Aerodynamic and Flexible Trucks for Next Generation of Long Distance Road Transport

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Publishable Executive Summary

The mission of the AEROFLEX project is to support vehicle manufacturers and the logistics industry to become prepared for future challenges in road transport. The main objective of the AEROFLEX project is to develop and demonstrate new technologies, concepts and architectures for complete vehicles that are energy-efficient, safe, comfortable, configurable and cost-effective. Work package 1 contributes to the overall project objective by describing the needs of the European logistics market in order to enable a vehicle development in line with the market requirements. The present report represents deliverable 1.1. The objectives of this deliverable are:

- to describe the European transport market
- to describe trends and market drivers in logistics
- to describe variables which influences actor's mode choice in freight transport
- to derive first recommendations regarding use cases coming from the market analysis.

The results of the deliverable 1.1 are used in other work packages to support the selection of use cases. A first stakeholder workshop has shown that it is difficult to translate the requirements of the logistics service providers directly into technical details of new vehicle concepts. Therefore it wasn't possible to define primary candidates immediately and solely based on the input that was given by the FALCON project.

Instead, the results are based on the one hand on the analysis of literature and reports of European projects like TRANSFORMERS, FALCON or ALICE. On the other hand a first workshop with stakeholders (e.g. logistics service providers, shippers) have been conducted and analysed regarding user needs and requirements. The results and requirements are compiled as follows.

Increase of efficiency for freight transport

First of all, the improvement of efficiency is one important driver of European freight transport market. Co-modality and synchromodality are key elements to improve the efficiency. Freight transport should be organized by the consideration of the strength and weaknesses of the transport modes that are relevant to fulfil the requirements of the shipper that are defined by lead and transport time, weight and volume of the order /the shipment and further specific costumer and good related characteristics. The transport by only one transport mode could be the most efficient way in case the strength of this mode fulfil the given constraints, e.g. to carry goods due to time constraints, direct link between origin and destination without detours, availability of infrastructure and specialised equipment, sum of working time. Furthermore, it is necessary to fulfil the costumer related expectations regarding transport costs.

The available European 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 e.g. in terminals and hubs. From the perspective of tonne-kilometres, new vehicle concepts could address all goods classes and not only selected ones due to the objective to develop a configurable and cost-efficient vehicle concept that is not dedicated for only some commodities.

Vehicle concepts should be developed for low density goods, long transport distances and high revenue logistics segments

New vehicle concepts should address good classes with high transport performance measured in tonne-kilometres (e.g. food products, beverages and tobacco, agricultural products) in combination with long transport distances. Furthermore, the potential revenues in logistics segments (e.g. Contract Logistics, full and less than truck load with palletized goods and Courier/Express/Parcel) should be considered. These segments should be addressed, because the balance between market size, expected revenues and small order sizes expect a high demand for advanced vehicle concepts using modular loading units. Finally, it is recommended to realize an optimum trade-off between payloads and transport volumes in order to maximize the use of the loading capacities.

Fast and frequent road transport between hubs and industrial sites become important

Due to the increasing amount of courier/parcel/express cargo and general cargo, hub and spoke concepts are increasingly used to consolidate the shipments and thus, to increase transport efficiency. Therefore, a promising and growing segment for new truck concepts can be identified in transports between hubs (e.g. terminals, ports,

huge warehouses) as well as between industrial sites and hubs. Here, it is essential that loading units can be optimally manoeuvred and placed at the gateways in cross-docking stations or in warehouses, even if there is a limited infrastructure conditions. Further, the organisation of a fast exchange of loading units between different vehicles or between transport modes is important.

New vehicle concepts have to be compatible with the existing infrastructure

Infrastructure conditions and constraints of the existing road infrastructure – road, bridges, yards, driveways, roundabouts, parking areas and docks – are key issues for new vehicle concepts. Currently, most parking areas and docks are not suitable for long commercial vehicles. The new vehicle concepts should be compatible with the existing road infrastructure to avoid an extensive enhancement of the European road infrastructure or sophisticated technical solutions supporting manoeuvring in confined spaces on motorways and inter-urban roads.

Platooning, autonomous driving and the digitalization of logistics processes are relevant trends

The digitalization of logistics processes supporting the driver, simplifying vehicle routing and route planning, and enabling the monitoring (e.g. smart loading units) of the whole transport chain is ongoing. Based on these digital opportunities, new transport services and processes are expected to emerge. Further approaches (in particular platooning and automated driving) reduce the stress for the driver and may contribute to a reduction of transport costs. However, they require sensors, communication technology and energy supply within the vehicle.

Further trends with an effect on the transport and the vehicle are seen in:

- Dematerialisation, i.e. the amount of materials used in products might be reduced.
- 3D-printing technology will be developed, i.e. personalised, small scale local production in regional production sizes or for spare parts retailing.
- Postponement of final product assembly, i.e. local assembly close to the consumer, leading to the transport of intermediate products (parts and components) rather than final products, with the potential to reduce the amount of space required for transport.
- Transport of Intermediary goods instead of final products is increasing and may enable a higher packaging efficiency and higher density of goods in the loading unit. This may help to meet volume restrictions.

Use Cases should represent the European transport market

The AEROFLEX project develops an innovative vehicle concept for a major percentage of the European transport market, which shall simultaneously contribute to an efficient overall freight transport system. The use cases considered in the AEROFLEX should meet the requirements of significant sub-markets in the current transport market in Europe. Based on the analyses we conducted, the uses cases should:

- include own account transports as well as transports conducted by own company and conducted by third parties (e.g. by logistics service providers)
- offer the possibility to use intermodal transport chains in cases of long transport distances
- address preferably logistics segments with high expected demand for advanced vehicle concepts like Contract Logistics, full and less than truck load with palletized goods and Courier/Express/Parcel, food products, beverages and tobacco
- address transports that are mainly conducted on motorway and inter-urban roads today.

It is not sufficient to identify and validate primary candidates only based on literature analyses and aggregated European transport and logistics data. Instead, is additionally necessary to get more information in direct contact with stakeholders and potential users of new vehicle concepts. Thus, further stakeholder workshops will be conducted within the Work Package 1. The results will be described in the deliverable 1.2.

Purpose of the document

This present document is the AEROFLEX deliverable D1.1 summarizes the first results of WP 1 in the AEROFLEX project and covers the following topics:

- Characterization of the European road transport market in general
- Description of the role of road transport in intermodal transport
- Analysis of load factors measured in France and the Netherlands
- Description of trends and drivers in the transport market.

The achieved results base on a literature analysis of European studies and project reports, an analysis of available data, and discussions with logistics service providers. The document describes the relevant information that has to be considered in the AEROFLEX project to determine the relevant and suitable use cases for new vehicle concepts. It gives necessary input to WP2-WP6 of AEROFLEX based on the requirements towards WP 1.

The figure below shows the schematic project plan with main phases and milestones within the project as a guide to better understand the Initial Dissemination Plan. The present deliverable contributes to Milestone 1 (MS 1) in the first quarter of the project.

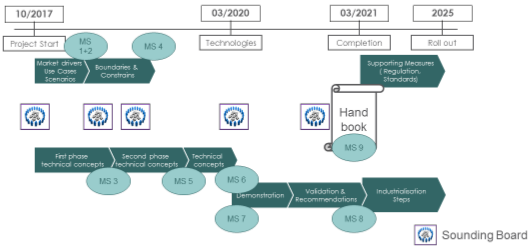

Figure 1-1 AEROFLEX Project plan, project phases and milestones

Several members of the sounding board were represented in the stakeholder workshop, which was contributed by WP 1. The sounding board consists of representatives from authorities, policymakers, and employees of logistics and manufacturing firms. The purpose of the sounding board is to advice the process of defining the recommendations for implementation of the solutions and measures developed within the AEROFLEX project.

In order to facilitate an efficient decision-making, three types of **dedicated meetings** with members of the sounding group during the course of the whole project are foreseen:

- Technical Assessment Assembly (TAA) –Initiatives leaders, research & industry partners & relevant associations
- Policy Regulatory Consolidation Group (PRCG) – Regulatory groups & Public administration
- Complete Sounding Group (CSG) – All type of stakeholders will be involved in such meetings.

Keywords of this deliverable are: vehicle engineering, logistics, road freight transport, vehicle concepts for heavy commercial vehicles (HCV), green logistics and trends

Supported by sub themes within the different keywords:

Multimodality, combined transport, intermodal transport, logistics hubs, smart loading units

1 Introduction

1.1 Overall objective of project AEROFLEX and of WP1

The mission of the AEROFLEX project is to support vehicle manufacturers and the logistics industry to become prepared for future challenges in road transport. The main objective of the AEROFLEX project is to develop and demonstrate new technologies, concepts and architectures for complete vehicles that are energy-efficient, safe, comfortable, configurable and cost-effective. Work package 1 contributes to the overall project objective by describing the needs of the European logistics market in order to enable a vehicle development in line with the market requirements. The present report represents deliverable 1.1. The objectives of this deliverable are:

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Instead, the results base on the one hand on the analysis of scientific literature and reports of European projects like TRANSFORMERS, FALCON or ALICE. On the other hand, workshops with stakeholders (e.g. logistics service providers, shippers) have been conducted and analysed regarding user needs and requirements. The results and requirements are compiled as follows.

1.2 Requirements of other AEROFLEX work packages towards work package 1

WP 1 provides basic input for the other work packages. During the preparation of the AEROFLEX project and the presentations given by the WP leaders at the AEROFLX kick-off meeting, certain requirements towards WP 1 were detected. They are summarized in the table below. Certain requirements can be answered by conducting literature analyses or stakeholder discussions. They are covered by the present document. Other requirements demand further qualitative and quantitative analysis conducted in later project tasks in WP 1. Therefore the present document answers partly to the requirements. It is one goal of WP 1 to provide the expected input to the other WPs by the use of the described methods and based on validated results.

Table 1-1 Requirements of results and findings coming from WP1

No	Requirements	comments
1	Load and Mission profiles From the mission profiles, detailed cycles (speed and slope over time) have to be derived by WP2+WP1. These cycles are necessary to derive the fuel saving potential of an advanced powertrain. The saving potential computed in WP2 is strongly related to the driving cycles we consider. - load of the Demo Vehicle (EMS1: Truck/tractor, Dolly, Trailer) - basic set of Vehicle Configurations and Mission Profiles - complete set of Vehicle Configurations and Mission Profiles	Literature and public data analyses couldn't meet this requirement; Further (private) Data sources have to be identified
2	Requirements and/or information on limitations for the handling of goods (e.g. side loading, rear loading, docking requirements etc.). This information will have an influence on the choice of concepts in WP3	Question for the workshops in task 1.2
3	Information on the willingness to invest in devices for low aerodynamic drag, and fleet owners requirements on ROI/pay-off. This information will be considered in the design of the concepts conducted in WP3. Depending on the expected ROI, we may derive conceptual development in different directions. Also, the targets for the concept development (drag reduction potential and cost) will be influenced.	Question for the workshops in task 1.2
4	Information on shares of volume and weight restricted transports for different vehicle combinations (tractor and semitrailer, rigid and trailer & EMS). This information will have an effect on the optimum choice of loading units, and also defines the range of adaptability (volume needed for different transport tasks).	Results of data analysis will be described in D1.2
5	Logistics/Transport segments that should be covered by the use cases, based on secondary statistics and survey results	See chapter 3 and 4; Further information given by data-analysis described in D1.2
6	Requirements towards loading units, reasons why certain types of loading units are used	See chapter 3.2.2 and D 4.1; Question for the workshop in Task 1.2
7	Will the next generation long haul truck be used only on motorways (hub-hub transport relations) or also in a rural or even urban context? In the case of urban/rural missions, which truck combinations (e.g. rigid and trailer) is suited?	See chapter 3.1.7
8	Could provide some hypothetical statements about structural and functional evolutions of hubs? Who will surround the truck during transit and in the loading / unloading phases? Only professional users? Which other means of transport will circulate there?	Question for the workshops in task 1.2
9	While driving, only the driver will be present in the cabin or there will still be a co-driver on board?	Question for workshops in task 1.2
10	Are forecasts available for the share of sales between different truck types (N2 and N3) in the next years? Are forecasts available for the mileage travelled in different areas (e.g. rural vs. urban) for different truck types (N2 and N3) in the next years?	Results of task 1.4 of WP 1

11	driving conditions:
	• Road type: urban, rural, motorway. The focus lies on rural areas and on motorways. If urban cycles can be easily gathered, this will be valuable in the assessment of concepts in logistics operations.
	• Traffic conditions: congested, average, free-flow
	• route profile Evaluation: flat, hilly, mountainous
	  ○ Flat: e.g. <200m/100 km
	  ○ Hilly: e.g. 200-<1200m/100 km
	• Mountainous: e.g. >1200m/100 km
	• Payload: empty (1t), average (15t), full (25t)
	In total, the application range spreads a space of max. 81 (3^4) driving conditions. A driving cycle is typically defined second-by-second or meter-by-meter.
	○ for the road type and traffic conditions, a speed profile is required (second-by-second).
	○ for the hilliness, an altitude profile is required (meter-by-meter).
	○ for the payload, a fixed weight is required. This is fairly straight-forward (fixed).
		Literature and public data analyses couldn't meet this requirement;
		Further (private) Data sources have to be identified

12	The economic assessments will differ among logistics sectors and be dependent on the typical operations in these sectors. In order to provide a broad overview in each case, as a suggestion, WP6 will differentiate between the following sectors:
	  ○ Parcels and express
	  ○ Temperature-controlled
	  ○ General cargo and retail
	  ○ Waste logistics
	  ○ Facility logistics
	  ○ Construction logistics
	  ○ Bulk dry/bulk wet
	Depending on the use case study in WP1, for each logistic sector a typical operation is required from WP1.
		See chapter 4.1 Description of use cases in D 4.1

2 Methods

For being able to describe the European freight transport market and its drivers with the purpose of developing new vehicle concepts a comprehensive literature analysis was carried out. Furthermore, data-bases covering figures of the European transport market were compiled and analysed. The research was supplemented by feedbacks from stakeholders. The exact procedure is described in the following.

