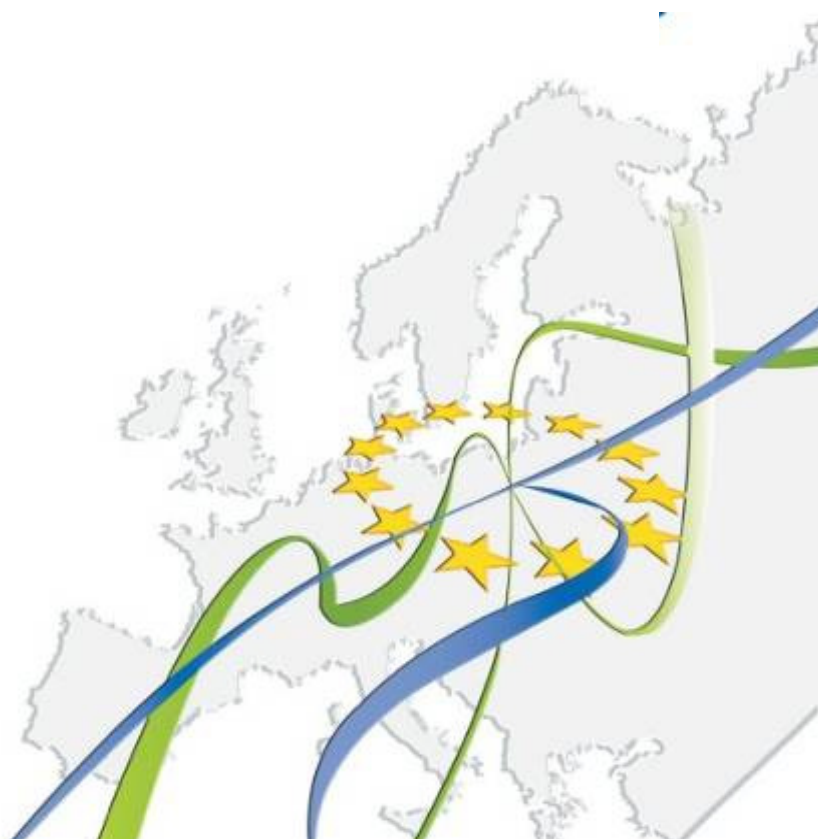




EUROPEAN
ROAD
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European Roadmap
Heavy Duty Truck

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1 Introduction

The economic development and competitiveness of Europe depends on an effective and efficient transport and logistics system. The mobility of people and the flow of goods to, from and within the Europe must be cost efficient and at the same time safe and environmentally sustainable. Increasing globalisation and competition in most sectors further emphasize the importance of a competitive European transport system. The importance of the European transport system is further emphasized in the European Commission's communication on "A sustainable future for transport" (COM(2009) 279) stating that 7% of European GDP and 5% of employment can be attributed to the transport industry at large.

Despite efforts to decouple GDP growth from freight transport during the last decade, demand for freight transport has increased with 2.7% whereas GDP increased with 2.5%. This should be compared with passenger transport that grew at a pace of 1.7% during the same period (ibid). The European transport sector is not yet on a sustainable path in several aspects.

Transportation is responsible for the major part of the increase in oil consumption during the last three decades, a trend that is expected to increase. In the EU the environmental footprint of transport corresponds to 23.8% of greenhouse gases and 27.9% of CO₂. As the sector is to 97% dependent on fossil fuels, the environmental concerns are well aligned with efforts to improve energy security (COM(2009) 279). Hence, the entire transport sector, and particularly road freight transport by trucks and lorries has been focused as a main policy area where further environmental and overall efficiency improvements are critical for a sustainable future of European transport.

The future of commercial transportation, to ensure sustainability and global acceptance, requires the development of systems that reduce the dependence on oil and minimise the emission of greenhouse gases. Today, the transport sector accounts for 58% of the global oil consumption and approximately 20% of the global, energy-related emissions of greenhouse gases. The whole transport system needs to be restructured and reorganized. Transport emanates from needs of private citizens, business and public organisations to get goods and employees moved from selected geographic locations. To accomplish that, a number of modes with their individual infrastructures and traffic operations are available. For each mode there are different types of sub-modes with separate and common infrastructures and traffic operations. Between and within the modes there are hubs making it possible to consolidate and change mode for the transport "packages". Furthermore, transport and traffic "packages", carriers, vehicles, drivers, flows, infrastructures, etc are connected to a varying degree through wireless communication infrastructures. The transport operations are planned and managed with different cycle times from months to real-time. The transport system as a whole is gradually being more effective but there is an untapped potential for improvement.

Furthermore, its sustainability, safety, and reliability must be improved. A significant amount of these requirements will need new business concepts, and new technologies as well as pan-European standards and regulations developed in public private collaboration.

Examples of new concepts, also found in the ERTRAC Scenario document, is for instance the 'green corridor' concept which could be introduced and used for highly-populated multimodal corridors in Europe by 2030. The criteria for access to these corridors could be related to new vehicle concepts, performance and transport efficiency. In the road part of these corridors, more transport and energy efficient vehicles could possibly be coupled electronically into convoys that are "platooning". Thereby, the throughput of trucks and goods, safety and energy consumption per load unit (volume, weight) could be higher compared to present highways. The trucks and trailers would need to be optimized for the load carried so that the speed can be harmonised. Emissions would fall, and the levels would depend on the increased

throughput, reduction of congestion and the fuel efficiency of complete vehicle concepts. On average, the CO₂ emissions could be 25 per cent lower in a corridor, compared to the overall average vehicle emissions.

In 2030, tri-modal land hubs could provide fast transshipment of people and goods between rail, inland waterways and road services. Conventional inland terminals, as exist today, will still be operating, serving regional traffic and local distribution. At these sites, fast but cost-effective ‘horizontal’ transshipment could take place, including the loading and discharge of trains and barges for inland waterways. Small lifting equipment could be used for loading trucks, when needed for short hauls. Dual-container loading facilities could be provided, both ‘horizontal’, i.e. making use of automatic shuttles rolling on and off the vessels; and ‘vertical’, using batteries of container cranes in parallel loading several containers at the same time. A standard loading unit (worldwide) would have been agreed and would be used globally, as well as RFID technology (an ICT protocol which can be used for the remote tracking and tracing of freight consignments).

A network of intermodal transfer points of various sizes and degrees of reach would facilitate the seamless transfer of cargo between the backbone of interconnecting multimodal corridors and the regional networks. Automatic locking on container castings and tray castings, in combination with the automatic positioning of the train at the loading floor, would be standard as would enhanced communication technology to enable cargo and pallets to remotely communicate their status, and smart dust providing physical security for loading units. For delivery trucks, this would also enhance road security for cargo and drivers. Transport of goods for delivery to local shops or customers would become autonomous. The system would be further enhanced by efficient information usage and driver support systems (vehicles will be fully ‘connected’ and able to communicate with each other as well with the road operator, transport planner, etc.) and by the development of strategically located, advanced hubs for both intermodal transfer and the transfer between urban and non-urban freight transport.

2 General Expectations and Approaches for Road Transport Improvement

All transport modes are needed in seamless coordination due to capacity limitations. ERTRAC has recently issued scenarios and objectives for road based transport proposing that, with the combined commitment and assumption of responsibility by all stakeholders concerned, transport efficiency should become 50% more efficient by 2030 compared with today. This target is translated into three main areas and a number of indicators with corresponding guiding objectives as shown in Figure 1 below.

Table 1 Guiding objectives for 2030

	Indicator	Guiding objective
Decarbonization	Energy efficiency: urban passenger transport	+80% (pkm/kWh) *
	Energy efficiency: long-distance freight transport	+40% (tkm/kWh) *
	Renewables in the energy pool	Biofuels: 25% Electricity: 5%
Reliability	Reliability of transport schedules	+50% *
	Urban accessibility	Preserve Improve where possible
Safety	Fatalities and severe injuries	-60% *
	Cargo lost to theft and damage	-70% *

* Versus 2010 baseline

Figure 1. Summary of Guiding objectives of ERTRAC’s “A Strategic Research Agenda aiming at a ‘50% more efficient Road Transport System by 2030’”. (ERTRAC, 2010)

A number of important research, innovation and policy challenges, that will contribute towards these targets and gain from a pan-European approach, have been identified. These targets can only be achieved by a system approach.

This document aims to address the contribution for *heavy duty trucks* to these targets. The detailed contribution is specified in chapter 4.

Whereas aspects relating to co-modality&logistics are mainly covered in separate documents, a correspondingly a number of cross-cutting issues exist, and are treated in both documents from different perspectives, in particular: green corridors & hubs, city logistics, and intelligent logistics solutions.

Today many bottlenecks in the road, rail, sea, and air transportation “infrastructure” exist where it is not possible to create new links. The concept of green corridors is aimed at addressing this problem by among others increasing capacity through different means requiring a systems approach involving vehicle and trailer manufacturers, road and ICT infrastructures, logistics operators, etc. Another resource that should be made more effective is the co- and intra-modal hubs. By co-utilisation between different forwarders and speeded up transfer times land resources can be freed. In both cases vehicles, load carriers and switching equipments must be optimised to work in these new physical environments. In general, full vehicles supporting consolidation of freight loads enable the highest level of transport effectiveness and also fewest number of freight movements thus reducing congestion. However, the need for rapid delivery and short-stock piling times make it sometimes difficult to fill or use large vehicles. This situation can be improved significantly by implementing intelligent logistics solutions including the optimization of e-freight initiatives and the concept of bundling freight flows controlled by goods operators which necessitates common platforms for information and business exchange. Research, innovation and policy development to adequately address this issue is required, in addition to focusing attention on business models, service platforms & databases, ICT & protocols, modularized goods carriers & vehicles, etc.

Following this approach has important implications on both vehicles and infrastructures. While respecting the limitations on vehicle size given by the road infrastructure, it should be possible to tailor vehicles and load carriers for a better match with the goods transport assignment. Correspondingly focused research on the layout and design of vehicles which are optimized for a more specific mission profile and better overall efficiency is required. Moreover a significant part of long distance transport using heavy trucks is associated with connecting to customers in urban areas. In this context, city logistics issues are a crucial part of the overall picture. Usually hubs at the city periphery are used as switching points for the goods, with concepts based on tailoring of vehicles and goods carriers to facilitate movement within city environments to load and unload at local consolidation centres. An interesting concept to be developed further in this context is the extension of green corridors into the urban environments.

Current interest regarding electricity as the energy carrier especially for cars operating in urban areas will be explored also with respect to commercial vehicles. Electrification will open up for a transfer to sustainable energy sources such as wind, hydro, solar and biomass. Limited energy storage capacity and energy transfer speed will require considerable investments in the whole energy supply infrastructure. For heavy duty trucks, a broad approach aiming at developing sustainable trucks which can run on onboard fuels but also have opportunities to attach to available grid sources along the roads are under way. The partial electrification of certain drive train systems will assist in this development.

It is important to emphasize, however, that CO₂ neutral liquid fuels and combustion engines are the basic energy conversion concept for the foreseeable future. A challenge will be to improve the internal combustion efficiency for different fuel

As indicated in Figure 1, of the forecast improvement in the efficiency of long distance freight approximately half must be provided by increased energy efficiency of the vehicle itself.

Improved driver support systems and logistics and infrastructure should also contribute significantly to improvements in efficiency. Furthermore significant improvements for heavy duty trucks are expected in the area of safety, reducing accidents and fatalities.

All transport modes are needed in seamless coordination due to capacity limitations.

ERTRAC has recently issued scenarios and objectives for road based transport proposing that, with the combined commitment and assumption of responsibility by all stakeholders concerned, transport efficiency should become 50% more efficient by 2030 compared with today. This target is translated into three main areas and a number of indicators

2.1 Complementarities with other ERTRAC Roadmaps

The heavy duty truck roadmap summarises key opportunities to meet future challenges for this segment. This can only be achieved with a system approach and coordinated actions from society and industry. This roadmap connects and is in-line with other ERTRAC roadmaps according to the table below:

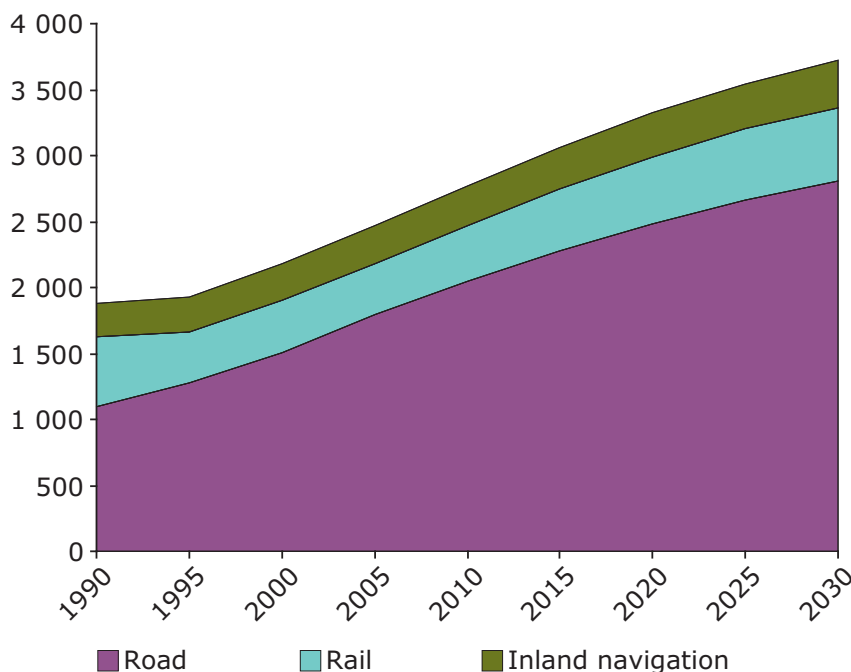
- Tailored Trucks & Load Carriers
 - Logistics & co-modality road map (EGCI)
 - Long distance freight road map
- Self-Operating and Resilient Trucks
 - Electrification road map (also item 3 & 5) (EGCI)
- Sustainable & New Energy Trucks
 - Future light- & heavy- duty powertrain technologies & fuels
 - Hybridisation of road transport

