Autonomous Vehicles to Evolve to a New Urban Experience…

… following "**a roadmap for the smooth integration of automated vehicles into existing transport infrastructure while maintaining high level of quality, safety and reliability**"

DELIVERABLE D9.2 (V3.2, 9/2022)

<Transition roadmap for safety & service quality>

Co-funded by the Horizon 2020 programme of the European Union

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 769033

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Document Information

Grant Agreement Number	**769033**
Full Title	Autonomous Vehicles to Evolve to a New Urban Experience
Acronym	AVENUE
Deliverable	D9.2 < Transition roadmap for safety & service quality >
Due Date	01.09.2022
Work Package	WP9
Lead Partner	<CEESAR >
Leading Author	<Philippe CHRÉTIEN>
Dissemination Level	Public, restricted

Document History

Version	**Date**	**Input authors**	**Description of change**
0.1	31.08.2021	<Philippe CHRETIEN>	First internal draft
0.2	26.10.2021	<Philippe CHRETIEN>	First presentation to WP9 meeting
0.3	24.11.2021	<Philippe CHRETIEN>	Coordination with T9.1
0.4	21.12.2021	<Linda MATHE>	Accessibility inclusion
0.5	11.01.2022	<Lionel BINZ>	T9.1 inputs + completion
0.6	17.01.2022	<Philippe CHRETIEN>	Safety targets evaluation
0.7	15.03.2022	<Philippe CHRETIEN>	Passive safety requirements
0.8	18.03.2022	<Clement VAL>	Safety evaluation methodology
0.9	24.03.2022	<Lionel BINZ>	Flexible European regulation
1.0	21.04.2022	<Philippe CHRETIEN>	Reviewed executive summary + acronyms
1.1	10.05.2022	<Philippe CHRETIEN>	Vehicle occupancy for safety targets + …
1.2	10.06.2022	Philippe CHRETIEN	Form + accordance with shared D9.1 draft
2.1	19.06.2022	Philippe CHRETIEN	General Meeting 9 inputs integration
2.2	27.06.2022	Philippe CHRETIEN	WP6 + comparison with US strategy
3.1	22.08.2022	Philippe CHRETIEN	Recommendations shared with D9.1
3.2	20.09.2022	Philippe CHRETIEN	Recommendations order and names

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Acronyms

ADS	Automated Driving Systems
AI	Artificial Intelligence
AFGBV	German ordinance for regulation
AM	Automated Minibuses
AMW	Automated Minibus Web
API	Application Protocol Interface
ASIL	Automotive Safety Integrity Level
AV	Automated Vehicle
BAAC	French accident database
BMM	Business Modelling Manager
CAV	Connected & Automated Vehicles
CB	Consortium Body
DC	Demonstration Coordinator
DI	Department of Infrastructure
DMP	Data Management Plan
EDR	Event Data Recorder
EM	Exploitation Manager
ER4	Feared event with safety risk
EU	European Union
EUCAD	European Conference for Connected & Automated Driving
F2F	Face to face meeting
GDPR	General Data Protection Regulation
GNSS	Global Navigation Satellite System
GRVA	UNECE WP29 working party on Automated & Connected Vehicles
HARA	Hazard Analysis & Risk Assessment
IPR	Intellectual Property Rights
ISO 26262	Automotive international norm for functional safety
IT	Information Technology
ITU	International Telecom Union
LA	Leading Author
LIDAR	Light Detection And Ranging
MEM	Monitoring & Evaluation Manager
MOSAR	Organised Method for Vehicle Risk Analysis (IRT SystemX, France)
NATM	New Assessment Test Method AD
NHTSA	US road safety organization
OEM	Original Equipment Manufacturer
ODD	Operational Domain Design
ONISR	French road safety observatory
PMHS	Post Mortem Human Subject
PRM	Persons with Reduced Mobility
QRM	Quality and Risk Manager
QRMB	Quality & Risk Management Board
SOTIF	Safety Of The Intended Functionality
SUV	Sport Utility Vehicle
SWOT	Strengths, Weaknesses, Opportunities, and Threats
T9.2	Task dedicated to Quality & Safety
TM	Technical Manager
UNECE	United Nations Economic Commission for Europe
VMAD	Validation Method for Automated Driving
V2I	Vehicle to Infrastructure communication
WP	Work Package
WP9	WP targeting transition roadmaps
WPL	Work Package Leader

Executive Summary

AVENUE project demonstrated that **Automated Minibuses** (AM) are attractive in terms of urban mobility services and now technically accessible. Most of all, they **can contribute to the urgently required urban ecologic transition,** if carefully integrated into the existing mobility system.

To get a **sustainable transition** and a **sustainable business**, the new AM services have also to:

- **Be able to manage blocking situations and to avoid traffic disturbance**, which implies infrastructure adaptation and human solutions to be used: the US strategy for Automated Driving (AD) is **driver mimicry based on vehicle Artificial Intelligence**, which is different from the **strict application of driving regulation,** leading to other impacts.
- **Satisfy AM users and other citizens for their** explicit but also **implicit requirements: quality and safety**, which also implies technical reliability, cybersecurity, regulation compliance and juridical responsibility, which are behind quality and safety.

The roadmap begins from the current automated transport demonstrations and has to establish progressively a durable customer paid service. To avoid future regressions, the roadmap **has to anticipate the probable risks** concerning traffic impact, service quality and road user safety, especially vulnerable users, and to organise the global improvement of these new services.

To reach a safety level comparable to transport services (coaches, buses…), the **target should be 10^{-6} Injury/running hour** (I/h), but 10^{-5} I/h would be **acceptable and measurable for market introduction.** Two strategies are possible to reach these targets:

1. <u>Active safety ambition</u>: less than 1 Accident during 100 000 running hours (**high active safety**), less than 1 Injury among 10 accidents (**passive safety**), less than 1 Fatality among 1000.
2. <u>Shared ambitions</u>: less than 1 Accident during 10 000 running hours (**active safety**), less than 1 injury among 100 accidents (**high passive safety**), less than 1 fatality / 10 000 accidents.

In terms of **fatality roadmap**, 10^{-7} Fatalities per running hour (F/h) would be requested for market introduction, $2*10^{-8}$ F/h after improvement, at the end of the roadmap.

This is **not feasible without passive safety,** required in the US as identical to conventional vehicles:
- Citizens will consider they are **protected** from external vehicles **when installed in the minibus;**
- Pedestrians will refuse that the minibus vertical front face would be **less protective than a car.**

Innovations are necessary for **passive safety**, which is also **fundamental for vehicle architecture.** The **adapted requirements should to be urgently defined**, and integrated in the vehicle certification process, differentiating **two different usages**:

- **<u>Urban usage</u>** requires **vertical faces with a specific architecture** to protect vulnerable street users and to facilitate vehicle stop & go with PRM and standing passengers. To allow such vehicle developments (low production volume, limited investments), passive safety requirements have to be adapted: hopefully, in that case, **performances can be limited** (speed, acceleration, braking…)
- On the contrary, the **<u>Liaison usage</u> between suburbs and cities at higher speed** (or for rural usages) can reuse industrial vehicle platforms, with conventional passive safety requirements: it **will have to be dissociated**, as suggested recently by OICA.

The AVENUE experimentations showed that some **preliminary conditions** are not met, and have to be improved before market introduction:

- **Automated vehicle reliability** (nominal behaviour defined and guaranteed, according to ISO 26262 and to cybersecurity recommendations) at **acceptable maintenance** level (sensor cleaning or protection, components…)
- **Robustness** of the **connected infrastructure** (V2I) in the urban and complex environment.

When such basics will be satisfied in service, the guaranteed nominal behaviour of the Minibus will have to be confronted to **risky scenarios, leading to incidents, sometimes to accidents.**

SOTIF approach (ISO/PAS 21448, complementary to ISO26262) has been applied, and some risky situations have been identified during the experimentations, but the real benchmark will have to be built progressively, from **feedbacks coming from the future reality**.

As proposed in AVENUE vision, the automated transport system will have to be **self-learning**: the proposed improvement process implies a **systematic incident analysis,** with anonymized feedback transmitted to operational actors for **corrective actions**.

Public Transport Authorities (PTA) will have to drive the process to get these corrections (continuous and general improvement), to share lessons learned across European countries, and to use field experience to establish future **norms or regulations, in cooperation with technical representatives,** ensuring technical feasibility.

Road safety methodologies can be reused to **conciliate data availability with privacy,** but also to satisfy commonly **legal treatment needs** with **data needs for scientific analysis**:

- Beyond the system daily management, **incidents will be collected and data protected**
- **Data will be analysed by trusted experts:** scenario coding, simulation and statistical analysis.
- The **technical feedback** will be **shared, as anonymized,** without personal data.

Justified by safety and included in the AVENUE vision recommended to the European Community, this **continuous improvement process will also contribute to the service quality** improvement: all incidents will have to be analysed, leading to **corrective actions in all domains**, from the usage rules to the urban infrastructure.

As a conclusion, **we now know what is targeted in terms of safety,** and we have to use **6 levers**, which will **also contribute to service quality**:

1. Systematic and limited **incident data collection**
2. Continuous and general **improvement process**
3. **Functional safety and SOTIF** ISO norms (26262 & 21448)
4. Appropriate effort repartition between **active and passive safety**
5. **Dissociation of Urban needs from Liaisons needs** at higher speed
6. **Innovation for Urban shuttle** architecture, especially for **vulnerable protection**.

From the early beginning (**from now**), the roadmap to develop the proposed automated minibuses services must **include** active but also adequate **passive safety, for 2 different usage modes**.

The potential advantage of this coming **"Automated Minibus step"** is to be secured by the public control on their applications. It is **crucial to prepare the** introduction of **private automated cars in towns:** it will be **later** with benefits from this AM experience, **or never** because of unacceptable risks…

Recommendations for safety & quality

The names of these 19 recommendations associate the AVENUE Deliverable name (D9.2) and a letter:

<u>D9.2_a : multipillar approach</u>

As requested for Automated Driving System (Validation Method for Automated Driving, VMAD from UNECE WP29/GRVA), use a multi-pillar approach to get robustness, with ODD scenarios, virtual testing, real world usage monitoring, systematic incident reporting and audit.

<u>D9.2_b : incident registering</u>

Organise the systematic registering of all incidents leading to accidents or compromising the service quality, for example punctuality (including vandalism and all unacceptable behaviours…).

<u>D9.2_c : incident data collection</u>

In case of an incident, keep and protect data according to GDPR, so lessons can be learned and formalised after analysis and anonymisation by trusted organisations, under PTA control.

<u>D9.2_d : AD disengagements and safety indicator</u>

Refuse Automated Driving disengagement frequency proposed by U.S. actors as a safety indicator (or as a safety demonstrator…): disengagements are not representative of safety issues, and should stay free to improve safety and avoid accidents.

<u>D9.2_e : injury indicator and target</u>

Replace rare fatalities by road user injuries (including AM passengers, pedestrians, cyclists…) per hour of service to get a measurable indicator, with a target close to one per million hours of service (10^{-6} I/h), to be consistent with the existing results of public transportation.

<u>D9.2_f : target mitigation for market introduction</u>

For first commercial applications, accept higher rate of injuries (e.g. 10^{-5} I/h) during a transition phase, but request the systematic reporting and build the improvement process, driven by lesson learned and regulation to avoid regressions.

<u>D9.2_g : trusted organisations for lessons learned coming from incidents</u>

Organise trusted analysis of incident data, with same type of data protection guarantees and technical skills as for road accident analysis, already defined and used for scientific analysis or juridical treatment.

<u>D9.2_h : data analysis and virtual test tools</u>

Reuse the same tool chain among trusted organisations in Europe, could be SALSA for data analysis, could be MOSAR for scenario library, as they are already used for ADS validation.

<u>D9.2_i : improvement process</u>

Share the lesson learned and require best practice application, with aim to lock earnings using regulation when main actors of Automated transportation are able to apply best practices.

D9.2_j : traffic fluidity

Request the application of pertinent driver strategies to solve issues when the traffic is blocked, using the remote control for action, with modern tools to decide, including digital twins.

D9.2_k : different usages and regulations

Dissociate liaison needs between town and suburbs (or rural usage) from central town usage (low speed in a busy and vulnerable traffic), requesting very different passive safety characteristics.

D9.2_l : passive safety requirements

Existing tests are not adapted to such usage: establish quickly ambitious and reasonable targets for road user protection and for passenger protection, as it is structuring for vehicle development.

D9.2_m : street user protection

Promote innovation for active road user protection when driving in streets, avoiding injuries of citizens, e.g. with adapted new technologies, analogue to airbags inside cars.

D9.2_n : performance limitation

Require automatic performance adaptation to street typology (e.g. pedestrian street), to traffic reality (e.g. busy, with many vulnerable road users) and to passenger postures.

D9.2_o : passenger coaching

Reduce performance when passengers are not seated or not belted, inform passengers of such situation to get the requested behaviours, as well when somebody is blocking the door closing.

D9.2_p : vehicle maintenance

Introduce maintainability requirements in the vehicle certification rules to get in-service reliability (condition for safety and quality) with a realistic maintenance.

D9.2_q : cybersecurity

As fundamental to avoid dangerous misuses and highly dependent of the system architecture, act early in the commercial projects, organising European audits, providing best standards

D9.2_r : design norms

Require ISO 26262 and ISO/PAS 21448 application for Functional Safety and Safety Of the Intended Functionality (SOTIF), as requested and now applied for future private cars.

D9.2_s : automated private cars

In towns, consider public transportation at controlled and low speed as a priority, preparing potential next steps. In terms of social interest, Automated Minibus has high potential, but the automatization of private cars in towns can be considered as optional.

1 AVENUE project introduction

AVENUE aims to design and carry out full-scale demonstrations of urban transport automation by deploying, for the first time worldwide, fleets of Automated minibuses in low to medium demand areas of 4 European demonstrator cities (Geneva, Lyon, Copenhagen and Luxembourg) and 2 to 3 replicator cities. For future public transport in urban and suburban areas, the AVENUE vision is that Automated vehicles will **ensure safe, rapid, economic, sustainable, accessible and personalised transport of passengers**. AVENUE introduces disruptive public transportation paradigms on the basis of on-demand, door-to-door services, aiming to set up a new model of public transportation, by revisiting the offered public transportation services, and aiming to suppress prescheduled fixed bus itineraries.

Vehicle services that substantially enhance the passenger experience as well as the **overall quality and value of the service** will be introduced, also targeting elderly people, people with disabilities and vulnerable users. Road behaviour, **security of the Automated vehicles and passengers' safety are central** points of the AVENUE project.

At the end of the AVENUE project four-year period, the mission is to have demonstrated that Automated vehicles will become a future solution for public transport. The AVENUE project will demonstrate the economic, environmental and **social potential of Automated vehicles** for both companies and public commuters while assessing the **vehicle road behaviour safety**.

1.1 On-demand Mobility

Public transportation is a key element of a region's economic development and of the quality of life of its citizens.

Governments around the world are defining strategies for the development of efficient public transport based on different criteria of importance to their regions, such as topography, citizens' needs, social and economic barriers, environmental concerns and historical development. However, **new technologies, modes of transport and services are appearing, which seem very promising to the support of regional strategies for the development of public transport.**

On-demand mobility is a public transport service that works when a reservation has been recorded and will be a relevant solution where the demand for transport is diffuse and regular transport is inefficient.

On-demand transport differs from other public transport services in that vehicles do not follow a fixed route and do not use a predefined timetable. Unlike taxis, on-demand public transport is usually also not individual. An operator or an automated system takes care of the booking, planning and organization.

It is recognized that the use and integration of on-demand Automated vehicles has the potential to significantly improve services and provide solutions to many of the problems encountered today in the development of **sustainable and efficient public transport**.

1.2 Fully Automated Vehicles

A self-driving car, referred in the AVENUE project as **a Fully Automated Vehicle** (**AV**), also referred previously as Autonomous Vehicle, is a vehicle that is capable of sensing its environment and **moving safely with no human input.**

The terms *automated vehicles* is preferred to *autonomous vehicles,* but often used together.

The 2019/2144 Regulation of the European Parliament and of the Council of 27 November 2019 on type-approval requirements for motor vehicles defines "automated vehicle" and "fully automated vehicle" based on their autonomous capacity:

- An "**automated vehicle**" means a motor vehicle designed and constructed to move autonomously for certain periods of time without continuous driver supervision but in respect of which driver intervention is still expected or required
- "**fully automated vehicle**" means a motor vehicle that has been designed and constructed to move autonomously without any driver supervision

In AVENUE we operate ***Fully Automated minibuses for public transport***, (previously referred as Autonomous shuttles, or Autonomous buses), and we refer to them as simply *Automated minibuses* or *the AVENUE minibuses.*

In relation to the SAE levels, the AVENUE project will operate SAE Level 4 vehicles (Figure 1).

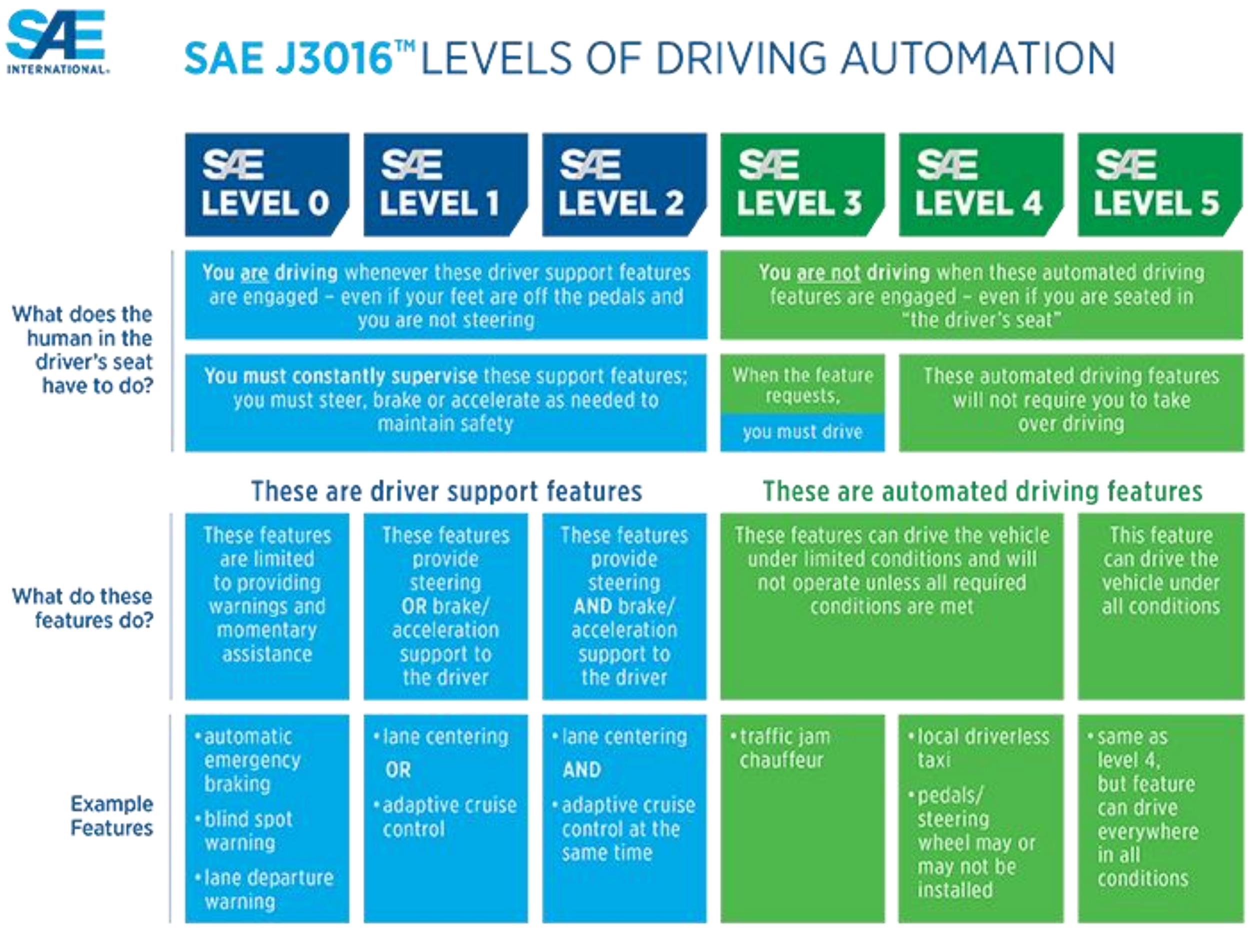


Figure 1: Levels of driving automation according to SAE

1.2.1 Automated vehicle operation overview

We distinguish in AVENUE two levels of control: micro-navigation and macro-navigation of the AV. Micro navigation is fully integrated in the vehicle and implements the road behaviour of the vehicle, while macro-navigation is controlled by the operator running the vehicle and defines the destination and path of the vehicle, as defined the higher view of the overall fleet management.