2.1 Literature analysis

In a first, step relevant literature for describing the European transport market was collected for being able to derive requirements for future vehicle concepts. The literature survey included projects, incl. deliverables and reports, studies, articles:

- The focus was on scientific literature and on European projects (web pages, deliverables) dealing with the configuration of trucks, relevant input from European Technology Platforms (ETP) ALICE and ERTRAC as well as project results of other relevant projects e.g. TRANSFORMERS, FALCON are considered in this literature analysis.
- In addition, the European white paper on transport was screened.
- Also, public statistics in reports were taken into account.

2.2 Data mining

One objective of the present document is to describe the European transport market. Therefore, publically available data provided by EUROSTAT will serve as a basis for describing the European freight transport market. Due to a poor data basis of the European transport market, it was further decided in WP 1 to analyse the EUROSTAT micro data about road freight transport with heavy duty vehicles over 7.5 tones gross weight in order to describe the European transport market. Due to a delay in receiving these data, it wasn't possible to do the descriptive analyses yet. Therefore the results will be reported in D1.2 and D1.3.

2.3 Stakeholder discussions

One of the objectives of WP1 is to understand the needs of the European logistics market and to describe how innovative vehicle concepts can be designed in order to respond to the today's needs and the future demands of road freight and intermodal transport. Logistics service providers and shippers play a major role for the identification of the logistics requirements as they are the most important stakeholders in this segment. For being able to consider the stakeholders' requirements a workshop was organised and held in March 2018 in Dortmund (Germany). The objectives of this workshop were:

- the identification of user needs and stakeholders' requirements regarding new vehicle concepts
- understanding the logistics requirements and opportunities also for loading units in a multi modal context
- to match the logistics sectors with the most appropriate innovative vehicle concepts
- to define criteria and KPIs to judge the impact and the cost/benefit of new vehicle concepts and features on the logistics operation in a multimodal context
- to define possible applications of vehicle concepts and to develop possible test use cases for the new vehicle concepts.

In total, two logistics service providers and five shippers participated in the workshop. Beside logistics experts of OEMs, also a logistics expert of construction material production and retailing took part in the event. In addition, an expert of intermodal transport rail/road, a representative of an association of international road transport companies and a representative of the ETP ALICE participated in this workshop.

Conclusion

The methods to generate the output of D1.1 were selected in line with the description of work and the planned timeline. It has to be concluded that data mining was only limited to free public available data and will be given more focus in deliverables D1.2 and D1.3. The discussion with stakeholders will also be continued in the next months and deliverable D1.2 will further address methods and the results coming from the planned workshops.

3 Results of market analyses

This chapter will pursue the description and analysis of the European freight market based on publically available data and a literature analysis. A special focus will be put on road transport since AEROFLEX vehicle concepts are constructed for this transport mode. Interfaces for enabling intermodal transport and future developments and trends will be considered as well.

3.1 Road transport market

3.1.1 Market volume concerning transport volume and distances

The transport of goods can be performed by air, pipeline, rail, road or water (sea and inland waterways). In total about 3,516.5 billion (bn) tonne-kilometres (tkm) were performed on the territory EU28 in 2015. Annual growth rates are actually between 0.5 and 1.2% (European Union 2017). It is expected that commercial transport will further grow. The most important driver is the dynamics in international trade (figure 3-2). In Germany for example, a growth of 42% cross-border and 52 % transit traffic compared to 2010 is expected until 2030 (BVU et al. 2014). In Europe the ITF expects a doubling in freight by 2050. Globally transport demand is even expected to triple increase by 2015(International Transport Forum 2015). In Europe, road transport plays here an important role.

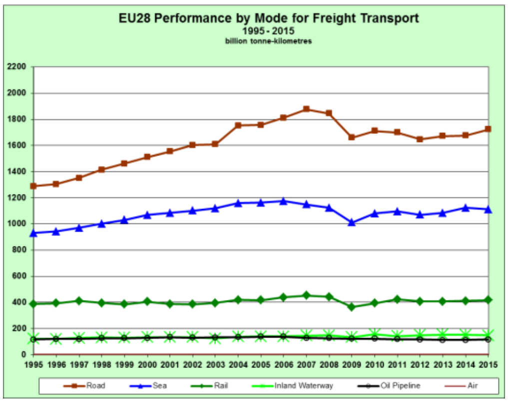


Figure 3-1 EU28 Performance by mode for freight transport (European Union 2017)

Looking on the current share of road freight transport in EU-28, the share is 48.9 %, (1,722.3 bn tkm) (European Union, European Commission, and Eurostat 2017). Considering only total inland freight transport in the EU-28, three quarters of the total freight transport performance was conducted over roads in 2014 (EUROSTAT 2017). It is generally predicted, that the share of road freight transport will remain constant (figure 3-2). The European Commission's latest Transport Reference scenario indicates an expected growth of 28 % in tkm between 2015 and 2030, and a 48 % growth for 2050 in the EU28 (European Commission 2016). At present the EU road freight transport industry is composed of about 553,873 companies, including one-man companies as well as multinational fleet operators (European Union 2017).

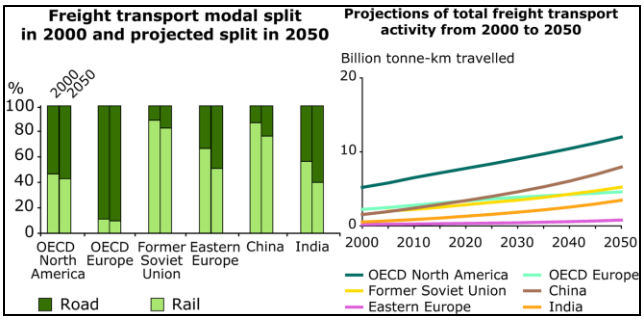


Figure 3-2 Freight transport development until 2050 (European Environment Agency 2007)

According to EUROSTAT (tables 2.2.4d, 2.2.5, 2.2.6, 2.2.7), about 71.2 % of all European freight transport on land was realised via road in 2015.

According to EUROSTAT, 85.3 % of EU-28 road transport was performed by vehicles with a maximum permissible laden weight over 30 tonnes, whereas vehicles with a maximum permissible laden weight under 10 tonnes carried only 0.6 % of the transported tonne-kilometres in 2016 (EUROSTAT 2018d). Looking on the payload capacity (maximum weight of cargo that could be carried by the vehicle), around 81 % of the EU28 road transport were conducted by Heavy Commercial Vehicles (HCV) with a payload capacity over 20.6 tonnes. There was an increase in 2016 of 27.9 % of transport performed by vehicles with a payload capacity below 3.5 tonnes, compared to 2012. This is mainly caused by the growing market of parcels, courier and express goods, that are increasingly used in last mile distribution in B2B and which are also driven by E-commerce in B2C.

Furthermore, the vehicles with a payload capacity above 30.5 tonnes and between 3.6 and 9.5 tonnes experienced an increase in transport performance of 25.9 % and 25.8 %. Only vehicles with a payload capacity between 15.6 and 20.5 tonnes decreased in their transport performance by 3.3 % (EUROSTAT 2018e).

According to Barbarino et al (2013), round about 6.5 million HCV with payload capacity of more than 3.5 tonnes were registered in the European Union in 2008. 76.6 % of road freight transport in the EU is carried out with articulated vehicles consisting of a tractor unit and a semitrailer (EUROSTAT 2018c).

87.4 % of the semitrailers used have a payload capacity of more than 20 tonnes. The articulated vehicle consists of a two-axle tractor unit and three-axle semitrailer with one axle which can be lifted. This vehicle configuration is estimated to be the most common vehicle combination used intra-EU freight transport. The average empty weight of such a combination running on diesel is about 14 tonnes. Considering a maximum authorized weight of 40 tonnes in most EU countries, such a vehicle combination can carry a maximum payload of 26 tonnes or between 85 and 90 m³ of volume."(Barbarino et al. 2013).

The improvement of efficiency is one important driver of European freight transport market. Co-modality and synchromodality are key elements to improve the efficiency. That means to use the appropriate mode of transport to carry goods in an efficient way e.g. with less energy consumption, less infrastructure requirements and less working time. Freight transport should be organized by the consideration of the strength and weaknesses of the transport modes that are relevant to fulfil the requirements of the shipper that are defined by lead and transport time, weight and volume of the order /the shipment and further specific costumer and good related characteristics. Solutions that combine the strength of more than one transport mode in an intermodal freight transport have the potential to be the most efficient way to carry goods. Otherwise, the transport by only one mode could be the most efficient way to carry goods due to time constraints, direct delivery, shortest distance to be covered or other (e.g. necessary infrastructure and working time). Furthermore, it is necessary to fulfil the costumer related expectations regarding transport costs.

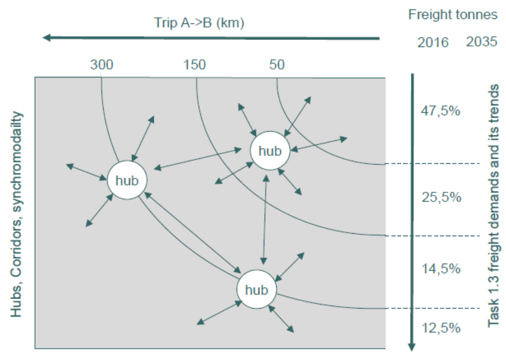


Figure 3-3 Transport demand related to transport distances (EUROSTAT 2018c)

The transport demand in relation to the transport distances shows the decreasing demand in relation to the transport distances. The shipments (e.g. LTL, Courier/Express/Parcel) are consolidated to increase the load factor of vehicles and to organise the collection and distribution of cargo in hubs and terminals.

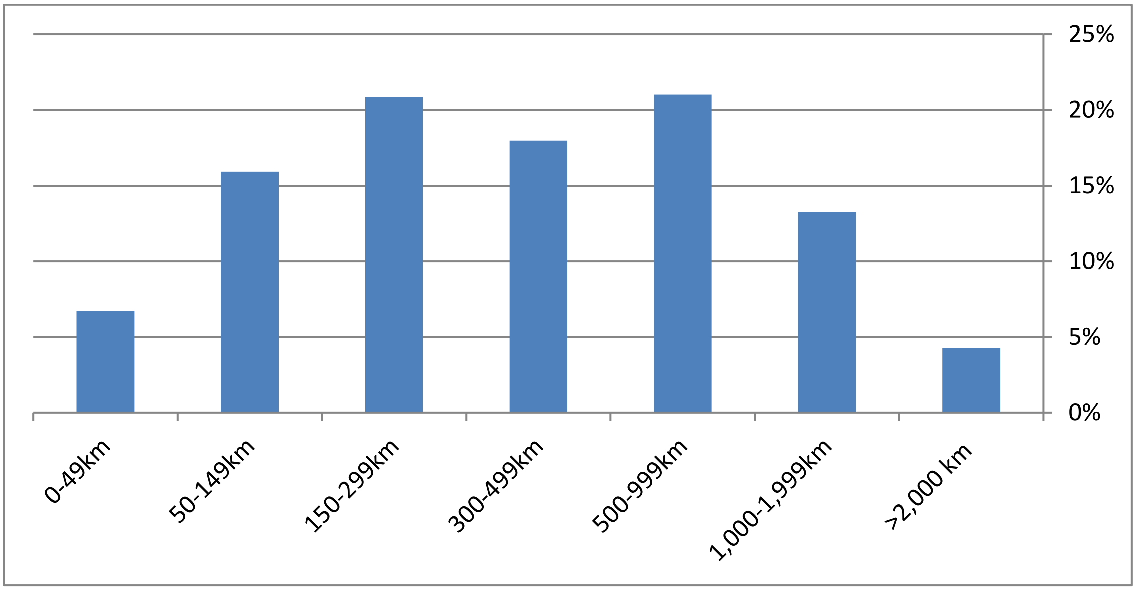


Figure 3-4 Distribution in tonne-kilometre of European transport market related to the transport distance of the freight (EUROSTAT 2018c)

Figure 3-4 shows the European transport market related to tonne-kilometres and the covered transport distances and have a frequency distribution with the highest values between 150 kilometres until 1,000 kilometres. In terms of tonne-kilometres, about 80 % of all freight transport is realised on long haul (over a distance of 150 km or more)) (EUROSTAT 2018c). 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 freight transports e.g. in terminals and hubs. The optimization of freight transport according to sustainability goals requires a combination of all transport modes, where all modes contribute with their respective strengths.

Figure 3-5 shows the European transport volumes and tonne-kilometres of all good classes. The most relevant goods group (in terms of tonne-kilometres) is 'food products, beverages and tobacco' (NST 2007, group 04), followed by 'agricultural products' (NST 2007 group 01). From the perspective of tonne-kilometres, new vehicle concepts could address all goods classes and not only selected ones due to the objective to develop a configurable and cost-efficient vehicle concept that is not dedicated for only selected commodities.

