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Executive summary

There is no doubt that road transport will continue to lay its foundation for sustained economic development. If one thinks of modal shift as an alternative option for long haul trucking (*distances above 300km*) in the EU. A 50% shift would result in greater share of short haul road freight transportation with the tonne.kilometers of non.road transport accounting for about 30% in total.

Technologies like digitization and vehicle connectivity are already a market reality that will continue to grow, yet we always have this question as to: whether this growth will effectively capture the value creation opportunities offered at the interplay with value drivers of the logistics industry?

Also the changes in structure of our society also influences the way goods and services are delivered. Some of the key changes that influence road freight transport are:

- Congestion in road infrastructure
- Ageing population
- Automation and ubiquitous connectivity
- Changes in regulation supporting eco-friendly solutions

The above forces will influence vehicle design and supply chains and the answer to this will be determined by whether public and private stakeholders manage to successfully design and implement the enabling conditions required to overcome the challenges discussed in some of the topics.

As solutions evolve rapidly, so too must the European Commission work continuously to evolve its regulatory environment and governance in order to create a platform where technology can provide benefits. When you look at the recent changes in the directive on Weights and Dimensions, a payload of one additional ton is allowed for alternative technologies like hybrid electric systems, but the additional one ton is not valid for an articulated vehicle, thus putting solutions like TRANSFORMERS at a disadvantage, as it results in loss of payload!

Looking ahead with a broader perspective, one can envisage staggering benefits, though it remains an open question to what extent and how fast this potential will be harnessed.

From the perspective of trailer industry the following issues need to be addressed for future concepts:

**No disadvantage in payload and volume**

Additional components for "Hybrid on Demand" (HoD) will add weight to the truck and trailer combination. Using a trailer with such components would mean economic disadvantage in payload for transporters in the competition. Interaction between shippers and transport companies would be more difficult, for different payload standards.

For legislative matters the weight of the hybrid system should be subtracted from the legal total weight of the truck/trailer combination. Legislation already allows 44t of payload for combined transport via railway.

Trailer manufacturers have to create a transparent display of weights for executive organisations. This needs standardization in the European context.

**Common interface between truck and trailer**

Using technologies like "Hybrid on Demand" or energy management can put energy to a better use and reduce waste. Therefore a new level of communication between truck and trailer is needed. Here, there will be a new level of electronic interface between the units.

Missing industry standards have often stopped technologies’ success. Sometimes inferior systems have made it to market, because they could define the standard first.

A moderated process between truck and trailer manufacturers should bring a European standard for the interface that enables "Hybrid on Demand" and energy management. It should be based on the existing standard ISO 11992.

**Energy management systems inside the trailer**

One of the key success factors of road transport with truck/trailer combinations is its flexibility. Trucks can be exchanged with different trailers. Even if it has a common interface to the truck, the future trailer should still be able to manage the energy-system inside, by itself. So even if the truck is not equipped with steering systems the trailer should be able to adjust the roof or the "Hybrid on
Demand” to the best conditions. Otherwise the potential for saving energy is lost, as soon as a non-equipped truck picks up a trailer.

**No economic disadvantage through aerodynamic measures**

Commercial vehicles and especially trailers are optimized to offer maximum payload and volume. Aerodynamic measures like air diffusors or spoilers may add length or height to the trailer. So using these would have a large impact on the volume available for transport. Legislation should also take aerodynamic measures out of the calculation for length measurements, as already quoted in the Council’s position (EU) No 1/2015. Restrictions from road safety and road infrastructure need to be taken into account.

**Make changeover to new technology easier for users**

The transport companies’ business is under heavy competition with average margins of 1-3% and a significant higher rate of insolvency proceedings than the average business. Average quota for equity capital is around 16.1% (ref: Wittenbrink, Paul (2014): Transportmanagement, Kostenoptimierung, Green Logistics und Herausforderungen an der Schnittstelle Rampe, 2. Auflage, Springer, Wiesbaden, 2014.) and therefore the possibilities to invest in new technologies are very limited. Every financial incentive that reduces the amortization period for investments makes the changeover to ecological friendly technologies more likely.

**Include “Hybrid on Demand” in national registration options and EU-harmonization**

For transporters it is important to be sure that registration of a trailer with “Hybrid on Demand” systems is possible with their national authorities and that for international hauliers this is recognised across Europe. It is important to create legal certainty here, and harmonisation of legislation across Europe to allow “Hybrid on Demand” systems is required and in particular to deal with the electric brake on the trailer which is essential to recuperate energy.

**High Capacity combinations**

A few possible outcomes that could be realized with longer vehicles, intelligent assets and modular concepts that are to be further designed, developed and deployed in accordance with Physical Internet principles. TRANSFORMERS offers new technical options to save energy in road transport. To get these concepts to maturity and create benefit for society, political support is a major trailblazer. However a pure TRANSFORMERS is not enough. As goods get lighter maybe there will be a need for longer – voluminous vehicles to do more with less or if goods get heavier one may not need a lot of volume but relaxation in weight restrictions or a combination of both. To get more from current regulations conditions infrastructure must also be well suited.

The deliverable looks at different combinations for high capacity combinations for different goods types as seen in the figure below:
Along with various vehicle combinations

25.25 m

For the 25.25 m combination: The total allowed weight of the combination when loaded is 80 tonnes, and the load capacity is 50 tonnes. It is used for terminal to terminal transports for consumer goods where the average total weight is 60 tonnes. The combinations rarely reach the maximum allowed weight due to the low density of the goods (on average 160 kg/m³. The tests show that compared to a tractor with a single semi-trailer, the DUO-trailer combination can transport the same amount of goods with 73% of the fuel, i.e. a transport efficiency improvement by 27%.

The TRANSFORMERS combination aims to improve the transport efficiency of tractor and semi-trailer combinations, specifically for palletized goods, by the improving load optimization and load efficiency, improved aerodynamics, and by the use of a distributed “Hybrid on Demand” system. To take further steps to increase road freight efficiency, it is necessary to explore how the measures can be applied for other industry segments and vehicle combinations. The load optimization and load efficiency measures designed for palletized goods can be applied to other current combinations such as a truck and trailer combination, as well as for longer and heavier vehicle combinations. In the case where a combination consists of two loading units, additional challenges to manage (un)loading of both units in an efficient way becomes important to handle. The aerodynamic features also need to be developed to handle the gap between the units.

For other industry segments such as bulk goods and container transports that were identified as interesting for longer and heavier vehicle combinations, similar challenges as for the tractor and trailer combination exist. However, the solutions will look different as the design of the units and the optimal combination design will vary. The high capacity vehicle combination examples show that there are significant efficiency improvements in longer and heavier vehicle combinations, particularly when the combinations are optimized for the transport assignment. With additional improvements to aerodynamics and further optimized drivelines, larger gains can be expected. It is clear that all vehicle combinations are not suitable in all types of transports and logistic types. There is also a limit
in infrastructure for the size and weight of vehicle combinations. To be able to use the potential efficiency improvements there is a need to match efficient vehicle combinations to the infrastructure where the impact is high and where the infrastructure can handle the combinations. The applications may vary from heavy transports from sea harbors to dry harbors where the goods flows are high, to long distance transports on the main transport routes in Europe. Currently, longer and heavier vehicle combinations are not commonly used on the European road network. Sweden and Finland are the only countries where such combinations have been very extensively used and have been commonly accepted for a very long time. However, other countries have also started to show an interest in the use of such vehicles and have started trials. The most advanced trialing is taking place in the Netherlands and in Denmark. Also in Germany, Belgium, Norway and Spain are trials taking place. Official evaluation reports of these trials have further illustrated the advantages of the use of such combinations in terms of efficiency, road safety and environmental performance. Further development of the use of such combinations is still restricted by European legislation. Further modifications to extend the scope for the use of longer and heavier vehicle combinations could open new opportunities for their deployment and for the deployment of the Transformer solutions.

Further research in this area is necessary. Extensive information on the use of these combinations in the EU, including trial evaluation reports for the Netherlands, Denmark and Germany can be found on the following website: [http://www.modularsystem.eu/](http://www.modularsystem.eu/)

Thus as summarized above, the deliverable report covers broadly on topics on new length combinations and measures concerning load efficiency, load densities and load optimization methods which can be applied in present and future truck-trailer combinations other than the tractor-semitrailer combination which is the target application for the TRANSFORMERS project.

The report also highlights trends that can impact the future of the goods supply chain and how these trends can affect road transport. It also shows that despite aiming for a modal shift, road freight will continue to be a major mode by means of which products will be moved efficiently in terms of Tonne.kilometers. It also discusses various longer and heavier combinations, load optimization options and technological advances which the authors believe have the ability to improve lives, transform industries and safeguard the planet. It also provides an opportunity to debate technological, societal, economic or environmental risks and concerns that the concepts may pose prior to widespread adoption.
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1. Introduction

The freight transport and logistics industry is an important driver of economic growth in Europe. In parallel, man-made greenhouse gas emissions and their contribution to climate change are among the biggest global challenges and will increasingly shape the way we should approach logistics and transportation needs in the near medium and long term future. Global society needs to actively address the global greenhouse gas challenge by building sustainable models for reliable, efficient, safe, clean and affordable freight transport and logistics that supports the needs of a growing, shifting, globalizing and digitizing population.

Supply chain managers might think that demographics and consumer dynamics matter only to economists, marketers, and government policymakers. But in fact these factors have a tremendous impact on international trade patterns and distribution logistics. That’s why evolutions in consumer behavior are so important to be monitored by supply chain managers.

1.1 Mega Trends

A. Congestion

Congestion is a result of scenarios where the annual vehicle movements on the road far surpass that of annual highway mileage capacity. With strong trends in more and more consumers moving to digital lifestyle and shopping habits changing i.e. purchasing one off products online and expecting same day delivery as value add, downscaling and visiting stores frequently or shippers trying to find out new ways to deliver consumers to meet their need, is adding stress particularly to the urban infrastructure.

Traffic congestion has a number of negative effects, namely:

- Increased wasted time resulting in non-productive activity.
- Delays resulting in missed opportunities and commitments.
- Inability to forecast travel time accurately.
- Wasted fuel increasing air pollution and carbon dioxide emissions.
- Wear and tear on vehicles and infrastructure.
- Stressed and frustrated motorists.

This would particularly impact city logistics and last mile distribution in the supply chain.

B. Ageing Population

In many countries, populations are noticeably aging due to falling fertility rates, this combined with longer lifespans due to improved work conditions, health care, and sanitary conditions are contributing to an aging population and a smaller labor force. The net result is that many emerging and developed economies will have a smaller percentage of their populations supporting those who are too young or too old to work. In line with this trend, population growth has been stagnant in many European countries. Such a population will demand for different types of products and services. The UN projects that close to 2 Billion people will be above the age of 60 during 2050 versus 0.5 Billion in 2015, the distribution and extension of lifespan is seen in figure below:

C. Automation and ubiquitous connectivity

Automation could reduce the total cost of ownership for medium and heavy trucks by 35 percent compared to current levels, as vehicle utilization increases and other parameters change due to the phase-in of autonomous driving capabilities. A recent McKinsey study shows that the Level 5 automation (Level 5 is where vehicle becomes fully autonomous and it’s performance becomes equal to that of a human driver under all driving scenarios) will reduce the TCO by up to 35%, thus enabling stakeholders to generate the necessary financial means to pay for the extra costs of the technology.

Full automation will also change utilization patterns of logistics vehicles, especially of trucks. Specifically, we expect trucks to operate for much longer periods on the road since no driver will be necessary. The resulting higher utilization (in terms of hours per day) will likely make it possible for operators to reduce the size of their fleets – although this comes at the cost of shorter average truck lifetimes.

D. Urbanization

Urbanization holds important implications for supply chains. The increasing levels of urbanization and the concurrent development of "megacities" worldwide will place greater pressure on supply chain managers to ship goods via parcel delivery to consumers, to better manage intracity and intercity logistics, and to further increase productivity in the food supply chain.

With urban mobility accounting for 40% of all CO2 emissions of road transport and up to 70% of other pollutants from transport. A continuing trend towards urbanization, coupled with strong population growth, suggests that by 2050 an additional 2.5 billion people will be added to cities around the world, by which point, two-thirds of the world’s population will be based in urban areas. (United Nations, Department of Economic and Social Affairs, Population Division. World Urbanization Prospects: The 2014 Revision, 2014.) At the same time, cities will continue to become even more densely populated. Today, the world has over 20 megacities (cities with more than 10 million people). In the coming decades, there could be over 50 megacities worldwide. According to McKinsey Global Institute, by 2030 over 60% of the world’s gross domestic product will be generated by a mere 600 cities.

Urbanization rates (or the percentage of the population that resides in an urban setting) had stabilized in most developed countries by the 1900s. The U.S. urbanization rate did not surpass the 50 percent mark until 1920, and by the 1990s three out four Americans lived in an urban area. Strong drivers of "going urban" are industrialization, higher agriculture productivity, immigration, and the attraction of the "bright lights" of the city.
E. Green regulation

Transport is an important building block in the EU energy-climate policy. Europe's climate and energy package includes targets for 2020 for energy efficiency, a target minimum share for renewable energy and targets for reducing greenhouse gas emissions. These cannot be reached without a significant contribution from transport. The Commission’s strategy to reduce CO₂ emissions and fuel consumption from heavy goods vehicles starts primarily with VECTO, which is a simulation tool that can calculate expected fuel consumption and CO₂ emissions from new heavy goods vehicles. Secondly, the Directive on alternative transport fuels and their infrastructure (Directive 2014/49) is putting targets for the deployment of alternative fuels and their infrastructure. Thirdly the July 2016 Communication on Low Emission Mobility is setting out a number of measures to further green road transport. This includes the introduction of performance standards (CO₂ and fuel consumption) for new heavy goods vehicles.

The indicator of infrastructure taxes and charges for heavy road vehicles is governed by a separate Directive (Directive 2006/38/EC). By laying down common rules on how EU states may charge heavy goods vehicles for using the road network, the 'Eurovignette' Directive aims to ensure that road usage better reflects its true impact on society and the environment. It does this by introducing a "user pays" and a "polluter pays" principle. An aim of this Directive is to shift freight away from roads onto other less-polluting modes of transport such as rail and waterways. The indicator tracks the impact of the Directive. This is not CO2 related yet. However in an upcoming revision, expected in 2017, the Commission wants to build in a CO₂ component.

Directive 2001/14/EC (last amendment by Directive 2007/58/EC) sets out the allocation of railway infrastructure capacity and the levying of charges for the use of railway infrastructure and safety certification. Charges are set and collected by an independent charging body; generally the infrastructure manager provided it is not dependent on the railway undertakings. The Directive defines the minimum access package and the mandatory access to services to which railway undertakings are entitled. The undertakings in turn are under an obligation to provide certain mandatory services, to which additional and ancillary services may be added.

F. Summary

Having briefly described the trends above, the trend chart developed by the Consumer Goods Forum clearly highlights as to where the supply chains are heading.
Supply chains of the future will have to be more transparent, nimble and greener. One approach that comes to mind in order to become green is to shift long distance road transport to non-road transport. Looking at the figure below, to the left side of the graph - what we can clearly see is that in today’s date road transport in Europe has the largest percentage share of tonne.kilometer’s moved in inland transport and accounting for 81.5% of the ton kilometers. If we apply a 30% modal-shift in long haul trucking to non-road transport, we can see that the non-road transport will constitute around 25% of the total tonne.kilometer and road would still account for 75% of the tonne.kilometer’s, however this will increase the share of short haul trucking in road freight transport from 45% to 56% tonne.kilometer as seen in the figure below.

Similarly for a 50% shift of long haul trucking to non-road transport (figure below) will improve non-road transport’s share from 18.5% to 30% of the total inland ton-kilometer; however road will still accounting for 70% of the total tonne.kilometer’s. As seen in the scenario analysis above we see increased share of short haul trucking in road freight transport from 45% to 69% of the tonne.kilometer’s.

**Inland Road Transport 2030 Whitepaper Scenario**
30% mode shift to non-road

**Inland Road Transport 2050 Whitepaper Scenario**
50% mode shift to non-road
G. Outcome from TRANSFORMERS Workshop on Future Concepts

The TRANSFORMERS project focuses on three main areas for the development of efficient vehicle combinations, a hybrid-on-demand system, aerodynamics of complete vehicle combinations, and load optimization and efficiency. To explore how the measures developed in the project, and specifically how the measures in task 4.2 concerning load efficiency, load densities, and load optimization methods, can be applied in present and future truck-trailer combinations, future concepts have been explored during a project workshop. The ideas of the project partners were collected and assessed in the workshop.

A total of 3 future concepts workshops were held, with one workshop limited due to the terror attacks in Brussels. The aim of the first workshop was to tap into the learnings of visiting distribution centres, interacting with logistics and vehicle experts and shape a roadmap on various components in the transport and logistics along with external factors that would influence the vehicle concept of the future.

