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AEROFLEX – *AERO**dynamic and* *FLEX**ible Trucks, Rethinking Long Distance Road Transport*

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Abstract

THE VISION OF THE AEROFLEX PROJECT IS TO SUPPORT VEHICLE MANUFACTURERS TO ACHIEVE THE COMING CHALLENGES FOR ROAD FREIGHT TRANSPORT. A new vision of future logistics for physical goods is required to achieve a sustainable logistics and transport system, a paradigm shift described as "The Physical Internet"[1]; rethinking future freight transport by the optimisation of multi-modal transport chains by drawing on the advantages of the different modes. Thus, it is essential to develop flexible and adaptable vehicles and loading units with optimised aerodynamics, powertrain for low emission and highly efficiency. The optimal matching of novel vehicle concepts and infrastructures is crucial, requiring intelligent access policies for trucks, load carriers and road infrastructures.

This paper summarises its overall preliminary results. It covers boundaries and constraints from a market perspective, hybrid distributed powertrain and aerodynamic features for the complete vehicle, smart loading units, front-end design and finally consequences regarding the regulatory framework.

Keywords: multi-modality; aerodynamics; energy management systems; distributed drive trains, regulatory framework; heavy duty vehicles

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[1] The term "Physical Internet" was 'invented' by prof. Benoit Montreuil, who describes the Grand Challenge in logistics, i.e. how to decouple economic growth and transport demand, and who presented a roadmap for implementing the Physical Internet vision as the way to meet the grand challenge and to achieve a sustainable logistics and transport system..

Abbreviations

ACEA	European Automobile Manufacturers Association
AEMPT	Advanced Energy Management Powertrain
ALICE	Alliance for Logistics Innovation through Collaboration in Europe
CEDR	Conference of European Directors of Roads
CFD	Computational Fluid Dynamics
DG MOVE	EC's Directorate-General – Mobility and Transport
DG GROW	EC's Directorate-General - Internal Market, Industry, Entrepreneurship and SMEs
EC	European Commission
EMS	European Modular Systems
EU	European Union
EUCAR	European Council for Automotive R&D
FALCON	Freight And Logistics in a Multimodal Context
GHG	Greenhouse Gases
HCV	High Capacity Vehicle
HVTT15	15th International Symposium on Heavy Vehicle Transport Technology
IFT/OECD	International Transport Forum at the OECD, Organisation for Economic Co-operation and Development
IRU	International Road Transport Union
km, km/h	kilometre, kilometres per hour
KPI	Key Performance Indicators
NGOs	Non-Governmental Organisations
OEM	Original Equipment Manufacturer
R&D	Research and Development
SB	Sounding Board (of Project AEROFLEX)
SIAP	Smart Infrastructure Access Policy
SME	Small and Medium Enterprises
tkm	ton kilometre
US	United States of America
VRU	Vulnerable Road User (e.g. cyclist, pedestrian)

1. Introduction

The transport sector contributes to about 25 % of total CO^2 emissions in the EU and is the only sector where the trend is still increasing. Taking into account the growing demand on the road transport system and the ambitious targets of the EC's Transport White Paper[1], it is paramount to increase the efficiency of freight transport.

The vision of the AEROFLEX project is to support vehicle manufacturers and the logistics industry to achieve the coming challenges for road transport.

The project website [1] and a first publication [2] provide an overview over the different project developments.

2. Goal and objectives

The goal of the AEROFLEX project is to develop and demonstrate new technologies, new concepts and new architectures for complete vehicles with optimised aerodynamics, powertrains and safety systems as well as flexible and adaptable loading units with advanced interconnectedness contributing to the vision of a "physical internet" [3]. The optimal matching of novel vehicle concepts and infrastructures is highly important, requiring the implementation of smart infrastructure access policies for new truck concepts, load carriers and road infrastructure.

