



## TRANSFORMERS HVTT13 CONFERENCE REPORT

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## Abstract

The Transport White Paper of the European Commission presents a CO<sub>2</sub> reduction target of 60% by 2050 for the transport sector. Improving the energy performance of transport, including heavy duty vehicles is identified as one of the routes that could possibly contribute in reaching this objective. PROJECT TRANSFORMERS is a response to EU Call – Configurable and Adaptable Truck to reduce transport energy-use/tonne-km by 25% in the direction of achieving the above mentioned objective.

The TRANSFORMERS project combines a modular approach for mission rightsizing by means of hybridization, truck engine downsizing and a trailer design that addresses simultaneously aerodynamics and load efficiency improvements. The overall goal is to achieve 25% energy load efficiency (in energy/km.tn) in a real world application taking into account the needs to maintain road infrastructure and traffic safety. The technology selection and sizing of the electric drive system will include analysis of the economic viability.

This paper will give an introduction to the project, and also a summary of the deliverables that are already reported by the project.

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## 1 Introduction

### 1.1 Background to the project TRANSFORMERS

Transportation of raw materials and finished goods from the Manufacturing Centre to the Distribution Centre and then from the Distribution Centre to the end consumer can be done either by air, rail, road or water-based freight services or a complex combination of many modes, known as '*multimodal*' logistics. Applications for air based logistics can be seen in the transportation of high value and time sensitive goods, and bulk shipping by this mode can be commonly found in postal, military, electronic chips or relief operations to name a few. This mode of transport constitutes about 0.1% of the total freight transport in Europe based on tonne-kilometers. Road transport constitutes 45.3% of the total freight transport based on tonne-kilometers. This mode of transportation has a near monopoly in the distribution of finished products at the lower level of the supply chain, particularly in the delivery of retail supplies. Much of the rail or water based system of transporting goods can be seen at the upper level of the supply chain. With the result of the opening up of markets and the results in the harmonization of social, fiscal, technical and safety rules between Member States resulted in the predominance of road freight transport. This had more to do with the introduction of qualitative criteria (instead of quantitative). Competition has been introduced in price setting as well. Realizing the Single Market in road freight transport is much more advanced compared to the other modes. This has contributed in a greater measure for making road freight transport very customer-friendly. Thus, it is clearly evident that transportation of goods by trucks is often a requirement for the function of the logistical system in parts or as a whole and being a versatile mode of transport it plays a unique role in the transportation system – as a sole door-to-door service provider and as a complement to other modes. Whether it's for local transportation or a part of the long distance transport chain, road transport lays a pivotal role. Presently, road freight transport is to a very large extent dependent on oil. Some alternative fuels are already available but their economic viability needs to be further improved. In its 2011 Transport Policy White Paper, the European Commission indicates that road freight transport is expected to continue to play a predominant role in the multimodal freight transport network and therefore needs to be given the tools to allow greening at-source.

The Transport White Paper of the European Commission presents a CO<sub>2</sub> reduction target of 60% by 2050 for the transport sector. Improving the energy performance of transport, including heavy duty vehicles is identified as one of the routes that could possibly contribute in reaching this objective. PROJECT TRANSFORMERS is a response to EU Call – Configurable and Adaptable Truck to reduce transport energy-use/tonne-km by 25% in the direction of achieving the above mentioned objective. In response to the call, the consortium aims to develop and demonstrate innovative and energy efficient trucks and load carriers for long, medium and short distance transport assignments with an improved load efficiency leading to an overall 25% less energy consumption on a tonne-km basis and a lower impact on the wear and tear of the road infrastructure.

This could be achieved using the following key innovations:

1. A distributed, modular, and mission adaptable Hybrid-on-Demand (HoD) driveline concept that is applicable to both, existing and future trucks,
2. A pre-standard electric Hybrid-on-Demand Framework that supports a broad market introduction of hybrid commercial vehicles and provides planning certainty for future RTD activities.
3. Mission-based configurable overall truck-trailer design (toolbox);
4. Loading efficiency optimized trailer interior design (toolbox); TransFormers focus on achieving these key innovations within the existing European legal and regulatory framework in terms of weights and dimensions, general road safety and type approval.

The focus is on optimizing road transport operations by improving the load efficiency (handling as well as load capacity) and fuel efficiency. The new Commission proposal on weights and dimensions [COM(2013)195], the "Clean Power for Transport" package, the initiatives relating to the reduction of toxic and non-toxic emissions and the type approval legislation could all have an impact on how the optimal vehicle combination can be developed and should be included in the considerations.

Other objectives include:

1. An innovative truck-trailer/tractor-semitrailer driveline with up to 8% energy saving per tonne-km in long haulage compared to state-of-the-art truck-trailer/tractor-semitrailer vehicles;
2. First-time demonstration of a distributed hybrid driveline concept with an internal approach on rightsizing the driveline for each transport mission;
3. Enable a potential market penetration of the mission-adaptable distributed hybrid driveline of up to 70% in medium-term for already existing state-of-the-art and future truck-trailer/tractor-semitrailer vehicles;
4. Support of fast dissemination and a lively commercial competition in the field of mission-adaptable distributed hybrid drivelines including a substantially improved environment for future SME developments;
5. Build-up of demonstrator to evaluate the energy savings of mission-adaptable distributed hybrid drivelines. Design and development of mission adapted aerodynamic solutions giving up to 10% in reduction of fuel.
6. Optimization of vehicles combinations and road freight, by introducing high capacity vehicles – B-double.