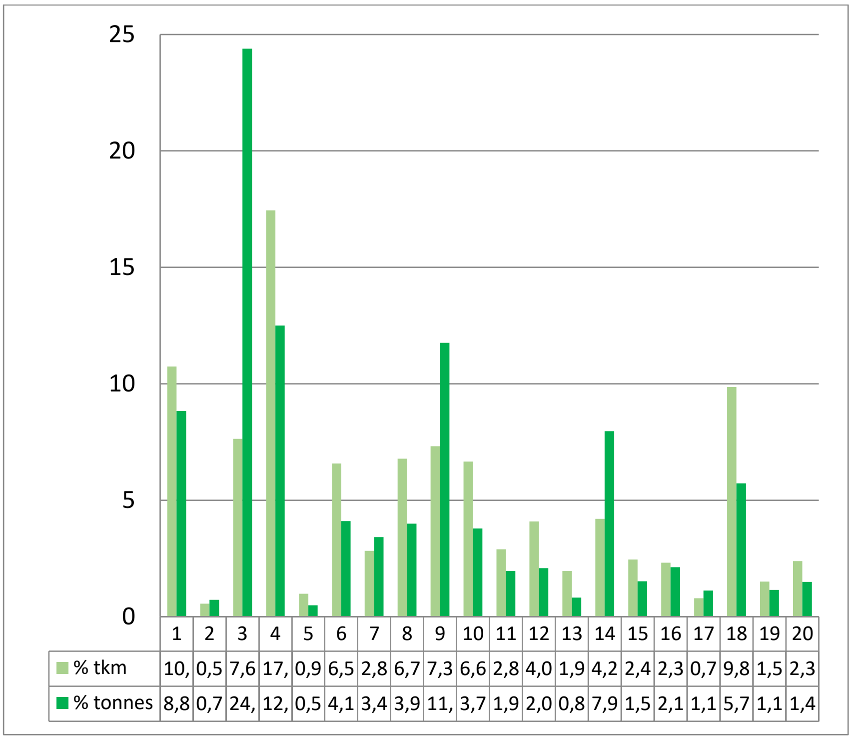


Figure 3-5 Transport volumes and tkm of all good classes (classification based on NACE 2007,see Table 3-1 below and in Appendix B) (EUROSTAT 2018c))

Table 3-1 Explanation of biggest good classes of figure in 2016 (NST 2007, see Apendix B)

No (NACE 2007)	Good class	Volume in thousand tonnes	Share in percent	Volume in million tonne-kilometres	Share	Share of transport >300km
01	Products of agriculture, hunting, and forestry; fish and other fishing products	1,295,879	8.8	199,451	10.7 %	55 %
03	Metal ores and other mining and quarrying products; peat; uranium and thorium	3,581,505	24.4	142,902	7.7 %	16 %
04	Food products, beverages and tobacco	1,836,364	12.5	324,863	17.4%	59 %
06	Wood and products of wood and cork (except furniture); articles of straw and plaiting materials; pulp, paper and paper products; printed matter and recorded media	134,265	8.24	122,667	6.6 %	65 %
08	Chemicals, chemical products, and man-made fibres; rubber and plastic products; nuclear fuel	586,082	4.0	126,515	6.8 %	69 %
09	Other non-metallic mineral products	1,726,057	11.8	136,842	7.3 %	38 %

No (NACE 2007)	Good class	Volume in thousand tonnes	Share in percent	Volume in million tonne-kilometres	Share	Share of transport >300km
10	Basic metals; fabricated metal products, except machinery and equipment	142,549	8.74	124,229	6.7 5	69 %
18	Grouped goods: a mixture of types of goods which are transported together	841,274	5.7	183,928	9.9	68%

Standardised loading units are important for international transportation of goods by maritime transport. They allow to shift from one mode of transport to another e.g. by gantry cranes or by reachstackers. Stackable ISO containers could be efficiently loaded and be transported on maritime vessels. The premier types of standardised loading units are ISO containers, swap bodies; and trailers as well as semitrailers. ISO containers are mainly used for maritime transport (and thus, in hinterland transport on rail and on barges). The proportion of ISO containers in total road transport is only 6.2 % in EU-28 in 2015 (EUROSTAT 2018b). The most common type of loading devices of cargo for land transport is palletised goods which recorded 42.9 % of the EU-28 road freight transport in tonne-kilometres, followed by solid bulk with almost one fifth of total road freight transport (EUROSTAT 2018a). It is conspicuous that palletised goods are a lot used for distances over 50 km (see Figure 3-6) and therefore they are very relevant for being considered in the AEROFLEX project. It is an objective that new vehicle concepts should contribute to an increased efficiency of various goods transport based on shipment size (weight and volume) and to be flexible for helping to reduce empty trip kilometres.

Another important aspect is the density of cargo. An optimum cargo density is strived to use the mode of transport efficient. The ITF (International Transport Forum) defines the optimum cargo density as the density of freight that would occupy the total available cubic capacity of a truck while simultaneously its cargo mass limits is reached (International Transport Forum 2011).

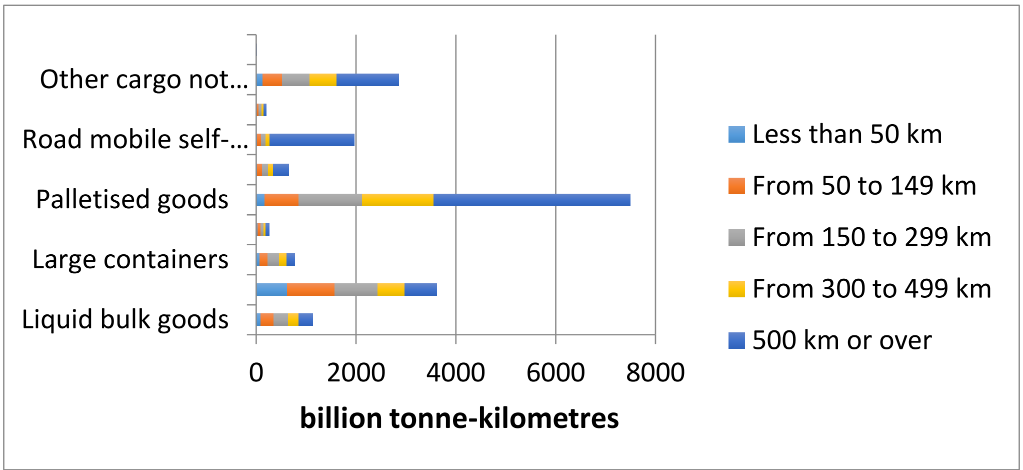


Figure 3-6 Characterisation of transported cargo in EU-28 in 2016 (EUROSTAT 2018a)

The analysis of ITF showed that tanker vehicles for example carry high density liquid products whereas very high capacity vehicles are better applicable to lower density freight. “This finding is of particular interest to assessment of potential shifts from rail to HCV, given that rail is best suited to dense bulk freight while increased truck size is best suited for freight of decreasing density.” (International Transport Forum 2011, p.32) The loading capacity of a vehicle is limited either by weight or volume whereas the density of the load determines the case for any respective vehicle. The ITF gives examples of the density of different goods (see Table 3-2).

Table 3-2 Density of selected commodities (in tonnes per cubic metre)

Commodity	Density (tonnes/m³)
Water, Milk, Beer, etc.	1
Fuel, Oil, Ethanol, etc.	0.6 – 0.8
Earth	1.3 – 2.0
Concrete	2.2
Bricks	1.9
Alloy	2.7
Steel	7.9
Wood (dry)	0.5 – 0.9
Rubber	1.2
Beer boxes with 20 empty bottles (0.3mx0.3mx0.4m) weigh 10 kg	0.3
Beer boxes with 20 filled bottles (same size, but 20 kg)	0.6
Refrigerators (white goods)	0.13
Nine passenger cars,1.5 t each, on a 100m³ transporter	0.13
Single dispatched items (parcels)	0.15
Plastic foam	0.04

3.1.2 Market volume concerning revenues

One objective of this deliverable is to derive recommendations regarding the choice of use cases. Therefore, chapter 3.1.1 described aggregate transport market indicators such as transport volume and tonne-kilometres. However, for a proper understanding of the logistics segments, further aspects regarding potential revenues and order size have to be considered for a reasoned selection of use cases. This chapter presents results coming from the study "TOP 100 in European Transport and Logistics Services" (Schwemmer, 2017), which analysed the European transport and logistics market and their drivers.

Logistics volume based on revenues

More than € 1,000 bn. logistics volume – a share of about 7 % of the European GDP – are assigned to the logistics, and the logistics volume has recently grown by 2.7 % (2015) and 1.9 %(2016). The following figure depicts the general structure of European logistics costs. The figure bases on data that were evaluated for Germany and projected to 30 European countries.

Furthermore, we analysed the total transportation cost by country. In year 2016, the sum of truck transport costs over 30 European countries amounted to € 337.267 bn. at a weighted average yield of € 22.47 per ton or € 0.23 per tonne-kilometre. In comparison to road transport, the cost of rail freight transport in total amount to € 17.6 bn.; this means in average € 14.55 per ton resp. € 0.08 per tonne-kilometre (Schwemmer, 2017, p. 23). These general figures show the dominance of road transport in the European transport logistics.

Additionally, the study considers that about the half of the logistics activities in Europe is insourced, that means it is directly organised by the company e.g. manufacturers and retailers. The other half is outsourced and logistics service providers (LSP) are in charge of the organisation (Schwemmer, 2017, p. 1)

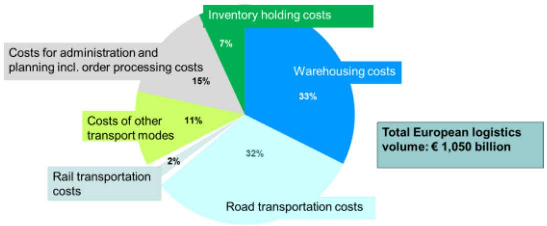


Figure 3-7 European logistics expenditure by costs type (assumption for 2016 based on German data evaluation); (Schwemmer, 2017 p. 26)

Volume of different logistics segments

One of the main questions in the AEROFLEX project is to select vehicle concepts, which have a high potential for usage. To support this selection, the structures of the different logistics segments have to be analysed. Schwemmer distinguishes nine different segments by revenues and further key figures like number of orders, average revenue by order, average revenue by tons and average order size in tonne per order. The Table 3-3 shows that the segments less than truck load, courier/express/parcels and contract logistics have on one hand side the highest revenue volumes – about € 615 bn or 52 % – in addition on the other hand side and average order sizes of two tonnes per order or less. That means that in these logistics segments, transports have to be consolidated by logistics service providers to increase the load factor of transport vehicles.

Table 3-3 Expenditure on logistics services by according to segments and logistical functions

Logistics segments	Sum of cumulated revenue of the segment in billion €	Ranking revenue	average order size (t/order)	Ranking order size
Bulk	96	7	500	1
General truckload	100	6	8	3
Less than truck load	65	8	0.6	7
Special Transportation	106	5	8	3
Courier/Express/Parcel	120	3	0.01	9
Contract Logistics	430	1	2	6
Warehousing	130	2	8	3
Ocean Cargo	110	4	20	2
Air Freight	28	9	0.2	8

(selected data of source: Schwemmer 2017, p.35 table 8)

Summarizing, these three segments have the highest potential and should be supported related to an increased efficiency of road transport by new vehicle concepts in terms of:

- the consolidation of several orders/shipments to a high use of capacity and volume in one truck
- 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
- the reduction of empty runs by using standardises trucks (length and weight) and loading units

3.1.3 User Needs and Requirements for logistics concepts and new vehicle concepts

Cargo properties are closely linked to logistics requirements and thus, they are used to distinguish logistics markets: full truckload transports (FTL), system transports (less than FTL=LTL (B2B), parcel delivery services (B2B and B2C)), contract-logistics, other logistics (e.g. construction-logistics, distribution of mineral oil fuels), transports for own account → dimension of markets

Barbarino et al (2014) identified the following six key performance indicators as relevant for evaluating the operational parameters of a tractor-semitrailer configuration: (i) transport efficiency, (ii) operational parameters, (iii) vehicle uptime, (iv) loading parameters, (v) safety and limitations, and (vi) driver comfort (see Table 3-4). These indicators seem to be drivers in the freight transport market and have to take in consideration of new vehicle concepts to be developed by project AEROFLEX and in the use cases.

The requirement to reduce greenhouse gas emissions of road freight transport is also a key issue. It is expected to be an important driver for the development of freight transport and logistics in the next decades because of the high contribution the whole transport sector to the climate change.

The following levels in the freight transport system can be addressed by measures to reduce emissions (McKinnon 2017)

- reducing the demand for freight transport,
- reducing the carbon content of freight transport energy,
- shifting freight to lower carbon transport modes,
- optimising vehicle load factors,
- increasing the energy efficiency of freight movement.

Table 3-4 Overview of KPI for road freight transport (Barbarino and Hariram 2014)

Transport Efficiency	Operational Parameters	Vehicle Uptime	Loading Parameters	Safety and Limitations	Driver comfort
Aerodynamic efficiency	Trailer depreciation	Combination uptime performence	Compatibility for automatic and manual loading	Breakdown of control system	Cabin comfort
Fuel performance	Impact on tyre lifetime	Trailer uptime performance	(Un)Loading performance	Trailer component secrurity	Driving ease
Fill speed	Trailer maintenance costs/km	Roof component uptime performence	(Un)Loading Safety	Power System (Un)Loading	Emergency repairs
Payload capacity	Trailer mainainance infrastructure	Refueling stops/1000km	Component safety during (un)Loading	Electric shock and spark hazard	(Un)Loading ease
Load factor	Spare parts	Failure mode and effect analysis	Loading Security	Battery heat and gas emissions vs trailer ambience	(Un)Docking ease
Euro Palette/ Floor space	Trailer tare weight				
Intermodality	Combination tare weight				
Route accessibility	Compatibility with different tractors				
Average haulage speed					

The shift of freight transport to modes with lower greenhouse gas emissions has the highest impact on a further reduction of energy demand and the exhaust of greenhouse gas emissions per tonne-kilometre in compliance with the calculation standard of Euro Norm 16258 (ifeu Heidelberg, INFRAS Berne, IVE Hannover 2016). Therefore, new vehicle concepts should support the spirit and the opportunity to realize synchromodality and comodality transport. New technologies for shifting loading units to rail are still developed like System LOHR Railway, Cargo Beamer® technology or the system NiKRASA (see chapter 4.2 and deliverable D4.1 of AEROFLEX for further details).

