



Long Distance Freight Transport

A roadmap for System integration
of Road Transport

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1. SCOPE AND OBJECTIVES

1.1. Mission and scope

In the context of a 'truly integrated transport system' (i.e. self-organized connected and automated logistics, enabling smart intermodal transport and efficient use of infrastructures in all modes), long distance and regional freight transport should become even more resilient and sustainable, while keeping transparency and being affordable for users and actors in the system.

The MISSION is to enable decarbonized, highly-automated and connected long-distance freight transport, in order to improve environment, safety and health for the benefit of the whole society, as well as to improve efficiency of the European freight transport market.

Inter-modality is a key element to improve the transport efficiency. That means to use the appropriate mode of transport to carry goods in an efficient way (e.g. with less energy consumption and GHG emission, less infrastructure requirements and less working time). Freight transport should be organized by the consideration of the strengths and weaknesses of the different transport modes. 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 scope of the ERTRAC Roadmap is to study long distance and regional transport of goods on roads, taking a whole system approach (not only the vehicle but also infrastructures and services). The ERTRAC long distance freight transport (LDFT) Roadmap is focused on road transport, as it is the mission of ERTRAC, and therefore does not address research activities of other modes of transport. But the Roadmap objectives and R&D priorities have been checked for consistency and aligned with the other modes of transport, with the objective to contribute to the overall improvement of the transport system.

1.2. Connections to other ERTRAC Roadmaps and other technology platforms

The ERTRAC LDFT Roadmap is a research agenda where elements from other roadmaps are coming together. The ERTRAC LDFT Roadmap has also been discussed with the other European Technology Platforms (ETPs) in order to exchange and develop common roadmap objectives and R&D priorities.

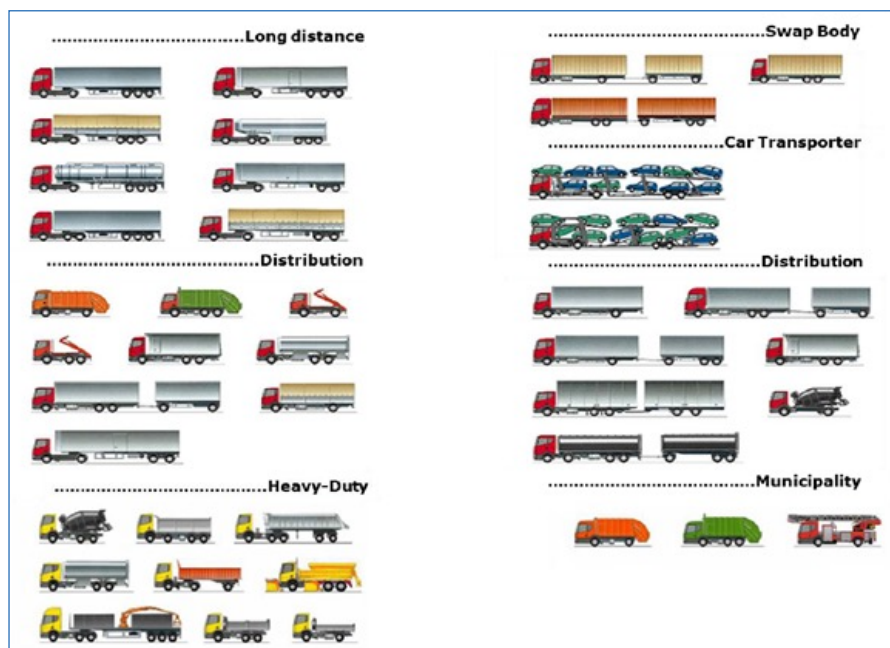
- **ALICE – Alliance for Logistics Innovation through Collaboration in Europe**
- **ACARE – Advisory Council for Aviation Research and Innovation in Europe**
- **ERRAC – European Rail Research Advisory Council**
- **Waterborne – European Maritime Industries Advisory Research Forum**

1.3. Introduction – Facts and Figures

Learning from the past, we should work on the gaps between research activities and the real-world implementation: how to accelerate the penetration of innovations and breakthroughs into the industry.

One major challenge in this aspect is how to use heavy vehicles in a flexible and efficient way, aligning with diverse needs¹ of upcoming logistical service and business models innovations.

Looking at the future, we should analyse the implementation barriers, monitor potential game changers and prioritize actions, in order for the road transport sector to influence positively the cross-sectorial challenge of freight transport efficiency. Ambitious but realistic research actions are listed by application domains: confined area, hub-to-hub, open roads and urban environment, in chapter 3.



"No truck is like another", ACEA Position Paper 2016

1.3.1.1. Key figures of freight transport - All modes

According to Eurostat 2018², road still keeps its leading position in the modal split calculated on the basis of transport performance (measured in tonne-kilometres of five transport modes), followed by maritime transport (but ships carry nearly 90% of EU external freight according to the European Commission DG Research and Innovation³).

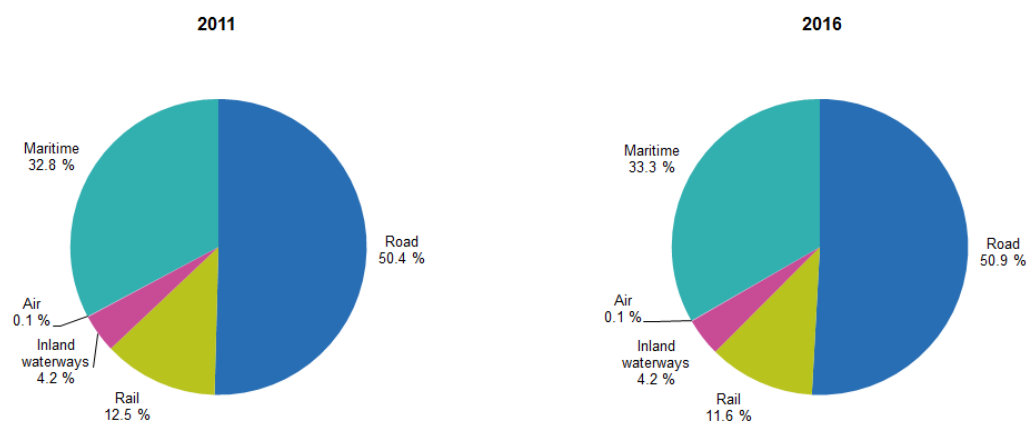
In 2016, road accounted for just over half of all tonne-kilometres performed in the EU. Maritime transport came next, with a third of the total transport performance, followed by rail (11.6 %) and inland waterways (4.2 %). In terms of tonne-kilometres performed, air transport plays only a marginal role in intra EU freight transport, with a share of 0.1 %. But according to the IATA cargo strategy (2018), it represents over than 35% by value on a global level, and the interface between air-cargo and road transport is highly relevant as well. The value of goods carried by airlines is expected to exceed 6.2 trillion in 2018, representing 7.4 % of world GDP. E-commerce companies rely on the express delivery services made possible by aviation and represent a huge potential for air-cargo to grow in the years to come.

¹ ACEA Position Paper 2016, Position Paper - https://www.acea.be/uploads/publications/ACEA_Position_Paper_Reducing_CO2_Emissions_from_Heavy-Duty_Vehicles.pdf

² Eurostat 2018 https://ec.europa.eu/eurostat/statistics-explained/index.php/Freight_transport_statistics_-_modal_split#Modal_split_in_the_EU

³ European Commission DG Research, <https://ec.europa.eu/research/transport/index.cfm?pg=transport&lib=water>

Freight transport in the EU-28: modal split based on five transport modes (% of tonne-kilometres)



Note: Air and maritime cover only intra-EU transport (transport to/from countries of the EU) and exclude extra-EU transport.
Source: Eurostat (online data codes: rail_go_typeall (rail), iww_go_atygo (inland waterways), road_go_ta_totl (national road transport), road_go_ca_c (road cabotage transport), Eurostat computations (international road transport, air and maritime transport).

eurostat

1.3.1.2. Key figures – Heavy duty vehicles

According to the ACEA Position Report – ‘Reducing CO₂ Emissions from Heavy-Duty Vehicles’ – 2018, heavy-duty vehicle manufacturers are part of an automotive industry which generates 2.4 million jobs in the road freight transport sector, which makes a significant contribution to the European economy. Around 417,000 heavy duty vehicles (N2/M2 with >3.5t GVW and N3/M3 vehicle categories) were produced in the EU in 2016, with 7 million heavy duty vehicles being operated in the EU-28. On top of that, heavy-duty vehicles generated a €4.9billion trade surplus for the European Union last year alone, while all motor vehicles generated around €400 billion of fiscal income for 14 EU member states. Moreover, the automobile and parts sector has established itself as Europe’s number one private investor in R&D, spending around €53,8billion on innovation in 2016⁴. All this keeps Europe’s heavy-duty vehicle manufacturers ahead of global competition.

With trucks carrying more than 71% of all freight transported over land in 2017, the heavy-duty vehicle sector is the backbone of efficient freight transport in Europe, with the sector contributing €550 billion in gross value added (GVA) to Europe’s economy in 2011.

In addition, 29 million vans are on the EU roads today, and an increasing number of them are used for long distance freight transport. Illegal operations are frequently reported, mainly of cabotage and overloads.

1.3.1.3. Energy efficiency, road capacity and safety improvements necessity

Overall efficiency improvements of long distance freight transport are critical to the society, in order to solve environmental, road capacity (congestion), as well as safety-related issues.

According to the Impact assessment of the 2017 EU HDV CO₂ standards and Clean Vehicle Directive⁵, the HDV sector is a significant source of GHG emissions. In 2014, GHG emissions from HDVs represented 5% of total EU emissions, a fifth of all transport emissions and about a quarter of road transport emissions⁶. During the period 1990-2014, overall GHG transport emissions⁷ have increased by 20% and HDV emissions by 14%⁸, while the performance of road freight transport (measured in billion-tonne-kilometres) grew by 14.3% between 2000 and 2014.⁹

⁴ ACEA Automobile Industry Pocket Guide 2018-2019, page 66 https://www.acea.be/uploads/publications/ACEA_Pocket_Guide_2018-2019.pdf

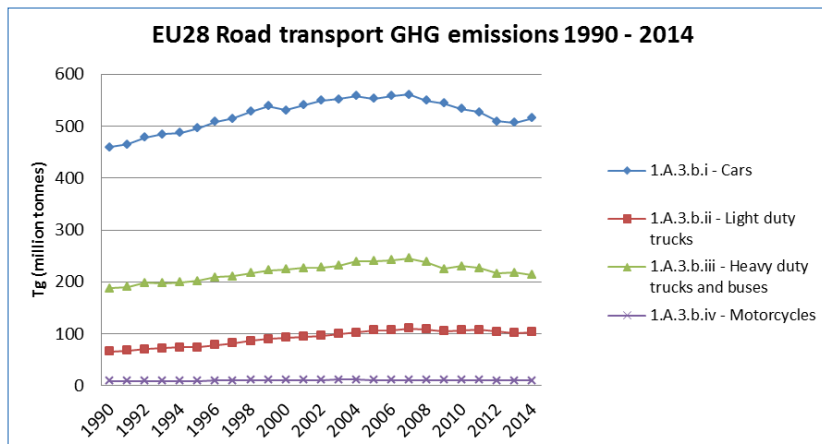
⁵ 2017 EU HDV CO₂ standards and Clean Vehicle Directive, <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52017SC0188>

⁶ GHG Inventory data 2016, <http://www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer>

⁷ Including international aviation but excluding international shipping.

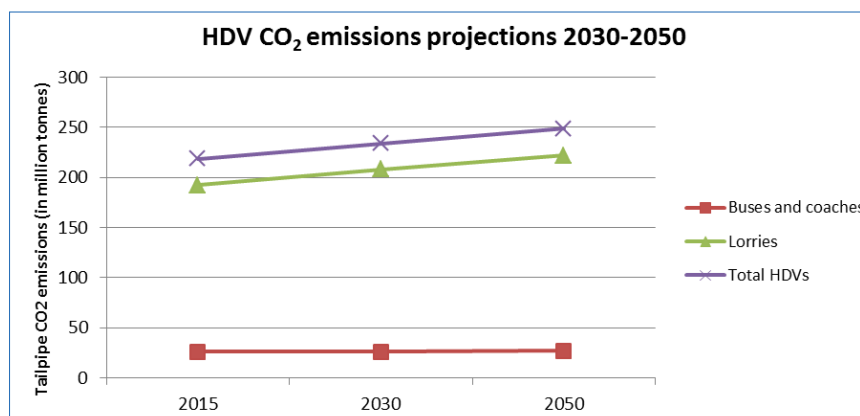
⁸ GHG Inventory data 2016, <http://www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer>

⁹ ACEA factsheet on trucks, 2017 <https://www.acea.be/publications/article/factsheet-trucks>



Note: 1.A.3. b.ii / Light duty trucks includes light-duty vehicles < 3.5 t
Source: GHG Inventory data 2016¹⁰

As shown below, without further action, HDV CO₂ emissions are set to increase by up to 10% between 2010 and 2030¹¹. Given action already taken to curb emissions from cars and vans, HDV CO₂ emissions are bound – particularly as regards emissions from lorries – to represent an increasing share of road transport emissions, from around 25% in 2015 to around 30% in 2050.



