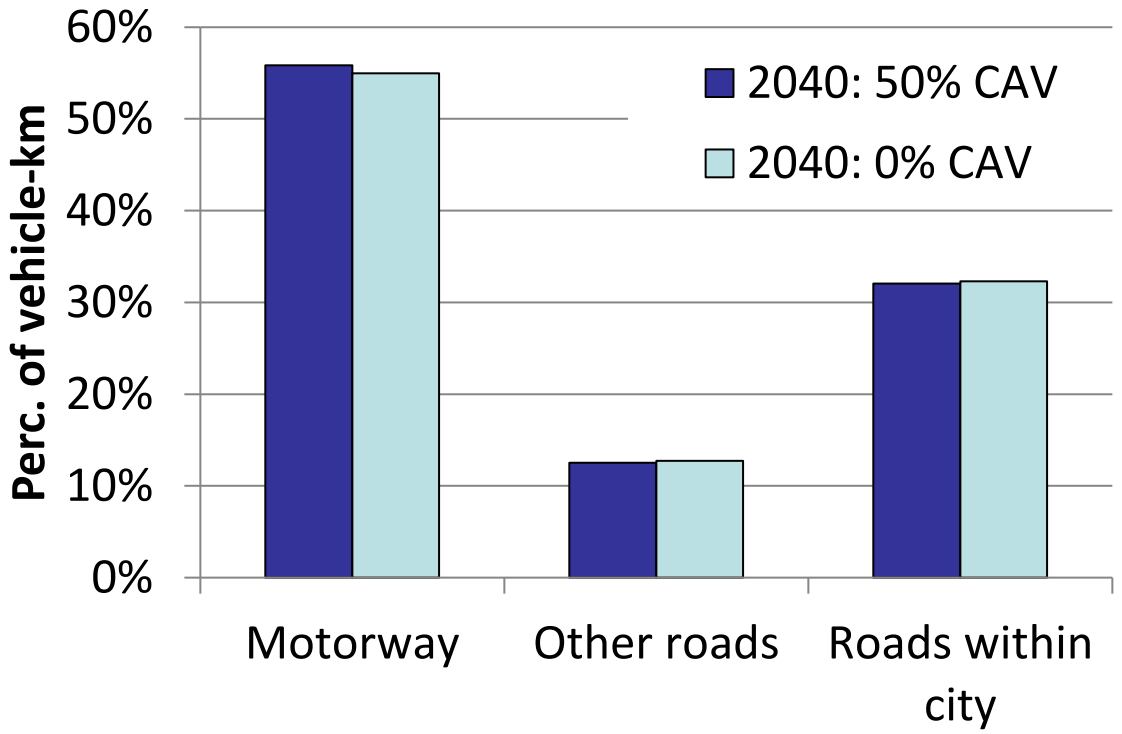
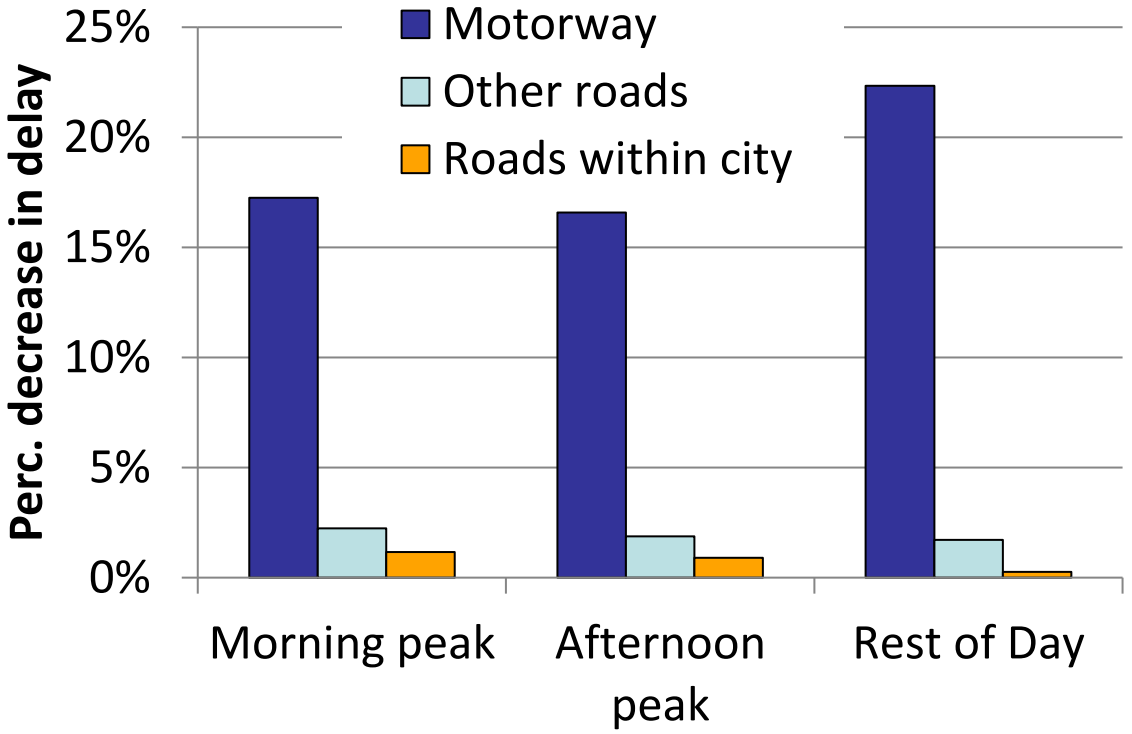
Total vehicle-km increase with 0.5%



