



Funded by the Horizon 2020 research and innovation programme  
of the European Union (GA 769638)



Project Acronym: **INTEND**

Project Title: INtentify future Transport rEsearch NeedS

Project Number: 769638

Topic: **MG-8-7-2017**

Type of Action: **Coordination and support action**

---

## **D2.1 Transport projects & future technologies synopses handbook**

---

(Version 0.4, 25/04/2018)

<b>Deliverable:</b>	D 2.1Transport projects & future technologies synopses handbook
<b>Work Package:</b>	WP2 : Define the landscape: mapping the future prospects of transport
<b>Due Date:</b>	M5
<b>Submission Date:</b>	28/02/2018
<b>Start Date of Project:</b>	01/10/2017
<b>Duration of Project:</b>	12 Months
<b>Organisation Responsible of Deliverable:</b>	Centre for Research and Technology Hellas (CERTH)
<b>Version:</b>	0.4
<b>Status:</b>	Final
<b>Author name(s):</b>	Alkiviadis Tromaras, Aggelos Aggelakakis, Mirjana Bugarinović, Danijela Pjevčević, Massimo Moraglio
<b>Reviewer(s):</b>	Eleni Anoyrkati, Alba Avarello, Thomas Trachsel, Merja Hoppe, Norman Döge, Massimo Moraglio, Vladislav Maraš
<b>Nature:</b>	<input checked="" type="checkbox"/> R – Report <input type="checkbox"/> P – Prototype <input type="checkbox"/> D – Demonstrator <input type="checkbox"/> O - Other
<b>Dissemination level:</b>	<input checked="" type="checkbox"/> PU - Public <input type="checkbox"/> CO - Confidential, only for members of the consortium (including the Commission) <input type="checkbox"/> RE - Restricted to a group specified by the consortium (including the Commission Services)

Document history			
Version	Date	Modified by	Comments
0.1	23/02/2018	Alkiviadis Tromaras, Aggelos Aggelakakis,	Draft
0.2	28/02/2018	Eleni Anoyrkati, Alba Avarello, Thomas Trachsel, Merja Hoppe, Norman Döge, Massimo Moraglio, Vladislav Maraš	Draft
0.3	23/4/2018	Alkiviadis Tromaras, Aggelos Aggelakakis, Afroditi Anagnostopoulou, Maria Boile	Draft
0.4	25/04/2018	Alkiviadis Tromaras, Aggelos Aggelakakis, Afroditi Anagnostopoulou, Maria Boile	Final

## Contents

Contents.....	4
List of figures .....	5
List of tables .....	5
List of abbreviations.....	6
Executive summary .....	7
1 Introduction .....	15
1.1 D2.1 in the frame of INTEND work structure.....	15
2 Data collection methodology.....	17
2.1 The transport projects/ reports synopsis templates.....	18
2.2 Data collection methodology .....	21
2.3 Review of research projects and pertinent literature .....	23
2.4 Data analysis framework .....	24
3 Future transport technologies .....	25
3.1 Road transport .....	25
3.1.1 Future road transport at a glance .....	25
3.1.2 Analysis of results in road transport technologies.....	32
3.1.3 Summaries of road transport technologies identified from projects.....	35
3.2 Aviation transport .....	48
3.2.1 Future aviation transport at a glance .....	48
3.2.2 Analysis of results in aviation transport technologies.....	54
3.2.3 Summaries of aviation transport technologies identified from projects.....	57
3.3 Rail transport.....	64
3.3.1 Future rail transport at a glance.....	64
3.3.2 Analysis of results in rail transport technologies .....	69
3.3.3 Summaries of rail transport technologies identified from projects .....	72
3.4 Waterborne transport .....	78
3.4.1 Future waterborne transport at a glance.....	78
3.4.2 Analysis of results in waterborne transport technologies .....	83
3.4.3 Summaries of waterborne transport technologies identified from projects .....	86
4 Technology themes in the international scene.....	92
4.1 Russia .....	92
4.2 USA.....	95
4.3 India .....	98
4.4 China.....	100
4.5 Japan .....	103
5 Conclusions.....	106
References.....	112
Annex 1- Templates .....	120
1. Road transport technologies projects & reports synopsis template .....	120
2. Aviation transport technologies projects & reports synopsis template .....	124
3. Rail transport technologies projects & reports synopsis template.....	128
4. Waterborne transport technologies projects & reports synopsis template .....	131
Annex 2- Results from reviewed projects and reports.....	139
2.1 Road transport reports .....	139
2.2 Aviation reports .....	153
2.3 Rail transport reports.....	161