The TRANSFORMERS project consortium represents a broad collaborative approach including OEMs: Volvo (co-ordinator), Daimler and DAF; Trailer manufacturers: Schmitz Cargobull and Van Eck Group; Suppliers: Bosch; Research institutes: Fraunhofer, TNO, Virtual Vehicle, FEHRL and IFSTTAR; End users: Proctor & Gamble and IRU. The project duration is 42 months starting September 2013 and the total budget is 8 m€ of which 5.2 m€ is funded by FP 7 through DG Research & Innovation.

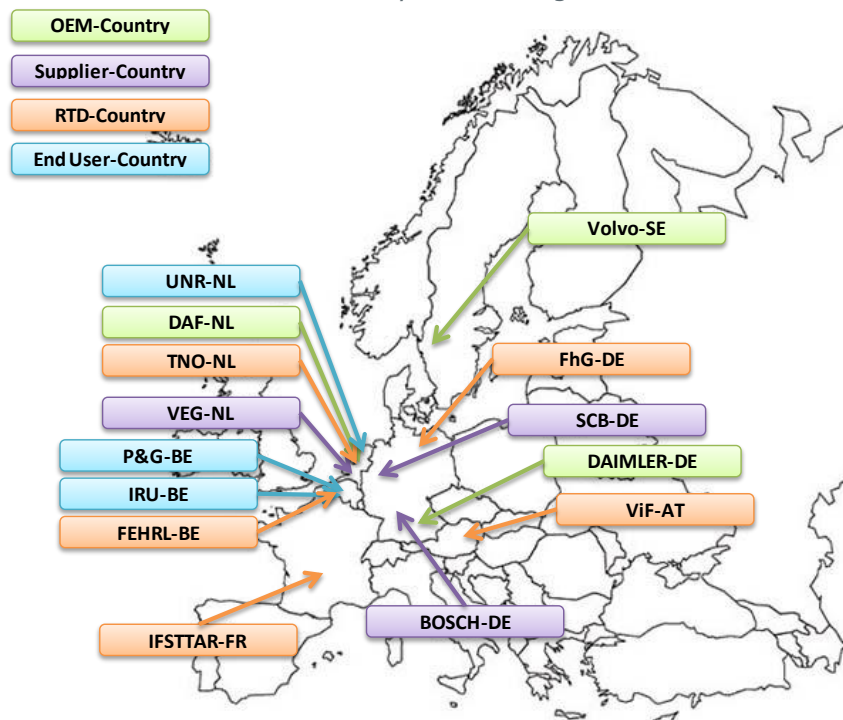


Figure 1 - Geographical overview of consortium partners

## 1.2 Work package breakdown

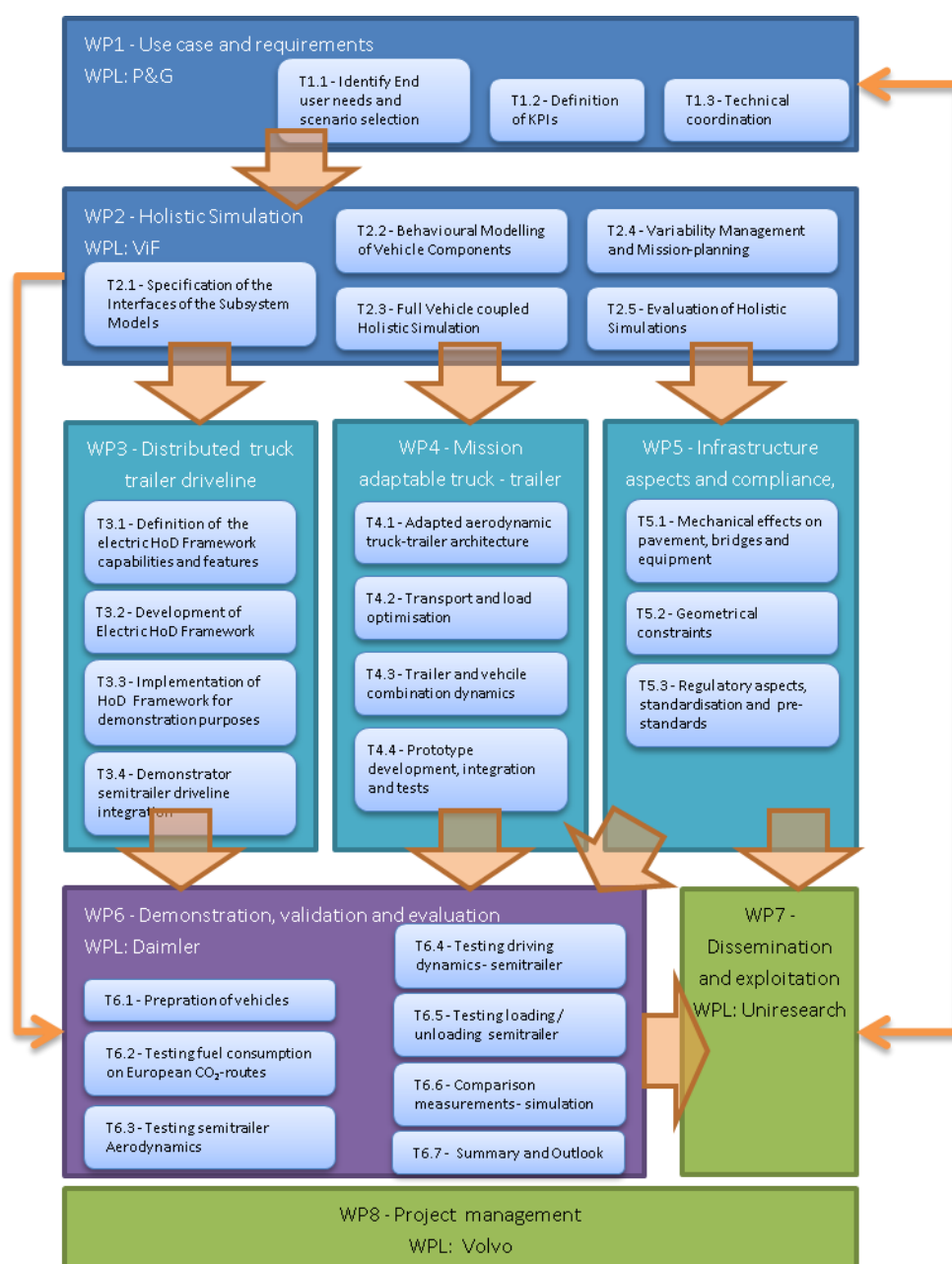


Figure 2 - Work package overview of Transformers

### WP 1 – Use cases and requirements

The objective and aim of this WP1 is to identify the major needs and expectations from the industry, users and Authorities for a new configurable and adaptable truck coping with an increasing need for optimised load efficiency for each mission. The end user group will be an important key input in this work. This WP will provide basic information based on key performance indicators that will help to compare current situation with further developments. And will be the input for WP 2, 3, 4, 5 and 6

## **WP 2 – Holistic simulations**

The challenging tasks of tool interfacing and the configuration of such a holistic simulation are addressed within WP2. On the basis of a holistic system simulation the evaluation of the component selection/dimensioning of electrification components (e.g. motor-generator, battery-pack) is possible as well as the design and evaluation of purpose designs (e.g. planning-control strategy, truck-trailer configurations). Providing essential inputs for the evaluation / demonstration task – amount of fuel reduction of special truck & trailer assemblies and/or impact of specific components or approaches on the overall truck-trailer's system.

For the development and the design of the Hybrid-On-Demand (HoD) drive-line concept a primary component selection is carried out in an earlier stage of the project in WP4 based on a simplified system considerations. However, in a second evaluation step these proposed configurations of vehicle components are evaluated from a more general point of view using the established holistic full-vehicle simulation approach. State of the art simulation tools will be used (no simulator development) and extended models to take into account the properties of the configurable and adaptable vehicle concepts (no new simulator) will be used. And the Main results are: Updated simulation models, Holistic system simulation for purpose designs and evaluation and Optimal component selection.