Average delays decrease 20%

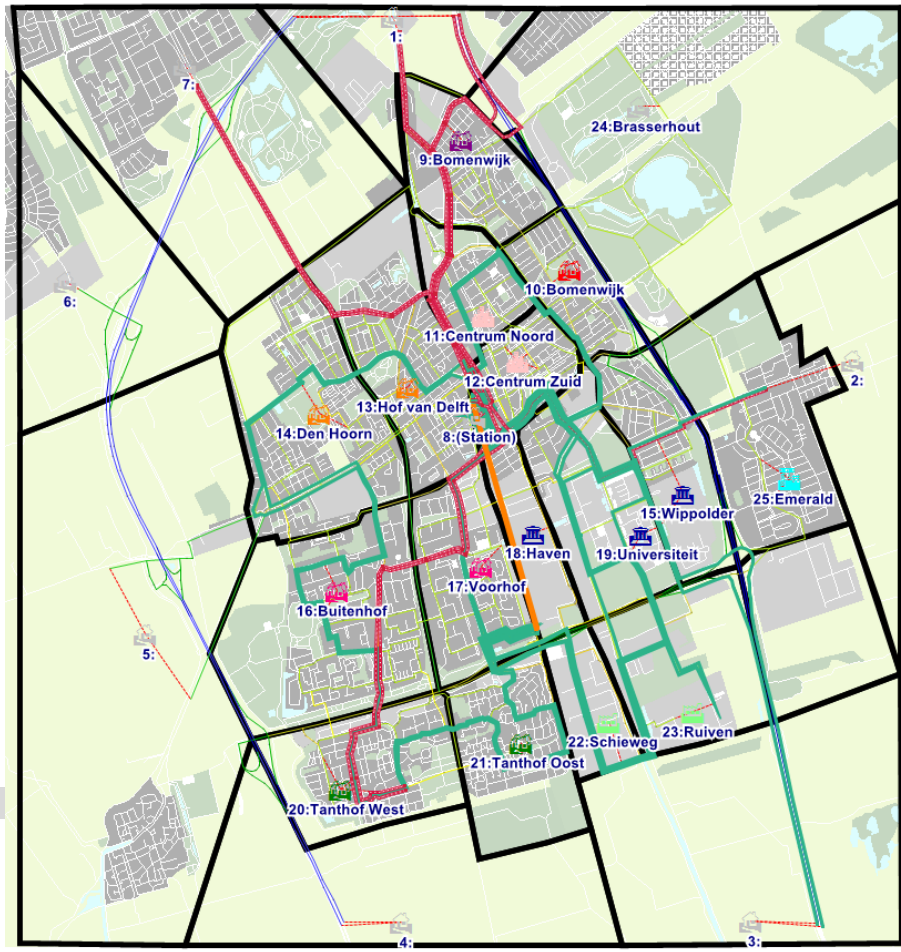


RoboTaxi – impact on mobility

- Waiting time: 2, 4, 6, 8, 10 minutes
- Price: € between €0.10 and €0.60 per km

- Accounted for empty taxi trips

- Delft Network
- DAT.Mobility, OmniTRANS 8.0.16 software



RoboTaxi – Impact on mobility

- 30% share of robotaxi – shift mainly from car

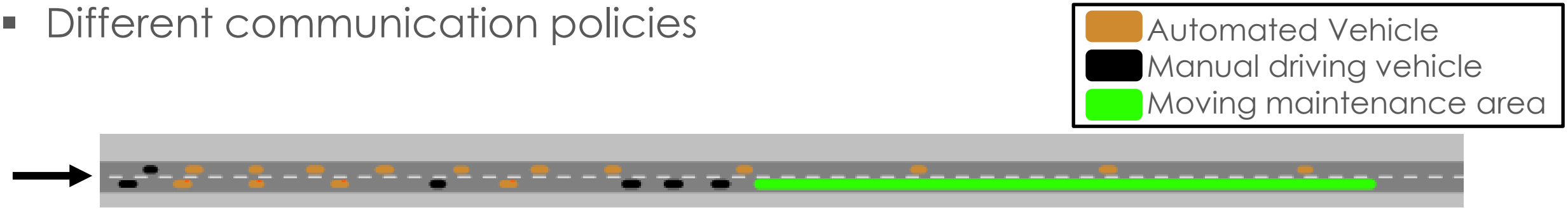
Modal split	Car	Robotaxi	Bike	PT
No robotaxi	70%	0%	22%	7%
With Robotaxi	42%	32%	20%	6%

- No large differences with different waiting times or pricing

- Total vehicle-km increase 10%
- Delays increase 10-30%
- Mostly caused by empty taxi trips!

Driverless maintenance

- Microsimulations for safety trailer & winter maintenance vehicles
- Different AV penetration rates
- Different communication policies



- Conclusion: communication advices have large effects on traffic efficiency and favoring of automated over manual driving vehicles.

Automated freight vehicles

- Microsimulation (AIMSUN) of impacts of L4 freight vehicles on:
  - » Own travel
  - » Travel of other vehicles
- No change in demand: so flows of various types of vehicle stay the same
- But among the heavy trucks, there is increasing penetration of L4 Avs
- The automated trucks could engage CACC with another close-by automated truck
- Scenarios modelled:

Behaviour of Automated Trucks	Penetration of Automated Trucks in the truck fleet				
	0%	25%	50%	75%	100%
Maximum platoon size of 3 vehicles and inter-vehicle gap of 4 metres	✓	✓	✓	✓	✓
Maximum platoon size of 4 vehicles and inter-vehicle gap of 4 metres					✓
Maximum platoon size of 3 vehicles and inter-vehicle gap of 10 metres					✓

Automated freight vehicles

- Modelled road: M62 west from Leeds in peak period (morning)

Automated freight vehicles

Conclusions:

