

MAVEN (Managing Automated Vehicles Enhances Network)

Validation: Metrics & KPIs for Autonomous vehicles

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 690727



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European H2020 project

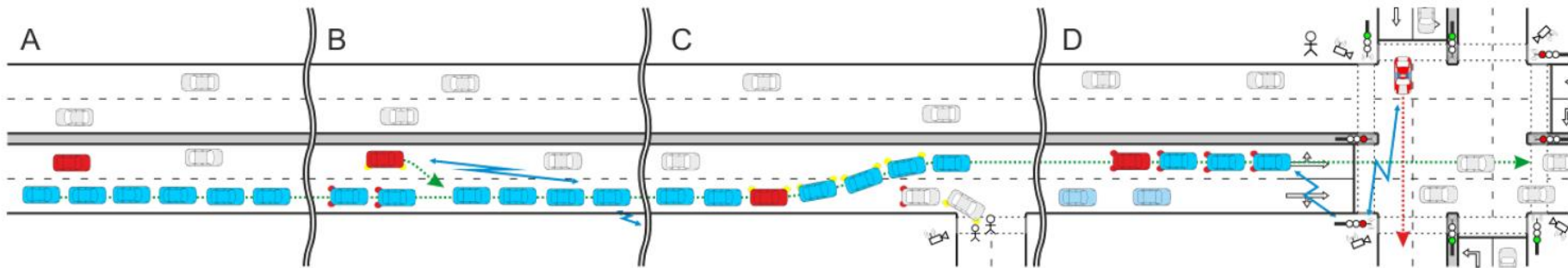
- Period: 01-09-2016 ~ 31-08-2019
- Budget: M€ 3.1

Focus:

- Platooning on arterial roads in urban areas
 - maximises throughput and efficiency of urban road networks.
 - Esp. at signalized intersections
- Hierarchical Traffic Management
- Traffic light phases negotiated with the demands of the traffic participants (e.g. platoons)



Gemeente Helmond



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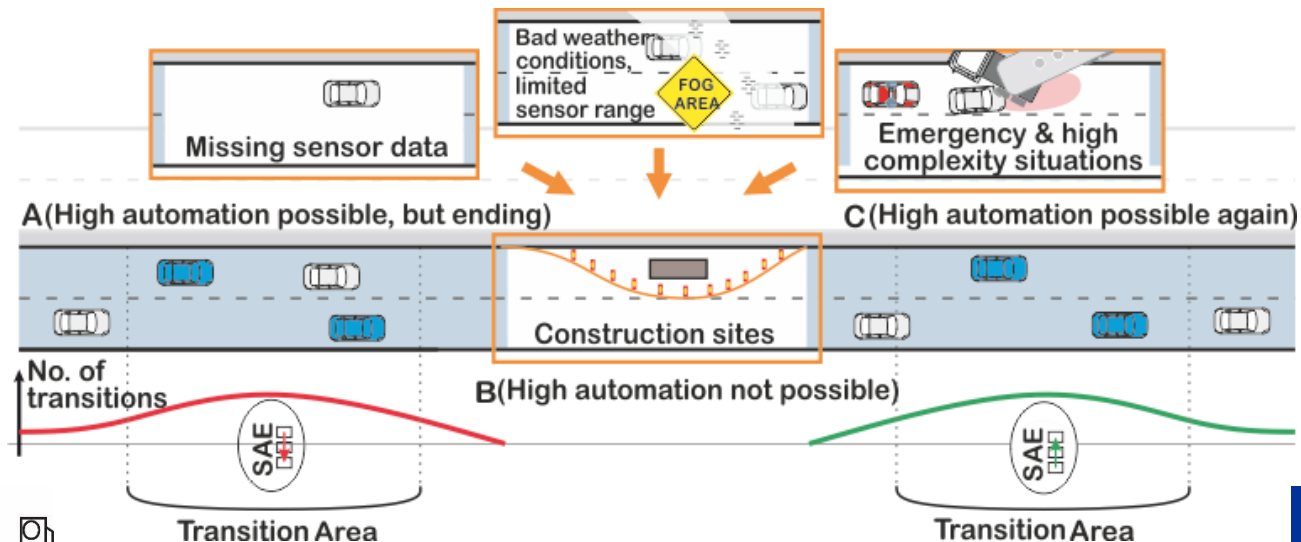
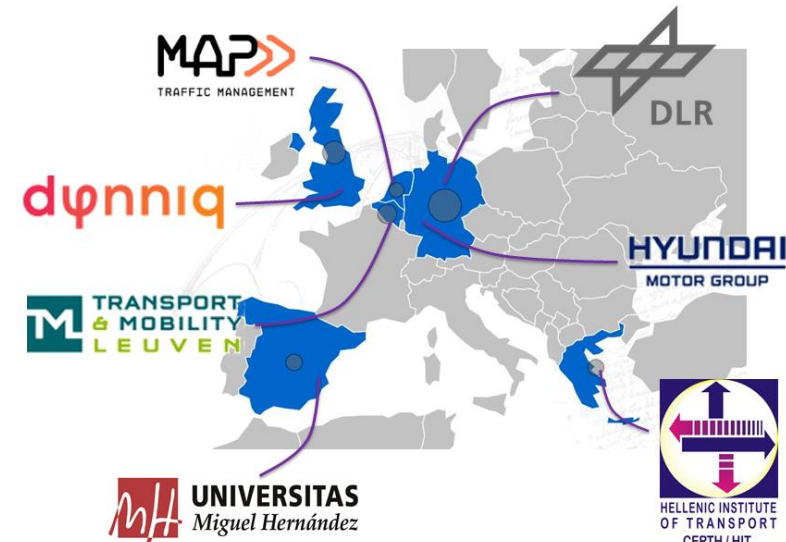
TransAID