## **WP 3 - Electric Hybrid-on-Demand Framework**

The objectives for WP3 are developing the novel modular, distributed, and mission-adaptable Hybrid-on-Demand driveline concept, a first-time design of an electric Hybrid-on-Demand framework, and the demonstration and evaluation of the mission-adaptable distributed Hybrid-on-Demand driveline within real-world test vehicles.

Therefore WP3 is subdivided into 4 tasks. Task 3.1 defines the capabilities and features of mission-adaptable distributed Hybrid-on-Demand (HoD) drivelines for truck- (semi)trailer vehicles based on use cases and requirements analysed in WP1. The capabilities and features defined in Task 3.1 are used in task 3.2 to specify the HoD framework in terms of specific infrastructure, necessary interfaces, and required software functionalities. Furthermore functional safety and potential risks will be investigated. An important factor is the openness of the pre-standard framework for the electric Hybrid-on-Demand driveline concept as it is the basis for a subsequent industrial standardisation process. Therefore the results will be shared and communicated closely with the end-user group. Task 3.3 implements the HoD framework for the first time and gives feedback and additional input for the HoD specification that will be refined in parallel. At the end of task 3.3 the demonstrator HoD driveline will run on a test rig. Task 3.4 integrates a HoD driveline into the semitrailer demonstrator. An initial start-up and an approval (street release) will be performed so that the demonstrator can be evaluated in terms of energy savings afterwards in WP6.

## **WP 4 - Mission Adaptable Truck Trailer Architecture**

The Mission Adaptable Truck Trailer architecture focuses on optimising the cargo filling and dynamically adapting the aerodynamic form depending on the fill rate. Optimising the fill rate can gain about 10% in transport efficiency. When the fill rate is lower and when this is not possible it should be possible to reduce the air drag to achieve the similar savings. This WP will also address safety issues of the new vehicle concepts, assessing the stability and on road safety with respect to the truck and trailer architecture, loading conditions, road geometry and performances (e.g. skid resistance). Main outcome: Optimised aerodynamic architecture for tractor-semitrailer configuration – validation of technical and economic feasibility, Overview over the technical and economical possibilities for the semitrailer design with focus on optimised transport efficiency, theoretical validation of the driving controls strategy and safety/stability assessment by simulation and benchmarking and Prototype semitrailer for the WP6 test phase, included the electric driveline of WP3 and all defined concepts on aerodynamic and fill rate optimisation in WP4.