- Flow improves as more and more freight vehicles get automated
- There is some non-linearity in the speed and travel time benefits with respect to the share of vehicles automated
- The speed and time benefits are the largest when the motorway is congested
- In a congested situation, the benefits are more egalitarian, i.e. they accrue to all types of vehicles — automated or non-automated; in free-flow conditions, it is the automated freight vehicles which benefit the most, for other vehicles benefits are marginal
- Smaller inter-vehicle gaps allow a slight increase in average freight vehicle speed, but only in congested stretches, with no effect in other stretches
- A larger number of vehicles in the convoy increases average freight vehicle speed, but only in congested stretches, with no effect in other stretches

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Impacts and consequences on physical and digital road infrastructures

Sandra Ulrich

6 November 2020

Consequences of Automation on Infrastructure

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KEY TARGET

To formulate concrete **consequences** of and **necessary changes** due to the selected automated functions to **infrastructure** and the **conservation*** of infrastructure

Workflow

Input WP 2

Status quo

› What are key infrastructure problems and challenges

Impact & Consequences

› Assessment of impact on infrastructure (physical and digital) for relevant use cases

Input WP 3

Required Changes

› Infrastructure standards and legal requirements

› Data requirements

Input to WP 5

Changes in road operators core business due to infrastructure requirements

Assessment of impact in 3 categories (tasks)

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The impact and the resulting consequences and necessary changes to infrastructure will have various sources. In WP 4 at least the following will be analysed.

Impact, consequences and necessary changes to infrastructure due to…

	1	2	3
What?	**Automated function's operation itself**  With deployment of various automated function's impact on infrastructure will change in terms of road design, maintenance assumptions and required ITS	**The necessity to provide required ODD**  Digital Infrastructure will need to be defined and amended based on ODD requirements in order to facilitate CAD Incl. ISAD levels	**The possibility to improve O&M**  Operation and maintenance (O&M) of infrastructure could benefit by means of CAD in terms of automation of work procedures and new data sources
Who?	ARNDT IDC Infrastructure & Development Consultants Supported by VTT	TRAFICON Supported by HiTec marketing	ARNDT IDC Infrastructure & Development Consultants Supported by TRAFICON

Impact, consequences and necessary changes to infrastructure

1 Key results: Consequences due to operation of AV

Of all use cases, automated freight vehicles are expected to have the biggest impact on infrastructure due to their operation. Following areas have been identified as most crucial

Pavement	• Faster deterioration due to higher loads and convoys to be analyzed • Focus on complex areas of highways (junctions, merging lanes) • Need for additional emergency bays and safe harbors • Changing requirements/standardization for road marking
Tunnels	• Need for additional guiding functions (tunnel wall finishing) • Lighting in exits/entries • Total emergency systems: new requirements
Road Equipment	• Most effects on ITS and telematics which are mostly covered through ODD requirements. • International standardization of road signs to be machine & human readable • Toll plazas need automated lanes

2 Key results: ODD requirements

Road operator related ODD attributes

ODD attribute	Physical / Digital infrastructure	Static / Dynamic
Road	Physical	Static
Speed range	Physical	Static
Shoulder or kerb	Physical	Static
Road markings	Physical	Static
Traffic signs	Physical	Static
Road equipment	Physical	Static
Traffic	-	Dynamic
Time incl. light conditions	-	Dynamic
Weather conditions	-	Dynamic

ODD attribute	Physical / Digital infrastructure	Static / Dynamic
HD map	Digital	Static/Dynamic
Satellite positioning	Digital	Static
Communication	Digital	Static
Information system	Digital	Static
Traffic management	Digital	Dynamic
Infrastructure maintenance*	Physical/Digital	Dynamic
Fleet supervision*	Digital	Dynamic
Digital twin of road network*	Digital	Dynamic

* In order to deal with the dynamic non-infrastructure attributes of the ODD MANTRA has identified these three elements that should likely be added to the road operator relevant list of ODD attributes

2 Key results: ODD requirements

ODD relevant collection of impacts for road operators

- ODD requirements for each of the attributes and each use case today
- ODD evolution for each attribute until 2020, 2030 and 2040
- ODD effects on different road types
- Responsibilities for establishing, operating and maintaining ODD
- Cost of establishing ODD