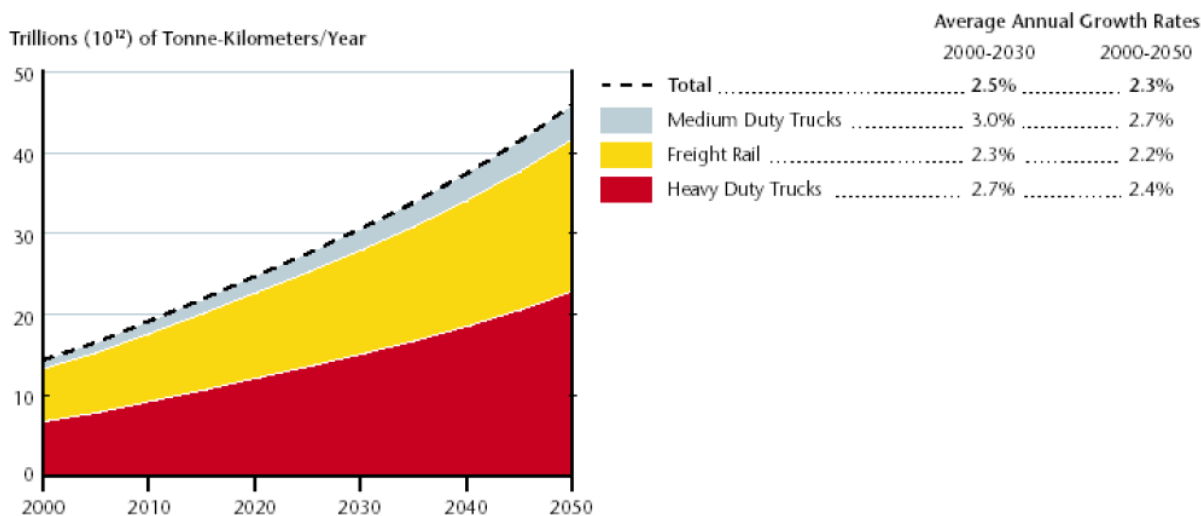
- European technology and production concept for electric vehicles
- Transport System Integrated Trucks
 - Towards an integrated urban mobility system
 - Road user behaviour and expectations
 - Safe road transport
- Traffic & Infrastructures Integrated Trucks
 - Sustainable freight system for Europe: green, safe, and efficient corridors
 - Climate change resilient transport
 - Infrastructure for green vehicles
 - Land use planning

3 Challenges and Prospects for Heavy Duty Truck Innovation

In the 2006 mid-term review of the White Paper 2001 of the European Commission, goods transport (tonne-km) in Europe is projected to increase by 50% between 2000 and 2020. The TERM report (EEA, 2010) suggests that road transport accounts for about 75% of goods transport on land today, and continues to develop rapidly, not least because of its transport and quality characteristics. Regardless of the future scenarios chosen to meet this challenge it is evident that goods transport on European roads will have to absorb the lion's share of the increasing transport demand, as indicated in Figure 2.

Gtkm (freight transport activity)





Source: WBCSD (2004): *Mobility 2030: Meeting the challenges to sustainability*. Geneva

Figure 2: Predicted transport demand.

Modal shift from road to rail, short sea shipping and inland waterways are of course put forward as a more sustainable alternative but the potential is intensely debated and limited at best, compared to the potential for energy efficiency improvements in the road transport system. Modal shift indications can be found in studies of the UK situation which showed that the road share could decrease with 14% (tonne-km) to 2050. Studies in Sweden have indicated the potential to move freight from road to rail and sea is around 10% (McKinnon & Piecyk, Logistics 2050, 2010 and SIKA, 2008:10). Efficient use of incentives may stimulate the use of innovative logistics solutions such as e-freight, online load and capacity sharing platforms. Considering the projected increase in transport demand, Europe will probably continue to rely on long distance trucks to maintain a competitive transport system.

A key factor for the transport sector is to be flexible enough to adapt to possible changes in the transport patterns. Logistics will be much more complex and flexible due to new trading partners, due to increasing integration of order & production process with transport and delivery and due to changing transport corridors, e.g. road and rail transport between Asia and Europe.

Road transport accounts for about 75% (EEA (2010) TERM report) of goods transport today, and continues to develop rapidly, not least because of its transport and quality characteristics. One major challenge in road transport is congestion. It will be addressed in different ways.

There is for instance the concept of green corridors which among others aims to improve the safe and clean usage of transport infrastructures. In principle it can be applied in both inter-urban and urban environments. This concept will put a strong demand on the development of more effective vehicles, standardised load carriers and supporting ITS/ICT systems.

The potential for increasing energy efficiency and safety of heavy duty trucks is structured into three main areas in which timely R&D, demonstrations, production, market introduction and regulatory framework development are pointed out in a roadmap format.

The Heavy duty trucks roadmap covers all truck types above 3.5 ton for both urban and long-distance, focusing on long-distance issues as it has the most negative effect on the emission.

In the term truck is the driver always included.

In order to connect the issues and opportunities with the system solution has the following innovation domains been identified:

Tailored Trucks & Load Carriers (incl. new standards):

The domain focus on adaptable and configurable trucks fulfilling future logistics and co-modality needs for different segments and markets. Key areas are:

- Cost effective architectures for different transport segments and assignments
- Configurable modules
- Aerodynamic & light weight solutions

The research should not be limited on existing standards, but should be an input for new ones.

Self-Operating & Resilient Trucks: The domain is focusing on self-operating trucks to achieve an optimising vehicle in terms of efficiency and safety in relation to the transport mission where the driver impact on the performance is limited or eliminated. The term resilient includes the aspect of availability. Key areas are:

- Safe & Efficient self-operating trucks based on reality sensing, preview & loading, reducing or eliminating the driver impact of the vehicle performance.
- Available trucks based on real time diagnostics, maintenance and repair

A key difference between the ‘Traffic & Infrastructures Integrated Trucks’ domain is that there is no vehicle to vehicle cooperation

Sustainable & New Energy Trucks: The domain focusing on future truck powertrain technologies for increased combustion efficiency (diesel and alternatives), hybridisation and electrification. Key areas are:

- Energy effective vehicle architectures
- Energy effective propulsion architectures
- Energy carriers and conversion
- Breakthrough concepts

Transport System Integrated Trucks: The domain focusing on truck integrated in the mobility system for new services. Key areas are:

- Driver, truck, load & localization status & instructions data transfer (e.g. E-freight)
- Inter-urban transport and co- and intermodal hubs
- Urban transport and consolidation centers
- Truck & Driver Security

Traffic & Infrastructures Integrated Trucks: The domain is focusing on trucks fully integrated with the physical infrastructure for efficiency, safety and security. Key areas are:

- Safe & efficient cooperative driving
- Dedicated corridors with adapted trucks & semi-automatic driving
- Energy/Information interface

3.1 Tailored trucks & Standardized Load Carriers

As freight transport operators are likely to require even more flexibility in the future accessibility to a set of tailored vehicles or to vehicles able to adapt to its operation is crucial. Today, single vehicles are often used for many different tasks, often inefficiently. Trucks built to carry 40 tonnes will often only carry 20 tonnes because they are carrying low density goods and are full on volume not mass. In these cases a large quantity of “dead” weight is transported, therefore the vehicle load carrying ability would need to be “upsized” to the absolutely maximum volume but “downsized” both from a structural mass and powertrain point of view. Research as well as internationally agreed and harmonized standards are needed to determine present load factors/fill rates, to make data collection cost efficient and unambiguous and to agree on realistic targets. The domain focus on adaptable and configurable trucks fulfilling future logistics and co-modality needs for different segments and markets. Key areas are:

- Cost effective architectures for different transport segments and assignments
- Configurable modules: load carriers, axles, steering, power train elements
- Aerodynamic & light weight solutions

The research should not be limited on existing standards, but should be an input for new ones. Performance Based Standards (PBS) is a key enabler for improved productivity for a given freight task, safer performance and the least possible effects on roads and bridges. The PBS focuses on how well the vehicle behaves on the road, rather than how big and heavy (length and mass) it is, through a set of safety and infrastructure protection standards.

3.1.1 Cost effective vehicle combination architectures for different transport segments and assignments

An optimized match of vehicles to the tasks will contribute to improving the efficiency of transport. For the operator to be able to adapt to changing operational conditions it is important to look at aspects such as access to the vehicle that best matches the needs and/or vehicle adaptation strategies to freight/cargo composition (weight, volume, shape, sensibility etc) and to its operational environment, for example efficient transition between long distance transport and urban delivery. The vehicle needs to be flexible with regard to powertrain capabilities and chassis design and to the freight modules composition, set up and weight (e.g. flexible tire sizes). The vehicle needs to have upsize/downsize capability optimising payload. Innovative leasing solutions, that could be offered to transporters, so that vehicles can be leased (short, medium, long-term) and towing units can be switched on a given trip in line with their customers’ requirements according to capacity and engine power needs, will be explored.

3.1.2 Configurable modules

The use of (internationally agreed) modular concepts for pallets, swap-bodies, containers, etc will result in increased efficiency of transport in general and road transport in particular. Standardised load modules give high flexibility and an opportunity to standardize vehicles which are adaptable to different situations, and to use optimised combinations. Increased level of modularisation of freight modules is crucial for freight inter-modality and efficiency. Common standards need to be agreed and implemented for the design, dimensions

of freight modules (goods containers) in order to optimize the inter-modal vehicle. Automated operation and coupling/decoupling of the freight modules as well as built in intelligence e.g. cargo on board monitoring, tracking and distribution are interesting areas for research. Inter-modal shipping involves the movement of freight by multiple modes, preferably in a single freight module (container). The freight modules have to be flexible enough to fit all modes and handling, loading and unloading needs to be efficient and flexible. In other words; a level of increased operational flexibility is needed to be able to implement an efficient inter-modal transport system. In term the freight modules will be powered and be a part of a distributed drive line but also being capable of driving automatically or semi-automatically in urban areas for delivery purposes.

Ensuring smooth, safe and swift transshipment between modes could remove an important bottleneck in intermodal transport chains and obstacle to an increased share for intermodal / combined transport.

The use of modular concepts throughout Europe could have a positive effect on transport efficiency and on the environment, and could also support intermodality. Initiatives to agree on standards and facilitate the implementation of modular concepts in which industry, authorities and policy-makers collaborate are vital. In order to support the setting of this regulatory framework, extensive impact assessments will have to be performed, taking into consideration the whole transportation system, and analyzing the impacts on the environment, on safety, and on mobility aspects (e.g. congestion, users acceptance, etc.).

According to MacKinnon et al ¹, we can expect several developments over the next forty years promoting consolidation of freight loads into larger and heavier consignments to make better use of the vehicle capacity.

To meet these expectations vehicle design needs to be optimized. Research areas important are: mapping and predicting how much of different types of load that are carried by trucks on the road, impact and consequences of road vehicle mass and dimensions on transport efficiency, modal split, infrastructure capacity, safety, traffic generation etc., strategies to optimize payload, chassis control (braking, handling, traction) and modular vehicle architecture.

3.1.3 Aerodynamics & Light weight solutions

Lightweight materials and design

Reducing the weight of the truck has many advantages like increased payload capacity (increasing energy efficiency) i.e. less fuel consumption (especially for start-stop situations), reduced road wear (per ton transported goods). However, this is a challenge that needs to find an optimum balance between many demands and requirements – safety is not to be neglected; production cost, too. As a heavy duty trucks is most likely to have a life of several 100 thousands of km, durability is a key element.

For a truck cab, new light weight designs and materials have many possibilities; improving aerodynamics for the hood, if present, roof and air deflectors. The weight reduced cab will also be optimised with regard to manufacturability, structural integration, durability and safety. Lessons and synergies from the passenger car industry are increasing and transferred not only to trucks, but also to busses and other heavy equipment. Similar approaches will be adopted for the chassis and trailer structures.

¹Effects of adapting the rules on weights and dimensions of heavy commercial vehicles as established within Directive 96/53/EC, TREN/G3/318/2007, Griet De Ceuster et al., 2008

Being a place of work, the importance of the interior design of the vehicle must not be overlooked. New solutions for thermal, acoustic and vibration comfort must be sought by improving in the design of the cab interior and its sub-systems including the seat, controls and HVAC system, and through the development of multifunctional materials. The use of advanced materials and innovative technologies could also lead to weight reduction in addition to improving the real and perceived comfort which will also lead to improved safety through enhanced driver performance.

Furthermore, the passive crashworthiness of cab can further be improved by multifunctional materials with enhanced or controlled energy absorption capabilities.

In this context, the development of materials as an enabler must not be underestimated. As regards the structure of the vehicle the trend must be to first design “smart” with existing traditional materials, like steel, ultra high strength steels, magnesium, aluminium, etc low weight alloys, and then turn to low cost composites for certain structures (roof, panels, etc) and then using the extreme weight saving properties of carbon fibre reinforced plastics or other advance lightweight materials for certain key elements.

The development of smart structures (e.g. nanotechnologies and the integration of actuating and sensing capabilities) will have a significant impact on future manufacturing and designing of components. It will be possible to tailor material properties for specific applications; high stiffness and high damping in the same material, for example. Nano reinforced (thermo-) plastic matrices will also make it possible for more rational manufacturing processes.

When considering novel materials, one must maintain a rational view on the benefit, from a Life Cycle Assessment perspective, or cradle-to-cradle analysis. This means that the introduction of new materials, for instance compared to steel, the life of the product must be analysed – from manufacturing, via usage, to recycling and “rebirth”. Key here is to find the most effective solution for increased transport efficiency and lowered energy consumption, both laden and empty.