Source: EU Reference scenario 2016, PRIMES-TREMOVE Transport Model (ICCS-E3MLab)

Congestion in the EU is often located in and around urban areas and costs nearly EUR 100 billion, or 1 % of the EU GDP, annually¹². Because there are limits to how much new road infrastructure can be built, and because there is a strong demand for increasing the lifetimes of road assets, the challenge will be even more on how to improve the utilization of the existing road capacity. The recent Falcon/CEDR project underlines that existing European infrastructure will not be able to accommodate an increasing freight flow of nearly 40% for the forthcoming growth of transport demand and the risk of severe traffic congestion seems unavoidable with the current legislative framework. Road utilization could be influenced by emerging ways of organizing road freight transport and logistics in order to cope with increasing e-commerce, new technologies (e.g. automation of trucks and processes), as well as new trends in the organisation of work impacting the labour environment.

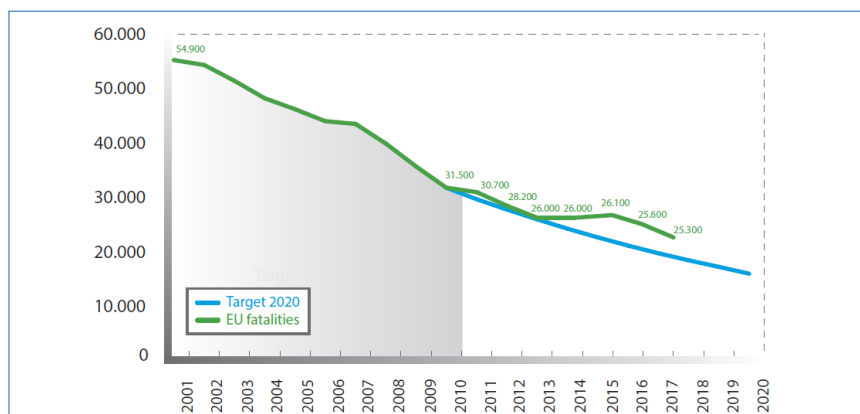
Regarding safety issues, according to DEKRA road safety report 2018 (Transport of goods), thanks to the progress made by manufacturers in developing driver assistance systems, the number of road users killed in accidents involving commercial vehicles has decreased significantly in recent years across the EU. While 7,233 people died in accidents involving commercial vehicles in 2006

¹⁰ GHG Inventory data 2016, <http://www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer>

¹¹ EU Reference Scenario 2016: Energy, transport and GHG emissions - Trends to 2050, http://pure.iiasa.ac.at/id/eprint/13656/1/REF2016_report_FINAL-web.pdf

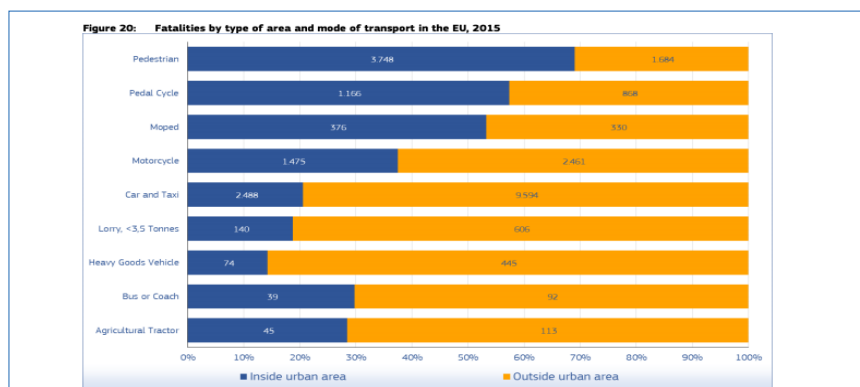
¹² https://ec.europa.eu/transport/themes/urban/urban_mobility_en

in the EU, this figure fell by over 47 percent to 3,848 by 2015 according to latest data from the European Commission. However, this figure represents around 15 percent of all deaths caused by road traffic in the EU – a figure that has remained more or less constant over recent years¹³.



Source: CARE (EU road accidents database)

The CARE report¹⁴ shows that safety remains a key issue and that the large majority of fatalities from heavy good vehicles accidents happen outside the urban area.



Source: CARE (EU road accidents database) or national publications
Last update: May 2017

1.3.1.4. External drivers: consequences of disruptive technologies and the new coming logistic landscape

As mentioned in the TML/ IRU report¹⁵ 'Commercial Vehicle of the Future', innovation is revolutionising and speeding-up the way people and goods are moving. Digital transformation, e-commerce, electro-mobility, automated driving, connected vehicles and infrastructure, as well as new logistical concepts and practices, are among the initiatives reshaping mobility and transport.

¹³ Road Safety in the European Union, April 2018, https://ec.europa.eu/transport/road_safety/sites/roadsafety/files/vademecum_2018.pdf

¹⁴ Annual Accident report, 2017 https://ec.europa.eu/transport/road_safety/sites/roadsafety/files/pdf/statistics/dacota/asr2017.pdf

¹⁵ TML/ IRU report, Commercial Vehicle of the Future, <https://www.iru.org/sites/default/files/2017-07/iru-report-commercial-vehicle-of-the-future-en%20V2.pdf>

Innovations made in one sector will be facilitators for accelerations of innovation in other sectors. Over the last years, there has been a rapid adoption of automation and predictive analysis and these innovations should have major impact on the organization of the logistics sector: automation should bring efficiency improvements that are driven by the associated cost savings. About 3¹⁶ or 4%¹⁷ reduction in fuel consumption is the expected benefit from platooning, but further costs could be saved by driverless stretches. As such, for shippers to remain competitive, they would need to adopt these cost reduction opportunities, leading to a transition to automated services whenever possible.

Finally, modal thinking is making way for complementary multimodal freight and worldwide interconnected logistics networks.

1.4. Focus areas

There are some promising solutions and technologies that can be progressively introduced to increase the sustainability of long distance freight transport. These solutions and technologies have been categorized in different focus areas.

1.4.1. Vehicle

The improvement of vehicle performance is one of the key issues for reducing the environmental footprint of the long distance freight transport but also for improving road safety and increasing operational efficiency.

Starting with the measures oriented to reduce the emission of pollutants, there are several solutions that can be classified in two blocks, namely propulsion system and vehicle design.

Propulsion system: nowadays 98% of the current heavy-duty vehicle fleet is propelled by internal combustion engines and most of them burn diesel to generate energy. In the next step, the first measures are to improve the combustion engine system efficiency combined with waste-heat recovery, improved automated transmission and high efficiency exhaust after-treatment system. Optimization and adaptation of engines for renewable liquid and gaseous fuels are to be investigated in parallel with electrification/hybridization of the powertrain. Another trend is the increasing rate of electrified (HEV/PHEV/BEV) vehicles, including the electric energy storage not only using batteries, but also from fuel cell or from high efficient ICE energy converters running on hydrogen, as well as electric road systems.

Vehicle design: the main forces slowing down the advance of vehicles (including trailer), are the aerodynamics and the rolling resistance. The optimization of the aerodynamics is today restricted by regulatory constraints, which are likely to be relaxed soon. The implementation of low rolling resistance tyres could, in the future, be combined with the implementation of tyre pressure monitoring systems (TPMS) to ensure the right tyre pressure any time.

¹⁶ <https://www.acea.be/news/article/what-are-the-benefits-of-truck-platooning>

¹⁷ <https://www.energy.gov/eere/articles/platooning-trucks-cut-cost-and-improve-efficiency>

In addition, innovative vehicle architecture concepts for 'multi-use' and 'fit-for-purpose', combined with light weighting (new materials) would allow increasing the payload of the vehicles and reduce the carbon footprint. New design for vehicles (HCV) and performance based standards (PBS) are among the solutions to investigate for improving vehicle performance, fostering innovation and ensuring a better compliance with the infrastructure requirements (Falcon project by CEDR).

Also important for the reduction of the environmental footprint and the road safety is the implementation of Advanced Driver Assistance Systems (ADAS). Some of these are clearly oriented to fuel economy, for example Adaptive Cruise Control (ACC), Green Zone Indicator, Predictive Cruise Control, Acceleration Control Limits and Eco-rolling (coasting). Others are clearly oriented to increase road safety, for example Vulnerable Road Users Detection, Electronic Stability Program (ESP), Advanced Emergency Brake System (AEBS), Road Sign Recognition (RSR), Lane Departure Warning System (LDWS) and Curve Speed Warning (CSW).

1.4.2. Energy

The energy solutions for decarbonising Long Distance Freight Transport should be different depending on the average distances travelled by the vehicles: renewable fuels (liquid, gas, biofuels and synthetic fuels) in combination with hybridization seem to be a realistic scenario for long distance application, while electrification by battery seems to be applicable for urban and regional distances.

On a more long term perspective, there are three different approaches that will technically evolve in parallel for the complete electrification on long distance: the full electric battery supply, the electric road systems, as well as the chemical to electricity conversion by Fuel Cell or ICE electric generators. The technical evolution, the market needs and the policy measures will show prevailing solutions.

1.4.3. Services and operations

Seamless transport of freight is essential for improving operational efficiency and avoiding congestion. Freight transport should progressively continue to evolve into integrated-bundled-services, such as systems-of-systems services, increasing the load factor, avoiding empty runs and progressively converging into the physical internet¹⁸. Valorisation of digitalisation capabilities is a key factor for seamless movement of goods.

Another key point in operations is the establishment of multimodal solutions fostering standardisation and modularisation of freight packaging and automating loading and unloading processes to minimize transshipment time and complexity between different modes of transport.

1.4.4. Infrastructure

The evolution of the digital and physical infrastructure has to run in parallel. From the physical point of view, right maintenance of the roads and the use of pavement reducing rolling resistance will reduce the vehicles' environmental footprint. Renewable fuels supply has to be provided along the road network together with charging stations.

In the case of solutions based on electricity, it is foreseen that full battery solutions will be applied to short and medium distance services¹⁹. The charging stations, which will be mainly linked to the fleet parking and truck stops, have to be sized in number and electric power to cover the energy needs. In the electrified road systems case (ERS), the infrastructure cost is high compared to common roads. The business model and the depreciation time should be carefully assessed and a well-established planning is needed to prioritize the high occupation routes.

For solutions based on hydrogen, a complete refuelling infrastructure is needed that differs for the already existing one, which is raising safety and technological challenges.

Directive 2014/94/EU²⁰ on alternative fuel infrastructure has to be implemented in order to obtain a gradual decarbonisation of the transport. The 3rd Mobility package²¹ will lead to the enforcement of EU measures to accelerate the deployment of alternative refuelling infrastructures.

1.4.5. Society

Society perception and public acceptance is important for successful deployment and should not be underestimated. There are several regulatory aspects, such as the ones foreseen in the 3rd Mobility package, that need to be reviewed in order to facilitate the implementation of some of the proposed solutions. The legal framework to modify the vehicle length and weight, to remove the restriction on the cross borders and to adapt the driving time regulation, have to be reviewed.

The driver also plays an important role. In the short term, the driver behaviour is one of the most effective and quick to implement solutions to reduce the environmental footprint. In the mid-term, driver training using new driver support systems, and in the long term, as automation level increases, the role of the driver will evolve. Several scenarios of driver involvement have been assessed by IRU²².

¹⁹ EU Electrification of the Transport System, http://ec.europa.eu/newsroom/horizon2020/document.cfm?doc_id=46368

²⁰ <https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A32014L0094>

²¹ https://ec.europa.eu/commission/commissioners/2014-2019/bulg/announcements/presentation-third-mobility-package_en

²² Managing the Transition to driverless road freight transport, <https://www.iru.org/resources/iru-library/report-managing-transition-driverless-road-freight-transport>

2. IMPLEMENTATION BARRIERS

●● 2.1. Shippers and logistics service providers' business model

The freight transport business is highly competitive and cost efficient. High-technology and collaboration (both of data and assets) for improved logistics efficiency and CO₂ emissions reduction targets are required but in certain cases, low business profitability may have a negative impact on business investments capability.