For **micro-navigation**, Automated Vehicles combine a variety of sensors to perceive their surroundings, such as 3D video, LIDAR, sonar, GNSS, odometry and other types of sensors. Control software and systems, integrated in the vehicle, fusion and interpret the sensor information to identify the current position of the vehicle, detecting obstacles and movements in the surround environment, to choose the most appropriate reaction of the vehicle, ranging from stopping to bypassing the obstacle, reducing its speed, making a turn etc.

For the **Macro-navigation**, that is the destination to reach, the Automated Vehicle receives the information from either the in-vehicle operator (in the current configuration with a fixed path route), or from the remote control service via a dedicated 4/5G communication channel, for a fleet-managed operation. The fleet management system takes into account all available vehicles in the services area, the passenger requests, the operator policies, the street conditions (closed streets) and send route and stop information to the vehicle (route to follow and destination to reach).

1.2.2 Automated vehicle capabilities in AVENUE

The AVENUE Automated vehicles fully and automatically manage the above defined, micro-navigation and road behaviour, in an open street environment. The vehicles are Automatically capable to recognise obstacles (and label some of them), identify moving and stationary objects, and automatically decide to bypass them or wait behind them, based on the defined policies. For example, with small changes in its route the AVENUE minibus is able to bypass a parked car, while it will slow down and follow behind a slowly moving car. The AVENUE Minibuses are able to handle different complex road situations, like entering and exiting roundabout in the presence of other fast running cars, stop in zebra crossings, communicate with infrastructure via V2I interfaces (ex. red light control).
The minibuses used in the AVENUE project technically could achieve high speeds, but **this speed cannot be used** in the project demonstrators **for several reasons, ranging from regulatory to safety**. Under current regulations, the maximum authorised speed is 25 or 30 Km/h (depending on the site). In the current demonstrators, the speed does not exceed 23 Km/h, with an operational speed of 14 to 18 Km/h. Another, more important reason for limiting the vehicle speed is **safety for passengers and pedestrians**. Because the current LIDAR has a range of 100 meters and the obstacle identification is done for objects no further than 40 meters.
Considering that the vehicle must **safely stop in case of an obstacle** “seen” at less than 40 meters distance on the road, we cannot guarantee a safe braking if the speed is more than 25 Km/h. Technically, the vehicle can make harsh brake and stop with 40 meters in high speeds (40 -50 Km/h) but then the **braking would be too harsh, putting in risk the vehicle passengers**. The project is working in finding an optimal point between **passenger and pedestrian safety**.
Due to legal requirements, a **Safety Operator** must always be present in the vehicle, able to take control any moment. Additionally, at the control room, a **Supervisor** is present controlling the fleet operations. An **Intervention Team** is present in the deployment area ready to intervene in case of incident to any of the minibuses.

1.3 Deliverable 9.2 preamble

The european **Automated driving deployment roadmap** is **targeting a "zero fatalities mobility service"** in 2050, following the facts that we have still too many road fatalities on European roads, and that 90% of accident involve human errors. This formulation is dangerous for two reasons:

- The majority of accident risks are **avoided, thanks to human reactions**, giving uncertainty to the gains we are waiting from Automated Driving.
- The **societal weight of road injuries** is as important as fatalities, and reducing fatalities do not lead automatically to injury reduction, for example for such urban applications.

Therefore, the road safety reality is more complex, but the deployment of shuttle services would provide societal benefits and can contribute to road safety: H2020 AVENUE project experience supports the target to get **first commercial services in 2025**, which is ambitious. The cooperative work should be accelerated because of its **high societal interest**, but with **strong attention to road user safety and service quality.**

Safety, security of the Automated Vehicles **and users' satisfaction** are central points of the AVENUE project, as the target is to establish a sustainable business, useful to the society: public power will have to steer the introduction of Automated Driving, requesting to develop the regulation in parallel with the technological developments, through a short window of opportunity, as developed in D9.1.

This D9.2 deliverable has to **guarantee the citizen safety and the quality in service,** which are implicit requirements, beyond the confirmed attractiveness of such solution for urban public transport.

To satisfy this central aim of AVENUE project, the WP9 (dedicated to the transition roadmap for Automated Vehicle public transport) has included a T9.2 task, to **plan this transition in terms of safety and service quality.**

In this associated Deliverable D9.2, we have defined **relevant conditions to be respected by the automated minibus development roadmap,** to guarantee the citizen safety and the quality in service, and so **to avoid any future regression**. Innovations will be necessary, especially for passive safety, which is often forgotten when speaking of Automated Vehicles.

In terms of plan for this Deliverable D9.2, we have chosen to present our different steps:

- **Where** do we have to go, to a **feasible goal**? Chapter 2
- **What** are the preliminary **technical conditions**? Chapter 3
- **Which** situations or **scenarios** do we have **to take into account**? Chapter 4
- **How can we manage these challenges**?

  Data? Chapter 5

  Lesson learned? Chapters 6 &7

  Organisation? Chapter 8

  Improvements? Chapter 9
- **What** are the **safety results to be measured**, is it **feasible?** Chapters 10 &11

The roadmap has to include all these elements…

2 Shuttle target and roadmap goal

The target of the Shuttle or Automated Minibus (AM) services is what we are dreaming commonly from such technology: it defines **the direction of the roadmap** we have to build.

As H2020 AVENUE includes experimentation, **this roadmap is starting from now and going to a feasible goal**, based on the experience gained with experimentations and scientific analysis. The goals define the commitments we will be able to make if roadmap conditions are respected.

2.1 Shuttle target description coming from WP2

The AVENUE WP2 has defined in 2019 the current State of the Art (SoA) and a preliminary Public Transport target for Automated minibuses in terms of **requirements and use cases**, based on passenger needs, best practices, regulatory perspective and demonstrator experiences.
Ten main criteria have been discussed concerning this target:

1. **<u>Speed & time management, passenger coaching:</u>**
   Thanks to the AVENUE project, the SoA of 2022 has been improved: the maximum speed is now 23 km/h, but the target expressed by PTOs is far higher, 50 km/h, which is a real challenge in terms of Passive Safety.
   This target is coming from the urban speed limitation, but this is also the maximum speed for experimentation, especially in France. This target aggregates a **mix between different usages**, liaison usage with suburbs, and in the town centre, but the **real goals should be defined for each application in terms of average speed and maximum time variability from A to B**, to be able to guarantee service timing.
   The AVENUE proposal is to target the punctuality, with an efficient management of stops and starts, and a reasonable maximum speed: one way to optimise both is to coach the passengers to get the right behaviours, using interaction between passengers to get the door closed, but also clear performance limitations when passengers are not seated and belted.

2. **<u>Driving redundancy:</u>**
   As seen in new regulations from France and Germany, for public transport, **the current physical "safety driver" should be replaced by a distant operator** (as accepted in principle, validated this summer by the Vienna convention, and economically necessary), with **possible legal liability** in case of an accident.
   It is mandatory to reach a profitable business, but this represents an important gap between the SoA and the target, between the demonstration phase and the operational business.
   This evolution introduces a huge pressure over PTO and OEM concerning the vehicle connection, which has to be efficient and reliable, but what is waited from a distant operator is not distant driving:
   - **Supervision**, which means checking that everything is running correctly, using regular information collected from the field.
   - **Arbitration**, in case the Automated Driving System (ADS) is blocked, which does not mean that automated driving is replaced by a distant and manual driving.

3. **Passenger capacity:**

   The autonomous transportation is a real opportunity to improve the flexibility of current buses, which should be easier without a permanent driver and associated costs: this flexibility reduces the vehicle capacity target.

   With 11 seated places and 4 standing places, the current vehicle appeared as a good compromise for urban usage, in between capacity and flexibility for the complementary mission requested from automated minibuses. The safety driver removal will give one additional place, so the size target has to be between a car and a bus, a relatively small and light vehicle: the current curb weight is 2400 kg, not far from new electric SUVs, but the current shuttle cannot support the same crash tests…

   There are discussions to consider a bigger vehicle reusing an existing platform, but the urban usage will be limited, especially in touristic areas where the available place is limited for the traffic: this should be logical for Liaison usages (radial Liaisons from suburbs, or rural applications).

4. **Fleet operation:**

   In the SoA, Automated Minibuses (AM) are managed and controlled differently from other vehicles in the operator fleets, because of daily maintenance and weather limitations. This gap will have to be closed to **guarantee the nominal behaviour in every condition**, with normal maintenance, which has to be preventive: An **acceptable maintenance level** has to be requested for the vehicle certification.

5. **On demand service:**

   On demand implies that different routes are possible, with associated stop positions, and open timing. Off-route means higher capacity of Automated Driving, but also **stop & go everywhere to catch or deliver passengers**, with external information always available, with a repeatable and acceptable delay. A new mission changing the route has also to be analysed at vehicle level, for safety reasons: it is challenging for the cooperation between PTO and OEM, but also for the connected infrastructure, as discussed in D9.4.

6. **Safety level:**

   The target is that all accidents leading to personal injuries have to be avoided. In the initial SoA, some material accidents are reported, most of them in manual mode with safety drivers, because some necessary securities are off: this point has been improved during the project.

   Several cases of physical safety risk have been registered because of harsh braking: the occurrence has been reduced, with help from infrastructure improvement: shrubbery cuts, furniture distance from the AM route…

   The quantitative target is **close to zero injury accident, at same level as the current bus standard:** this Deliverable quantifies and details later this goal (9: safety requirements), in order of magnitude (power of ten).

7. **Service and vehicle regulation:**

   Experimentations depend on local authorities, but **the operational business will have to be based on a common regulation**, with a specific European type approval for automated minibuses, to be proposed outside of Europe at UNECE level or within the EU legal framework.

   As seen in new Automated Driving regulations from France and Germany, for public transport, the local agreement will be complementary, and based on the safety evaluation done by the authorities and/or under delegation to a trusted organisation.

   These **evaluations are required before service start and regularly updated,** according to an audit process.

8. **Infrastructure standard:**

   To get good performance at reasonable cost, **infrastructure environment has to be standardised** in terms of connectivity, road panels, street lanes…

   The current reality is diverse in each European country, depending on cities. The infrastructure and driving rules are depending on countries, and no real work is really engaged at european level, outside of some communication standards: AVENUE D9.4 has to propose a **realistic and minimum package for shuttle business**.

9. **Cost effective:**

   The experimentation process is often financed locally for political reasons, and far from a public transportation business, driven by political and technical progress wills, without any cost requested from the customers, as they participate in an experimentation: real customers can be more demanding than current passengers.

   A paid service can be **cost effective, but without the physical safety driver in each AM**, which is on the way in terms of regulation acceptance and technical feasibility.

10. **Service accessibility and quality:**

    Services have to be accessible and available to all citizens: the service quality is generally measured through real customer satisfaction, with clear needs to **avoid bad surprises** and to **manage environment uncertainty**, as identified in the SoA.

    In the target, satisfaction has to be higher than the public transportation standards, which already includes the software mobile applications. Even without a price to pay, with a positive innovation image, user satisfaction is not always at this level today.

2.2 Goals to be reached by the roadmap

2.2.1 One goal or two goals ?

The goals of Automated Minibus services have to be feasible, according to the experience gained in H2020 AVENUE project, based on experimentations, but also cost and scientific analysis.

The discussions concerning feasibility led to a **necessary trade-off, based on usage case distinctions**: the safety requirements are clearly higher and more difficult to reach if the speed is high, and less difficult if the passengers are all seated and wearing seat belts, without any vulnerable road user outside.

At least, we have to **associate to driving conditions** (vehicle environment, passenger installation…) **different packages of speeds and decelerations**. A proposal with four modes has been established, with figures to be discussed more in detail (Table 1):

1. **URBAN LIAISON**: on radial routes between suburbs and central town, which is really strategic in big towns where railway stations are saturated, like Paris area.
   It can be on the reserved lane of a radial motorway at 50 km/h maximum (#14 m/s), with all passengers seated and belted, better than they are today in the demonstration shuttle.
   In case of traffic in this reserved lane, the inter-vehicle distance has to be defined in time and sufficient to allow a maximum deceleration of 7 m/s^2 (2 s to stop) in case of urgent braking of the previous vehicle. With the help of automation, the distance between vehicles will be adapted, braking information will be shared, and this maximum deceleration will not be installed brutally, using initial jerk (deceleration variation) to alert passengers before installing progressively the maximum deceleration.

2. **CITY in GENERAL**: in towns, we do consider that the general limitation will be 30 km/h, to be reachable when passengers are seated. In such a case, we have to take into account sudden introductions of pedestrian, cyclists, scooters or other vehicles in the bus lane. The deceleration has to be limited to 3 m/s^2 and managed progressively to avoid any injury in the vehicle, which means that an accident can occur with a vulnerable user: passive safety protection will be necessary, but impact speed for crash test can be lower than for cars.
3. **CENTRAL**: In the central town, when some passengers are not seated, a reasonable limitation should be 20 km/h, with a maximum deceleration of 2 m/s^2.
4. **MIDDLE**: in the central town, among vulnerable users, a reasonable limitation should be 10 km/h, with a maximum deceleration of 2 m/s^2 (1,4 s to stop).

2.2.2 Adapted dynamic performance

For standing passengers, the deceleration (m/s^2) is limited but also the jerk (m/s^3): based on human experimentation, the jerk has to be limited to 19 m/s^3, and then quickly reduced to establish a deceleration of 3 m/s^2 in 0,6 s (Figure 2).

With these limitations, it is comfortable for 90% of young people:

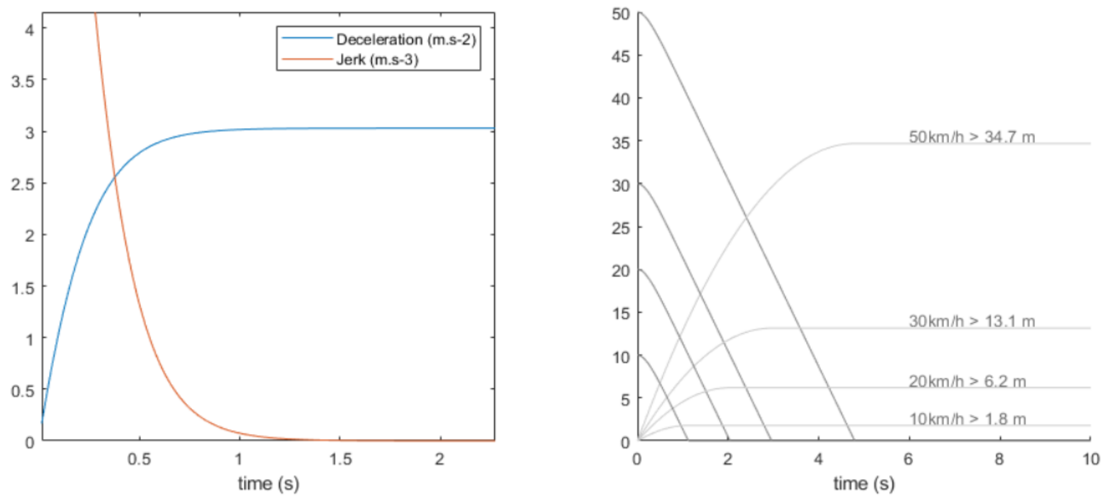


Figure 2: Deceleration law for standing passengers

This deceleration of 3 m/s^2 is also the **limit of braking stability for e-scooters** (small front wheel and high centre of gravity), now accepted among other vehicles on the street, more and more present in big cities, following buses without any visibility...

For cities, a general limitation could be **30 km/h** and 19 m/s^3 to establish progressively a deceleration of **3 m/s^2 in 0,6 s**, associated to old passengers seated, and young people standing when seats are occupied: 3s and 13 m to stop. The same limitation should be applied to acceleration.

When arrived in the city centre, **in shared streets**, the speed can be **automatically limited to 20 km/h** (2s and 6 m to stop), **or to 10 km/h** (1s and 1,8m to stop) in **pedestrian streets** (Table 1).

Table 1: Dynamics performances adapted to shuttle usages modes

MODES		CONDITIONS			LIMITATIONS (GOALS)	
		LANE	**TRAFFIC**	**PASSENGERS**	**DECELERATION**	**MAX SPEED**
URBAN	**LIAISON**	reserved	Managed	Belted	7 m/s^2	50 km/h
CITY	GENERAL	Bus priority	Limited	Seated	3 m/s^2	30 km/h
	CENTRAL	Shared street	Limited	Standing	3 m/s^2	20 km/h
	MIDDLE	Pedestrian	Busy	Standing	3 m/s^2	10 km/h

These modes (with limitations to be discussed more in detail) lead to different trade-off in terms of passive safety and accessibility.
In terms of vehicle architecture, two usages have to be clearly dissociated:

- **Inside the CITY**, the travels are short, with little time to enter or get out of the minibus, the accessibility has to be easy but the speed is low for all vehicles, reducing the passive safety constraints, focused to vulnerable street users.
- **For URBAN LIAISON** between suburbs and cities (for example on the radial motorways liaisons of the "Grand Paris" project), the travels are longer and can be organized at higher speed, on dedicated lanes: it is possible to accept more time to access and to install passengers, but their safety has to be correctly guaranteed in terms of passive safety (seated and belted, like in a conventional vehicle).