The figure below shows the proposed potential directions for the Future concepts beyond TRANSFORMERS, and external factors that can influence vehicle design. In the chapters below we will explain topics that have been mentioned in the metro map.

Some of the topics mentioned in the map have briefly been explained in Annex 01, since they do not form the core of the deliverable but mainly act as influencing factors.

Having developed the trend map a second workshop was undertaken where the key members were participants of Task 4.2 and a voluntary participation of other project partners to share their insights. The aim was to discuss future concepts for longer and heavier vehicles, and to elaborate on some of the key areas of interest for the deliverable. The outcomes of these discussions have been elaborated in the chapters below. We structure the chapters according to the description of work where we start discussing on longer and heavier combinations, followed by load optimized concepts. Additional topics that are not a part of the description of work, but discussed during workshops have been included as annexes.
Sustainable logistics
2. Discussion on Longer and Heavier Combinations

One of the main tasks of the deliverable is to look at the future concepts for longer and heavier combinations.

2.1 Method

The participants in the workshop attempted to answer three questions related to high capacity vehicles and how applicable the load efficiency, load densities and load optimization measures developed in TRANSFORMERS can be applied to other vehicle combinations. The participants were divided into groups of 2-3 people to discuss each question. The results from each group was then presented and discussed together with all workshop participants.

1. In what types of transport assignments do high capacity combinations have the most potential to be efficient? Consider type of industry segment, type of routes (regional, national, international etc.), type of combinations, and list the three transport assignment examples.

Examples of industry segments considered in the workshop:

- Agriculture
- Daily Commodities
- Consumer goods
- Industrial
- Container Transport
- Parcel & Post
- Building & Construction
- Mining
- Forest & Paper
- Petroleum & Chemical
- Public Service
- Waste & Recycling

Examples of high capacity vehicle combinations

25.25 m

![25.25 m diagram]

27.5 m

![27.5 m diagram]
2. Considering the three examples, could the TRANSFORMERS volume optimization and load efficiency solutions be applied? If so, how?
   - Consider e.g. increasing inner space, double floor options, moveable roofs, load volume indicators, efficient loading/unloading solutions.

3. Do the high capacity vehicle combinations in your examples have other, new challenges when it comes to volume optimization and loading efficiency compared to the TRANSFORMERS combination?

2.2 Results

The industry segments considered being most suitable for high capacity transports were palletized goods such as daily commodities and consumer goods, bulk goods such as agricultural, petroleum and chemical, and container transports.

Palletized goods including e.g. daily commodities and consumer goods stand for a 41% of the goods shipped in Europe (D1.1). Efficiency improvements could be considerable for terminal to terminal transports where large goods flows are currently the case today. These types of transports are often volume limited and the increased length of the vehicle combination can improve transport efficiency considerably.

For palletized goods, the TRANSFORMERS measures for load optimization and load efficiency can be implemented for other combinations. The flexible floor would increase load optimization for also other types of units than the semi-trailer in TRANSFORMERS, e.g. for a truck box or full trailer. Longer combinations would in most cases consist of more than one loading unit, and the efficiency at terminals for loading and unloading needs to be considered. The units takes up more space at loading bays and solutions to position the vehicle in terminals, at loading bays etc. would be beneficial, as well as solutions to make the (un)loading more efficient.

Figure below shows a high capacity test vehicle from the DUO-trailer project (duo2.nu), a Swedish national project. The combination consists of a tractor and two semi-trailers connected by a dolly with the total length of 32 m. The total allowed weight of the combination when loaded is 80 tonnes, and the load capacity is 50 tonnes. It is used for terminal to terminal transports for consumer goods where the average total weight is 60 tonnes. The combinations rarely reach the maximum allowed weight due to the low density of the goods (on average 160 kg/m³). The tests show that compared to a tractor with a single semi-trailer, the DUO-trailer combination can transport the same amount of goods with 73% of the fuel, i.e. a transport efficiency improvement by 27%.
The DUO-trailer combination consists of a tractor and two semi-trailers connected by a dolly.

Considering the aerodynamic measures of the TRANSFORMERS project, such as the moveable roof, side skirts, boat tail and front bulk head, they could with some adaptations be applied to the longer and heavier combinations such as the DUO-trailer. The gap between the trailer units is, however, an additional aerodynamic challenge to consider. For the distributed hybrid system, the longer combinations make it interesting to evaluate the possible benefit to electrify several units, such as the second semi-trailer and the dolly. A very important consideration is the added weight for any type of features for load optimization, aerodynamics or a distributed hybrid system. For a feature to be efficient it should both give higher efficiency improvements than the negative effect of its own weight, and any reduction in loading capacity of the combination. For volume limited goods the risk of having a decreased loading capacity is generally lower, and may possibly have greater effects than for weight limited transports.

For bulk goods the vehicle combinations are often designed specifically for the task and there is a need to transport large amounts of goods in specific routes. In this case it would be beneficial to be able to transport more goods with one vehicle combination and increase the efficiency in CO₂ per tonne.km. This transport segment is weight limited and there is a need to transport more weight, but the length of the vehicle is not usually a limiting factor. The load optimization and load efficiency measures from TRANSFORMERS are not directly applicable as the loading units have a very different design and way of (un)loading. However, a low roof height is desired to keep the aerodynamic drag to a minimum.

Figure below shows a truck with dolly and semi-trailer of 25.25 m from a Swedish national test (http://www.volvotrucks.se/sv-se/trucks/hct.html). It has a total weight of 80 tonnes and a 56 tonnes load capacity. The combination has been proven have an increased transport efficiency of 25% compared to a 60 tonne combination. The density is approximately 1500 kg/m³, almost ten times higher density compared to the palletized goods in the DUO-trailer transports.
Due to the regulatory requirements for maximum axle weight and distance between groups of axles, the combination cannot be made shorter than 25.25m and the gap between the truck and the semi-trailer is large and cause high drag forces. Hence, managing the gap between units is an important consideration, also for this type of industry segment and combination type. The combination is usually loaded to its maximum allowed weight and any type of features that add weight means that the load capacity will decrease. For weight limited transports like this one, it is even more important that added features increase the overall transport efficiency even when the load capacity decreases.

The third segment considered is container transports, specifically to increase the efficiency in intermodal transports, to, from and within harbors and other confined areas. As the container units used in most transports are 20, 40 or 45 feet, the vehicle combinations need to be specified to manage those. The efficiency improvements can therefore be made stepwise, by adding another container to a combination. The allowed weight for containers is 25 tonnes for a 20’ container and 27.6 tonnes for a 40’ container. The maximum density for 20’ containers is thereby 753 kg/m³ and for 40’ containers 408 kg/m³. The container transports can be both volume and weight limited, and used for both 20’ and 40’containers, which cause some challenges in optimizing the vehicle combination. Specific aerodynamic and hybrid driveline features operate in very different weight and configurations of the combination.

Figure below shows a test vehicle combination from a Swedish national research project of approximately 23 m, consisting of a tractor, link and a semi-trailer. The maximum allowed weight considering the two 20’ containers of maximum 25 tonnes and the combination weight of 18 tonnes, is 68 tonnes. Compared to a tractor with a semi-trailer, the test vehicle combination has a transport efficiency improvement of 35%. However, improved aerodynamics and possible benefits of hybrid drive of the combination needs to be considered for container transports as well as for the previously presented transport examples.

![Test vehicle combination of 23 m, consisting of a tractor, link and a semi-trailer, carrying two 20’ containers.](image)

### 2.3 Discussions and conclusions

The TRANSFORMERS combination aims to improve the transport efficiency of tractor and semi-trailer combinations, specifically for palletized goods, by the improving load optimization and load efficiency, improved aerodynamics, and by the use of a distributed “Hybrid on Demand” system. To take further steps to increase road freight efficiency, it is necessary to explore how the measures can be applied for other industry segments and vehicle combinations. The load optimization and load efficiency measures designed for palletized goods can be applied to other current combinations such as a truck and trailer combination, as well as for longer and heavier vehicle combinations. In the case where a combination consists of two loading units, additional challenges to manage (un)loading of both units in an efficient way becomes important to handle. The aerodynamic features also need to be developed to handle the gap between the units.
For other industry segments such as bulk goods and container transports that were identified as interesting for longer and heavier vehicle combinations, similar challenges as for the tractor and trailer combination exist. However, the solutions will look different as the design of the units and the optimal combination design will vary. The high capacity vehicle combination examples show that there are significant efficiency improvements in longer and heavier vehicle combinations, particularly when the combinations are optimized for the transport assignment. With additional improvements to aerodynamics and further optimized drivelines, larger gains can be expected. It is clear that all vehicle combinations are not suitable in all types of transports and logistic types. There is also a limit in infrastructure for the size and weight of vehicle combinations. To be able to use the potential efficiency improvements there is a need to match efficient vehicle combinations to the infrastructure where the impact is high and where the infrastructure can handle the combinations. The applications may vary from heavy transports from sea harbors to dry harbors where the goods flows are high, to long distance transports on the main transport routes in Europe. Currently, longer and heavier vehicle combinations are not commonly used on the European road network. Sweden and Finland are the only countries where such combinations have been very extensively used and have been commonly accepted for a very long time. However, other countries have also started to show an interest in the use of such vehicles and have started trials. The most advanced trialing is taking place in the Netherlands and in Denmark. Also in Germany, Belgium, Norway and Spain are trials taking place. Official evaluation reports of these trials have further illustrated the advantages of the use of such combinations in terms of efficiency, road safety and environmental performance. Further development of the use of such combinations is still restricted by European legislation. Further modifications to extend the scope for the use of longer and heavier vehicle combinations could open new opportunities for their deployment and for the deployment of the Transformer solutions.

Further research in this area is necessary. Extensive information on the use of these combinations in the EU, including trial evaluation reports for the Netherlands, Denmark and Germany can be found on the following website: http://www.modularsystem.eu/
3. Load Optimization

Optimization of loading of a vehicle is another way to reduce the number of trucks on the road and the overall carbon footprint coming out of road transport.

3.1 Load Density Monitoring

Load density monitoring depends on two indicators that have been subject in some deliverables in TRANSFORMERS, the weight and the volume of a shipment.

The weight and volume of the pallets are known in the Distribution Centers (DC’s), but the data is not added to shipment data. The easiest method would be to add the data from the products (packed pallets) to freight letters so the data gets into shipment data systems. If the data from the pallets would be in shipment data systems all what is needed to optimize or analyze the trailer filling would be available. From the volume and weight, pallet heights can be calculated. This would be the easiest way to get insight in these important data.

The weight of vehicles is monitored in the truck and the trailer, so in theory the data could be collected from this per shipment. But commonly the sensors from the systems are not calibrated so the figures are not accurate enough to collect good data. The load volume indicator is in development and the accuracy of these sensors also needs to improve.

Thus, in near future it would be best to develop systems that would transfer the data of pallets into the data systems of the shipments to be able to do load density monitoring.

3.2 Adjustable Trailer Shape

The idea behind adjustable trailer shape comes from the TRANSFORMERS concept of a moving roof. Wherein a vehicle can benefit from aerodynamics when the weight restriction has reached. The roofs must move to an optimal height based on the data provided by the sensors. This concept works well for heavier goods where the load volume is underutilized and the aerodynamic shape of the vehicle changes. The following solution has been discussed in TRANSFORMERS Deliverable D 4.2, but the sensors have not been integrated in the prototypes in order to study the practical application of this solution.
### 3.3 Adjustable Truck Shape

The idea behind adjustable trailer shape comes from the TRANSFORMERS concept of front bulk head and side diffusors. The air deflector on the truck can be adapted based on the height of the trailer roof. This is a add on aerodynamic feature that is added to the tractor, but is controlled based on the position of the roof that the trailer is in. As far as warehousing and logistics operations is concerned these features do not interfere much except for their impact on the payload.

![Adjustable Truck Shape Diagram]

### 3.4 Space reduction between truck and trailers

The most fuel efficient and profitable trucking fleets employ aerodynamic trucks that minimize the gap between the truck and trailer. With a hydraulic driven dish plate, which can slide on the truck frame in length direction, the gap between truck and trailer can be closed while driving in straight line. The system must be strong enough to withstand all forces that can be applied on the dish plate. When the front wheels of the truck goes in a corner the cylinder must open the gap and push the dish plate away from the carbine while turning. Such a system is foreseen not to impact the logistics operations and work smoothly when taking a turn while driving.

![Space Reduction Diagram]
3.5 Megatrailer and Swap Bodies

There is an on-going discussion about new truck / trailer combinations in Europe. Large volume trailers have been used in the Nordic countries, especially Sweden, for a long time. These “road trains” are very useful for long distance, high volume transport. The Netherlands have issued permanent registrations for such truck / trailer combinations. Germany is running a field test and the number of participating federal states is increasing. There is a high potential for fuel savings, around 15% -25% in comparison to a standard trailer (Bundesanstalt für Straßenwesen („bast“)(2014): Feldversuch mit Lang-Lkw, Zwischenbericht, Bergisch Gladbach, September 2014). But since the usage profile is very specific (high volume goods, no stops in urban areas, well defined tour, and docks that can handle longer vehicles) the limiting factor is the changeability of the tour. With rough estimation, around 2 % to 9% of transport in Germany could be replaced by road trains. (Bundesanstalt für Straßenwesen („bast“)(2014): Feldversuch mit Lang-Lkw, Zwischenbericht, Bergisch Gladbach, September 2014) For transport companies the compatibility of road trains with their existing vehicle fleet is of major importance. The combination displayed above requires mainly investment in a powerful pulling unit and a dolly. These investments are minor in comparison to other truck / trailer combination. The rear unit can be used as a standard trailer. The truck can be used as a single unit. Still these new units create price pressure in transport, since users of road trains can offer better prices than their competitors can.

The first step in TRANSFORMERS was to develop concepts that are suitable for the “workhorses” of European transport: Standard tarpaulin trailers and box trailers. If an aerodynamically adjustable roof and “Hybrid on Demand” proof to be useful in the given context, the concepts should be scaled to other trailer types. The logical next step would be to include the adjustable roof and “Hybrid on Demand” into Mega-Trailers. Here there are additional restrictions: because of the lower ride height of the Mega, the hybrid has less build space available. Obviously for swap-bodies there is no possibility to adjust a roof. But “Hybrid on Demand” would still be a useful technology in the area of container-transport.

3.6 Standardization in pallet height

Pallets have a standardized length and breadth, for example: Euro pallet has length and width of 800x1200 mm. However, height is not standardized, and is free for the manufacturer to choose. In D4.2 it has become clear that double stacking of pallets can bring benefits to loading efficiency. If the height of pallets could be more standardized it would bring even a lot more efficiency gains. In the picture below it can be seen that trailers will be filled optimally if the pallet height is the internal height of trailer minus 100 divided by “X” (2700/“X”mm) or a plurality of it. So if the standard pallet height would be i.e. 900-1350-1800mm a lot of combinations can be made to fill the trailer up to 100%.
Replacement of Europallets by Modulushca boxes would have a similar effect

3.7 Autonomous Loading and Unloading

Automatic (un-)loading systems can reduce the effective time needed to get goods in and out of a trailer. Uptime is reduced and the effective utilization time of the trailer goes up. Increased productivity of the single truck/trailer combination helps to reduce non-productive activities. Today there are already a lot of technologies available for automatic (un-)loading of goods from a vehicle. But in many cases the systems are not working with a standard trailer and quiet often expensive equipment needs to be installed in the Distribution Centre’s. A system that would work “autonomous” with a standard trailer and on a standard dock would open a lot of possibilities.

A big aluminium plate where the pallets are pre-loaded on with rollers in the bottom would only need some flat surfaces in the trailer and in the floor of the DC, usually they are very flat. The plate has the same dimension as the internal dimensions of a trailer. You can also pack the plate to the optimal aerodynamic shape very easily. The plate is shifted into the DC, out of a previous trailer who brought the plate. In most DC’s they may have the place for it. It can be loaded in the DC from all sides and independent from a trailer. When it is filled the trailer comes to the DC and picks it up.
When the plate is filled and the load is secured the plate is pushed into the trailer, in one go. The wheels steer the plate into the trailer. It also could be possible to do a volume and weight check of the plate before it goes into the trailer.

Plate halfway the trailer.

Trailer completely filled.
Compatibility with automatic (un-)loading systems

Automatic (un-)loading systems can reduce the effective time needed to get goods out of or into a trailer. Uptime is improved and the effective utilization time of the trailer is higher. Increased productivity of the single truck/trailer combination helps to reduce waste.

Today there are already a lot of technologies for automatic (un-)loading available. But in many cases the systems are not working with a standard trailer. Usability in a highly flexible business environment is limited, since dedicated trailers with special equipment are needed. For fully automatic loading it is necessary to have a smooth trailer interior with defined dimensions. An industry wide standard for trailer dimensions, standard equipment with smooth floor and side walls and an information exchange standard would help to spread automatic loading systems.