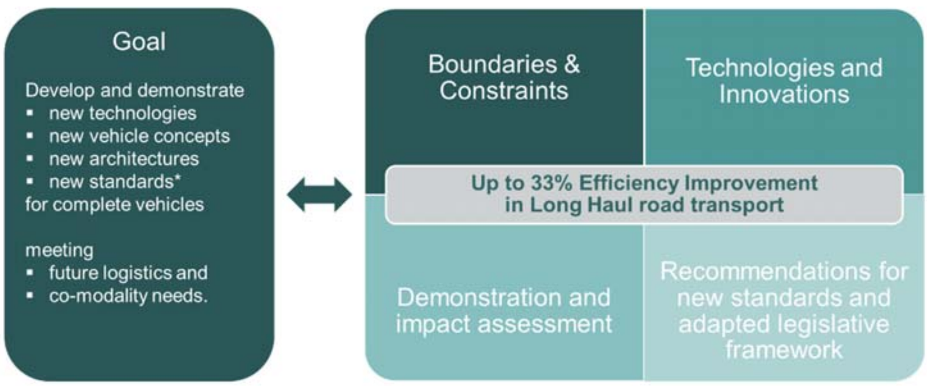
[1] WHITE PAPER Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system /* COM/2011/0144 final */, https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52011DC0144

2.1 Goal and technical objectives

The specific technical objectives, main innovations and targeted key results are:

1. Characterise the European freight transport market for 2035 (map, quantify and predict),
2. Develop new concepts and technologies resulting in adaptable trucks with a reduced drag, improved safety, comfort, cost efficiency and multimodal transport.
3. Demonstrate potential of truck aerodynamics and energy management improvements with associated impact assessments.
4. Drafting of coherent recommendations for revising standards and legislative frameworks in order to allow the new aerodynamic and flexible vehicle concepts on the road.
5. Achieve an overall efficiency improvement up to 33 % in long haulage road transport.

See also Fig. 1:



*new standards for hybrid-distributed powertrain, aerodynamic devices for complete vehicle, utilisation of loading units, performance based standards (PBS), access to infrastructure in a multi-mode context

Fig. 1 AEROFLEX: goal and technical objectives

2.2 Sounding Board

The AEROFLEX project is seen as key for the European road transport and logistics and has the full support from ACEA, EUCAR, ALICE and IRU among other associations. This support is mobilised through the **Sounding Board** that includes key representatives from all stakeholders: industry, logistics, authorities, policy-makers and NGOs. This group of experts is seen as a main pillar for the project and currently already over 50 members have applied sharing and working within the project. During the first phase of the project three meetings have been held to exchange and agree on the content within all work packages.

3. Research approach

The first publication [2] describes in detail the research approach. In this paper the focus is on the innovations developed within the AEROFLEX project. The innovations are in the field of loading units, powertrain, aerodynamics, all contributing to energy-saving and efficiency. The innovations on the front-end design contribute to increase survivability in crashes up to 50 km/h.

The overall efficiency target and innovations will be achieved by broken down targets shown in below in Fig. 2:

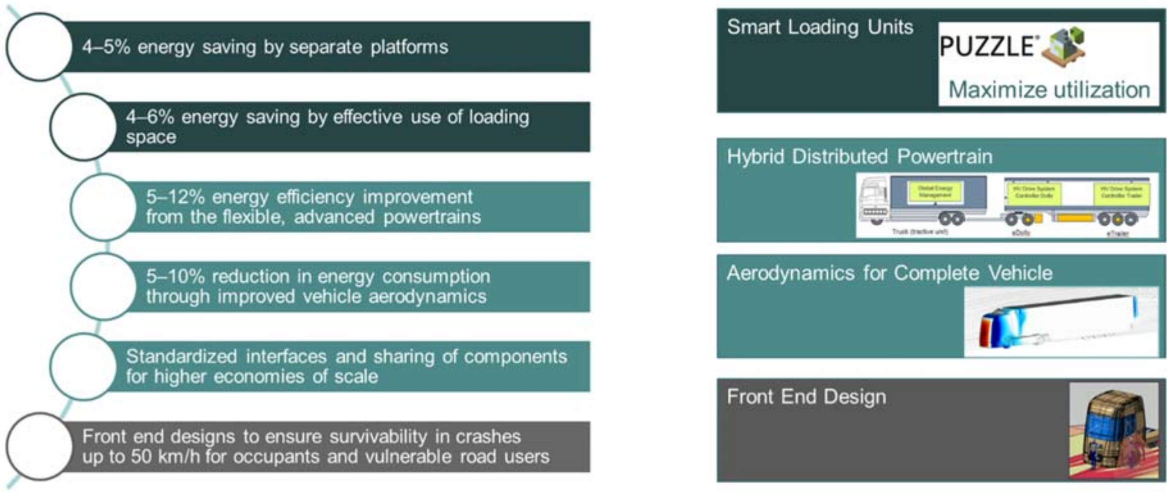


Fig. 2 Key targets broken down in field of actions

4. Results

This chapter gives an overview of the results achieved during the first phase of the project. The closure of this phase was agreed during the SB meeting at the HVTT15, Rotterdam (NL) November 2018. (See first publication [2]).