## **WP5 - Infrastructure aspects and compliance, Regulatory framework**

This WP will ensure that all the new concepts and vehicle configurations proposed will fully comply with the existing road infrastructures. That is a necessary condition to allow the circulation of these trucks and vehicle combinations on the European network. The task 5.1 will address all the mechanical issues, mainly the effects of axle and vehicle loads on pavements, bridges and road equipment (e.g. safety barriers). The task 5.2 will check the compliance of the vehicles to the geometry of the infrastructures, both in quasi-static and in dynamics. Finally, the task 5.3 will check the compliance with the existing European regulation and propose any necessary revision, without increasing the risks for the infrastructures and the road safety.



### WP6 - Demonstration, validation and evaluation

In this WP6 all WPs are coming together and will evaluate the fuel efficiency improvement of the realised tractor-semitrailer. Target is to measure the improvement on test tracks under defined conditions and, after a positive evaluation of the roadworthiness of the combinations, onroad under realistic conditions, both under comparison between the improved and standard vehicle configurations. After the real life testing all collected data will be compared to the simulation results in WP2.

Boundary conditions are: ensure common interfaces and ensure practical usage: The body entrance is the same as for standard bodies. Main results are a database with test results for further use in the analysis.

### WP 7 – Dissemination and exploitation

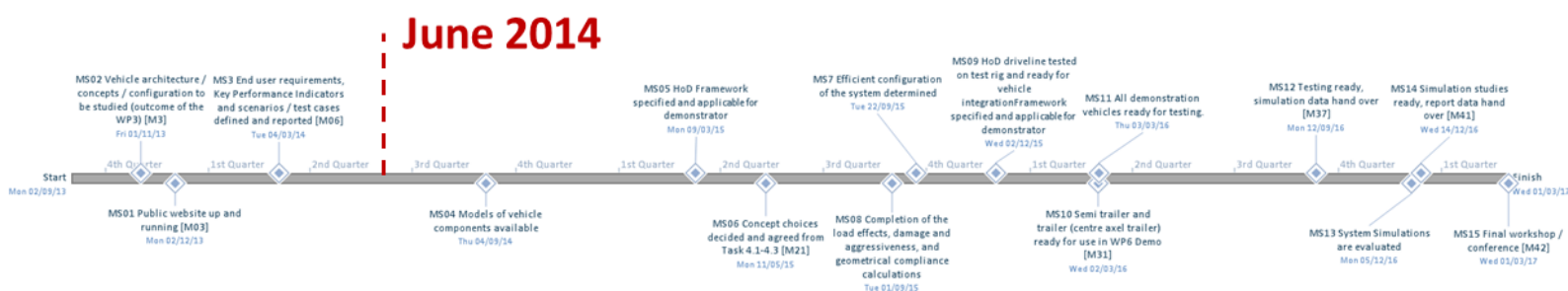
Main objective of the Dissemination WP is to establish an appropriate and effective communication of the project results to relevant stakeholders and the automotive community in general. Sharing of results is essential to ensure that project outcomes will be used by European and international industrial organisations and will lead to standards. Stakeholder workshop will be organised at the end of the project. In addition, various common strategies will be used to disseminate the project results beyond the consortium: publications in scientific journals, branch magazines, press messages, trade journals and presentations at (international and national) scientific conferences, industrial exhibitions and seminars. Also, a project specific public website will be launched, for the dissemination of the project results.

### WP8 – Consortium management

Project coordination activities are included in WP8.

## 1.3 Project Timeline and Status

The project is now well into the second year, and in the process of successfully closing the first work package. Work package 1 has successfully delivered reports on end user expectations on a future Transformers vehicle combination, elaboration on how to measure the benefits and a description of the testing scenarios. Work package 3 has delivered an extensive report on the features and capabilities of the future framework, and is now progressing in concretizing the findings into the final proposed framework, and software and hardware development for the demonstrator. In parallel with these activities, the integration of the electric driveline into the demonstrator semi-trailer and the loading/unloading measures are being investigated and evaluated by the trailer manufacturers in tight collaboration with the other partners.





## 2 Summary of reported deliverables

### 2.1 WP1 – Use Cases and Requirements

#### 2.1.1 D1.1 - REPORT ON END USER REQUIREMENTS FOR A NEW CONFIGURABLE AND ADAPTABLE TRUCK

Deliverable 1.1 for project TRANSFORMERS assesses the road freight transport industry with respect to the interaction of a truck-trailer configuration and the key stakeholders involved. Its purpose is to provide a tool for identifying relative areas of strength and weakness and to prioritize opportunities for collaborative action to build scale for a new configurable and adaptable Hybrid-on-Demand Truck Trailer configuration.