3.8 Lightweight materials

There are different ways to achieve lightweight design. The first is the conceptual lightweight design, where a highly integrated part combines multiple functions. The second way is to design for lightweight construction, where you analyze load cases for new designed parts and optimize the geometry to be able to remove as much material as possible. The third way is the lightweight material construction, where you use new lightweight materials to substitute heavier materials like steel. Trailers or trailer components can be designed using carbon fiber reinforced plastics (CFRP). These developments already have been done, some prototypes have been built and have won several design awards for technical innovation. A mega curtain-sider trailer and a reefer have been built.

The trailer with chassis and deck in carbon fiber sandwich composites, it has reduced the weight of the trailer, while still meeting the required levels of strength and stiffness. With the new optimized designs the trailer is approximately 3,500 kg lighter than a trailer made from steel. Also the design freedom provided by sandwich composites allows to produce a more aerodynamic shape.

The Trailer is only a prototype because of the enormous costs of the base materials and the amount of work to build the trailer and the components. If there will be developments in the price of the components and automation or reducing the labor it can be a future material for trailer building.

[Website Link]

3.9 Modularization and physical internet for load optimization

The logistics in the supply chain is constantly evolving, take for example shipment moving from Le Havre to Chicago. Looking at the bar’s in the bar chart the top and bottom i.e. the ‘pink’ and ‘blue’ section represent the costs related to road transport and the blocks in between represent the costs linked to maritime transport including container cost. In the 1960’s maritime cost was huge and can be seen much more clearly when the equivalent costs for it in 2010 value has been plotted in the second bar. However when you compare the equivalent cost to the current costs; operations in maritime shipment has made great progress, but on the other hand the costs related to the land transport haven’t much evolved!
Indeed, the containers are placed in an efficient way on the cargos, but once the ship has arrived the system lacks optimization: the containers aren’t very flexible and the loads have to be reorganized before being sent to their destination. The challenge would be to have the possibility of passing easily from the cargo to the truck and then to a smaller vehicle that could distribute to the customer or shop. This can be done in an efficient way with modularity, the possibility of combining different packages together into one.

Another challenge would be to optimize the network capacity. For example, you can have two trucks from two different brands which aren’t full and go to the same destination without sharing their space; everyone has their separate logistics. This is not the case in the maritime transport with containers, so why not expand this to the land transport? A solution would be to merge the individual transport companies into one big network, working as one in the effort of maximizing the network capacity. This is called the Physical Internet.

In conclusion, land transport is still expensive because:

- Each company has his own network of hubs.
- Handling containers do not always fit into transport containers
- Handling and packaging containers aren’t standardized.
- Manipulations are needed to pull handlings out of transport containers.

### 3.9.1 The vision for tomorrow
In order to solve a lot of logistics issues, a European organization, ALICE, was established. Keeping the physical internet in mind, it first tries to improve the handling of containers. In fact, as mentioned above, it is the bottleneck of the logistics. A group of companies joined this project, known as "Modular Logistics Units in Shared Co-modal Networks" or "MODULUSHCHA".

With the goal of having a standardized system for handling containers. In the same way it has been implemented for transport containers some decades ago. The benefits of this standardization are very wide; Logistics will tend to be leaner.

As mentioned in the next chapter, the final goal with the Physical Internet is having a total standardized modularization. Where packaging containers are able to combine or divide endlessly to fit on the best way into a bigger container.

Examples of the types of concepts and implementations linking to the various visions contained in the pillars of the above figure are mentioned below.

A. Urban logistics

Physical Internet vision for urban logistics defines all movements of goods into, out of, through or within the urban area. The European organization ALICE has as target to implement a fully automated and sustainable mobility system in the cities by 2040. The scope of the roadmap is urban freight transport, defined as all movements of goods into, out of through or within the urban area, made by light or heavy vehicles, including:

- Delivery of goods (business and home).
- Service transport and demolition traffic.
- Shopping trips made by private households.
- Reverse logistics for waste removal and for returns management.
- Service vans for maintenance, supply and removal of parts.

Projects below highlight some of the concepts taking a first step in this direction:

**Lockerpoints by bpost and DHL**

- Serve as alternative delivery addresses for recipients
- The number of returns due to recipients not being present at the time of the delivery attempt is eliminated
- Open from early until late, for your convenience
- It is a great way for your courier to drop off a parcel for you when you are not at home it is even more ideal if you don't have a safe place for the courier to leave your parcels as well
Drones

- Affordable: you can buy a drone for $500 to $1,000 today
- It is the future: drone technology is currently accelerating, thanks to the smartphone industry, which relies on the same components — sensors, optics, batteries, and embedded processors — all of them growing smaller and faster each year
- Visionary idea: do for physical transportation what the Internet did for the flow of information.

In the figure below, when you look at a study conducted by McKinsey, a drone delivery is 35% more expensive versus a traditional van delivery.
**Base intelligente de logistique**

BIL or « Intelligent Logistics Base » has been developed to respond to the antipollution plans, taking place gradually in many urban areas in France as well as in Europe, in order to reconsider the distribution and the delivery of goods at the shops’ doorsteps. During the SITL exhibition in 2015, the BIL solution, invented, designed and manufactured by LIBNER, has generated a tremendous level of interest, as it can deliver goods in city centres emissions free, in perfect harmony with the environmental regulations.

The Intelligent Base BIL is the combination of a rigid truck vehicle equipped with a BIL LIFT at the rear that can carry a small electric vehicle called BIL Truck. The BIL BOX can then be loaded onto the BIL Truck, once the two loading platforms line up. This system:
- Can deliver easily in city centers.
- Don’t need the truck for the last miles.

**Shakey**

It is a robot which deliver boxes in front of clients door. It has a range of 2 miles and a maximum speed of 4 miles/hour. The goal is take over the last part of the delivery, where nowadays postmen have to start and stop their car on very small distances. Consumers will open their door and pick-up their box thanks to a special app on their phone. It is equipped with a GPS system and cameras for the localization and avoid obstacles. It has also a mic and speakers to communicate with humans around.

B. Corridors, hubs and synchromodality

Information and communication technology, inter-firm collaboration, process re-engineering and innovative business models are important enablers for corridors, hubs and synchromodal solutions. Synchromodality provides pathways towards improvements in the integrated European freight service network. The concerned stakeholders are at the supply chain level (e.g. manufacturers), at the transport service level (e.g. transport operators) and at the infrastructure network level (e.g. public road authorities). The overall goal of the Physical Internet vision is to arrive at an integrated system, the direction of innovations is the improvement of the linkages between these levels. The main ambition of this roadmap is to achieve a sustainable system in synchromodality- synchronization of the different modes of transport- within an organized network, using corridors and hubs.

Projects below highlight some of the concepts taking a first step in this direction:

From A to green
A good illustration of modularization can be seen in this example. The g-combi is a platform with g-modules, the platform has a system with winches, locking mechanism and rails. The g-modules are containers with empty space where the g-box (a plastic box to carry groceries) fits into. These boxes can divide the big container on top of the truck into micro delivery modules to increase the efficiency and effectiveness of the distribution of goods in cities, decreasing the amount of kilometers per route.

[Image of g-combi]


Underground cargo
The example of underground cargo is illustrated below. The key advantage of this system is that:
- It requires no interferences, and is quick and secure.
- It is fully automated, and is cheaper on long term.

[Image of underground cargo]
The Green Corridor Projects in Europe
Corridors have been selected by their traffic and their "greening potential". The goal is improving the network.
**Furbot**

- Full electrical vehicle prototype
- Energy efficient
- Dexterous mobility
- Equipped with robotic load/unload device
- Light weight high strength material
- Endowed with perceptual system and intelligent control
- Standardized freight units
- A discrete time simulator for FURBOT fleet networking analysis and management

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C. **Sustainable, safe and secure supply chains**

The objective of Physical Internet vision in sustainable, safe and secure supply chains is to solve environmental and societal problems linked with logistics while maintaining or enhancing profitability. The goals are to minimize emissions, improve security, enable circular economy and achieve standardization and modularization. These goals can only be achieved if logistic service providers, shippers and authorities closely cooperate. Example projects are given below:

**Rethinking container management system**

- Automatized system, reduce spaces and employees
- Quick unloading.
**Excalibur SL-Tainer**
- Hydraulic legs provide a stable foundation and provide a lifting height of 1.6 meters
- Safely Load and Unload the SL-Tainer within 15 minutes.
- Convenience of loading in remote locations
- No waiting for special equipment and staff to unload or load the containers
- Advantage of ground level access
- Onsite relocation is easy

**Cargoshell collapsible container**
- It’s collapsible
- Reduce cost of empty containers
- It will significantly lower CO2 emissions worldwide
- It’s much lighter than present steel containers
Automated Driving Program (TNO)
The idea is to build a Cooperative Adaptive Cruise Control (CACC): steering, acceleration and braking is automated using sensors, radar and camera. It’s not like in today’s Adaptive Cruise Control, based on a wireless connection. This leads to suppressing traffic jams, safer roads and cutting fuel consumption and emission. But the project goes even further for trucks; the objective is to have a platoon of trucks where the leader is human-driven, but the rest follow using vehicle-to-vehicle communication (via a wireless connection).

https://www.youtube.com/watch?v=UOMYqZSND2U

D. Information systems for interconnected logistics
The Physical Internet vision on information systems and interconnected logistics is to achieve real-time (re)configurable supply chains in (global) supply chain networks with available and affordable Information and Communication Technology (ICT) solutions for all types of companies and participants. In essence, this is a requirement to enable a Physical Internet: an open global logistic system founded on physical, digital, and operational interconnectivity, enabled through encapsulation of goods, standard interfaces and protocols. These components act as the “brain” of the future logistics system. Affordable and standard ICT help to achieve a real-time and effective supply chain network.

Open Tracking Container
Reusable packaging used to track and pilot influx of loads. A RFID chip is put on the packaging, workers only need to scan it to know all the information needed (where and when it has to be stocked/delivered).

- Traceability: identification of the packaging using RFID
- Load piloting: use of routage algorithms to optimize production, collection and repositioning of the loads

http://www.4snetwork.com/activite/produits-services/otc-kaypal-mr/

Waspmote (from Libellium)
Libelium’s Waspmote sensors can be used to monitor and control logistics operations. Not only can the sensor locate and track a package from origin to destination, but it can monitor its transportation conditions throughout the journey (if it has been opened, the temperature, humidity etc.). The sensors are connected to the internet and can also send an SMS in case of an emergency like a container falling, a fire, etc. It can also, via machine-to-machine communication, learn about containers or pallets surrounding it and locate incompatibilities, like a pallet of dangerous goods placed side by side with flammable materials.

- Consistent tracking of goods throughout the transportation chain.
- Detection of unexpected container openings.
- Monitoring of transport conditions.
- Identification of storage incompatibilities.

http://www.libelium.com/wireless_sensor_networks_m2m_logistics_operations
**The Things Network**
The Things Network is a global, open, crowd-sourced Internet of Things data network. It allows for things to connect to the internet without using 3G or WiFi. This technology is called LoRaWAN (radio modulation technique) and is a low battery usage, long range, and low bandwidth technology. The network is composed of four components:

- **Nodes (N):** a node is a device that collects information, does measurements or performs actions. They interact with the gateways using the LoRaWAN technology.
- **Gateways (G):** Antennas that receive broadcasts from Nodes and send data back to Nodes. Gateways are connected to the Internet and communicate with The Things Network's servers. Gateways have a long range, so they can provide connectivity to nodes that are multiple kilometers away.
- **The Things Network Backend:** route messages from Nodes to the right Application, and back.
- **Your Application:** receives and sends messages from the Things Network to interact with the corresponding nodes.

https://www.thethingsnetwork.org/

**Cargomatic**
Cargomatic is an application that connects shippers with carriers with the objective of maximizing the used space inside the trucks; a truck can pick pallets at several companies on the way to its destination. You can follow your loads online.

https://www.youtube.com/watch?v=X06q76Bo10A
https://www.cargomatic.com

**AT&T M2X**
AT&T is banking on its broadband network being a key enabler of Internet of Things (IoT). The company has launched M2X, a cloud-based data storage service and Data Flow, a development portal for building applications for the world of IoT. AT&T hopes to have 10 million vehicles connected to its network by 2017, including 1.2 million fleet vehicles and 243,000 shipping containers.

**E. Global supply network coordination and collaboration**
The vision here is to realize full collaboration horizontally (between supply chain actors) and vertically (between suppliers and consumers): and supply chains are operated as a whole. Coordination deals with the synchronization and dynamic update of logistics and transport plans and collaboration deals with maximizing resource utilization (i.e. vehicle capacity).
Collaboration in transportation
Carrefour, Nestlé Waters, Coca-Cola, P&G and CHEP are participants in a program to share road transportation in Italy. This program is important to better the figures and make logistics more efficient. On average, only half of the available load capacity is used. In Italy, about 91,000 transport companies operate, 93% of which have fewer than 10 drivers and just 1.7 trucks on average. Meanwhile, tighter regulations have caused decreased volumes and increased delivery constraints. The goal is avoiding empty trucks and improve distribution.
http://www.chep.com/resources/case_studies/collaboration_in_transportation/

In the same way, Baxter collaborate with Kimberly Clark to share trucks between Belgium and Paris. Baxter goes one way with loading and Kimberly Clark takes it over for the return trip. The hopes for the future is illustrated in the video below:

The modularization of the supply chain can lead to wider projects and ideas such as the Physical Internet. The Physical Internet provides a sustainable solution for organizing the supply chain by creating an open network which ships freight just like the information flows on the internet; the supplier doesn’t worry about the route the product takes and where it is stored but relies on the network to deliver it to the consumer.

The network is organized in open hubs. A hub is a temporary warehouse used to divide and combine different loads into standardized volumes that can be transported efficiently. Hubs store loads from multiple manufacturers and other hubs to reorganize the goods (maybe with the help of the Internet of Things) and assemble a new load based on the next destinations. Packages will travel from hub to hub until they reach the one closest to the consumer or to the shop. The links between the hubs are assured by many different parties which is why full horizontal and vertical collaboration is needed. Moreover, the shipments have to be optimized and fully compatible, just like in a computer, the capacity of the network has to be maximized.

There is still a long way to accomplish this change in the way of thinking about logistics in the supply chain: the loads have to be standardized, a total collaboration between the firms is necessary and the communication between the packages has to be perfect.

In conclusion, the benefits of the Physical Internet are a faster delivery; a better asset utilization; a more agile response to the market (a consumer far from any production site or warehouse can ask the network for a certain product and receive it easily without the need of a suggestion from the producer, the network will sort out itself how to create a new route to the consumer); an environmentally, socially and economically more sustainable system and an open protocol logistics collaboration.
4. Conclusion

There is no doubt that road transport will continue to lay it’s foundation for sustained economic development. Technologies like digitization and vehicle connectivity are already a market reality that will continue to grow, yet we always have this question as to: whether this growth will effectively capture the value creation opportunities offered at the interplay with value drivers of the logistics industry?

The answer to this will be determined by whether public and private stakeholders manage to successfully design and implement the enabling conditions required to overcome the challenges discussed in some of the topics.

As solutions evolve rapidly, so too must the European Commission work continuously to evolve its regulatory environment and governance in order to create a platform where technology can provide benefits. When you look at the recent changes in the directive on Weights and Dimensions, a payload of one additional ton is allowed for alternative technologies like hybrid electric systems, but the additional one ton is not valid for an articulated vehicle, thus putting solutions like TRANSFORMERS at a disadvantage, as it results in loss of payload!

Looking ahead with a broader perspective, one can envisage staggering benefits, though it remains an open question to what extent and how fast this potential will be harnessed.

From the perspective of trailer industry the following issues need to be addressed for future concepts:

**No disadvantage in payload and volume**
Additional components for “Hybrid on Demand” (HoD) will add weight to the truck and trailer combination. Using a trailer with such components would mean economic disadvantage in payload for transporters in the competition. Interaction between shippers and transport companies would be more difficult, for different payload standards.

For legislative matters the weight of the hybrid system should be subtracted from the legal total weight of the truck/trailer combination. Legislation already allows 44t of payload for combined transport via railway.

Trailer manufacturers have to create a transparent display of weights for executive organisations. This needs standardization in the European context.

**Common interface between truck and trailer**
Using technologies like “Hybrid on Demand” or energy management can put energy to a better use and reduce waste. Therefore a new level of communication between truck and trailer is needed. Here, there will be a new level of electronic interface between the units.

Missing industry standards have often stopped technologies’ success. Sometimes inferior systems have made it to market, because they could define the standard first.

A moderated process between truck and trailer manufacturers should bring a European standard for the interface that enables “Hybrid on Demand” and energy management. It should be based on the existing standard ISO 11992.