Such recommendation has been already produced end of May 2022 by the European side of the "Organisation Internationale des Constructeurs Automobiles" (**OICA/CLEPA**), during the 13th session of the "Groupe des Rapporteurs sur les Véhicules Automatisés" (**GRVA**):
*" Check whether it would make sense to have different requirements based on different maximum design speed for example: **Urban shuttles** operating at (very) low speeds should maybe not be required to comply with crash requirements at the same level as **robotaxis** driving in a different environment at high speeds."*

GRVA working group deals with safety provisions related to the dynamics of vehicles (braking, steering), Advanced Driver Assistance Systems, Automated Driving Systems and well as Cyber Security.

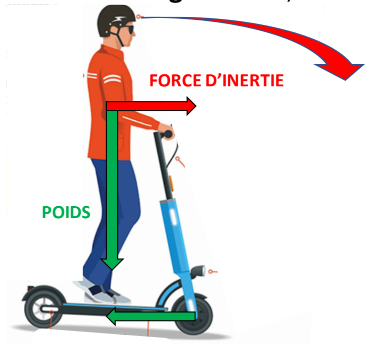
From H2020 AVENUE point of view, **both categories are necessary** among automated shuttles:

- **URBAN shuttles**, Automated Minibuses dedicated to city usage, at low speed, with limited accelerations and decelerations.
- **LIAISON shuttles,** Automated Minibuses able to join suburbs to cities, at higher speed, with passengers seated and belted, with same level of crash requirements as conventional vehicles. The wording LIAISON has been selected, as this type of vehicle should be able to satisfy also rural needs.

2.2.3 Goal description on selected parameters

<u>Sum-up of dynamic performance:</u>

Over 3 m/s², braking is considered by shuttle passengers as strong and **uncomfortable**. **Over 5 m/s²** in a shuttle, that's considered by passengers as "harsh braking" with **risk of dangerous falls inside the vehicle**, even when seated, even if cars are able of 9 m/s^2: the current seats of the demonstrators are not designed for such usage, and the belts have been shortly resigned to improve restraint of human bodies.
Over 3 m/s^2, it is also **a challenge for some following vehicles**, like electric scooters…



They are now accepted in the streets among cars by the public authorities in some countries, but their usage is risky, because of their ability to change direction without blinker information, and because of their **low stability coming from a small wheel diameter associated to a very high centre of gravity**…

- For **urban shuttles**, the goals should be **30 km/h** which is the future general limitation in towns, and **3 m/s^2** could be the best trade-off in terms of **acceleration and deceleration**. These shuttles are able to detect their environment (pedestrian area, density of street users, …): it will be possible **to limit automatically the speed** to 20 km/h and 10 km/h **when surrounded of pedestrians**…
- For **liaison shuttles**, the ambition has been increased as passengers should be correctly seated and belted, in vehicle platform reusing the standards of the car industry: a feasible goal should be now **60 km/h** and **7 m/s^2** as an acceptable trade-off in terms of acceleration and deceleration.

Safety & service quality goals:

To make it feasible, an acceptable level has to be obtained for market introduction, with commitment to **reach quickly the public transport standards**, when measured with the same tools, through the PTA coordination: the comparable transportation services are buses and coaches, with excellent results in terms of passenger safety, especially in case of an accident (passive safety in the heaviest vehicle): **this ambition is shared between urban and liaison shuttles**, but the technical levers are different.

The necessary improvement process has to be quick and reactive to **avoid any rejection**: a communication on the improvement process will probably be necessary, which means that the AM business organization has to include the improvement process from the beginning, at an international level.

The priority is to **formalize the different safety goals**, as it is structuring to define the relevant technology, embedded on the vehicle, but also for the connected infrastructure.

The quantification of such goals is discussed in the safety requirements section (chapter 9), as it will be measured in terms of deaths or injuries, where passive safety is the second barrier, behind active safety. All accidents will not be avoided, as they often result from external situations, depending from other road users, **sometimes without solution to avoid the accident**, because of physical laws…

Regulation and costs:

The first point has been be to define the requirements in terms of accessibility for all, and passive safety, in relation with the vehicle dynamic performances: a wheel chair can enter using an automatic ramp, and it can be maintained in case of harsh braking by a special belt (like the Q'straint system, for example).
Another vehicle key point is the **coming acceptance of distant interventions** to avoid the cost of a physical safety driver, which is now probable (as discussed and recommended in D9.1), so introduced as a goal:

- Revision of the **Vienna convention** (Art. 1 and 34bis), on the way (entry into force scheduled on 14 July 2022) and adoption at UNECE level of a new legal instrument on the use of automated vehicles in traffic.
- New **local regulations**, defining associated responsibilities: it has been done in France and Germany. The EU Commission is working on a draft implementing regulation regarding automated driving systems.
- **Technical solutions** (connection, visibility, actuators…) to allow distant operator to intervene safely
- Adequate **user interface** to reassure the automated minibus passengers (screen, voice…)

Cost reduction suppose that:

- such **efficient technologies** should be more **accessible in the future**
- **maintenance rules** should be close to conventional public transport standards

Regulation should be harmonized, at least in Europe: the ongoing implementing regulation shall play the requested harmonization role. Another way would be to use the vehicle certification for that, and to introduce maintenance limitations in the regulation, as it is so close to the safety requirements.

2.2.4 Goal concerning Automated Driving strategy

Service quality and performance rate depends on the **ability to respect the time schedule**, so on the ability to surmount traffic difficulties, **not to stay blocked**, because of an obstacle or because of other vehicles at crossroads. This is also one **essential condition to maintain traffic fluidity**, as cars can be trapped behind an Automated Minibus. With our experience of automation tests in real traffic, it is also necessary to **avoid brutal reactions and risky situations**.

The European Union has to take into account the **pragmatic US strategy** concerning Automated Driving, which is to be "same as a conventional vehicle" to get a **transparent insertion**:

- **Same** passive safety requirements, no reduction based on a supposed better active safety
- **Same** active management of decision making, reproducing the human behaviour

The "**human decision making"** is based on **self-learning using Artificial Intelligence**, where driving rules and local signalisation are considered as information:

❖ when a parked car limits the lane, the vehicle can try to overtake carefully…

❖ when blocked by heavy traffic at an intersection, the vehicle can move to request a path...

In Europe, **the goal is not clearly defined** between this driver mimicry and a strict application of driving rules, **putting at risk traffic fluidity and service quality**. For example, when a difficulty occurred on the defined route of an AVENUE Automated Minibus, the intersection has been changed to give priority to the public transport by addition of traffic lights on a runabout, which is not a general solution…

In the US approach, if a conventional driver is autonomous in such situation, the vehicle has to be autonomous in the existing infrastructure and traffic : *"a vehicle equipped with ADS aims to perform the entire dynamic driving task on a sustained basis within a defined operational design domain without driver involvement"* (Standing General Order on Crash Reporting | NHTSA). This way, **it is not necessary to change the infrastructure**, which is a real competitive argument. For technology observers, Japanese car manufacturers are following this US strategy.

Their proposal is to measure the performance by the number of **ADS disengagements**, which are **considered as failures, not as safety measures**: this metric has been reused by the UNECE/GRVA/VMAD and shows very different philosophies. In H2020 AVENUE experimentations, the disengagements were often decided by the safety driver before the difficulty: the vehicle is never trained to find a solution…

To justify this metric, it is explained that fatality rate is measured by billions of kilometres, which is not realistic: to bypass this issue, H2020 AVENUE project will propose an **injury safety goal**, easier to measure, especially with a **systematic reporting of all incidents**.

This is really sensitive, and the **European strategy** has to be explained if different from existing driving strategies, based on driver observation: when critical scenarios will be identified, our proposal will be to associate to each scenario a "**requested AM behaviour**", not only for safety, but also for service quality, traffic fluidity… Presented as the goal (Figure 3), the intended behaviours are not easy to define…

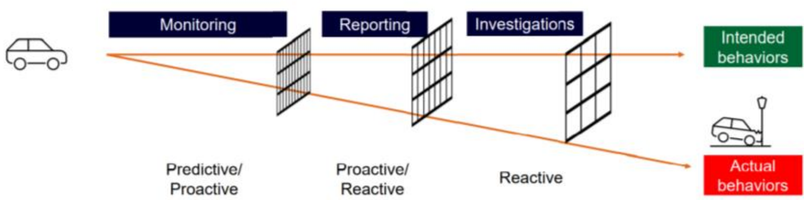


Figure 3: Intended behaviors, goal of reporting and investigations

3 Preliminary technical conditions

3.1 Connected infrastructure and cybersecurity

3.1.1 V2I, the connection between Vehicle and Infrastructure

V2I (Vehicle to Infrastructure communication) is necessary to define and **follow the missions affected to the vehicle**, but also to guarantee the **active safety** (accident avoidance): to move safely, a Fully Automated Vehicle (AV) as an Automated Minibus (AM) must continuously analyse its environment, with two main conditions requested:

- The **embedded system of the vehicle** has to include multiple and complementary sensors: the data are merged to establish a correct static and dynamic diagnosis concerning the vehicle environment, with the adequate redundancy, satisfying functional safety rules (cf ISO 26262)**.**
- In case of a visibility mask between the risk factor and the embedded sensors of the vehicle, the control system has to get the necessary information from external sources, through **a connected infrastructure**.

The second condition is particularly important for **urban driving**, as driving situations are **more complex, with multiple targets to be analysed, and high risk that some of them are hidden.**
The current technology to connect a moving vehicle to the urban infrastructure is not at a sufficient level in terms of reactivity, precision and reliability. **The standards** are not yet established, and **will have to be compatible with the future automotive standards**. The cybersecurity relies mainly on the system infrastructure, developed in WP6.

3.1.2 Connected vehicle and cybersecurity

Over a certain level of weight and dynamic performance (kinetic energy), a connected vehicle cannot be assimilated to other Connected Objects, connected together in the Internet of Things (IoT): in case of aggression, a car can be considered as a "lethal weapon", and **a connected car can be considered as a " distant lethal weapon"**, like some military drones: 2500 kg at 60 km/h = 21 000 Joules accumulated. The **cybersecurity** has to be **at highest levels** to avoid any risk of misuses, as terrorism.

In H2020 AVENUE, recommendations have been established by the WP6 in terms of norms to be applied, but also in terms of assessment methodology: **technical solutions are available**.
In parallel, **many organisational issues have been identified**:

- Difficulties to **get the information** from the different actors contributing to the same service
- Many norms and redundancy can lead to **costs and difficulties if all have to be satisfied**
- Cybersecurity norms are **not regulations, and GDPR regulation** is often used to hide data
- The economic competition installs a **secret culture, to be balanced by a regulation**

As a conclusion on today situation and perspective, nobody will be able to certify the cybersecurity level without **a regulation and a trusted organisation** to get the information, to evaluate solutions and to certify that the level of protection is sufficient, at least that it is at the right level.
It should be internationally organised (like nuclear risk management), at least at European level.
In the system design approach, **cybersecurity is one part of the reliability,** a very sensitive part.

3.2 Reliability

The behaviour of a reliable system has to be **predictable**, which means that the **functional behaviour is well defined and guaranteed.**

This demand is behind service quality and safety, but **fundamental.**

3.2.1 Infrastructure reliability

The urban infrastructure is particularly diverse and closely occupied, with multiple crossings and disturbances, which can be partly circumvented by a defined route (some experimentation cases), but this is not compatible with a real on-demand service.

The robustness of the transportation service (for quality and safety) suppose that the connected **information will be always available, with a repeatable and acceptable delay.**

As a conclusion, a reliable infrastructure has to be harmonised, with adequate technology and sufficient equipment level, which is more detailed in the D9.4 deliverable.

3.2.2 Vehicle reliability

The road vehicle **State of the Art** (SoA) for safety has been established by the automotive industry, with the associated **functional safety international norm**, named **ISO 26262.**

This risk classification defines the **Automotive Safety Integrity Level** (ASIL) **for road Vehicles**, which is an adaptation of the Safety Integrity Level (SIL) used in IEC 61508 for the automotive industry: this classification helps defining the safety requirements.

There are four ASILs identified by the standard (ASIL A, B, C, or D): ASIL D dictates the highest integrity requirements on the product. The ASIL level is established by performing a risk analysis of a potential hazard by looking at the **Severity, Exposure and Controllability** of the vehicle-operating scenario.

The safety goal for each hazard is resulting from the ASIL classification.

Some Hazards are identified as QM (Quality Management), which means that **the ISO 26262 covers for safety and quality,** as requested from this Deliverable: it can determine if the vehicle can be declared as **reliable**, which means that the functional behaviour is well defined and guaranteed.

As the annexes of the German ordinance (AFGBV) are referring expressly to ISO 26262, t**he AVENUE assumption is confirmed: ISO 26262 will be applied** for future automated minibuses. No specific work has to be done on that subject in AVENUE, to concentrate the technical effort to specific needs.

A priority has been given to SOTIF requirements (Safety Of The Intended Functionality, ISO PAS 21448), to get a sufficient **robustness in face of human behaviour diversity, and in face of different situations,** for example meteorological conditions, as a city transportation service cannot be cancelled because of the weather, like sometimes done for flights.

3.3 Maintenance requirements

Behind the functional safety analysis, **there is always a maintenance assumption**.

The current situation shows a huge gap between conventional vehicles for public transportation and automated minibuses needs. **The conventional maintenance standards are not applicable to automated minibuses**, which is understandable because of sophisticated external sensors.

A trade-off will be necessary, which has to be defined transversally, as Public Transport Operators (PTO) can use different vehicle types.

AVENUE recommendation is that **maintenance requirements** would be governed by specific rules **in the vehicle certification process**, in order to ensure that certified vehicles will be really safe and compatible with the requested quality of the transportation service, when operated by a PTO.

4 Risky situation collection

The robustness of a service in terms of safety or quality has to be evaluated in front of the **future risky situations**, which are not known, yet. They **have to be urgently collected**, firstly with a theoretical approach, secondly with experimentations, and finally during the real and totally representative service.

4.1 Experimentation: beside public transport

These experimentations are **not totally representative**, in terms of performance but also in terms of customer behaviour, as the service is free during experimentation.

In addition, the demonstrator nominal behaviour was scalable, not totally defined and guaranteed, a technical subject which was outside of the project scope: to be solved by ISO 26262 application.

The data collection process was not in place during the first project phase, and usable data was missing for the safety analysis: it has been done in WP6 (dedicated to Safety, Security and resiliency evaluation), but **limited by the available data** shared among AVENUE partners.

Therefore, **WP6 has combined available data analysis with a theoretical approach** of Safety Of the Intended Functionality (SOTIF, ISO PAS 21448 complementary to ISO 26262), in line with the new road safety standards, already applied in the automotive industry.

4.1.1 Theoretical approach

Field data collection:

Data collection aims at identifying situations which currently pose problems, but also emerging problems, which will cause concern in the future. To identify new situations, **it is recommended to put in place a continuous monitoring**, where data are registered for **analysis in case of incidents**, when the behaviour is not normal. All data can be useful for analysis, which means that **data have to be protected, and analysed by trusted organisations**.

<u>**Scenario building:**</u>

To satisfy the needs for Automated Driving development and validation, standards have been developed to **structure a scenario catalogue, with three categories** (Menzel, Bagschik, G., & Maurer, A. M., 2018):

- <u>Functional Scenarios:</u> high-level description of **a safety-relevant situation**, which can be extended to a service quality issue. It describes the actors, the environment and the overall timeline/steps of the situation: it can be documented as a pictogram and a textual description.
- <u>Logical Scenarios:</u> they describe in a **quantitative manner** a functional scenario, and list the variables/parameters of interest and the range of values that each of them can take. A logical scenario ideally provides **distributions for each parameter** and multivariate distributions between parameters, to account for inter-parameters correlations.
- <u>Concrete Scenarios:</u> they are **a specific instance of a logical scenario**, associated with the corresponding parameters values. Generally, they are actual measured events or specific runs of a simulation. Based on accidentology and biomechanics, **a level of risk** can be associated.

The associated scenario referential is now international, and can be extended to incidents impacting the service quality, to feed the quality improvement process.

4.1.2 Experimentation data analysis

Such databases are generally massive and heterogeneous, as gathering data coming from different sensors or technologies, as video.

A toolchain was developed for that, and used for H2020 AVENUE project: this toolchain could be applied and used at a much larger scale than what was possible given the limitations of the data collection process.

According to AVENUE experience, harsh braking and disengagements are not sufficient to qualify incidents: an iterative process will be necessary to **improve smart filtering of the interesting instances**.

The raw data include personal data, which have to be protected, but the associated deliverables have to be anonymised, at least pseudonymised: this way, they can be used by a high diversity of actors.

To be usable, these deliverables have to **explain clearly the chronology and the links between causation and consequences, which means structured as a scenario** for:

- Lesson learnt to PTOs, vehicle manufacturers…
- Infrastructure improvement
- Regulation optimisation

4.2 Service included in the public transport

The organisation to include the automated minibuses in the public transport system will be more detailed in the D9.3 deliverable, targeting a sustainable urban mobility ecosystem.

We have recommended including in this organisation a **systematic process to capture available data in case of an incident** (maybe an accident). Such data include personal data, so it has to be protected and analysed only by trusted experts, under Public Transport Authorities' control.

The upcoming EU Regulation 2019/2144 provides that all new vehicles in the EU will have to be equipped with a so-called "**Electronic Data Recorder**" ("EDR") by 6 July 2022, but specific requirements will have to be added to EDR to cover all aspects of automated minibuses (automatic doors, public transportation…) and service quality.

The current EDR regulation is targeting automated cars for personal usage, and mainly for safety: this EU regulation 2019/2144 focuses on collection of data related to collisions, but not to "near collisions", which are also relevant for the automated minibuses safety and service quality. In addition, it does not provide information regarding the proceedings of how the data will have to be shared.

The format of the collected data can be different on each operating site, depending on vehicle manufacturer or PTO, but **the feedback format has to be standardised in terms of scenario description**. Such formats already exist for accident risk, as libraries are under construction to prepare car safety auto-certification process, based on simulations (ex: MOSAR in France).

This approach can be extended to other risky situations, specific to automated minibus usage, for example in terms of automatic door closing, fight between passengers, vehicle blocked by external actors, …

Doing so, **the approach will be adapted to automated minibus needs, and extended to service quality** issues, to improve both safety and quality, and not only for the local application.

5 Data availability and privacy

5.1 Normal process, transport management

With their multiple sensors, automated minibuses will be natural data providers, including video and localisation, but such raw data include personal data, and their usages are restricted.