While there is an increasing consolidation in the freight transport business, the extensive use of sub-contraction to smaller companies is a significant feature of the market, and serves to reduce the overheads of larger companies, extend geographical reach, meet periods of peak demand and increase supply chain efficiency.

Access to the road haulage market and certain social and safety conditions (such as drivers hours) are regulated at EU level. There are significant variations in operational cost structures throughout the EU, most notably fuel and driver wages. Whilst this provides competitive advantages for some haulers and preferential freight rates for the shipper, the opportunity for further EU market liberalisation is controversial and not supported by all Member States and all transport operators.

●● 2.2. Swift connectivity implementation is a must

Full connectivity with other vehicles and with infrastructures (road, rail, port, airport), as well as in the supply chain setup (road operators and their logistic providers) is far from being implemented yet.

ICT systems and devices interconnections are still complex, and costly infrastructures are aging and not always at the right standards. Harmonization of systems, standardization and interoperability initiatives are complex and require involvement of many stakeholder groups. For instance, communication between smart vehicles and infrastructure require harmonization of infrastructure investments of national, regional and local governments as well as the private sector. Timely anticipation and early start of these processes and investments is essential.

●● 2.3. Information exchanges and automated processing

Cloud-based collaboration platforms should further evolve using the already existing standards (C-ITS-DATEX II, RIS, TAF-TSI, e-CRM) and managing the data interfaces by integrating all the stakeholders (driver, vehicle, service provider, logistics service provider, transport operator, hub operator and public authorities/road traffic managers).

There are legal and governance issues to be anticipated: data ownership handling and sharing for CAD services, data privacy and security (handle GDPR and other regulations), role of public and private actors. The adoption of neutral business models / platforms allowing for management of data exchange and storage will be a key success factor.

Last but not least, the security of ICT hardware and functions is to be addressed by the whole system (architecture, access verification, trustworthiness of procured information). As a fully interconnected system becomes vulnerable, consequences of attacks will be at large scale and system robustness required. Sharing of data between business parties is hampered by lack of security, lack of trust, lack of rights management. Technologies such as blockchain should be further investigated as a possible enabler.

To conclude, although the new services have the potential to establish a highly interconnected transport system, they can only incorporate the options for which information can be made available to the system. In order to enable inter-modality, data integration should include not only road options but also options from the other transport modes. Active high-level governance of information sharing and collective and multi-modal information platform development could ensure a more balanced availability of transport services.

2.4. Implementation barriers to overcome

In order to be able to achieve the ERTRAC LDFT roadmap mission, some implementation barriers should be overcome – This goes far beyond the transport industry ability. Among the prioritized activities to remove these implementation barriers:

- Recognize freight transport for its real value, in order to enable the required investments, while granting a competitive TCO for logistics operators at the same time. New mechanisms and legislation for keeping fair competition are required to maintain the balance, as new business models/services platforms that arise tend to result in market domination by a few large players.
- Design and secure resources in order to build the infrastructures that enable inter-modality (corridors/terminals/ hubs...)
- Increase the speed of supra national data regulation: secure the evolution of the network of platforms in order to secure data exchange interfaces in logistics, while respecting the legacy of the platforms. A pre-competitive ICT-network moderator authority might be required to grant fair and equal market conditions for users.

3. STRATEGIC ROADMAP FOR ROAD FREIGHT TRANSPORT

3.1. Wanted Position: “Adaptable Transport Solutions” by application domain

According to ERTRAC ‘SRA vision 2050’²³ and ALICE ‘Integrated transport system Vision’²⁴, the overall objective is to develop affordable and efficient freight delivery solutions for the European citizens. This will include intelligent logistics solutions, smart co-modal infrastructures and robotized freight delivery.

- Physical Internet 2030 will bring efficiency and sustainability to logistics (digitalization and connectivity)
- Focus on decarbonisation towards zero emission logistics by 2050

The supply chain of the future should be seamless and green. As explained in the reports of the Falcon²⁵ and Transformers²⁶ projects, we should enable synchromodality to increase and work further on transport efficiency. All in all, we should understand the future role of road vehicles in the context of inter-modality, with regards to CO₂ emissions, connectivity and automation, and flexible/ modular vehicle concepts able to operate in long distance (more efficient long haul combination) as well as in urban environment (freight breakability).

The needs are obviously different by vehicle usage and application domain. Also the stakeholders are different. There will be a mixed situation depending on the transport market segment with progressive extension of high-technologies to different use cases, from ‘simple’ environments to more and more complex environments:

- **Confined Area:** ports and terminals → simple environment: repetitive tasks, private area, fully controlled traffic management
- **Hub-To-Hub:** from factories to ports or terminals → relatively simple environment: repetitive tasks, partly public road, partly controlled traffic management
- **Open roads:** highways, roads → complex environment: tailored tasks, public roads, no controlled traffic management
- **Urban Environment:** cities → very complex environment: made-to-order tasks, public roads, non-adapted infrastructure in dense cities, no controlled traffic management

The different application domains are obviously intermixed in real operations. As an example, hubs and ports are often located in the peri-urban areas. To get the different use cases connected is a key challenge for long-distance freight, and actions should focus on routes connecting the interurban corridors with roads to ports or terminals.

²³ <https://www.ertrac.org/uploads/documentsearch/id52/ERTRAC-Strategic-Research-Agenda-SRA-2018.pdf>

²⁴ <http://www.etp-logistics.eu/wp-content/uploads/2017/03/Truly-integrated-Final-Edition-WEB.pdf>

²⁵ Falcon project, <http://www.cedr.eu/strategic-plan-tasks/research/cedr-call-2015/call-2015-freight-logistics-multimodal-context/>

²⁶ Transformers project, <https://cordis.europa.eu/project/rcn/110632/reporting/en>

Examples of transport solutions, challenges and impacts by main application domain

CONFINED AREAS	HUB-TO-HUB	OPEN ROADS	URBAN ENVIRONMENT
EXAMPLES OF TRANSPORT SOLUTIONS <ul style="list-style-type: none"> Autonomous and electrified vehicles and systems (including load handling systems) to be put in use in ports and terminals Transshipment, including information exchange 	<ul style="list-style-type: none"> Automated freight transport on short distances from factories to ports or terminals (X km, XX km/h) → operating partly on public roads (connected to traffic control authorities) and fully linked in the interconnected Logistics chain 	<ul style="list-style-type: none"> Highway pilot platooning: automated driving on highways from entrance to exit, on all lanes, incl. overtaking and lane change High Capacity Transport 	<ul style="list-style-type: none"> Autonomous electrical-dollies for last-mile transport the trailer (without the truck) Low-noise and emission-free vehicles leading a convoy of electrical semi-autonomous trailers from different logistic centers on its way to the city centre Transport Management System ensures connectivity between vehicles, users, and infrastructure and logistics partners. It enables selling/buying load capacity → flow after demand through co-distribution and city logistics management
CHALLENGES <ul style="list-style-type: none"> EU Standardization among Nodes (rail, port) and Hubs (factories, distribution centres) Congestion, traffic jams, land use Load handling efficiency Link to traffic management centres, Nodes, Hubs and service providers Multiple stakeholders around confined areas Safety Security 	<ul style="list-style-type: none"> EU Standardization among Nodes (rail, port) and Hubs (factories, distribution centres) Traffic management control/ authority Handover, connectivity Modularization and standardization of load units and vehicles System integration Physical-Digital infrastructure integration Services provision for hub-to-hub Priority access Pre-clearance 24/7 operations, driverless (separate regulation) Safety & Security 	<ul style="list-style-type: none"> Mobility/Road capacity, no congestion Lifetime and resilience of road assets, mitigating infrastructure wear Best operation of infrastructure, SIAP*, availability and self-correcting road Energy supply (and efficiency), reducing CO₂ equivalent emission and noise Data exchange (V2I-I2V), network coverage Road safety Vehicle and driver efficiency Cross border facilitation 	<ul style="list-style-type: none"> Infrastructure (Energy & Digital) Use of space (i.e. Road infrastructure) (Intelligent) Access Programmes Emissions (noise, NOx, CO₂); congestion Integrated logistics (today fragmented) Understanding current situation (data missing) Consolidation of goods and business models E-commerce (B2C, home deliveries, return logistics etc.) Safety (especially VRU) Security (driver, users, data, goods) User behavioural aspect

IMPACTS <ul style="list-style-type: none"> Cost & safety – employment and job shift Transport efficiency and throughput (PBS) ** 	<ul style="list-style-type: none"> Transport efficiency and throughput (PBS) Transport precision and predictability (just-in-time" lead time) Priority access 	<ul style="list-style-type: none"> Transport precision and predictable time of arrival Affordable cost Energy efficiency and Emission reduction Safety, Security 	<ul style="list-style-type: none"> Emission free and CO2 free (TTW) Transport precision and predictable time of arrival Transport efficiency Contribute to Vision Zero road safety objective
MAIN STAKEHOLDERS <ul style="list-style-type: none"> Rail transport operators Waterborne transport operators, shipbuilding and maritime equipment suppliers Ports and terminals Airfreight transport Road transport operators ICT and Technology companies Vehicle manufacturers 	<ul style="list-style-type: none"> Rail transport operators Waterborne transport operators, shipbuilding and maritime equipment suppliers Ports and terminals Airfreight transport Road transport operators ICT and Technology companies Vehicle manufacturers 	<ul style="list-style-type: none"> Road transport operators Road authorities Road infrastructures ICT and Technology companies Vehicle manufacturers 	<ul style="list-style-type: none"> Road transport operators Local/ Cities authorities ICT and Technology companies Vehicle manufacturers Airfreight transport

*SIAP: Smart Infrastructure Access Policies – see chapter 4.3.4.1

**PBS: Performance Based Standard – see chapter 4.3.4.1

3.2. Targets by application domain

3.2.1. Prioritized operational targets

CONFINED AREAS	HUB-TO-HUB	OPEN ROADS	URBAN ENVIRONMENT
<p>Increased transshipment efficiency by 30%*</p> <p>Increased automation up to level 4: Easy to maneuver and high security levels</p>	<p>Increase Load factor by 30%*</p> <p>Increased automation up to level 4: New solutions to enable a fast exchange of loading units</p>	<p>More than 3% CO₂ reduction per year TTW</p>	<p>Urban commercial vehicles offering zero emission driving with suitable range and payload</p> <p>Noise reduction</p> <p>Increase Load factor by 30%*</p>

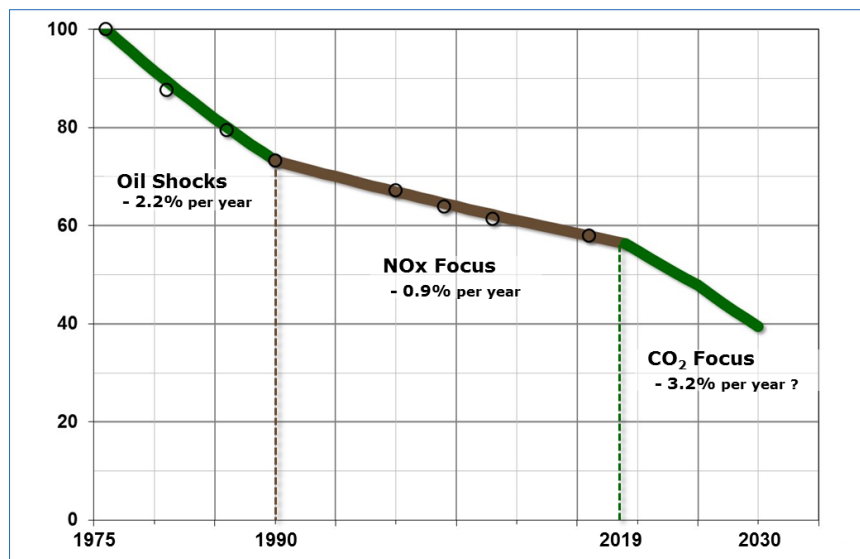
*For logistics efficiency - There is no baseline and no measurement as of today. Looking further into measurements and targets for logistics efficiency (in particular for transshipment efficiency and load factor) should be a prioritized research topic.

- **CO₂ equivalent emission reduction targets**

The EU 2030 framework for climate and energy includes a target of at least 40% reduction of domestic EU GHG emissions compared to 1990 levels. All sectors will have to play their part if this level of ambition is to be achieved. The road transport sector is of key importance for reducing GHG emissions and decarbonizing the EU economy.