**Energy management systems inside the trailer**
One of the key success factors of road transport with truck/trailer combinations is its flexibility. Trucks can be exchanged with different trailers. Even if it has a common interface to the truck, the future trailer should still be able to manage the energy-system inside, by itself. So even if the truck is not equipped with steering systems the trailer should be able to adjust the roof or the “Hybrid on Demand” to the best conditions. Otherwise the potential for saving energy is lost, as soon as a non-equipped truck picks up a trailer.

**No economic disadvantage through aerodynamic measures**
Commercial vehicles and especially trailers are optimized to offer maximum payload and volume. Aerodynamic measures like air diffusors or spoilers may add length or height to the trailer. So using these would have a large impact on the volume available for transport.

Legislation should also take aerodynamic measures out of the calculation for length measurements, as already quoted in the Council’s position (EU) No 1/2015. Restrictions from road safety and road infrastructure need to be taken into account.
Make changeover to new technology easier for users
The transport companies’ business is under heavy competition with average margins of 1-3% and a significant higher rate of insolvency proceedings than the average business. Average quota for equity capital is around 16.1% (ref: Wittenbrink, Paul (2014): Transportmanagement, Kostenoptimierung, Green Logistics und Herausforderungen an der Schnittstelle Rampe, 2. Auflage, Springer, Wiesbaden, 2014.) and therefore the possibilities to invest in new technologies are very limited. Every financial incentive that reduces the amortization period for investments makes the changeover to ecological friendly technologies more likely.

Include “Hybrid on Demand” in national registration options and EU-harmonization
For transporters it is important to be sure that registration of a trailer with “Hybrid on Demand” systems is possible with their national authorities and that for international hauliers this is recognised across Europe. It is important to create legal certainty here, and harmonisation of legislation across Europe to allow “Hybrid on Demand” systems is required and in particular to deal with the electric brake on the trailer which is essential to recuperate energy.
DISCLAIMER ON ANNEXES

The annexes in this report aim to bring together the views from the stakeholders and experts during the workshops on Future Concepts and a summary of various projects that are responsible for improving transport efficiency and road efficiency.

With respect to Annex 01, some of the topics mentioned are still not tested, debated and may never see the daylight as matters stand now. For alternative fuels, propulsion systems, aerodynamics etc. in this chapter, we demonstrate the relevance of what we are doing in TRANSFORMERS to such concepts. For more reading The IRU Commercial Vehicle of the Future report (available 1st quarter 2017) could be one source. ACEA, ERTRAC and Green Car Initiative has some very nice reports, ALICE has some reports, the Dutch Platooning Challenge Reports and we recommend that the reader could use this as a guide to dig further on topics and concepts that generates interest.

The views expressed in the annex is a collection of those of the different stakeholders involved in the TRANSFORMERS Future Concepts Group. As such, everyone involved in this initiative may not necessarily fully support all views expressed in this report. All the stakeholders involved do however share a common interest; encouraging positive change to enable CO2 emissions reduction together with road safety and operational efficiency improvements.
Annex 01 Trends affecting logistics that go beyond TRANSFORMERS

Aerodynamics

In the following sub chapters we will discuss various aerodynamic components that could be a part of the future vehicle concept. The interesting areas that have not seen broad acceptance are:

- Air Diffusors and Spoilers
- Space reduction between tractor and trailer

And a few key topics mentioned below

A. Vortex generators

Vortex generators are basically flow control devices. They are attached to the trailer in order to lower the turbulence of the air flowing along the length of the trailer. There are multiple designs available with the parts about six inches in size and requiring two to be used for every foot of vertical (or in some cases horizontal) surface. Parts are mounted to the roof and trailer side to moderate cross wind conditions.

Source: NASA Spinoff - Aeroserve Technologies Ltd

It is clear that these components do not impact the loading and unloading performance nor the payload of the vehicle significantly.

B. Plasma Actuators

Plasma actuators are electrical devices that generate a wall bounded jet without the use of any moving parts. For aerodynamic applications they can be used as flow control devices to delay separation and augment lift on a wing. The standard plasma actuator consists of a single encapsulated (ground) electrode. A startup company called plasma stream has developed this concept.
Investigating the technology further, we summarize our findings as seen in the figure below:
Energy Sources

Energy sources are mainly fossil fuels (diesel and gas) or renewable fuels (biodiesel, synthetic diesel, biofuels, biomethane, synthetic methane) or electric driveline in different combinations as explained in the figure below, but it’s not clear how that the use of alternative energy sources and powertrains could have an impact on the weights and dimensions of vehicles/combinations and on their load capacity, one case could be that lower load capacity would lead to more vehicles on the road.

A. Natural Gas Propulsion

Here we talk about vehicles that use natural gas as a source of energy for transportation. Natural gas has the highest energy/carbon ratio of any fossil fuel, and thus produces less carbon dioxide per unit of energy, hence it offers an alternative as a clean burning fuel. A concept developed by Kogel Shows how trailers can be used to extend the range of natural gas vehicles. Another possibility is to combine gas combustion with electric drive.

Source: A Short Field Guide to Hybrids

Source: Kogel Trailer with CNG Module
The challenge with gas propulsion vehicle is the absence of a strong fueling infrastructure and the gross vehicle weight is higher due to the weights of the tanks. The tractors also do not have higher horsepower.


B. Bio Fuels / E-Fuels

Biofuels are liquid or gaseous transport fuels such as biodiesel and bioethanol which are made from biomass. These fuels help reduce the overall carbon intensity when mixed with normal fuel used for mobility.

C. “Hybrid on Demand” /Energy Recuperation

“Hybrid on Demand” is a TRANSFORMERS concept where we have an electrical motor and battery placed in the semi-trailer. It is meant to act like a spring meaning, that the vehicle charges it’s electrical propulsion while braking and is activated when there is a need for additional torque. Other potential application of “Hybrid on Demand” is for the trailer to have an independent propulsion system for easier mobility in dock areas. Whereas energy recuperation is a similar concept that can be applied to the tractor. While loading or waiting a plug which could be used if the correct charger was available.
D. Photovoltaic System

Photovoltaic panels on a trailer roof are still at the stage of single experiments. The space available on the roof is limited to 35m². Depending on route attributes and external factors (region of use, season, daytime, weather conditions etc.) the electrical output is highly variable. The panels do add additional weight to the trailer.

But for secondary users like e.g. cooling units, the additional energy source might prove useful. With increasing solar panel efficiency and improvements in reduction of weight and space needed, the utilization of the entire trailer surface can become an option. Thus getting more electrical energy out of the system would become feasible.

Source: Solarion
E. **Plug in hybrid**

The TRANSFORMERS “Hybrid on Demand” is a system that feeds from recovering braking energy. Yet there is no option, to use break times in the transport to charge batteries again. A useful expansion of the reach of the electric system would be by charging batteries via plug-in.

In many cases motorway services nowadays already offer the option to feed cooling units of reefers with electrical energy, to keep sound emission low. This infrastructure would need adjustment, but the general service is available already. Distribution centres also could provide energy for the semi-trailers to charge the battery during dock operations. The combination could start the transport with a full battery and use the whole efficiency of the system from the beginning.

![Plug in hybrid](image)

**Source:** MAN

F. **Fully Electric Drivetrain**

A fully electric truck runs on pure electric power coming from a battery or an onboard power plant like the fuel cell. Additional electrical power comes from recuperative braking. Given the state of the current technology these vehicles would be extremely heavy for long haul applications. A number of medium and short distance applications have been seen, example the etruck as seen below.

![Fully Electric Drivetrain](image)

**Source:** Mercedes-Benz Urban eTruck

G. **Electric Highway**

Electric Highway is a relatively simple concept wherein commercial vehicles can connect to specialized traction based overhead cables in a similar way to trams or trains, their engines then switched from diesel to electric. Purpose-built hybrid trucks seamlessly connect to the grid through a pantograph on the roof, then run on an electric motor.

![Electric Highway](image)

**Source:** Overhead Line for Electric and Hybrid Trucks
It is also been seen that other systems are used for supplies which are built into the road surface, with under vehicle collectors.

H. Hydrogen Fuel Cell Technology

Hydrogen as a fuel source works well in fuel cell technology, which basically acts as a power plant in the vehicle converting hydrogen into electricity in order to move the vehicle. The technology is still in its nascent stage and a lot of development activities need to happen to make it possible. The technology has been tried for buses, where the roof is used for storage tanks and the power plant, however for commercial tractor trailer combination a different design has to be explored.

I. Intelligent energy management systems

Intelligent energy management system is at the core of different energy systems. This management system will link together various energy technology with the aim that the mission has the lowest possible emission. The management system should be able to recognize different vehicle configuration and be connected to the route profile entered by the driver. The intelligent system will provide recommendations and nudge the driver towards better driving habits.
**Standardization**

Standardization talks about interoperability of systems, and deals with combinations and systems.

**A. Intermodal traffic: truck / trailer / train**

This concept deals with the European whitepaper objectives of creating a more streamlined transport where road and rail transport go hand in hand. For intermodal traffic with lower handling two solutions are widely used, namely the Container or trailers designed for intermodal transport.

**B. Better insulation**

A major part of fuel consumption for refrigerated transport derives from the need to keep the transported goods on a constant temperature level. Legislation allows for refrigerated transport 2600mm outer width and a total length of 12000 mm from kingpin to rear closure plus 2040mm for the front beam. The total height is in most European countries limited to 4000mm, but there are major exceptions (e.g. United Kingdom or France). From the technological point of view it is relatively easy, to generate a better energy use by adding isolation to a trailer. When allowing additional space for aerodynamic measures, it would increase fuel efficiency if additional isolation would be treated as equal to aerodynamic measures.

**C. Compensation systems for shared resources**

Shared resources mean that the revenue pool has to be shared by a fair mechanism. In order to do so the CO3 Project funded by the EC has demonstrated and shown that Shapley Value could be one of the best way where organizations could work together.
D. Open and Shared Hubs

Ongoing research efforts show that the translation of the working principles of the Digital Internet to the routing of freight, thus creating the Physical Internet (PI), has the potential to be a real game-changer. In the PI world freight travels from hub to hub in an open network rather than from origin to destination directly. Each parcel is routed automatically and at each section it is bundled for efficiency. In the PI network of networks many (if not all) transport and logistics services would be accessible on demand to all users.

E. Shared Infrastructure

When it comes to individuals, we share common infrastructure like airports, airplanes, trains etc. to meet our mobility needs. However when it comes to logistics and supply chain there are not a lot of examples wherein the transport capacity or a transport infrastructure is shared. Shared infrastructure is a concept emerging from Open Logistics Platform.

Source: KaneisAble Inc.
Connectivity

A. **Electronic Data Interchange**
To create a seamless supply network, a standardized format for sending information electronically has been created and is widely used across industry to manage vendor relationship within their supply chain. This standardized information can be used for logistics planning, capacity allocation, customs and taxes. The technology linked to block chain can work wonders in the supply chain of tomorrow. This technology when handed over to the masses to manage transportation can change the way in which things are moved.

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**Diagram:**

- **Company A**
- **Company B**

**Electronic Data Interchange (EDI)**

B. **Digital Images and open transport planning for Logistics Entity**
Digital images of logistics entities helps in sharing information across the network for better planning, utilization and sharing of assets. In today’s world, customers ask for a basic type of vehicle to come pick up a load, and even if the transport provider comes with a better vehicle configuration the customer is not able to take advantage of this. Also the customer does not have a lot of visibility on what similar vehicles are going to the same location. With digital images of logistics entity and lead times for fulfilling the delivery, the supply network can be managed in a much more efficient manner. So imagine a moveable floor trailer is coming to the DC to be loaded, the shippers can adjust their loading pattern based on this vehicle and the vehicle can be shared with other potential partners heading to the same destination due to transparency in the data.

C. **Standard interface truck / trailer Modules**
Today a Mega trailer connected to a standard tractor and a low rudder tractor cannot be connected to a standard trailer. This causes difficult interoperability between tractors and trailers, thus making the drop-lot operations complicated. With standard interfaces we can have better interoperability. Also when it comes to the concept of modular systems in vehicles, it is necessary to have a standard connection that allows combinations of existing loading units – also called modules – into longer and sometimes heavier vehicle combinations to be used on some parts of the road network. EMS improves road freight transport efficiency and reduces its environmental impact. In practice, it allows national authorities to authorize trucks longer than the ‘normal’ maximum for a heavy truck of 16 meters in length and a weight of 40 tonnes.

D. **Standard interface truck / trailer Energy**
The energy which is stored in the battery in the trailer could not only be used by the trailer drivetrain, but also by auxiliary electric loads in the trailer and the truck. If the HoD system is installed in a refrigerated trailer, the energy could be used for the cooling machine to support the Diesel Engine which normally provides the energy for it. New features could be developed, since now more energy is available in the trailer, even when it is decoupled. One possible function could “heat strips” on the roof to prevent ice on the roof. Additionally an energy interface between truck and trailer has to be developed, to be able to use the energy of the trailer battery in the truck. In that case it might be possible that the truck has its own electric drivetrain and the battery in the trailer could be used as additional energy source. Other fields of application could be comfort application for the driver, like stationary air conditioning fed with energy from the trailer battery.
Intelligent Truck/Trailers

A. Monitoring systems for intelligent access control

The concept is similar to electronic toll collection on highways, but in a scaled down manner where the sensors are connected to DCs to allow vehicles to move in and at the dock door to load the right shipment into the truck. In order to do so, it is necessary to have digital images of the vehicle along with setting up a standard format for information sharing. Such a system will boost productivity and help both shippers and fleet managers tap into complete use of asset utilization.

B. Autonomous Dolly

With the HoD system and drivetrain, autonomous shunting without truck on closed areas on a factory site might be possible. A passive carriage with a steering axle under the king pin is necessary, the propulsion and the necessary energy would be provided by the HoD system. This could also be used for autonomous driving of the trailer to the ramp in a DC. The truck delivers the trailer until the gate of the DC, the trailer will be coupled to a passive carriage under the king pin and brought to a ramp. On the other side the truck can drive away with a full trailer, which will drive autonomously to the gate, immediately.
C. Telematics
Telematics refers to the use of wireless devices and “black box” technologies to transmit data in real time back to an organization. Typically, it’s used in the context of automobiles, whereby installed or after-factory boxes collect and transmit data on vehicle use, maintenance requirements or automotive servicing. Telematics can also provide real-time information on air bag deployments or car crashes and locate stolen vehicles by using GPS technology. In addition, telematics can serve as the platform for usage-based insurance, pay-per-use insurance, pay as you drive (PAYD) insurance, pay how you drive (PHYD) programs for fleet insurance, or teen driving programs for retail business.

Telematics has expanded beyond personal line deployments, and can also be used by commercial auto insurers for fleet products, driver data and vehicle monitoring. New models are emerging, however, called “mobile telematics,” in which smartphones connect to the car’s computer system to pull data and send this to the insurer using the phone’s wireless network. (http://www.gartner.com/it-glossary/telematics/)

D. Advance Driver Assistance Systems / On Board Diagnostics
Advance driver assistance systems help with monitoring, warning, braking, and steering tasks of the vehicle to improve safety, protect drivers and reduce accidents. Conventional ADAS technology can detect some objects, do basic classification, alert the driver of hazardous road conditions, and in some cases, slow or stop the vehicle. This level of ADAS is great for applications like blind spot monitoring, lane change assistance, and forward collision warnings. - See more at: http://www.nvidia.com/object/advanced-driver-assistance-systems.html#sthash.PbFXAFCU.dpuf

E. Platooning
Truck Platooning comprises a number of trucks equipped with state-of-the-art driving support systems – one closely following the other. This forms a platoon with the trucks driven by smart technology, and mutually communicating. Truck platooning is innovative and full of promise and potential for the transport sector.

With the following trucks braking immediately, with zero reaction time, platooning can improve traffic safety. Platooning is also a cost-saver as the trucks drive close together at a constant speed. This means lower fuel consumption and less CO2 emissions. And, lastly, platooning efficiently boosts traffic flows thereby reducing tail-backs. Meanwhile the short distance between vehicles means less space taken up on the road.
F. Autonomous Driving and Platooning

Recently Anheuser-Busch hauled a trailer loaded with beer 150 kilometers in an autonomous-drive truck, completing what's believed to be the first commercial shipment by a self-driving vehicle. The truck drove based on the technology developed by Otto.

Where drivers are restricted by law from driving more than 11 hours per day without taking an 8-hour break, a driverless truck can drive nearly 24 hours per day. That means the technology would effectively double the output of the transportation network at 25 percent of the cost. The savings become even more significant when you account for fuel efficiency gains. The optimal cruising speed from a fuel efficiency standpoint is around 70 kilometers per hour, whereas truckers who are paid by the kilometer drive much faster. Further fuel efficiencies will be had as the self-driving fleets adopt platooning technologies, like those from Peloton Technology, allowing trucks to draft behind one another in highway trains.