Coupled to mass optimisation are the noise and vibration issues – higher speeds more aerodynamic noise, lower speeds with more acceleration – higher engine and transmission noise. Tyre-road interaction also plays an important role for speeds over 50 km/h. Noise from auxiliary systems should also be examined and reduced, as well as noise lifting equipment, reversing signals and door slamming which are relevant for urban (night-time) deliveries. Smart solutions should reduce weight and noise, without compromising safety or productivity. Smart materials, like nano-material reinforced composites have shown potentials in this direction – also making possible tailoring properties like damping and stiffness. Tyre noise is a challenge, as friction, noise, rolling resistance could all pose conflicting demands on the material.

Aerodynamics

Aerodynamic drag is an important loss factor for long distance highway freight, and is key target to optimise the complete vehicle efficiency as reduced aerodynamic drag shows a near linear effect on fuel consumption².

Vehicle aerodynamics can be optimised by changing the design with regard to shape and contour. Configurable active flow control or adaptable surfaces might have a significant impact on the aerodynamic drag as well

As a first step towards true optimization of the aerodynamic design of trucks, it is essential to study and identify best-practices in order to enable standardised methodologies for

²An optimised transport concept for tractor-semitrailer combination, ATZ 0212008 Vol 10, M Colombano, L Consano, Iveco SpA, 2008

aerodynamic simulation and analysis to be defined, referring also to other sectors of industry where finely-tuned aerodynamic analysis is critical (aeronautics, performance cars, etc). Tractor and trailer is the most common configuration in Europe. Only optimising the tractor, or trailer, will not result in any major gain; it is by investigating the whole system a significant impact can be reached. Seeking both increased transport capacity and reduced carbon footprint, aerodynamic solutions have shown a great potential³. Robustness for different speeds and conditions combined with adaptive configurations and control of the whole vehicle will have a big impact. Front geometry for optimised cooling, better safety and minimised drag, tractor-trailer air-gap control, coupled with rear end solutions and aerodynamical side-skirts covering wheels have all shown to reduce drag significantly. New aerodynamic solutions should, however, not compromise operational efficiency of cargo handling. Integrated solutions need to be developed.

3.2 Self-Operating & Resilient Trucks

The domain is focusing on self-operating trucks to achieve an optimising vehicle in terms of efficiency and safety in relation to the transport mission. The driver impact on the performance is limited or eliminated. The term resilient includes the aspect of availability. Key areas are:

- Safe & Efficient self-operating trucks based on reality sensing, preview & loading, reducing or eliminating the driver impact of the vehicle performance.
- Available trucks based on real time diagnostics, maintenance and repair

A key difference between the ‘Traffic & Infrastructures Integrated Trucks’ domain is that there is no vehicle to vehicle cooperation

3.2.1 Self-Operating Safe & Efficient Truck

The driver has an important impact on the safety and efficiency. 95% of the accidents are human error related. Automated driving at different levels has the potential to reduce such accident by eliminating the human factor. On the efficiency side there is up to 20% difference between the worst driver behaviour and an optimal one. Driver coaching systems are on the market and should have reached full maturity around 2015-17. Still, the disadvantage is that no improved efficiency can be guaranteed, the driver is still in control. Based on current advances in automated driving the next step can now be taken where the driver’s impact on the performance is reduced or eliminated in combination with optimising the vehicle’s internal energy management systems. This would guarantee the optimal performance to have optimal efficiency. In parallel, driver coaching systems advancements should continue.

Driver Efficiency

Driving behaviour has clear impact on the quantity of emissions as a function of fuel consumption. Therefore, the behaviour of drivers is a critical factor that has great impact on emissions. By combining cooperative systems using V2I communication, there is the potential for a fuel saving of 20%⁴. Driving behaviour is a key issue for eco-driving/fuel-efficient driving. Today, eco-driving can result in 10% to 12% fuel savings with the use of

³Long Distance Trucks, Strategy paper, L-G R et al, Volvo Group (?) Version 3.2 2009-11-27

⁴Proposal to FP7, ICT Programme, Objective ICT-2009.6.1, ICT for Clean and Efficient mobility.

Driver Coaching Systems (DCS). DCS are technologies supporting drivers and fleet managers to improve fuel efficiency. The DCS on the market today are based on technologies that register information from the vehicles. Information can be displayed directly to the driver while or can be configured as post-trip reports to support fuel-efficient driving. With this information fleet managers can take measures to improve fuel efficiency in the fleet, e.g. by supporting the drivers to improve their eco-driving.

The next generation of DCS is believed to have a potential fuel saving of 20% and will be characterised by a systems perspective combining cooperative systems using V2I communication. Further research is however needed in the area of driver compliance and automated DCS reducing the impact of individual compliance, if the full potential of DCS is to be reached.

Active Safety

Today, several types of warning systems exist on the market, primarily in premium segment vehicles. Recently, vehicle manufacturers took the next step to further enhance safety by introducing systems like Automatic Emergency Braking which autonomously takes control over the brakes when necessary to mitigate rear-end collisions. In the near future, active safety will be increasingly deployed in lower-cost segments. To achieve this, research needs to be directed at systems with multiple functions, with high accuracy / reliability, and reduced cost.

Deployment in heavy goods vehicles and buses will be accelerated by 2013/2015 legal requirements on mandatory CMbB and LDW systems. On the sensor side, accuracy and reliability will be further enhanced, in particular regarding the detection of vulnerable road users. Moreover, in the near future, short-range communication technologies (V2V, V2I) will function as additional sensors. In combination with digital maps and e-Horizon, this will substantially enhance the robustness and predictive capacity of today's warning systems, thus minimizing false warnings and enabling automatic intervention across a wider range of scenarios. Enhanced predictive capabilities are also essential for systems supporting green driving, so synergies between those two application areas may be exploited.

Automation

Highly or full automation will contribute to the enhancement of traffic safety by reducing the driver's workload, in terms of driving, and minimizing the human errors and incidents due to the driver's distraction or reduced vigilance. Another important impact will be the reduction of congestion, mainly in urban areas and on motorways by ensuring an optimal driving, minimizing speed variations and avoiding cases of stop and go. This will reduce vehicle emissions and fuel consumption per kilometer driven and will therefore have a positive impact on the environment.

From a technical point of view, current technology for highly automated driving in controlled environments is quite mature. However, further research and enhancements of existing prototypes and systems are needed in order to succeed in mixed traffic scenarios and real driving conditions. One very important enabler is the capability to perceive the traffic environment in a very accurate real time and integrated manner. To achieve this enhanced perception the vehicle should be equipped with numerous sensors such as laser scanners, radars and cameras to monitor the complete surroundings of the vehicle. At the same time other components such as highly accurate and dynamically updated maps and very accurate positioning systems are needed. To reduce costs and to increase synergies advanced signal processing and data fusion techniques should be investigated and applied.

The research area of cognition and human factors is essential since partially and highly automated driving still includes the human driver at least in certain phases. Hence, the system behavior and HMI must take into account the role of the driver in highly automated vehicles and an appropriate interaction design should be tailored to the driver's needs.

Finally, legal and regulatory frameworks for automated driving need to be developed in order to enable large scale deployment.

HMI and Driver distraction

Today, driver support systems are still, to a large extent, interacting with the driver independently of one another, but this situation will quickly become infeasible as the number of functions increases. In addition, seamless connectivity (internet and connected vehicles), the use of increasingly internet-capable smartphone functionality (e.g. apps, cloud services), and associated connected lifestyle changes increase the potential distraction risk for the driver. This, coupled with the fact that strong recent research says very clearly that Looking-away/Handling must be drastically minimized, shows that there is a need for more holistic approaches to automotive HMI design.

In-vehicle HMI technologies will develop towards increasingly intuitive and distraction-free driver support systems, involving in particular more advanced speech-based interfaces, based on natural speech understanding, which minimise the need to take the eyes off the road. A key concern today is the great distraction potential of consumer electronics systems not designed for use while driving. Another potentially important piece of a solution is to make use of intelligent technologies for context adaptivity. Contextual knowledge is used to optimize information, warnings, and interventions to improve safety (e.g. delaying potentially distracting information, arbitration of conflicting warnings/interventions, assessment of automated driving needs) by taking into account relevant aspects of the driver-vehicle-environment state such as driver distraction, driving demand, secondary task demand, driver impairment, traffic risk, and individual driver characteristics

Passive safety

The introduction of more and more active safety system in the truck have positive effect on truck safety but at the moment a crash becomes inevitable the active and passive system needs be fully integrated to minimize the impact, e.g. there exist a threshold in a crash situation between maximum braking that will move the body forward making the airbag less efficient and keeping the current speed, i.e. no braking and letting the airbag absorb the energy.

With the convergence of active and passive safety, human-like reactions, as they would occur in the pre-crash respectively low-g phase, will play a more and more important role in the development and fine-tuning of safety systems. This should be supported by research on active human models for all kinds of road users. The bio-fidelity and injury prediction capability of these numerical representations of the human body and in particular their ability to reproduce muscular activity need further improvements. Research in biomechanics will be the basis of such advances. So far most of the knowledge in biomechanics has been focused on so-called structural effects caused by various types of impacts. However, there is an urgent need to get a better understanding about functional effects, e.g. injuries to the nervous system frequently causing long lasting or disabling injuries. This knowledge will be a prerequisite for the definition of refined injury criteria and reference values.

Research is also needed concepts mitigating accelerations acting on the driver. Areas like multifunctional materials, advanced design e.g. by a smart interior (smart pads, high energy

absorbing materials,...), advanced constraints system (not the common safety belt), automated driver positioning to minimise impacts on the body, etc. should be investigated.

3.2.2 Truck availability

During the last ten years, riding on the maturation of the connected truck, automotive companies have made good progress on reducing the time vehicles spend in the workshop by developing solid methods for remote diagnostics. Previously the truck had to be brought to the workshop before technicians could diagnose faults, sometimes using guided diagnostics tools. The advantages of remote diagnostics are obvious. The advance warning can trigger re-supply messages to the spare part stocks, reducing the risk of vehicles waiting in the workshop for the right parts, as well as reducing the cost of capital carried by the workshop. For the customer, the obvious benefit is less time spent in the workshop, thus enabling higher vehicle availability

The next step for securing higher vehicle availability is to start prognostic faults before they occur. Significant progress has been made by researchers in developing methods for estimating the remaining useful life of individual components. The field of load and condition monitoring, prognostic diagnostics (& predictive health monitoring) hold the promise of enabling condition based maintenance. This is the key cornerstone for replacing parts based on their actual state of degradation rather than on fixed maintenance schedules based on the manufacturers estimate (maintenance on demand). The benefits for the customer and the environment is higher resource utilization, reduced maintenance costs and total cost of ownership and increased vehicle availability. For the automotive manufacturers, condition based maintenance is a key cornerstone for making the transition from spare part sales, to pay-for-performance service contracts.

Prognostic diagnostics come with significant challenges.

- Interpreting/modelling and predicting degradation is extremely complex, many different events can generate similar data.
- Past events and data will always look less random than they are
- Low probabilities (rare events) are hard to predict
- Remaining Useful Life (RUL) is a function of a future unseen. There is a need to consider usage patterns, environment, workloads
- The availability of the system is a function of hundreds of individual components with different actual RUL
- The cost of mistakes (both false alarms and missed detections) can be high for both customer and maintenance operator.

On a medium to long-term basis will artificial intelligence further refine the predictive diagnostics.

3.3 Sustainable & New Energy Trucks

Heavy duty transport operational cost is to a large fraction related to the energy cost of operating the vehicle. Competitiveness in energy efficiency is therefore a key element, and simultaneously a key driver to develop high efficient technology solutions.

Sustainable and new energy focus on powertrain and vehicle & powertrain integration solutions is also an enabler to reach higher energy efficiency improvements by new energy carrier usage, high energy conversion, utilization, and recovery. The heavy duty manufacturer

sustainability on CO₂ will also be highly dependent on high efficient utilization with low or zero CO₂ signature.

3.3.1 Energy carriers and conversions

In order to reduce the heavy duty transport CO₂ foot print, sustainable and new energy carriers need to be used in an efficient way. Energy carriers ranging from bio and fossil fuel with a minimized CO₂ production foot print to solar and wind based energy carrier's solutions with minimum production energy losses, need to be addressed with focus of vehicle energy efficient use.

Different kind of efficient on-board vehicle energy conversion solutions or powertrain is therefore addressed. Different operational demands and heavy duty transport tasks make different powertrain technology solution feasible. Transient operation task makes e.g. dedicated hybrid PT (hybrid tailored, engine transmission and electric drive important to develop, while green corridor solution may enable more narrow range operation powertrains with a fuel or energy carrier functional for the corridor. For modular truck and load carrier solution, distributed PT solutions may be considered, and for areas where road infrastructure allow full electric infrastructure a full electric operational mode or PT solutions needs to be developed and used.

The fundamental energy conversion to mechanical energy is critical to further development in efficiency, ranging from combustion based energy conversion to electric energy conversion, or as in hybrid solution in an efficient combination. The combustion based energy conversion is targeting the basic efficiency of the combustion engine concept, tailored to specific energy carrier/fuels or for a range of sustainable fuel. Future CO₂ constraints and the availability of different fuel on the world transportation markets, make high efficiency conversion for a set of energy carriers or fuel important.

Long term, new energy carriers from bio, sun or wind power may provide a variety of energy carrier solutions possible to utilize in heavy duty truck vehicles. A number of different technologies and energy solutions may emerge. Examples are direct electrification, electrification through electric energy carriers in the form of a more energy dense battery solutions than today, or in form of e.g. renewable produced hydrocarbons from bio or sun/wind electric + water generated Hydrogen, and e.g. waste streams of CO₂. Production and high efficiency chain utilizing simple hydrocarbons fuel, could provide a smooth transition path from fossil to renewable energy sources. However, new energy solutions of this kind also need an efficient energy conversion process and utilization on-board the vehicle.