Road freight transport is essential for the development of trade on the European continent. Trucks carry around 70% of freight transported over land. CO₂ emissions from heavy-duty vehicles (trucks, buses and coaches) account for about 6% of total EU emissions and 25% of road CO₂ emissions in the EU. Without any further action, CO₂ emissions from HDV are projected to grow by 9% over the period 2010-2030 due to the increasing transport activities.

On 17 May 2018, the European Commission presented a legislative proposal setting the first ever CO₂ emission standards for heavy-duty vehicles in the EU. Targets for average CO₂ emissions are under decision at the time of publication. In order to reach the proposed objectives for the new vehicles coming into the market, truck OEMs should most likely manage more than 3% fuel consumption decrease by year.



Trucks OEM average CO₂ consumption

According to EUROSTAT 2018c, about 80 % of all freight transport (in terms of tonne-kilometre) is realized on long haul (over a distance of 150 km or more). The long-haul on the 'open roads' application is responsible for the large majority of the CO₂ emissions. The 'urban environment' or 'confined areas' have less-significant numbers in terms of volumes of CO₂ emissions. However, we should look into alternative electrified vehicles due to air pollution and noise, in particular in cities.

- **Logistics efficiency targets**

In addition of the vehicle-related CO₂ emissions targets, it is a priority to consider logistics efficiency improvement as a whole, in order to limit congestion and CO₂ emissions. The ALICE roadmap sets an overall objective to improve the logistics efficiency by 30%, but the logistics industry is still missing agreed references and measurements.

An important component of optimizing efficiency is avoiding empty runs or sub-optimally loaded vehicles. According to the AEROFLEX project report²⁷, 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.

Regarding the benefits of automated driving by 2030, the higher level of automation are foreseen in confined areas and hub-to hub applications, where the traffic environment is foreseeable and the vehicle speed relatively low, and the traffic can be fully controlled. Safety and unplanned issues can be minimised as there is no mixed traffic. Automatic maneuvering of large trucks in low speed will be a support to the driver in tricky situations like reversing long truck combinations in narrow areas and for loading bay docking.

3.2.2. Inter-modality enhancement

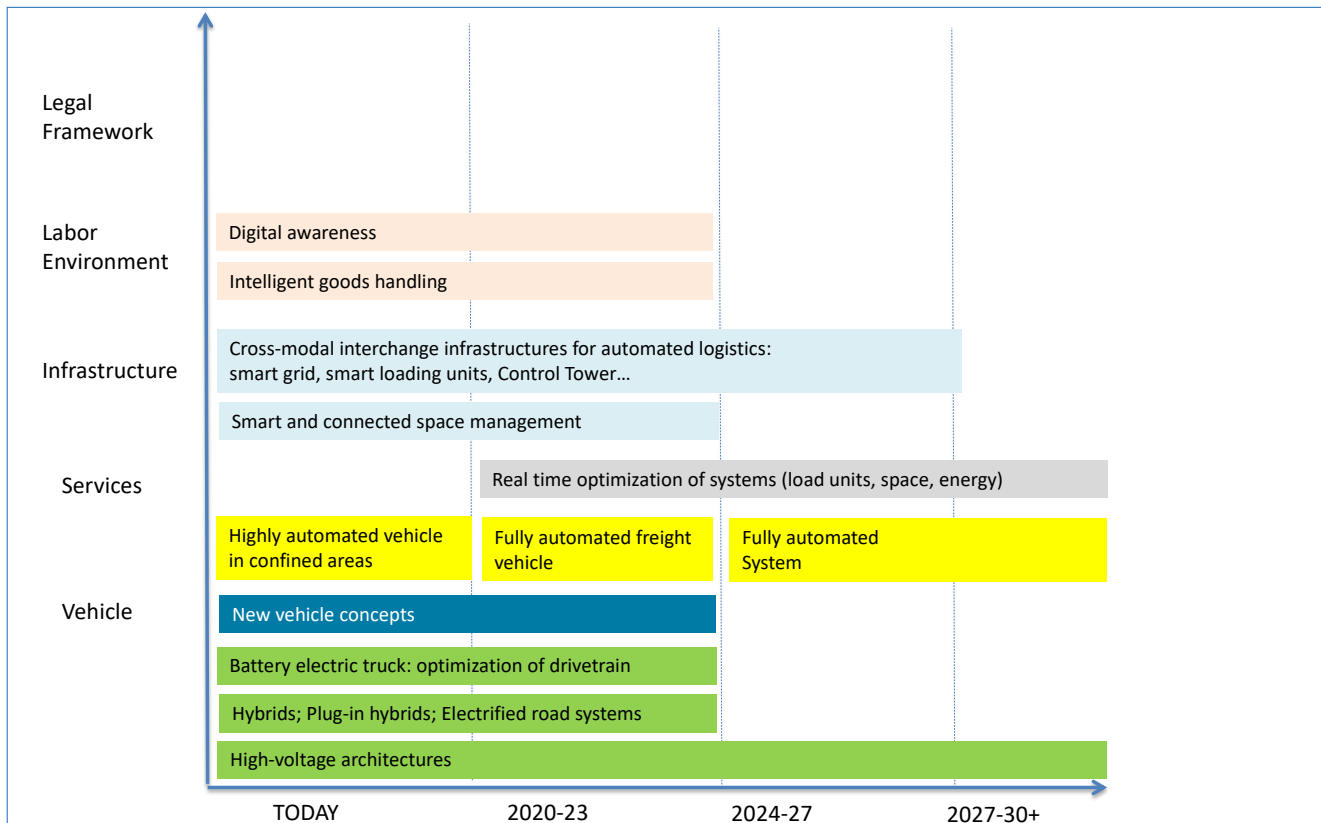
Activities that support increased interchangeability between modes should be enforced in order to be able to cope with the general increase in freight. We should also leave the necessary flexibility to all the modes of transportation: different type of freight on different transport modes. Three main objectives have been identified.

- To overcome the captive business models of large freight operators towards sharing their data
- To research transaction systems to determine the right business rules in the logistic chain
- To improve Transport Management systems and optimize trip planning

In addition, we should strengthen knowledge transfer between modes, with carry-over of technologies, wherever possible, or with suitable cooperative research and innovation activities when beneficial to all.

3.3. Strategic roadmaps

3.3.1. Confined Areas



Logistics service providers are always striving for managing their hubs efficiently and safely, and thus to develop new solutions for automated warehousing processes.

Propulsion system: Battery life time and energy density increase, as well as high voltage concepts, electrified road systems (ERS) and depending on the specific requirements of the area, optimization of drivetrain.

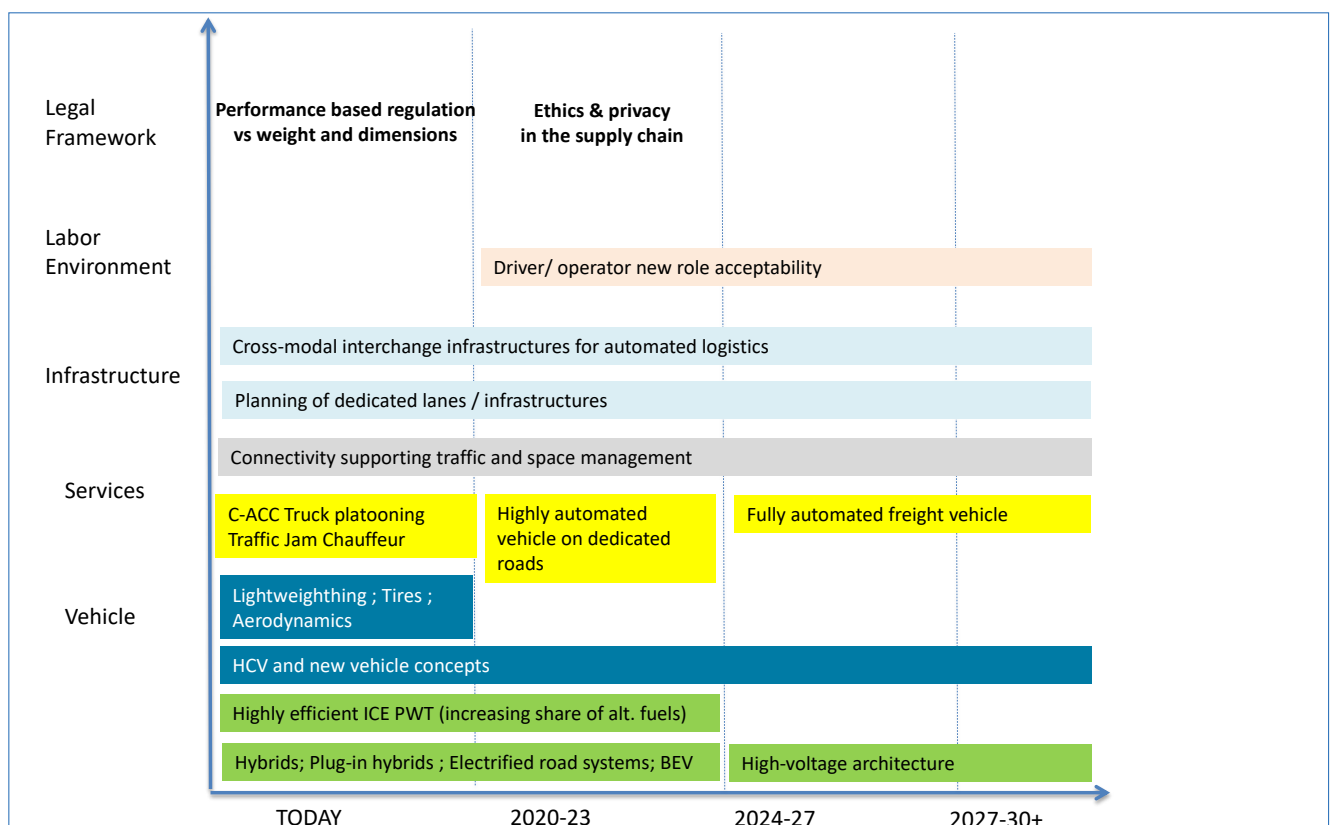
Vehicle: Automated freight transport carriers in confined areas for potentially un-manned freight transport. Vehicles can be modular, designed without cab for driver. As a next step: loading, handling, self- and /or remote maneuvering.

Services: Research areas should include real-time optimization services, electric charging services and optimizing charging times, interfaces to smart grid, real-time (IoT) based performance, capacity, operation and emission measurements, AI based optimization and solution engines, highly automated vehicle services and fully automated freight moving systems.

Infrastructure: The most important research topic in this application domain is the cross-modal interface infrastructures for automated logistics (both digital and physical). These includes research activities for smart loading units, smart and connected space management, control tower related infrastructure, interfaces towards the incoming and outgoing modes (including interfaces to traffic management and information systems), smart grid and fast charging infrastructure.

Labour environment: Tasks will drastically change due to automation and ICT systems and we should look into skills adaptation and training. Another topic is 'Intelligent goods handling coaching' that requires specific trainings for the workers on the infrastructures and machines.

3.3.2. Hub-to-Hub



Hub-To-Hub (e.g. from factories to ports or terminals) has a relatively controlled environment and is rather close of the confined areas environment in terms of solutions and technologies.

Propulsion systems: Hub-to-Hub is the application domain where electrified road systems (ERS) could be the most easy to implement in the short-term, with limited investments to cover short distances (infrastructure needs and business models should be further assessed).

New concept vehicles: New vehicle concepts and architecture enabled by electrification and automation, as well as intelligent automated loading units. But also new length combination and measures concerning load efficiency, load density and load optimization methods, which can apply in truck trailer combination. In terms of legislations, SIAP and PBS should enable implementation.

Automation: The automated / remote controlled vehicles inside and between hubs provide an opportunity to improve the efficiency of the transport processes. As a next step, automation should include automated load handling and self-maneuvering.