European H2020 project

- Period: 01-09-2017 ~ 31-08-2020
- Budget: M€ 3.8

Focus:

- Reduce impact of transitions of control in local areas
- Hierarchical Traffic Management
- Development of new V2X message sets
- Simulation and feasibility assessment



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Validation of Vehicle Automation

Both projects:

- **Prototypic implementations & feasibility assessment**
- **„Show that it is working“**
 - Vehicle automation handles V2X messages and reacts appropriately
 - Traffic light sends out correct V2X messages and reacts to automated vehicles
- **Show higher penetration rates in simulation**



MAVEN:

- **Impact assessment plan with KPIs**

TransAID:

- **Review of metrics of other projects**
- **Definition of safety and efficiency metrics and KPIs**



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MAVEN specific KPIs

KPI ID	KPI description with units	Expected impact
KPI 1	Number of stops at traffic lights (-)	Reduction
KPI 2	Control delay time (s)	Reduction
KPI 3	Produced emissions (g)	Decrease
KPI 4	Fuel consumption (l)	Reduction
KPI 5	Throughput (veh)	Increase
KPI 6	Travel times (s)	Reduction
KPI 7	Minimum time to collision (s)	Increase
KPI 8	Number of human interventions for safety (-)	Decrease

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TransAID specific KPIs: Network efficiency

No.	KPI Name	KPI Description
1	Mean time headway (THW)	The mean value of the time gap to an object (e.g. a lead vehicle (bumper to bumper) or pedestrian, which is travelling in the vehicle's path of travel).
2	Standard deviation of time headway	Defined as the standard deviation of the THW.
3	Average delay time (per distance)	Extra travel time due to negative deviation from the intended speed profile.
4	Average travel time (per distance)	Time required to travel from origin to destination for a vehicle.
5	Average stop time (per distance)	Average time at standstill per vehicle per kilometre.
6	Throughput	Total number of vehicles per hour through a particular road section or intersection approach, normalised to number of lanes and proportion of green time (where relevant).
7	Average network speed	Average space mean speed of the vehicular fleet on a specific road network.
8	Average density	Average number of vehicles per kilometre for a specified road segment.
9	Average flow rate	Average number of vehicles per hour that have passed through a specific location of the road network during the simulation period.
10	Number of stops	Average number of stops per vehicle per kilometre.
11	Number of lane changes	Total number of lane changes per kilometre.
12	Average queue length	Average queue in a specific road segment during the simulation period. It is measured in vehicles.
13	Maximum queue length	Maximum length of the queue in a specific road segment, expressed as number of vehicles per lane.
14	Total travelled distance	Total number of kilometres travelled by all the vehicles that have crossed a specific road segment.