3.3.2 Propulsion Energy utilization and energy recovery

The energy converted on the vehicle for mechanical or electric energy use is highly dependent on the transportation task and transportation conditions. The potential to improve and reduce the energy usage and energy recovery on heavy duty trucks are significant, from a theoretical point of view. A number of optimized power requirements for the transportation task in combination with refined auxiliary usage, and waste energy recovery from all available sources within the truck operational path could be utilized. Important areas with energy recovery to investigate further are both thermal and brake energy recovery but also other sources of waste energy, e.g. vibration and aerodynamics. A functional linkage between the vehicle aerodynamics design and the powertrain cooling demands can be utilized to reduce the total vehicle requirement.

Key challenges addressed are:

- Efficient Energy Conversion
- Scalable Powertrain architecture
- Dedicated hybrid Powertrains*
- El. Components for electrified heavy duty propulsion demands*
- Energy Integrated Truck and on-board energy management (incl. tractor-trailer or chassis-body integrated solutions).
- New energy propulsion*

* synergies with light duty

3.3.3 Breakthrough concepts

A number of key breakthrough can further improve the efficiency of the Brake through concepts:

- Scalable Powertrain Architectures
- Dedicated Hybrid Powertrain*
- Electrical components*
- New energy*

* synergies with light duty

Scalable Powertrain Architectures

To find energy efficiency gain for future transportation tasks the powertrain architecture may be dimensioned and fully designed for its use to gain improved energy efficiency. Scalability in power by e.g. a uniform piston-liner-combustion system solutions are well known, both in vehicle and industrial production solutions, but is then mainly used to capture cost reduction. Further energy efficiency potential in scalability of power demand may be gained if the powertrain system can designed to be scalable in e.g. energy conversion technology, in term of downsizing or right sizing, or by scalability in the engine platform design or in platform key system solutions to closer match the vehicle application spectra. Scalability may also provide cost reductions that enable different new sub system solutions to be utilized.

Dedicated Hybrid Powertrain*

Passenger car vehicles has for a long time been in the focus of hybridization. For heavy duty application the hybridization may be even more viable, since a number of heavy duty vehicle and transport task applications includes a large degree of transient operations with large vehicle weights, were hybridization make even more energy efficiency sense than in a passenger car application. The complete engine system needs to deliver high efficiency in the defined hybrid driving modes which may differ considerably depending on the type of hybrid application. Research on a full integration of the hybrids power-train, including all sub system as well as a hybrid optimized after-treatment is therefore paramount for realization. Both series or parallel or a combination system may be applicable for heavy duty Hybrid Vehicles. Specifically for HD truck is the requirement for high voltage development solutions, due the high demand of power in these hybrid vehicles. Several steps of energy efficiency and cost reduction actions can be applied for engines dedicated to be operated in combination with a hybrid power-train with or without or with any kind of grid power energy transfer. Engine transient operation requirements may e.g. be possible to reduce significantly, which opens up

for engine simplifications and further essential improvement of the engine efficiency and potential alternative fuel utilization. High efficient combustion modes, like e.g. different derivatives of Homogeneous Charge Compression Ignition (HCCI), may then be developed and realized, due to reduced transient requirements. This is also valid for the after-treatment and waste heat recovery hybrid optimized solutions, although different fuel need special after-treatment considerations. Special attention is to be taken of how to start and stop the engine in an efficient, silent and durable way.

Electrical components*

Heavy duty electrical motors and power electronics: HD electric propulsion requires a high efficiency, high durability and a cost situation that enables a volume growth. The price and price fluctuations on permanent magnets is a limiting factor, therefore development of electric motor drives with non or low PM content electric machine designs is important. The HD electric machine are often used in relatively long high power sequences, in comparison to passenger car and this require other means for cooling designs and technology. The power electronics could also be further improved by different means of optimized power cycling. The total efficiency of an hybrid or fully electric HD vehicle is to a large extent influenced by the ability of brake energy recovery. New solutions need to be developed to further improve this ability, both concerning the electric drive and the batter ability proved electric brake energy recovery. Further, Due to the high degree and demands on uptime and durability different solution for fault tolerant electric drive systems that can continue functioning in a degraded mode, is also highly desirable.

New energy

In a period of 10 to 30 year from now, gradual need of utilizing energy generated from unconventional fossil bio sources will increase, but besides of that the need for solar, wind, waterpower and nuclear sources will most likely emerge in order to meet the expected general CO₂ reduction demands and due to future expected capacity issues. The utilisation of this energy source for the transport sector will require a production of a versatile and practical attractive energy carries for the transport sector, other than conventional Diesel.

Unconventional fuel and fuel blends will probably emerge, in combination with, a growing infrastructure of grid solutions for supply of electric energy directly to the vehicles or through a locally produced or regenerated energy carries. A number of liquid energy carriers can be produced by re-cycled CO₂ by combining it chemically with H₂ produced by electrolysis from water to form a desirable hydrocarbon based energy carrier. H₂ could also be the primary energy carrier source, but new solutions for H₂ storage on-board HD vehicles of needs to be identified before the requirement of distance and safety can be achieved. Several technologies for storage in polymers, metal hydrides, oxides etc has and is investigated, but the still with energy densities or process in the vehicle situation that is far below the desired level.

If CO₂ is to be extracted from the atmosphere a closed-loop production process for carbon-neutral fuels is possible providing an energy-dense and easily distributed storage medium for renewable energy. However, since the transition time from fossil to renewable sourcing of energy will be considerable, the existence of CO₂ from other stationary industrial sectors, this pathways will probably be the favourable one to produce energy-dense carbonaceous liquid fuels for a long period of time.

The synthesis and storage of carbon-neutral liquid fuels offers the possibility of decarbonising heavy duty transport without the paradigm shifts required by either full infrastructure based

electrification of the vehicle fleet or a total conversion to a hydrogen economy. These fuels can be supplied either as drop-in hydrocarbon fuels or, in the form of e.g. low carbon-number alcohols which can be burnt at high efficiency levels if the heavy duty engine are fully energy optimized for low carbon number fuels. Example are e.g. CH₄, Methanol and Dimethylether. Another energy carrier pathway is solar processed metals as a clean energy carriers and water splitter to form these fuel or as a using the reduced metal as a more direct energy carrier in vehicles. be a separate path way.

So, in the long energy supply perspective the use simple hydrocarbon may be one plausible track as prime renewable energy carrier for HD transports.

For this track, new and high efficient innovative energy converters needs to be developed that can utilize the full fuel energy efficiency regions that approaches the thermodynamically limits, and that has an ability to reach above 60% in the conversion to partial and fully usable mechanical power, in conjunction with or without additional electric propulsion.

One of the key development areas besides the basic energy conversion units are the powertrain and vehicle integrated control systems that can take into account the variety of energy streams of primary of recovery origin that is possible to utilize within the truck operation. It's essential that this control can be as adoptable and self-learning as possible to enable full energy utilization.

3.4 Transport System Integrated Trucks

The demand for freight transport, both over long distances as well as in the urban environment, is growing continuously; road haulage is taking the lion's share of the market. Nevertheless, today's European transport system is still inefficient. For road haulage on average 24% of goods vehicles in Europe run empty. The other lorries are only partially loaded and have an average load capacity of only 57%.

To increase efficiency the trucks needs to be fully integrated into mobility systems. Key areas are:

- Driver, truck, load & localization status & instructions data transfer (e.g. E-freight)
- Inter-urban transport and co- and intermodal hubs
- Urban transport and consolidation centers
- Truck & Driver Security

3.4.1 Driver, truck, load & localization status & instructions data transfer (e.g. E-freight)

Existing infrastructure and vehicles can be used more efficiently by developing sophisticated logistic chains and networks, which use advanced information and communication technologies (ICT). While the foremost imperatives of introducing such logistics chains are to reduce costs and to maximise benefits, it is also essential to manage the degree of co-modality, the environmental footprint of transportation activities, the efficiency of the use of transport modes, and the negative effects of transportation. This management requires data that needs to be generated to a much larger extent than is currently the case. Efficient supply chain management or intelligent logistics systems therefore have a two-fold bonus: security and carbon footprint reduction.

The provision and generation of information from transport activities that can be used to better plan and coordinate other transport activities requires substantial new solutions in information management, data processing, real time planning, data capture technology and monitoring and evaluation, both by businesses and by authorities. There is also an important connection to the development of Single Window Platforms, which are expected to play an increasingly important role in the future efficiency and sustainability of freight. This is a key area in the EU Freight Logistics Action Plan. More effective provision of information will not only, for instance, match loads to capacity more efficiently, but information availability will also enable government agencies (customs, police etc.) to improve their performance in supervising business activities, increase their hit-rates and remove administrative burden and bottlenecks.

The main targets are to:

- improve **load factors** across the European freight transport system due to the use of better and more timely information on freight supply and demand
- reduce **CO2 emissions** as well as other emissions, due to better measurement, and more appropriate performance-based regulation
- remove **congestion**, delay and time loss in and around the green hubs, due to improved information provision to transport operators.

3.4.2 Inter-urban transport and co- and intermodal hubs

This domain covers the development of efficient interfaces in the transport system, or ‘green hubs’. Efficiency in this context is defined as high operational performance, effective use of resources, limited impact on the surroundings and the environment. The approach to develop hubs according to this ambition has two dimensions:

- the improvement of the hub itself, focusing on operational improvements, reduction of energy use of processes in the hub, etc.
- relieving the hubs of temporary or geographically concentrated pressures by connecting the hubs with each other.

The latter approach is also included in this domain, through the development of ‘Green Corridors’. This means that the connections between the hubs should adhere to the same standard as the green hubs: high operational performance, effective use of resources and limited impact on the surroundings and the environment.

As a first step, more extensive measurement of the problems, bottlenecks and transport system performance is required, as well as the development of a vision on the definition of green hubs and Green Corridors. One of the main challenges is to select the candidates for green hubs and corridors, as well as develop a method of selection that is appropriate in the European context.

Furthermore, new coordination and control mechanisms are required to guide the balance between transport modes from the green hubs. These mechanisms can build on current state of the art in information and decision sciences, where new allocations and governance mechanisms are being developed in wholly different contexts, such as agricultural auctions, packet routing in telecom networks, and so on. Apart from a measureable ‘green performance’ this type of capability will be a main characteristic of green hubs.

Further challenges are:

- continuous innovation in equipment design and deployment
- improved integration with hinterland transport technology and infrastructures

- organisational innovation to achieve optimum performance
- defining the appropriate investment (e.g. via the revised TEN-T Programme) to remove infrastructure constraints around transfer nodes.

3.4.3 Urban transport and consolidation centers

With more than 50% of global population in cities, still increasing urbanisation and suburbanisation in the dynamic European regions, road transportation is a crucial topic for both, cities and their inhabitants as the need for efficient urban transportation is still growing. By 2020 75% of all Europeans will live in city regions.

This growth results not only in increasing transportation flows, but also in changes in modes of transportation – The rise of megacities could lead to specific transport demands and thus to specific product requirements (e.g. new vehicle categories bridging the increasing distances between urban logistics hubs and the city/urban centers).

Heavy duty truck has and will have a significant part the city deliveries. Today, for a city as Paris heavy duty trucks are responsible for about 50% of the city deliveries.

A new class of trucks will provide a solution for megacity goods transport fulfilling demand on efficiency, emission-free and silent trucks (e.g. to allow night deliveries).

3.4.4 Truck & Driver Security

Secure transport of freight is an important factor for efficient transport and economical growth. A study published by the European Parliament in 2007 has shown economic losses due lost or stolen goods in the European Union to amount of 8,2 Billion Euro annually. According to TAPA (Transported Asset Protection Association) this number is only a fracture of the economic damage as it doesn't account all costs the industry suffers (e.g. replacement goods, re-shipping etc).

On a European level is the importance of this identified and the white paper for Roadmap to a Single European Transport Area recently published by the commission stated for example "Make sure that the EU is a world leader in safety and security of transport in all modes of transport."

Countermeasure solutions shall be developed and promoted to reduce the amount of lost, stolen or damaged goods to ensure free trade and economical competitiveness. These measures will also help reducing illegal freight transport (drugs, weapons, etc.) or illegal border crossing in freight compartments. There is also a continuous challenge to prevent vehicles from being stolen or broken-up.

Technological improvements over the last decades have increased the complexity to manipulate antitheft systems. This leads to the situation that criminals are better organized and use more sophisticated methods to disable remote access or immobilization systems. Trafficking with stolen vehicles has become to a regular field for economic activity of criminal organisations and is often accompanied with other criminality. Novel systems will have to be developed to hinder, discourage and prosecute thieves as well as increase the recovery rate of stolen vehicles and goods.

Along with the emergence of vehicle telematic (ITS), cooperative traffic, co-modality and particularly vehicle tracking systems, data security questions will need to be solved to ensure user acceptance and avoid data misuse.

3.5 Traffic & Infrastructures Integrated Trucks

The domain is focusing on trucks fully integrated with the physical infrastructure for efficiency, safety and security. Key areas are:

- Safe & efficient cooperative driving
- Dedicated corridors with adapted trucks & semi-automatic driving
- Energy/Information interface

3.5.1 Safe & efficient cooperative driving

With cooperative systems the vehicle efficiency and safety can be improved both in highway and urban driving situations. The penetration rate of the system is an important factor to achieve the full gains, but also with limited penetration can give significant improvement (e.g. platooning).

Platoons present an opportunity to both improve traffic efficiency and safety of vehicles on highway driving. However, for platoons to be viable there should be minimal impact on supporting infrastructure which implies that platoons will operate on unmodified public motorways. The efficiency gains of platooning are both a vehicle level due to reduced aerodynamic drag and reduced road congestion. Result from the SARTRE project shows that fuel consumption decreases for about 8% for the lead truck and about 14% for the following trucks when in a platoon at 85 km/h and a distance of 6m due to the aerodynamic drag.