The primary remaining barriers for autonomous driving are regulatory and public acceptance. We still need to create on- and off-ramps so human drivers can bring trucks to the freeways where highway autopilot can take over. We may also need dedicated lanes as slow-moving driverless trucks could be a hazard for drivers. These are big projects that can only be done with the active support of government. However, regulators will be understandably reluctant to allow technology with the potential to eliminate so many jobs. Shifting to driverless freight could resolve the long-standing problems of truck driver shortages, significantly cutting costs for freight companies. The technology also could be more fuel efficient than human drivers and safer in terms of accidents.
G. No Driver/ No Cabin / Maximize Loading

When driverless trucks become mainstream, the next question would arise how the cabin design would change. When you look at the shuttle bus in the figure below, the entire design has changed from a driver to a driverless ecosystem.

![Shuttle Bus](image1.png)

H. Vehicle to Vehicle/Vehicle to Infrastructure/Vehicle to Cloud

In the future a “paperless” transport could be achieved by developing a new communication platform or strategy between trailer and dock. The trailer should be able to recognize the type of cargo, the volume, number of pallets, weight, etc. This data will be sent directly to every corresponding DC. The communication and recording of all needed data could substitute the standard shipment papers and also make the process at of (un-)loading at the DCs easier. By scanning the cargo by the trailer during (un-)loading process the shippers are always aware of the cargo which is in the trailer. With the improved communication directly with the DC, a comparison between current and desired cargo in the trailer is always possible.

![Communication Platform](image2.png)

I. Adaptive route planning

In today’s world, when it comes to mobility of people a lot of people rely on the GPS for directions and the choice of road they take. Adaptive route planning takes into consideration the choices people have made and is a self-optimizing route planning that helps the driver reach the destination on time. Going beyond regulations, what is evident that certain segments of the journey are well suited for driving using a longer and heavier combination, with adaptive route planning one can enter the vehicle specs and the route planning tool will pick out the best possible journey that the vehicle can take to reach its destination. This in turn will enable the use of special combinations on a frequent basis.
Future Materials

A. Carbon nanotubes

Carbon nanotubes (CNTs) are cylindrical carbon molecules formed by rolling one-atom-thick sheets of carbon, called graphene. They can be single-walled (SWNTs) or multi-walled (MWNTs) and be rolled at specific angles, these differences influence the nanotubes’ properties (i.e. metal or semi-conductor depending on the rolling angle).

The type of bond holding the carbon atoms together is very strong, plus the hexagonal pattern of the atoms themselves gives rise to a phenomenon known as electron delocalization. This means that under the right conditions electrical charge can move freely in a nanotube. The regular arrangement of the atoms also can vibrate in ways that effectively move heat through the tube, so thermal conductivity is high as well as electrical (1000 times more than copper). These nanotubes are also very elastic (~18% elongation to failure), highly flexible, good light-absorbers, good electron field emitters, have a low thermal expansion coefficient, a high specific surface area (1315 m²/g in theory) and a high thermal stability (up to 2800°C in a vacuum).

<table>
<thead>
<tr>
<th>Material</th>
<th>Young’s modulus (TPa)</th>
<th>Tensile strength (GPa)</th>
<th>Elongation at break (%)</th>
<th>Thermal conductivity (W·m⁻¹·K⁻¹)</th>
<th>Electric current density (A/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWNT</td>
<td>~1</td>
<td>13-53</td>
<td>16</td>
<td>3500</td>
<td>4 x 10⁸</td>
</tr>
<tr>
<td>Stainless steel</td>
<td>0.186-0.214</td>
<td>0.38-1.55</td>
<td>15-50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kevlar-298149</td>
<td>0.06-0.18</td>
<td>3.6-3.8</td>
<td>~2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td></td>
<td></td>
<td></td>
<td>385-410</td>
<td>3.1 x 10⁶</td>
</tr>
<tr>
<td>Diamond</td>
<td>1,22</td>
<td>&gt;0.0012</td>
<td></td>
<td>900-2320</td>
<td></td>
</tr>
</tbody>
</table>

These properties open the way for innovations in diverse sectors of technology:

1. Researchers have found that carbon nanotubes can fill the voids that occur in conventional concrete. These voids allow water to penetrate concrete causing cracks, but including nanotubes in the mix stops the cracks from forming, helping build better and stronger infrastructure. This can be coupled with self-healing materials; example: carbon nanotubes-nanoreservoirs are filled with healing agent molecules and embedded in a hosting matrix, they are released when the surrounding environment undergoes changes such as temperature, pH, cracks, impact.

http://iopscience.iop.org/article/10.1088/0957-4484/20/33/335704/meta
With the discovery of new, more flexible, lightweight, miniaturized and effective materials in the industry (i.e. for supercapacitors) comes new challenges, especially when those materials are subjected to practical applications; fractures, high temperatures, pH, etc. The aim of self-healing materials is to augment the reliability and lifetime.

2. Another technique consists of spreading carbon nanotubes films onto self-healing substrates. This technique has been used to fabricate self-healing and robust supercapacitors, upon being subjected to mechanical damage, lateral movement of the self-healing composite layer brings the separated areas of the SWNT layer into contact, hence enabling the restoration of the device's configuration and conductivity (the specific capacitance can be restored up to 85.7% of its original value even after the 5th cutting).

3. Carbon nanotubes can be used as self-cleaning coatings in various applications such as glass windows, solar panels, and microchannels. The CNT composite structure showed high mechanical strength and wear resistance.

http://iopscience.iop.org/article/10.1088/0957-4484/20/33/335704/meta

Concept of the self-healing process using carbon nanotubes.


http://pubs.acs.org/doi/full/10.1021/nn901509r
http://pubs.acs.org/doi/abs/10.1021/nl0727765
Researchers at the University of Delaware have demonstrated increased energy density for capacitors with the use of carbon nanotubes in 3-D structured electrodes.

4. Use of silicon coated carbon nanotubes in anodes for Li-ion battery. The use of silicon can increase the capacity of Li-ion batteries by up to 10 times.

5. A catalyst made from nitrogen-doped carbon-nanotubes could be used in Lithium-air batteries. can store up to 10 times as much energy as lithium-ion batteries.

6. Researchers at Rice University have developed electrodes made from carbon nanotubes grown on graphene with very high surface area and very low electrical resistance.

7. Carbon nanotubes can perform as a catalyst in a fuel cell, avoiding the use of expensive platinum on which most catalysts are based.

8. A lot of research has been made for supercapacitors made using carbon nanotubes; the high specific area of the carbon nanotubes increases energy storage, and its elasticity and resistance results in a retained performance when the supercapacitor is under stress or flexibility. A team of Nanyang Technological University tested their supercapacitor at 10,000 charge/discharge cycles and came up with a performance retention of about 93 percent. Conventional rechargeable generally lose performance before they hit the 1,000-cycle mark. These supercapacitors could be used as batteries in miniaturized portable electronics and microelectromechanical systems.

(\url{http://www.nature.com/nnano/journal/v9/n7/full/nnano.2014.93.html}, \url{http://cdn.intechweb.org/pdfs/10024.pdf})

9. Studies have shown that CNT can be used to fabricate thermo cells to recollect the ("free") heat discarded by chemical plants, automobiles and solar cell farms. These cells can continuously generate electricity, instead of running down like a battery, can be lower-cost ($2.76 per watt versus $4.31 per watt for solar cells) than today’s thermo cells, have a longer life cycle and have a three times more efficient energy-conversion efficiency.

(\url{http://pubs.acs.org/doi/full/10.1021/nl903267n})

10. Researchers at Rice University have developed a lithium-ion battery combined with carbon nanotubes that can be painted on virtually any surface. The hand-painted batteries were remarkably consistent in their capacities, within plus or minus 10 percent of the target. They were also put through 60 charge-discharge cycles with only a very small drop in capacity. The “jellyroll” design strategy of traditional batteries don’t give much flexibility to the forms of devices using them; paintable batteries could lead to infinite design possibilities!

(\url{http://www.nature.com/articles/srep00481#sthash.qtXSrE1T.dpuf}, \url{https://www.youtube.com/watch?v=qJDI5cAdhys})

Ragone plots for various electrodes evaluated at a discharging current of 0.01 A (Liu et al., 2003).
(d) Charge-discharge curves for 1st, 2nd, 20th and 30th cycles and (e) Specific capacity vs. cycle numbers for the spray painted full cell (LCO/MGE/LTO) cycled at a rate of C/8 between 2.7–1.5 V. (f) Capacities of 8 out of 9 cells fall within 10% of the targeted capacity of 30 mAh, suggesting good process control over a complex device even with manual spray painting.


B. Graphene

Graphene is thin (1 atom thick) 2-D layer of carbon atoms bonded together in a hexagonal honeycomb lattice.

Graphene has a high specific surface area (2630 m²/g in theory), a remarkable electron mobility (more than 15 000 cm².V⁻¹.s⁻¹ and could go up to 200 000 in theory), a high level of white light absorption (2.3%), the best heat conductor at room temperature (5300 W.m⁻¹.K⁻¹) and it is very strong (200 times more than steel) and flexible. Another main advantage of graphene is that carbon is the fourth most abundant element in the universe (by mass), and graphene could therefore be very cost-effective. The comparison between carbon nanotube and graphene can be seen in the table below:
1. Graphene can be used as an alternative to silicon or ITO in the manufacture of photovoltaic cells. Can be used in the production of photovoltaic cells, while silicon cells are very expensive to produce, graphene based cells are potentially much less so. In addition, these cells could be flexible, opening the possibility of integrating them in clothes, paper, foldable phones and computers, as retro-fitted photovoltaic window screens or curtains to power your home/phone, etc.

2. Graphene is an ideal material for sensors. Every atom in graphene is exposed to its environment allowing it to sense changes in its surroundings.

3. It is expected that graphene is utilized (probably integrated into plastics such as epoxy) to create a material that can replace steel in the structure of automobile, improving fuel efficiency, range and reducing weight. (Graphene is strong, stiff and very light)

4. Due to its electrical conductivity, it could even be used to coat vehicle surface material to prevent electrical damage resulting from lightning strike

5. Graphene is highly inert and so can act as a corrosion barrier between oxygen and water diffusion. This could mean that future vehicles could be made to be corrosion resistant as graphene can be made to be grown onto any metal surface (given the right conditions).

6. Graphene could dramatically increase the lifespan of a traditional lithium ion battery, meaning devices can be charged more quickly - and hold more power for longer. Batteries could be so flexible and light that they can be stitched into clothing. Or into the body.

7. Graphene is being studied and developed to be used in the manufacture of supercapacitors which are able to be charged very quickly, yet also be able to store a large amount of electricity.

8. With graphene tin oxide being used as an anode in lithium ion batteries for example, batteries can be made to last much longer between charges (potential capacity has increased by a factor of 10), and with almost no reduction in storage capacity between charges.

C. Nanocellulose

Nanocellulose is a natural material obtained from plant matter. It is composed from nanosized fibrils of cellulose. It is a pseudo-plastic, which means that it can be deformed when it is warmed. However, it has the particularity to be very viscous in normal conditions, even at low concentration. After being deformed, it regains its original shape. Nanocellulose-based materials are carbon-neutral, sustainable, recyclable and non-toxic. They thus have the potential to be truly green nanomaterials.

There are 3 types of nanocellulose: the cellulose nanocrystal (CNC) which mainly consists of chemically extracted nanoparticles; the cellulose nanofibrils (CNF) which is made of mechanically extracted nanoparticles and the bacterial cellulose (BC).
As written above, like all plastics, it can be deformed due to temperature and regains its original aspect and properties when it comes back to normal conditions. It is a very resistant material. In fact, its tensile strength is about 500MPa, while its stiffness is about 140–220 GPa. We can compare it with the tensile strength of aluminum or 8 times higher than steel, and with the stiffness of Kevlar.

Applications in the automobile industry is also very interested by this material. Indeed, it is cheap, easy to make, very resistant and light-weighted. Ford think they can knock 250-750lb (120kg) off the weight of their vehicles using this material. An interesting use of nanocellulose is as a battery. Indeed, after a special treatment with the cellulose, it has a 3D structure that enables storage of significantly more power in less space than it is possible with conventional batteries. The material resembles foam in a mattress, though it is a little harder, lighter and more porous. You can touch it or even press it very hard without it breaking.

D. Spider silk

Spider silk is a fibrous biopolymer produced by spiders. It is composed by a well done structure of proteins, giving it special properties that perfectly match with several spider’s needs. It is a sustainable material that can be used on an industrial way.

Spider silk is stronger than steel but less than Kevlar. It has a strength as high as 1.75 GPa. However, like we can observe on the graph below, it is tougher than both (5 times tougher than Kevlar). Besides, these features depend a lot on humidity and temperature. Albeit, the degradation temperature is very high (250°C) and it keeps its strength with temperatures as low as -40°C.

It is a very extensible material, it can stretch up 5 times its length before breaking. Moreover, 70% of the energy imparted to silk in his extension is dissipated as heat through viscoelastic processes and is not recoverable as elastic recoil. This fact has two important implications. First, a projectile that collides with a spider silk material is not likely to be catapulted back out of the material by the elastic recoil. Second, the mechanical energy that is converted into heat is not available to drive the processes that cause fracture.

Other properties is that it is very light-weighted and spiders consume only a few material to make it. More surprising, in contact with water, it shrinks more than the half of its length. In the same vain, dry fiber gets rigid and increases a lot its stiffness.
One of the possible applications of spider-silk is Rust-free panels for motor vehicles or boats, but more concrete, a composite material composed of a certain amount of spider silk can considerably reinforce cars or planes shapes, as well as reducing its weight. The fact that spider silk maintains its strength as low as –40°C is a good point of these industries.

E. **Shrilk**

**Shrilk** (shrimp - silk) is a composite material developed in 2011. It is composed of chitosan extracted from shrimp shells and fibroin extracted from silk. It is the first biologically inspired engineering material using a biological design at molecular scale with the biomolecules associated to it.

The goal was to produce a material as strong as insect cuticles that could replace plastic on a low-cost, biodegradable, and biocompatible way.

Shrilk has the strength, toughness and laminar design of arthropod cuticle. It is also very lightweight. Taking the same weight, this composite material has twice the strength of chitosan, the stronger of the two components and ten times of both components blend. The researchers affirmed that “it is similar in strength and toughness to an aluminum alloy, but it is only half the weight”. By controlling the water content in the fabrication process, the researchers were also able to vary the stiffness of the material, ranging from elastic to rigid. This makes it easy to make complex 3D shapes such as tubes by using traditional casting or injection-molding techniques. The material is a transparent film.

Finally, it is a biodegradable material. This is very important if we think in a sustainable way. It would avoid very actual issues like plastic pollution in oceans.
Several uses are possible with this environmental friendly material. The most important one is replacing plastic for trash bags, single used bags or packaging. In fact, it is very resistant, it can be elastic, rigid or between both, it is low-cost to produce, it is biodegradable and it even uses waste to be produced. In the same vain, thanks to the quickly degrade property and the high resistance, diapers are also possible to be made with this material. Because it is as tough and strong as aluminum, it could certainly have industrial or transportation applications as well.

F. Stanene

Stanene is a polymer of tin (Sn) arranged in a similar way as graphene, a hexagonal layer. It is a new material, that has a 2D shape and, like graphene, has the particularity to be a topological insulator. This kind of insulator behaves as a normal insulator in its interior but whose surface contains conducting states. So the only difference with graphene is that it is made out of tin and not carbon.

As mentioned above, the main particularity of statene is being a topological insulator with super conductor properties. And this, with room temperature. Moreover, if fluorine is added to the structure, it could maintain its super conductor capability until 100 °C. It could transport electricity in normal conditions without heat lost. This makes it the most efficient material ever made to conduct electricity.

For more information about quantum properties, follow these links: thermal conductivity of stanene & Quantum thermal transport in stanene.

The main use that scientists prospect for statene is as electrical circuit in electronical devices. In fact, thanks to its super conductor ability and its extremely small size, it could decrease power consumption (100% efficient electricity connection inside), temperature (no overheat anymore) and size while in the same time it increases the performances. Chips with statene or staten-fluorine inside could be the next step in the evolution of informatics. It could even replace silicon in transistors, and could be used to build information technology infrastructure to manage a well-connected infrastructure.

However, the hypothetic aspect of this technology makes it very difficult to know the possible uses, or even if it is realistic as a mass produced material.

G. Super conductors

A superconductor is an element, inter-metallic alloy, or compound that will conduct electricity without resistance below a certain temperature, the critical temperature. Resistance is undesirable because it produces losses in the energy flowing through the material. Once set in motion, electrical current will flow forever in a closed loop of superconducting material, making it the closest thing to perpetual motion in nature. Scientists refer to superconductivity as a “macroscopic quantum phenomenon”.