4.1. Boundaries & Constraints, the market drivers and use cases

The European transport data shows that in terms of tonne-kilometres, about 80 % of all freight transport is realised on long haul. Freight transport services up to 150 km are also relevant for new vehicle concepts in combination with smart loading units in order to support more efficient transport services at the interface between long and short distance transports.

Based on the evaluation of the logistics segments, the highest potential for new vehicle concepts is considered for (i) the consolidation of several orders/shipments to a high use of capacity and volume in one vehicle, (ii) the use of loading units that could be quickly loaded and unloaded for consolidation, shifted from or to other modes as well as for collecting and distribution tasks, and (iii) the reduction of empty runs by using standardises vehicles (length and weight) and loading units.

The digitalisation of logistics processes supporting the driver, simplifying vehicle routing, route planning and monitoring of the whole transport chain is an ongoing process that makes transport planning efficient and increases utilised transport capacity.

A survey and interviews with shippers and logistics companies have shown big interests to test and implement new vehicle concepts in daily transport logistics. The evaluation of 25 use cases - considering different type of cargo, transport distances and volumes - underlines the potential reduction of Total Costs of Ownership (TCO) and GHG emissions. The potential savings in transport cost (€/tkm and cost/tour) are 23 % on average. GHG emissions savings are at 13 % resp. 16 % on average on tank-to-wheel and well-to-wheel level. These analyses are not yet including the savings coming from the technical innovations to be expected end 2020.

4.2. Advanced Energy Management Powertrain

Already in the EC's funded project TRANSFORMERS (Acronym for "Configurable and Adaptable Trucks and Trailers for Optimal Transport Efficiency a conventional truck", Grant Agreement No 605170) was combined with an electrified semitrailer to create a hybridised combination called Hybrid on Demand (HoD), which reduces the fuel consumption even with a simple energy management strategy, [4]. The AEROFLEX project enhances this idea towards the Advanced Energy Management Powertrain (AEMPT). The AEMPT contains a global energy management in the truck, which can use all powertrains – especially electric powertrains – in the whole vehicle combination as driving and recuperation devices. In contrast to the simple strategy, used in the TRANSFORMERS demonstrator, higher fuel savings can be achieved with this new global approach. Furthermore, the global approach enables a supervisor safety controller, which ensures driving stability for the vehicle combination. On top the e-dolly, ready for testing by end 2020, enables automation at terminals through autonomous operation for increased efficiency and safety (see Deliverable 2.1[5])

A recent publication of the new distributed powertrain concept [6] describes in detail the powertrain's structure and the idea of the torque distribution among the different powertrains. Furthermore, first simulation results of the fuel consumption reduction (5-15 %) are given. See Fig. 3.

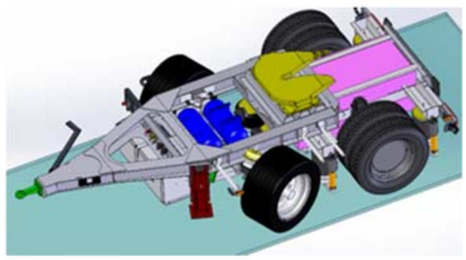


Fig. 3 Draft engineering design of the e-dolly

4.3. Aerodynamic concepts for the complete vehicle

Aerodynamic drag is a major contributor to the fuel consumption needs of trucks, especially at cruise speeds for long-haul transportation. Any improvement in aerodynamic characteristics to reduce drag pays off in lower fuel consumption and less emissions. The approaches applied for aerodynamic drag reduction, however, should be balanced in the sense that cost and robustness of the implemented concepts are in line with the actual benefits achieved. Successful concepts are therefore those concepts that improve the overall air flow along the entire vehicle, avoiding the adverse effects of selecting a suboptimal combination of tractor and trailer. Therefore, we need to consider developing aerodynamic features and devices for the **complete vehicle** to reduce drag that are adaptable to their logistics task and circumstances.