Normal usages are:

- **Vehicle manufacturer**: to get information concerning vehicle operation, identify failures, repair the vehicle, improve the products…
- **Public Transport Operator and MaaS organisation** (data & service platform, service aggregator): to get information on vehicle usage, to inform their customers, and to check the operations
- **Public Transport Authorities (**City and agreed stakeholders): to evaluate the transports needs and possibilities, to coordinate the operators

Among these usages, the customer relationship (between PTO and service users) requires personal data: it is a common and already regulated situation, with known firewalls, based on customer coding. This management system is fundamental in terms of service quality, but do not differ when the service is offered with a human driver, already in place.

For normal usages, it is recommended that data are filtered and pre-treated in the vehicle, to limit the exported data: it limits the GDPR risks, but also the energy consumption for data exchange, which is a risk concerning CAV environmental impact (cf D8.5).

5.2 Incident process, data protection

5.2.1 Data collection, only when necessary

The absence of a human driver introduces new risks in terms of vehicle safety and passenger behaviour: to manage these new risks and to avoid bad incidents which could lead to a rejection of the solution, it is necessary to **add a specific process when an Incident occurs (**Figure 4**).**

An Incident will be defined as **a situation that could compromise the safety or the service quality**, and lead later to a rejection, most probably to expensive corrective actions. It can be an accident, but also a harsh braking, a difficulty to close the door, a vehicle blocked, vandalism facts, an aggression…

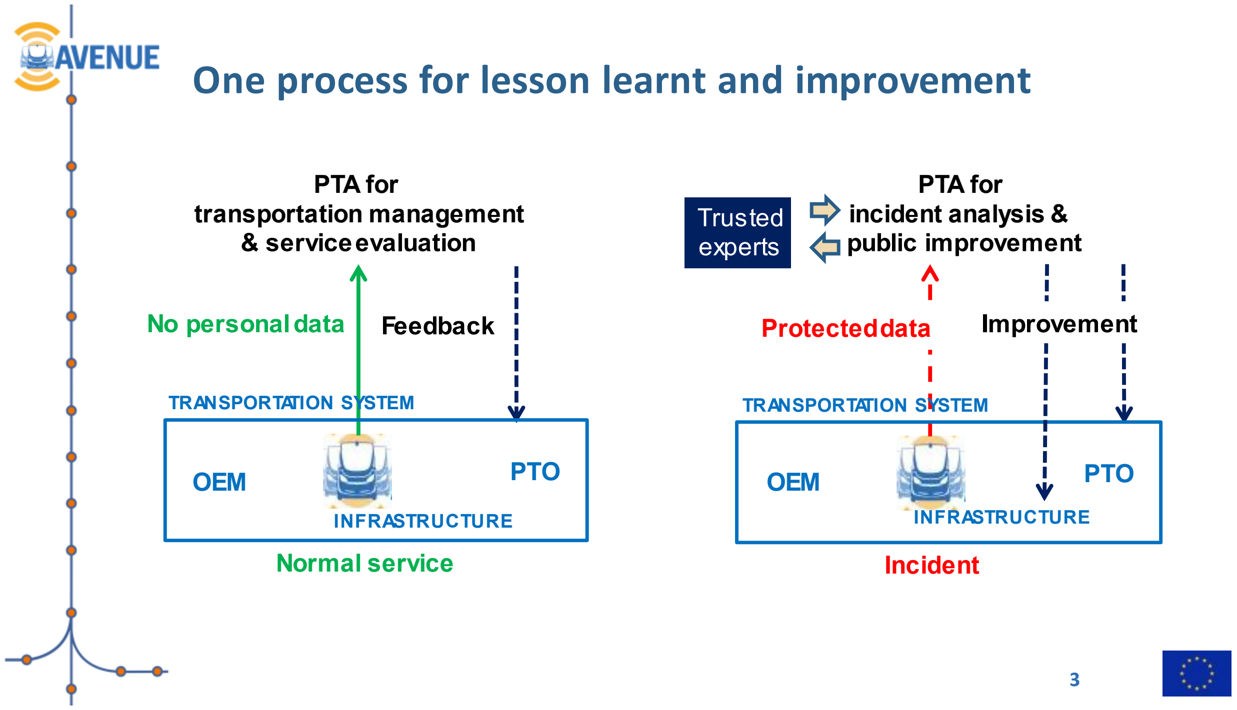


Figure 4: Data collection process in case of incident

5.2.2 Lesson learnt and improvements

The PTA lesson learnt process would be the biggest improvement loop (Figure 5):

1. **Capture** on the vehicle **all available data** concerning the time sequence before the incident
2. **Create a protected file** (with some personal data) to be exported to PTA, habilitated for that
3. **Affect the treatment to a trusted expert** giving guarantees concerning such personal data usage
4. **Request from** this expert a systematic and scientific **analysis** of the available incident data
5. **Formalise the lesson learnt** for feedback, without any personal data, as not useful for that
6. **Organise the feedback** circuits, to be able to get corrective actions from all implicated actors
7. **Disseminate the lesson learnt** to feed the European reflexion for new regulations

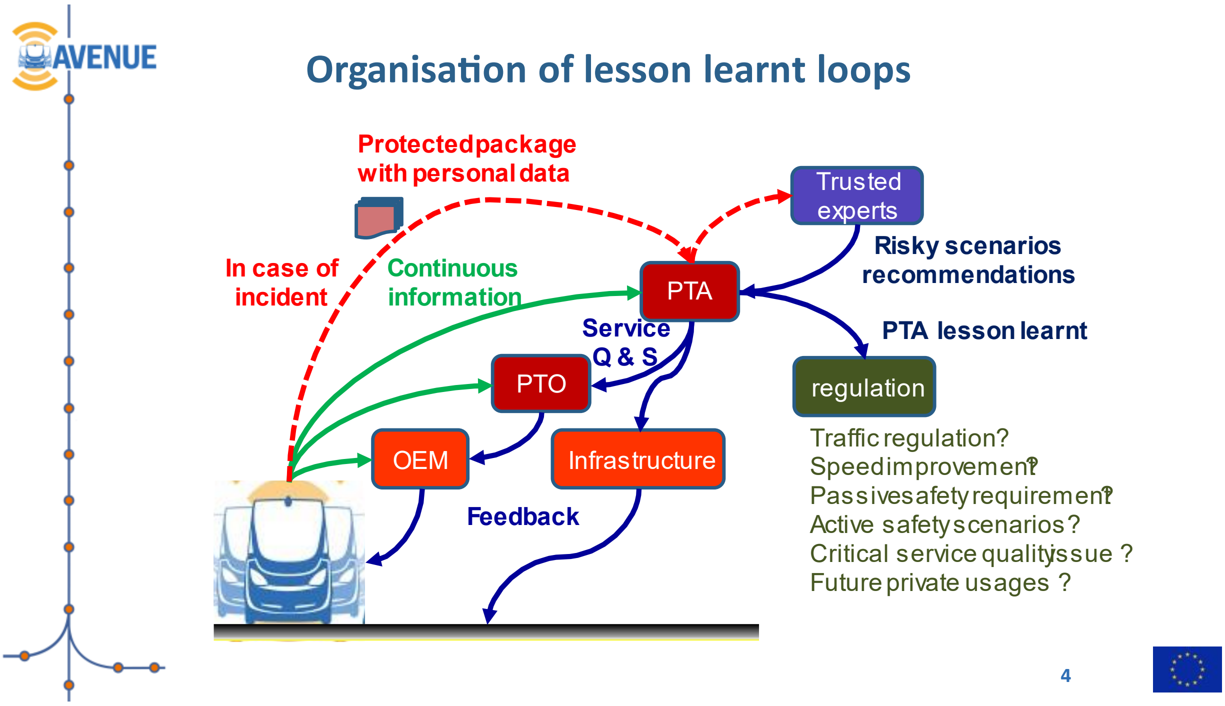


Figure 5: Lesson learnt process for anonymisation and sharing

The trusted expert **organisations have to be defined previously**, for example among organisations giving such guarantees of professional secret for road accident analysis.

5.2.3 Trusted organisation authority

As explained for cybersecurity assessment, a specific international organisation is also necessary, but it can be only **a coordination of the trusted organisations existing for road safety improvement** in each country, which specific agreements to get and to analyse accident data.

The required skills are not new, already necessary for road safety, and not so specialized as for cybersecurity.

The lesson learnt are anonymised, risky scenarios are modelized, with aim to be used for specification, design, integration, validation, but also auto certification, based on numeric tests, realised on a shared scenario benchmark.

This coordination for **road safety** already exists at European level, but should be improved: **Automated Driving** is both for road safety, **a risk but also an opportunity in terms of European coordination**.

6 Data trusted analysis, lesson learned

6.1 1rst step: tests beside public transport

This is the first step, done in the H2020 AVENUE, project which has given a **priority to Safety**, with a WP6 dedicated to the Safety, Security and resiliency evaluation.

These analyses were driven by CEESAR, a trusted research team, already equipped with tools and methodologies for road safety, habilitated by the French government for **road accident lesson learnt**, as a no profit research laboratory dedicated to road safety improvement.

The technical process, skills and tools necessary for AM service evaluation and improvement are similar (Figure 6**)**, with same difficulty to respect GDPR on data collection and analysis, if it is not organised in the system design phase.

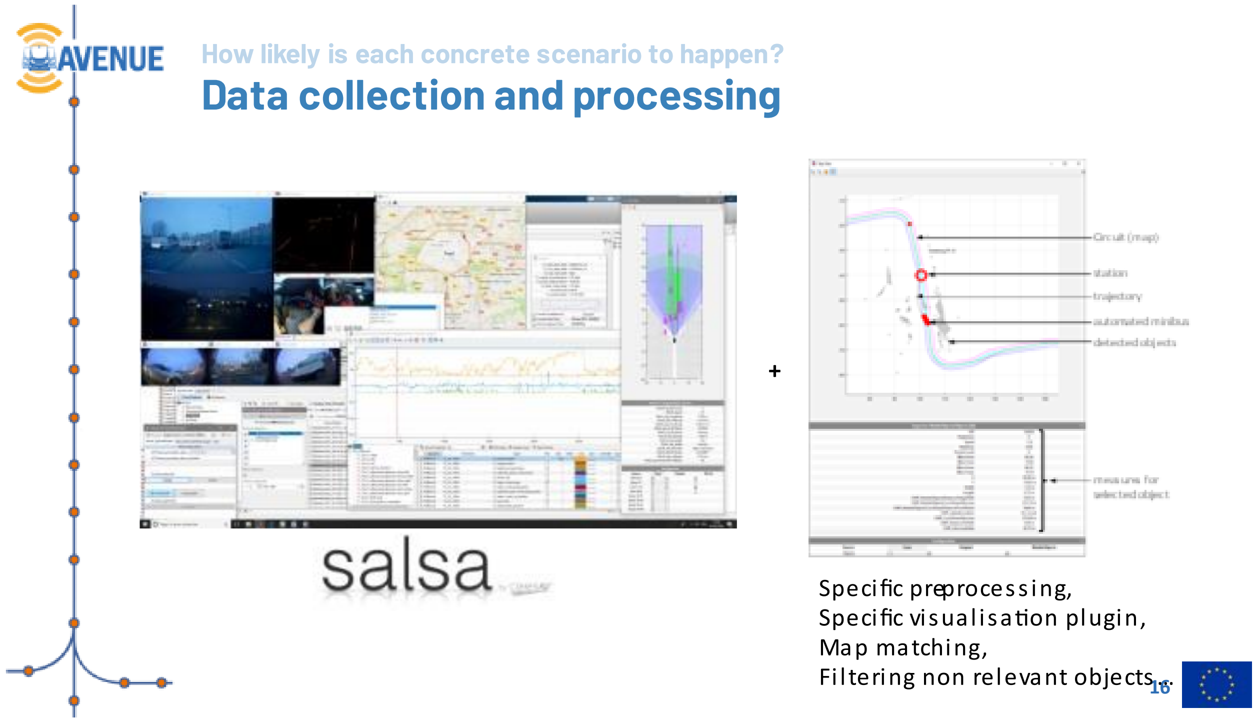


Figure 6: AVENUE data collection and processing with SALSA

Nevertheless, **available data** from NAVYA shuttles **has been limited to samples**, giving the opportunity to demonstrate tools and methodologies, and to deliver some **lesson learned and recommendations**, mainly based on theoretical analysis.

6.2 2nd step: service included in the public transport

During a coming project, the service will be really included in the public transport, when **paid by users and based on certified vehicles**: this is an opportunity to guarantee that **automated minibuses** will be good **data providers**, in terms of necessary data availability, but also privacy.

For that reason, **a trusted partner should be in charge of such analysis**, so this new project will establish a 2nd step towards the future organisation, with **new lesson learned**.

6.3 Market introduction, commercial applications

The target is to accelerate this real introduction of automated minibuses in the public transport system, but the regulation framework has to be established before the market introduction, with many points to be controlled, especially through the **certification requirements for this new vehicle type**:

- As well as active safety requirements, maintenance level and communication protocols, **we recommend that data protection and export control would be taken into account in the certification rules** for this new European type of vehicle.
- The timing constraint will come from **passive safety requirements** (pedestrian impact and passenger protection), as it is structuring for the vehicle design, especially for the vehicle platform, which could be specific…

Commercial applications will contribute to the continuous improvement, with best efficiency as all lesson learned will be anonymised and shared.

7 Safety validation and certification

7.1 New Assessment Test Method for AD

At the 178th session of the United Nations Economic Commission for Europe (UNECE), a working Group has been mandated to create harmonized **Validation Methods for Automated Driving (VMAD),** targeting future vehicle regulations.

VMAD developed a **New Assessment Test Method (NATM)** framework for validating the **safety of Automated Driving Systems (ADS)**: the 2nd version was submitted to the 185th session, in November 2021. This method has to be **repeatable, objective and evidence based**, while remaining **technology neutral.**

The **multi-pillar approach (**Figure 7**)** is based on **scenarios** describing real driving situations in the Operational Design Domain (ODD), available for **virtual and track testing,** completed by **real world testing,** with **audit procedures** and **in-service monitoring with systematic reporting.**

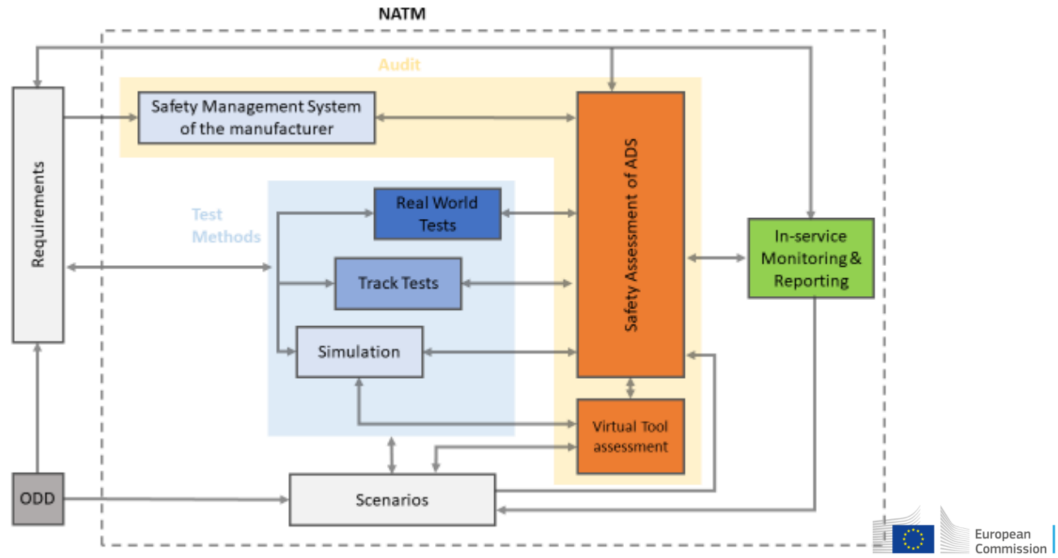


Figure 7: The European multi-pillars approach for ADS validation (NATM)

This **scenario-based validation covering the ODD** consists of reproducing specific **real-world situations that exercise and challenge the capabilities of an ADS**-equipped vehicle to operate safely.

In-service monitoring with **Event Data Recorders (EDR)** give in-service data for safety, which has to be considered as a global concern, with **systematic accident reporting**, as done with the ECCAIRS application for Aviation in Europe: **European Coordination Centre for Accident and Incident Reporting Systems**. These relevant data leads to **risky scenarios and safety recommendations**, which have **to be shared** in a common-centralized repository, for the global **improvement of safety and service quality.**

The **scenario coverage** is difficult to guarantee, and **requires real word observation, lesson learned collection and catalogue enrichment,** especially for Automated Minibus as it is really new usages, to be discovered: share information, confirm safety assessment, and **feed scenario catalogue** (Figure 8).

The scenario catalogue that should be considered for validation (also for specification, before design, for the vehicle and for the infrastructure) **can be reused for auto-certification.** It has to be **sufficient for market introduction**, and **based on real-world tests**, which will come after H2020 AVENUE project.

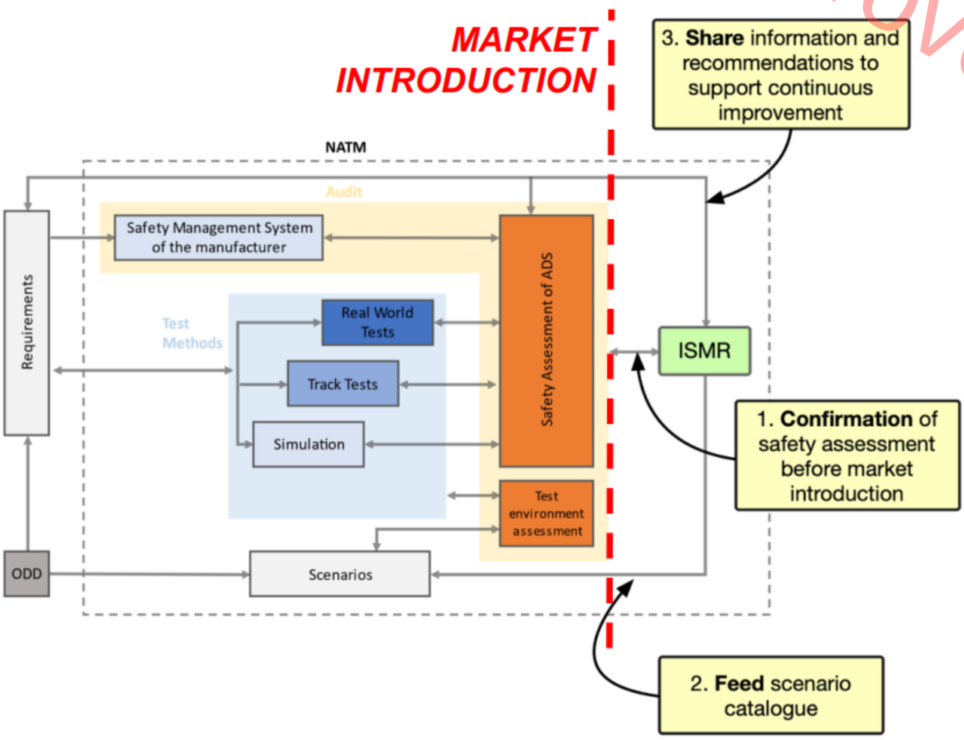
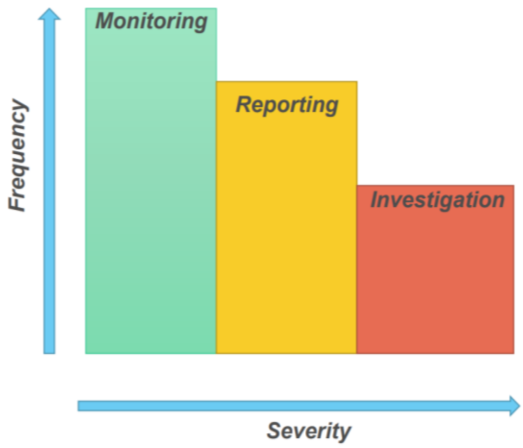


Figure 8: Market introduction and in-service monitoring

As proposed by AVENUE, 3 "legs" are defined for different levels of severity and occurrence (Figure 9):

1. **Normal service**: internal monitoring, data collection for internal analysis (PTO, OEM…)
2. **Incident**: reporting of occurrences, for shared lesson learned and service quality improvement
3. **Accident**: reporting for investigation, scenario reconstruction and safety recommendations



Process	Focus
Monitoring	Overall Data collection and analysis
Reporting	Critical and not critical occurrences
Investigation	Critical occurrences

Figure 9: The three levels of incident monitoring

The criticality level of a scenario is obtained by combination of severity and frequency, generally called "gravity x occurrence" for accidentology.