The *Report* defines the development of the road freight transport service in terms of the key drivers across the regulatory, institutional, market and end-user environments that lead to adoption and scale. Measures of transport services development are captured across four pillars, namely:

- Transportation Efficiency
- Logistics Efficiency
- Social and Environmental Impact
- Safety and Operating Features



The use of an electrically propelled trailer system and an aerodynamically adaptable trailer design is a relatively new phenomenon, and consensus is still emerging on which drivers are the most important and how they should be measured. In the hope of building consensus, *the Work Package 1* for PROJECT TRANSFORMERS therefore proposes a taxonomy and analytic structure for assessing the road freight landscape with a comprehensive data set in the first deliverable *D 1.1*, in addition to the provision of Key Performance Indicators in the second deliverable *D 1.2*.

Readers of the Report are urged to look at the detailed information contained in the Transport of Goods profiles explained in Chapter 4 in performing analysis and drawing conclusions. Comparison of distance classes, shipment types and goods shipped, along with the inherent structure of the long distance road freight transport sector yield some interesting observations:

- **The EU road freight transport industry is composed of some 580,000 companies**, ranging from one-man companies to multinational fleet operators with hundreds of vehicles and employees. **Road freight transport accounts for 45.3% of the total goods transport activity based on tonne-kilometer which amount to 1734.1 billion tonne-kilometers.**
- **In 2008, about 6.5 million heavy goods vehicles above 3.5 tonnes were registered in the European Union.** On average 72% of road freight transport in the EU is carried out with articulated vehicles consisting of a tractor and semi-trailer. 87.4% of the semi-trailers used have a payload capacity of more than 20 tonnes. The articulated vehicle consisting of **a two-axle tractor and three-axle semi-trailer with one axle which can be lifted is estimated to be the most common vehicle combination used intra-EU freight transport.** The average empty weight of such a combination running on diesel is 14 tonnes. Considering a maximum authorized weight of 40 tonnes, such **a vehicle combination can carry a maximum payload of 26 tonnes or between 85 and 90 m<sup>3</sup> of volume.**
- **In tonnes, two of the dominant groups relate to materials for the construction industry (sand gravel and cement) and agricultural products.** Food, beverages and tobacco and the products of agriculture are the second largest element with secondary raw materials, including municipal wastes, another important group. **In terms of tonne-kilometers, the most important product groups are food, beverages and tobacco and agricultural products (27% of the total together),** both groups being carried for relatively long distances and feeding into the food supply chain. Construction related materials, including wood products, form a second group and make up a combined 26% of the total. These are followed by chemicals (8%) and metal products (7%). One final important category is grouped goods carried together, mainly palletized transport, (8%), an important group to ensure full use is made of road freight capacity
- **41% of the goods shipped over all distances are palletized and 56% of the goods transported are greater than 300 kilometers.**

