Management of CAVs through transition areas

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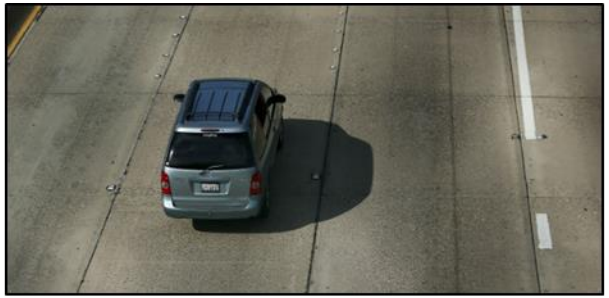
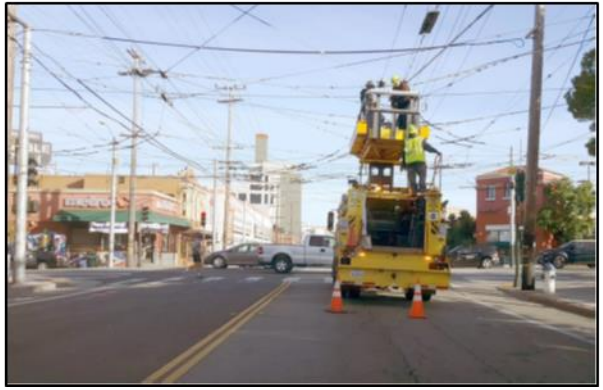
Background

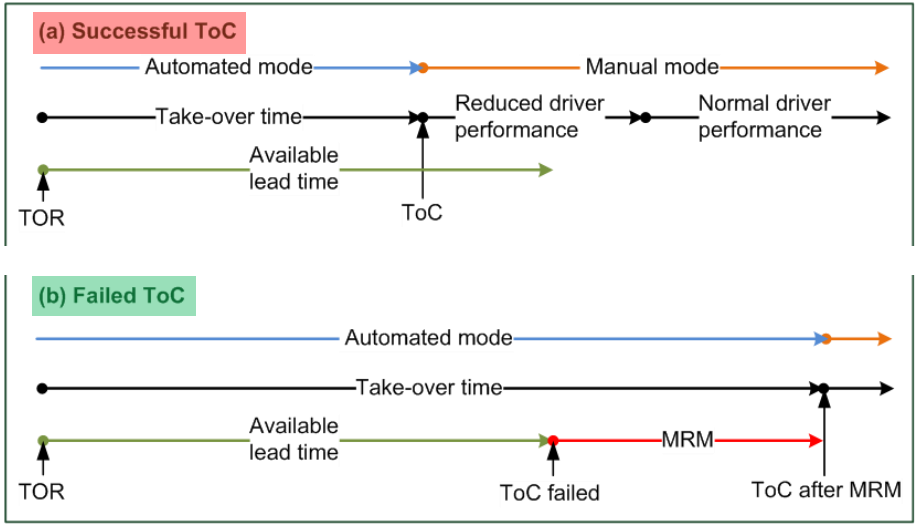
Situations in which (C)AVs may struggle





Sequence of events when AD disengages

- Take-over request (**TOR**) issued by the car
- Transition of Control (**ToC**) from car to driver
- Minimum-Risk Maneuver (**MRM**) by the car



Cooperative management as a solution

- Different SAE levels, (C)AVs, legacy vehicles, … share the road
- Missing sensor inputs, highly complex situations, adverse weather conditions, …
  - Current limitations of automated driving may require a change of level

  ➡ **Transition Areas**
- The EC's Horizon 2020 TransAID project focuses on:
  - Realistic driver/vehicle behaviour and V2X communications
  - Hierarchical traffic management procedures for transition areas
  - Field tests in The Netherlands and Germany
  - Guidelines and roadmap for stakeholders (OEMs, authorities, cities, …)