Example: ODD effects on motorways

ODD attribute	2030	2040
roads covered	Selected core TEN-T roads without severe congestion to mitigate against possible capacity reduction	60% of motorway network covering core TEN-T network and other motorways with highest accident rates
shoulder or kerb	Safe refuges on some of the roads selected, half suitable for freight as well; digital information on all safe refuges, intact game fences on high risk sections	Safe refuges on some of the roads selected, half suitable for freight as well; digital information on all safe refuges, intact game fences on high risk sections
road markings	Harmonised machine readability of road markings. Enhanced maintenance on selected roads to ensure consistent and minimum quality of solid or dotted lines and symbols painted on the pavement	Harmonised machine readability of road markings. No enhanced maintenance due to automated vehicles

3 Key results: Impacts due to O&M improvement

Operational tasks with identified biggest optimization potential

		Safety Hazard	Cost driver	Operational importance	Total Score
Winter maintenance	Preventive salting on highway main-carriageway	8	7	6	21
	Snow ploughing and salting on main-carriageway	5	5	5	15
Work zone protection	Unplanned incidents on first lane (accident, litter removal)	10	4	5	19
	Unplanned incidents on fast lane (accident, litter removal)	12	5	7	24
Operational highway works	Maintenance and repair of road assets and furniture	7	4	5	16
	Road marking	5	5	6	16

3 Key results: Impacts due to O&M improvement

Traffic Management Improvements

Digital traffic management plans

- Classification of roads according to network flow hierarchy; "not always the shortest path will be fastest, nor the safest"
- Geo-fencing mechanism.
- Establishing a network performance Level of Service (LoS).
- Defining triggers to engage a cooperative traffic management.

Cooperative traffic management services

- **Common Operational Picture**
- **ODD Aware Traffic Management**

Impact on infrastructure in relation to NRAs core business fields

Common agreement of NRAs

> “main impact expected and planned for digital infrastructure
>
> dependencies on physical infrastructure need to be limited because of time and cost impact”