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TransAID specific KPIs: Vehicle Operations

No.	KPI Name	KPI Description
1	Mean speed	Mean vehicle speed
2	SD speed	Standard deviation of vehicle speed
3	Maximum longitudinal acceleration	Peak level of longitudinal acceleration achieved during a scenario.
4	Maximum lateral acceleration	Peak level of lateral acceleration achieved during a scenario.
5	Frequency of left lane changes	Time frequency of performed left lane changes (either time or distance based).
6	Frequency of right lane changes	Time frequency of performed right lane changes (either time or distance based).
7	Deviation from desired lane	Number of lanes from the current lane to the desired lane (0 if driving in the desired lane).
8	Frequency of active overtaking	Time frequency of active overtaking (i.e. overtaking conducted by the subject vehicle), either time or distance based.
9	Frequency of passive overtaking	Time frequency of passive overtaking (i.e. overtaking in which the subject vehicle is overtaken), either time or distance based.
10	Frequency of lane exceedances	The number of times per a certain distance or time the vehicle leaves the own lane boundaries.
11	Minimum accepted gap in lane changes	Minimum space or time gap accepted by a driver or vehicle to perform a lane change.



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TransAID specific KPIs: Energy and Environment

No.	KPI Name	KPI Description
1	Average fuel consumption (l/km)	Fuel consumed per road-km for a vehicle's trip from origin to destination.
2	Total fuel consumption (l)	Total fuel consumed by all vehicles on the road network during the analysis time-frame.
3	Average CO ₂ emissions (g/km)	CO ₂ emitted per road-km for a vehicle's trip from origin to destination.
4	Total CO ₂ emissions (g)	Total CO ₂ emitted by all vehicles on the road network during the analysis time-frame.

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TransAID specific KPIs: Traffic Safety

No.	KPI Name	KPI Description
1	Mean of time-to-collision (TTC)	The mean time required for two vehicles (or a vehicle and a object) to collide if they continue at their present speed and on the same path. Measures a longitudinal margin to lead vehicles or objects.
2	Post Encroachment Time (PET)	Time lapse between end of encroachment of turning vehicle and the time that the through vehicle actually arrives at the potential point of collision.
3	Deceleration Rate to Avoid Collision (DRAC)	The rate at which a vehicle must decelerate to avoid a probable collision.
4	Time exposed Time to Collision (TET)	Summation of all time intervals that a vehicles experiences TTC values that are lower that a specific TTC threshold value.
5	Time integrated Time to Collision (TIT)	The difference between observed TTC and threshold TTC value for a given time interval cumulative to the time the vehicle traverses the study area.
6	Number of instances with hard braking	Number of instances that decelartion rate exceeds a minimum pre-determined threshold.



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TransAID specific KPIs: Transition Area specific

No.	KPI Name	KPI Description
1	Mean duration of the transfer of control	Mean duration of the transfer of control between operator/driver and vehicle (when requested by the vehicle).
2	Maximum duration of the transfer of control	Maximum duration of the transfer of control between operator/driver and vehicle (when requested by the vehicle).
3	Total Number of ToCs	Number of ToCs performed in the whole network.
4	Number of ToCs (per distance)	Number of ToCs performed per kilometre.
5	Total Number of Lane Changes	Number of Lane Changes performed in the whole network.
6	Number of Lane Changes (per distance)	Number of Lane Changes performed per kilometre.
7	Total Number of MRMs	Number of MRMs performed in the whole network.
8	Number of MRMs (per distance)	Number of MRMs performed per kilometre.

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TransAID specific KPIs: Communication related

No.	KPI Name	KPI Description
1	Neighbourhood Awareness Ratio	The proportion of vehicles in a specific range from which a message was received in a defined time interval.
2	Neighbourhood Interference Ratio	The ratio between the number of vehicles outside the specified range from which the given vehicle received a message, and the total number of vehicles from which the given vehicle has received a message.
3	Latency	The time difference between the transmission and reception time of a packet.
4	Date age	The time interval between the instant when the data is generated in the source vehicle and the actual time.
5	Packet Delivery Ratio	The ratio of packet successfully received over the total number of packets transmitted.
6	Footprint	The total channel resources consumed by the radio of a single vehicle in time and space.
7	Channel Busy Ratio	The percentage of time that the channel is perceived as busy for a given time interval.
8	Messages received per vehicle	The number of messages of a specific type received by a vehicle in a determined time interval.
9	Inter Package Reception Time	The interval of time elapsed between two successful receptions of packets of the same type.