As mentioned above, super conductor materials are materials that conduct electricity without any resistance (0Ω), if it is cooled enough to reach its critical temperature. Highest Tc reached yet is 147K, by a special molecule. Because there is no resistance, the system will not produce heat by Joule effect.

When a material is cooled enough to be in its super conductor phase and you put a magnet next to it, the magnet will be repelled. In fact, the super conductor will behave as a magnetic mirror. So the north (or south) pole of the magnet will repel itself through this “mirror”.

Another property is that electrical current flows between 2 superconducting materials, even when they are separated by a non-superconductor or insulator. However, if the magnet is too strong, the super conductor will lose its effect.
Knowing that 10 to 15% of electricity is lost during transport due to resistance in the cables, superconductors could be very useful. In fact, it eliminates the need of extra voltage to be able to transport electricity on long distances.

![Superconductor cable diagram](image)

Researches has found out that it would be possible to transmit 100 times more electricity by superconductor cable than by a similarly sized copper cable. A Finnish team affirms that if we use superconductors in energy plants around Europe, it will reduce the European CO₂ emissions by 1%. The technology can also be useful for motors. It is not very relevant to make them more efficient, because they are already very efficient. However it is possible to have the same power output with only one tenth of the actual weight thanks to superconductors. It is mainly intended for ship motors. The most commonly known usage of this technology is for magnetic trains. Several systems exist, with super conducting system built under the wagon or with super conducting system build on the track. The first option is easier to build. This video explains exactly how it works.

**H. DuoSkin**

A gold leaf is put on your body, like a temporary tattoo. It will be an interface to an electronic device. And NFC tag can be added.

![DuoSkin images](image)

http://duoskin.media.mit.edu/
I. Ultrathin platinum

Ultrathin platinum for reducing the amount of metal needed to catalyze reaction to obtain hydrogen fuel. The approach might make it possible to manufacture fuel cells that have significantly thinner layers of platinum than what’s typically used now. This approach that could eventually contribute to making fuel cells commercially viable.


J. Goodyear’s Eagle 360

The Goodyear Eagle-360 is a spherical-shaped design concept tire that would provide self-driving cars ultimate maneuverability, connectivity and biomimicry to increase safety.

**Maneuverability:** The multi-orientation of the spherical-shaped tire allows the car to move in all directions, contributing to safety for passengers, as well as coping with space limitations such as tight parking lots or city streets.

**Connectivity:** Embedded sensors further increase safety by communicating road and weather conditions to the vehicle control system and other nearby cars, while tread and tire pressure monitoring technology regulate even wear of the 360-degree tire to extend mileage.

**Connected via magnetic levitation:** The tires would rely on a magnetic levitation system to suspend the car resulting in a smooth, quiet ride for the passenger.

**Biomimicry:** Inspired by nature, the 3D printed tread mimics the pattern of brain coral and behaves like a natural sponge – designed to stiffen in dry conditions and soften when wet to deliver excellent driving performance and aquaplaning resistance.

Observations in the press from IAA 2016

A. MAN Truck

**EfficientCruise:**
The truck uses a stored map data and GPS to know if the road will be uphill or downhill. It allows anticipation far before having it within sight. The truck can save lot of fuel by having the exact momentum needed to reach the top of a hill or going out of a hollow.

**MAN TipMatic:**
Thanks to a special gearbox, three very useful functionalities are nowadays possible. The time it was difficult to change quickly from gear when you are on an uphill track is just a bad memory. The shifting time between the three highest gears has been considerable dropped down thanks to a new process. Moreover, on a slightly downhill track, the gear will automatically switch to the neutral point, in order to save the brakes and avoid lowering speed. The last property is making stop-and-go traffic more comfortable.

**The third topic is safety:**
MAN trucks are built with Adaptive cruise control (ACC), which calculates the distance with the vehicle in front and adapts the distance if needed. Lane guard system (LGS) also equips MAN trucks, it recognizes the lanes and keep the truck in the middle of them. Emergency brake assistant (EMA) is a system of sensors that avoid collisions by braking automatically if something is too close from the truck.
**MAN TeleMatics:**
Fleet management is much easier this way. The data (total weight, road topography etc.) are collected thanks to sensors and is sent to the fleet manager. It plans the roads and even the maintenances that need to be done. This functionality increases productivity while reducing costs and make the fleet manager job easier. The MAN TeleMatics can be managed by MAN thanks to their MAN ServiceCare subscription.

**Concept S:**
The new streamlined design gives a large truck the air resistance of a car, reducing fuel consumption and CO₂ emissions by 25%.

[Image of MAN TeleMatics]

[Image of Scania truck]


**B. Scania**
Scania develops a program for having trucks following each other on roads with only 0.5 seconds or 6 to 12 meters on highways. The vehicles communicate between them with wireless connection and treat the information coming in with advanced software system. The goal is having a truck that leads a train of autonomous trucks. The drivers of the following ones don't have to do anything, or can even not be inside the truck, if the law allows it. According to Scania’s experiments, it drops the fuel consumption by 12% with 10 distance between trucks.
Another project Scania works on is an **electrical truck related to a catenary road**. The company will test it in real-life conditions during 2016 in Sweden. It is an interesting project when you have in mind that trucks powered by electricity are capable of reducing fossil fuel emissions by 80 to 90% and energy consumption by 50% or more.

![Image of a Scania truck](image)

**360 degrees visibility** for the driver means much more security for the surrounding. It is made by cameras all around the truck and screens inside the cabin, around the driver.

![Image of 360 degrees visibility](image)

On the windscreen, the progression bar is projected. So the driver can anticipate brakes, acceleration, weather conditions, and even follow other drivers progress.

![Image of progression bar](image)

Another project called de-weathering is very innovative. It uses sensors that calculate the road lanes, obstacles, and other important aspects. With the information it create an image on the windscreen that represents the road, but without the particles that obscures the vision (rain, snow, fog, etc.).
Technology can also help drivers improve the performance of their vehicle. Indeed, Scania is collaborating with Ericsson to develop 5G for on-board telematics. 5G allows up to 5Gb/s transfers, opening the gate of wireless internet without any delay. Before, WLAN where used to communicate between trucks, now 5G will make it much easier. Autonomous vehicles are also really possible with this technology. Radars and cameras will gather the information and with 5G it will be transmitted to other trucks or call centers.

C. Daimler

Active Brake Assist 4:
Automatic brake and hazard warning light system to react to stationary and moving obstacles (not only vehicles but also pedestrians and cyclists)

Tyre pressure monitoring:
Tyre pressure is monitored wirelessly via sensors

Attention assist:
Monitors steering behaviour, directional consistency and driver activity to detect increasing signs of fatigue and inattiveness and warns the driver to take a break.

Mercedes-Benz Uptime:
Anticipates repair and maintenance requirements and provides recommended courses of action in real time. It continuously monitors the status of the vehicle systems and sends the information to a server that analyses automatically the information and sends a feedback to the Mercedes-Benz service organization to contact the client.

Autonomous Driving - Distronic Plus:
Automatically keeping a safe distance from the vehicle in front by braking and accelerating automatically and keeps the car in the center of the lane on straight roads and also in slight curves.

Also, Daimler plans by 2025 to commercialize a self-driving truck, using all of the previous skills and adding a more precise and wide camera to detect traffic lanes and signs. The truck will be able to communicate with other vehicles and has a 3-D map to ensure that the Highway Pilot is able to perfectly negotiate every bend and gradient.

(https://www.youtube.com/watch?v=7bFc0rBoFY8)
**SuperTruck**

The features of the supertruck are as follows:

- 12.2 miles on a gallon of diesel (most of the trucks can only do half as much)
- The truck is designed in an aerodynamic manner:
  - Active grille: open to maximize cooling at low speeds and closes automatically at high speeds for better aerodynamics
  - The ride height can be adjusted; raised to gain maneuverability at low speeds and reduce drag at high speeds
  - The overall shape of the vehicle has been designed to minimize air drag
- The chassis is lightweight (700 pounds lighter than standard trucks) and has reduced friction
- Waste Heat Recovery: converts a portion of the exhaust heat into usable energy.
- Engine Control: optimizing engine performance in real time for maximum fuel efficiency. The controller continuously monitors the engine's operating conditions as well as the external environment, and uses an on-board computer to determine the most efficient course of action during real-world operation.
- Using GPS and 3D digital maps, the SuperTruck can automatically manage vehicle speed, shifting and eCoast. It can also optimize hybrid battery-charging strategies to the terrain of the road ahead.
- There are solar panels on the roof to charge the hybrid battery
- The SuperTruck also incorporates a hybrid system as well as Predictive Hybrid Control

http://freightlinersupertruck.com/#main

**D. Volvo**

- Connecting the vehicle to a smartphone app; this feature gives the driver instant status information and control of the vehicle remotely. They can check the current fuel level, battery status, light status, and more. This technology lets the workshop see information about engine, mileage and fuel consumption. Technicians can also get a view of diagnostic trouble codes and monitor the status of crucial components like the brake pads, clutch, and battery.

- Volvo is also working on fully automatic connected trucks and platoons to reduce CO2 emission and costs.
- Zone management: matches the truck’s behavior to restrictions imposed by its location or the time of day. For example, a truck would perform night deliveries at reduced noise levels, or automatically switch to zero-emissions mode when entering a regulated zone.
- Volvo is actively working on energy-efficient and sustainable fuel sources: Methane, HVO and DME.
E. Renault

- Renault is extending their onboard IT solution with a new functionality to assist the drivers in driving in an eco-friendly manner. The reports (downloadable via smartphone) indicate drivers’ performance via a comprehensive rating, a color code (green, orange or red), a general classification and the trend over time. The classification criteria doesn’t focus on actual consumption as such, but on items that drivers can control (anticipation, correct use of the vehicle and length of time the engine is allowed to idle).

F. Chinese manufacturers

A project is coming up from China by Beijing Foton, a truck manufacturer. They launched the “China Internet Super Truck Global Innovation Alliance”, in other words, a collaboration with Cummins and Daimler AG for creating a green and safe Internet-driven super truck. It is not a new truck model, but a new way of thinking trucks. It is like an internet of vehicles with autonomous trucks. First of all, the project wants to focus on reducing fuel consumption and increase freight efficiency.
## ANNEX 02 – Summary of Innovative Projects on Vehicles

### Aerodynamics

<table>
<thead>
<tr>
<th>Project Description</th>
<th>Details</th>
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</thead>
<tbody>
<tr>
<td>Truck Aerodynamic Styling (GPG308)</td>
<td>Evaluate the effectiveness of aerodynamic styling relative to other fuel-saving methods. Be aware of the range of aerodynamic devices available; assess the relevance of sales claims made by manufacturers of add-on aerodynamic features. <strong>Estimate the fuel savings offered by application of aerodynamic devices</strong> to your fleet. Anticipate any secondary effects (either beneficial or adverse) conferred by each of the devices. <strong>Maximize the fuel savings offered by any aerodynamics fitted.</strong></td>
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<td>Duration: 06/00 - 06/01</td>
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### Safety

<table>
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<tr>
<th>Project Description</th>
<th>Details</th>
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<tr>
<td>ROADART - Research On Alternative Diversity Aspects for Trucks <a href="http://roadart.eu/">http://roadart.eu/</a></td>
<td>Due to the importance of tunnel safety, significant research effort is needed in order to <strong>check the behavior of the antenna pattern, diversity algorithms and ray tracing models especially for trucks passing through tunnels.</strong> The ROADART project aims to demonstrate especially the road safety applications for T2T and T2I systems under critical conditions in a real environment, like tunnels and platooning of several trucks driving close behind each other. Besides that traffic flow optimization and therefore reducing Greenhouse Gas emissions are positive outcomes of the use cases demonstrated in this project.</td>
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<td>Duration: 05/15 - 05/18</td>
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<tr>
<td>Project Name</td>
<td>Description</td>
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<td>SENSOLWEIGHS - Solar energy and pressure sensor based solution for truck weighing</td>
<td>Overloading of lorries is one of the most common infringements found in road freight transport: one in three lorries controlled is overloaded by 10%-20% over safe legal weight limits making roads much less safe. European Directive 2015/719 establishes maximum gross vehicle weights and urges for regular weight checks for commercial vehicles in the 28 EU countries. Truck scales are therefore essential for hauliers or public authorities. In addition, accurate truck scales are key for businesses delivering their products on the road as they are used to determine the weight of bulk goods being bought and sold in truckload-sized quantities being a crucial part of the business transaction functioning much as a cash register. Sensolweighs is a truck scale powered by solar energy (with wireless connection) giving the possibility to work off-grid in remote locations, based on an innovative hydraulic system to measure weight. Its light resistant materials make its relocation and installation an easy task, reducing costs by more than 32% with just 2% of the time currently needed to set up a truck scale.</td>
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<td>UPP - STPRMS - Sustainable Truck Parking Reservation Management System</td>
<td>Not enough parking spaces → truck drivers search 1.5 hours to find a parking and drive to 8 parking spaces. Solution: app for parking reservation. Payment per SMS</td>
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<tr>
<td>Truck Security - Fuel and cargo theft detection alarm system</td>
<td>Fuel and Cargo theft is a significant problem and a continuous threat to European road transport companies. Objective is to develop and execute a market replication of IDTEQ’s alarm system for road transport vehicles. IDTEQ incident detection technology samples and analyses sound. Sensors and proprietary signal processing algorithms detect specific incidents and to discard false incidents. Fuel and cargo theft alarm systems on road transport vehicles.</td>
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<tr>
<td>Project</td>
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<td><strong>OPTIBODY</strong>&lt;br&gt;Optimized Structural components and add-ons to improve passive safety in new Electric Light Trucks and Vans (ELTVs)&lt;br&gt;<a href="http://optibody.unizar.es/">http://optibody.unizar.es/</a>&lt;br&gt;Duration: 04/11 - 03/14</td>
<td>OPTIBODY is a concept of modular structural architecture for electric light trucks or vans (ELTVs) that will focus on the improvement of passive safety in order to help to reduce the number of fatalities and severe injuries. This structural concept is composed of: i) a chassis, ii) a cabin improving current levels of electric vehicles' comfort, occupant protection and ergonomics and iii) a number of add-ons bringing specific self-protection in case of impacts or rollover, and providing partner protection (crash compatibility) while interacting with other vehicles or vulnerable users. Each module can be individually optimized.</td>
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<tr>
<td><strong>Implications for Ireland's Road Infrastructure of Heavier European Trucks</strong>&lt;br&gt;NVA&lt;br&gt;Duration: 11/02 - 10/05</td>
<td>The White Paper on a Common Transport Policy, published by the European Commission in September 2001, states that heavy goods vehicle traffic on European roads could increase by nearly 50% by 2010 relative to its 1998 level. There is an active interest in increasing the legal truck weight limit to 48 tonnes, consisting of six 8-tonne axles. The objective of this proposed research is to determine the implications for Ireland's road infrastructure of the arrival of such heavier trucks on Irish roads.</td>
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<tr>
<td><strong>XCYCLE</strong>&lt;br&gt;Advanced measures to reduce cyclists' fatalities and increase comfort in the interaction with motorized vehicles&lt;br&gt;<a href="http://www.xcycle-h2020.eu/">http://www.xcycle-h2020.eu/</a>&lt;br&gt;Duration: 06/15 - 12/18</td>
<td>Cyclists suffer a disproportionate share of serious injuries and fatalities, and indeed in recent years that disadvantage has been growing. At the same time they often are not treated equally by traffic systems (e.g. traffic signals frequently fail to register their approach or presence)&lt;br&gt;&lt;br&gt;<em>XCYCLE has the aim of developing the means to equalize the treatment of cyclists in traffic and thus both encourage cycling and make cycling safer.</em> XCYCLE will develop: technologies aimed at improving active and passive detection of cyclists; systems informing both drivers and cyclists of a hazard at junctions; effective methods of presenting information in vehicles and on-site; cooperation systems aimed at reducing collisions with cyclists.</td>
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<td>Project Name</td>
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<td>MATISSE - Modelling And Testing for Improved</td>
<td>MATISSE aims to take a significant step forward in the capability of the automotive industry to model, predict and optimize the crash behavior of mass produced Fiber Reinforced Polymer (FRP) composite structures, which will be extensively used in Alternatively Powered Vehicles.</td>
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<td>Safety of key composite Structures in</td>
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<td>alternatively powered vehicles</td>
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<td><a href="http://www.project-matisse.eu/">http://www.project-matisse.eu/</a></td>
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<td>Duration: 10/12 - 09/15</td>
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<td>FanBrake - High heat dissipating Brake for</td>
<td>A major factor contributing to the poor safety record of HGVs is the limited ability of their brakes to remove heat at a sufficient rate to avoid brake fade, a condition where the thermal capacity of the brake has been exceeded and the brake operates at reduced effectiveness or failure. FanBrake aims to address these limitations through the development of a high heat dissipating brake that will remove heat at a faster rate than brakes that are currently used, thereby improving the safety performance of HGVs. The result of the proposed project has the potential to significantly improve safety, provide light weighting benefits and reduce cost through reduced number of brakes installed and component replacements in HGVs. Other potential applications for FanBrake include rail and construction vehicles.</td>
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<td>heavy duty vehicles through an enabling</td>
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<td>annular disc Fan effect</td>
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<td><a href="http://cordis.europa.eu/project/rcn/196431_en.html">http://cordis.europa.eu/project/rcn/196431_en.html</a></td>
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<tr>
<td>Duration: 06/15 - 12/15</td>
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<td>EVADER - Electric Vehicle Alert for Detection</td>
<td>Studies suggest that vehicles, driven in electric mode, either hybrid or pure electric vehicles, are considerably quiet and, thus, that they constitute a safety hazard for pedestrians and bicyclists in traffic. It is claimed that such electric vehicles are not acoustically perceived. The EVADER project investigates the interior and exterior sound scape of electric vehicle for safe operation, considering drivers feedback, feasible pedestrian reactions, driver and pedestrian warning systems and pedestrian safety. The project will also analyze innovative methods to improve the acoustic detectability of electric vehicles in urban scenarios. The project will define solutions to warn vulnerable users of a nearby moving vehicle while providing means for heightening the awareness of drivers in critical situations.</td>
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<tr>
<td>and Emergency Response</td>
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<td><a href="http://www.evader-project.eu/">http://www.evader-project.eu/</a></td>
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<td>Duration: 10/11 - 09/14</td>
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</table>
### AdaptIVe - Automated Driving Applications and Technologies for Intelligent Vehicles

AdaptIVe develops, tests and evaluates automated driving applications for passenger cars and trucks in daily traffic. AdaptIVe will demonstrate automated driving in eight demonstrator vehicles in close-distance, urban and highway scenarios. **The project provides guidelines for the implementation of shared control involving both the driver and the automation.**

To enhance the performance of automated systems the project improves the communication capabilities of the system. It defines and validates new specific evaluation methodologies and assesses the impact of automated driving on the European road transport. AdaptIVe examines existing legal conditions with regards to barriers to implementation.