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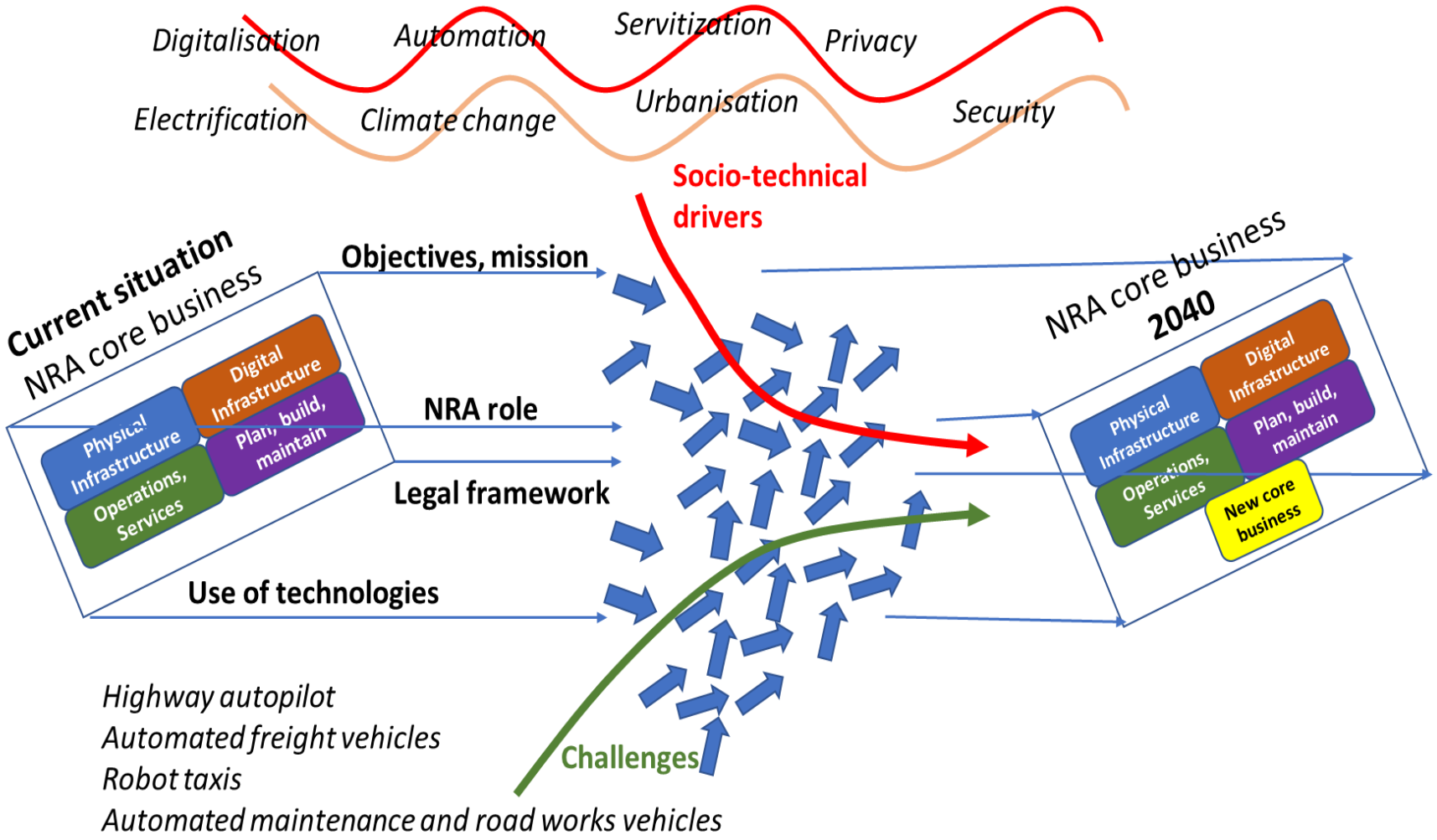
Road map for developing road operator core business utilising connectivity and automation