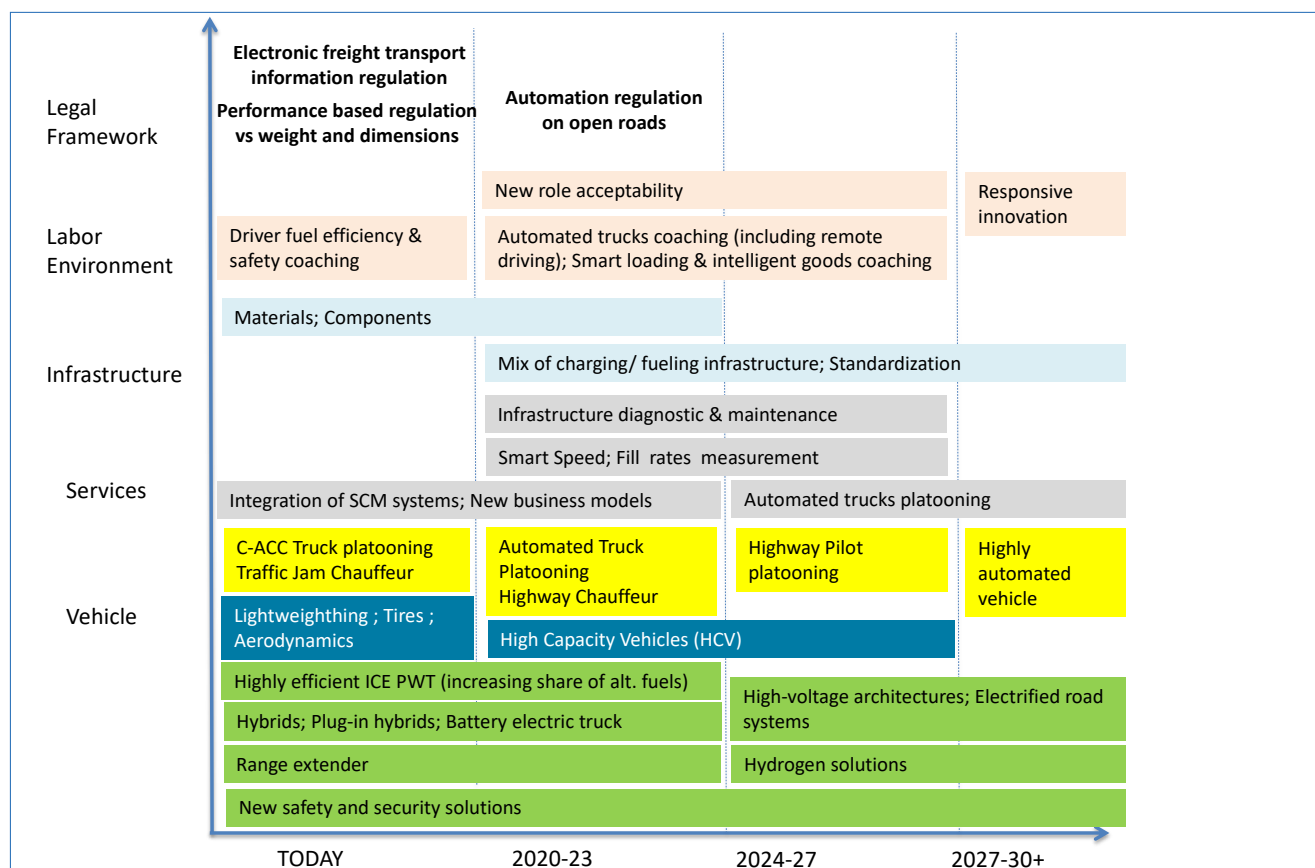
Infrastructures: Cross-modal interchanges infrastructures (physical, digital) for automated logistics. Look for flexible interchanges, build autonomous units that can automatically connect to trucks/ land (automation within yard) in order for rail/ maritime/ roads to come together – automated handling at rail/ road hubs. In addition, modular load devices that goes along with the need for repacking when changing modes (especially relevant for air cargo).

Services: Connecting supported traffic and space management. The right load unit must be on the right location at the right time, with the relevant transport modes available and ready for the transfer.

Labor environment: Fully automated vehicles where a driver is not anymore required within the vehicle and with less labour at the hubs. Automation should create new professionals related to operations, flows, surveillance and logistics planning for example.

- Partly automated → driver adaptation and acceptance of new roles and new skills
- Fully automated → operator role: planning, supervising, quality control, etc.

3.3.3. Open Roads



Propulsion systems: Internal combustion engine propulsion systems are expected to remain the technology of choice for long distance intercity freight transportation. This will require continued focus on low emissions and very high energy conversion efficiency. Renewable fuels, work-heat recovery and hybridization would be an option for short/medium term and full electric battery/fuel-cells for long-term. For ICE-electric or Fuel Cell-electric solutions, hydrogen offers better alternative than electric batteries on vehicle energy density. But production efficiency of hydrogen and re-fuelling/charging infrastructure development need also to be addressed.

High Capacity Vehicles, also unit combination and measures concerning volume and load efficiency, which can apply for efficient truck-trailer combinations, is important. In terms of legislations, SIAP and PBS should enable implementation for dedicated market with high volume/load in the same route.

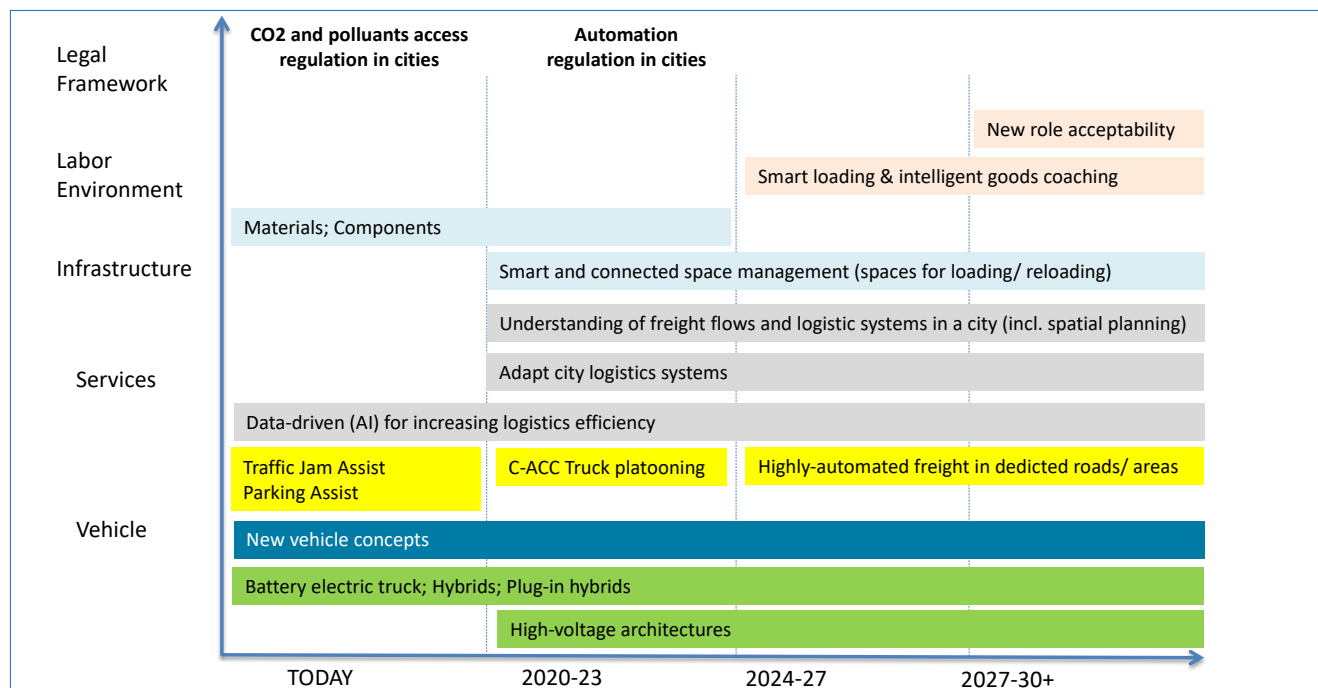
Automation: In the short-term, implementation of truck platooning at short distances (»5 m or 0.3 s) and management of “platoons-on-the-fly” (platoons formed dynamically). In the medium-term, Highway Pilot platooning: automated driving on highways from entrance to exit, on all lanes, including overtaking and lane change.

Services: to increase network utilization, services to improve load factors (weight and volume) for improving load optimization and to check movement of the load units in time and space. In addition, propose also a certified telematics framework for Europe, a European wide harmonized infrastructure access framework including payment for use and environmental cost.

Infrastructures: extend and implement the concept of green corridors²⁸. The right refueling/recharging infrastructure is a key enabler for mass-market deployment of alternative solutions. Each infrastructure is designed for certain load and dimensions. Therefore, advance systems should monitor vehicle characteristics and provide the smart access conditions.

Labor environment: The driver should be present in some open roads operations (Highway Pilot Platooning) and when entering in urban areas. Automation technology will initially be regarded as a support to the driver but will later on be able to take over the driving task for highly automated vehicles. There is a need for further research on highly automated driving in mixed traffic on open roads to fully understand the impact of automated long distance freight transport. Effort on driver coaching regarding fuel economy and safety issues should remain important. Training should be extended to automation systems. An open issue is how to manage the driver time during highly automated driving.

3.3.4. Urban Environment



This roadmap is not exhaustive and takes only the perspective of road freight transport. There are other research areas in the field of Urban Mobility and these are covered by the ERTRAC Urban Mobility working group²⁹, by ALICE, and by the EUCAR Expert Groups.

Propulsion system: zero emissions in cities. Short and medium distances in the future may be more fitted for electric batteries or alternative powertrains to reduce NOx, particle and noise emission. Fully electric vehicles, improvements in battery technology, reduction of cost, mass and improvement life cycle impact are essential for the market up-take of electrified heavy-duty vehicles for urban use.

Vehicle architecture: city-adapted and citizen-accepted-vehicles with, for example, modular and detachable vehicles systems during days and larger and silent vehicles for night distribution. **Automation:** Automated freight transport carriers on dedicated and controlled lanes/roads/ areas and for potentially un-manned freight transport. Vehicles could be designed without a cab for innovative freight transportation, and potentially also in passengers-freight transport combinations.

Services: Artificial intelligence and data-driven research activities for increasing logistics efficiency of urban freight logistics, i.e. optimizing the routing, loading factor, co-modality and inter-operability enhancements, geofencing, for new transport-as-a-services, and sharing solutions opportunities such as cooperative vehicle sharing with passengers vehicles.

²⁹ Integrated Urban Mobility Roadmap <https://www.ertrac.org/uploads/documentsearch/id45/2017%20ERTRAC%20Urban%20Mobility%20Roadmap%20-%20web.pdf>

Better understanding of freight flows and logistic systems in cities: to increase efficiency of freight transport in urban areas by increasing load factor both of vehicles driving into the city and passing by on the city road network, a system approach including enhanced business models is needed. Research and demonstration activities will be necessary to increase efficiency with an acceptable business model for each stakeholder while respecting the competition laws within the EU and the Member States. Land use planning is important.

Infrastructure: Design and equipment of logistic centers and facilities for the next generation of vehicles. Smart and automated connected space management (e.g. parking lots, terminal and storage areas). How to meet the growing demand of city logistics spaces and the lack of affordable spaces? Integration of charging infrastructure for electrified vehicles. Business models for the interoperability and sharing of infrastructures.

Labor environment: We foresee that there will still be a driver by 2030. The driver role might evolve more and more as a service provider / being a human interface with the customer (more than driving). Besides, new challenges raised by self-employed working for E-platforms³⁰ (i.e. Uber) need to be considered.

4. RESEARCH AND INNOVATION ACTIVITIES

4.1. Vehicle

4.1.1. Towards Zero-emission: ultra-low well to wheel emissions on highways, with zero emissions in cities

In order to ensure an effective and sustainable transition towards decarbonized low-emission transport sector by 2050, all technological options and fuels (including electricity), need to be allowed to compete for reducing emissions in the different transport modes. See ERTRAC Energy & Environment roadmaps as reference³¹.

The applicability of the solution depends on multiple factors, and the potential of alternative technologies and fuels varies depending on the typical usage profile of a HDV, and its particular requirements.

All in all, short and medium distances by 2030 and beyond may be more fitted for electric batteries and local stationary charging stations, while long-distance may be better equipped with highly efficient ICE powertrains for long-distances with low emission liquids or gaseous fuels, or alternatively with electrified fuel cell or hybrid solutions using dynamic charging along electrified roads.

4.1.1.1. Highly efficient ultra-low emission ICE powertrains for long-distances with an increasing share of renewable liquid or gaseous fuels (from biomass or produced by green electricity).

In the short to medium term, there is still a great deal of potential to improve the efficiency of the existing internal combustion engines (ICE) running on fossil and advanced biofuels.

HD ICE research needs to focus on areas such as improved fundamental engine thermodynamics efficiency, engine downsizing and/or engine downsizing solutions (where applicable) as well as improved HD ICE operational cycle efficiency in an increased diversity of transport missions. Combustion process improvements (cylinder pressure, chamber shape, improved heat rejection, fuel injection, etc.) will also be needed and can still deliver potential efficiency improvements of about 3-5% (ref. chapter 3).

In addition for conventional and low carbon fuels, new ignition and combustion concepts and exhaust gas aftertreatment for Natural Gas (in particular for reduced exhaust temperature levels) will be needed as well as other potential areas of improvement e.g. charging efficiency (for example turbo efficiency/turbo-compound waste heat recovery, waste heat recovery in combination with hybridization, engine friction and fluid pumping, also in combination with hybridization).