The next level of solutions will be the use of adaptable surfaces to optimise the aerodynamic characteristics of the vehicle for the actual operational conditions. Multiple companies and stakeholders are involved (truck OEM, trailer OEM, component suppliers, research institutes and service providers) to tackle a complex challenge (transient aero, marginal gains, complete vehicle, yaw angle) by a multi-disciplinary/holistic approach.

Demonstrating the potential fuel savings is crucial, so the development of the solutions are built up in phases: from CFD analyses of the complete vehicle to scaled wind tunnel testing (rolling road, 1:3) to full-scale track testing (constant speed) to public road (fuel economy). See Fig. 4.

Fig. 4 CFD model of tractor semi-trailer

For CFD, the inflow conditions are perfectly controllable and geometrical details can be included at will. For the wind tunnel, the flow conditions are well known although the detailing of the configuration depends on the scale and the Reynolds scaling effect has an impact on the results. For full-scale track testing, the speed and scale is under control but the test results are subject to statistical atmospheric inflow conditions. For public road testing, which is the most common situation for any transportation system, only the vehicle configuration is strictly controlled, all other aforementioned aspects are subject to statistical influences. Such an exhaustive approach is truly unique as it is executed within a Project Consortium like AEROFLEX with multiple OEMs, research organisations and suppliers.

Most of the concepts (passive geometry, active geometry, passive flow control, active flow control) have been assessed on a stand-alone basis using CFD. Promising concepts are proposed for wind tunnel testing, planned July 2019 onwards. Next phase of CFD-research will focus on combinations of concepts for optimal aerodynamic performance. For details see deliverable 3.1. [7]

4.4. Smart Loading Units

Smart Loading Units for overall efficiency gains by separate platforms for volume and weight freight and by more effective loading space utilisation. See Fig. 5.

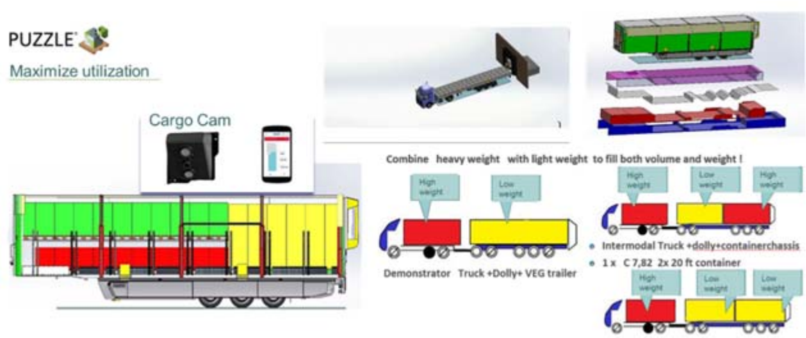


Fig. 5 Small Loading Units for different platforms

A detailed analyse of the requirements is published as deliverable 4.1 and 4.2 [8]. Three use cases are agreed in close collaboration with the stakeholders to demonstrate the potential savings and efficiency improvements.

The results are expected to be available by mid-2020:

1. Use case for combined transports performed within AEROFLEX together with Luxemburg based CFL, the rail connection Bettembourg and Le Boulou, to prove the aerodynamic devices on semi-trailers at high speed (< 200 km/h).
2. Use case at Procter & Gamble to prove milk run deliveries, the improved loading efficiency as well as horizontal and future automatic (un)-loading for goods in combination with double floor, flexible and smart loading units e.g. Moduluschka modules, new trailer concepts e.g. moveable roof.
3. Use case in co-operation with Clusters 2.0 using a new Puzzle Software for loading optimisation and a new CargoCam to enable monitoring of loaded amount of goods in order to enhance the filling factor. Both systems are developed within the AEROFLEX Consortium.

4.5. Front-end design to improve survivability in crashes

A full paper "an analysis of European crash data and scenario specification for heavy truck safety system development within the AEROFLEX project" is submitted for TRA2020 [9]. Below a summary is given of next steps and what can be expected by mid-2020.

An increased front extension as designed in AEROFLEX (about 0.5 m) allows an improved field of vision for the better recognition of other road users and this, combined with Active Safety systems such as the AEB, allows accidents may be drastically avoided. See Fig. 6.