Risto Kulmala

6 November 2020

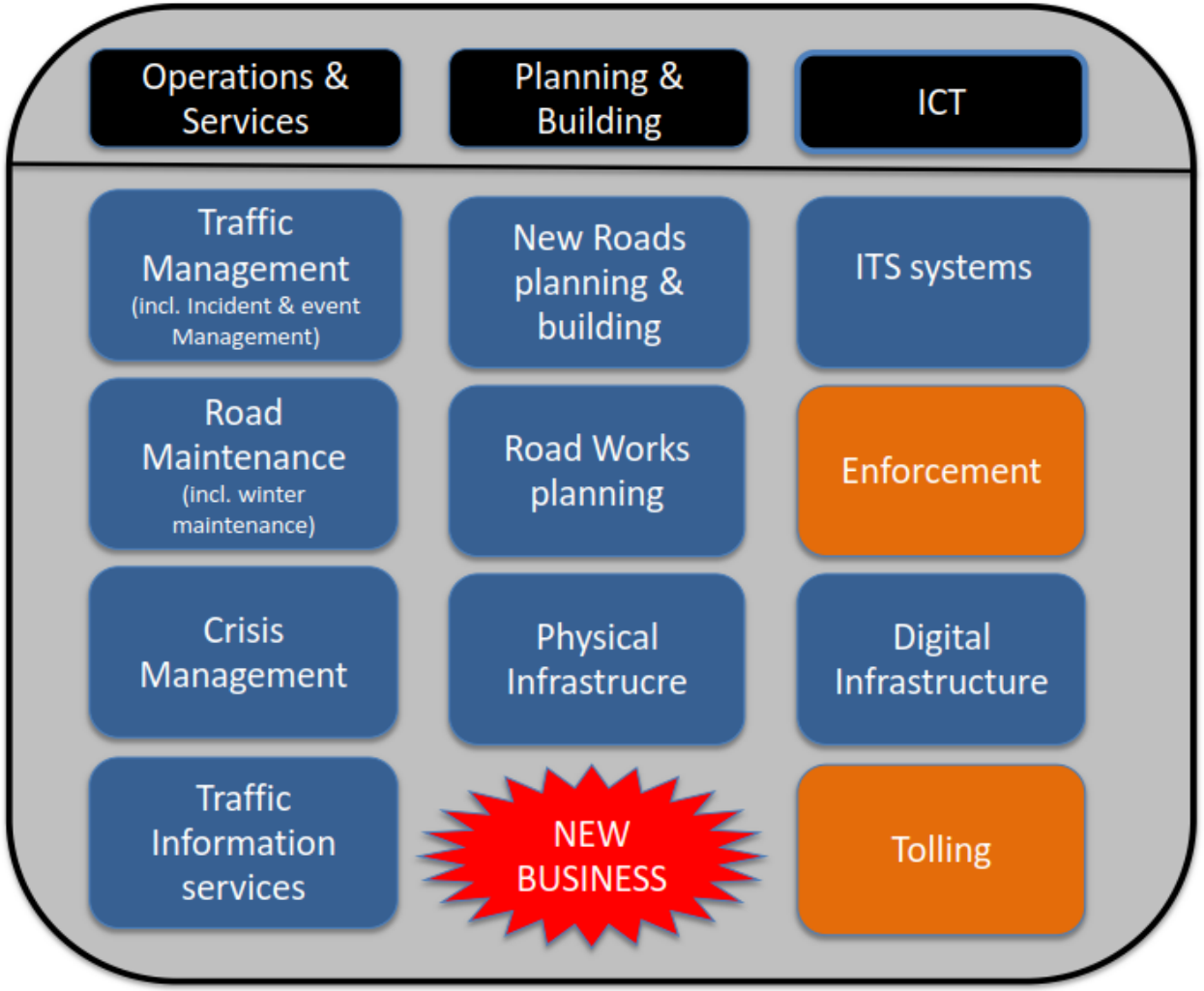
Adaptations to NRA core business – approach



- Input from previous work in MANTRA
- Desktop analysis
- PEB workshop on 13 March 2020
  - » 92 actions
- Survey of priorities directed to NRAs and experts- deadline 30 April
- 45 responses
  - » 22 priority actions

Core business areas of road operators

- Physical road infrastructure
- Digital infrastructure
- Operations and services
  - » incident and event management
  - » crisis management
  - » traffic management and control
  - » road maintenance
  - » winter maintenance
  - » traffic information services
  - » enforcement
  - » road user charging
- Planning, building, heavy maintenance
  - » new roads planning and building
  - » road works planning and management
  - » heavy maintenance planning
- New business.



Description of priority actions

TM2	Digitalise traffic rules and regulations
Business area	Traffic management and control
Description of action	The rules and regulations including current traffic management measures in force need to be digitised and made available to automated vehicles and other stakeholders in need of this information such as fleet operators and managers, police, rescue organisations, and security establishments. Specific access points to digital traffic rules and regulations (e.g. a Trusted Electronic Regulations Access Point) and ODD related infrastructure attributes need likely to be set up to facilitate the cooperative traffic management in practice as well as to provide this necessary safety-relevant information to automated