The optimization of vehicle loading addresses the reduction of empty running because at EU-28 level, a quarter of all trips were performed by empty vehicles (25.4 % in 2016). The share of empty journeys grows to 30.3 % for national transport, but is only 14.3 % for international transport in 2016 (see Eurostat http://ec.europa.eu/eurostat/statistics). Reasons for inefficient capacity utilisation might lie in (i) poor management capabilities of the forwarders, (ii) trade of between transport and warehousing cost and (iii) strict time constraints imposed by the shippers inhibiting consolidation. Since these reasons are in connection with communications and transactions, cooperation between shippers and logistics service providers could significantly contribute to a decarbonisation of freight transport by a much greater sharing of logistics assets (McKinnon 2017).

Furthermore, McKinnon points out, that the raise of HCV size and changed weight limits – within infrastructural constraints – will be a strategy for lower greenhouse gas emissions if this would be realized in line with the increase of modal shift for transport modes with a lower carbon footprint.

The increase of energy efficiency of freight movement could be reached by the following measures (McKinnon 2017):

- Use of fuel economy standards to drive efficiency improvement (e.g. improving energy efficiency of ICE)
- Improving the aerodynamic profiling of individual trucks and platoons
- More fuel efficient truck driving by driver's behaviour
- Down-speeding freight transport.

The European Road Transport Advisory Council defined the objectives for implementing its 'European Roadmap – Heavy Duty Trucks' (ERTRAC European Technology Platform 2012). The objectives in the category decarbonisation are determined by an increase of energy efficiency for long road haulage by 40% for the year 2030 compared with 2012 related to energy consumption per tonnes-kilometres measured in kilowatt-hour. The roadmap highlights milestones and measures that should be realised. The scope of AEROFLEX addresses the following measures of this roadmap(ERTRAC European Technology Platform 2012).

Milestone	Measure, that should be realised
• Year 2020	• Improved aerodynamics, more flexible directives, new vehicle combinations • Modularity of vehicle concepts • Vehicle optimised for all infrastructure • Intermodal efficiency by improvement of efficiency at the interface between the transport modes
• Year 2025	• Adaptable exterior geometry, suspension, air gap and speed control, 20 % drag reduction. • Efficient, real time, flexible truck

3.1.4 Driving patterns of vehicle used in long road haulage

For different vehicle choices the authors Abate and de Jong describe the theoretical approach based on analyses of empirical data. First they determine that firms are assumed to minimize total logistics costs by trading off between order costs, transport costs, capital costs on the inventory in transit and warehousing costs. Other criteria that influence decisions with regard to production technology, choice of input suppliers and/or receivers of their output, and location, are all assumed to be exogenous (Abate and de Jong 2014, p. 264).

Second, they derive their framework which can equally well be used as a theoretical foundation for the joint choice of vehicle type (trucks of different sizes) and shipment. In cases, where the flexibility and frequency of a delivery are important, firms tend to choose smaller vehicles. High value products are also rather shipped in smaller quantities to save inventory holding costs (de Jong and Ben-Akiva 2007). It has also be observed, that on longer trips, firms tend larger shipment sizes. The reasons might lie in economies of scale in relation to the vehicle and in safety considerations. The shipment size decreases as the value of a shipment and its inventory storage cost increase (Abate and de Jong 2014, p. 265). Moreover, for interregional road freight transports, it has turned out that the total flow of goods between two firms is able to explain a huge proportion of heterogeneity with respect to the chosen shipment size whereby the shipment size increases with the total flow of goods resulting in lower transportation frequencies (Piendl, Liedtke, and Matteis 2017; Piendl, Matteis, and Liedtke 2018). Finally, these authors also showed that the omnipresent and strong heterogeneity of shipments can additionally be captured in a manageable way by building homogeneous segments related to commodity characteristics.

The vehicle and derived the transport equipment choice is influenced by characteristics of transport goods that are determined by the packaging units, hazards for the environment, their value and if they are perishable (see Table 3-5).

Table 3-5 Characterization of good determining vehicle use and transport equipment in long road haulage

Cluster of Goods	Characteristics
Perishable goods	High frequency of delivering and a higher request for fast transports, in case of foods temperature regulated transport due to negative impact of too warm or too cold environment

High value goods	High frequency of delivering and a higher request for fast transports
Mass density: bulk and liquids	High volume of shipments with bulk and liquids coupled with a high price sensitivity; shipment size is further influenced by the trade-off of order costs, transport costs, capital costs on the inventory
Mass density: General cargo on pallets or in boxes, packing units	General cargo as FTL and LTL depends on procurement processes of the delivered company and the opportunity and costs for storage, delivery time could be different and depending on lead time of orders and supply chain frameworks. The weight, length, height, the packing units and if the single pieces or pallets in the shipment are stackable determine also loading and unloading as well as the load factor of the standardized transport equipment.
Special cargo like timber, paper roll, coils, vehicles, cement/ building materials for direct deliver to end user, heavy haulage, …	The specification of the cargo and the structure of the usual shipments determine specialized equipment to realize high transport efficiency as well as load securing. This considers the load length and number of axels, special devices for load securing, the time of loading and unloading processes.
Dangerous goods	There has to be considered special rules for transport, handling, load security and storage of dangerous goods. There are used pallets of special packing and some of them are not allowed to transport together with other dangerous goods and special goods have to be transported separately.

Source: own representation by MAN/DLR survey

The shipment size is regarded as continuous variable. The vehicle's size can neither be infinitely increased nor reduced towards zero. This means that there exist always minimum and maximum capacity constraints due to regulations and technical characteristics.

The vehicle choice is also be influenced by fact if a shipper organizes transport services on his own account or if this task is allocated to a transport service supplier. For the last case, there exist further criteria for the vehicle choice like vehicle age, operating cost per-tonne, and fleet size (Abate and de Jong 2014, p. 266).

It can be concluded, that in cases of increased variable costs of trucking operations (induced by, for instance, an oil price shock or labour market policies) firms prefer to use heavier vehicles and shipment sizes. Policies or other changes which increase fixed costs (e.g. registration tax, permits, licenses, etc.), induce the usage of smaller vehicles (Abate and de Jong 2014, p. 270). Thus, it could be expected that firms will use more heavy commercial vehicles (HCV) and new vehicle concepts in cases if fuel prices and wages increase will arise. Fuel costs will probably further increase in the next decades, but this effect will be damped because technological progress will lead to a higher energy efficiency of ICE and trucks

Finally Abate and de Jong conclude that '…the increase of trip distance increases in total demand for the origin-commodity combination per period, less voluminous goods and the decision-makers being a for-hire carrier lead to a larger shipment size. The first two effects indicate economies of distance and scale. Almost all of the selectivity correction terms are significant at least at the 5 % level, which implies that ignoring the simultaneity of shipment size and truck size will lead to biased estimates. Higher operating cost, lower total cost, higher total demand, dense and bulk cargo and the decision-makers being a for hire carrier make the use of heavier vehicles more likely. Older vehicles are used less, especially for heavy vehicles.' (Abate and de Jong 2014, p. 274).

In case autonomous driving will become in practical use in a mid-term period, driver's costs will become substituted by new vehicle technologies without legislative regulation on the organisation of the working time because there are not people performing mobile road transport activities. Furthermore, in case of platooning as a kind of autonomous driving of HCV the personnel costs could decrease as well (Nowak et al. 2016, exhibit 4).

The structure of costs (see next chapter) will be changed in the future due to external influences and that could also change the choice of vehicle sizes by the shippers and logistics service provider. It could be expected that autonomous driving encourages the use of smaller vehicles because of weaker economies of scale in regards to vehicle size. The choice could be changed in case the relation of cost of autonomous driving HCV with different laden weights will be modified. The impact of autonomous driving is described more in detail in the chapter that describes trends of long road haulage (see chapter3.4.1).

3.1.5 Vehicle cost structure of a tractor semitrailer combination in long road haulage

The cost structure of a standard tractor and semitrailer differs among member states in the EC due to different fuel and driver's costs. Figure 3-8 shows the average cost elements and their structure for a standard tractor and semitrailer in long road haulage that is registered and operated in Germany.

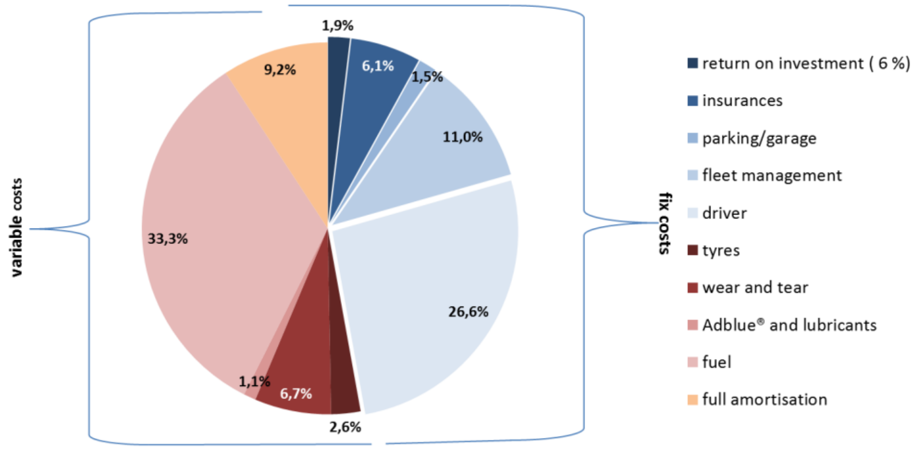


Figure 3-8 Structure of costs of a standard tractor and semitrailer operating national and international freight transport with an annual mileage of 135.000 km based on German data in year 2010 (source: own figure based on BVU Beratergruppe Verkehr and Umwelt, TNS Emnid 2015).

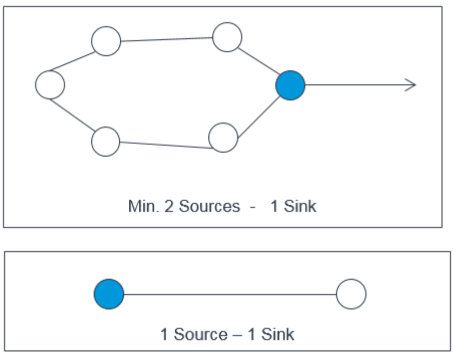
The main cost components are driver's cost, fuel cost and capital cost of the vehicle. The vehicle choice will be influenced by this structure. Lower fuel and lower driver cost will lead to a reduced willingness to adopt new vehicle concepts with higher vehicle cost but higher capacity. Light commercial vehicles as well as heavy commercial vehicles that are preferably used for the collection and distribution of cargo have a different cost structure. The focus of AEROFLEX is related to the use of new vehicle concepts for long road haulage and the interface to regional/local transport for collecting and distributing cargo.

3.1.6 Hub and Spoke concepts

Hub and spoke concepts are used for the transport of consolidated cargo: these are generally less-than-full truck-load (LTL) and courier, express and parcel transports. Both logistics segments have been growing during the last two decades, and it is expected that the growth continue (Schwemmer 2017, 109) (BIEK e.V. 2017). Therefore, hub and spoke concepts are of special interest for the use of new vehicle concepts. Hub and spoke concepts could be a driver to use new vehicle concepts for road freight transport between production sites and hubs, as well as between several hubs (a hub network), and finally, between hubs and the distribution area. A hub and spoke concept is characterized by the following elements:

Consolidation tour

(milk run to collect cargo of different shippers)



Main run

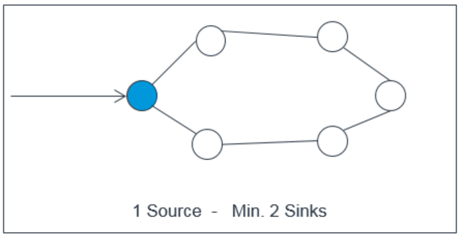
(tour between one hub to another hub)	
Delivering tour (milk run to distribute cargo to different consignees)	

Figure 3-9 Hub and spoke concepts (MAN)

The operational performance of such hubs is influenced by factors such as commercial land use and warehousing patterns in the urban areas, its geographical size and layout, and the logistics management inside the hub as well as the supply chain management based on different costumer demands. That determines the total amount of freight vehicle activity that is required to deliver and supply a given quantity of goods to an urban area with different costumers (Allen, Browne, and Cherrett 2012).

The characteristics of logistics hubs are summarised in Table 3-6. It could be concluded that the logistics hubs are influenced by many aspects, dedicated to several functions and have a high complexity. New vehicle concepts have to be applicable in relation to all these characteristics. Hence, new vehicle concepts should address the transport between the hubs. This means that new vehicles

- Should be easy to manoeuvre
- Should enable a fast exchange of loading units (from HCV and hub and within the hub)
- Should enable the efficient combination of cargo within the vehicle
- Have high security levels for operations in cross docks and at warehouses.

Logistics service providers are interested to manage their hubs efficiently. To do so, they develop new solutions for the automatization of warehousing processes, and the digitalization of data exchange by defined interfaces (e.g. barcode, RFID, data interfaced between shipper/transport company and logistics service provider). Further automated loading and unloading is coming more and more into the centre of interests. One challenge results from this tendency to automated processes: the security of workers in the hub and of the drivers that temporarily stay in the hub. The (semi) automated manoeuvring of vehicle combinations inside the hub also provides an opportunity to improve the efficiency of the transport processes. Based on a discussion with some practitioners during an AEROFLEX project presentation on February 20th 2018, some of the participants stated that only about 10 percent of their drivers would be able to manoeuvre longer heavy vehicle configurations (LHCV) inside the yards to the ramps for loading and unloading. One option is to develop highly automated solutions that support manoeuvring inside the yards. Another option consists in a modified design of the hubs so that longer vehicles can be handled. In most cases, hub areas and yards are owned by private companies and the access is restricted to authorised staff only. Nevertheless, the solutions for autonomous and highly automated manoeuvring have to consider the safety of the staff inside this operation area of the vehicles.