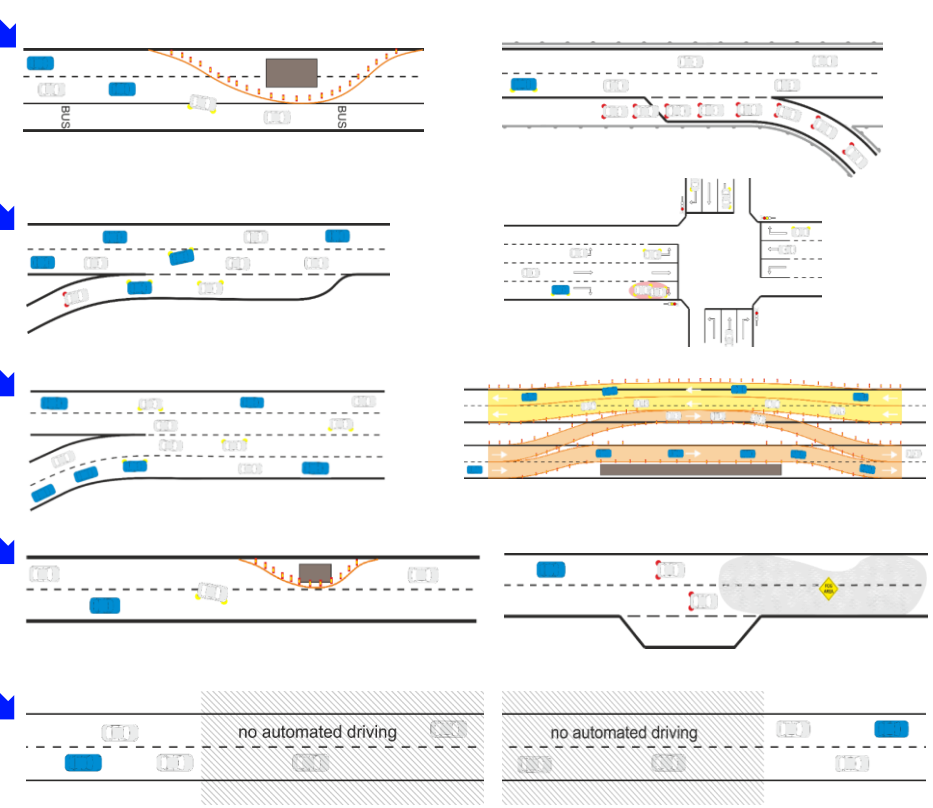
Use Cases

Identification of transition areas

- Search for ‘problems’ (i.e. Transition Areas)
  - Some disturbance affecting automated vehicles in the same (small) area
  - Many automated vehicles must be affected
- Use cases are derived from:
  - Involved actors/stakeholders
  - Possibilities of measures (C-ITS messages, VMS messages, V2V display, traffic laws, road signs, …)
  - Problems (i.e. causes)
  - ToC urgency (i.e. how much time for ToC?)
  - Contextual factors:
    - Location type (fixed / random, predictable / unpredictable)
    - Affection range and cause duration
    - Environment (static, dynamic, semi-static)
  - Vehicular factors:
    - Share of vehicles impacted by the cause per SAE level
    - Automated driving functions (AD functions, MRM implementation)
    - Possible implementation feasibility in real world prototypes
  - Expected impact with ⇔ without measures

Initial selection of services / use cases

1. Prevent ToC/MRM by providing vehicle path information
2. Prevent ToC/MRM by providing speed, headway and/or lane advice
3. Prevent ToC/MRM by traffic separation
4. Manage MRM by guidance to safe spot
5. Distribute ToC/MRM by scheduling ToCs



Traffic conditions, vehicle mixes, …

	LOS A	LOS B	LOS C
Urban (50km/h) – 1500 veh/h/l	525	825	1155
Rural (80 km/h) – 1900 veh/h/l	665	1045	1463
Motorway (120 km/h) – 2100 veh/h/l	735	1155	1617
Intensity / Capacity (IC) ratio	0.35	0.55	0.77

Class Name	Class Type	Vehicle Capabilities
Class 1	Manual Driving	– Legacy Vehicles – (C)AVs/CVs (any level of driving automation) – Driving Automation: Off
Class 2	Partial Automation	– AVs/CVs equipped with Level 1/2 driving automation systems – Driving Automation: On – Instant ToC (driver responsible for monitoring road environment) – Emergency braking in case of distracted driving
Class 3	Conditional Automation	– (C)AVs equipped with Level 3 driving automation systems – Driving Automation: On – Basic ToC (normal duration)/MRM capability (ego lane)
Class 4	High Automation	– (C)AVs equipped with Level 4 driving automation systems – Driving Automation: On – Proactive ToC (prolonged duration)/MRM capability (right-most lane)

Vehicle Mix	Class 1	Class 1 (Conn.)	Class 2	Class 2 (Conn.)	Class 3	Class 3 (Conn.)	Class 4	Class 4 (Conn.)
1	60%	10%	-	15%	-	10%	-	5%
2	40%	10%	-	25%	-	15%	-	10%
3	10%	10%	-	40%	-	25%	-	15%