2.4 Waterborne transport reports .....	167
2.5 Road transport projects .....	178
2.6 Aviation projects results .....	212
2.7 Rail transport projects results .....	238
2.8 Waterborne transport project results .....	260

## List of figures

Figure 1. Overall structure of the WPs and role D 2.1 .....	16
Figure 2 Review and assessment approach of literature .....	17
Figure 3. Methodology steps followed in D 2.1 .....	18
Figure 4. Data collection process for projects and reports .....	21
Figure 5. Road transport technology thematic areas of the reviewed research projects.....	32
Figure 6. Road transport- applicable technology sector .....	33
Figure 7. Road transport- Reviewed projects funding scheme .....	33
Figure 8. Road transport- dominant identified technology themes .....	35
Figure 9. Aviation- technology thematic areas of the reviewed research projects .....	55
Figure 10. Aviation- applicable technology sector .....	55
Figure 11. Aviation- Reviewed projects funding scheme.....	56
Figure 12. Aviation- dominant identified technology themes .....	57
Figure 13. Rail transport- technology thematic areas of the reviewed research projects.....	69
Figure 14. Rail transport- applicable technology sector .....	70
Figure 15. Rail transport- Reviewed projects funding scheme .....	70
Figure 16. Rail transport - dominant identified technology themes.....	71
Figure 17. Waterborne transport- technology thematic areas of the reviewed research projects.....	84
Figure 18. Waterborne transport- applicable technology sector .....	84
Figure 19. Maritime transport- Reviewed projects funding scheme.....	85
Figure 20. Waterborne transport - dominant identified technology themes .....	86
Figure 21: National technological priorities (percentage of total number of technologies). ....	95
Figure 22: Technology developments required by the Indian Government. ....	100
Figure 23. Expected timing for the realisation of commercialisation and servicing of automated driving systems .....	104

## List of tables

Table 1. Information clusters and subclusters per transport mode .....	19
Table 2. Number of reviewed technology development research projects .....	25
Table 3. Road transport brief synopsis of technology themes.....	106
Table 4. Aviation brief synopsis of technology themes.....	108
Table 5. Rail transport brief synopsis of technology themes .....	109
Table 6. Maritime transport brief synopsis of technology themes.....	110

## List of abbreviations

ACARE	Advisory Council for Aeronautics Research in Europe
ACFM	Alternating Current Field Measurement
BWB	Blended Wing Body
CAE	Computer Aided Engineer
CFD	Computational Fluid Dynamics
CFRP	Carbon Fiber Reinforced Polymer
CMC	Ceramic Matrix Composite
CITS	Cooperative Intelligent Transport Systems
DPF	Diesel Particulate Filter
ETCS	European Train Control System
ERTMS	European Railway Traffic Management System
ERTRAC	European Road Transport Research Advisory Council
EUCAR	European Council for Automotive Research and Development
FCH	Fuel Cells and Hydrogen Joint Undertaking
FEA	Finite Element Analysis
GFRP	Glass Fiber Reinforced Polymer
HEFA	Hydroprocessed Esters and Fatty Acids
HYER	European Association for Hydrogen and fuel cells and Electro-mobility in European Regions
HVAC	Heating Ventilation Air Conditioning
ICE	Internal Combustion Engine
LNT	Lean NOx Traps
MaaS	Mobility as a Service
MARAD	US Maritime Administration
NDT	Non Destructive Testing
OOA	Out of Autoclave
PV	Photovoltaic
SCR	Selective Catalytic Reduction
STRIA	Strategic Research and Innovation Agenda
TCMS	Train Control & Management System
UAV	Unmanned Aerial Vehicle
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
VTOL	Vertical Take of Landing