Table 3-6 Characteristics of logistics hubs and transport services (Thaller et al. 2014)

Characteristics of the logistics hubs		
Logistical master data • Size of the total area • Size of the transshipment area • Size of the storage area • Maximum handling capacity • Total transshipment volume in previous year • Number of ramps for local and long-distance transport	Hub integration in network structures and transport chains • Geographical position of the location • Interface between local and long-distance transport • Number of further locations • Network density • Network structure	Transport and transshipment objects • Type of goods handled • Handling equipment used and volume • Loading units entry/exit and volume
Characteristics of transport volumen and transport performance		
Transport modes and transport infrastructure • Connections to transport modes • Vehicle type used per transport mode • Transport volume per transport mode • Transport performance per transport mode • Maximum and average transport distance for delivery in local and long-distance traffic • Intra-day distribution of in- and outbounds • Load factor of transportation means • Share of empty trips		
Characteristics of the demand side		
Organizational structure of the logistics hub • Type of enterprise (type of logistics hub) • Industrial sector of the customer(s) • Organisational structure • Revenue of the location • Size of enterprise (Number of employees at the location) • Number of involved enterprises		

3.1.7 Mileage of HCV related to road classes

The energy consumption of HCV with more than 7.5 tonnes laden weight in daily operation is depending on the following criteria (see Table 3-7):

Table 3-7 Criteria influence the fuel consumption of HCV

Factor/criteria	Description: What is influencing the fuel consumption?
Load factor	influencing the total weight of the HCV
Used roads on a route	influencing the number of stops (signalling, congestion), with more stops in urban areas, less stops on rural roads and in most cases free floating traffic on motorways
Topography	flat, hilly or mountainous regions influence the gradients or the profile of the roads
Density of traffic	influencing the average speed an number of stops
Driver behaviour	Acceleration and gear shift influence the motor rotation speed
Weather conditions	Wind and temperature influence aerodynamics and friction

Source: own representation by DLR

All these factors are independent. An ideal solution to assess the impact of all these factors on fuel consumption would be an analysis of whole amount of representative trips/tours in regard to fuel consumption. Such data is not available. Instead, route specific data of trips could only be analysed on a company level. The EU project LEARN seeks to improve the 'GLEC Framework for Logistics Emissions Methodologies' that combines existing methods and fills gaps, making carbon accounting work for logistics services. For the first time, emissions can be calculated consistently at the global level across all transport modes and transhipment centres (see EU project LEARN: www.learnproject.net).

In order to get information of the used roads on the routes of trucks, we only find available data from Germany and Austria. Here, we find some aggregate information about the used types of roads. The data from Austria (**Error! Reference source not found.**) shows that about half of mileage of HCV (rigid and tractors) with more than 3 .5 tons laden weight is realized on motorways and 25 % on federal roads.

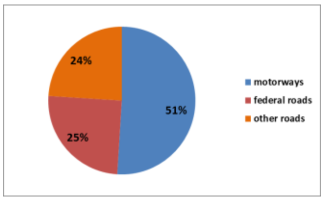


Figure 3-10 Used roads by HCV in Austria with more than 3.5 tons laden weight (ASFINAG and bmvit 2005)

In Germany, a survey of HCV vehicles with more than 3.5 tonnes laden weight is available. It shows a similar but a more differentiated picture. It is also distinguished between rural (inter-urban) road mileage and urban road mileage. It could be concluded that also near the half of the mileage is realized on motorways and about 15 % on federal inter-urban roads.

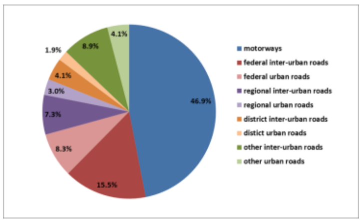


Figure 3-11 Used roads by HCV in Germany with more than 3.5 tons laden weight (Bäumer et al. 2017)

In general about 47 % of HGV mileage is realised on German motorways and 15.5 % on federal inter-urban roads. The separation of the data only related to tractor units shows an increase of about 55 % of the mileage that is realized on motorways and 16 % on federal inter-urban roads. In general, it could be assumed that the mileage on motorways and on federal inter-urban roads is positively correlated with the laden weights of HCV. Extrapolating this trend this means, that it could be assumed that at least about 70 % of the mileage of new vehicle concepts will be realized on motorways and inter-urban roads. The calculation of the fuel consumption should become part of the EC calculation tool VECTO.

3.1.8 Use of loading units in road freight transport

The current truck dimensions and maximum capacities are regulated by the Directive (EU) 2015/719. The following table summarizes some relevant dimensions of the loading units currently used in the EU.

Table 3-8 Dimensions of Loading Units used in the EU (source: Kraaijenhagen et al. 2014)

Loading Unit	Tare weight [kg]	Max. Payload [kg]	Internal Volume [m³]	External dimensions		
				Length [mm]	Width [mm]	Height [mm]
20'ISO	2,080	21,920	33.2	6,069	2,362	2,590
40'ISO	3,900	26,580	65.7	12,192	2,438	2,591
40' ISO high cube	4,150	26,330	76.1	12,192	2,438	2,896
45' pallet wide	4,300	29,700	84.3	13,716	2,500	2,775
C715	2,520	13,480	43.8	7,150	2,550	2,725
C745	2,620	13,380	45.6	7,450	2,550	2,725
C782	2,720	13,280	47.9	7,820	2,550	2,725
13.6 m semi-trailer	6,250	32,750	87.0	13,620	2,550	2,700
13.6 m mega trailer	6,500	32,500	about 100	13,620	2,550	3,000
10.5 m semi-trailer	8,820	24,180	56.4	10,536	2,550	2,848

3.1.9 Infrastructure conditions

Further project work in WP 6 plans to demonstrate the vehicles developed within the AEROFLEX project. Therefore, the typical profile data of the road infrastructure in Europe is required. For the construction of roads several characteristics like road grade, cross fall, lane width or road curvature have to be fulfilled in order to ensure road safety and the drainage of the road. The profile of a road corresponds closest to the road grade, which indicates the gradient of the road. In Germany, the road grades are specified in special guidelines for highways (Forschungsgesellschaft für Straßen- und Verkehrswesen and Hartkopf 2013) and motorways (Rohloff and Forschungsgesellschaft für Straßen- und Verkehrswesen 2008). The guidelines determine different design classes for roads and the road grade differs between these classes. For motorways the road grade is between 4 % and 6 %. On inter-urban roads, the road grade is between 4.5 % and 8 %. Other European countries have specified slightly different road grades.

The European Union developed guidelines for the development of the trans-European transport network (European Commission 2013). In section 3, article 18, the guideline specifies infrastructure requirements for the road transport infrastructure. Thus, the roads shall be of a high quality, contain parking and rest areas and further associated equipment. Further, the safety of the road infrastructure has to be assured and monitored. A road gradient for the roads isn't specified within this guide line.

Beside the end user requirements also compatibility with the European (road) infrastructure is a key issue. That means that restrictions for the use the existing European road network should be limited or avoided in general.

Another constraint for new vehicle concepts in relation to the road infrastructure is connected with truck parking along the motorways and inter-urban roads. Due to European regulation on working time of persons performing mobile road transport activities (EU regulation 2002/15/EC), each EC member states has to provide sufficient parking opportunities. Due to the increase of road freight transport in the last decade certain bottlenecks exist in some European regions. It has to be considered that several parking areas are overflowing by parked trucks. New vehicle concepts could contribute to fewer trucks on the roads but – due to longer tractor/rigid and trailer combinations – there might not be a positive effect on space occupancy on parking areas. Furthermore, there might be changed design requirements. Based on several interviews with truck drivers Aarts and de Sutter (2014) stated , that parking areas are used (i) to wait for return cargo; (ii) to stay overnight because the customer wants the delivery early in the morning but doesn't allow him to park on his site; (iii) united companies on a business park forbid truck parking because of conflicting with the good appearances of the park; (iv) to exchange vehicle units; (v) to change drivers etc. Parking areas alongside European motorways form infrastructural as well as logistics hubs with different functionalities for the road freight transport. Another issue is the increase of criminal activities on parking areas alongside motorways. Everything on and inside a truck represents value and new vehicle concepts and the infrastructure of parking areas should perform new solutions to secure the driver, the truck as well as the load inside the truck.

3.2 Intermodal Transport – Role of road transport

3.2.1 Mode Choice Criteria

Shippers have different requirements (e.g. concerning transport and lead time and transport costs, reliability damage risks, flexibility, availability of additional services) towards freight transport whereby the choice of the transport mode depends on these requirements. Vierth et al. (2017) approached this subject and give an introduction in firms' mode choice. According to Vierth et al (2017) mode choice describes the selection of a transport solution and involves the choice between different options and the combination of transport modes whereby the following factors are of high importance for the mode choice:

- shipment characteristics,
- firm organization and management,
- modal characteristics.

The shipment is characterized by the value, weight, volume, time-sensitivity, transport distance and regularity of the shipment. Road freight transport is considered to be advantageous regarding the following characteristics: service frequency, reliability, flexibility (compared to rail or waterborne transport). Therefore, it especially attracts time-sensitive goods and products with a high value-to-weight ratio. But the comparative advantage of road freight transport is also dependent on the transport distance. Rail and waterborne transport require additional transhipments additional causing cost. These additional transhipments still make economically sense in, if the transport distance exceeds a limit of around 300 km. Road transport is therefore the dominant mode on shorter distances. However, by increased value density of the transported products, road freight transport increasingly undertakes also international intra-EU and extra-EU transports (Vierth et al. 2017).

For the analysis of the impact of firm's organization and management on mode choice, seven in-depth interviews with shippers and logistics service providers (LSP) were conducted in the Netherlands. It can be summarized that the mode choice decision is normally done by the LSP, who conducts the transport. The shippers put little weight on that decision, as long as the requirements like delivery time, load locations or the collection time are met. Some of the shippers have put an emphasis on the energy reduction objective. The shippers receive offers from different LSP for the transportation and select the best option. Here, transport cost is the most important choice criteria under the assumption, that also the other shipper requirements are met. Sometimes, the transport is requested on a short term. Then the road freight transport is the only practical solution due to the high flexibility to provide quick freight transport services (Vierth et al. 2017).

The modal characteristics are well described in the literature. The most relevant factors for mode choice are cost, transport time, reliability, service frequency and damage risk. They are generally described with elasticities, which "give the percentage change in demand for a mode following a one percentage change in price, holding total transport demand constant"(Vierth et al. 2017). Transport cost is considered the most important factor in the literature. Compared to the other modes, the demand for road transport is less cost and time sensitive. It is assumed, that (i) trucks are seen as superior in several aspects so that changes in cost and time have minor impact on mode choice and (ii) trucks are urgently needed for door-to-door transports and therefore are less cost and time sensitive (Vierth et al. 2017)

The freight model used for Germany's infrastructure planning added some further aspects that are important for the shippers for mode choice. Behind transport cost and transport time, further criteria identified such as punctuality and late arrival as well as the damage of carried goods and the availability of additional services. All these factors influence the mode choice significantly (BVU Beratergruppe Verkehr and Umwelt, TNS Emnid 2015); their impacts, however, differ across logistics segments.

Furthermore, the mode choice depends on logistics concepts and the supply chain planning. In these processes, many stakeholders are involved such as the LSP, shippers, procurement and production planning departments, or the retail management. In the end, freight transport is determined on an overriding strategical, tactical an operational planning process and the interactions of the stakeholders. That means that the integration of new vehicle concepts can only be successful in cases where logistics and production is able to adopt these new vehicle concepts. This will be a process and will be done by the evaluation of the benefits for different stakeholders. The transport cost will probably be an important criteria but it is not the only one.

3.2.2 Loading units in Combined Transport

In domestic combined transport approximately 75 % of the loading units are containers (20', 30' and 40' containers), the remaining loading units are swap bodies, 45 ft container and semitrailers (BSL Transportation Consultants GmbH & Co. KG. 2017). Semitrailer are slightly used in continental intermodal transport chains with an amount of 18 % (BSL Transportation Consultants GmbH & Co. KG. 2017). For more information, see deliverable 4.1.

3.3 Load factors

The load factor describes the utilization of a vehicle and is therefore an important aspect for the decision which vehicle concepts should be pursued in the AEROFLEX project. The transported volume and weight of single vehicles in comparison to the vehicles dimensions is an indicator, whether vehicles with higher volume and/or weight are necessary. Therefore, it is essential to analyse data about the current use of vehicles in the European transport market. The Eurostat micro data about the European road freight transport provides the opportunity to analyse transport data on the level of single vehicles and trips in order to derive statements with regard to the load factor. WP 1 applied for these data. Unfortunately the data were provided too late by EUROSTAT to realize this comprehensive data evaluation in this deliverable. Thus, the results of the analyses will be presented in later deliverables of WP 1.

In addition, the availability of further data of project partners and sounding board members regarding load factors were checked. Up until now it was impossible to acquire data from the Weight-In-Motion measurement devices. The evaluation of load factors in this step is based on reports from the Netherlands Ligterink, Tavasszy, and Vonk (2014) and Kuiper and Ligterink (2013) as well as from France with the available paper from Schmidt, Bernard, and Domprobst (2016).

Results from the Weight-In-Motion data from the Netherlands

The Dutch study of 2013 uses WIM data to distinguish vehicle categories based on their axle configuration and total mass. Most vehicles on 3 or 4 axles on Dutch roads weight around 19 tonnes. Vehicles with 5 or more axles (mostly tractor-semitrailer combinations in practice) have two dominant weight classes: one also around 19 tonnes (2/3), and another around 43 tonnes (1/3), with a global average for tractor semitrailer configurations around 28 tonnes. For truck-trailer combinations (non-LHCV), the amount of axles on the truck is the key parameter for the gross vehicle weight: a 2 axle truck and trailer weights around 23 tonnes, with 3 axle truck and trailers are at nearly 40 tonnes.