Traffic Management in Transition Areas

Main observations of SotA

- General approaches
  - Coordinated network-wide traffic management
  - Using KPIs, hierarchical controls via layered architectures, TMaaS
- Cooperative systems
  - V2X / VANETs / C-ITS
- Machine learning techniques (AI)
  - Traffic light control and congestion / queue length predictions

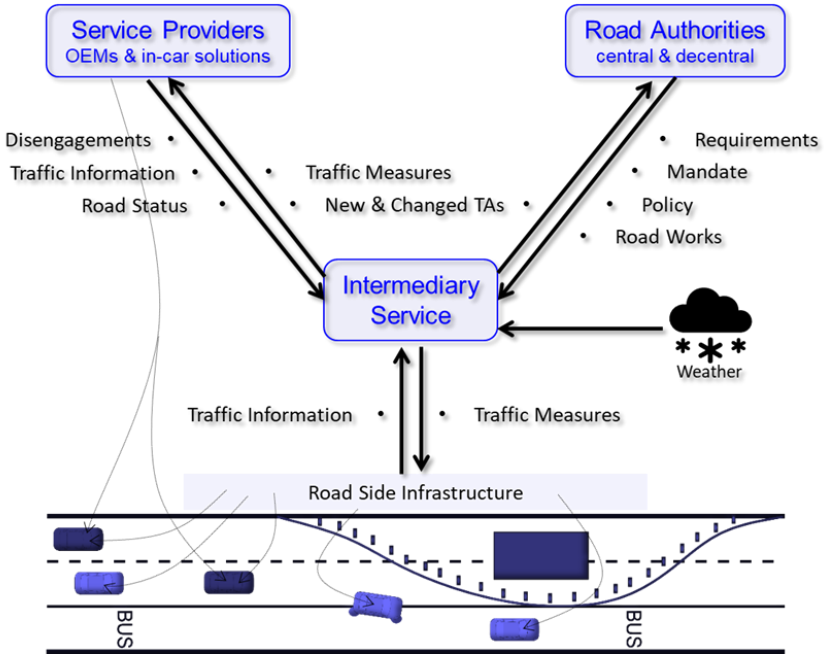
- **Conclusion**
  - No (readily available) implementations of more advanced TM schemes
  - Focus on solving partial problems with specific measures

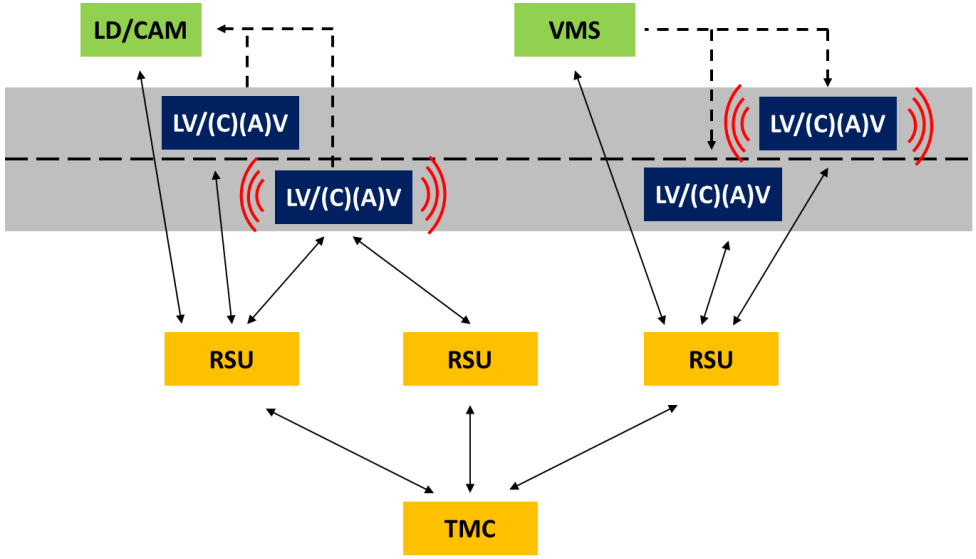
Traffic management by TransAID's services

- Solutions take the form of these actions:
  - **Prevent** ToC/MRM
  - **Manage** or support ToC/MRM
  - **Distribute** (in time and space) ToC/MRM