## Executive summary

Deliverable D 2.1 main is to provide a transport projects and future technologies synopses handbook. The overall aim is to gather, review and analyse relevant research documents from the European and international literature that has been produced through sponsored research projects, scientific publications, forward looking exercises, industry studies and strategic research agendas, with emphasis on transport. The aforementioned combination of research projects and pertinent literature has been reviewed with the purpose of identifying technologies that require advancing or future technologies that will be used by the transport sector within a time horizon of 2020- 2035 thus enabling the sector to meet future demand and needs within the future context. The transport modes that were covered include road, aviation, rail, and maritime while transport systems and infrastructure are treated horizontally across the four modes.

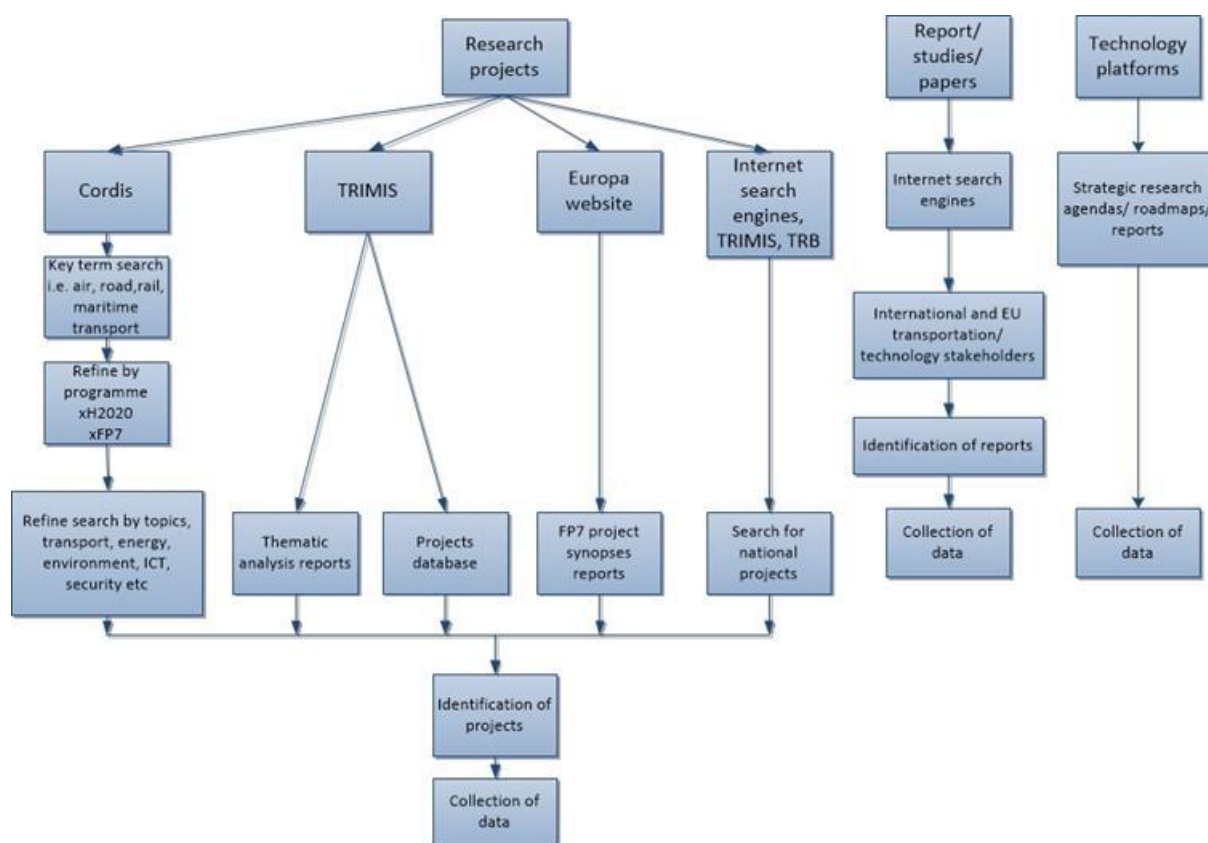
The approach taken, combined a backward looking exercise in terms of reviewing completed and ongoing research projects in order to extract the specific technologies that each project had researched or developed from 2010 and onwards, including relevant pertinent literature such as technology roadmaps from transport stakeholders, technology websites and other forward looking reports. D 2.1 looked predominantly into EU FP7 and H2020 funded research projects with some additional international and national projects. The table below presents the number of projects that were reviewed under D 2.1.