7.2 Application to Automated Minibuses

Automated Minibus is a difficult application of these principles for two main reasons:

1. It is a **fast pace of innovation with limited funds** compared to the car industry
2. The **scenarios are more complex**, in terms of human interactions

In an **Automated Minibus**, the situation of passengers has to be considered at the same level as vulnerable road users outside, because of the "**trolley dilemma**": *is it possible to choose between a harsh braking with injuries inside the AM, and an accident against a vulnerable and imprudent pedestrian or cyclist?*
We have to minimise the global risk (Figure 10): as the two risks (passenger and pedestrian for example) are going in opposite directions, it is fundamental to evaluate the **injury risk curves** by calculation, with Human Body Models able to support quick dynamic calculation (e.g. GHBMc, for example).

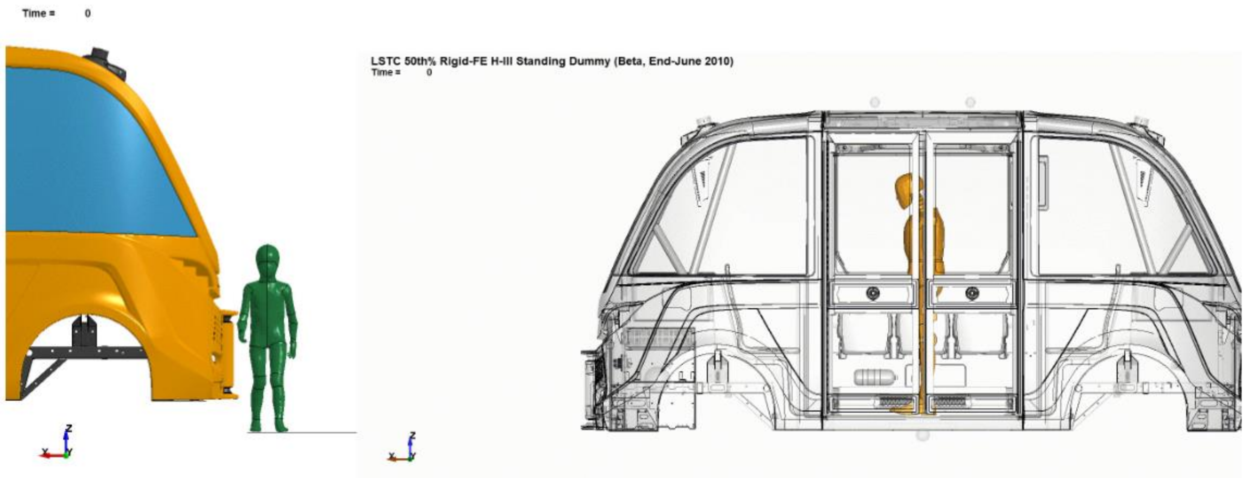


Figure 10: Dilemma between a vulnerable and a standing passenger

For main lesion scenarios, **the criteria and injury risk curves have to be defined**. They are based on real human body characteristics, with statistical mechanical limits to be established from PMHS (Post Mortem Human Subjects) experimentation, using the "**body donation to science"** (shared international results).
In addition to this dilemma and to these specific lesion risks, this **Automated Minibus usage is totally new**, and the real world of an Automated Minibus service in urban public transportation has to be **observed from the blank page:** AVENUE experimentation is only the first step…
In the car industry, the Functional Safety is mastered (ISO 26262) and SOTIF is only complementary. In comparison, the Automated Minibus **Functional Safety is not yet mastered**, (ISO 26262 to be applied) **and SOTIF is the major challenge:**

- The **ISO 26262** standard has to be required, and **will be mastered** if requested
- The **SOTIF** (ISO/PAS 21448) has **to be applied before and after** market introduction

This SOTIF work has been only initiated during the H2020 AVENUE project, with **incident forms, scenario referential and data samples to test tools and complete theoretical analysis, to get recommendations** based on recorded situations like:

- Avoid parallel parking along AM path…
- Adapt the speed to the human context…
- Be careful, but not hesitant…

Tools and methodologies (Figure 11) exist and are **now validated for Automated Minibus applications**. After the EuroFOT experience, they are coming from developments initially done for example:

- For Naturalistic Driving (ND) projects as UDRIVE (European FP7) and MOOVE (VEDECOM), especially salsa .
- For scenario libraries as MOSAR and ADScene (**A**utomated **D**riving **Scen**arios), financed by the French public power and by the car industry.

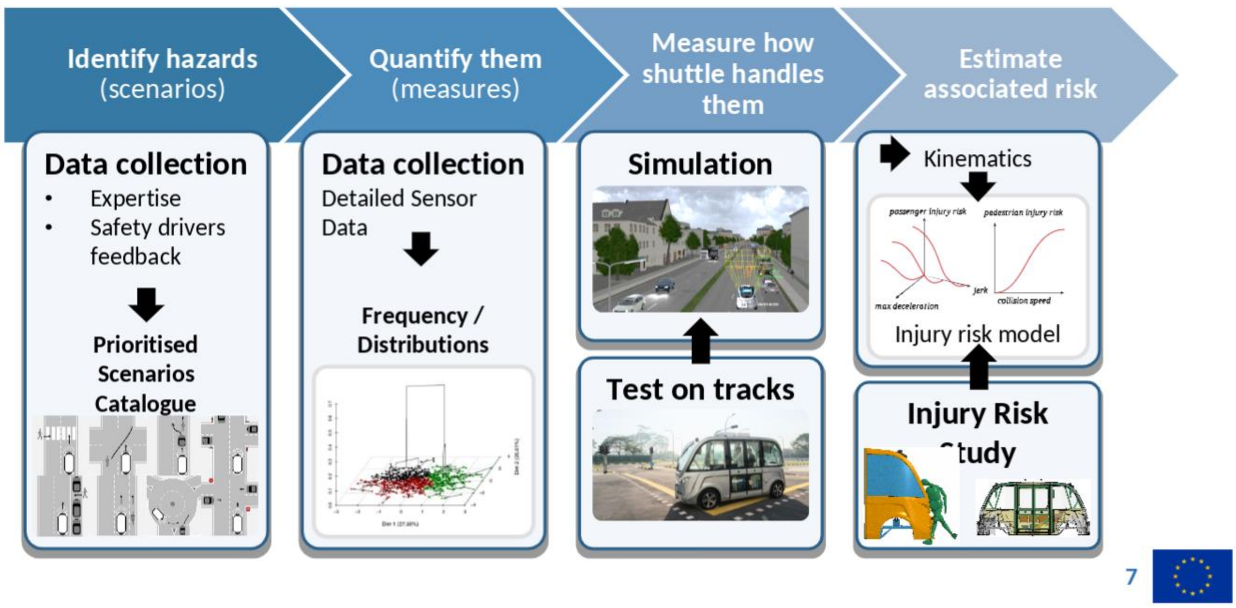


Figure 11: Automated Minibus safety evaluation methodology

In the scenario catalogue, **prioritized scenarios are coming from occurrence and severity analysis**, based on accidentology pictograms to establish the typology, in terms of initial situations and potential impact position (Figure 12):

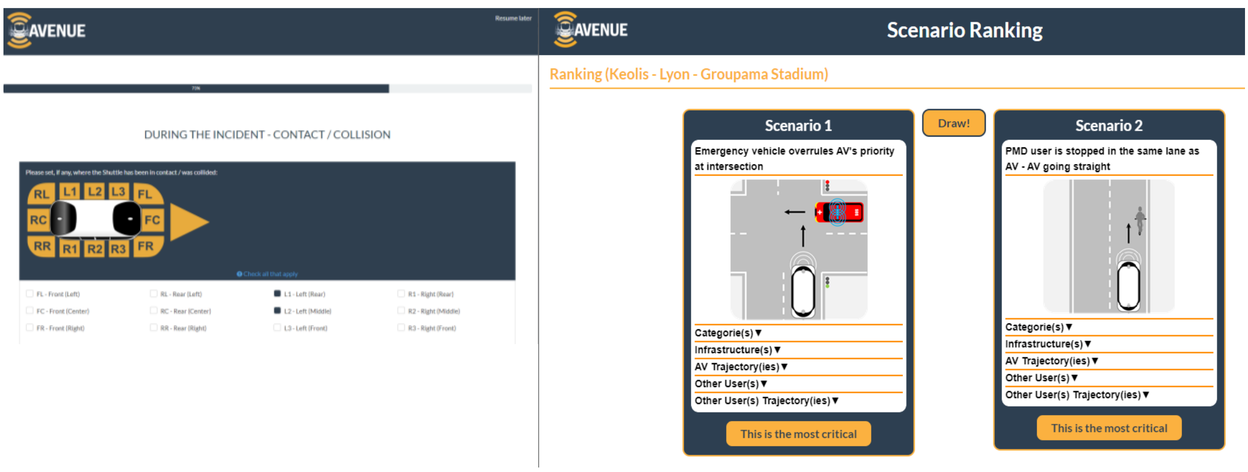


Figure 12: General scenario ranking and incidents database

For **each application site**, the most critical (gravity x occurrence) **scenarios are different**, as presented Figure 13 for H2020 AVENUE:

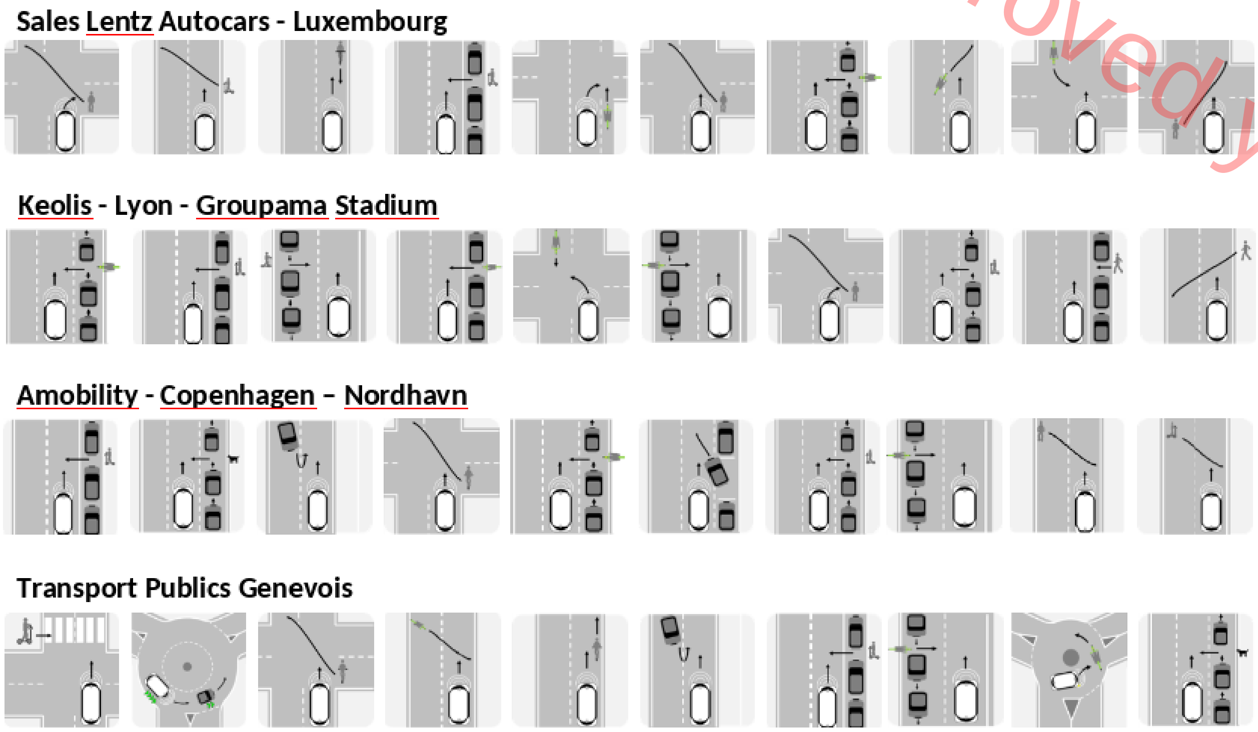


Figure 13: Scenario ranking for AVENUE demonstration sites

8 Public power role and needs

8.1 Sensitive personal data for different usages

The mobility or Public Transport Operators (PTOs, public or private companies) have a public mission: **their business and responsibility is under delegation and control of a Public Transport Authority (PTA).**

The AVENUE project recommends that a **public organisation** would be formalised **to coordinate the public automated transport**, but also to be able to collect and analyse sensitive data, as personal data become sensitive when related to a severe accident, or to an aggression.

The need is similar to **road accidents**, where **two processes are necessary for the public power**, juridical treatment and road safety improvement, based on same data (Figure 14):

1. A **juridical process** in case of a severe offense, where responsibilities and liability have sometimes to be established, later…
2. A **scientific lesson learnt process**, interested by causation, to be differentiated from responsibilities and liability questions: this process should be qualified as performing a task carried out in the public interest (1rt paragraph from GDPR 6th Article).

To satisfy these two needs, habilitated organisations are generally defined in each country to analyse such data: this gives solutions to build lesson learnt, which is particularly necessary in our case. To optimise the work, we recommend to standardise some inputs for the two processes, for example examination report, infrastructure map, phasing structure, vehicle dynamic… **A common need is to understand the scenario.**

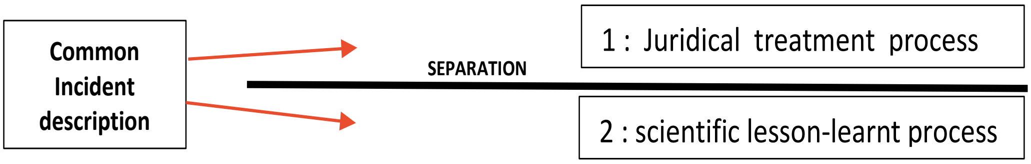


Figure 14: Process separation based on same incident analysis

As defined under the privacy protection framework, **the lesson-learnt process has to be separated from the juridical treatment**, but the incident description can be shared to reduce the costs and to improve the robustness of the two processes.
Trusted organisms are defined separately for juridical treatment (insurance companies, justice organisation…) and for scientific analysis (non-profit research organisations, with data protection guarantees).

The **right for different parties to access to accident police reports** is already defined in the various laws of the Member States. In France, the penal code defines the authorities and organisms in charge of scientific research on accidents or in charge of the compensation of road victims: they have full access to accident data, and professional secret to protect personal data.

The French target is described here (Figure 15), as an example to explain how **GDPR can be managed to satisfy separately juridical or legal needs** (including personal responsibilities) **and scientific needs** (including human causes) to be able **to improve road safety**, in our case, user safety and service quality.

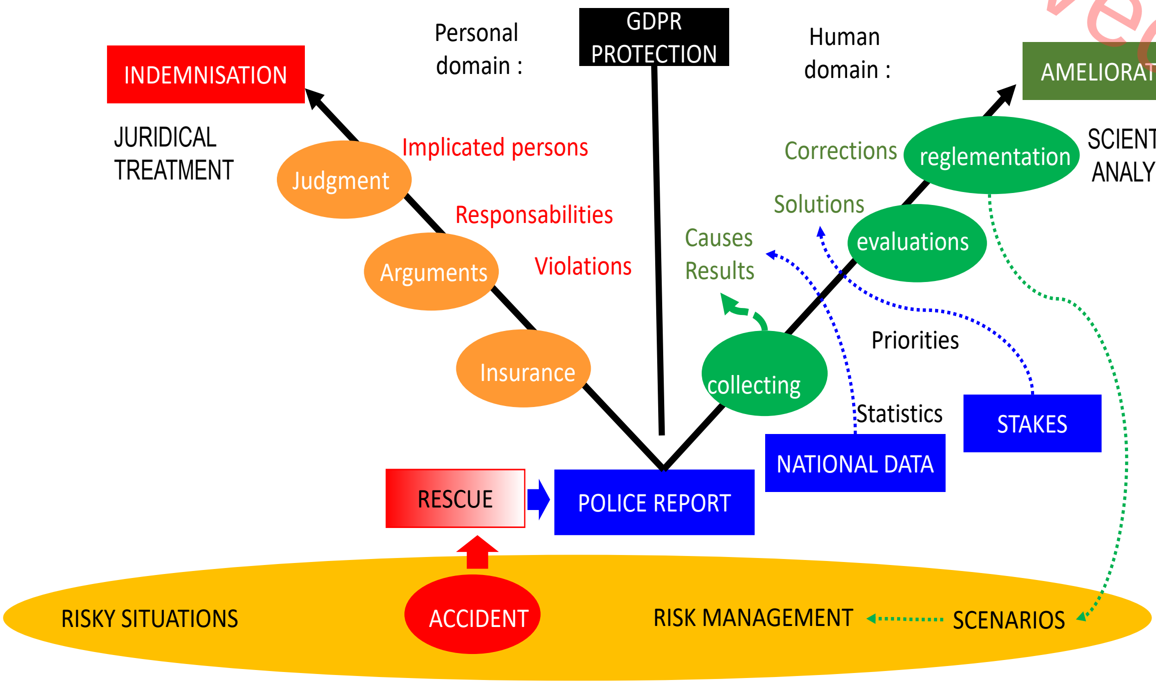


Figure 15 : Existing application for road accidents treatments in France

<u>Explanations of figure 15:</u>

On the road, in the streets, risky situations can lead to an accident.