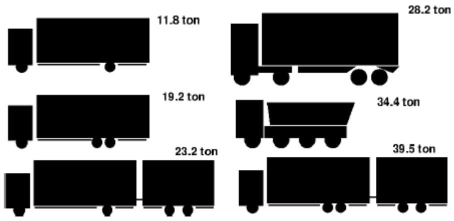


Figure 3-12 **Vehicle categories (axle configurations) linked with weight (Kuiper and Ligterink 2013)**

However, this reveals little about the daily logistics practices by freight operators and their vehicle choices. From Ligterink, Tavasszy, and Vonk (2014) it can be found that tractor-semitrailer combinations become more prevalent as trip distances and cargo weight increase. However, no firms' conclusions with regard to the link between good types and vehicle types are drawn.

Table 3-9 Share of tractor-semitrailer combinations as a function of trip distance and cargo weight

trekker-oplegger	0..3ton	3..8ton	8..18ton	18..27ton	27+ton
0..25km	38.4%	46.8%	43.0%	51.8%	53.1%
25..60km	47.7%	57.9%	63.4%	69.9%	75.2%
60..135km	52.3%	59.5%	72.7%	81.0%	85.7%
135..315km	44.5%	53.6%	73.4%	87.4%	86.6%
315+km	50.0%	58.9%	79.2%	88.7%	88.8%

(Source: Ligterink, Tavasszy, and Vonk 2014)

Results from the Weight-In-Motion data from France

The WIM-data from France result from the national WIM database owned by the Ministry of Transport. The measurement devices recorded 2,933,331 HCV on three sites between September 2013 and August 2014. Based on criteria that were defined to classify the HCV, 19 categories, combining silhouette shape and drive axle rank were distinguished.

The first category has almost a mono-modal PDF (or 2 very close modes) with a long tail on the right. The authors concluded that the density function on the left at 2 and 5 tons show that the 2-axle rigid HCV are mostly full in volume before to reach the maximum permitted laden weights. For the tractor and semitrailers on the right the authors confirmed that around 20 % of vehicles measured are fully loaded (Schmidt, Bernard, and Domprobst 2016).

It has to considered, that the presented information doesn't allow any assumptions about the future market of new vehicle concepts, because any information about the distance of the road transport and the transported cargo are missing. Therefore, the information cannot be used to identify which vehicle concepts may improve the efficiency of transports by addressing cargo groups or logistics requirements.

3.4 Trends and drivers

The following sections give an overview of trends and drivers in long road haulage and in the combined transport.

3.4.1 Trends and drivers in long road haulage

The transport system is embedded in an overall framework of social, technological, economic, ecological and political circumstances. These circumstances can be called Mega Trends (Vierth et al. 2017). One of the Mega Trends is the Climate Change and pollution, inducing that the EU has set up goals regarding energy efficiency, reduction of greenhouse gas emissions and air pollution. To achieve these goals new mobility concepts, higher energy efficiency of internal combustion engines, possibilities for electric vehicles and alternative fuels for the long road haulage are being developed.

The long road haulage is further embedded in the national and international logistics systems and supply chains. Changes in the national regulative framework, technological development or increased requirements towards the transport may affect also the road freight transport.

Vierth et al. describe trends within the logistics sector and form four groups of trends: Demand and Production, Logistics, Technology and Transport Policy (Vierth et al. 2017). Within the group Demand and Production, it can be summarized, that rising competitive constraints in the production sector have led to a rationalisation within the firms and to a reduction of the real net output ratio. This in turn resulted to a change in the organization of value chains towards an outsourcing of the production sites to foreign countries and outsourcing of transportation processes to subcontractors. For the suppliers of long road haulage that means an increased interest in cost efficient and customer-oriented service. Within the group 'Logistics' it can be summarized that especially the scope of logistics services has increased over the last decades. Therefore special third and fourth party providers (3PL, 4PL) emerged, which offer value-added services like commissioning, warehousing, packaging or after-sales-services or even organize the whole supply chain which includes also e.g. the procurement logistics. The 3PL and 4PL are most of the times huge companies which are able to fulfil the demand for a periodic and high transport volume of the industry and enable a periodic transport between the logistics centres as well as production sites all over Europe.

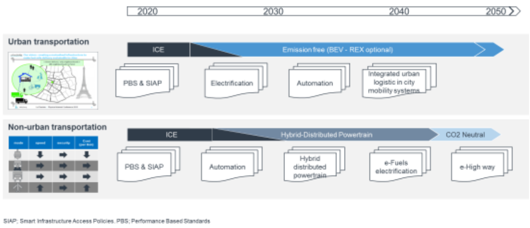


Figure 3-13 Expected innovation in urban and non-urban transportation (MAN)

Within the group 'Technology' there are trends, which refer especially to vehicle technology. The Figure 3-13 shows the expected development of technology of non-urban transportation compared to urban transportation until 2050. The trends in technology are:

- automatization,
- (truck) platooning,
- and new developments of vehicles and loading units.

An important trend for the long road haulage is seen in the automation until 2030 with the potential to reduce transport costs, increase safety, system efficiency, and energy efficiency but may also to change the logistics processes on a medium term. Already today first prototypes of autonomous trucks are developed (e.g. Mercedes Future Truck, autonomous Volvo-Truck). Automation is expected to be most helpful in two phases of the transport cycle: in the long haul stage (motorways, where relatively little action is required from the driver) and in the final delivery stage (in small vehicles in urban environments, or in large logistic yards where e.g. long vehicles are split and all units move to their docking gates automatically).

Another potential development is seen in the platooning, where trucks equipped with smart communication and vehicle technology are closely following each other on motorways. Advantages are seen here mainly in lower fuel but also labour costs.

A further progression is seen in the development of high capacity vehicles as well as loading units (containers with 48’ and 53’ft), which shall contribute to a cost/CO_2 reduction compared to conventional long road haulage (see group ‘Policy’). High capacity vehicles are used in Sweden and Finland for several decades, whereas the rest of the continent has only recently started working with the concept (since the early 2000’s). At present, eight EU countries (Sweden, Finland, Netherlands, Denmark, Germany, Belgium, Spain and Portugal, plus Norway) allow high capacity vehicles (mostly as 25.25 m vehicles of the European Modular System EMS; the maximum weight restriction varies) on their roads in some form. While these vehicles are considered by many to mainly be useful in long distance transport, they can be deployed on connections of every distance provided that there is sufficient cargo to fill the added capacity. It remains true that cost savings become greater with increasing trip distance, but the amount of cargo per trip is the principal driver. High capacity vehicles become an interesting option when the amount of cargo is limited, by legislation or by physical dimensions.

Results from the Dutch test regarding long vehicles

In De Ceuster et al. (2008) assumptions were made on the maximum share of high capacity vehicles (or in this case longer heavier commercial vehicles – LHCV, of 25.25 metres and 60 tonnes) by good type, provided that all conditions (with regard to infrastructure, safety, sufficient volume and distance) are fulfilled. The study suggests that 20-30 % of total road freight tonne-kilometres could be done using high capacity vehicles. In countries such as Sweden and Finland, with a profile particularly conducive to LHCV use, market shares are in the range of 70 to 90 %.

Table 3-10 Maximum share of LHV in road freight transport by good type (De Ceuster et al. 2008, NST 2007 see Annex B)

No (NACE 2007)	Good class	Maximum share of LHCV in total road in the Netherlands (%)
01	Products of agriculture, hunting, and forestry; fish and other fishing products	80
02	Crude oil	100
03	Metal ores and other mining and quarrying products; peat; uranium and thorium	90
04	Food products, beverages and tobacco	50
07	Liquid refined petroleum products, solid mineral fuels	90
08	Chemicals, chemical products, and man-made fibres; rubber and plastic products; fertilizers, nuclear fuel	100
09	Other non-metallic mineral products	60
10	Basic metals; fabricated metal products, except machinery and equipment	80
11	Machinery and other manufactured products	50

Further assumptions on the market for LHCV were made in Christidis and Leduc (2009), regarding the distance class of the transport: 2-15% (<800km), 10-40 % (800-1500 km) and 5-75 % (>1500 km), as a % of tonnes lifted. These are useful figures but they also indicate that the range of uncertainty is important to consider.

Further interesting information on the use of high capacity vehicles can be drawn from an evaluation study from the Netherlands (Kindt, Burgess, and Groen 2011). This study looked at the application of different LHCV configuration in certain operations. From Figure 3-14, D-type configurations were used the most, followed by A & B types. Here, it should be noted that the used configuration could have slightly changed in the last seven years but more recent studies were not found.

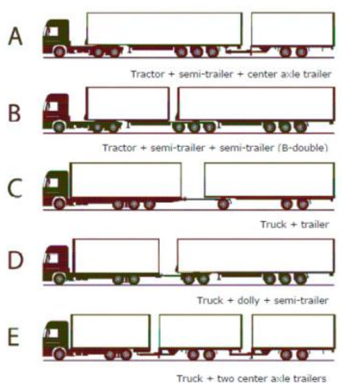


Figure 3-14 LHV configurations

In terms of their application, B types are the most common form in container transport, whereas A types are most frequently used in "ornamental horticulture" (i.e. flower & plant transport). D types are used across all operations, for a large part due to the prevalence of the individual parts of the vehicle in the fleet.

Table 3-11 LHCV type applications by market segment (Kindt, Burgess, and Groen 2011)

Market segment	A configuration	B configuration	C configuration	D configuration	E configuration	Total
Retail	43	19	0	57	1	120
Containers	0	39	3	19	0	61
Ornamental horticulture	21	1	1	21	0	44
Other	4	0	0	17	9	30
Volume	3	0	1	18	0	22
Waste/bulk	0	0	0	14	1	15
Packaging	1	1	0	3	5	10
Total	**72**	**60**	**5**	**149**	**16**	**302**

Results from the German field test regarding long vehicles

Germany permits high capacity freight vehicles on its roads but only allows for additional transport volume. The weight limit for "Lang-Lkw" was set for 40 tonnes and in intermodal transport for 44 tonnes (instead of 60). High density goods, which are typically also transported by rail or inland waterways, are thus less likely to be moved with "Lang-Lkw".

A German filed test was realized from January 2012 until December 2016 and contains five different types of long HCV (LHCV). The test was accompanied and evaluated by the Bundesanstalt fuer Strassenwesen (BASt) the German road authority (Irzik et al. 2016). The German field test included the following five types of vehicle configurations with a maximum laden weight of 40 tonnes (44 tonnes in operation in intermodal transport chains).

Table 3-12 Field test in Germany – included vehicle concepts and share of usage

Type	technical parameters	number of vehicles registered	share of usage
		in the German field test	
1	Tractor with a semitrailer with a maximal length of 17.80 metres, trailer offers additional lane meters for four Euro-pallets	13	8 %
2	Tractor with a semitrailer and an additional trailer (length 7.82 meters) with a maximum length of 25.25 meters	43	27 %
3	Rigid with a dolly and a semitrailer with a maximum length of 25.25 meters	92	58 %
4	Tractor with an additional semitrailer with a maximum length of 25.25 meters	4	3 %
5	Rigid with a trailer and with a maximum length of 24 meters	6	4 %

Source: (Irzik et al. 2016)

Further, the test was limited on a designated road network with a length of about 11.600 kilometres – a share of about 70 % are motorway and represent 60 % of the German motorway – that was selected by the responsible Federal stated transport ministries.

Further, relevant data of this field test for LHCV in the year 2015 was:

- About 61,900 road trips were realized.
- A mileage of about 13.6 million kilometres was driven by 46 different road transport service providers with 120 LHCV (type 1 – type 5).

- The mileage of the LHCV represented 0.5 per mil of the mileage that was realized by all HCV that have to pay a toll on German motorways 29.7 billion kilometres.
- About 843,500 tons of cargo was carried.
- The average transport length per road trip was about 240 kilometres.

It could be observed that 91 % of the road trips were realized between warehouses and/or production sites as the main run without intermediate stops for loading and unloading. Additional six percent of the road trips started or ended in ports or air cargo centres. Further the road trips have reached a quiet high load factor –degree of capacity utilisation was in average 80 % related to the lane meters/pallets.

The cargo that was carried mainly came from NST groups 10 (17 %) 18 (10 %) and 19 (35 %). There were observed the following cargo: parts for the automotive industry, clothes, air cargo, foods, white goods, packing materials.

Under the assumption that the whole road network could be used by LHCV, the study estimated that up to 9 % of all road trips and up to 7 % of the mileage could be realized by LHCV. To realize a reduction of transport cost, the utilization of capacity should not be less than 70 % in average.

The share of different typical cargo carried by road transport did not differ between conventional HCV and LHCV – e.g. general cargo, goods in swab bodies and containerized goods dominate all vehicle concepts (HCV and LHCV).

Based on the results in the field tests, two scenarios were defined to calculate the potential of reduction of fuel consumption and greenhouse gas emissions in year 2030. These scenarios consider the impact of intramodal and intermodal transfer of freight transport to LHCV.

The vehicle configuration type 1 is feasible to carry all cargo types that are carried in road freight transport and the transport costs are not significantly influenced. Therefore, the type 1 was partly excluded in the scenarios that are mainly related to type 2 – type 5 vehicle configurations.

The results of the two scenarios were summarized as follows:

The use of LHCV has a positive impact in relation to a reduction of road transport mileage based on the assumption that LHCV will have a high average utilization of capacity not less than 70 % and this will contribute to decrease of greenhouse gas emissions. The shift to road freight transport from rail and barge will be not relevant due to the limitation of the laden weight of LHCV and the limitation of the designated road network. Further, it was concluded that LHCV could contribute to the objective to reduce the impact of road transport to climate change but further measures are necessary to reduce greenhouse gas emissions of road transport and reach the targets of climate policy.

Scandinavian experiences regarding long vehicles

Sweden and Finland are already pushing further ahead with the HCV concept, as Sweden currently allows 74 tonnes, whereas Finland is testing 34 m vehicles with even higher maximum weights.