vehicles in a comprehensive manner. The rules need to included restrictions imposed to the automated use of vehicles or specific use cases due to inappropriate MRMs or other reasons. High level data security is necessary for these access points.
Timeframe	2021-2025 Studies, pilots, cross-sectoral agreements, standardisation (METR standardisation already commenced); pilot deployments by fore-runners 2026-2030 Deployment; development and standardisation of Trusted Electronic Regulations Access Points or similar
Aspect of CAD affected	Planning of routes and target speeds
Stakeholders affected	Ministries, road authorities and operators, transport safety agencies, traffic management operators, police, OEMs, fleet operators and managers, ADS developers and providers, drivers and users of connected and automated vehicles
Legal prerequisites	European regulation is needed to mandate the setting up, maintaining and operating access points for digital traffic rules and regulations with specific quality and coverage.
Responsibilities	Owner/champion: Ministry or a road safety agency under it; necessary stakeholders: traffic managers, road authorities and operators, OEMs, ADS providers, fleet operators and managers, police; Other stakeholders: drivers and uses of connected and automated vehicles
Role of CEDR/NRAs	NRAs to participate in studies and pilots as well as deployment depending on their national role.
Risks involved	Risk of vendor-specific solutions.
Other relevant aspects	Physical signs are still needed as long as the system includes human driven vehicles and other human road users.