In the longer term new advanced fuels, with very low / near zero WTW CO₂ emissions, will be available whose use may or may not involve combustion. An example of the latter would be those based on fuel cell technology which is described in more detail in section 4.1.1.2. New fuels for combustion may be in liquid or gaseous form. Advanced ICE powertrains designed to use these fuels for long distances will be optimized and will most probably be different from current powertrains, in order to take full advantage of potentially new fuel properties. Otherwise, the benefits will only be partial. This will not only concern engines but will also apply to their after-treatment systems which will need to be robust in order to treat the emissions from a wide variety of fuels. Research needs will include the powertrain control management systems which will be crucial in providing the flexibility to handle different fuels, and which will need to be optimized for these fuels. This may include fuel quality sensing capability to allow the engine to adapt. Connectivity to the environment and other vehicles will also be desirable to improve the overall system efficiency even further. Reduction of catalyst materials will be needed to preserve resources and durability and reliability of engines or energy conversion systems will also be key.

4.1.1.2. Highly efficient electrified/ fuel cell long distance trucks and electrified roads including parallel or series plug-in hybrids with combustion engine off, or fully electric, range extender and hydrogen solutions.

Heavy-duty commercial vehicles driven long distances are a specific challenge for electrification, where reliance only on battery is not a solution in the short-term due to weight, payload and mileage (ref. chapter 1.4.2, showing that the energy solutions for decarbonising Long Distance Freight Transport will be different depending on the average distances travelled by the vehicles).

Hybrid powertrains and architectures must be developed, and solutions relying on integration with the road infrastructure have to be assessed. Energy storage capacity of electric batteries for trucks will be important including on-route charging in combination with efficient operation,

improved energy recovery and logistics to enable use for longer range trucks and coaches. Research into zero emission energy conversion systems such as fuel cells is required. Scenarios costs/benefits and energy well-to-wheel assessments. Exploring interfaces between long distance and urban transport is also needed.

The electricity sector is not yet fully decarbonized, though this is of course the goal in a far-future scenario. Currently, gas and coal play important roles in the mix and thus the lifecycle aspects need to be considered until full decarbonisation can be achieved. Energy storage, sourcing of battery materials and grid balancing might be the biggest practical issues at the time of increasing demand for electricity. Hydrogen is an energy carrier. Despite hydrogen being largely present in nature, it is not available as a pure element, so it must be produced using other sources of energy. Life cycle GHG emission of the whole value chain (feedstock and energy) should be considered. Additionally, we should look further into scenario(s) with low CO₂ emissions generated to produce hydrogen.

4.1.1.3. Renewable, low carbon fuels: production, storage and distribution

Considering that the internal combustion engines are expected to keep playing an important role for long-haul transportation, a key ingredient to future decarbonisation of the transport system will be the availability of low carbon fuels, both liquid and gaseous, either first or second generation biofuels (Bio-CNG or LNG, FAME, HVO, BTL, Ethanol, DME), or “e-fuels”, i.e. synthetic fuels using green electricity (H₂, CH₄, DME, OME...)

The production of e-fuels may potentially reduce, and eventually remove existing CO₂ from the environment, may occur exterior to the vehicle or on board e.g. reformers, on-board Carbon Capture System. These fuels may also have the potential advantage of providing improved vehicle efficiency and reduced emissions through better combustion. R&D challenges include more energy and CO₂ efficient ways of production of e-fuels. Novel ways of storing and distributing these fuels may be required. However, we should consider that e-fuels product cost is high today (investments and production). In addition, we should consider that the amount of sustainable biofuel is limited by its strong impacts on land and water and could be earmarked for aviation needs (sector harder to be decarbonised).

OEMs have already demonstrated the technical feasibility via local application or field test and are already offering products on the market. According to a recent study by Transport & Mobility Leuven (TML), the additional greenhouse gas (GHG) reduction potential of biofuels by 2020 (compared to 2014) is estimated to be 0.5% to 1.4%, according to discrepancies in projections and assessment of the fuel industry. The study concludes that benefits in terms of greenhouse gas emissions and Total Cost of Ownership depend on the market penetration and can be significant only in a medium term (around 2030). A recent study³² commissioned by the EC gives messages consistent with this with a prediction of biofuels providing around 10% of transportation fuels by 2030 but also predicts that that by 2050, low carbon fuels will account for 50% of the fueling needs of the HD sector. The same study predicts that by 2050 5% of the HD transportation will be fueled by hydrogen and 6-7% by natural gas. In the long term (beyond 2025), sustainable biofuels thus have the potential to realize a much higher reduction, depending on how fast technology will advance and to which extent different feedstock, transformation processes and distribution will reduce (well-to-wheel) CO₂ emissions.

4.1.1.4. Renewable, low carbon fuels: Taxation will have an impact on fuel choices

The WTW CO₂ impact should be taken into account in the tax system. Discussions on the alternative fuels options should consider their cost-effectiveness in terms of CO₂ reductions possible in relation to additional operating and capital costs for operators.

Taking into account the CO₂ abatement costs is crucial as not only is there a high level of fragmentation in the sector with SMEs making up the majority of operators, but profit margins for the industry are also very low. Therefore, alternative fuels must be viable, not only in terms of technological readiness but also in terms of commercial feasibility. Governments can also help by ensuring sufficient financial mechanisms exist in order to encourage fleet renewal.

Ultimately, there should be a clear cost-benefit analysis to make sure that measures to decarbonize the road transport sector meet all the principles of sustainability – economic, social and environmental.

4.1.2. Connected automated safe vehicles by usage

Connected Automated Commercial Vehicles will enable the logistics sector to:

- Increase traffic safety and reduce accidents by human errors
- Increase transport system efficiency and improve traffic fluidity
- Enable the driver to perform other tasks when the vehicle “takes-over”

4.1.2.1. Progressive deployment of automated heavy commercial vehicles for improved safety and efficient road transport

Automation technologies are expected to re-shape the future of freight road transport with the potential for new freight transport patterns as well as organisational structures, processes and business models for the sector. There will be progressive deployment towards higher level of automated heavy commercial vehicles depending on the application domains and the Operational Design Domains (ODDs). See ERTRAC Connected Automated Driving Roadmap³³ for reference.

Today parts of the driving task are supported through active safety systems and various driver assistance functions. Gradually more advanced and partially automated functions will be introduced, such as **cooperative adaptive cruise control (C-ACC)**, **truck platooning** and **traffic jam assist**. **Multi-brand-truck-platooning**, in the ENSEMBLE projects, is one area of particular importance as this involves both partial automation and cooperative, connected vehicles. Conditional automated driving functions may be introduced from 2020. This would include functions such as; **traffic jam chauffeur** and **highway chauffeur** prerequisite that the driver is prepared to “take-over” the driving task if required.

For higher level of automation where the vehicle performs all aspects of the driving tasks without requiring that the driver “takes-over” will strongly influence the logistical operation. This would potentially provide shippers/companies a competitive advantage and change structures and transport processes. This would open for highly automated functions such as **highly automated**

³³ ERTRAC European Roadmap on Connected Automated Driving, <https://www.ertrac.org/index.php?page=connectivity-and-automated-driving>

vehicles in confined areas, highly automated vehicles on dedicated roads, highly automated vehicles on open roads and for highway pilot platooning. It would also open up for radical new concepts such as “driverless” vehicles without driver cabin.

It is important to foster the dialogue between the different stakeholders to ensure integrated and harmonised deployment of automation. There are many stakeholders that needs to be involved in this dialogue, such as; shippers, transport authorities, fleet operators, road operators and drivers. It is foreseen that deployment will be starting in confined areas and hub-to-hub, towards later in open roads and in urban areas where the traffic and regulatory landscape complexity increases dramatically.

4.1.2.2. Connectivity and Automation technologies for vehicles and infrastructure

The complexity of the Connectivity and Automation technologies for vehicles and infrastructure is constantly increasing.

In the short-term, it is important to look into mastering complexity and affordability built upon modularity, scalability, standardization, systems-of-systems and maintenance. It is also important to develop decision strategies in relation to the Operational Design Domains (ODD) for automated driving, in particular for heavy duty commercial freight vehicles. Convergence of systems is a priority. It is of key importance to provide robust, complementary and highly reliable perception systems (e.g. solid state laser scanner) and vehicle location technologies. A specific safety issue is task-sharing between automated and human controlled operations³⁴.

In the medium-term, we should get ready high computation, networked, on-board artificial intelligence and machine learning systems. In addition, we should integrate software defined intelligent systems in modular scalable architectures seamlessly in vehicle, infrastructure, and traffic management and back-office systems.

In the long-term, the focus should be on new physics for sensors and perception analyses, as well as new concepts of Artificial Intelligence based on neuronal computers and human-machine cooperation strategies.

To ensure functional safety requirements/safety cases and cyber-security requirements is a key area as connected automated vehicles and the digital infrastructure need to ensure fail-safe operation and resist external threats such as cyber-attacks, especially data security within the complete system (vehicles, communication networks and clouds).

4.1.2.3. Digital Resilience

The prevalence of connectivity in vehicle presents the industry with significant challenges. One of the most significant is digital resilience to cyber-attack, as potential malicious attacks could lead to vehicles being compromised. Failure to build **digital resilience** into vehicle systems could lead to events that undermine public trust in connected automated vehicles, potentially disrupting or delaying adoption.

All actors need to embrace cyber security measures in each subsystem and then extend towards a concept of **digital resilience** throughout the complete transport system. To achieve this effectively, vulnerabilities that threaten existing vehicles needs to be assessed to integrate digital resilience into the design processes to ensure future models are also secure-by-design. This will

be achieved through a systematic approach to design that identifies vulnerabilities and mitigates risk in an appropriate way, incorporated into existing risk management practice. This will realize the ambition of vehicles that are both resilient to attack and continue to function safely and securely if breached.

Over the last decade processing power has crossed a threshold by which communication; sensing and control technologies are possible that enable automated transport to be realized. Such a change to the adoption of automated transport could revolutionize ownership models, precipitating fundamental changes in the economics of transport and the urban spaces it operates in, and create a new, global industry.

4.1.2.4. Societal benefits and social acceptance

Labour currently accounts for an estimated 35 to 45% of operating costs of road freight in Europe (Panteia, 2015). Further, restrictions on the time a driver can drive for over a given day or week limit the speed and reach of long-distance road freight, where individual drivers are allocated to each truck. At the same time, road freight operators can struggle to attract drivers to undertake such long-distance trips. Clearly the possibility opened by automation to change the labour costs input costs and relaxing the driving-time constraints on vehicle productivity would be of great interest to road freight businesses and their ultimate customers, without forgetting that the driver will still remain a key figure (ref. chapter 4.3.1 The new role of the driver).

Connected automated vehicles provide the opportunity to revolutionize the trucking industry and the way fleets operate. If used properly, automated commercial freight vehicles could improve fleet efficiency, flexibility, and the total cost of ownership. It has also great potential to effectively reduce traffic congestion-related costs through vehicle platooning, improve driver behaviors, reduce driver costs, and increase fleet mobility as well as safety.

According to the IRU report 'Managing the Transition to driverless road freight transport (2017)', the operating cost reductions are likely to be significantly higher in long-distance freight where drivers will account for a greater share of the cost base than in urban freight. Overall, operating cost reductions for long-distance freight in the order of 30% are possible under driverless operation.

4.1.3. Services solutions

Improving the market positioning by providing additional services is becoming increasingly important in most industries. Companies are exploring and implementing new product-service systems, bundled service solutions and other types of advanced service offerings. This is about achieving customer value and sustaining competitive advantage.

New service solutions in transport should be innovative, inclusive, user centric, reliable, fair transport services based on global standards and systems and with links to other modes of transport. They will support consolidation, synchronisation of flows, automation and efficient co-modality, which all are important in reaching the targets in the transition towards a sustainable transport system.

Rapid ICT development and digitalisation have opened up new possibilities to organize cheaper, more reliable and dedicated user-oriented services. It is not only a matter of automation of

current practices, but new ICT applications, new business practices (e.g. sharing economy) also result in new services, and new business models. This will result in new roles and actors and important questions are who will offer the services and who will be liable. The responsibility of authorities and their influence on the services and need for services is also of importance.

New business models³⁵ benefit from the new technological possibilities and the acceleration of innovation. Known examples of transport related services using new business strategies are for instance Amazon and Uber. Tim O'Reilly (2017³⁶) has generalised these 'Business model of the new economy' and differentiates for instance by delivering an exceptional user experience and relying on information instead of material (e.g. reduced stocks).