The maximum capacity of a highway is today about 2200 vehicles/hour/lane. Due to vehicle speed variations will so called shockwaves be created when more vehicle are present, lowering the throughput. With platooning the vehicle following gaps and the speed variations can be reduced. Traffic flow simulations indicate that with full penetration of CACC can the capacity be doubled but also in mixed traffic will there be significant improvements.

Intelligent traffic management systems, where the vehicle is a connected part with a high degree of automation can reduce the traffic congestion about 50%, 8% less traffic accidents and 5% reduced CO₂ emission and fuel consumption⁵ in urban situations.

Cooperative highly automated driving offers high potential benefits if combined with traffic management, especially within urban environments. Traffic management can then intervene cooperatively at different levels of the driving task, such as navigation or vehicle guidance, its intervention can range from purely informative systems to direct influence on the vehicle motion, and it could influence the availability and selection of a certain automation level within the vehicle. Here further research is necessary in order to fully exploit the potential in a manner that is safe, understandable and acceptable to the driver and other stakeholders. This area of research includes:

- Interaction of onboard-navigation with information from traffic management center
- Arbitration (negotiation between driver, onboard automation and traffic management center)
- Distributed traffic management (tasks typically handled by a traffic management center might be carried out by a network of highly automated vehicles, possibly supported by further information provided by sensors at intersections, etc.)

⁵ TNO report 2008-D_R0996/A: “Smarter and better – the benefits of intelligent traffic”

- Integration of navigational level with guidance (manoeuvre) level, (direct influence of traffic management on movement of vehicle or arbitration on choice of manoeuvre, for example the vehicles where the driver has chosen to temporarily hand over control to his automation could be rerouted and automatically follow alternative routes to achieve the given goal of avoiding congestion.)
- Supervision of automation by traffic management centers (an intelligent infrastructure could provide an additional safety layer by supervising the movement and status of highly automated vehicles and thereby increasing their reliability and possibly open wider application areas to highly automated driving)
- New logistics applications (highly automated driving (and its combination with traffic management) might enable new logistics concepts and business models to support the costs of such systems, such as allowing highly automated trucks exclusive or priority access to certain areas.)

3.5.2 Trucks in Corridor

The ‘corridor’ concept⁶ could be introduced in different degrees between 2020 and 2030 in Europe. The corridor concepts can first as virtual corridors in existing infrastructure and later on in specific infrastructure. The first corridors will focus on specific issues e.g. optimized load capacity, decreased congestions or energy reception technology (e.g. LNG) and later have a more holistic approach.

Key challenges are:

- Interfaces and interoperability between different transport modes
- Logistics design; Goods flow optimization
- Interface and interoperability with local/urban network.
- Vehicle concepts
- Intelligent corridor access requirements
- Corridor specific services
- Infrastructural support measures

For the heavy duty trucks vehicle concepts

- Vehicle technically specified for running in corridors:
- Vehicle dimensions for optimized load capacity within corridors
- Vehicle safety in corridors

The corridor concept includes vehicle designs and propulsion, e.g. LNG

Vehicle technically specified for running in corridors

For efficient transport operation within corridors the vehicle parameters need to be optimized. The vehicle should be adapted to its operation and to the freight it is carrying. The vehicle propulsion can also be specific to the corridor concept like LNG in blue corridors or in long term electrified highways.

⁶ Sustainable Freight System for Europe Green, Safe and Efficient Corridors

Vehicle dimensions for optimized load capacity within corridors

As freight transport operators are likely to require even more flexibility in the future, accessibility to a set of tailored vehicles or to vehicles able to adapt to different operations is crucial. Today, single vehicles are often used for many different tasks, often inefficiently. Trucks built to carry 40 tonnes will often only carry 20 tonnes because they are carrying low density goods and are full on volume not mass. In these cases a large quantity of “dead” weight is transported, therefore the vehicle load carrying ability would need to be “upsized” to the absolutely maximum volume but “downsized” both from a structural mass and powertrain point of view. Research as well as internationally agreed and harmonized standards are needed to determine present load factors/fill rates, to make data collection cost efficient and unambiguous and to agree on realistic targets. Key areas are

- mapping and predicting the quantities of different types of load that are carried by trucks on the road
- impact and consequences of road vehicle mass and dimensions on transport efficiency
- modal split
- infrastructure capacity
- strategies to optimize payload
- chassis control (braking, handling, traction)
- modular vehicle architecture

3.5.3 Energy/Information interface

As in-vehicle drivetrain technologies advances with different concept in parallel and mature will the infrastructure support in term of energy supply and interfaces be of key importance for viable business cases and deployment.

Green Energy Supplies

Energy security is a pressing concern within the European Union because of its influence on economic development and the well-being of citizens. Presently, the EU is dependent upon energy imports to meet its demand for energy, and if current trends and policies continue, this external dependency is likely to increase. There is a need for the EU to develop its own internal energy infrastructure.

Natural gas is utilised by heavy duty vehicles for municipal use (urban buses, garbage collection trucks) in many parts of Europe, this type of operation is generally based on a return-to-depot principle for refueling. Practically all these vehicles run on CNG (compressed NG/biomethane). CNG, five times more volume of fuel over diesel prevents the use of CNG in heavy road transport, because its volume and weight would be too big for a long distance truck.

For the heavy long distance truck a solution is LNG Blue Corridor principle

A 40 tonne road tractor in Europe needs a tank of 400 to 500 litres for a 1.000 km trip; its equivalent volume with liquid gas would be 700 to 900 litres of LNG, a tank dimension that could be easily fitted to the lateral of the truck chassis. LNG is therefore opening the use of natural gas to medium and long distance road transport, with new trucks able to travel up to 1100 kms between fueling stations. The installation of a limited number LNG, in some strategic points of central Europe would permit a much more economic and clean way for long-distance freight transport along the main European transit routes.

This demands a close collaboration with the infrastructure sector and a clear agreement on deployment timeline.

Grid connected trucks

The need for a coherence of R&D activities, business development and regulatory measures across various disciplines and sectors can exemplarily be described for the topic of grid integration of the EV. For EVs, no expensive infrastructures like that which would be needed to deliver and store hydrogen are required. However even for the most simple case, that is the conventional home plug, controlled uni-directional charging is desirable, and to take advantage of the full potential of an EV, a bi-directional smart charging V2G capability may be aimed at in the longer term. This will be based on an appropriate interface allowing the exchange of both electricity and data between the vehicle and the grid.

A large-scale implementation of grid integration requires the definition of safety standards at the charging station as well as regulations to avoid undesired effects when connected to the grid [29]. Bi-directional charging or V2G will rather be a second step as the timing to get the infrastructure ready will critically depend on the speed with which the standards and regulations come into force, and on the availability of the required smart grids technology and the necessary investments. In this sense, experimentation with large fleets appears necessary so that enough data and experience on best practices could be collected prior to implementation.

ERS (Electric Road Systems) shows several variants of a promising technology that cost effectively, safely and robustly facilitates an almost complete transfer of both light and heavy road transport to electric propulsion.

ERS with energy transfer from the road surface to the vehicle either inductively or conductively are the most important technologies to be investigated.

	Inductive	Conductive
Top	<ul style="list-style-type: none"> - Unrealistic due to size and weight - Low efficiency - Visual impression 	<ul style="list-style-type: none"> + Already in use with trolley systems + Low cost - Does not work for cars - Visual impression
Side	<ul style="list-style-type: none"> + Works for all road vehicles - Unsafe for objects on roadside - Low efficiency - Heavy, bulky and expensive - Only one lane possible 	<ul style="list-style-type: none"> + Works for all road vehicles + Already in use with subway trains + Low cost - Unsafe for objects on the roadside - Only one lane possible
Bottom	<ul style="list-style-type: none"> + Rugged and Safe - Expensive - Low efficiency - EMC? 	<ul style="list-style-type: none"> + Works for all road vehicles + Low cost + High efficiency

Table 1: Possible energy transfer

4 Milestones and Improvements Targets

The aim with the milestones is to show key concept how they contribute to the ERTRAC guiding objectives, see Figure 1. As the guiding objectives covers the complete road transport system where the heavy duty truck is only one part of the system, the contribution for heavy duty truck is translated as:

- **Indicator energy efficiency:** The Energy efficiency target (40%) on long distance freight corresponds to the target for heavy duty truck and so is the share of renewables from Biofuels. As the urban distribution is not included in the target there is a small potential for higher improvement due to advanced traffic control & logistic solutions and hybridization and electrification. As the total freight (tonne-km) is mainly long-distance, the additional contribution is small. There is a contribution on the share of electricity (5%) in specific heavy duty segment (3,5 to 16 tonne), but on a global scale the contribution will be small.
- **Indicator on Reliability:** The major part of the contribution (~60 %) will come from the infrastructure and logistics and only a small part from the vehicle part (~10%). 10 % includes both direct and indirect effects on reliability. It is estimated that about 30% will come from production and supply chain that is not included in the roadmap
- **Indicator on Cargo Security** (cargo lost to theft and damage): -70% guiding objective is adopted fully in the HDT road map. Contribution of 20% by vehicles (enabling), 10% by user behavior, and 40% by logistics and infrastructures.
- **Indicator on Safety:** The heavy duty roadmap adopts an objective on -60% on fatalities. The improvement will mostly be on surrounding traffic and especially vulnerable road users. The truck drivers themselves seldom are victims of accidents.

4.1 Tailored Trucks & Load Carriers

Contribution to 2030 targets:

- Energy efficiency: 8% tonne-km/kwh

Tailored Trucks & Load Carriers	Milestone1 Milestone 1: 2015 Market 2018-2020	Milestone 2 Milestone 2: 2020 Market 2023-2025	Milestone 3 Milestone 3: 2025 Market 2028-2030
<p>Cost effective architectures</p> <p>Configurable modules</p> <p>Aerodynamics & Light weight solutions</p>	<p>Optimised vehicle parameters for efficient transport operation.</p> <p>More flexible vehicle leasing concepts.</p> <p>Vehicle optimised for Green Corridors.</p> <p>Aerodynamically efficient complete vehicle (tractor and trailer),</p> <p>Systematic re-design and material optimisation. Both traditional and novel composites.</p>	<p>Vehicle fully adapted to its operation and freight.</p> <p>Modularity</p> <p>Inter-modal efficiency.</p> <p>Vehicle optimised for all infrastructure.</p> <p>Improved aerodynamics, more flexible directives, new vehicle combinations</p> <p>Novel materials optimally used through multidisciplinary optimisation.</p> <p>Multi-functional materials.</p> <p>Lower weight and better performance.</p>	<p>Vehicle dedicated to its operation</p> <p>Efficient, real time, flexible truck.</p> <p>Adaptable exterior geometry, suspension, air gap and speed control, 20% drag reduction.</p> <p>Significant weight reduction, integrated design of components in optimal material.</p> <p>Nanomaterials with multifunctional properties</p>

4.2 Self-Operating & Resilient Trucks

Contribution to 2030 targets:

- Energy efficiency: 4% tonne-km/kwh
- Safety: - 40 % (fatalities)
- Availability: + 35% (5% from vehicle and 30% from logistic and infrastructure)

Self-Operating & Resilient Trucks	Milestone 1	Milestone 2	Milestone3
	<p>Milestone 1: 2015 Market 2018-2020</p> <p>Active VRU protection</p> <p>Partial automated driving</p> <p>Driver eco support</p> <p>On-board condition monitoring/guided diagnostics</p> <p>Integration with maintenance planning</p>	<p>Milestone 2: 2020 Market 2023-2025</p> <p>Automatic VRU protection</p> <p>Situation sensing and adaption for improved safety</p> <p>Highly automated driving</p> <p>e-Horizon data for optimal overall control and performance.</p> <p>Predictive diagnostics: Monitoring health</p> <p>Vehicles that's accurately in real time monitors remaining useful life of components & systems</p>	<p>Milestone 3: 2025 Market 2028-2030</p> <p>Full Automated driving</p> <p>Reliable fleet</p>

4.3 Sustainable & New Energy Trucks

Contribution to 2030 targets:

- Energy efficiency: 16% tonne-km/kwh
- Share of Renewables, Biofuel: 25 %

Sustainable & New Energy Trucks	Milestone 1	Milestone 2	Milestone3
	Milestone 1: 2015 Market 2018-2020	Milestone 2: 2020 Market 2023-2025	Milestone 3: 2025 Market 2028-2030
Energy effective vehicle architectures Energy effective propulsion architectures Energy carriers and conversion Breakthrough concepts	Transmissions dedicated for hybrids and flexible drivelines Downsizing, downspeeding and high pressure charging Combustion and EATS concepts with high efficiency or low cost dedicated for hybrids and flexible drivelines High efficient minimized NOx aftertreatment Waste Heat Recovery	High efficiency scalable powertrain concepts Variable Valve Actuation (VVA) Efficient integration in vehicle energy management system Alternative NOx aftertreatment / Non Precious Metal Aftertreatment Systems Scalable electric HD components	Intelligent and mission/environment adaptive powertrain controls Multivariable based + single cycle combustion control Multi-fuel aftertreatment Combustion & energy conversion systems for renewable and high octance fuels (CH ₄ , EtOH, Gasoline, MeOH) Mixed energy HD propulsion control strategies

4.4 Transport System Integrated Trucks

Contribution to 2030 targets:

- Energy efficiency: 4% tonne-km/kwh
- Security: - 70 %

Transport System Integrated Trucks	Milestone 1	Milestone 2	Milestone 3
<p>Truck, load & localization</p> <p>Inter-urban transport & co- and intermodal hubs</p> <p>Urban transport & consolidation centers</p> <p>Truck & Driver Security</p>	<p>Milestone 1: 2015 Market 2018-2020</p> <p>Deployment of a an information exchange platform for freight delivery stakeholders</p> <p>Large scale pilots on integrated Intermodal hubs</p> <p>All new vehicles with optional tracking systems available, pan- European service available, promotion by insurances</p> <p>10% of all parcels are continuously monitored</p>	<p>Milestone 2: 2020 Market 2023-2025</p> <p>Interoperability between modes & networks, IT application for logistic</p> <p>Solutions for sustainability footprint of logistic transport chain</p> <p>Hubs that supports : high automation and eFreight</p> <p>Close-to-zero possibility to illegally unlock and start a novel vehicle with ICT connectivity</p> <p>50% of all freight transport protected with tracking systems</p> <p>50% access to safespots on key corridors</p> <p>Open standard security system</p>	<p>Milestone 3: 2025 Market 2028-2030</p> <p>Internet of freight</p> <p>Seamless modular integration of hubs and corridors</p> <p>50% of all parcels are continuously monitored</p> <p>100% of all freight transport protected with tracking systems.</p> <p>80% access to safespots on key corridors</p>

4.5 Traffic & Infrastructures Integrated Trucks

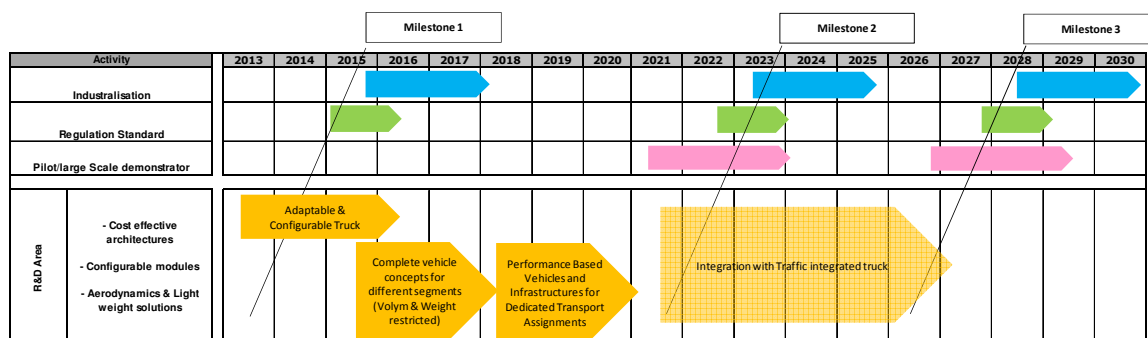
Contribution to 2030 targets:

- Energy efficiency: 8% tonne-km/kwh
- Safety: - 20 % (fatalities)

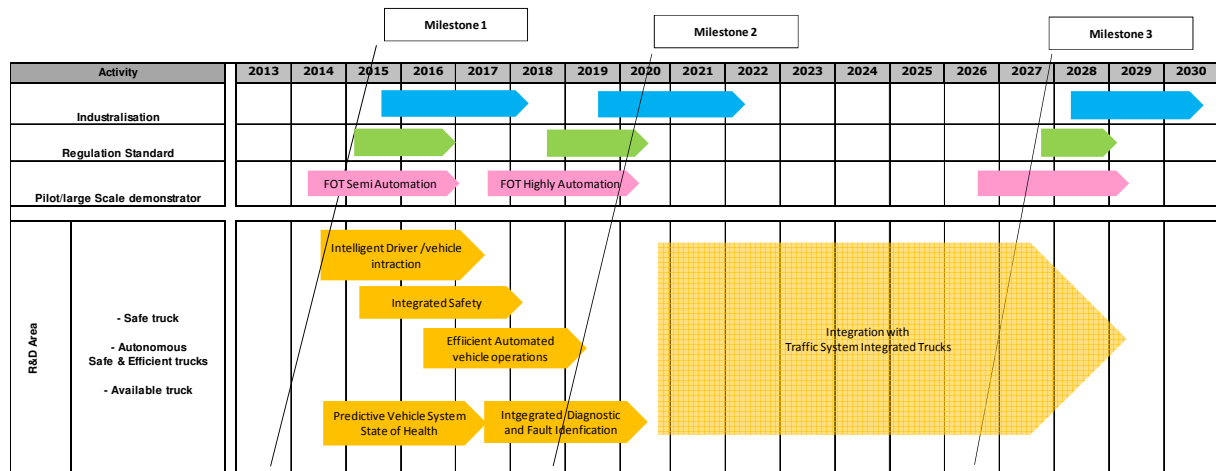
Traffic & Infrastructure Integrated Truck	Milestone 1	Milestone 2	Milestone 3
	Milestone 1: 2015 Market 2018-2020	Milestone 2: 2020 Market 2023-2025	Milestone 3: 2025 Market 2028-2030
Safe & efficient cooperative driving Trucks in Corridors Energy/Information interface	Green light optimisation & Cooperative ACC Vehicle optimized length, weights and design for key corridors Large scale pilots running with liquefied natural gas Adaptive on-board/in-plug charging devices Open standards and protocols for V2G communication	Vehicle driveline adopts to traffic management system optimizing Advanced Platooning Truck and load are fully integratable into smart transport network in dedicated urban areas Expanded LNG/SNG/DME infrastructure in Europe Truck technically adapted to performance based standards within the corridor Quick charging	Vehicle operation adopts to traffic management system optimizing Mass market corridor Truck and load are fully integratable into key transport corridors Fully developed infrastructure for liquid & gaseous energies Electrified driveline with continuous power supply

5 Roadmaps

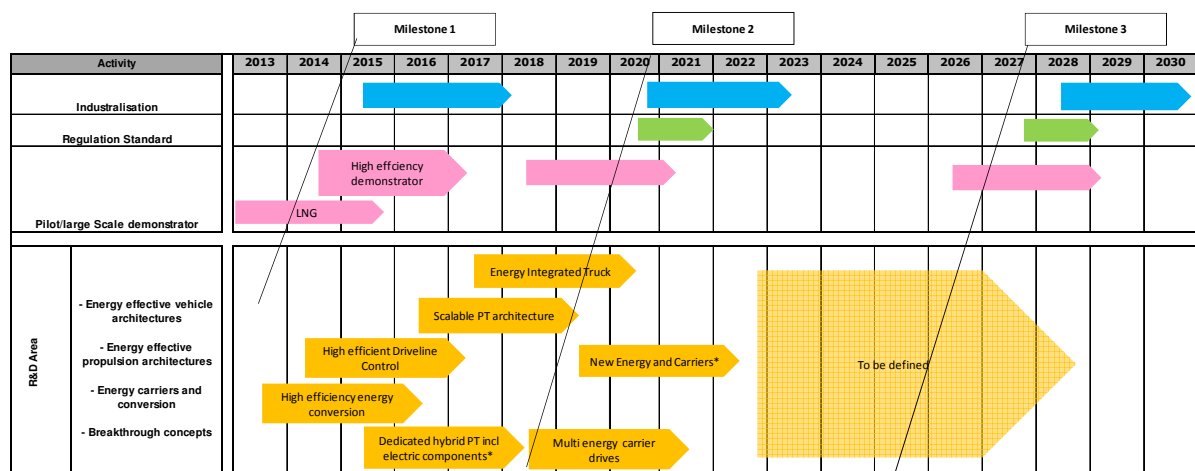
5.1 Tailored Trucks & Load Carriers



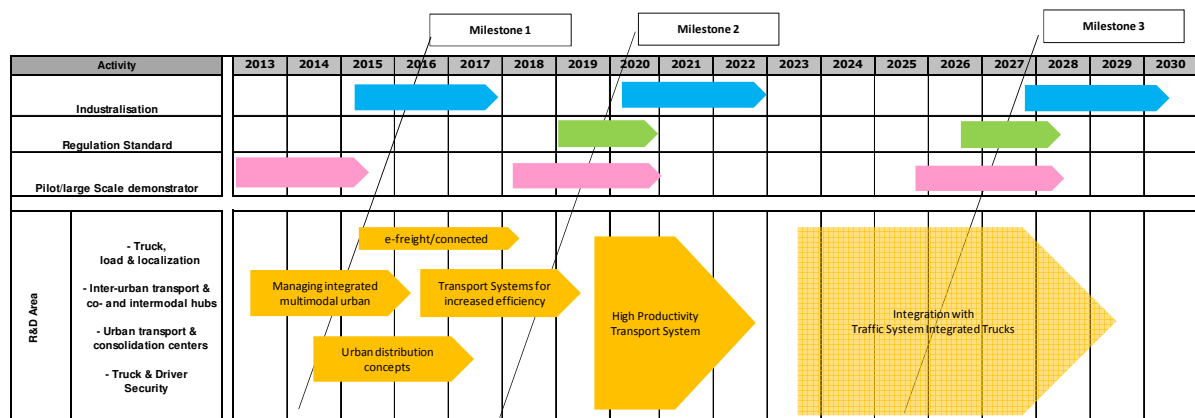
5.2 Self-Operating & Resilient Trucks



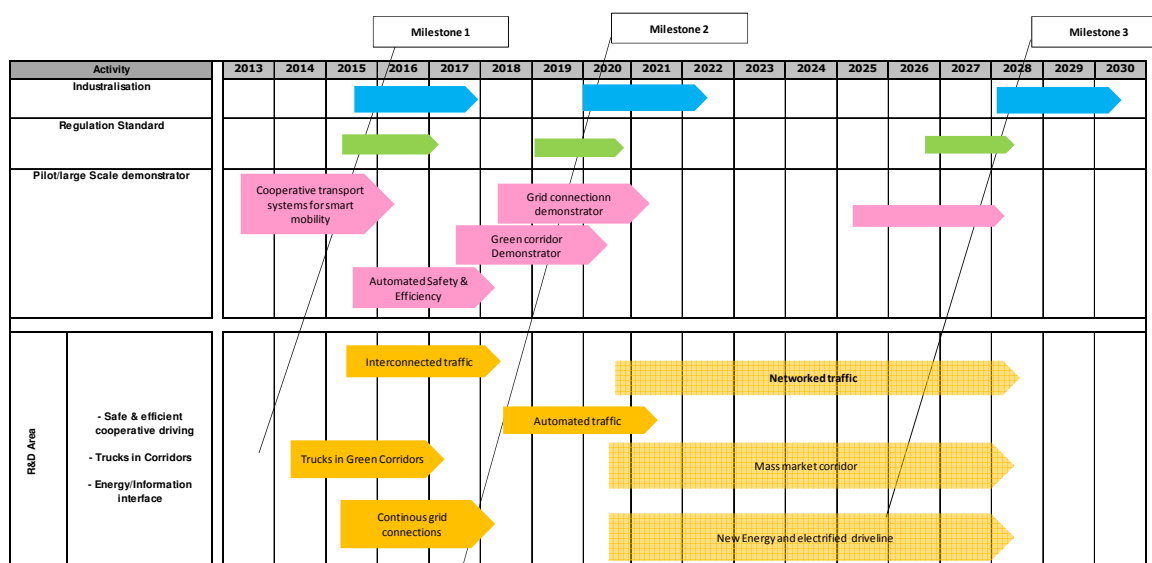
5.3 Sustainable & New Energy Trucks



5.4 Transport System Integrated Trucks



5.5 Traffic & Infrastructures Integrated Trucks



6 Recommendation of Research & Innovation activities

6.1 Tailored Trucks & Load Carriers

6.1.1 Preliminary themes 2014

No activites for 2014

6.1.2 Preliminary themes 2015

Complete vehicle combination concepts for different segments with respect to volume and weight restrictions

Content and Scope: Tractor and semi-trailer concepts tailored for increasing transport efficiency with respect to transport missions that run below optimal utilization due to either weight or volume restrictions.

Transport missions are increasingly restricted by volume rather than weight due to low density (and high value) shipments. There is a need to explore innovative vehicle combinations that could better meet the demands of maximum volume and/or improve the capability to mix high and low density goods to reach more optimal utilization of the vehicle combination.

- Research should include:
- Volume maximized semi-trailer architecture
- Volume measurement technologies, automatic and/or manual
- Self-supporting trailer superstructures and bodies including light weight designs

- Tractor – trailer integration with respect to improved aerodynamics, driveline right-sizing
- Terminal handling efficiency with respect to terminal infrastructure such as bays, ramps, yard management, loading and unloading equipment

6.1.3 Preliminary themes 2016

Topic not included?

6.1.4 Preliminary themes 2017

Performance based vehicle combinations and infrastructure for dedicated transport assignments

Content and scope: With the increasing transport demand and limitation to invest in road network capacity, Europe will need to improve the capacity utilization of the existing network. By identifying performance criteria related to vehicle safety and infrastructure wear such as stability, braking and bridge stress, the network capacity could be improved by allowing dedicated transports with higher efficiency on a dedicated road network in combination with a compliance monitoring scheme.

Research should include:

- Development of performance criteria for vehicle combination safety and handling as well as infrastructure wear
- Development and validation of test and simulation methods to verify the performance of a specific vehicle combination
- Development of criteria and performance level requirements for classifying the road network
- A monitoring scheme assuring compliance and supporting legal enforcement in case of compliance breaches
- Regulatory and legal implications with respect to jurisdictions on member state and EU level

6.2 Self-Operating and Resilient Trucks

6.2.1 Preliminary themes 2014

FOT Semi Automation(Large scale demonstrator)

Contents and scope:

Naturalistic driving studies with semi-automatic systems

Research should include:

- Investigations of European driver behavior and acceptance of mixed operations
- Safeguard error-free interaction of driver with semi-autonomous assistance
- Drivers habituation to semi-autonomous assistance (and European differences)

Based on earlier project like e.g. HaveIT

Intelligent Driver /Vehicle Interaction

Content and scope:

Research should include:

- HMI strategies for minimizing the distraction potential of in-vehicle information systems with a special focus on usage of mobile phone and internet applications.
 - Minimized Visual-manual interaction,
 - Maximized use of spoken interaction (speech UI, Text to speech, talk to operator “on-star” style),
 - Context adaptivity,
- Low-cost technologies for non-intrusive sensitive and reliable real-time driver monitoring and detection of distraction, drowsiness and intoxication (alcohol, any drugs etc...).
- Inattention detection with and without eye-tracking systems (Eyes-On detection instead of Hands-Off detection to allow freehand driving in (semi-)automated driving
- Inattention prevention and mitigation strategies, including warnings, interventions and behavior-based feedback.
- Accident/incident research with the aim of better understanding the basic mechanisms whereby distraction, drowsiness, alcohol and drug intoxication cause crashes.
- Qualitative and quantitative driver behavior modeling (reference for design, assessment, layout of semi-autonomous and autonomous systems; decision making in pre-crash sit.)
- Connect to key function developed in earlier project, e.g., interactive.