In case of a corporal accident, the priority is to rescue injured persons: during the accident, the police help firemen and medical teams.

After the accident, a report is established, to be used in case of a juridical treatment, but also to be used for lesson learnt, when it is interesting for road safety improvement. In the future, this report will benefit from EDR data, collected from recent vehicles under the new regulation (EU Regulation 2019/2144): it is complementary.

Using these reports by coding, a national database is established (BAAC) to observe road safety statistics, and to define main stakes for the future. This good practice is shared among the European countries.

Research organisms can get main causes and main injury consequences from national data, but also from data collection, in the field.

With such information, they are able to identify and to evaluate solutions, locally or not.

To improve road safety, the necessary corrections have to be implemented in the regulation, at least in new standards or norms.

The accident report can be used for both legal treatment or scientific analysis, but the two domains are separated:

- On one side, that's **personal** evaluations of **responsibilities**, including law violations
- On the other side, for system analysis, a person is an example of **human behaviour**.

This approach is validated and can be easily extended to incidents, to improve safety, but also service quality, as it will also depend on human behaviour, and law respect (vandalism, aggression, door blocking…).

A centralized EU platform has been requested by insurers, for accident technical analysis:

“The results and findings of manufacturers, suppliers, technology companies and insurers on the topic of autonomous driving [should be] collected internationally and exchanged with each other on an independent platform - both vehicle and system data as well as accident data."

It can be created as a web gathering habilitated organisms. If able to work with the local language (English recommended) and recognised by the other PTAs in Europe, these habilitated organisms can work in different countries **to establish robust lesson learnt**.

8.2 Extension of the applied organisation

As proposed, the necessary organisation can **reuse what has been done for accidents**, to be extended for the automated minibuses to **all incidents justifying a lesson-learnt**.

When this service will be totally mastered (safety and quality goal reached), it will be possible to limit this process to severe incidents, where a juridical treatment is necessary: in such a case, there is an opportunity to keep, to build the lesson learnt and to get improvements.

In the PTA perspective, **this extension can be pushed forward, in another direction**:
The AVENUE project considers that the automated minibus deployment is the best opportunity to introduce automated driving in towns (low speed, PTO control, public delegation…), but the PTA have also to prepare the future introduction of private automated cars in towns (on going for separate carriageway).

To do so, it will be necessary to collect the risky situations and to specify these scenarios, to guarantee the adequate behaviour with appropriate regulation.

As a conclusion, not only the automated minibuses will contribute to the urban transition to a sustainable future (Driving Urban Transition European platform), but **their efficiency in terms of data providing will prepare the future deployment of automated driving in towns**.

9 Feedback and corrective actions

9.1 Local improvement

From safety to service quality, **incidents requesting corrective actions** can be:

1. Crash against an obstacle, which can be material or lead to injuries
2. Crash avoided thanks to harsh braking (criteria used by WP6)
3. Difficulty avoided by a disengagement, controlled by the safety driver (criteria used by WP6)
4. Vandalism or bad behaviour in the minibus
5. Difficulty to close the door, minibus delayed at the station
6. Passenger standing when seats are available, not belted when necessary…

Locally, **when incidents are identified, the corrections have to be quick, to give confidence** in the improvement process to deliver safety and service quality.
This request is logical, but not so simple to implement, as:

- necessary data are not always collected, and when they are…
- confidentiality is requested, as including personal data, protected by GDPR regulation
- such data are restricted to trusted organisms in terms of access and treatment
- feedback has to be pseudonymised, pertinent and usable, a real know how

Among local actors, the users of this **local improvement loop** are the concerned Public Transport Operators (PTO), the vehicle designer and manufacturer, the service in charge of the infrastructure…

This improvement loop is bigger than the small ones, related to vehicle diagnosis for Original Equipment Manufacturer (OEM), transportation performance for PTO,… It has to include:

- Data collection and protection
- Data exportation to PTA, then to trusted experts
- Anonymisation, scenario analysis, recommendations to local actors
- Recommendations, solution research, quotation, decision, implementation

As explained by VMAD for UN/UNECE, **In-Service Monitoring and Reporting** (Figure 16) addresses the in-service safety of the Autonomous Driving System after its placing on the market: the first condition expressed is this **operational experience feedback loop**.

To be objective, this experience relies on the **collection of in-service data** (fleet monitoring) to assess whether the Autonomous Driving System continues to be safe when operated on the road and to identify safety risks.

This data collection can be used for the **identifying of real-world scenarios** not tested during the type approval, and to improve the testing methodologies and interaction between human and vehicle.

Most of all in terms of global efficiency, the associated **systematic reporting** allows the whole Autonomous Driving System community to **learn from major Autonomous Driving System accidents/incidents through information sharing**.

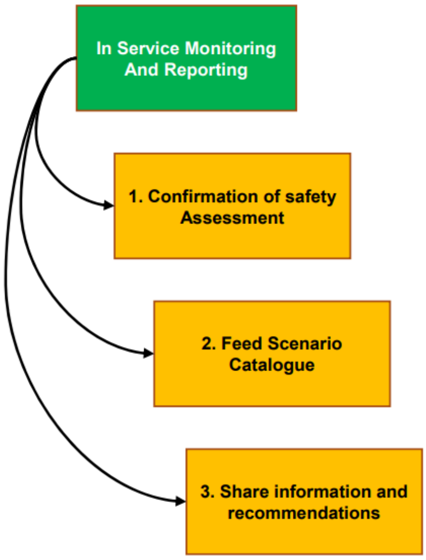


Figure 16: In-Service Monitoring & Reporting principles from VMAD

This shared lesson learned process will contribute to the general improvement of Automated Minibus services in Europe, in terms of **general safety and service quality.**

9.2 General improvement

To accelerate the service improvement, **the main lessons learnt have to be shared** among the different concerned Public Transportation Authorities (PTA), which have to be organised as an Automated Minibus Web (AMW), with a **central repository of lesson learned, recommendations and regulation projects**.
The shared information has to be restricted to the upper level, describing scenario type, associated recommendation, and solution deployed. A scenario catalogue structure has to be developed, coming from incident types, with adequate codification (same principle as accidentology standards, with numeric codes and pictograms).

A shared codification is required to build indicators, which will also allow performance measurements and comparisons to establish benchmarks:

1. Accident occurrence per million kilometre or running hour (with injury or not)
2. Avoided accident per million kilometre or running hour
3. Average time or distance between two disengagements
4. Behavioural incidents per running hours
5. Punctuality robustness, scheduling respect
6. Performance, compared to other transportation means

H2020 AVENUE should be considered a **first step of lesson learnt** sharing concerning AM service in towns.

10 Safety level requirement

Safety results are **difficult to measure and available too late** for reaction, as the Automated Minibus deployment has to **quickly reach a safety level comparable to existing means**, bus or coaches for public road transportation. To get the improvements, the Public Transport Authority will have to **use regulation**, which means that they will have to be sure that **this effort is the right one to get**, and that **it is really necessary.**

Based on the defined conditions and validated methodologies, we have now to **quantify where we have to go**, on measurable driving indicators.

10.1 Safety demonstration framework

In Europe, three pillars will support the safety demonstration of Automated Driving before regular service introduction, or more generally commercialisation:

- **Design process**, functional safety, especially ISO 26262
- **Safety tests**, physical or numeric, under discussion:
  - Crash avoidance manoeuvre, for active safety
  - Human protection in case of crash, for passive safety
- **Safety targets**, in terms of overall threshold to be respected

10.1.1 Safe by design

Road accidents are coming from **vehicles**, running on a road **infrastructure**, with **road users**, some of them protected in a vehicle, others being vulnerable.

For the future, new vehicles will be designed, the infrastructure can be redesigned or improved, but the human body (for passive safety) and the human mind (for active safety) will not be redesigned:

- The main effort is placed on the **vehicle design**, where the ISO 26262 coming from the car industry is the best reference: it will be mandatory for Automated Minibuses.
- A supporting effort from the infrastructure should be to separate different flows, but the public space is limited, especially in towns: new slogans are “share the public space”, “give place to individual mobility means” (if electric), and “take care of vulnerable users”… In reality, the main contribution will be **connected infrastructure**.
- As usual, road users will be diverse Homo Sapiens, with same reflexes and human behaviours, but also with same mechanical fragilities in case of crash, **especially when they are old,** as it will be more often the case…

10.1.2 Tested as Safe

Crash avoidance:

Thanks to Advanced Driving Assistance Systems (**ADAS**) **deployment**, some tests and tools (test tracks, moving dummies, automatically driven targets…) have been developed for car safety evaluation, under pressure from EuroNCAP.

They will be available to test Automated Minibuses, but these tests are not representative from AM needs. We have to learn new risky situations with in service monitoring.

For Automated Driving Systems (**ADS**) **development**, numerical approaches have been developed, with aim to validate technical design, not yet to certificate vehicle design. Scenario databases are under construction, but the content will be adapted to car usage, not to public transportation. The acceptance of simulation to demonstrate safety for vehicle certification is under discussion.

The target is to **reduce the number of crash occurrence**, but the reference is not known as only crashes with consequences (material, physical…) are reported (systematically in case of death).

It is like the invisible side of an iceberg (Figure 17):

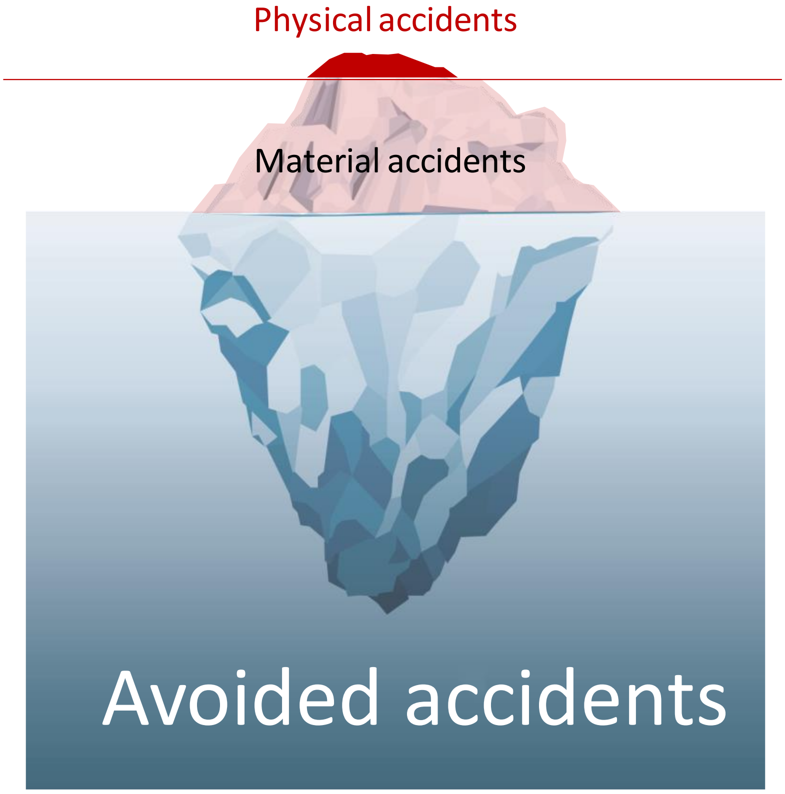


Figure 17: Importance of the avoided accidents for lesson learnt

With technical work, there is high confidence that typical accidents coming from human errors will be reduced, but **high risk that some accidents avoided thanks to human reactions will be added**: the main issue that the reservoir of avoided accidents is not known, and much bigger than the reservoir on known accidents.

<u>Human protection in case of crash:</u>

The hope of an active safety improvement calls for a **mitigation of passive safety requirements**, with possibilities to reduce weight and to choose an open architecture to allow easy entrance or exit of the vehicle.

This hope is behind the **miss of passive safety requirements** in the current assessment method of Automated vehicles: the **general safety requirements** cannot be limited to the active safety requirements, as presented today (Figure 18, 2022.05.16) by UNECE (WP29/GRVA/VMAD).

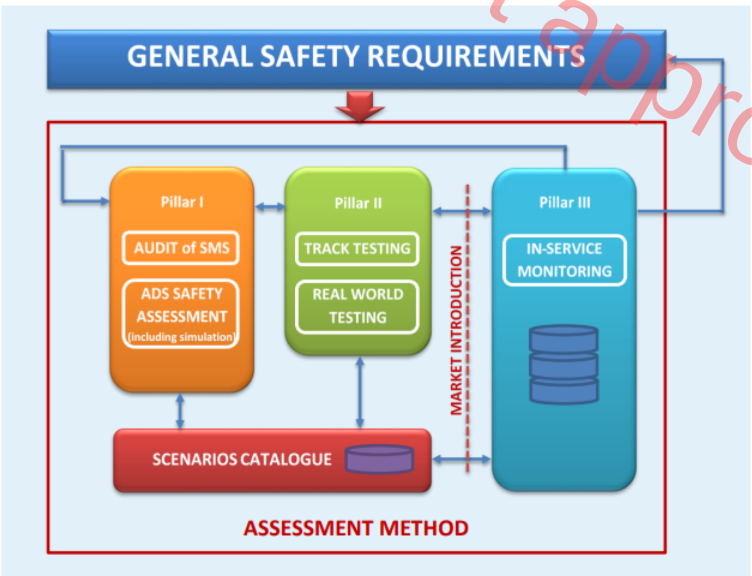


Figure 18: Assessment method for active safety, not for road safety

When looking at demonstrators, this dream has been translated in a reality, as **current Automated Minibuses are far from being compatible with existing crash tests**.
Even if their active safety performance is high, the AM will drive among a high diversity of conventional vehicles, sometimes quick and heavy, exposed to human errors.

10.1.3 Safety goals to be respected

The **safety assessment** has to be **global and based on future measurements**: to check if safety level is acceptable, we have to define **suitable and measurable criteria, with thresholds** to be respected.

- The road safety experience shows that **only fatalities are really measurable**, that injury figures have to be discussed before analysis, and that accident numbers are not known.
- The acceptable level of fatality occurrence implies **hundreds of thousand hours in service** to get a demonstration, and this service has to be representative, not a free experimentation...

As a consequence, there was before H2020 AVENUE **no evident solution coming from road safety:** the project work had to include the choice of acceptable criteria, adapted to the AM usage. In addition, the thresholds to be build and proposed will have to be feasible and consistent with the current State of the Art, to guarantee the social acceptance of such safety level.

10.2 Global road safety goals

Necessity and limitations of the Functional Safety:

The draft regulation for the European type-approval of **Automated Driving Systems** (ADS) mentions an “indicative target” of 10^{-9} fatality/hour, which is not specific: it is coming from the **automotive functional safety** target, formalised in the **ISO 26262 norm**.

In terms of functional safety State of the Art, the automotive industry estimates the current level around 10^{-8} fatality/hour, which means that the **10^{-9} target is already ambitious for fatalities resulting from a car failure**, even with the considerable experience cumulated by the car industry...

In the real word, **the car State of the Art cannot be limited to accidents resulting from a car failure**: it has to include all accident causes, taking into account the realities of driver behaviour and road infrastructure. **The reality is called Operational Safety**, and figures much higher.

<u>Transportation modes and Operational Safety:</u>

UK "Statista Research Department" published the user (occupant when it is a car, passenger or driver) fatality rates per kilometre for different transportation modes in UK, which can be considered as a good reference for road safety (Figure 19).

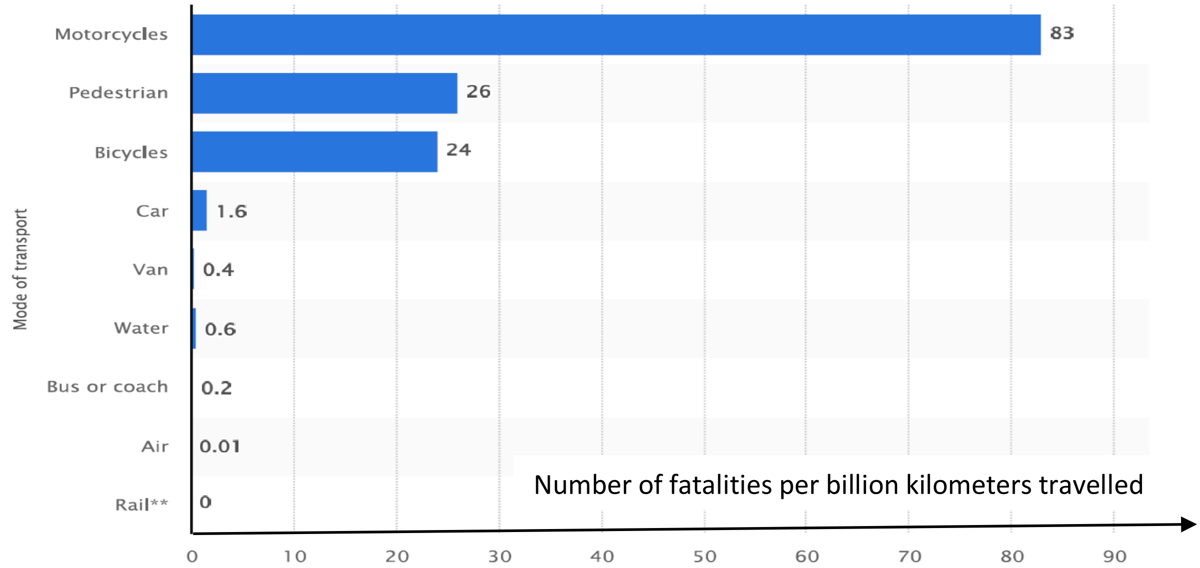


Figure 19: Level of risk of different transportation modes in UK

Based on that (1,6 measured in UK), the car State of the Art can be considered as **2 * 10^{-9} user fatality risk per km.**
Considering 1.2 or 1.3 person per vehicle, this means **10^{-7} user fatality / hour of service** at 40 km/h as average speed (source: speed of European cars from UDRIVE European project in 2014, 45 km/h reduced to 40 km/h for the future).

This 10^{-7} user fatality / hour result is far from the "bus or coach" State of the Art: **2 * 10^{-10} user fatality risk per km.** Considering 20 km/h and 10 persons per vehicle as average, this means **4*10^{-8} user fatality / hour of service.** Thanks to their relative weight, "Bus or coach" results are better than cars when compared in kilometres and hours, with an order of magnitude for **target around 10^{-8} user fatality / hour.**

When looking to road safety results, we find higher rates, as car occupants are not the most exposed to road fatalities: **vulnerable road users show much higher rates**, as their bodies are not protected, with very low level of passive safety in case of an accident against a car, maybe against a minibus.