- Assess solutions based on impacts measured by **KPIs**:
  - **Traffic efficiency**
    - Network-wide: average speeds and throughput
    - Local: tempo-spatial diagrams
  - **Traffic safety**
    - Number of events with time-to-collision < 3 sec
  - **Environmental impact**
    - CO_2 emissions

Positioning of traffic management services





High- and low-level
traffic management operations

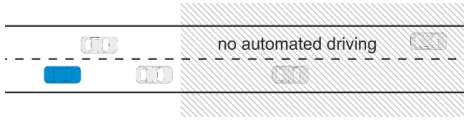
Traffic management procedures

- Description of each use case
  - Functional constraints / dependencies
  - Spatial overview

- Context of the related traffic measures
  - **When** to apply
    - After considering baseline simulation results
  - **Where** to apply
    - What is the spatial extent of the transition area?
    - When does the system need to inform vehicles/drivers?
  - **How** to apply
    - What traffic management measures should be taken?

Vehicle mix	LOS A	LOS B	LOS C
1			
2			
3			

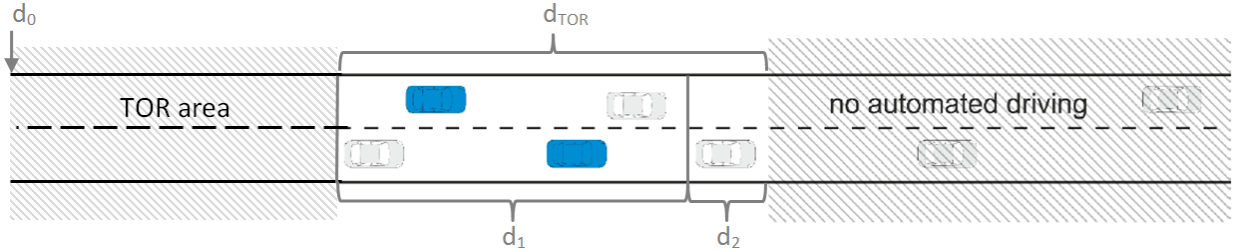
Example service 5 / use case 5.1



- When?

Vehicle mix	LOS A	LOS B	LOS C
1			
2			
3			

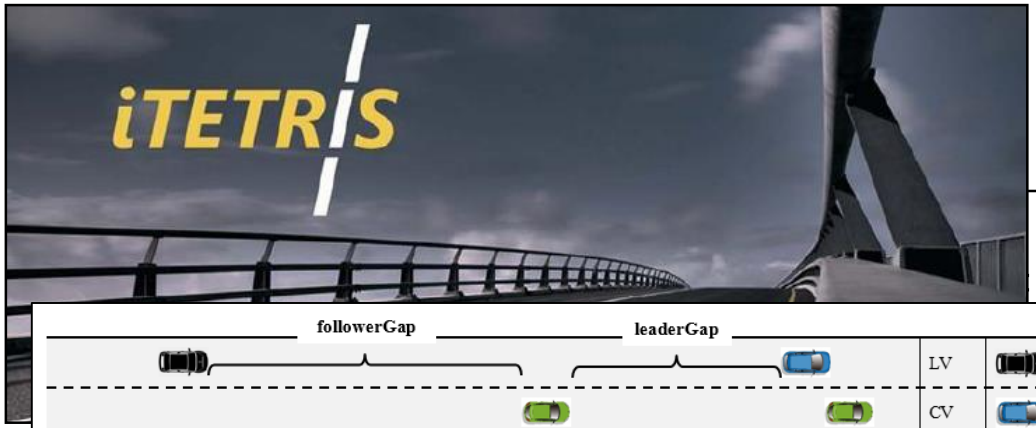
- Where?



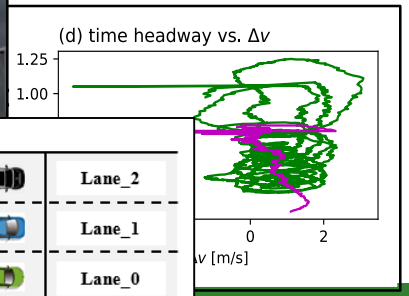
- How?
  - **Distribute the TORs** within a dedicated TOR area ranging from d_{TOR} farther upstream to a distance of $d_0 > d_{TOR}$