### WATCH-OVER - Vehicle-to-Vulnerable Road User Cooperative Communication and Sensing Technologies to Improve Transport Safety

The WATCH-OVER project aimed at avoiding road accidents that involve VRUs, namely pedestrians, bicyclists and The core of the system, based on sensor and communication technologies, is the interaction of an on-board module and a user module, in order to cover a wide traffic scenario, including blind spots motorcyclists, by developing an integrated cooperative system for accident prevention. Current sensor technologies cannot 'see' behind obstacles and have a limited view of lateral and longitudinal areas. The main difficulty in detecting VRUs is therefore the limited 'visibility' of car drivers and of in-vehicle sensor based systems. **WATCH-OVER aimed at improving these soft spots, by combining the most promising communication technologies with the most promising sensor technologies.** Besides focusing on the exploitation of these advanced communication and sensing technologies, the main focus of the project was the design and development of the human machine interface (HMI) for both the driver and the vulnerable road user. Therefore, different solutions for the HMI have to be found: One would be **an in-vehicle device, whereas the others would be based upon wearable devices for pedestrians, bicyclists and motorcyclists.**
<table>
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<th>Economic</th>
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<tr>
<td><strong>Lightweight</strong></td>
<td><strong>ALIVE - Advanced High Volume Affordable Light weighting for Future Electric Vehicles</strong>&lt;br&gt;<a href="http://www.project-alive.eu/index.php?content=project&amp;a=menu_sub1&amp;b=item2">http://www.project-alive.eu/index.php?content=project&amp;a=menu_sub1&amp;b=item2</a>&lt;br&gt;Duration: 10/12 - 09/16&lt;br&gt;The ALIVE Project is working towards <strong>developing light-weight materials for use in future electric vehicles</strong>. The key objective is to achieve affordable solutions for vehicle weight reduction (around € 15k selling price excluding battery or € 20-25k including battery) targeting a further 20 % weight reduction of the Body-in-White (BiW) compared to the 30 % weight reduction already demonstrated in recent EU funded RTD projects, with respect to benchmark state-of-the-art electric vehicles recently introduced to the market, while also achieving substantial weight savings with the hang-on parts, chassis and main interior sub-systems.</td>
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<td></td>
<td><strong>WIDE-MOB - Building blocks concepts for efficient and safe multiuse urban electrical vehicles</strong>&lt;br&gt;<a href="http://eeepro.shef.ac.uk/wide-mob/index.html">http://eeepro.shef.ac.uk/wide-mob/index.html</a> (N\A)&lt;br&gt;Duration: 12/10 - 05/14&lt;br&gt;The WIDE-MOB project addresses the design and development of electric vehicles basic building blocks. This includes:&lt;br&gt;- <strong>Optimized aerodynamic</strong>&lt;br&gt;- <strong>Lightweight and low cost bodies</strong>&lt;br&gt;- <strong>Solar panels distributed on both horizontal and vertical surfaces</strong></td>
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<tr>
<td>Project/Innovation</td>
<td>Description</td>
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<tr>
<td>Plume - Reducing the weight of interior and exterior woodworking on motor vehicles</td>
<td>In order to reduce CO2 emissions lightening vehicles through the development of new materials is one of the solutions. <strong>PLUME project aims at reducing the weight of auto parts</strong>, like interior materials (e.g. the component pad located in the trunk) or external linings (e.g. the beltline dressing the doors) <strong>by 30 to 50%</strong>. To do this, the thermoplastic compounds having a reduced density were developed to adapt to an innovative injection foaming method. On the whole vehicle, the expected gain in terms of weight was in the order of 5 to 7 kg per vehicle. The PLUME project therefore proposed to address this problem by proposing to lighten 30-50% of the mass of auto parts like interior and exterior trims.</td>
</tr>
<tr>
<td>NEWIR - NEW WIRING for VEHICLES</td>
<td>The goal of our project is to address the issue of the <strong>reduction of the electrical wiring weight in vehicles</strong>, developing a new technology that produces galvanic plated aluminum electric wire that can replace electric wire made of copper. We plan to develop an integrated plant that will electro-plate aluminum wire with copper and normalize it, so that it can be subsequently drawn and used to produce innovative electric cables. These new cables for the transport sector will weigh about half as much as the equivalent copper cables and will have an approximately 40% lower production cost, all conditions being equal in terms of electrical and mechanical properties.</td>
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<tr>
<td>EV's</td>
<td>The limited capacity of electric batteries combined with the substantial amount of energy needed to run auxiliary equipment dramatically affects range capability of electric vehicles (EVs). For instance, the climate control system in summer conditions can absorb up to 40-60% of the available energy. The aim of the project is to <strong>develop an energy friendly climate control system capable to reduce of at least 50% the energy used</strong> for passenger comfort all over the year (i.e., heating, cooling and dehumidifying).</td>
</tr>
<tr>
<td>iPHEV - Advanced Plug-in Hybrid Electric Drive System for Commercial Fleet Trucks</td>
<td>Economic, environmental (improving air quality) and energy security factors provide a rational basis for switching to more efficient and less polluting vehicle technologies. <strong>iPHEV system that can be installed in new LCVs to save fuel costs per work cycle, reduce emissions and noise, improve capacity, and cut operation and maintenance costs.</strong> The system can be installed in different OEMs models with a retarder. iPHEV can be used in 3.5t LCV: utility work trucks, delivery vans, and minibuses.</td>
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</table>
### DESTA - Demonstration of 1st European SOFC Truck APU

**https://www.avl.com/**  
**Duration:** 01/12 - 06/15  

Within the DESTA project the first European SOFC (Solid Oxide Fuel Cell) Truck APU (Auxiliary Power Unit) will be demonstrated. **SOFC technology offers big advantages compared to other fuel cell technologies due to compatibility to conventional road fuels like diesel.** Within the last years significant improvements have been made to bring SOFC stack technology and APU BoP components to prototype and product level.

![SOFC Truck APU](image)

### NaNu! - Multiple Shift Operation and Night Delivery with Electric Commercial Vehicles

**Duration:** 01/13 - 12/15  

Deliveries to and within inner-city areas are a fundamental cause of temporary local bottlenecks in traffic and dominate the local peak concentration periods of relevant pollutants. **A shift of deliveries into night time would contribute to decongesting roads. A conflict arises in trying to protect sleeping hours (e.g. from delivery noise) and decongest the traffic at the same time.** The researchers involved in the NaNu! project are evaluating whether night delivery by electric commercial trucks could be the solution to the conflict.  

The idea of the NaNu! project is to test the usability of an electric truck under field conditions, that means with real logistical concepts and within a regional cluster. The project is assigned to the areas of commercial transport and city-logistics.
The project’s main objective to evaluate the multiple shift operation of mid-weighted electric commercial vehicle (ECV), by making better use of less frequented periods. The aim is to achieve a greater overall economy of ECVs. To guarantee and optimize 24-hour usage of ECVs, the project will develop a battery changing and charging system and reconstruct a 12-ton electric truck. By using trucks 24-hours, load rate is almost doubled and better use is made of infrastructure by inner-city freight transport, without negatively influencing noise abatement measures.

MARS-EV - Materials for Ageing Resistant Li-ion High Energy Storage for the Electric Vehicle
http://www.mars-ev.eu/homepage
Duration: 10/13 - 09/17

MARS-EV aims to overcome the ageing phenomenon in Li-ion cells by focusing on the development of high-energy electrode materials (250 Wh/kg at cell level) via sustainable scaled-up synthesis and safe electrolyte systems with improved cycle life (> 3000 cycles at 100%DOD). Through industrial prototype cell assembly and testing coupled with modelling MARS-EV will improve the understanding of the ageing behavior at the electrode and system levels. Finally, it will address a full life cycle assessment of the developed technology.

GEM E-drive - In-wheel electric drive for E-commercial vehicles
http://cordis.europa.eu/project/rcn/196235_en.html
Duration: 01/15 - 07/15

The goal is to develop a new electric drive inside the wheel for mobility market of electric buses and electric transport vehicles (E-commercial vehicles). The classical conceptual solution with electric motor positioned at the place of combustion engine has several drawbacks: heavy weight since mechanical transmission is needed, complex solution with many moving parts, low efficiency because of transmission losses and need for extra place. With our new solution that is simple (direct drive with no mechanical transmission), efficient (up to 92%), light (lighter up to 50%) and cost effective (simple production) we want to enhance the usage of electric drive for city traffic (buses and vans). In addition, our developed technology is easily adaptable for different applications and power levels due to its unique modular concept. Therefore our new electric drive solution together with low driving cost using electric energy and with reducing pollution, noise and CO2 emission in cities and urban areas, especially in Low Emission Zones (LEZ), represent excellent business opportunity for emerging E-mobility market of commercial vehicles.
For the realization of the project a feasibility study is required with delivered elaborated business plan as an outcome with following objectives:
- Technical feasibility study of in-wheel electric drive development for 25kW power and customization to other applications – modular concept
- Impact study of regulations and homologation on the product development
- Market analysis and detailed customer requirements study
- Strategy definition for entering to the market and product development
- Analysis of manufacturing process and cost evaluation with optimal process definition
- Risk evaluation with measures for risk minimization
- Identify strategy for IP management with timeline

**FURBOT - Freight Urban RoBOTic vehicle**  
**Duration:** 11/11 - 10/14

The project proposes novel concept architectures of **light-duty, full-electrical vehicles for efficient sustainable urban freight transport.**  
The project will develop FURBOT, a vehicle prototype, to factually demonstrate the performances expected. The main paradigms of the new vehicle design are: energy efficiency, sustainability, mobility dexterity, modularity, intelligent automated driving and freight handling robotization.
- Full electrical vehicle
- Energy efficient
- Dexterous mobility
- Equipped with robotic load/unload device
- Light weight high strength material
- Endowed with perceptual system and intelligent control
- Standardized freight units
- A discrete time simulator for FURBOT fleet networking analysis and management
ELECTRIC_AXLE - Electric axle for hybrid / electric commercial vehicles
http://cordis.europa.eu/project/rcn/196477_en.html
Duration: 05/15 - 10/15

Silex's goal with the project is to increase its turnover, profit and size by innovation, in order to become a medium size enterprise. During the project an 8.5 - 9 ton axle will be developed with integrated in-wheel electric motors, for electric/hybrid commercial vehicles (city buses, small trucks distributing products and fork lifts). Currently there are no commercially available axles designed for these vehicles, which is the novelty of the project. Vehicles using available axles, designed for combustion engines are heavier; consume more energy than necessary and contain components (propeller shaft, differential), which can be omitted in another architecture. Using the in-wheel motors ABS, ASR, retarder functions will be solved electronically. The axle will be 30% lighter than available ones, reducing vehicle’s energy consumption by 6-8%.

Efficiency

Potential measures for fuel savings with heavy duty vehicles - towards the development of compulsory mitigation measures
NVA
Duration: 02/15 - 02/18

This project seeks to contribute further knowledge to the technical basis for the introduction of CO2 limiting measures and to undergo a practical test for existing methods of CO2 enquiry. In the course of the study a concept shall be developed including the step by step introduction of concrete measures.

SRDE - System to Reduce Dust Emission from braking system of automotive vehicles
https://cordis.europa.eu/partners/web/req-12525
Duration: 10/14 - 10/17

The subject of low environmental impact brake systems to reduce micro and nano particles emissions has also been a priority in the research and development works undertaken by the Automotive Industry Institute (PIMOT). One of the outcomes of such works is an innovative and PIMOT-patented technology and system to reduce dust emission from disc brake and drum brake mechanisms of motor vehicles.

In the method developed at PIMOT, the dust emitted from a braking mechanism is absorbed by a filter thanks to the use of forced air flow around friction linings

The project involves the development of the system to the different type of vehicles: passenger car and bus. The system research on real traffic conditions, at least a 50% reduction of particle emissions should be demonstrated.
### THROTTLE FREE NATURAL GAS ENGINE - High performance throttle free gas engine for trucks on LNG
**http://www.nonox.nl/**
Duration: 11/14 - 08/16

NONOX developed a **mechatronic throttle free load control system for Otto engines which makes them almost as efficient as diesel engines** over the entire engine map.
They have a NOx emission that is almost zero (0,02 gr/kWh), a CO2-emission that is ±25% lower than a diesel engine, no emission of particulates and a NO (ZERO) methane slippage.
The noise level of these engines is about 50% lower compared to diesel engines.
Integration of this engine type into two heavy duty trucks and the road testing of these trucks while monitoring/logging the load level, fuel consumption, emission of CO2 and CH4, NOX, particulates etc.