<u>Road safety improvement, depending on traffic increase:</u>

French evolutions of traffic and road fatalities can illustrate the global trends and results in the **three next Figures** presented below:

Firstly, the traffic in France (metropole, European continent) has hugely increased, by 10 in 50 years, before stabilization around 550 * 10^9 km per year since 2007 (Figure 20):

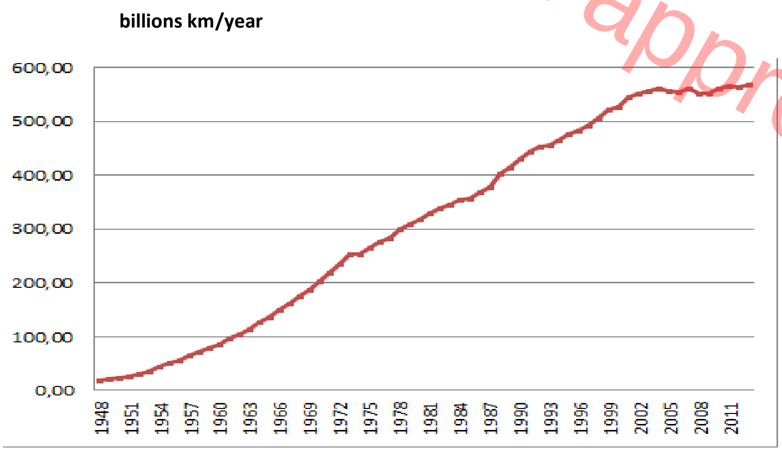


Figure 20 : Traffic increase and stabilisation in France

Since 1972, in spite of this traffic increase, fatality numbers have been reduced, taking benefits from huge **efforts concerning car technology, infrastructure improvement, driving regulation and driver behaviour (**Figure 21**)**.

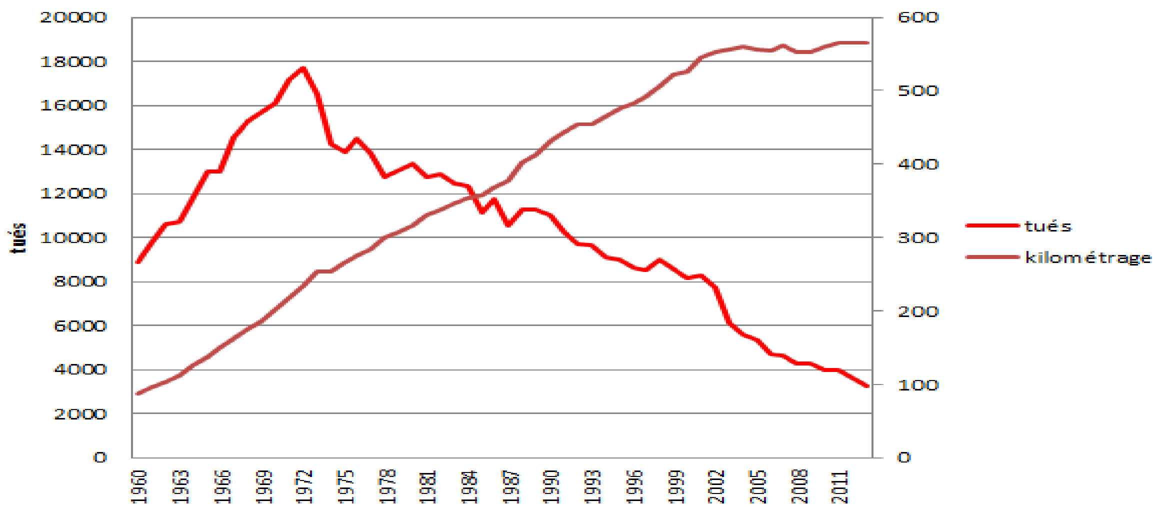


Figure 21: Fatality reduction in France since 1972

To evaluate correctly the road safety in terms of risk against service, **these two curves have to be associated**, and fatality numbers compared to the associated traffic.
When comparing fatalities to kilometres, we observe that the fatality/km has been **continuously improved during decades**, but it is now stabilized since 2013 (Figure 22).

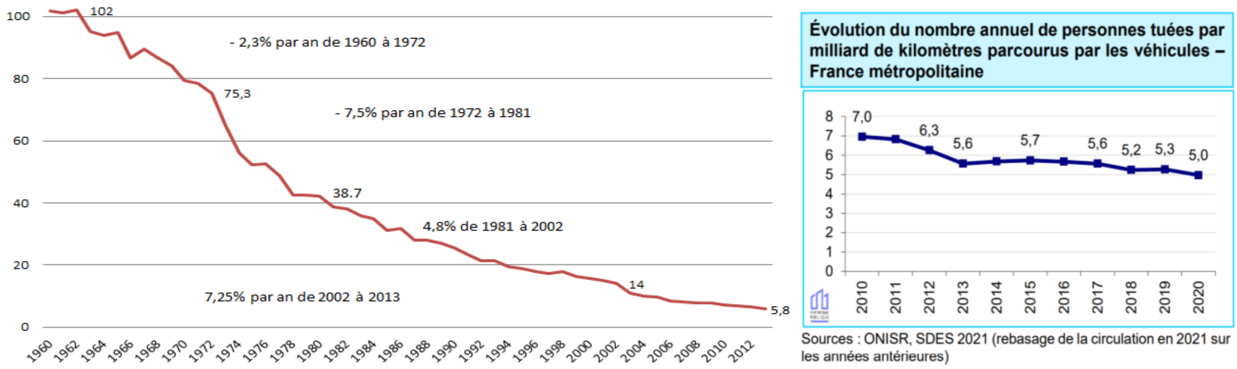


Figure 22: Fatality risk stagnation in France since 2013

Road safety State of the Art:

France can be considered as a good reference of the developed countries State of the Art, **stabilised at average level in Europe**, far from a benchmark represented by road safety champions. The french **fatality stagnation since 2013** shows that **road safety** State of the Art in France can be considered as **stable at $5*10^{-9}$ fatality / km.** This means around **$2*10^{-7}$ fatality / travelling hour**, which is consistent with the UK estimation of 10^{-7} car user fatality / hour of car usage, as a car passenger is much more protected than a vulnerable road user (pedestrian, cyclist, motorcyclist…).

The number of **road accidents** in France is estimated to $3*10^{6}$ every year, when the **fatality number** is close to $3*10^{3}$. The **ratio accidents/fatalities** is well established and **close to 10^{3}**, when the number of **injuries** is depending on the definition: it can be considered around $3*10^{5}$, with a **ratio of 10^{2}** when compared to fatalities. In terms of **operational active safety** (all accidents), we can consider the current situation as $5*10^{-6}$ accident / km, or $2*10^{-4}$ accident / road usage hour.

Automated Minibuses for public transportation should be based on same technical target as cars in terms of functional safety (**10^{-9} fatality caused by vehicle failure / running hour**): it has been already presented as an “indicative target” in the draft regulation for ADS European type-approval.

In addition, it has to include the **uncertainty of SOTIF impacts**, which means Safety Of The Intented Functionality, everything that can occurs when the vehicle is running properly, in nominal mode.

Globally, the road safety States of the Art and Targets per running hour of car and coach industry can be summarised in the following matrix, with Targets for Automated Minibuses reflecting the will to **reach the well accepted State of the Art of buses or coaches**, helped in terms of passive safety by the weight of such vehicles in comparison with other vehicles (Table 2).

Table 2: Proposed targets in terms of fatalities per running time

Fatalities / running time		**Road safety => Active and Passive Safety**			**Active Safety**
Fatalities/h **F / h**	Measuring	Functional Safety	User Safety	Road Safety	Accidents
	Safety norms	ISO 26262	SOTIF: ISO / PAS 21448		statistics
Perimeter	Causes	Technical failure	All causes		
	Persons	User fatalities		All , including vulnerable	
Measured	Cars	# 10^{-8}/h	# 10^{-7}/h	#$2*10^{-7}$/h	# $2*10^{-4}$/h
Targets	Cars	10^{-9}/h ISO norm extended	10^{-8}/h ?	#$2*10^{-8}$/h	
	Bus or coach		10^{-8}/h ?	$2*10^{-8}$/h ?	?
	Aut. Minibus		10^{-8}/h proposed	$2*10^{-8}$/h proposed	?

Dedicated to “**performance requirements**”, the annex 2 from the current Draft of the “Commission Implementing Regulation”, “laying down rules as regards uniform specifications for the type-approval of ADS of fully automated vehicles” has a footnote concerning art. 7.1.1 proposing “an indicative aggregated acceptance criteria of **10^{-7} Fatalities per hour of operation for market introduction of ADSs**”. Globally, the roadmap should be **10^{-7} F/h for market introduction, and $2*10^{-8}$ F/h for target**, with improvements.

Translation into injury risks:

Unfortunately, **Fatality statistics will not be applicable to Automated Minibuses**, because the figures are too low, and will stay low for years: from these fatality targets, an injury target should be derived. Between the orders of magnitude of fatalities and injuries, the ratio can be estimated to 10^{2}.

Concerning Automated Minibus safety, the fatality figures will be too low for any statistical analysis: **injury measurements will be much more efficient** as all accidents will be reported and analysed, with the improvement process we have to put in place.

For this AM application, the definition of injury will have to be very large, as every injury is susceptible to be reported: the ratio of 10^2 versus fatalities can be reused.

Concerning road safety, that's different: the injury measurement is much more difficult than fatality measurement, as many injuries are not reported.

In France, the ratio is only measured in one department (Registre du Rhône, 69), and evaluated now to 4 (coming from 3) from the hospital reality: the injured person numbers from road accidents are close to four times higher than what is measured in official recordings, and the reality is probably higher as minor injuries do not lead to the hospital...

A correct assumption in terms of **injury target** (all injuries) could be **10^{-6} user injury per running hour**. With 10 km/h as average speed for Automated Minibuses, that means 10^{-5} road user injury per kilometre: this will be measurable when 10^7 km (10 million km) will have been realised with Automated Minibuses in service, which is reachable in some years (thanks to H2020 AVENUE project).

When applying this ratio to the different SoA and Targets, we can consider the following matrix as a first reference for injuries (Table 3).

Table 3: Proposed targets in terms of injuries per running time

Injuries / running time		**Road safety => Active and Passive Safety**			**Active Safety**
Fatalities/h	Measuring	Functional Safety	User Safety	Road Safety	Accidents
I / h	Safety norms	ISO 26262	SOTIF: ISO / PAS 21448		Statistics
Perimeter	Causes	Technical failure	All causes		
	Persons	User injuries		All, including vulnerable	
Measured	Cars	# 10^{-6}/h	# 10^{-5}/h	#2*10^{-5}/h	# 2*10^{-4}/h
Targets	Cars	10^{-9}/h ISO norm extended	10^{-6}/h ?	#2*10^{-6}/h	
	Bus or coach		10^{-6}/h ?	2*10^{-6}/h ?	
	Aut. Minibus		10^{-6}/h proposed	2*10^{-6}/h proposed	**10^{-5}/h ?**

Reaching the same level as bus or coaches is very ambitious for Automated Minibus, as the mechanical deficit in terms of passive safety will have to be compensated by a remarkable active safety performance, which should be 10^{-5} accident / hour.

Globally, the roadmap should be **10^{-5} Injury / hour of operation for market introduction, and 2*10^{-6} I/h for target**, with improvements obtained from lesson learnt.

To dissociate this target between active and passive safety contributions, the orders of magnitude with high active safety ambition would be (Table 4):

Table 4: First repartition of targets based on high active safety performance

Per hour	**Active Safety**	**User safety => Active and Passive Safety**			
Problems:	Accident	Light injury	Bad injury	Fatality	Fatality from technical failure
Targets:	**10^{-5} /h ?**	10^{-6}	10^{-7}	10^{-8}	10^{-9}
PS Ratios:		1 out of 10	1 out of 100	1 / 10^3	1 out of 10^4
Vulnerable		No more	No more	No more	No more

These targets are calculated per hour, which is adapted to a service, but road safety is more often reported to a billion of kilometres, and we also need such comparison.

The **10^{-5} accident /hour assumption is very ambitious, probably not realistic.**

To get a **translation between hour and km**, the current State of the Art in France is $5*10^{-9}$ Fatality /km or **$5*10^{-7}$ Injury /km**, which means $2*10^{-5}$ Injury /h to be affected to cars driving at 40 km/h, as it is an average and main transportation mode on the road.

As an assumption for calculation, future Automated Minibuses would have an average speed of 20 km/h: reaching this target of 10^{-6} Injury / hour of service would mean **$5*10^{-8}$ Injury /km**, ten times better than current cars, which is **really ambitious!**

10.3 Active and Passive Safety balance

Estimated here to 10^{-5} user injury / travelling hour or 10^{-7} user fatality / travelling hour as orders of magnitude, **the road safety** in best countries **has benefited of decades of safety effort** (Six for passive safety, only four on active safety): as proposed, the shared **target of 10^{-6} injury / travelling hour is challenging both active and passive safety.**

In any case, the technical solutions can avoid accident occurrence, and even high gravity accident, as **the deformation energy is depending** not only of the Automated Minibus kinetic energy, but **also from the opposite vehicle energy**.

In case of crash, the buses or coaches mechanically benefit of their higher weight, which cannot be transposed to Automated Minibuses, as their weight is comparable to an electric SUV, which will run in the same streets. The EuroNCAP requirements on such SUV lead to a very rigid structure, protective for the SUV's occupants, but **aggressive against an Automated Minibus, as built today for experimentation**.

Technically, the AM active safety challenge (accident prevention) is comparable to an automated car in town, with some additional challenges, in relation with the automatic doors and the accessibility from the kerb, but **the performance will have to be much better than the current active safety** with conventional drivers.

If the active safety performance is only 10^{-4} accident / hour (more realistic balance between active and passive safety), the Passive Safety Ratios will have to be 10 times better, which is ambitious (Table 5).

Table 5 : Second repartition of targets based on high passive safety performance

Per hour	Active Safety	Active and Passive Safety			
Problems:	Accident	injury	Bad injury	Fatality	Fatality from technical failure
Targets:	10^{-4}/ h	10^{-6}	10^{-7}	10^{-8}	10^{-9}
PS Ratios:	1 out of…	10^2	10^3	10^4	10^5
Vulnerable		No more	No more	No more	No more

Passive safety requirements will be highly necessary to reduce user injuries (road users and passengers) and to **limit the Ratios between safety** measured through injury/hour **and intermediate technical targets**:

- **passive safety targets**: one injury for 100 accidents, one fatality for 10 000 accidents
- **functional safety target**: one user fatality out of 10 coming from a technical failure

This high **passive safety performance should benefit from specific innovation for urban usage**, especially when confronted to vulnerable road users.

10.4 Passive safety requirements

10.4.1 Main risks to be controlled:

This global safety target (10^{-8} fatality/h, 10^{-7} bad injury/h, 10^{-6} injury/h) is clearly not feasible without ambitious passive safety requirements.

As for functional safety (ISO 26262, 10^{-9} ER4/h), the passive safety reference to be discussed for Automated Minibuses will be what is targeted by the car industry.

This is structuring for vehicle architecture, in four domains:

1. Damage to the **battery pack** in case of a frontal accident:

   Lithium-Ion technology can be dangerous in case of crash, as mechanical impacts can initiate fire with toxic gas exhaust. Generally, such a battery is located under the cockpit, which will be difficult to apply to AM because of the accessibility target. Another battery position has been tested for an electric bus, in the roof, with other issues (high centre of gravity, vehicle stability, battery temperature, fire risk…)

2. Vehicle **intrusion in the cockpit** in case of lateral crash:

   This constraint is problematic, as such accidents can occur at many intersections in a city centre, without any solution to avoid the accident from the AM perspective. The vehicle intrusion can "use" the door side, which will be difficult to protect.

3. **Passengers projections** in case of harsh braking or slight crash:

   Harsh braking or accident avoidance can injure passengers, creating a risk which does not exist in cars (seated and belted), when passengers can be standing inside an Automated Minibus.

4. **Pedestrians or cyclists injury** against the front face of the AM:

   This is fundamental when speaking about public transportation in the streets, but the front face of AM will have to be vertical to optimise the ratio between space and length, critical for urban vehicles.
   In case of a crash, the body kinematic is highly different from what is requested from a sedan car, and can increase injury risk, even at lower speed: **innovations are necessary** to improve this situation, and to **obtain a correct body kinematic**, to avoid that the body would be projected and crossed by the vehicle.

In terms of vehicle development and business feasibility, the **visibility on passive safety requirements** is low, although they are more **urgently requested** than the active safety requirements, as passive safety is **structuring for the vehicle architecture**.

10.4.2 Automated driving and passive safety

USA situation concerning automated driving : passive safety maintained

Keeping the current high level of **passive safety is required by the NHTSA** federal regulation (USA National Highway Traffic Safety Administration), published on the 10th of March, 2022:

- Docket No. NHTSA-2021-0003 RIN 2127-AM06
- Occupant protection for vehicles with Automated Driving Systems (ADS)

As defined in their guiding principles, their vision is very conservative:

“The level of performance required by the amended FMVSSs is just as appropriate for ADS-vehicles as it is for non-ADS vehicles in protecting the public against unreasonable risk of death or injury in a crash. More specifically, NHTSA sought to **maintain the level of safety currently provided to occupants** by applying the crash test performance requirements, wherever possible. “

ALERT: applying **standard crash tests** to existing automated minibus would be critical.

European situation concerning automated driving: integrated safety

In Europe, for example at EuroNCAP, the general approach is to improve safety using a more global and innovative vision, called “integrated safety”: **active and passive safety devices have to be cooperative** to optimise the protection when the crash cannot be avoided.

This vision is **more open to take into account the probable reality of crashes**, to establish appropriate trade-off, especially in our case of Automated Minibuses.

One example of integrated safety could be the **pedestrian protection in front of the vertical front face of an Automated Minibus (**Figure 23**)**, where the active safety control can initiate a passive safety device:

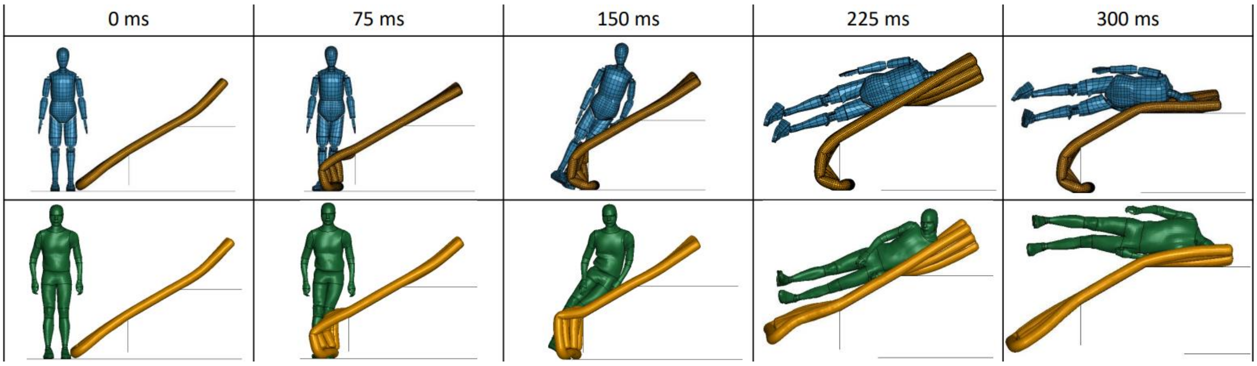


Figure 23: Body kinematic as requested in case of a pedestrian crash

In case of unavoidable crash, a specific airbag structure could be deployed, to obtain:

- **A correct kinematic**, where the body is not projected to the ground (and crossed)
- **An energy absorbance**, based on airbag characteristics, to be adapted
- **A body restraint**, using structure geometry and braking control

11 Strategy, planning and priorities

11.1 Improve the Automated Minibus strategy

Automated Minibus current strategy for Europe, versus US:

The European companies are proposing **specific vehicles, optimised on urban usages, respecting strictly the driving regulation, with the help of infrastructure modifications** when necessary: for example, different Automated Minibus experimentation, like Lyon site for AVENUE, have decided to add traffic lights on gyratory crossings, to give systematic priority to the public transportation vehicle.