Predictive vehicle system state of health monitoring and fault identification

Content and scope: During the last ten years, riding on the maturation of the connected truck, automotive companies have made good progress on reducing the time vehicles spend in the workshop by developing solid methods for remote diagnostics. Previously the truck had to be brought to the workshop before technicians could diagnose faults, sometimes using guided diagnostics tools. The advantages of remote diagnostics are obvious. The advance warning can trigger re-supply messages to the spare part stocks, reducing the risk of vehicles waiting in the workshop for the right parts, as well as reducing the cost of capital carried by the workshop. For the customer, the obvious benefit is less time spent in the workshop, thus enabling higher vehicle availability.

The next step for securing higher vehicle availability is to start prognostic faults before they occur. Significant progress has been made by researchers in developing methods for estimating the remaining useful life of individual components. This is the key cornerstone for replacing parts based on their actual state of degradation rather than on fixed maintenance schedules based on the manufacturers estimate. The benefits for the customer and the environment is higher resource utilization, reduced maintenance costs and total cost of ownership and increased vehicle availability. For the automotive manufacturers the transition enables customized offerings based on the actual usage of the vehicle.

The overall goal of predicting remaining useful life of a system or component is to improve the efficiency of the transportation assignment, this leads to that prediction of the remaining useful is also important on the whole vehicle combination, including trailer.

The technical solutions to predict the remaining useful life is then connected the computational power on the vehicle. Also on how we can be more efficient in providing solutions to identify specific faults for fast and accurate workshop stops.

Since the computational power on-board the vehicle is limited requires novel approaches connected to telematics and computational efficient diagnostic functions. Moreover, the large amount of different vehicle variants in various environment put further requirements on novel approaches to predict the remaining life time and pinpointing the actual fault.

Prognostic diagnostics come with significant challenges.

- Interpreting/modelling degradation is extremely complex, many different events can generate similar data.
- Past events and data will always look less random then they are
- Low probabilities (rare events) are hard to predict
- Remaining Useful Life (RUL) is a function of a future unseen. There is a need to consider usage patterns, environment, workloads
- The availability of the system is a function of hundreds of individual components with different actual RUL
- The cost of mistakes (both false alarms and missed detections) can be high for both customer and maintenance operator.

The overall objective is to Explore and demonstrate the functionality of the next generation prognostics methods for conventional, hybrid and electric drivelines.

The specific objectives for the project should be:

- Accurate prediction of remaining life time
- Fault identification of on-vehicle systems
- See the whole vehicle combination as part of the monitored system
- System level RUL estimation

6.2.2 Preliminary themes 2015

Integrated Safety

Contents and scope:

Research should include:

- Integration of active and passive solutions
 - Which of today's load cases for passive safety are more sensitive for an *active safety activation* ?
 - Development of test that takes in consideration of the whole safety aspect, this measured in criteria level in crash tests.
 - Quantify relationship between kinetic energy reduction and fatality reduction/injury reduction Target of life saves will enable target for speed reduction though mitigation system.
 - Redefined secondary
 - Impact on crash structure : revolutionary light-weight design, validated simulation tools for advanced materials and joining technologies, crash compatibility

- Crash safety in combination with energy storage system (e.g battery packs, hydrogen tanks...)
 - Pre-triggered occupant protection systems and new system concepts
- Active Safety functions
 - Evolution of existing, cover greater range of scenarios for safety functions
 - Demonstration of full collision avoidance
 - Intersections safety
- “Future traffic systems and vehicle systems are real “systems of systems” including and relying on several heterogeneous network topologies. There are several outstanding research issues to be addressed:
 - How to provide active safety related applications (example Automatic braking relying on information from other vehicles or infrastructure) fulfilling functional safety requirements as well as security requirements in systems of systems.
 - From a technical point of view there will be very tough real time requirements which has to be handled by solutions like global time and quality of services awareness.
 - Related technical aspects in wireless and wired architectures in vehicle as well as in infrastructure has to be addressed.

6.2.3 Preliminary themes 2016

Efficient Automated Vehicle Operations

Contents and scope:

Based on the result from earlier initiatives can automation to be connected to the operation to guarantee an optimal efficiency limiting the driver impact on performances

Develop concepts and methods for the continuous assessment of the integrity of the complete driving situation in autonomous driving with the goal of timely reactivation of human attention and action.

Research should include:

- From driver controlled (semi-automatic) driving to automatic hands-free driving
- Estimation of the driver’s readiness to take control in autonomous driving situations
 - Assess different concepts for driver attention monitoring and reactivation
 - Develop criticality measures for judging the complexity and manageability of the situation (traffic, weather, road, vehicle,...) w.r.t. the proven skills of the system
 - Design methods for early identification of upcoming situations with need of human action including statistical assessment of the effectiveness of such methods
- Developing the technological components, data fusion and situation analysis methods in a functional architecture enabling safe autonomous driving

- Develop criticality measures for judging the complexity and manageability of traffic, weather, road, vehicle etc. conditions with respect to the proven skills of the automated system.
- Proofing the impact of different levels of automation in driving and in traffic safety and efficiency.
- Preparing legal aspects and requirements for registration, regulation, liability, code of behavior for semi or highly automated and autonomous driving within EU- 27 and cross its borders.
- Defining requirements and methods for testing, approval and real life safety impact of highly and fully automated low and high-speed driving (how to do it with a common acceptance by the society).
- 360° environmental detection, understanding and task planning with n seconds time horizon, strengthen methods to guarantee stable vehicle dynamics in the needed physical borderline and with needed accuracy (longitudinal and lateral control)
- Understanding technical aspects of the increasing proportion of automation in maneuvering like flight path and trajectory decision for safe maneuvers.
- Understanding HMI to define a “⁷reference model for the driver” for the different levels of automation strategies from highly automated (low and high speed driving) to full automated driving (performance and limits in complex situations; hand-over; requests to keep the driver in the control loop in the field of monotonies and complex decision making or short reaction times ; measures of “risks in driving situations” that drivers are willing to accept;

6.2.4 Preliminary themes 2017

FOT Automation

Contents and scope: large-scale demonstrator showing result platooning (e.g. SARTRE) and highly automated vehicles.

Integrated diagnostics and fault identification during whole vehicle life time

Traditionally the diagnostic functions (and fault identification functions) are functions that are developed before start of production. This leads to that the a selection has to be made of the diagnostic functions that are estimated to be the most relevant once.

This leads to that a lot of work is done to develop diagnostic functions on systems that are not in production and will operate in various type of conditions and integrated with different systems and variants.

A way to meet these challenges is to develop methods and technologies that enables self-learning of diagnostic functions and fault identification algorithms (algorithms that are able to evolve during the whole vehicle lifetime in the actual conditions and for the specific vehicle variants).

⁷ Content and scope will be defined in later version of the document

To prevent any road side breakdowns (or other severe consequences of a malfunction vehicle) the diagnostic functions can not only indicate a faulty system or component, the diagnostic function must also affect the functionality of the faulty system to minimize the consequences. To further improve the integrated diagnostic the vehicle can be controlled to minimize the risk for any fault. Hence, dependent on the type of transportation assignment or ambient conditions the diagnostic functions can vary to secure efficient transports with fuel efficient and safe vehicles.

6.3 Sustainable & New Energy Trucks

6.3.1 Preliminary themes 2014

High efficiency demonstrator

Large scale demonstrator of the technology result from the final call in the 7:th framework projects, focusing demonstration high total PT energy efficiency under realistic operation conditions.

High efficient Driveline Control

Contents and scope:

Real time monitoring will increase the ability to learn and remember in order to improve the topology energy consumption planning, by preselect the best operational parameters for the complete driveline units and its connected auxiliary use. Real time emission exhaust control will make it possible to utilize storage function in the EATS systems in an improved manner. Specific real-time control strategy for inner city zoon's maybe be possible.

Real time energy efficiency control will make hybridization function more efficient, since hybrid, provides more energy storage flexibility and a thus a higher degree of control freedom. Iterative calibration of for optimized efficiency and emissions will open up for both reduced CO₂ and local environment emission benefits.

Research is needed in the field of local and global emission real time driveline control impact as well as in the area of technology solutions of hon hybridized, hybridized PT and vehicles.

6.3.2 Preliminary themes 2015

Dedicated Hybrid Powertrain

Contents and scope:

- *Transmissions dedicated for hybrids and flexible drivelines*
Research on new cost efficient transmission systems that are designed for hybrid drive operation is needed. Systems that can both receive and deliver torque to several torque providers and consumers have to be developed further as auxiliaries, waste heat recovery expanders and brake recovery power may need to be connected to the transmission unit. The complexity of today's powersplit concepts needs to be reduced.
- *Downsizing, downspeeding and high pressure charging*
Downsizing the combustion engine for heavy duty applications on traditional

drivelines does not offer the same improvements as for light duty vehicles since the size and power range of the engine is already well matched to the torque and power needs. Hybridization however enables torque addition from generators other than the combustion engine. The hybrid system is also adding other operational freedom for the combustion system in serial or parallel system modes. There is therefore a further need to study the potential of simplification and energy efficiency improvement of combustion engine for heavy duty application that are tailored for hybrid applications. Opportunities in reducing the operation range and less transient response requirement may be considered.

- *Combustion and EATS concepts with high efficiency or low cost* dedicated for hybrids and flexible drivelines

Hybridization of the heavy duty drive train puts new demands on the control of the combustion and engine after-treatment system (EATS). The potential disconnection between instant torque delivery demand and the combustion and aftertreatment operation makes new combustion and EATS concepts and modes of operation possible. In combination with downsizing further research is needed to fully utilize new high efficiency operational modes, like e.g. partially premixed combustion (PPC) or others in combination with strategic thermal management design and control of the EATS system.

- *High efficient NOX aftertreatment*

Operating the engine in a more narrow exhaust temperature operation range offers further potential of increasing the total NOx conversion by a re-redesign and/or by more selective coating reformulations. Further development and research for dedicated hybrid aftertreatment systems opens up for less fuel penalty and catalyst system cost reductions. Research into new catalysts, injectors, controls and system design is needed to reach the full potential of ultra-high efficiency NOx aftertreatment.

6.3.3 Preliminary themes 2016

Scalable Powertrain Architectures including electrical components

Contents and scope: To find energy efficiency gain for future transportation tasks the powertrain architecture may be dimensioned and fully designed for its use to gain improved energy efficiency. Scalability in power by e.g. a uniform piston-liner-combustion system solutions are well known, both in vehicle and industrial production solutions, but is then mainly used to capture cost reduction. Further energy efficiency potential in scalability of power demand may be gained if the powertrain system can be designed to be scalable in e.g. energy conversion technology, in term of downsizing or right sizing, or by scalability in the engine platform design or in platform key system solutions to closer match the vehicle application spectra. Scalability may also provide cost reductions that enable different new sub system solutions to be utilized.

New solutions that combine significant energy efficiency, application adaptability and cost reduction improvements are therefore important to develop.

- *High efficiency scalable powertrain concepts*

The fuel consumed by heavy duty transportation is large and therefore any

improvement in the prime energy converter will significantly contribute to a reduction in GHG emissions and of transportation costs. Since current drivelines are already very efficient, a further improvement is challenging. However, there is still a large potential to improve the energy conversion efficiency when taking the complete system architecture into account. While such a complete system approach is needed it also comes with a large complexity and needs large development efforts. It is therefore essential to develop systems that are scalable in power and torque for different applications.

- *Variable Valve Actuation (VVA)*

One of the key enablers for scalability and for maintaining high efficient combustion and aftertreatment emission conversion is a flexible and durable valve timing system. For diesel engines and similar engines application with high peak cylinder pressure, very few flexible valve timing concepts have been brought to the market, due to complexity, lack of durability, limited operability reasons. New research and inventions in this field is therefore still essential to reach the level of maturity that is needed for in future HD truck applications.

- *Waste Heat Recovery*

Even for highly efficient Diesel engines a majority of the fuel energy is lost to heat in the exhaust. Besides measures to improve the thermal efficiency of the engines itself, new less complex and scalable waste recovery systems are needed to reach the maximum potential energy conversion efficiency of a Diesel engine. While first generation Rankine and thermo-electric systems are under development, their complexity and cost has to be reduced and efficiencies increased to maximize the theoretical potential. Many Challenges to optimize the system integration of waste heat recovery systems also remain. In particular the integration with respect to the exhaust aftertreatment system and the cooling system still needs further research. A hybridization of the powertrain would also result in new challenges for the integration of waste heat recovery. A general improvement of the basic heat to power or heat to electricity conversion must also be achieved.

- *Advanced cooling*

The engine cooling system is an important sub-system of the heavy-duty powertrain and must be optimized to be able to reach minimal fuel consumption for the total system. Future developments such as hybridization, downsizing and waste heat recovery also put new requirements on the cooling system. Research is therefore needed on how to efficiently cool the engine and other parts of the driveline minimizing any potential losses. This includes an increase of cooling capacity but also more flexible systems that can adapt to the cooling need more efficiently both by means of new hardware design and optimized component and system controls.