### LORRY - Development of an innovative low rolling resistance truck tire concept in combination with a full scale simulation tool box for tire performance in function of material and road parameters
**http://cordis.europa.eu/project/rcn/105867_en.html**
Duration: 11/12 - 10/15

The aim of the LORRY project is to **reduce trucks carbon footprint by developing an innovative low rolling resistance tire concept combined with a comprehensive tool box for fleet fuel saving management.**
Steer and trailer tires developed in the framework of the project will demonstrate a minimum 20% gain in truck tire rolling resistance. Truck **tire wear and wet safety performance levels will be improved** additionally.
| **MAXITHERM - Innovative textile based heating system for technical applications**<br>http://cordis.europa.eu/project/rcn/196427_en.html<br>Duration: 05/15 - 09/15 | The objective of MAXITHERM is to contribute to the expansion of Electric mobility by extending Electric Vehicles' autonomy. We propose a heating system for EV that **reduces electricity demand of heating systems by 30% while maintaining passenger comfort**. MAXITHERM is a heating system based on a technical textile composed by a blend of electrically conductive and non-electrically conductive fibers that is integrated within the structure of the vehicles. It provides direct and fast heat to passengers and is 32% more cost efficient than current solutions. |
| **CONVENIENT - Complete Vehicle Energy-saving Technologies for Heavy-Trucks**<br>http://www.convenient-project.eu/fe#<br>Duration: 11/12 - 08/15 | The CONVENIENT project targets a 30% reduction of fuel consumption in vehicles for long-distance freight transport by developing an innovative heavy-truck archetype featuring a suite of innovative energy-saving technologies and solutions. Highly innovative solutions for improved efficiency:  
- Innovative energy efficient systems, including hybrid transmission, electrified auxiliaries, dual level cooling, parking HVAC  
- Energy harvesting devices, like photovoltaic solar roof for truck and semitrailer  
- Advanced active and passive aerodynamics devices for the truck and for the semitrailer  
- An Holistic Energy Management system at vehicle level  
- A Predictive Driver Support to maximize the energy saving benefits  
- A novel Hybrid Kinetic Energy Recovery System for the semitrailer |
<p>| <strong>SWH - Demonstration of a Binary-Logic Hybrid Transmission for Heavy-Duty Vehicles</strong>&lt;br&gt;<a href="http://swh-transmission.com/">http://swh-transmission.com/</a>&lt;br&gt;Duration: 10/14 - 04/15 | A vehicle powertrain includes the engine and transmission. In the segment of heavy-duty vehicles (&gt;16 tonnes) automatic transmissions include a torque converter to engage/disengage the transmission and the combustion engine in gearshifts. SAPA OPERACIONES has developed a new technology of automatic transmissions for heavy-duty vehicles called &quot;Binary Logic&quot; without torque converter, which bases its operation in clutches and planetary gears trains. This technology is characterized by high number of gears (24) and high efficiency (90-92%). Although high performance is achieved due to the high number of gears and gearshift quality, there are two gear shifting’s in which a power interruption is given (13, 21). To solve this problem and improve the performance, a hybrid module has been incorporated to the “Binary Logic” transmission. This hybrid transmission is called &quot;SWH&quot;. The following improvements have been obtained: Gearshift without interruption of power in all gears, performance over 96% and new operating modes (up to 7). |
| <strong>ECOEFFECT - ECO trainEr For Fleet CommErCial truCks and lighT vehicles</strong>&lt;br&gt;<a href="http://erti-co.com/eco-trainer-for-fleet-commercial-trucks-and-light-vehicles-ecoeffect">http://erti-co.com/eco-trainer-for-fleet-commercial-trucks-and-light-vehicles-ecoeffect</a>&lt;br&gt;Duration: 04/11 - 11/13 | The European Commission promotes the benefits of eco-driving in its Green Paper &quot;Towards a new culture for urban mobility&quot; (adopted in 2007), and eco-driving is recognized as a tool of delivering significant savings on fuel consumption and thus reducing emissions and costs in the road transport sector. <strong>ECOeffect aimed to equip training providers with the ability of delivering high quality eco-driving training</strong>; to provide knowledge and expertise to market eco-driving to transport operators; and to promote the integration of eco-driving into professional driver qualification and certification. |</p>
<table>
<thead>
<tr>
<th>Project</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMARTOP - Self powered vehicle roof for on-board comfort and energy saving</td>
<td>SMARTOP will create a technology that will revolutionize the auto industry and the cars that we drive, by converting everyday light into a form of power. The SMARTOP project addresses the needs of integrating power hungry devices and matching comfort and safety of customers.</td>
</tr>
<tr>
<td>HEATRECAR - Reduced Energy Consumption by Massive Thermoelectric Waste Heat Recovery in Light Duty Trucks</td>
<td>The consumption of automotive fuel due to electricity demand on board vehicles has been steadily increasing. The basic principle addressed in this project consists in directly converting the heat in the exhaust line into electricity. The main objective of the HEATRECAR project is to reduce the energy consumption and curb CO2 emissions of vehicles by massively harvesting electrical energy from the exhaust system and re-use this energy to supply electrical components within the vehicle or to feed the power train of hybrid electrical vehicles.</td>
</tr>
<tr>
<td>REDUCE - Active reduction of fuel consumption and exhaust emission for trucks</td>
<td>Reduce fuel consumption in transport work. Installing 'DV4' equipment in trucks. The equipment enabled instant feedback to the driver about fuel consumption and exhaust emission. Training concerning the equipment and fuel-saving driving and learning and use of DV4. Data on fuel consumption per driver and per road class were collected from the two trucks, and from another two trucks without DV4. A development of the instant feed-back to the driver about fuel consumption and exhaust emission. Reports could be generated from a web interface. Studies and analysis of collected data and how the use of the equipment.</td>
</tr>
</tbody>
</table>
## ANNEX 03 – List of EU Funded Innovative Projects

<table>
<thead>
<tr>
<th>Title</th>
<th>Category</th>
<th>Year</th>
<th>Website</th>
<th>ETP</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEXTRUST</td>
<td>Global supply network coordination and collaboration</td>
<td>2018</td>
<td><a href="http://nextrust-project.eu/">http://nextrust-project.eu/</a></td>
<td>ALICE</td>
</tr>
<tr>
<td>Potential measures for fuel savings with heavy duty vehicles - towards the development of compulsory mitigation measures</td>
<td>Efficiency</td>
<td>2018</td>
<td>NVA</td>
<td>ERTRAC</td>
</tr>
<tr>
<td>U-TURN</td>
<td>Urban logistics</td>
<td>2018</td>
<td><a href="http://www.u-turn-project.eu/">http://www.u-turn-project.eu/</a></td>
<td>ALICE</td>
</tr>
<tr>
<td>Collogistics</td>
<td>Global supply network coordination and collaboration</td>
<td>2016</td>
<td><a href="http://collogistics.com">http://collogistics.com</a></td>
<td>ALICE</td>
</tr>
<tr>
<td>Project</td>
<td>Description</td>
<td>Category</td>
<td>Year</td>
<td>Website</td>
</tr>
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<td>---------</td>
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</tr>
<tr>
<td>DESTA - Demonstration of 1st European SOFC Truck APU</td>
<td>EV's</td>
<td>2015</td>
<td><a href="https://www.avl.com/">https://www.avl.com/</a></td>
<td>ERTRAC</td>
</tr>
<tr>
<td>FlexiHyLifts</td>
<td>Information systems for interconnected logistics</td>
<td>2015</td>
<td>N/A</td>
<td>ALICE</td>
</tr>
<tr>
<td>Green^2</td>
<td>Sustainable, safe and secure supply chains</td>
<td>2015</td>
<td><a href="http://www.green2logistics.eu/">http://www.green2logistics.eu/</a></td>
<td>ALICE</td>
</tr>
<tr>
<td>LOGINN</td>
<td>Information systems for interconnected logistics</td>
<td>2015</td>
<td><a href="http://www.loginn-project.eu/">http://www.loginn-project.eu/</a></td>
<td>ALICE</td>
</tr>
<tr>
<td>Plume - Reducing the weight of interior and exterior</td>
<td>Lightweight</td>
<td>2015</td>
<td><a href="http://www.predit.prd.fr/predit4/pr">http://www.predit.prd.fr/predit4/pr</a></td>
<td>ERTRAC</td>
</tr>
<tr>
<td>Project/Program</td>
<td>Description</td>
<td>Domain</td>
<td>Year</td>
<td>Website</td>
</tr>
<tr>
<td>-----------------</td>
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<tr>
<td>woodworking on motor vehicles</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SWH - Demonstration of a Binary-Logic Hybrid Transmission for Heavy-Duty Vehicles</td>
<td>Efficiency</td>
<td>2015</td>
<td>ojet/43815</td>
<td>ERTRAC</td>
</tr>
<tr>
<td>Truck Security - Fuel and cargo theft detection alarm system</td>
<td>Safety</td>
<td>2015</td>
<td></td>
<td>ERTRAC</td>
</tr>
<tr>
<td>Cassandra</td>
<td>Sustainable, safe and secure supply chains</td>
<td>2014</td>
<td></td>
<td>ALICE</td>
</tr>
<tr>
<td>EVADER - Electric Vehicle Alert for Detection and Emergency Response</td>
<td>Safety</td>
<td>2014</td>
<td></td>
<td>ERTRAC</td>
</tr>
<tr>
<td>FURBOT - Freight Urban RoBOTic vehicle</td>
<td>EV's</td>
<td>2014</td>
<td></td>
<td>ERTRAC</td>
</tr>
<tr>
<td>OPTIBODY - Optimized Structural components and add-ons to improve passive safety in new Electric Light Trucks and Vans (ELTVs)</td>
<td>Safety</td>
<td>2014</td>
<td></td>
<td>ERTRAC</td>
</tr>
<tr>
<td>WIDE-MOB - Building blocks concepts for efficient and safe multiuse urban electrical vehicles</td>
<td>Lightweight</td>
<td>2014</td>
<td></td>
<td>ERTRAC</td>
</tr>
<tr>
<td>C- liege</td>
<td>Sustainable, safe and secure supply chains</td>
<td>2013</td>
<td></td>
<td>ALICE</td>
</tr>
<tr>
<td>ECOEFFECT - ECO trainEr For Fleet Commercial trucks and light vehicles</td>
<td>Efficiency</td>
<td>2013</td>
<td></td>
<td>ERTRAC</td>
</tr>
<tr>
<td>SMARTOP - Self powered vehicle roof for on-board comfort and energy saving</td>
<td>Efficiency</td>
<td>2013</td>
<td></td>
<td>ERTRAC</td>
</tr>
<tr>
<td>HEATRECAR - Reduced Energy Consumption by Massive Thermoelectric Waste Heat Recovery in Light Duty Trucks</td>
<td>Efficiency</td>
<td>2012</td>
<td></td>
<td>ERTRAC</td>
</tr>
<tr>
<td>EURIDICE</td>
<td>Sustainable, safe and secure supply chains</td>
<td>2011</td>
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</tr>
<tr>
<td>Integrity</td>
<td>Global supply network coordination and collaboration</td>
<td>2011</td>
<td></td>
<td>ALICE</td>
</tr>
<tr>
<td>BESTLOG</td>
<td>Global supply network coordination and collaboration</td>
<td>2010</td>
<td></td>
<td>ALICE</td>
</tr>
<tr>
<td>WATCH-OVER - Vehicle-to-Vulnerable Road User Cooperative Communication and Sensing Technologies to Improve Transport Safety</td>
<td>Safety</td>
<td>2008</td>
<td></td>
<td>ERTRAC</td>
</tr>
<tr>
<td>Cristal</td>
<td>Information systems for interconnected logistics</td>
<td>2007</td>
<td></td>
<td>ALICE</td>
</tr>
<tr>
<td>eDRUL</td>
<td>Urban logistics</td>
<td>2005</td>
<td></td>
<td>ALICE</td>
</tr>
<tr>
<td>Description</td>
<td>Category</td>
<td>Year</td>
<td>Sponsor</td>
<td></td>
</tr>
<tr>
<td>----------------------------------------------------------------------------</td>
<td>------------</td>
<td>------</td>
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<td></td>
</tr>
<tr>
<td>Implications for Ireland's Road Infrastructure of Heavier European Trucks</td>
<td>Safety</td>
<td>2005</td>
<td>N\A</td>
<td></td>
</tr>
<tr>
<td>REDUCE - Active reduction of fuel consumption and exhaust emission for trucks</td>
<td>Efficiency</td>
<td>2003</td>
<td>N\A</td>
<td></td>
</tr>
<tr>
<td>Truck Aerodynamic Styling (GPG308)</td>
<td>Aerodynamics</td>
<td>2001</td>
<td>N\A</td>
<td></td>
</tr>
</tbody>
</table>
# ANNEX 04 – Summary of Projects on Modularization

<table>
<thead>
<tr>
<th>Image</th>
<th>Project Info</th>
<th>Summary</th>
</tr>
</thead>
</table>
| ![Company : bpost](image1) | **Company :** bpost  
**Receiving and sending packages at lockerpoints**  
Authorized dimensions of the packages;  
- max weight 30 kg  
- not smaller than 14,4 *11,2 cm  
- not greater than 42*31*69 cm | |
| ![Company : DHL](image2) | **Company :** DHL  
**Receiving and sending packages at lockerpoints or parcelshops.**  
•Min. 15 x11,3.5 cm (l x w x h)  
•Max. 120 x 60x50 cm (l x w x h)  
•Max. weight per parcel 31.5 kgs  
•Volume 250 kg/m³  
•Max. 150 liter per parcel | |
| ![Site:](image3) | **Site:**  
https://logisticsviewpoints.com/2013/02/06/drones-the-birth-of-a-new-transportation-mode/  
http://www.supplychain247.com/article/a_drone_delivers_your_package  
**Aircraft that have the capability of autonomous flight, which means they can follow a mission from point to point.**  
**Visionary idea: do for physical transportation what the Internet did for the flow of information.** | |
| ![Site](image4) | **Site:**  
http://www.streatordependable.com/products/containers/  
**Streator Dependable can replicate an existing design, modify one of our current designs to fit your specific needs or design a custom unit to fit your application** | |
| ![http://www.parklogistics.co.uk/184115/use-a-yardramp-to-prevent-port-handling-charges-for-shipping-containers-says-thorworld](image5) | **http://www.parklogistics.co.uk/184115/use-a-yardramp-to-prevent-port-handling-charges-for-shipping-containers-says-thorworld**  
**Mobile yardramps for unloading goods off shipping containers can remove the need for expensive handling charges in ports, according to loading specialists Thorworld Industries.**  
**The payback on investing in a yardramp (whether it is bought or rented) can be achieved within a year – or sooner, depending on the frequency of deliveries from overseas.** | |
The chassis has been designed to contain two EU pallets (800x1200mm) with a maximum height of 1700 mm.

Modular boxes: According to the specific needs three different kind of boxes have been designed:

<table>
<thead>
<tr>
<th>Box Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid box</td>
<td></td>
</tr>
<tr>
<td>Isolated box</td>
<td></td>
</tr>
<tr>
<td>Multibox</td>
<td></td>
</tr>
</tbody>
</table>

One of the biggest challenges the port and shipping industry collectively faces is the repositioning of empty containers, with 24.1% of the total container transport volume empty units. This solution is the ‘Connectainer’; a new 20’ container that can be joined to another Connectainer to form a 40’ container. Francisco Aguilar of Connectainer explains: “Any 40’ can be disconnected to form 2x20’. And this easy operation can be done in 30 minutes by two smooth operators.

FROM A TO GREEN

The g-combi is a platform with g-modules, the platform has a system with winches, locking mechanism and rails.

<table>
<thead>
<tr>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>g-module – The g-modules are containers with empty space to organize different kind of goods.</td>
</tr>
<tr>
<td>For the case study this container has a system of panels that provide room for the g-boxes with a locker system, a card reader (to activate the lock system) and a podium with wheels. The g-module works as a dispenser of g-boxes in the P+R (Park and Ride).</td>
</tr>
</tbody>
</table>
The g-box is a plastic box to carry groceries (35cm x 35cm x 50cm) to deliver goods in P+R. It is only for the case study.

Cargoshell collapsible container
http://www.cargoshell.com/

The current steel containers use the same space whether they are empty or full, and waste valuable resources globally being transported and stored empty.

A Cargoshell can be broken down by one person in 30 minutes, to a quarter of its original volume.

Ecalibur SL-Tainer
http://www.excaliburshelters.com/#sl-tainer/c1uew
108 Fisher St
Okotoks, Alberta Canada, T1S 1A2
Tel: +1 403 995 1818

The principle behind the SL-Tainer is like something out of Thunderbirds. It looks very similar to a standard 20-ft (6.1-m) or 40-ft (12.2-m) container, except that the corners contain built-in hydraulic jacks that can lift the SL-Tainer to a height of 1.6 m (5.2 ft) and provide a clearance width of 3.1 m (10.2 ft), which is enough to reverse a flatbed trailer underneath, and then lower the container.

The power source is an included external two-speed hydraulic "power pack" with a 9 kW motor that generates up to 3,000 psi. The whole system is operated by a wired or wireless remote control unit. Excalibur says that SL-Tainer loads or unloads in 15 minutes, uses 120 ml (4 oz) of fuel, and has a self-leveling system accurate to within 20 mm.
According to Excalibur, the system has a number of advantages over conventional containers. The most obvious one being eliminating the need for a crane, which removes considerable expense. The other is that, unlike other self-lifting systems, the SL-Tainer is an integral part of the container rather than an add-on, which requires additional expense and effort.

To date available technology on the market focuses on to meet complex materials handling tasks that are modular or work multidirectional. The Celluveyor combines these features in a single system. As a modular and multi-directional conveyor system for complex tasks, it is suitable for virtually all intralogistics applications and fulfilled a variety of necessary product characteristics for industry 4.0.

A freight train loaded with containers pictured at the new container terminal of the Burchard quay in Hamburg, Germany.
Acknowledgment

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http://ec.europa.eu

PROJECT PARTICIPANTS:

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DAF DAF TRUCKS NV
FEHRL FORUM DES LABORATOIRES NATIONAUX EUROPEENS DE RECHERCHE ROUTIERE
FHG FRAUNHOFER-GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V
IFSTTAR INSTITUT FRANCAIS DES SCIENCES ET TECHNOLOGIES DES TRANSPORTS, DE L’AMENAGEMENT ET DES RESEAUX
IRU IRU PROJECTS ASBL
P&G PROcter & GAMBLe SERVICES COMPANY NV
SCB SCHMITZ CARGOBUll AG
TNO NEDERLANDSE ORGANISATIE VOOR TOEGEPAST NATUURWETENSCHAPPELIJK ONDERZOEK (NL)
UNR UNIRESEARCH BV (NL)
VEG VAN ECK BEESD BV
VIF KOMPETENZZENTRUM - DAS VIRTUELLE FAHRZEUG, FORSCHUNGSGESELLSCHAFT MBH

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