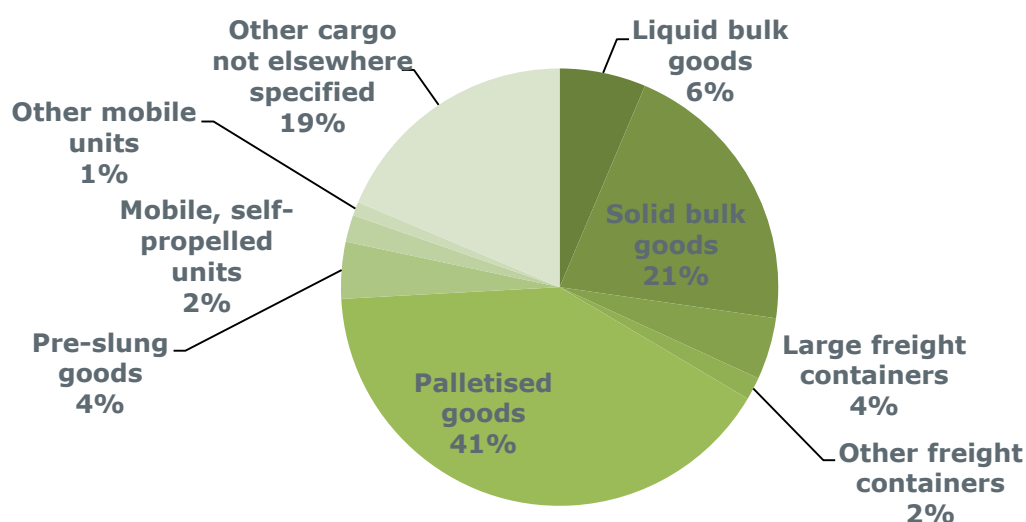


Figure 3 - Distribution of goods type in Europe

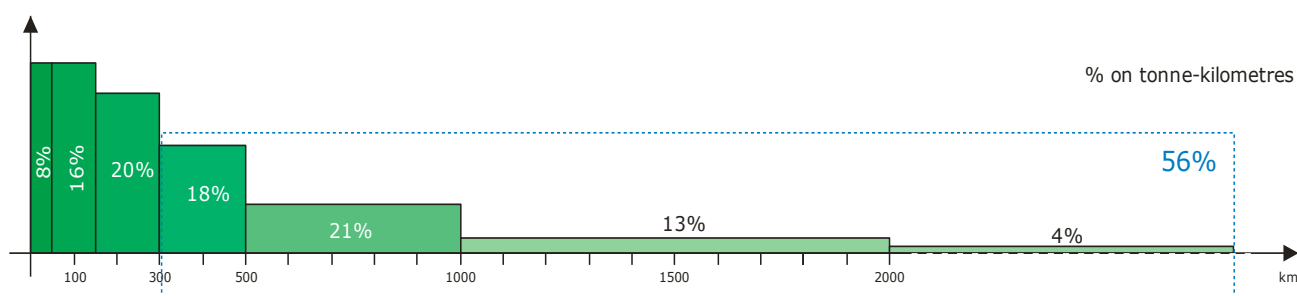


Figure 4 - Distribution of typical mission distances in Europe

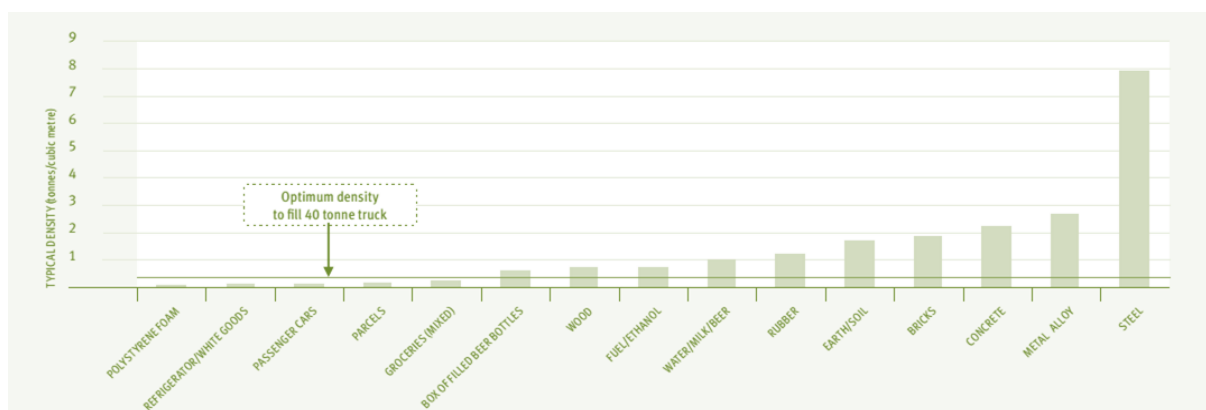
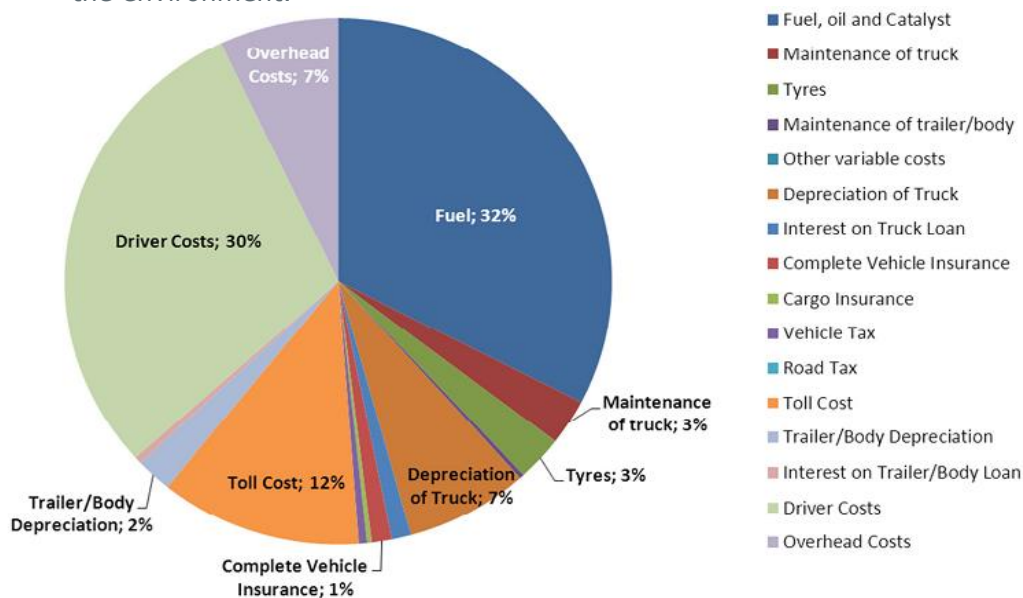


Figure 5 - Density overview for various types of common goods

- **Improved safety and reliability** results in fewer days lost due to injury, fewer vehicles off the road for repair, fewer missed orders, less need for investigation and follow up.
- **Fuel price accounts for more than 30% in the Total Cost of Ownership**, thus reducing fuel consumption provides a two pronged approach that can improve both the profitability and the environment.



Thus, looking across a high level summary of the road freight transport sector in Europe, it is clear that transport volumes will continue to grow, with economic growth; and the problem to accommodate freight flows in an efficient and sustainable way becomes increasingly alarming. The uptake of EURO norms linked with the taxation at tolls have definitely contributed towards the reduction of emissions in Road Freight Sector, however with an increasing momentum around issues such as climate change, resource scarcity, sustainability and pollution it brings to light critical challenges that the transport by road will face in the coming years. For companies, the greening of logistics not only has an environmental and social dimension, but is also a question of economics and efficiency.