The US approach is **dangerous for the Automated Minibus business in Europe**, as conservative for passive safety requirements with impacts on vehicle architecture, and innovative for Automated Driving, using a human driver mimicry, which is efficient and compatible with the existing infrastructure.

PASSIVE SAFETY:

Standard crash tests are incompatible with the basic architecture of current Automated Minibuses.

AVENUE has shown the importance of **accessibility and personal autonomy**, which are AM basic functionalities, **directly linked to the vehicle architecture**, mainly in 4 domains, already identified as risks:

1. The floor of the **cockpit** has to be low for PRM and for elderly. Generally, the **battery** is located under the floor, but this constraint implies to find another place for the battery: placed vertically and protected by an energy deformable zone in case of frontal crash, with impact on vehicle length (the roof solution has important disadvantages, as heavy and temperature sensitive).
2. The **sliding doors** allow a maximum entrance to limit the bus stop duration, but have to include a passenger protection in case of the lateral crash of a car, arriving for example to the same crossing.
3. The lack of **belt usage**, and the standing passengers increase the injury risk in case of crash, which has to be managed, coached, and **taken into account for vehicle performance**.
4. The vertical front face has to be designed to reduce the risk of pedestrian injury, which is difficult: it means using **adapted shapes and material**, but also keeping a low energy **absorption zone**.

To negotiate the necessary trade-off on future regulations, **active safety** performance can be claimed, but this **will not be sufficient**, as US require same passive safety performance for Automated Driving, which will be an international reference, to be taken into account.

AUTOMATED DRIVING:

The **operational efficiency** of driver mimicry based on Artificial Intelligence has been demonstrated in the US, which is not sufficient for Europe, where the infrastructure is much more complex, with a higher diversity of vehicle types, and a multiplicity of vulnerable road users.

The main arguments are that driving like humans make it **compatible with the existing infrastructure** and **will not disturb the traffic**. Today, the statistics are not demonstrating this situation, as 60% of ADS vehicle damages are on the rear side (source NHTSA), which is probably 70% of the Vehicle-to-Vehicle collisions, representing 90% of reported accidents (10% are against vulnerable road users).

Automated Minibus alternative strategy for Europe:

This transition roadmap for safety should not penalise service quality, and has also to be compatible with other types of mobilities in terms of traffic. A **trade-off is necessary for passive safety regarding passengers and vulnerable street users, and also for automated driving strategy.**

PASSIVE SAFETY:

In the transition roadmap, **this discussion concerning passive safety has to be placed at the beginning**, as the resulting trade-off will be a fundamental input for vehicle developments.
A late regression caused by unacceptable safety failures, would be a disaster for the realised investments.
This roadmap recommends preparing this negotiation with **other claims than active safety**, to be demonstrated…

Real usages, which minimize risks: vehicle speed limitation, belt usage and protected lanes…

To discuss the passive safety requirements, we will have to differentiate two main usages, which can be satisfied by different AM:

- **LIAISON between suburbs and cities**, at higher speed and braking capacity on protected lanes: passengers seated and belted, high energy deformable zone to protect the battery...
- **CITY usage** at low speed with braking limitations: easy accessibility, high capacity with standing passengers, low energy deformable face to protect vulnerable street users...

In addition, during CITY usage, **the speed and braking performance will have to be automatically adapted** to the environment: Middle town, Central town or General…

Innovation, protecting vulnerable street users from injuries

As explained previously, the **front face** should be **vertical**, which is **not the best geometry to protect pedestrians**, and some accidents will not be avoided.

Depending on vehicle speed, there is an area in front of the vehicle where a pedestrian cannot be avoided, for physical reasons, taking into account the fact that we also have to protect passengers.
With a front face, the pedestrian will not be toppled and received on a car hood, but projected and maybe crossed by the Minibus…

In such a case, **there are technical solution** to deploy in this area an airbag, able to topple the pedestrian, and to receive him smoothly on this airbag structure. Difficult to admit on a personal car, this innovation is perfectly adapted to Automated Minibuses for public transportation, using vertical front and rear faces, to minimise the vehicle length.

Passenger coaching, to promote safe and efficient human behaviour

In Europe, we do have to **analyse the passenger behaviour inside the shuttle**, to check COVID distancing, avoid vandalism, identify thefts, fightings, and so on… H2020 AVENUE has developed such applications, with personal data protection.

Our complementary proposal is to **use such information to coach passengers and to get the best and safe behaviours**, like:

- Allow a quick door closing
- Seat, if a place is available
- Belt, when possible

The coaching can use a voice, but will be also associated to vehicle speed: "*the Automated Minibus has closed the door and started, but at low speed as you are not seated*" …

AUTOMATED DRIVING:

Driver mimicry cannot be refused to demand the strict respect of driving regulation, and to obtain a better respect from human drivers, especially behind the Minibus.

The lesson learned from all AD experimentations have shown that this strict application would:

- Generate **risky situations**, which is detrimental to the objectives of driving regulation
- Be very **demanding concerning the infrastructure signalisation**, not maintained at that level
- Impact the traffic fluidity, with **blocking situations where human solutions are necessary**

11.2 Optimise different usages

Different usages of Automated Minibuses are pertinent for the urban transition, but require different trade-off between performance, capacity, accessibility…
Our proposal is to **differentiate LIAISON usage** (between suburbs and town on a protected lane) and CITY usage (in town, at lower speed, with standing passengers…) as no vehicle architecture will be able to satisfy all requirements:
In the CITY usage, the **performance characteristics can be continuously adapted** to the real situation (pedestrian area, people standing, bus lane), **and used to coach human behaviour**…

In our view, the classification of different usages of Automated Minibuses should be the next step after the H2020 AVENUE experimentation, leading to adapted passive safety requirements and resulting architecture constraints.

11.3 Organise data collection

The Automated Minibus is the best tool for data collection, where data exportation has to be automatically sorted, and sometimes pre-treated, as presented in the D6.4 Deliverable, “methodology for safety evaluation”:

- Continuously: technical data for vehicle or service monitoring, without personal data
- In case of incident: available data registered, and protected

To facilitate data analysis, some standards should be established, and H2020 AVENUE can contribute to this process with technical proposals, firstly with a basis concerning **incidents to be captured**.

11.4 Analyse data and share feedback

As done for workers in any company, to improve human safety, incidents (e.g. minor or avoided accidents) are collected as they are as important for improvement as real accidents: all **incidents** have to be analysed and **reformulated as risky scenarios**.

The feedback has to quickly address all contributing actors for corrective actions, as **reactivity is necessary to establish the confidence** for all stakeholders: service users, transport operators, public authorities…
At European level, that’s not sufficient: **lesson learnt have to be shared among European countries**, to allow later a **close loop for regulation improvement**.

11.5 Organise improvement process

The improvement process is **part of the safety culture** requested by the UN/UNECE WP29/GRVA working party on **Automated and Connected Vehicles** (VMAD) developing a **New Assessment Test Method** (NATM) for Automated Driving, based on a **multi-pillars approach**, where the Operational Design Domain (ODD) has to be consistent with Scenarios, to feed correctly Requirements.

Under the Plan, Do, Check, Act (PDCA) standard, this example is coming from the European Railway Agency, proposing an European Union Safety Management System (Figure 24):

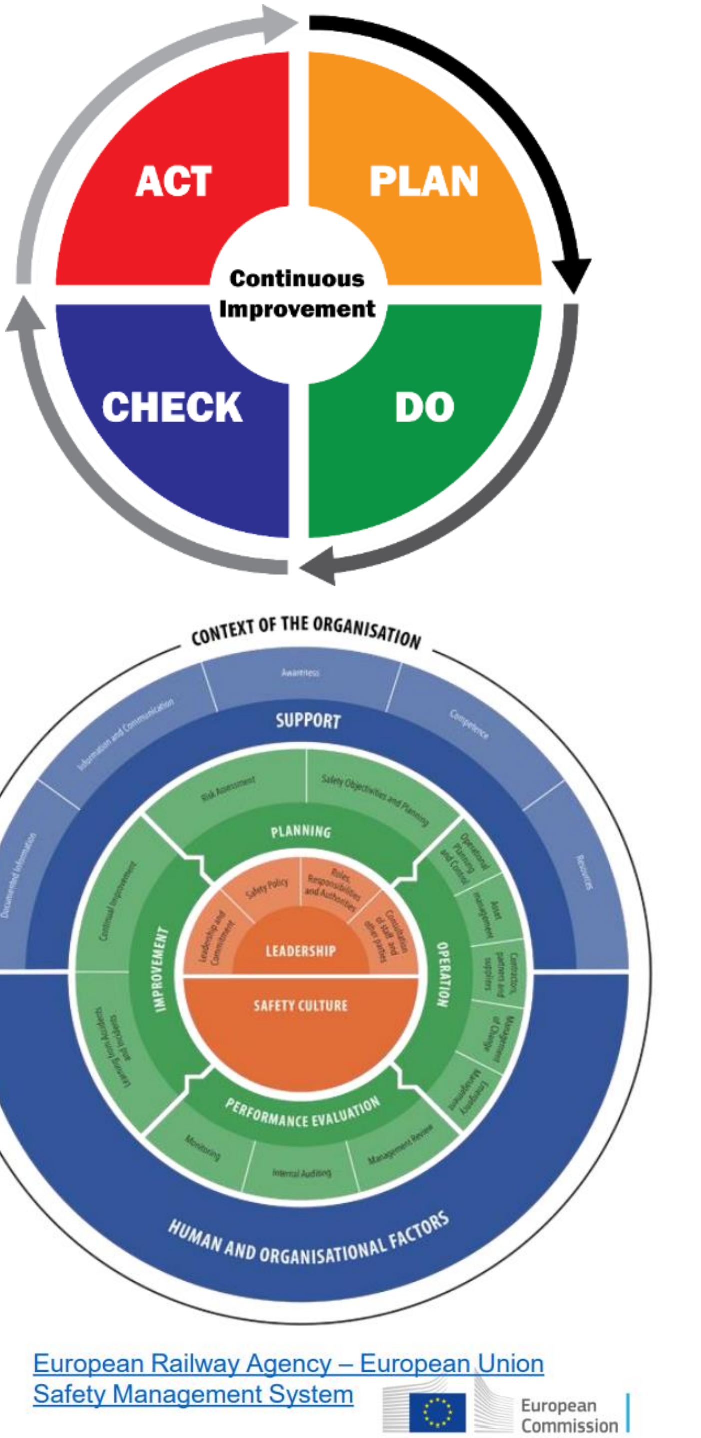


Figure 24: Conventional PDCA process for continuous improvement

This public transport improvement loop based on PDCA loop is presented as:

- **PLAN** is detailed as **Planning** with safety objectives and risk assessment, under public power leadership: the organisation is moving from information to awareness, then to competences…
- **DO** is called **Operation**, to manage the risks with adequate resources, introducing the safety culture with human and organisational factors, including SOTIF…
- **CHECK** is coming from the safety culture and called **Performance evaluation**, from review to audit and safety monitoring…
- **ACT** is going back to leadership for replanning, after loop **Improvement** based on lesson learnt and documented improvements,…

The same process is requested by UN/UNECE/GRVA/VMAD for Automated Driving.

To do that, In Service Monitoring and Reporting (ISMR) is required as fundamental by this UNECE WP29, as **necessary to drive the safety improvement** from the current State of the Art to the targeted goal, which has to **demonstrate a positive contribution to the general road safety**:

"Learning from in-service data is a central component to the safety potential of Automated Driving Systems (ADS)".

At least, **Automated Driving cannot be detrimental to road safety**, including passive safety:

1. Safety confirmation: identify risks and anomalies before market introduction
2. Scenarios generation: identify new unknown and unsafe scenarios (SOTIF)
3. Safety recommendation: share safety-relevant lessons learned

Through D9.2, H2020 AVENUE proposal is extending this required PDCA improvement process to service quality, and so extending data collection to all relevant incidents.

Technical standards using existing norms will have to be shared, and a central **public platform should be necessary to drive this transition** toward Automated Driving integrated into existing Public Transport, while **maintaining high level of safety and quality**.

12 Conclusions

As demonstrated by the creation of the "**Driving Urban Transition**" platform, the urban transition is a priority for Europe, and it has to be "**toward a sustainable future**".

A sustainable future implies that new mobility services will not sacrifice the general traffic fluidity, and also that this transportation service will be safe and satisfy users, quickly after his market introduction: **Safety & service Quality**, the aim of this Deliverable D9.2.

As shown by H2020 AVENUE project, deploying **Automated Minibus** can bring **strategic improvements to the urban public transportation**, improving service when reducing emissions at acceptable costs, **if their insertion in the traffic is correctly done**, with respects to the existing infrastructure, to the other mobilities, and to the human behaviour... The **US strategy**, based on self-learning human mimicry, using Artificial Intelligence, **has to be taken into account**.

To be sustainable, **this deployment has to be carefully prepared by the public authorities**, with the right strategy using pertinent innovations, and with necessary organisations, process and regulations: norms, criteria, and thresholds have been proposed, not only by H2020 AVENUE, as demonstrated in D9.2…

In Europe, another difficult coming step is the **acceptance of simulations for vehicle certification,** both for active and passive safety, with implications on Human Body Modelling and body donation to science, to get the adequate criteria and thresholds to be respected.

The AVENUE project has to be considered as **the 1rst step of this transition roadmap** to introduce **Automated Driving in the Urban Transportation system**, where next steps have been identified and explained.
The deployment will have to be **durably driven by the public authorities**, especially for safety:

- To allow **innovations** to be developed, especially for **urban optimised** shuttle
- To get an **acceptable level from the first commercial services**, using certified vehicles
- to reach the ambitious **safety goal**, using the **lesson learnt improvement process**.

With their limited speeds and their public control which reduces the risks, the Automated Minibuses are **the best way to introduce Automated Driving in towns.**

This deployment will give the opportunity to capture the risky scenarios which will be necessary to specify, design and validate the future automated private cars, when it will be accepted in towns, **under conditions of safety, but also under conditions of a positive societal contribution**.

13 Appendix

D9.2 recommendations for safety and service quality can be summarised in a table, with proposals and references in D9.2, chapters and pages:

H2020 AVENUE D9.2 RECOMMENDATIONS					
Number	**Short title**	**Recommendation**	**Proposal**	**Chapters**	**pages**
D9.2_a	**multipillar approach**	Associate ODD scenarios, virtual testing, real world usage, audit, in-service monitoring and systematic reporting	same as requested for ADS: european VMAD	7.1	22 to 23
D9.2_b	**incident registering**	Organise the systematic registering of incidents, including all corporal accidents	a shared incident definition	4.1, 4.2	14 to 16
D9.2_c	**incident data collection**	Keep and protect data in case of an incident for trusted analysis and feedback	encrypted data available for PTA analyse	5.1, 5.2	17 to 19
D9.2_d	**AD dis-engagements**	Refuse disengagement frequency as a safety indicator, not representative of safety, free to use when useful	disengagement when useful and safer	2.2.4 11.1	11 42
D9.2_e	**injury target**	Define a measurable target in terms of road user injury per hour of service	one injured for one million hours of service	10.1, 10.2	32 to 38
D9.2_f	**market introduction**	Accept higher rate of injuries for market introduction, under condition of improvement process	one injured for 100 000 hours of service	Executive summary	IX
D9.2_g	**trusted lesson learned**	Identify trusted organisations able to analyse data and formalise anonymised lesson learned	reuse of road accident trusted organisation	8.1, 8.2	27 to 29
D9.2_h	**data analysis & virtual testing tool**	Reuse existing and same tool chain among the different trusted organisations	SALSA + ADScene tool chain, available & validated	6.1 7.2	20 24 to 26
D9.2_i	**improvement process**	Share the lesson learned and require best practices, using regulation for improvement	an european platform for coordination and action	9.1, 9.2 11.5	30 to 31 45
D9.2_j	**traffic fluidity**	Request driver strategies and reactivity to manage blocking situations	driver mimicry, using Artificial Intelligence	2.2.4 11.1	11 42 to 44
D9.2_k	**different usages**	Dissociate liaison needs from urban usage at low speed	Suburb liaison using conventional platforms	2.2	7 to 9
D9.2_l	**passive safety**	Establish quickly ambitious and reasonable targets for road user protection	Different targets for urban and liaison usages	10.4	40 to 41
D9.2_m	**street user protection**	Promote innovation for an active road user protection (eg adapted airbag technology)	Correct pedestrian kinematic + energy absorption	10.4.2	41
D9.2_n	**performance limitation**	Require automatic performance adaptation to streets (eg pedestrian) and traffic (eg busy)	Limitations of acceleration, deceleration and speed	2.3	8 to 9
D9.2_o	**passenger coaching**	Reduce performance when passengers are not seated or not belted	same, depending on passenger behavior	2.2	8 to 9
D9.2_p	**Vehicle maintenance**	Introduce maintenability in the vehicle certification rules	reliable for service with an realistic maintenance	3.2	13 to 14
D9.2_q	**Cybersecurity**	Act early in the project of new AM services, as an european audit providing best standards	A small and dedicated team	3.1	12
D9.2_r	**Design norms**	Require ISO26262 and ISO PAS 21448 as for private cars	same standards as automotive industry	3.2	13
D9.2_s	**Private cars**	Consider public transportation at controled speed as a priority preparing potential next steps	use AM to collect data and to get urban risky scenarios	12	47

Table 6: Recommendations for safety, security and service quality

14 References

"Road vehicles – Functional safety" :

https://www.iso.org/ Standard Number: **ISO 26262-1:2018**

"Road vehicles – Safety Of The Intended Functionality" :

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GDPR European regulation:

General Data Protection Regulation (GDPR) – Official Legal Text (gdpr-info.eu)

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UK statistics concerning different transportation modes:

Vehicles & Road Traffic | Statista

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