- *Alternative NO_x aftertreatment / Non Precious Metal Aftertreatment Systems*

In order to have more flexible vehicle installations which can provide high efficiency operation of the EATS system, the fundamental catalyst formulations and emission aftertreatment design needs to be co-developed in-order to reach the needed stability and durability. With such a development focus a formulation for scalability could be

found and provide an aftertreatment solution which could be applied over a wide range of different heavy-duty vehicle conditions.

- *Scalable high efficient electric components*

In order to meet the demands of HD hybridization and electrification, scalable and high efficient propulsion components need to be developed, that is tailored for the HD tasks. Component ranging from motor, drive electric transmission, charger and grid connection interfaces.

6.3.4 Preliminary themes 2017

Energy Integrated Truck

By utilization of the full vehicle the powertrain may be distributed for propulsion of individual axles and thereby create a potential for improved energy efficiency and vehicle configuration for the transportation task. The longer combinations of vehicle will also benefit in safety, on-road handling and in energy efficiency, if the vehicle propulsion is distributed to more wheels or axles. This need also provides possibilities to utilize more than one energy conversion solution on-board the truck. One example could be combinations with fully electrified axles and distributed combustion engines utilizing different fuels or energy carriers

- *Efficient heat and energy management*

The future driveline will be a complex system of energy generating, energy consuming and cooling units. The engine itself will generate heat even if a substantial improvement of the thermal efficiency will lead to a general decrease in exhaust energy and temperatures. To reach optimal conversion efficiency the aftertreatment however will under certain conditions need heat either generated by the engine or by other devices or from heat storage. The introduction of hybrid systems with possible intermediate engine shut-off will increase this complexity even further. A waste heat recovery system installed after the aftertreatment unit however will need highest possible temperatures to reach high efficiencies but care must be taken since also the demand for cooling will increase depending on the choice of the waste heat recovery concept. Other units to be considered are auxiliaries, air handling and EGR system and possibly new insulating coatings for part of the engine to decrease heat losses. The energy that is generated must then be managed, distributed and possibly stored using intelligent controls which will adapt to the specific configuration and task of the vehicle but also to the current use and driving cycles using for example intelligent e-horizon functionalities.

- *Efficient integration in vehicle energy management system*

While the efficient and flexible heat and energy management of the driveline itself will be important to increase the efficiency, a close integration into the complete vehicle management system is key to reach the maximum potential for a holistic energy management. More research is thus needed to reach an overall optimization taking all energy and heat sources and consumers in the complete vehicle into account. Reducing inefficiencies on a component level and an intelligent control system that always optimizes the whole system including intelligent eHorizon and other self-

learning capabilities are the major challenges with the main focus on the integration of the powertrain.

- *Intelligent and mission/environment adaptive powertrain controls*

Today usually map based controls are used to optimize the powertrain over the complete range of operating conditions. To ensure the compliancy with regulations, ageing and variations of components, large margins are often necessary when the control system is designed. One set of maps is used for a certain engine specification but the variation of the complete vehicle configuration and the actual applications of the vehicles are often very different. This includes for example typical applications (eg. highway versus refuse) and missions of the vehicle which typically vary substantially geographically but also from fleet to fleet. It is thus envisioned that a more self-learning, intelligent and adaptive approach always optimizing to the current conditions could contribute to a significant decrease in fuel consumption. To be able to implement robust ways of achieving an adaptive control work on self-learning and intelligent systems and algorithms is needed but could also include the addition of new sensors and actuators. A smart fusion of different information from the vehicle, its history, GPS based and traffic data but also other information coming from future ITS implementations are envisioned. Further development of more advanced powertrain controls such as model based or single cycle control is also needed to fully and flexibly optimize the powertrain in such a way. Research is needed to obtain robust controls which ensure emission compliance at every instance and over the lifetime of the vehicle.

- *Multivariable based + single cycle combustion control*

When utilizing different fuel blends the powertrain and the engine control system need to be able to adapt to the current fuel in use. Different feedback control system could be utilized for this purpose, such as fuel quality sensors, in-cylinder pressure control, torque control sensing, non-uniform speed control, EATS temperature or emission level control, etc, measuring ideally from cycle to cycle or in an integrating mode. However all these sensing systems need a control strategy that optimizes the energy efficiency for the current operational condition and that make this transition from fuel quality to fuel quality in a seam less and emission optimized way. It's therefor important to develop control strategies and reliable operation schemes that both meet the energy efficiency target and the mission legislation in a practical manner.

6.3.5 Preliminary themes 2019

Multi energy carrier drives

The future scarcity of oil and the legal demands on lowering the CO₂ foot print, in combination with refinery local limitations has already lead to local shortage of diesel fuel and a gradual demand to utilize a number of different fuel. For different regions there may be different fuel from time to time that provides the lowest energy price for the transportation task. Since an important fraction of the transportation cost is influenced by the energy price, the may be a strong demand to select the energy or fuel supply that yields the lowest

operational cost. A key element in selection the fuel with the lowest energy price is the ability to store it and use it on-board in an efficient way. The engine and the powertrain systems need therefore to be easily adoptable to a new fuel or a new fuel blend without deteriorating the energy conversion efficiency or the emission aftertreatment function. New solution need for multi fuel usage and adaptation in HD truck engines need therefore to be developed.

Different fuels requires also different levels emission aftertreatment system (EATS) solutions and control considerations to maintain the emission conversion efficiency and durability.

Innovative EATS solutions that can be adopted for a number of emission condition due to different fuel and fuel blend emissions is needed. E.g. EATS system that can function both with high and low cetane or octane fuels emissions, without deterioration effects or efficiency drop due to EATS regeneration demands etc. Potential areas to explore are:

- *Multi-fuel aftertreatment*

The new European standards for diesel fuel blends and the development towards more fossil and bio methane fuel and worldwide addition of large variety bio fuel blends for heavy-duty transport, require often oversized and expensive aftertreatment systems with a large degradation margin. In this context, new formulations and control strategies need to be developed to achieve improved multi fuel flexibility, durability and cost efficiency. New alternative and more multi-fuel robust systems of after-treatment of soot and NO_x need to be developed. Development and evaluation of new innovative concepts of NO_x after-treatment better meeting different fuel demands is needed. Due to the on-going combustion development of HCCI and its derivative solutions such as e.g. partial-HCCI or PPC which may be operated with a number of different fuel qualities, new emission solutions compatible with these process need to be developed.

- *Combustion & alternative energy conversion systems for renewable and high octance fuels (CH₄, EtOH, Gasoline, MeOH)*

Hydrocarbons produced from sustainable sources at the right scale represent an attractive energy carrier in particular for heavy-duty long haul transport due to their high energy density. Hydrocarbon fuels can in general be classified in high cetane fuels such as Diesel or high octane fuels such as gasoline or methane. For alternative fuels with high cetane number typical Diesel engine systems with minor modifications can be used. For high octane fuels such as methane, ethanol or methanol major changes to the energy conversion concept, such as e.g. the diesel engine, have to be made to maintain and improve energy conversion efficiency.. There are also new set of combustion strategies such as e.g. partially premixed combustion where the high octane number is used to achieve a high efficiency compared with low engine-out emissions which is traditionally not possible with high cetane number fuels. Research on highly efficient combustion and alternative energy conversion systems for high octane number fuels or combinations of those and Diesel is needed in able to cope with a larger future fuel variety.

- *HD propulsion by grid to vehicle energy and on board energy carrier energy utilization*

Control strategies for mixed energy sourcing of HD propulsion is essential for and optimal energy utilization. Energy planning strategies as well as energy mix and

utilization strategies need therefore to be developed to full utilize and minimize the energy cost and to improve the operational freedom of multi energy carrier drives.

6.4 Transport System Integrated Trucks

6.4.1 Preliminary themes 2014

Urban distribution concepts

Content and Scope: Ever-increasing traffic problems in cities also involve the urban supply chain, which is both affected by and a cause of such problems. If no measures are undertaken in the future, statistics show that the risk of a continuous increase in traffic volumes will be due in part to freight flows (about 20%). Such a situation affects quality of life as well as the environment, and represents a significant loss of efficiency for freight transport itself.

Today solutions are often based on restrictive policies that include low emission zones, access control, road pricing or time limits for the logistics operations.

An innovative approach to the organisation of urban freight transport is required for the future, which is in line with political strategies to safeguard the “liveability” of cities, while being compatible with efficient logistics. Clearly the vehicle itself is a key factor in the definition and deployment of such a new paradigm of urban freight delivery.

Development of:

- Solutions for safe and quiet loading and unloading operations;
- Solutions for mission management;
- Solutions for efficient transshipment (Urban/region/Long-distance);
- Freight security;
- City-region tractor with freight train capabilities including silent mode with a modular design

Expected impact: New logistic solution for efficient freight delivery in urban areas.

e-freight

Content and Scope: Increasing volumes and growing societal demands for security and sustainability have created challenges for international freight transport and logistics chains striving to improve their efficiency and visibility. A key determinant of efficiency and visibility in freight transport and logistics is the capability to draw maximum benefit from information and communication technologies. In this, e-Freight denotes the vision for a paper-free, electronic flow of information associating the physical flow of goods with a paperless trail built by Information and Communication Technologies.

This call should focus on deployment of single window platform that optimize the current e-Freight initiatives including:

- Mapping of logistics processes and information flow
- Secure, safe and sustainable logistics
- Security monitoring

6.4.2 Preliminary themes 2015

6.4.3 Preliminary themes 2016

Transport Systems for increased efficiency

To be written in 2014 update of this document

6.4.4 Preliminary themes 2019

High Productivity Transport System

To be written in 2014 update of this document

6.5 Traffic & Infrastructures Integrated Trucks

6.5.1 Preliminary themes 2014

Trucks in green corridors

Demonstrate the interactive corridor concept for a selected number of international cross border corridors including:

- Performance based standards
- Intelligent access control and vehicle follow-up
- Trucks adaptable for corridors, i.e. modularity for load units and vehicles
- Improved safety measures.

Expected impact: Show impact of optimized performance based standards i.e. flexible weight and dimensions with trucks fully adapted for corridors

6.5.2 Preliminary themes 2015

Interconnected traffic

Contents and scope: The aim to show the full benefit of cooperative system and automation in the complete logistic chain, from long-distance to the door delivery. Key areas:

- Long-distance efficiency, i.e. self-organizing platoons
- Traffic management system optimizing for mix of cooperative and standard vehicles.
- Safety
- How to improve today's restraints system if information on other cars or objects where at hand ?research if mass, velocity, trajectory could benefit both participant in an integrated safety approach ? Optimized performance ?“
- "Understand with what degree of reliability is needed in the information for safety systems.Example: Is the communication information so reliable so an airbag can be deployed in advance fore maximum protection ? “

- "How is it possible to establish a mutual trust between vehicles. Research on Dependability and Security of information flow between cars."
- more than V2X : restraints system are still too un-flexible to tune to specific load cases on the spot.
- "Which are the most critical factors to achieve robust mobile communication ? How can timing be accurately predicted in those systems ? System understanding due to high velocity environment and movement between cars."
- Introduction Strategies of V2X systems/functions

Continuous grid connections

Contents and scope:

Stationary charging of EV's is not enough to facilitate an extensive transfer of energy supply to road vehicles from combustible fossil fuels to electricity, due to battery energy density and charging power limitations. However, technologies for a continuous supply of electric energy during driving have the potential to transfer almost all road traffic to electric energy, from small cars up to heavy duty long haul trucks. Both inductive and conductive versions of such technologies, here called Electric Road Systems, exist as prototypes or early commercial versions from several suppliers worldwide. Successfully applied, these technologies have the potential not only to a paradigm shift in energy supply but also to a general big increase in energy efficiency for road transport.

This call is intended to facilitate further development and demonstration of ERS technologies. Projects should address one or more of the following key research questions:

- Electric road system design and impacts (on societal level)
- Road power supply technology (conductive, inductive or capacitive)
- Design of the vehicle power pick-up solution (wireless as well as conductive)
- Related On board vehicle power electronics
- Safety issues
- Vehicle identification and billing technology
- Electric Power System impact
- Standardisation of road and vehicle interface

Automated safety & efficiency

Contents and scope:

Large scale demonstrator on automated safety and efficiency applications, e.g. platooning. The aim of the demonstrator is to overcome barriers for deployment and should show:

- Driver acceptance
- Error-free interaction of driver with semi-autonomous assistance
- Functional safety of system
- Validate efficiency and safety gains.

Based on earlier project like e.g. SARTRE & TEAM

6.5.3 Preliminary themes 2016

6.5.4 Preliminary themes 2017

Trucks in new corridors (large scale project

To be written in 2014 update of this document. The

6.5.5 Preliminary themes 2018

Automated traffic

To be written in 2014 update of this document

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8 Acronyms and Abbreviations

AMI	Automatic Metering Infrastructure
APU	Auxiliary Power Unit
BRT	Bus Rapid Transit
BTL	Biomass to Liquid
CCS	Carbon Capture and Storage
CH	Carbon Hydrogen
CNG	Compressed Natural Gas
CTL	Coal to Liquid
DME	Di-Methyl Ether
DSM	Demand Side Management
EV	(Full) Electric Vehicle
EVSE	Electric Vehicle Service Equipment
FCEV	Fuel Cell Electric Vehicle
GHG	Green House Gas
HCCI	Homogeneous Charge Compression Ignition
HDT	Heavy Duty Truck
HEV	Hybrid Electric Vehicle
HVO	Hydrotreated Vegetable Oil
ICE	Internal Combustion Engine
ICT	Information and Communication Technology
ISO	International Standards Organisation
LEV	Light Electric Vehicle (like e-bikes, motorbikes and small cars)
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
OEM	Original Equipment Manufacturer
PHEV	Plug-In Hybrid Electric Vehicle
R&D	Research and Development
RTD	Research and Technology Development
SAE	Society of Automotive Engineers
SNG	Synthetic Natural gas
SUV	Sports Utility Vehicle
V2G	Vehicle to Grid
WPT	Wireless Power Transfer
ZEV	Zero Emission Vehicle