### 2.1.2 D1.2 - REPORT ON DEFINED KEY PERFORMANCE INDICATORS (KPI)

This report presents the Key Performance Indicator's (KPI's) that have been defined for evaluating and comparing the operational parameters of a truck-(semi)trailer configuration. These indicators could link the topline metric to business outcomes through environmental benefits, societal benefits, transport efficiency, resource efficiency, capacity optimization and closes the loop back to the frontline. The model used to identify KPI's is illustrated in Figure 6.

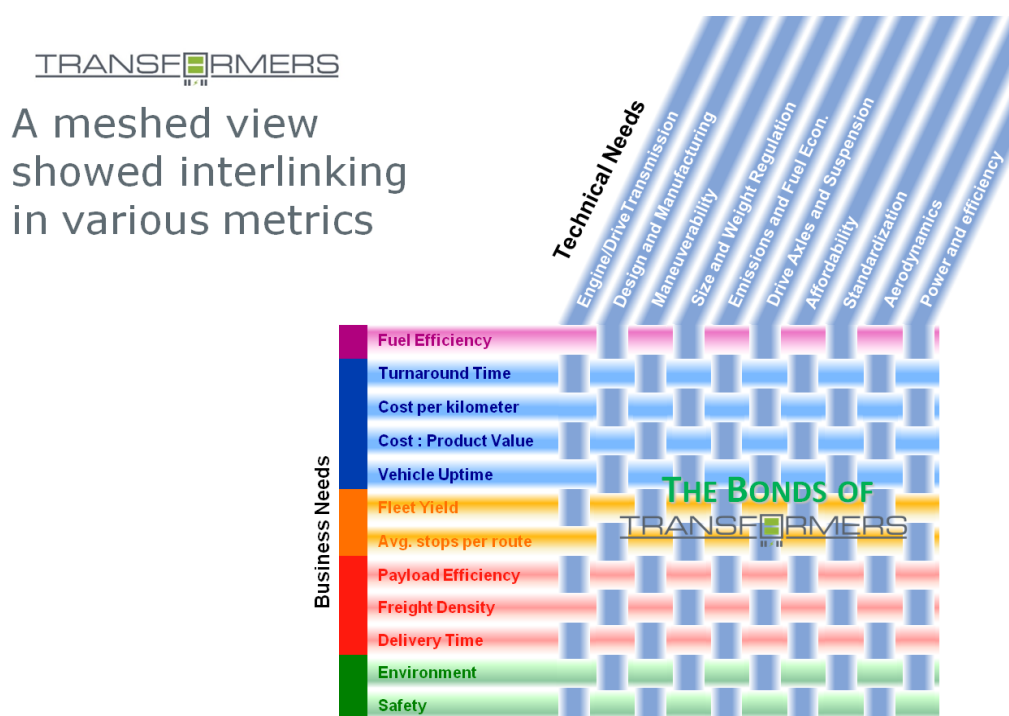
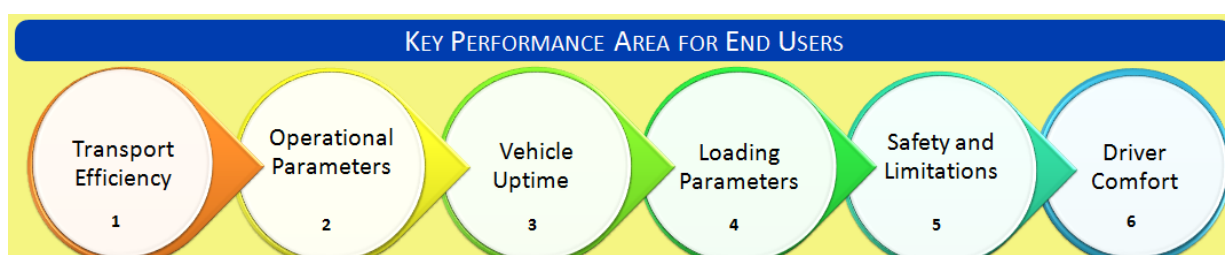


Figure 6 - KPI Identification Model

Keeping the identification model in mind; the 'End User' KPI's were identified. They are different since they do not dive into evaluating the articulated vehicle combination from a purely technical standpoint, but rather they are based on evaluating the vehicle on parameters that affect and matter to business which operate and use these vehicles. Figure 2 shows the KPI Area's identified. By studying the performance of the new truck-(semi)trailer configuration, against the existing state-of-the-art truck-(semi)trailer configuration would be constructive for the successful market acceptance of the proposed alternative.



### 2.1.3 D1.3 - REPORT ON DEFINED SCENARIOS AND TEST CASES

Based on the overview of the Road Freight Industry in Europe described in Deliverable 1.1, this *report* aims at identifying test cases and scenarios for testing the performance of the Transformers trailer against the defined Key Performance Indicators (KPIs) mentioned in Deliverable 1.2. This deliverable (D 1.3) provides general insight into key road transport infrastructure in the TEN-T network, important operating and regulatory environments that are representative for the majority of long and medium distance freight shipment, and an overview for scenario planning and testing. As Work Package 6 of the TransFormers Project is the key driver in defining business cases and scenarios, the authors believe that this report can serve as a guide to ensure that we test our results rigorously in the final part of the project. It is essential to understand that the test results must provide willing buyers with an attractive and viable solution compared to the existing solutions and which have a useful commercial value that meets the defined KPIs while making a profit.