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TransAID specific KPIs: Real world feasibility

No.	KPI Name	KPI Description
1	Mean duration of the transfer of control	Mean duration of the transfer of control between operator/driver and vehicle (when requested by the vehicle).
2	Maximum duration of the transfer of control	Maximum duration of the transfer of control between operator/driver and vehicle (when requested by the vehicle).
3	Total Number of ToCs	Number of ToCs performed.
4	Total Number of Lane Changes	Number of Lane Changes performed.
5	Total Number of MRMs	Number of MRM performed.
7	Mean speed	Mean vehicle speed
8	SD speed	Standard deviation of vehicle speed
9	Maximum longitudinal acceleration	Peak level of longitudinal acceleration achieved during a scenario.
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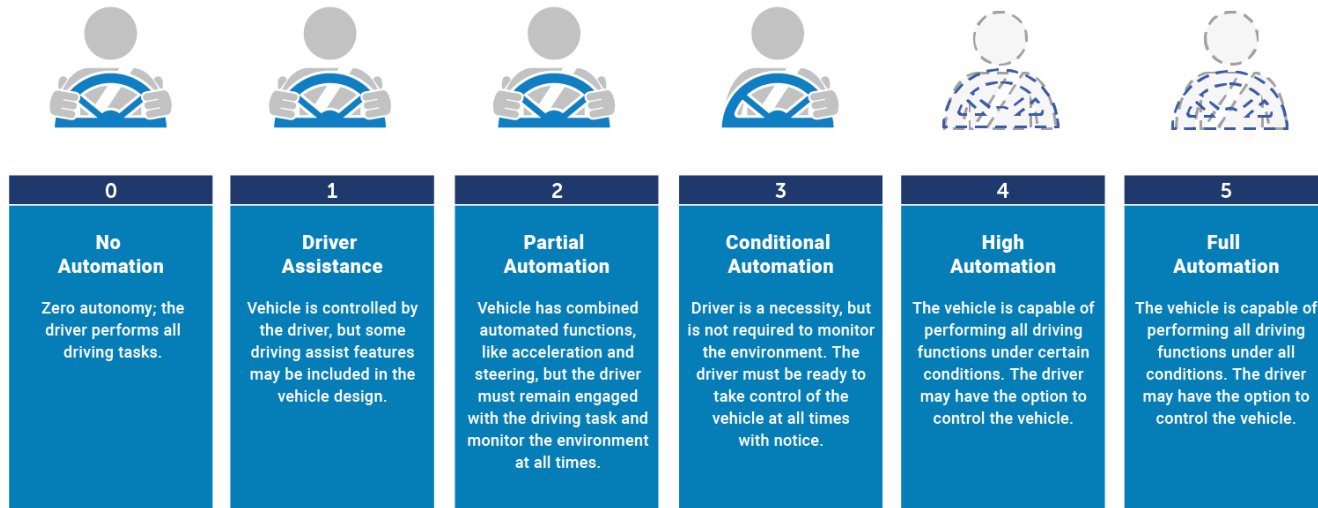


Metrics and KPIs: General Questions

What is the target level of automation?

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE) AUTOMATION LEVELS

Full Automation



Credit: <https://www.nhtsa.gov/technology-innovation/automated-vehicles-safety>

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Metrics and KPIs: General Questions

Individual

„Automation is good **for me** when...“

- Comfort, e.g. smooth accelerations, relax body & mind, free time
- Safety, e.g. avoid accidents and critical situations, reduce impact of crashes
- Environment, e.g. reduce waiting times, smooth accelerations, optimal routes
- SAE5: Availability of shared mobility



Social

„Automation is good **for my surrounding** when...“

- Safety, e.g. reduction of risks for others (vehicles, VRUs...)
- Environment, e.g. less pollution due to better routing and less waiting times
- SAE5: Shared mobility and smart routing



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Metrics and KPIs: General Questions

Traffic System

„Automation is good **for my city** when...”

- Safety, e.g. less accidents
- Environment, e.g. less traffic jams



OEM

„Automation is good **for my company** when...”

- Safety, e.g. better crash statistics
- Environment, e.g. better environmental impact, green impression (like Start-Stop etc.)
- Economic: cheap systems with high impact, low power or CPU requirements, low error rate



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