Classification of priority actions

- **Actions with no regret** – actions useful also for human-operated vehicles to be carried out due to present needs and other developments;
- **Study and learn** – actions to find out more about the technology, operation, benefits, costs and implementation issues in order to understand the potential, restrictions and feasibility of automated driving;
- **Key actions for deployment** – actions to safeguard NRA interests and with major future impact on NRA investments and operations.

- Most actions primarily in the "*Study and learn*" category

No regret actions

- Machine readability and digital twins of road signs (PI2)
- Road markings of sufficient retro-reflectivity in different conditions (PI3)
- Provision of road network related data to HD maps (DI2)
- Human resources with digital expertise (DI5)
- Digitalisation of incident and traffic management plans (IM2)
- Digitalisation of traffic management centres (TM3)

Study and learn actions 1/2

- Ensuring up-to-date content of HD maps (DI1)
- Cybersecurity issues for connected and highly automated vehicles (DI3)
- Information provision on incidents, events and crises (IM1)
- Harmonised marking of incident sites to be correctly recognised by AVs (IM3)
- Cooperative traffic management concept (TM1)
- Digitalise traffic rules and regulations (TM2)
- Improved information quality for automated vehicles (TI1)

Study and learn actions 2/2

- Standard communication protocols related to automated vehicles (TI2)
- Provision of hybrid C-ITS traffic information services (TI3)
- New infrastructure and regulations for traffic law enforcement (EN1)
- Environmental enforcement utilising geofencing and other tools (EN2)
- General physical road design changes (NR1)
- Harmonised management of road works sites (RW1)
- Awareness by automated freight vehicles of their own gross weight and individual axle loadings in order to determine ODD (new)

Key actions for deployment

- Optimised minimum risk manoeuvres and providing infrastructure for them (PI1)
- Digital twins for road transport system including ODD and ISAD information (DI4)
- Legal framework for driverless maintenance vehicles (MA1)

Concluding remarks

- This kind of project could not have been carried out in isolation

- Close interaction with CEDR CAD Working Group and PEB – **a big thank-you**
- Close liaison with
  - » EC's CCAM platform and especially WG3 Physical and Digital Infrastructure
  - » EU EIP
  - » CCAM partnership

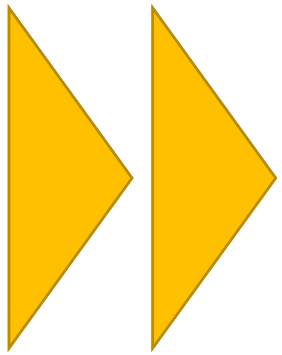
- Final deliverables at CEDR website, final drafts at project website along with workshop proceedings

www.mantra-research.eu

Question from MANTRA

The sensor, AI and other technologies of highly automated vehicles are evolving rapidly. Thereby, investments in infrastructure based on the capabilities of automated vehicles today might not be required by the highly automated vehicles of 2030 or 2040.

- **When should the road operators start to invest in the infrastructure required by highly automated vehicles?**
- **Where should the road operators start to invest in the infrastructure required by highly automated vehicles?**



Thank You

Any questions?

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