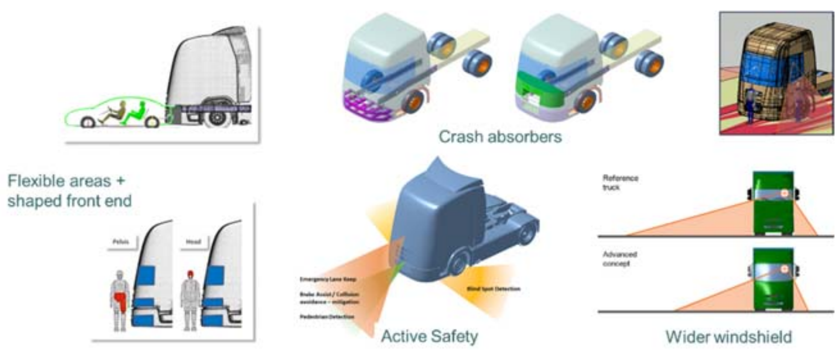


Fig. 6 AEROFLEX front-end design to improve survivability in crashes

Furthermore, in the case of a collision, it represents an opportunity to mitigate the consequences of the truck's impact with those crashing opponents. In the lower part, crash absorbers connected to a crossbar dissipate part of the accident energy, ensuring less damage to the occupants of the cars eventually involved. The rounded design, the softer outer skin and the greater distance between the contact surface and the chassis hard points make the frontend less aggressive and reduce the level of injury on the VRU in the event of an impact. A virtual simulation will be ready by end 2019 to validate and prove the benefits of the countermeasures adopted.

4.6. Demonstration and testing programme

To demonstrate, validate and analyse the feasibility of the AEROFLEX innovations, it is necessary to define **WHAT** will be tested and **HOW** the technical assessment will take place. The steps followed to achieve these objectives are:

a) Definition of the KPI's, the performance assessment, reference conditions and target values.
b) A description of the conditions under which the performance of the innovations is assessed based on use-cases.
   Two types of use-cases are defined:
   - **Customer use-cases** are real logistic operations of conventional vehicle combinations at different Logistic Service Providers or shippers using different types of goods.
   - **Test use-cases**, part of the AEROFLEX test matrix (see Fig. 7), cover the type of tests being executed by physical testing of reference and demonstrator vehicles. These use-cases are tests under controlled environmental conditions with limited external disturbances targeting for high measurement accuracies and reproducibility. The test programme include five test use-cases being:

- *Test use-case 1 – Steady-state speed test at proving ground*
- *Test use-case 2 – Real world Route Fraga*
- *Test use-case 3 – Air drag measurement on proving ground*
- *Test use-case 4 – Dynamic behaviour tests on proving ground*
- Test use-case 5 – Terminal (un-) loading tests

c) The specific test matrix and test programme defined to measure the performance of the innovations contains nine different vehicle configurations including tractor semi-trailers (16,5 m) and European Modular System (EMS) configurations (both EMS1 of 25,25 m and EMS2 of 32 m).