The services in the transport sector can be related to different systems and flows of goods and information (see table 4.1)

System levels	Actors	Examples of Services
Material flow	Shipper ↕ Logistic Service provider	<ul style="list-style-type: none"> Integrated Services for freight: ensure last mile delivery of goods by checking on deliveries options and carbon footprint Estimated time of arrival, carbon footprint, traffic information, track and trace, cargo monitoring enabled by automated vehicles and integration of supply chain management systems
Transport	↕ Transport & fleet operator ↕ Haulier	<ul style="list-style-type: none"> Weight and volume vehicle fill rates measurement "Smart speed" matching loading and unloading time windows
Traffic Infrastructure (Physical/ Digital)	↕ Road/ Toll operator	<ul style="list-style-type: none"> Next generation automated integrated traffic management network across the TEN-T: interfaces among automated road traffic management around hub (port, rail) traffic Adaptation of speed (bridges) and wheel trajectory lateral offset adjustment Infra-maintenance : the vehicle provides information on road maintenance

Table 4.1 - System levels, actors, examples of services

4.1.3.1. Material flow – Shipper services

The final user of transport services, the shipper, needs a range of different transport related services. Ultimately it may be an issue of integrated freight transport services, with least carbon footprint, including a combination of optional services involving different modes of transport and related information offering a one stop shop of services. These could include automated administration and document handling. New types of services requested by shippers may be consolidation services for goods, related to horizontal collaboration among shippers. Measurements and evaluation services are also of great importance in developing the transport system. Integration of supply chain management systems across borders in an interoperable way ensuring services should be harmonized in terms of specifications (cargo monitoring, estimated time of arrival, carbon footprint, visibility services, traffic information, track and trace).

³⁵ Ming Chen, Hans Quak, Isabel Wilmink, Jaco van Meijeren; TNO; 'Paradigm shifts by multimodal user oriented transport services and platforms', EARP Forum 2018

³⁶ O'Reilly, T. (2017), WTF? What's The Future and why it's up to us, Random House Business

4.1.3.2. Transport, Traffic and Infrastructures services

Other services are related to traffic management and dynamic (real time) route planning, including access control. These services are important in order to increase the utilisation of vehicles. Enhanced traffic management systems, such as the TM 2.0³⁷ model of cooperation between traffic management centres, service providers and vehicles, should combine in an optimal way the information coming from the point of departure, the traffic information and the routing service provider and the freight operator, towards optimising LDFT. The load capacity of freight vehicles is used, in the best possible way in this model, while there would be a need for further development of services to support this (e.g. optimisation of the load unit utilisation and monitoring of the load factor).

4.1.4. Enhance compliance & productivity of road freight transport (HCV, WIM)

4.1.4.1. Innovative and efficient vehicle architectures

According to the AEROFLEX project, new vehicle concepts should be developed for low density goods, long transport distances and high revenue logistics segments. New vehicle concepts should address in priority 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. 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 maneuvered and placed at the gateways in cross-docking stations or in warehouses, even if there is a limited infrastructure conditions. Further, the organization of a fast exchange of loading units between different vehicles or between transport modes is important.

Regulations and incentives will obviously affect the vehicle architecture and design.

4.1.4.2. Regulatory framework - Smart Infrastructure Access Policies (SIAP-infra): Performance based regulation versus weight and dimensions

Directives (EC96/53) and driving laws impose some limitations on heavy vehicle weights and dimensions. The aim is not only to prevent infrastructure wear or damage, but first to avoid unfair competition in the freight transport market, and to ensure a high level of road safety. With the increase of road flow traffic and of the individual vehicle payload (High Capacity Vehicles), and to prevent more road wear, a better compliance of heavy vehicles is required. Static checks are rather inefficient because of a lack of staff, of checking area and land, while the revised European Directive EC96/53 - revised May 2015 - requires more controls and reporting of weights and dimensions. Moreover, some EU Member States allowed operating longer and heavier vehicles (EMS) while other countries liberalized the operation of abnormal loads.

The concept of Smart Infrastructure Access Policy (SIAP) or Intelligent Access Programme (IAP) in Australia, aims operating heavy vehicles and using infrastructure more efficiently and safer, and with more flexibility.

³⁷ Enabling vehicle interaction with traffic management, <http://tm20.org/>

Implementing a continuous and automated monitoring of the vehicle loads, but also of their behavior and performances (e.g. suspensions, tires, breaking, lateral stability, etc.) allows the deployment of flexible and modular vehicle concepts in a multimodal context. Accessing to the individual vehicle data enables to implement Performance Based Standards (PBS) and Intelligent Access Programme (IAP) or SIAP. That would provide incentives for more « road friendly » vehicles. Road authorities such as CEDR, several ministries and concessionary motorway companies, expressed interest and even launched some research projects (e.g. FALCON). The WIM data may be used for direct enforcement, a major challenge for the next decade. Czech Republic and France are among the pioneering Member States on that.

4.2. Physical and digital Infrastructure

Besides the concept of Smart Infrastructure Access Policy (SIAP) or Intelligent Access Programme (IAP) elaborated above in the above chapter 4.1.4.2, we should strive for smarter and more flexible road infrastructure as a whole.

4.2.1. Adaptation of a well-synchronized, smart and seamless road infrastructure

Road infrastructure is designed for longer term periods than the vehicles (e.g. typical lifetimes are 20 to 40 years for a road structure, 10 to 15 years for the pavement upper layer, and 50 to more than 100 years for bridges and tunnels). Moreover, to cope with environmental and sustainable development constraints, economical, material and energy savings, there is a high pressure to extend the lifetime of road assets, while the heavy commercial vehicle traffic (frequency) and individual loads tend to increase continuously. Some major structural failures occur sometime (e.g. the Morandi viaduct in Genova in August 2018, but also other bridges in Italy, US and other countries over the last decades), and an increase of the road wear and pavement deterioration is seen in many EU Member States. Therefore, provisions should be made to mitigate these adverse effects and keeping the road infrastructure safety at a satisfying level, while accommodating the new vehicles, their operation and the environmental and economic constraints.

More and more (big) data are available, some of them collected by the (smart) infrastructure instrumented with various sensors connected to transmission networks. These data can be connected with those coming from the vehicles and other sources for various purposes: (1) to assess the vehicle-infrastructure interaction, (2) to assist the vehicle operation, provide some services, or increase their safety, (3) to assess the impact of heavy vehicles on infrastructure, the potential damages and lifetimes, and (4) to ensure a continuous monitoring of the traffic and the infrastructure.

4.2.1.1. Materials, components and physical integration

New materials are used in construction or repair to improve infrastructure lifecycle, material and energy savings and recycling. These materials should contribute to road structures increasing resistance and resilience (e.g. to traffic evolution, climatic change, etc.). New or existing infrastructure must be designed to serve high volumes of freight traffic. Road networks must be adaptable and automated.

The development of BIM (Building Information Modeling) open opportunities and tools to incorporate infrastructure and traffic data in 2D or 3D structural models, to ensure a better design,

to adapt the infrastructure to the current traffic conditions or reversely to adjust the traffic to the infrastructure capacities. Simulations and analyses can be carried out to assess energy, structural or operational impacts, to anticipate many potential issues and to save money. In this frame, digitalized infrastructure should be developed to provide the required data and information. Road and bridge sensors and software are expected to provide detailed data on vehicle weights and dimensions, tire pressure, traffic flow, occupancy rates, etc., to be used for infrastructure and maintenance and operation, road safety, routing, etc. Infrastructure should be self-explaining and provide the relevant information to the heavy vehicles. New physical and digital (virtual) road signs will be required to manage truck platoons, high capacity vehicles or automated vehicles.

ERS (Electric Road System) is also a challenge for the next 20-30 years, and for long distance road freight, it implies significant infrastructure equipment and investment, such as overhead catenaries or in-ground conductive or inductive electricity supply.

4.2.1.2. Road infrastructure monitoring, diagnosis and maintenance

Road infrastructure monitoring, diagnosis and maintenance are crucial to push forwards the current limitations, to increase the lifetimes in safe conditions and to optimize the costs. Many smart road and bridge sensors, connected in local or global networks and remotely managed, can collect cross information on the heavy vehicles and the infrastructure. E.g. collecting WIM (Weigh-in-motion) data on motorways and highways allows making preventive maintenance, which saves money and operation disturbances.

Vehicle on-board monitoring (ex: on-board weighing, road/tire friction force measurement, load transfer ratio assessment (LTR), etc.) provides data which may be used to continuously assess structural behavior of the infrastructure and thus performing an efficient diagnosis. That requires a high level of communication and connectivity between vehicle and infrastructure. Such an accurate and continuous monitoring is required to accommodate higher traffic loads or volume, longer lifetimes, but to maintain accepted coefficient safety factors and not compromising the structural and users' safety.

4.2.1.3. Smart adaptive operation of vehicles for preventing road lifetime

Because of the much longer infrastructure than vehicle lifetimes, it is not always possible to adapt the infrastructure to the traffic loads and volume. To prevent the existing infrastructure asset and lifetime without imposing too severe limitations to the road freight transport, the best solution consists in optimizing vehicle and traffic operation by a smart operation of heavy commercial vehicles.

An example, partly implemented for a few long span bridges, consists of installing a WIM system upstream to a sensitive bridge, or a bridge WIM system, continuously assessing the load effects and strains, encountered by the bridge sub-structures. In case of some threshold exceedance, different actions could be taken to mitigate the vehicle impact, such as reducing the velocity and thus the dynamic impact factors, increasing the vehicle spacing (on long spans, in case of platooning), banning overtaking to avoid multiple presence, and finally imposing some weight limitation if still needed. To mitigate pavement rutting or fatigue of steel orthotropic decks (local effects), an accurate vehicle path monitoring could be imposed, to spread transversally the wheel loads. If the temperature or climatic conditions have a significant impact, e.g. high temperature on pavement strain and rutting, high temperature gradients on concrete beam or slab cracking,

deicing process on pavement deflection, or strong wind on heavy vehicle stability or long span bridge strain, some adapted measures can be taken on the heavy vehicle operation. That is the aim of a Smart Infrastructure Access Policy (SIAP, ref. Chapter 4.1.4.2).

4.2.2. Get the right infrastructure for vehicle energy supply

As described in chapter 4.1, a key ingredient to future decarbonisation of the transport system will be the availability of ultra-low emission ICE powertrains with low carbon fuels, as well as of electrified vehicles.

The development of both depends upon the rapid growth of an energy distribution network. This is relatively easy for liquid biofuels and liquid e-fuels, as it requires minor adaptation of the existing one. It is more challenging for gaseous low-carbon fuels (Biogas, H₂), due to the cost of the refill stations. And it is also challenging for electricity, due to its strong impact on the electricity grid and power stations that need to be implemented in size (with appropriate design guidelines and policy for making charging stations accessible for trucks) and electric power, to cover fast-charging energy needs.

There is a high investment cost and a high risk factor for the transporters to move towards decarbonized logistics solutions. This is a main roadblock for implementation. There is a need for guidelines and incentives at European, national and local level to enable the implementation of the appropriate mix of refueling/ recharging solutions (ref. chapter. 4.1.1.4).

4.2.3. Interchange infrastructure and services and network traffic management

4.2.3.1. Cross-modal infrastructure for an integrated self-organized and automated logistics

The main challenge for the future is to provide effective, efficient, sustainable and safe intermodal transport services. One of the basic barriers for a modal shift is the lack of direct access of companies to the railway network or to waterways. Road transport is needed to provide door-to-door freight transport.

The terminal is a key component of the intermodal transport chain since it has to ensure an efficient and safe interchange between road, rail, air and water transport. The performance of an intermodal terminal is determined by the geographical position of the terminal within the transport network, the size and shape, the length of the rail handling tracks, and the number and capabilities of the handling equipment (cranes and stackers) as well as the operational efficiency to minimize movements in a terminal for a given throughput. Moving ahead, the performance of an intermodal terminal will be measured by the efficiency enabled by new data-driven technologies and the full availability of relevant data from the users; transport, logistics and shippers.

With connected vehicles and fully digitalized logistics, vehicles and infrastructure (managers) continuous exchange of information can be enabled. This allows dynamically managing transport resources related to space and infrastructure.

Design and equipment of logistic centers and facilities fitted to the future operation modes, including facilities for the next generation of vehicles, as well as smart and automated connected space management (e.g. parking lots, terminal and storage areas).