## 2.2 WP3 – Electric Hybrid-On-Demand Framework

### 2.2.1 D3.1 - REPORT ON DEFINED HOD DRIVELINE AND FRAMEWORK CAPABILITIES AND FEATURES

A key innovation of TRANSFORMERS is the so-called Hybrid-on-Demand-Driveline (HoD-Driveline). For the first time, this system enables an augmentation of conventionally driven trucks and tractors to fully functional mission-adaptable hybrid vehicles, simply by coupling them to an innovative trailer equipped with an electric driveline. Hence, the HoD-Driveline concept is applicable to many kinds of truck-trailer and tractor-semitrailer vehicle combinations.

In addition to the HoD-Driveline concept TRANSFORMERS develops a pre-standard HoD-Framework. The objective of this framework is

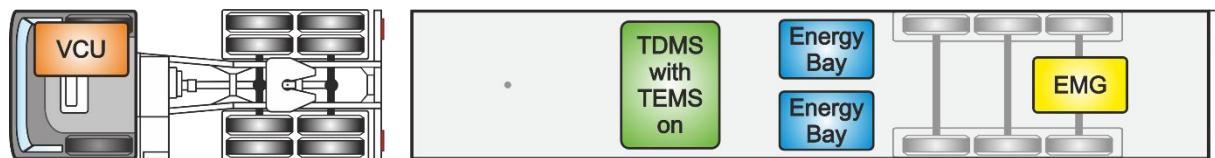
- to ensure the interoperability of the HoD-Driveline concept with today's trucks *and* with future trucks featuring advanced energy management capabilities,
- to provide a slim common interface between trucks and trailers, that requires only minimal changes in trucks.

Deliverable D3.1 describes the capabilities and features of the framework. The main outcome is the definition of

- the content and scope of the standardization process included in the framework,
- the main functional tasks of the HoD-Driveline, and
- logical and physical HoD-Driveline architecture.

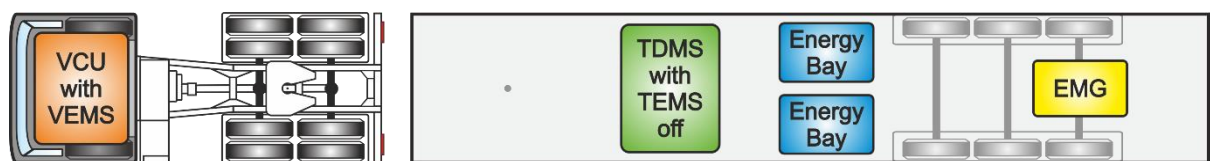
Therefore, the framework defines considered vehicle combinations that are clustered into two reasonable cases:

- Case A. - Standard truck without complete Vehicle Energy Management System (VEMS) is coupled to HoD-Trailer



**Figure 7 - Structure of the HoD-Driveline for a HoD-Trailer coupled to a standard truck (Case A)**

- Case B. - Future truck with HoDF-compliant Vehicle Energy Management System is coupled to a HoD-Trailer.



**Figure 8 - Structure of the HoD-Driveline for a HoD-Trailer coupled to a VEMS-Truck (Case B)**

This distinction is necessary, because standard trucks are not designed for driven trailers. Hence, for Case A the trailer driveline is allowed to operate only in carefully predefined scenarios, to avoid interferences with advanced fuel-saving technologies like e.g. gear shifting strategy, weight approximation, cruise control strategy, ECO-Roll or even vehicle dynamics. The scenarios defined for Case A will be part of the framework.

In contrast to that, the truck's VEMS is fully responsible for operating the trailer driveline in Case B applications. The framework will not define any operating scenarios for Case B. Thus, technological competition is ensured and supported.

Based on these findings, the HoD-Framework defines use cases, logic structure, main functionality, and interfaces for each case separately. Despite the significant differences, the consortium succeeded in defining a common E/E-Architecture taking into account not only the two cases but also key features like interoperability, mission-based rightsizing, and modularity.

The final outcome is a multi-domain driveline architecture for the HoD-Driveline concept, which ensures a broad interoperability with different trucks today and in future, while taking key parameters like costs and complexity into account. Furthermore, the driveline architecture including the associated capabilities and features are translated into a requirements specification that will support the development of HoD-Framework applications.

### 3 Outlook on coming activities next

In the coming months, the project will be finalizing and delivering the following reports:

- D4.1 Optimised aerodynamic architecture for arbitrary truck-trailer configuration – validation of technical and economical feasibility [M19]
- D2.1 Needed Simulation Models of Subsystems [M12]
- D3.2 Report on HoD framework including detailed specifications of infrastructure, interfaces, and ECU functionalities [M18]
- D4.2 Overview over the technical and economical possibilities for the trailer/semitrailer design with focus on optimised transport efficiency [M21]
- D4.3 Theoretical validation of the driving controls strategy and safety/stability assessment by simulation and benchmarking [M21]

A first complete reporting of the project will be done for the commission in [M18] (February 2015)



## 4 Acknowledgment



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[http://cordis.europa.eu/fp7/cooperation/home\\_en.html](http://cordis.europa.eu/fp7/cooperation/home_en.html)

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