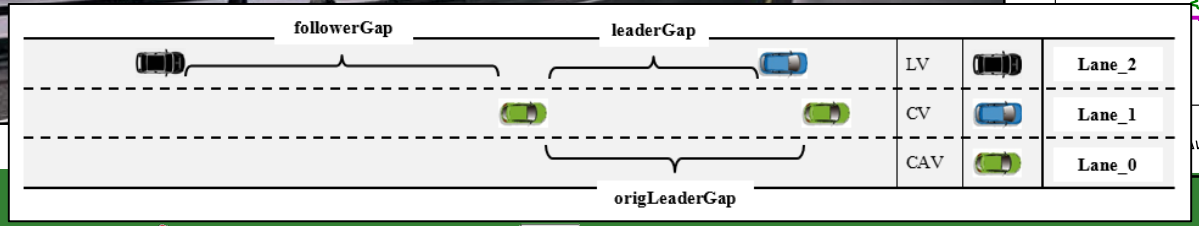
Results

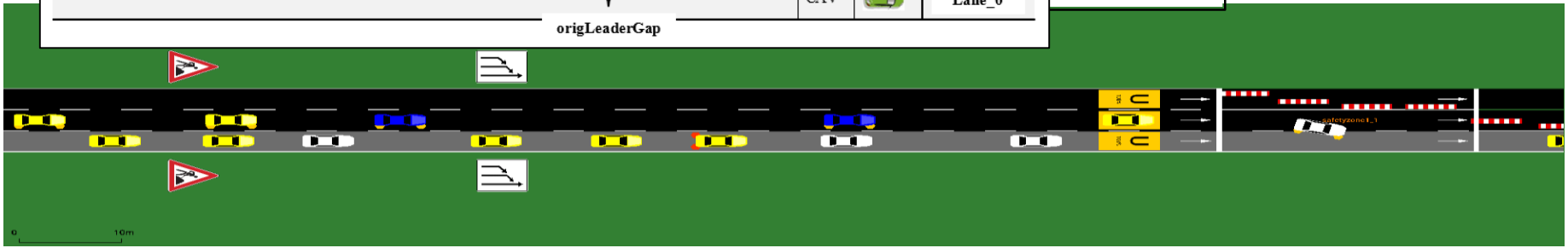
Simulation environment



SUMO
Simulation of Urban MObility

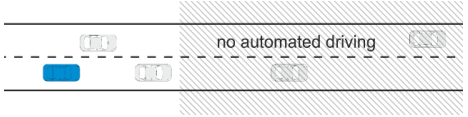




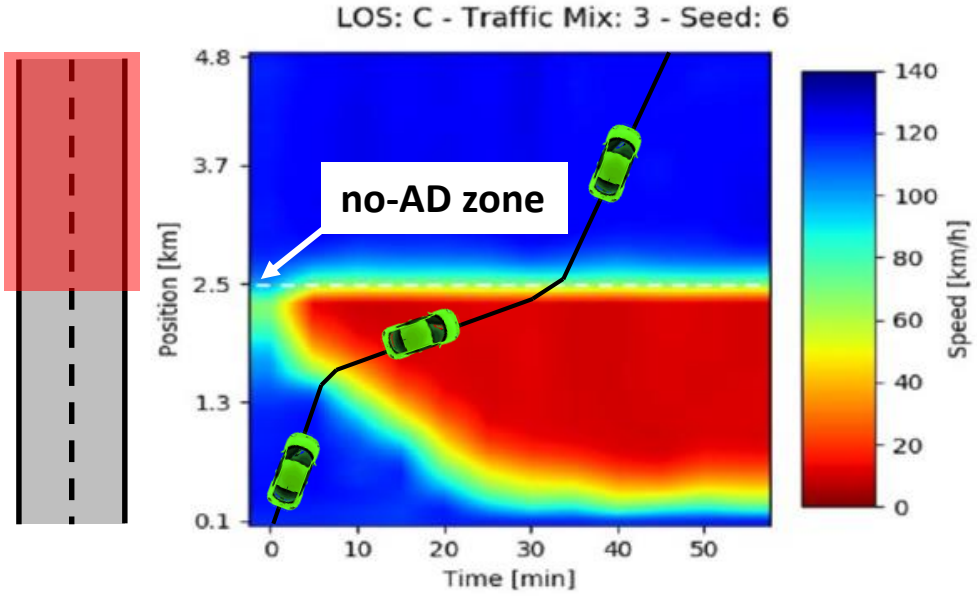


Example use case 5.1 (local speeds)