In terminals and hubs, the vehicles can be automatically directed to the right place and time to collect or deliver the right item, according to the vehicle length, weight, or to keep dangerous goods apart. Similar services are offered in the hubs and logistics center for the storage of the goods. Boxes, pallets or containers are stored on dedicated area (slots), with respect to their weight, size, time of arrival or removing, destination, or type of goods. Vehicles can be informed where to put or pick up any item, for logistic center optimization and planning.

4.2.3.2. Network Traffic Management

Network and Traffic Management (NTM) focuses on the new, enhanced way of managing traffic in the network by providing individual traffic and routing advice rather than collective. C-ITS and the evolution of connected and automated driving technologies along with the new public-private stakeholders cooperative models, such as the TM 2.0, to ensure that traffic management is performed in an informed holistic manner. The latter takes into account the needs of the freight operators and seeks to achieve balance with the entire NTM making optimal use of the full potential of established direct interaction between the vehicle's control intelligence and the traffic management centre (s) that work in a Network rather than in isolation. Every single vehicle can be individually included in NTM considerations and decisions.

As Freight transport is multimodal, rail, air and waterborne traffic management systems are also included in the NTM, which connects the intelligence of infrastructure and vehicles. NTM gives to freight transport the very much needed flexible "slot management" type toolbox. This coordinated and collaborative intelligence can decide for each individual freight transport journey to be served by the assignment of a bespoke time and network slot on its journey from A to B.

4.3. Labour environment changes, driven by automation

4.3.1. The new role of the driver

The digitalisation of transport operations and the introduction of autonomous vehicles constitute a dramatic shift in paradigm and provide challenges but also opportunities for a variety of policy objectives and transport operational issues. As technology and innovation advance, and systems are implemented and tested on a wider scale, one thing becomes clear: the transition phase needs to be proactively managed, including guaranteeing equal chances for all and preserving the key role and place of private transport operators, and the data they possess, in the future of an increasingly autonomous mobility chain.

Indeed, autonomous vehicles are already high on political agendas, and governments and international institutions such as the United Nations, the International Transport Forum and the European Union are currently actively reviewing their regulations to understand what changes would be required to allow self-driving vehicles on public roads. The question is however when autonomous vehicles will enter the market.

The ITF/IRU/ACEA/ITwF scientific report 'Managing the Transition to driverless road freight transport (2017) described 4 scenarios: the Baseline scenario is for zero adoption of driverless trucks on public roads in the next 20 years. The Conservative scenario assumes that driverless technology is slowly introduced from 2030 onwards, initially in a few long-distance markets, and (from 2033) a few cities in Europe and the US. The Regulated scenario assumes that driverless

technology is allowed on all long-distance routes from 2028 and in cities from 2030. In long-distance freight the technology is ubiquitous within three to five years, whereas in cities the take-up is less strong. The Disruptive scenario assumes that driverless technology is rolled out on only half long-distance routes from 2021 (and progressively expanded) and similarly in cities from 2022.

The report presents a simplified potential operating environment of driverless trucks. This operating environment considers a hybrid operating model where the trucks do not have hands-on or fall-back drivers within the cabin, but instead the fleet is connected to a pool of experienced remote drivers in a control centre who are able to intervene and remotely control a given vehicle in case of emergency. These remote drivers could be in place as a necessity (level 3 conditional automation) or as risk mitigation for higher levels of automation (level 4 or 5).

However, fully automating a job requires that all tasks undertaken by a human can be satisfactorily performed by a computer system or reallocated to another job. For example, computer systems that control truck motion and navigation would not be sufficient to automate a truck driver's role if a human driver was still required for re-fuelling and communicating with shippers and consignees. Job automation can therefore be seen as depending on the mix of tasks that make up any given job.

Urban truck driving jobs were argued to be more likely to persist than long-distance driving on motorways due to their different legislative and physical environments. Whereas drivers on long-distance routes may spend an entire work day focused on core driving tasks, in urban areas other tasks become much more prominent, such as route choice, communication with shippers and consignees, theft deterrence, as well as loading and unloading. In an urban freight context not all of these tasks will be easy or desirable to automate (or reallocate to other people), which dampens the adoption of driverless technology in this area compared with long-distance freight. If automated long-distance motorway operation were possible, while urban operations were not, there would be some costs associated with reorganizing supply chains (or driver shifts) around new hubs located at the city limits on motorways.

Automated commercial vehicles will dramatically change truck operations and the role for professional driver will change accordingly. According to the scientific report 'Managing the Transition to driverless road freight transport (2017), automated road freight impact on driver jobs requires a managed transition. Self-driving trucks could address the shortage of professional drivers faced by road transport industry, but automated trucks could also reduce the demand for drivers drastically by 2030. Potential negative social impact of job losses should be mitigated.

4.3.2. Impact on the needed capabilities, training, etc.

Automated driving technologies could significantly affect the trucking industry, especially regarding improving road safety, increasing transport efficiency, decreasing transport costs and reducing emissions.

For most levels of automation, the most important task for drivers is monitoring the automated systems to make sure they are performing as expected and intervening (resuming control) in situations that the automation cannot handle; for this reason the proliferation of autonomous driving technology is expected to still require a driver to have a commercial driver's license.

The shifting role of the human driver from one in which they are in total control to one in which they are responsible primarily for monitoring and supervising the driving task, may lead to problems of inattention, reduced situational awareness and manual skills degradation. In turn, these human factors may compromise the safety of manual control in cases where autonomous systems fail. A standardized HMI system is required to prioritize information, warnings, and decisions, and to manage handover of control to and from the truck driver in case of fault detection. Also, driver monitoring in order to ensure the correspondence between the automation driving level and the driver awareness status will be required.

Ultimately, transport workers and operators must be properly trained and fit for the new digital challenges. In this respect, it will be crucial for governments to support businesses, in particular small and medium-sized enterprises, to better understand and face challenges, related to automated mobility, and promote exchange together e.g. with the IRU Academy best training practices.

4.3.3. Responsible innovation: enhanced supply chain provenance and ethics

Given the importance and size of this technological change, and the transition to automated vehicles, it is important to engage in constructive dialogue with all stakeholders and supports governments, local authorities and legal experts in choosing the right policy/fiscal mix and best practices to be applied to all players in the transport sector.

The road transport industry embraces innovation and is in favour of a transition which allows for the safe, secure and sustainable (3 “s” strategy) operation of autonomous vehicles.

Safety

- Technical standards to operate autonomous vehicles need to be harmonised and interoperable. Technology must be proven and solid to ensure functioning without any problems in various climates and traffic conditions.
- During the transition phase, trials in a controlled or specific area and at specific times should be encouraged, and involve professional transport operators.
- Further work is needed on a system of technical controls, including roadside checks.

Security

- The risk of cyber-attacks on autonomous vehicles need to be minimised, data security needs to be ensured and privacy legislation must be respected. Ultimately, the ownership of data related to transport operations should stay with the transport operators.
- Ethical questions of road safety crash avoidance systems must be addressed, as well as questions related to passengers' perception of automated mobility

Sustainability

- A connection between new technological developments with labour law and specific, flexible conditions of the driver should be established.
- Governments need to provide real business incentives to fasten the penetration of latest technologies and practices.
- Policies incentivising the use of collective passenger transport and freight delivery must be put in place to promote efficient use of scarce public space and prevent autonomous vehicles congestion.

- As higher levels of autonomy are commercially introduced, the balance of liability shifts from driver liability to owner/product liability, ultimately leading to complete liability resting with vehicle manufacturers and technology providers. Therefore, governments, insurance companies and technology providers need to adapt existing liability laws in order to provide legal certainty and identify appropriate solutions for damage and injuries.
- Support businesses, in particular small and medium-sized enterprises, to better understand and face challenges, including business challenges, related to automated mobility, and promote exchange of best practices with mobility sectors with already advanced automation of their services.
- Ensure an equal and fair playing field and prevent monopolies within the automated transport industry.

4.4. Integration to the European transport system: guidelines to enhance inter-modality

Research topics to strengthen inter-modality have been raised in other documents. Here below are the cross-cutting issues to be prioritized seen from the 'road' perspective. This common view is shared between all the transport European Technology Platforms.

4.4.1. European standards

In order to enable a service platform approach, we need to have end-to-end processes and pan-European standards including the different transport modes³⁸. All the modes could have their own processes, as there are different requirements for different modes, but at the inter-modality level, we need agreed interfaces on the way to shift the freight, on digital layers, on modularization, on security, etc.

- End-to-end security – harmonized cross-modal security strategy facilitating flexible mode changes may help to reduce cost and time requirements.
- End-to-end safety – harmonized requirements to enable mode changes easily if desired

4.4.2. Digitalization and processes

Secure, robust, scalable and resilient open architectures and protocols will enable full interoperability. Internet of Things (IoT) and Artificial Intelligent (AI) will enable efficient capture, storage, management and interpretation of data, while transport businesses will strive to exploit new data-driven revenue streams. Big Data analytics enables a range of new and improved services to be developed and state of the art cybersecurity ensures reliable and secure ICT services.

It is important to underline again that cooperation between the transport providers is a key enabler for this to happen.

4.4.2.1. Digital systems and information related to goods should be reliable and seamless.

A 'system of systems' approach will allow informed mobility choices when planning and booking a shipment: seamless tracking of shipments and automatic reconfiguration in case of disruptions, increasing both predictability and reliability.

AI-driven systems/applications allow accurate **synchro-modal planning and scheduling of shipments**, with continuous adaptation to demand, including on-demand scenarios.

- **Transport as a Service** (first mile and last mile) includes all modes and will permit, among others, 'CO₂ real-time tracking' allowing for CO₂ real-time balancing when doing multi-mode transportation.
- **Infra-maintenance services**: the vehicle provides information on road maintenance.

4.4.2.2. Electronic transactions along the logistic chain

Development of the right connectivity and governance between peer-to-peer platforms and information exchange for performing and verifying secure transactions between actors involved in logistics chain.

- Verification, accounting, financial, payment and settlement transactions are performed digitally over a peer-to-peer network of all actors involved in the logistics chain, including manufacturers, shippers, forwarders, operators in other modes and public authorities (e.g. Customs, Inspectors, etc.)

The European Commission is currently working on this topic; see the Digital Transport and Logistics Forum.³⁹

4.4.3. Enable flexible interchanges, automated handling at hubs

We should increase the use of autonomous units that can automatically connect to trucks/ land (automation within yard) in order for rail and roads, aircraft and waterborne to come together. In order to overcome business uncertainties, we should work on the business model perspectives.

According to the Aeroflex project report⁴⁰, efficiency improvements in logistics will be enabled by automation technologies and operations (coupling/ decoupling of the freight modules, loading/ reloading of the freight) between transport modes and between modes (in warehouses/ hubs or terminals).

Automated terminals allow ports to handle containers more efficiently by using operating systems to plan transport, and storage in accordance with collection and transshipment times. This reduces unnecessary box moves, shortens cycle times, and enables consistent and predictable throughput numbers. Fully-automated terminals, comprising automated trucks, have in addition the advantage of low operating costs and reliable operations. The automated operability in ports or hubs is more or less carried out without errors and under favorable conditions, i.e.:

- higher added-value personnel
- utmost reliability in container tracking etc.

³⁹ <http://www.dtlf.eu/>

⁴⁰ Aeroflex project, <https://cordis.europa.eu/project/rcn/211935/factsheet/en>

- optimum and careful handling of vehicle and load
- less energy consumption, less wear and tear
- no accidents, more precise vehicle direction finding
- faster vehicle roots, faster transshipment

However, automated transshipment requires higher upfront costs, longer development, offer only low productivity increases at peak times and have the general difficulty to fully automate a working terminal. Similar concepts and principles for automation in industry (industry 4.0) may be considered for ports and hubs.

4.4.4. Modularization of load carriers at global scale

Global Standardised loading units are critical for international transportation of goods by different modes. They allow to shift from one mode of transport to another e.g. by gantry cranes or by reachstackers.

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 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 challenge would be to optimize the loading to have the possibility of passing easily from the cargo to the truck and then to a smaller vehicle. This can be done in an efficient way with modularity, the possibility of combining different package together. In addition, cargo on-board monitoring, tracking and distribution is a research area to further investigate as well.

4.4.5. Emerging type of new transports

We should investigate the potential of emerging type of new modes, like cargo-bikes and unmanned air systems (UAS), for the first/ last-mile part of the logistics chain. Even more important are the disruptive business models coming along with these new modes of transport (ref. chapter 3.3.4 Urban environment). A better understanding of freight flows and logistic systems, as well as a more system approach including enhanced business models is needed.

When it comes to UAS, we should consider that in addition to their potential role as means of transport, e.g. for remote or inaccessible areas they can play different roles as an enabler to generate data, or to guide transport in a terminal, or to inspect vessels/ rail infrastructures.







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