LHCV have a market share in transport of about 70 % of tonne-kilometres in Sweden. Based on the experiences transports of wood and products of wood; pulp, paper and paper products and for products based on mineral oil are identified. Further, a potential was also seen in the short distance transport of other non-metallic mineral products.

All of the three mentioned trends (automation, platooning and high capacity commercial vehicles) are seen as comparative advantages for road transport compared to the rail freight transport. However, there is likely a trade-off between the success of platooning and that of high capacity vehicles, as they both attempt move cargo using less road space and with lower personnel costs (although platooning is more flexible in practical operation, with platoons forming on the fly even for shorter parts of the trip). However, platooning can be considered as a first step in the process towards full vehicle automation, and the trade-off may only be a temporary phenomenon.

On a mid-term perspective until 2035, the development of more energy-efficient solutions is needed to reach environmental and climate goals. Electrification of the long-haul freight transport is challenging because of higher power and energy demands of freight vehicles compared to light duty vehicles for last mile logistics in urban areas and therefore a battery-powered electric vehicle is an unlikely option (Nicolaides, Cebon, and Miles 2017). For the application of electric vehicles for long-haul freight transport, the electricity has to be provided to the vehicles while they are in motion. This can be managed either by inductive power transfer technique or by the catenary technology. Vierth et al. see also the technical development of communication systems as a key for the development of improved logistics- and transport services (e.g. track and tracing) and new digital services e.g. mobile payment systems, cloud services and sharing platforms. This establish also the basis for the Physical Internet concept, where goods are transported, handled and stored within a future ‘Logistics Web’ like data in the Internet (Crainic and Montreuil 2015). The physical Internet can share transportation and distribution networks and therefore may increase the utilization of vehicles. The digitalisation also comes with challenges for the transport sector, such as high requirements regarding data security and privacy. Within the group ‘Policy’, Vierth et al. mention especially the allowance of different truck sizes in the European Countries. They differ from a maximum gross weight of 44 tonnes (Germany) up to 76 tonnes (Finland). Another trend is seen in the standardization of different parts of the transport system like vehicle dimensions, containers and other loading units, physical objects, self-routing systems, data interfaces or smart infrastructure. The implementation of standards gives a reliable framework condition to manufactures and operators of vehicles (Lemmer 2016). Standardisation is a necessary condition for modularity of vehicle components and loading units, and will be an important step towards realisation of the Physical Internet.

3.4.2 Trends and drivers in European logistics

Logistics and the supply chains development cause the demand for long road haulage. Figure 3-15 shows some trends and drivers of logistics that will influence the long road haulage in the future.

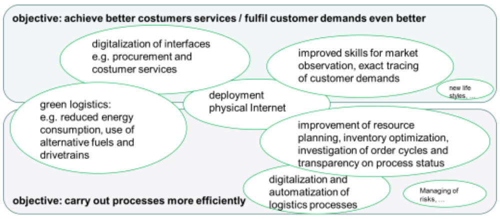


Figure 3-15 Drivers of logistics (source: own figure based on Schwemmer 2017)

Hub concepts are still well established in the transport sector. Based on the expectation that distribution and collection of light cargo shipments and for retail in urban areas will be realised more and more by battery electric vehicles or special cargo bikes, the number of logistics hubs in the outskirts of urban areas will increase. The main task of these hubs is to consolidate cargo for the different quarters in urban areas. Due to the limited daily mileage the tour planning of battery electric vehicles for milk runs inside the urban area has to consider the limited the tour length that is linked to the battery capacity and the opportunity to recharge the battery during the daily trip. This is an additional constrain behind the costumers demand for time windows of delivery, driver work time and the average speed – influences by peak hours, realised roadworks – of vehicles in the urban area.

Further big players of the retail business establish more and more regional delivery centres (small or big hubs) to be able to deliver direct to the end consumer (B2C) as well as to their own stores and supermarkets. This will also be a driver for more hubs that are warehousing and consolidation centres outside the urban areas. Transport between these large and smaller hubs has to be both frequent and reliable in order for them to function properly (ALICE and ERTRAC 2015):

- The frequency of transports is required to meet the service levels, but in the past and present this may occur at the cost of small load factors. In conjunction with that the need for specialisation in vehicles is emerging : in a more integrated logistics system, vehicles can be deployed in a fixed operational cycle, rather than having to be flexible and be able to perform any task, without the tools to really excel at it. For long road haulage, this would lead to increased vehicle dimensions (larger vehicles), while in urban transport, we could expect a downscaling of transport modes (e.g. cargo bikes) (ALICE and ERTRAC 2015). This will help cope with the most important efficiency restrictions on both sides (insufficient capacity for long haul, low load factors in urban transport).
- The reliability of freight transports is an indicator of transport service and is often mentioned in the same context as speed: in a system with limited possibilities to plan at a larger scale, in most cases the option with the quickest response time and the most capacity is chosen as the most reliable one. However, when flows are coordinated, different shipments could require a different level of reliability, with meeting the date of

delivery (especially when known sufficiently far in advance) in the most efficient manner as the measure of performance. This opens the door for cooperation between road and non-road modes in a multimodal, co-modal and synchromodal logistics system.

Building further on the trends described above, the ALICE framework identifies a number of trends for transport logistics that will lead to fundamental changes in the process, not just in terms of the amount of cargo moved, but also in the distance over which transport takes place and the nature of the transported goods. They are:

- Dematerialisation, i.e. reducing the amount of materials used in products
- 3D-printing technology, i.e. personalised, small scale local production in regional production sizes or for spare parts retailing
- Postponement of final product assembly, i.e. local assembly close to the consumer, leading to the transport of intermediate products (parts and components) rather than final products, with the potential to reduce the amount of space required for transport
- Reshoring, i.e. even for assembly of final products on a large scale, bringing the production site closer to the consumers
- Local sourcing, i.e. instead of moving raw materials over long distances before production, sourcing them near the production facility.

These trends also help with to better fit the logistics process in the circular economy, where end-of-life products are either repaired or recycled and reused as materials in the production process. The reverse logistics process will take on a more prominent role in the chain.

Last but not least, the development of the silk-road as a land bridge between China, some Asian countries and the EU will may also influence long road haulage (Griffiths 2017). Shipments that are time sensitive or have a high value will use this new faster connection instead of maritime transport that takes about four weeks. During the last two years, there could be observed a high increase of freight volumes and it is expected that this increase will continue.

3.4.3 Trends and drivers in intermodal road/rail transport

Within the white paper, the EU developed an emission reduction target for the transport sector. Thus, the greenhouse gas emissions shall be reduced by 60 % by 2050 with respect to 1990 (European Commission 2011). To reach this goal and to optimize the logistics services, modal shift targets from road to rail were developed. Until 2030, 30 % of road freight transports over 300 km shall be shifted to rail (European Commission 2011). This fosters especially the combined transport.

The combined transport is subject to several developments and trends which may affect the future development of the combined transport. KombiConsult GmbH et al. (2015) see the following external impacts with a major influence on the European Rail/Road Combined Transport:

- Increase of combined transport volumes due to the expected growth of maritime container throughput in European ports of 3.5-4.5 % in the next 10-15 years
- Increase of modal shift initiatives by sea ports to reduce capacity bottlenecks on road and road-side handling facilities
- Infrastructure development (TEN-T network) to reduce bottlenecks for the growth of cross border traffic.

Improvements of the competitiveness of services and costs are seen as crucial for the combined transport (KombiConsult GmbH et al. 2015). The need for action is for example seen in improved service quality and productivity (e.g. longer or heavier trains, increased frequency of services with 2-3 daily departures per destination) and in improved hub-production systems to consolidate freight flows. For more information see deliverable 4.1.

A crucial characteristic of the combined transport is the usage of different transport modes and therefore the necessity for transhipment. Former technologies like gantry cranes, reachstackers or straddle carriers enabled the transhipment of craneable loading units like containers or swap-bodies. Another common road freight loading units are semi-trailers, which are mostly not craneable. In combination with modal shift activities this caused the development of several technologies especially for not craneable loading units (see figure 3-16). A further description of these technologies is given in the deliverable 4.1. These technologies are developed for the transhipment of the whole loading unit like container, swap-body or semi-trailer. Highly automated loading and unloading technologies for less than truck load shipments couldn’t prevail in the past although there were technologies using rollers, conveyor belts or telescop forks available in the 1990 years (Günthner and Freudl 1999). In combination with the ongoing development of automated trucks, the former technologies may further developed for an automated loading and unloading of trucks and trains for the combined transport.

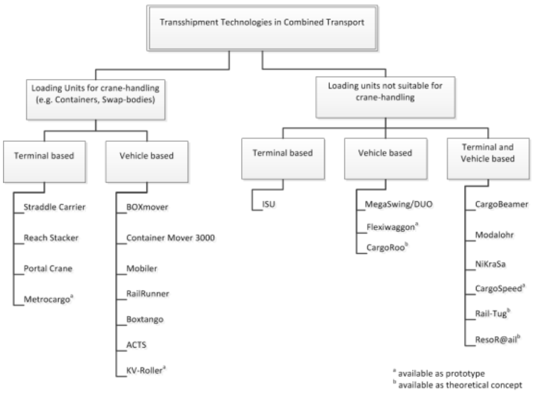


figure 3-16 overview over different transhipment technologies used in combined transport

source: DLR, according to Höft (2014) and BSL Transportation Consultants GmbH & Co. KG. (2017)

The use of combined transport (in intermodal, co-modal or synchromodal context) should be stimulated by the rise of information and communication technologies (e.g. electronic data exchange between stakeholders or via platforms) in the freight transport, which will help modularise transport chains and give way to a system of appropriately sized hubs as a physical network for cargo. Whereas the organisation of such networks is currently only feasible for companies of a sufficient size, a standardised data exchange system will open this up to enterprises of all sizes. Additionally, the development of regular services between large hubs creates possibilities for the integration of other modes, which before may not have been able to secure sufficient volume to service a certain connection.

The management of such a system to foster multimodality and synchromodality will likely be handled by a 3PL or 4PL service provider, who is able to combine cargo from multiple shippers and route them through a multimodal chain of hubs. A prime example of the practice, which originated in the Netherlands and is still gaining steam, is the “European Gateway Services”, which organises synchromodal freight transport from the port of Rotterdam mainly to the German hinterland. According to (Dong et al. 2017), synchromodality can mainly use the non-road modes for the steady flow of goods on the long distance leg of a trip, whereas road can be complementary to handle those supply missions to deal with peaks in demand and for the last mile. Important parameters in the consideration are the costs of storage and the ratio of stable demand levels vs peak demand levels. Applying synchromodality leads to lower costs and better environmental performance, driven by higher load factors and modal shift.

New vehicle concepts that include a higher transport capacity by trip can play a particularly important role in intermodal transport. Containers and swap bodies carried by rail and then moved to road can be transported more efficiently to their final destination using LHCV, requiring fewer tractive units and drivers, and less fuel.

3.5 Conclusions

Based on the analyses of several literature and public transport data related to road freight market situation and drivers, it could be concluded that the following points will be relevant for the further AEROFLEX project.

First of all, the improvement of efficiency is one important driver of European freight transport market. Co-modality and synchromodality are key elements to improve the efficiency. Freight transport should be organized by the consideration of the strength and weaknesses of the transport modes that are relevant to fulfil the requirements of the shipper that are defined by lead and transport time, weight and volume of the order /the shipment and further specific costumer and good related characteristics. The transport by only one transport mode could be the most efficient way in case the strength of this mode fulfil the given constraints, e.g. to carry goods due to time constraints, direct link between origin and destination without detours, availability of infrastructure and specialised equipment, sum of working time. Furthermore, it is necessary to fulfil the costumer related expectations regarding transport costs.

The available European 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 e.g. in terminals and hubs. From the perspective of tonne-kilometres, new vehicle concepts could address all goods classes and not only selected ones due to the objective to develop a configurable and cost-efficient vehicle concept that is not dedicated for only some commodities.

The most common type of loading devices of cargo for land transport is palletised goods which recorded 42.9 % of the EU-28 road freight transport, followed by solid bulk with almost one fifth of total road freight transport.

Based on the evaluation of the logistics segments, the highest potential for new vehicle concepts is considered for:

- the consolidation of several orders/shipments to a high use of capacity and volume in one vehicle
- 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.
- the reduction of empty runs by using standardises vehicles (length and weight) and loading units

Key performance indicators (KPI) indicators are identified: (i) transport efficiency, (ii) operational parameters, (iii) vehicle uptime, (iv) loading parameter, (v) safety and limitations, and (vi) driver comfort. These indicators describe the freight transport market and have to take in consideration of new vehicle concepts to be developed by project AEROFLEX

It could be expected that firms will use more heavy commercial vehicles (HCV) and new vehicle concepts in case the variable costs like fuel and personal costs will increase. Fuel costs will probably further increase in the next decades but based on technology progress higher fuel efficiency will limit the influence on transport costs.

The length of the transport distance in road transport is linked to voluminous goods and the decision-maker being a for-hire carrier lead to a larger shipment size. These two effects indicate economies of distance and scale. Almost all of the selectivity correction terms are significant at least at the 5 % level, which implies that ignoring the simultaneity of shipment size and truck size will lead to biased estimates. Higher operating cost, lower total cost, higher total demand, dense and bulk cargo and the decision-maker being a for hire carrier make the use of heavier vehicles more likely.

New vehicle concepts should address the main run between industrial sites and logistics hubs (e.g. warehouses, ports, terminals). It should be given attention to the processes inside the hubs, e.g. (i) the efficiency of the consolidation of cargo by manoeuvring of the vehicle, (ii) the organisation of a fast exchange of loading units between HCV, (iii) as well as the optimal placement of loading units on the gateways for cross-docking or the gateways of warehouses. The main elements that should be considered are the required area for manoeuvring as well as the safety of the operation inside the hubs.