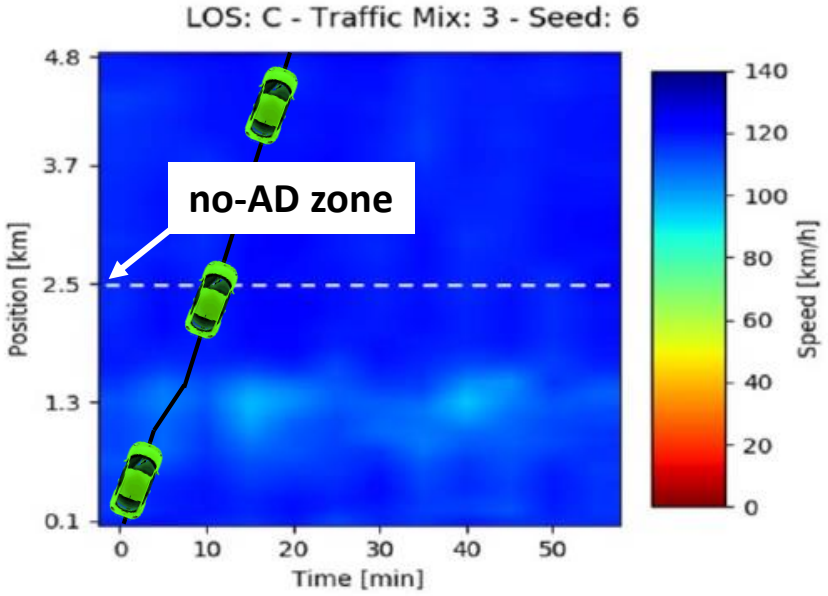
Distribute the TORs within a dedicated TOR area



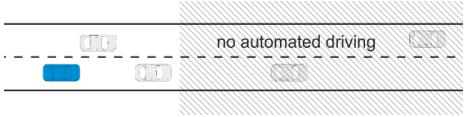
Without traffic management



With traffic management

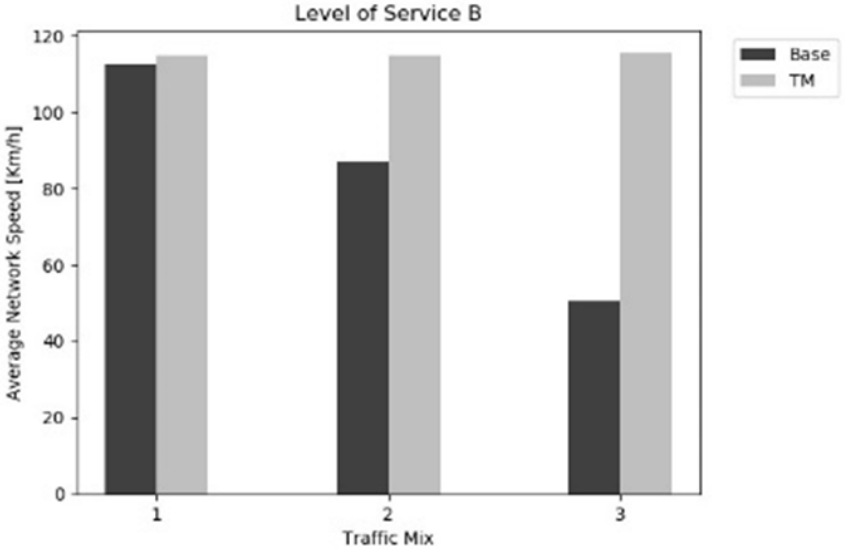


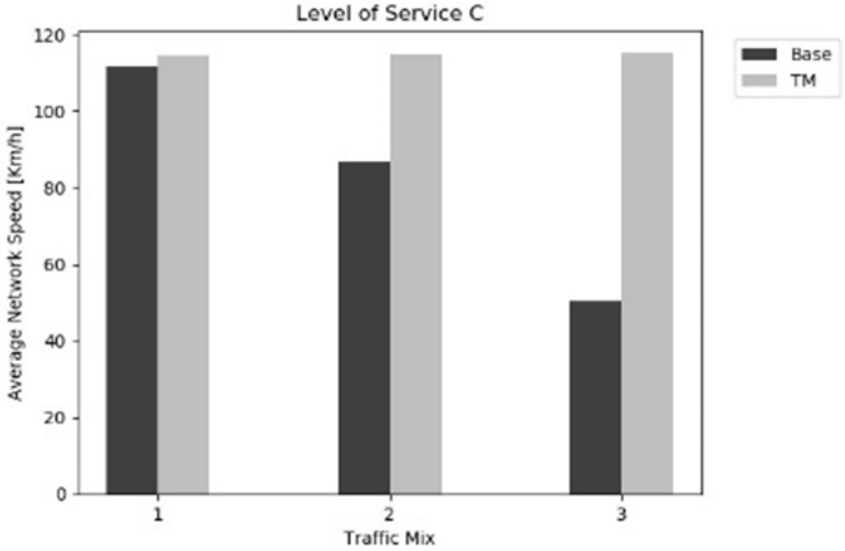
Example use case 5.1 (network speeds)