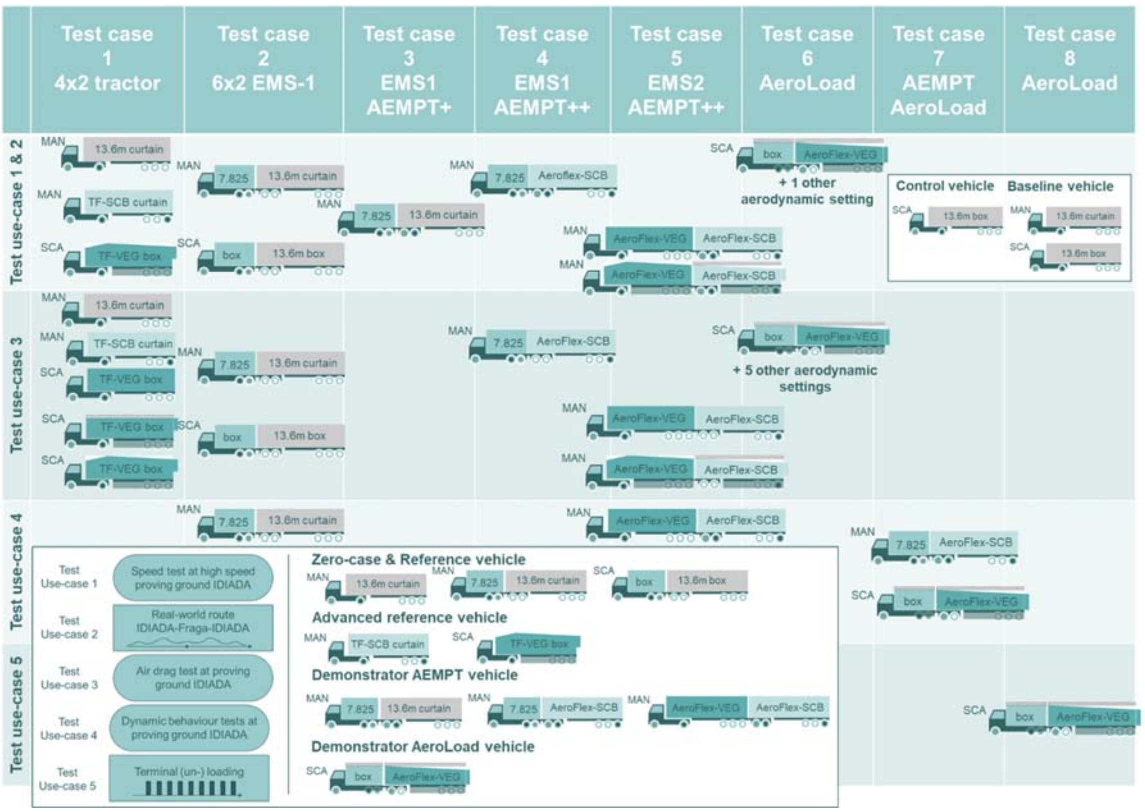


Fig. 7 AEROFLEX test matrix

4.7. Recommendations for implementation of AEROFLEX innovations

As a results out of the first project phase it is decided to focus on Regulatory Framework Workshop within the scope of the project.

In February 2019, the first workshop took place in Paris with two main objectives:

- to update the technical solutions of the technical innovations.
- to discuss the regulatory gaps in the current regulatory framework and to identify the relevant barriers for the implementation of the proposed technical innovations.

The most relevant barriers are the implementation of the aerodynamic devices, the e-dolly, integration in multimodality context for the logistics partners daily activities.

Concluded was the need for new meetings focused on Intelligent Access to explore the potential in relation to multimodality and logistics optimisation. It will be chaired by RDW in conjunction with ACEA. The objective is to have an overview of examples of application in other countries (e.g.: Australia, Estonia, Sweden or the Netherlands) and to work on different practical use cases where intelligent access could be applied.

In parallel, a dedicated workshop with representatives of the European Commission (DG MOVE and/or DG GROW) is being prepared. This high level workshop is going to be chaired by ACEA and it will include the main facts from past projects such as FALCON [10] or the High Capacity Transport report of the ITF/OECD [11]. The purpose is to make policy makers aware of the activities of the project and strengthen the relationship among all stakeholders involved.

All of this linked together with the synergies established between all stakeholders will help the project to achieve its short and long-term goals and the desired societal impact.

5. Conclusions and discussion

New vehicle concepts and new technologies developed within the AEROFLEX project do have a significant contribution to CO^2 reduction objectives and to increase efficiency in road transport in a multi-modal context.

The main first conclusions are:

1. The **new vehicle concepts** allow:
    - A wider use of HCV for efficient and cleaner road transport
    - An enhancement of EMS concept for optimised multi-modal transport

2. The **logistics operations** is able to handle in a better way:
    - Both low and high density goods as well as for long and short haulage
    - Consolidation of freight as a pre-condition

3. The ongoing **digitalisation** process will transform the assets (semi-trailers, boxes, wagons) into smart devices, forcing the transport industry to change and adapt the logistics processes (horizontal and vertical collaboration) to keep competitiveness against Asia and the US.

4. **Smart Infrastructure Access Policies (SIAP)** are crucial for optimal matching of novel vehicle concepts, infrastructure and operations (handling of goods, loading units and vehicles).

The AEROFLEX project will end phase two by the end of 2019 having the demo-vehicles ready for testing.
Test and demonstrations will be performed during Q1/Q2 in 2020 followed by an in-depth assessment programme. Final results will be available by the end of the year 2020.

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