In general, it could be assumed that the mileage on motorways and federal inter-urban roads will increase in relation to the laden weights of HCV. That means that for the simulation of average fuel consumption of new vehicle concepts it could be assumed that at least about 70 % of their mileage will be realized on motorways and inter-urban roads in parts of Europe with a good developed road network. Therefore, restrictions for the use of the existing European road network should be limited or avoided in general.

New vehicle concepts could help to reduce the amount of trucks on the roads but due to longer tractor/rigid and trailer combinations, the management of parking should also be considered e.g. by an easy manoeuvring of new vehicle trucks by taking into account the infrastructure conditions in parking areas.

The identified trends involve several aspects. It could be concluded that some trends will force the use of new vehicle concepts and other trends have the potential to prefer the use of existing vehicle concepts. Logistics trends could be categorized by trends that are aimed (i) to increase the efficiency of logistics processes or to fulfil the expectations of the costumers and provide better service transport solutions. The main trend that will force the use of new vehicle concepts is to realize green logistics and increase the transport efficiency. More efficient drive trains and the use of alternative fuels as well as autonomous driving have the potential to become barriers for new vehicle concepts on the road freight transport market. Working towards the concept of the physical internet, future road freight vehicles are expected to have a quicker turnaround (faster loading and unloading), higher load factors, more specialised roles (the vehicles themselves) and using versatile loading units on a hub-and-spoke network. Further, the competition between new technology developments for trucks on the timeline will determine the success of new vehicle concepts.

Finally, technical specifications could not be concluded for new vehicle concepts. But this literature analyses gives an overview about important developments and requirements of the users and is suitable to conclude performance and achievements that should be addressed by AEROFLEX project.

4 Recommendations

Within the AEROFLEX project use cases shall be developed in order to evaluate the developed vehicle concepts. The prior described results of the market analysis enable a first derivation of recommendations regarding the selection of use cases and vehicle concepts. They are summarised in the following sections.

4.1 Recommendations regarding the selection of use cases

The objective of the AEROFLEX project is to develop an innovative vehicle concept for an appropriate percentage of the European transport market, which shall simultaneously contribute to an economically as well as environmentally sustainable freight transport. The use cases considered in the AEROFLEX project shall therefore describe representative parts of the current transport market in Europe. Based on the qualitative and quantitative work described in chapter 3, the following recommendations can be made.

High market share of 52 % of revenues for transports with order sizes below 2 tonnes

The logistics segments with shipment sizes less than truck load, the courier/express/parcel segment and contract logistics have a high revenue volume of € 615 Billion which is 52 % of the logistics market volume. Simultaneously, these segments have a low average order size of 2 tonnes or less per order. This shows the importance of advanced vehicle concepts using modular loading units to consolidate these shipments. The use cases should therefore contain preferably these logistics segments.

In-house transports and transports conducted by third parties occurs equally

About half of the logistics activities in Europe is insourced and directly organized by the company. The other half is outsourced and conducted by third parties like logistic service providers. The use cases should therefore contain both types of transport organisation.

Intermodal Transport plays an important role in efficient and sustainable transport

New vehicle concepts should support the increase of efficiency of goods transport. Solutions that combine the strength of more than one transport mode in an intermodal freight transport have the potential to be the most efficient way to carry goods. The use cases should contain at least one intermodal transport.

Three-quarters of the transports uses motorways and inter-urban roads

About the half of the transport mileage is conducted by HCV on motorways and 16 % is realized on inter-urban roads. The use cases should concentrate on these road classes.

80 % of freight transport is realised on long haul distances of 150 km or more

In terms of tonne-kilometres about 80 % of all road freight transport is realised on long haul over a distance of 150 km or more. However, freight transport services up to 150 km may also be relevant for new vehicle concepts, if they are combined with smart loading units. The use cases should therefore contain different transport distances from regional to long haul.

4.2 Recommendations regarding the vehicle concepts (HDV and LHDV) and configurations

Within the AEROFLEX project several vehicle concepts and configurations could potentially be developed and a reasoned selection has to be made. The methods to generate the output of D1.1 were selected in line with the description of work and the planned timeline. It has to be concluded that data analysis was limited to available public data. These data are often on a high aggregated level and don't allow any detailed information about the vehicle's use. Therefore the recommendations regarding the vehicle concepts in this section base on the results of the literature analysis and the stakeholder discussions and are therefore very limited at this stage of the progress in WP 1.

Load capacity should be increased by higher volume and weight

First experiences with long and heavy commercial vehicles in the Netherlands show that the concept "rigid with a dolly and a semi-trailer" is the most universally used configuration. Other configurations are aimed to the container transport market and the ornamental horticulture. Experiences from the Scandinavian countries (Volvo

2018) showed that the increase of load capacity should be technically realised by considering the enlargement of both weight and volume. Furthermore, a higher amount of axles should be realized to utilize legal axle loads. All axles that are not needed should be lifted and weight should be actively distributed between the axles.

Modular loading unit is essential for recommended logistics segments

As stated in the section 3.1.2, the most interesting logistics segments are the contract logistics, the full and less than truck load with palletized goods and Courier/Express/Parcel transports. These logistic segments have a small average order sizes up to 2 tons per order, and transports must be consolidated to increase the load factor of transport vehicles and to collect and distribute freight on long road haulage. This pleads tendentially for modular loading units which enable the combination of different shipments on one vehicle.

New vehicle concepts have to be compatible with the existing infrastructure

Infrastructure conditions and constraints of the existing road infrastructure should be considered e.g. by solutions for using existing parking areas.

Loading unit, volume, payload and manoeuvrability are the most important aspects from the user perspective

The discussions with stakeholders at the workshop have shown that the user perspective regarding the vehicle concept is oriented to aspects of the vehicle's use:

- the loading unit
- the maximum volume
- the maximum payload
- the vehicle's manoeuvrability on existing road and yard infrastructure.

It has to be further evaluated if the number of loading units is subordinate to the stakeholders.

Platooning, autonomous driving and the digitalization of logistics processes are relevant trends

The digitalization of logistics processes supporting the driver, simplifying tour planning, enabling the monitoring (e.g. smart loading units) of the whole transport chain is ongoing and new transport services and processes will be established. Further approaches like platooning and automated driving reduces the stress for the driver and may contribute to a reduction of transport costs, but also requires sensors, communication technology and energy supply within the vehicle. Further trends with an effect on the transport and the vehicle are seen in:

- Dematerialisation, i.e. the amount of materials used in products will be reduced.
- 3D-printing technology will be developed, i.e. personalised, small scale local production in regional production sizes or for spare parts retailing.
- Postponement of final product assembly, i.e. local assembly close to the consumer, leading to the transport of intermediate products (parts and components) rather than final products, with the potential to reduce the amount of space required for transport

The question of future activities a driver could fulfil in the cabin has not been tackled in the present analysis. It could be assumed that due to trends and innovations (in particular: digitalization and autonomous driving) the driver will manage additional tasks in the future and will be relieved by new technical solutions for his driving activity. Autonomous driving will also lead to amended EU directive of working time of persons performing mobile road transport activities. The amendment of this EU directive will take a long time. Based on the current status one driver in the cabin will be the usual situation. A second driver is necessary in case of express cargo like air freight or perishable goods and a long transport distance. For that case a second driver could be temporary in the truck cabin.

Based on the literature analysis and the stakeholder discussion it wasn't possible to define primary candidates based on the pre-defined new vehicle concepts. Experiences with LHCV in some EU countries have shown that a market for such vehicle exists and further research is needed to investigate this market and the requirements of the users. It is necessary to get more information in direct contact with stakeholders and potential users of new vehicle concepts. WP 1 will therefore conduct further workshops with stakeholders in 2018 in order to evaluate possible vehicle concepts. The results will be presented in the deliverable 1.2.

4.3 Recommendations by SB members and other stakeholder

At the beginning of March 2018 a workshop with the sounding board members of AEROFLEX, representing the prospective users of new vehicle concepts, was realized with the objectives

- to better understand the logistics requirements and opportunities for innovative vehicle concepts and loading units in a multimodal context,
- to define criteria and KPIs to judge the impact and the cost/benefit of new vehicle concepts and features on the logistics operation in a multimodal context (rail & maritime)
- to identify user requirements concerning the feasibility and impact assessment of use cases.

The main outputs of this workshop could be summarized as follows:

- The comparability with infrastructure (road, bridges, yards, driveways, parking, roundabouts) is a key requirement.
- LHCV should be considered in AEROFLEX, nevertheless currently biggest difficulties are seen in end user requirements, lead time for orders, this is especially true for the last mile but has also consequences for long road haulage.
- Currently, the full use of the volume capacity is often realized but not in regards of weight capacity. Longer trailer with more volume would help to increase the average load factor.
- New vehicle concepts should be able to be used for consolidating urban delivery.
- The easiness for loading and unloading, safety and smart link to establish digital applications should be considered.
- Smart loading has manifold meanings: compatibility of goods and vehicles by volume and weight, smart loading and unloading, intelligence needed to have optimal loading, adaptability and safety, human safety access security. Safety is a big issue for stakeholders.
- For easily consolidation from long to urban haul smaller units than containers are conceivable.
- It is necessary that loading units are craneable.
- Different vehicle concepts serve different needs for different branches and logistics segments. Therefore not a specific prime candidate could be identified in the discussion with the stakeholders from different branches
- KPIs vary depending on the considered logistics segment, transported products, (end-)customers and also the strategic orientation of the company.
- The stakeholder workshop has shown that it is difficult to translate the requirements of the logistic service providers into technical details of new vehicle concepts enabling a first selection of high potential vehicle concepts. Therefore it wasn’t possible to define primary candidates based on the input that was given by the FALCON project.

4.4 Conclusion

The present deliverable D1.1 describes the following aspects:

- Road transport market with data concerning transport volume, distance and revenues,
- Use of loading units
- User needs and requirements for logistics concepts and new vehicle concepts
- Infrastructure conditions
- Logistics trends
- Vehicle choice behaviour
- Experiences with longer heavy commercial vehicles in some EU countries

The results base on literature review, analyses of available public data and stakeholder discussions. They enable first recommendations for a selection of use cases and for the vehicle development.

It can be stated that there is no direct demand for longer and heavier vehicle configurations but there is a request for concepts that enable to realise more efficient freight transport with less greenhouse gas emissions. Full truck load and less than full truck load with palletized commodities and commodities with high volume are the freight transport segments of main interest for new vehicle concepts. Some of them have been growing during the last years (e.g. less than truck load segment with general cargo and the parcel, courier and express segment NST 15).

Still, there are open questions especially regarding a linkage between transport segments and logistics concepts as well as the definition of typical trips. That’s why WP 1 needs further steps to close these gaps. The next steps are described in chapter 5.

5 Prospects for the further progress in WP 1

The present deliverable describes the European freight transport market, trends and market drivers and variables which influence actor's modal choice in freight transport based on the conducted literature analysis, public available data evaluation and stakeholder discussions. It was possible the meet several requirements from other WPs to WP 1. Nevertheless, the achieved results don't allow an assignment of the identified transport segments to related logistics concepts. Further, a definition of typical trips (distance, load factor, commodities) which can be identified and validated by data wasn't possible. Therefore, one of the next steps of WP 1 is to identify data from EUROSTAT to close the gap between typical trips and the transport segment, and generally use the data to build a more quantitative knowledge base on logistics (task 1.3). Further, the current results of WP 1 could not figure out which new vehicle configurations are related to the European transport market and which are less suitable from the view of the user. The planned workshops in WP 1 will help to answer this open question in the next months. The results will be presented in the next deliverable 1.2.

Further, the use cases should be compiled based on a two directional approach in cooperation with logistics practitioners (LSPs, carriers, shippers). One step should be to determine the commodity and distance category combinations, that represent significant partitions of overall European transport volume in terms of vehicle kilometres (focus volume transports) and ton kilometres (focus tonnage transports). These analyses should be based on the EUROSTAT database. On the other hand use cases should be determined in discussion with logistics experts. Applications that are evaluated as potentially suitable for the use of new vehicle concepts should be regarded and weighted by the corresponding market volume. This approach could provide a comprehensive data basis to conduct simulations of technical, economic and ecological implications of new vehicle concepts as input for the market impact assessment of new vehicle concepts. The proper frame to discuss and gather needed information could be small group expert workshops.

Task 1.3, also to be reported in D1.2, will first of all build up a quantitative dataset on the current logistics market, sourcing information from Eurostat (both published tables and raw input data), national statistics and other statistical sources (e.g. World Bank, UNECE, ETISPLUS, sector representative organisations,…) to support and complement the mainly qualitative results of this deliverable 1.1. Second, it will also collect data to prepare for the modelling exercise to be performed later in WP1, such as fleet composition, vehicle sales, cost components. Finally, trends for logistics will also be studied based on quantitative projections. The EU's own reference scenario will be part of that investigation, but many countries have their own strategies and projections on the freight market, which will be part of the research. Expected usage profiles of vehicles (e.g. regarding trip distance, good types, travel times) will be a main focus of the research, to provide further guidance to the vehicle concept development in AEROFLEX.

In general it can be concluded that this deliverable has provided necessary input to have a common basis of knowledge that is requested to realize the next steps in the AEROFLEX project. One step within the consortium is to discuss the fulfilment of the requirements for input of WP1 with the other work packages of AEROFLEX. The objective is to agree about the expected outcomes that existing data and discussions with stakeholders in WP 1

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5	VOLVO	VOLVO TECHNOLOGY AB
6	CRF	CENTRO RICERCHE FIAT SCPA
7	UNR	UNIRESEARCH BV
8	SCB	SCHMITZ CARGOBULL AG
9	VEG	VAN ECK BEESD BV
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24	WABCO-NL	WABCO AUTOMOTIVE BV
25	WABCO-DE	WABCO GMBH

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