Without traffic management

With traffic management

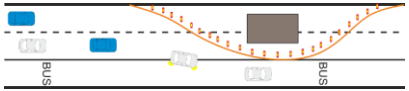




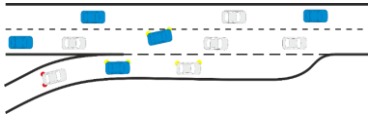
(varying the LOS and vehicle mixes)

Main findings for all the use cases

- **UC1.1**: Prevent ToC/MRM by providing vehicle path information
  - Traffic efficiency and CO_2 emissions: unchanged
  - Traffic safety: significant improvement (45% to 70%)
    (larger reductions for less traffic and more AVs)



- **UC2.1**: Prevent ToC/MRM by providing speed, headway and/or lane advice
  - Average network speed: slight improvement
  - CO_2 emissions: slight decrease
  - Traffic safety: significant improvement (75% less safety-critical events)
    (especially for higher demand, LOS C)



Main findings for all the use cases

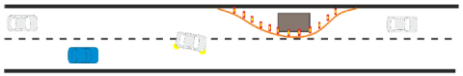
- **UC3.1**: Prevent ToC/MRM by traffic separation
  - For higher shares of AVs (>25% level 2 & 3) in combination with LOS B or C
  - Traffic efficiency: improvement
  - Average network speed: slight decrease
  - Traffic safety: decrease

➔ Similar performance to 'no measure taken'

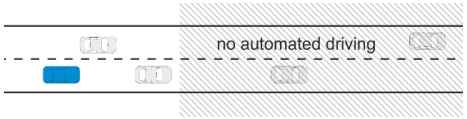
- Hypothesis: separating traffic can outperform uncontrolled merging when **cooperative manoeuvring** is applied

Main findings for all the use cases

- **UC4.2**: Manage MRM by guidance to safe spot (urban & motorway)
  - Open right lane remains unblocked
  - Traffic efficiency, safety, CO_2 emissions: improvements
  - Improvement diminishes in case of congestion (traffic is already moving slowly)

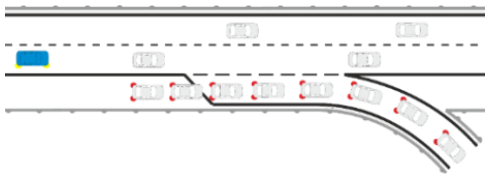


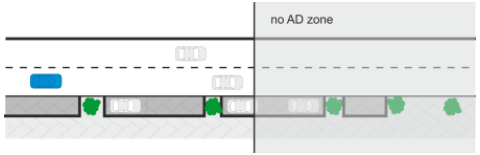
- **UC5.1**: Distribute ToC/MRM by scheduling ToCs
  - Greatly smoothened disturbances
  - Traffic efficiency, emissions, safety: improvement

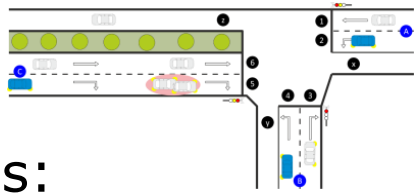


Futher refinement of services / use cases

- Improvements/extensions:
  - Combine services
  - Increase complexity
  - Add measures







- Start on 2 new scenarios:
  - Highlighting legal aspects
  - Including an intersection

Vehicle type	Share on urban roads	Share on motorways
Passenger vehicle	87%	77%
LGV	10%	10%
HGV	3%	13%

- Queue detection/control
- Speed harmonisation
- Speed, lane, and gap advice
- Collective perception
- Cooperative merging
- Guidance to safe spot
- Allow emergency lane
- Allow turning on through lane
- (Opposite traffic)

Let’s stay in touch

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