Transport mode	EU funded	International/National/private funded
Road	120	7
Aviation	111	14
Rail	68	6
Maritime	55	7
	354	34
<b>Total</b>	<b>388</b>	

Moreover, a projects/reports synopsis template was created in order to capture the information that was extracted from any type of project/literature, thus dividing the technologies into thematic areas (i.e. competitiveness, environment, energy, infrastructure and systems). Cluster and subclusters were used to further taxonomies.

A set of criteria was used to filter the number of projects that were available and would qualify to be reviewed. Specifically: a) FP7 projects funded under the last two calls from 2010-2013, b) Available projects from the beginning of the H2020 programme until the day of reviewing each transport sector between November 2017 and January 2018, c) Only technology oriented projects were selected to be reviewed. No projects that covered topics such as transport methodologies, soft systems, business models, market research were selected for further review. For EU projects hard technology-based projects were mainly Research and Innovation Actions, or Innovation Actions, rather than Coordination and Support Actions.

The following figure presents the methodology that was used in D 2.1. to identify the research projects and literature.



Technologies that were researched by research projects were crosschecked with the technologies that were identified by the rest of the literature in order to present the most dominant technology themes within the different transport modes. The results from this task are given below.

### **Brief main results**

Following a methodology of cross checking technologies of that have been researched by research projects and technologies identified in

In the road transport sector, it has been identified that the most dominant technologies in terms of research were: electric and hybrid vehicles; autonomous vehicles; materials development; internal combustion engine design; alternative fuels and refuelling infrastructure; Advanced Driver Assistance System; Computer Aided Engineering; Fuel cell vehicles; electric motor design and battery development.

The table below presents the road technology themes that have been researched by projects and literature in a more synoptic way.

Road transport brief synopsis of technology themes	
Electric Vehicle Design	Light weight small urban electric vehicles (EVs) with modular design
Electric Vehicles	Battery module design and materials for anodes and cathodes; battery recyclability



Batteries	
Electric motor design	Magnet free Switched Reluctance Motors (SRM) and Permanent Magnet Assisted Synchronous Reluctance Motors that do not use rare earth material
Electric Vehicles and fuel cell vehicles	EV and FCV demonstrators and required refuelling/ recharging infrastructure
Computer Aided Engineering (CAE)	CAE tool for crashworthiness; better engine design; electric motors and accurate EV modelling and simulations; Multiphysics tools for modelling Electromagnetic Compatibility (EMC) and health effects from electromagnetic fields (EMF) from EVs
Materials development	lightweight materials for EVs, Fibre Reinforced Polymers (CFRPs), Glass-Fibre Reinforced Polymers (GFRPs) or advanced metal materials (aluminium, magnesium, high strength steel)
Automated driving	Demonstrators of autonomous and Advance Driver Assistance Systems (ADAS);
Hybrid vehicles	Hybridisation of vehicles trucks buses and vans
Integrated emissions control	Advanced Selective Catalytic SCR; SCR integration with Diesel Particulate Filters (SCR/DPF); AdBlue processors and ammonium nitrate additives into AdBlue to improve operating conditions; Gasoline particulate filters and 3 way catalysts without precious metals; Electrified Diesel Particulate Filters (DPF); SCR and Lean NOx traps (LNT); Trapping Hydro Carbons ((HC) and NOx during cold start and making DPF operate under lower temperatures; New materials for catalytic converters and NOx conversion for natural gas engines
Aerodynamics	Aerodynamic improvement for vans and trucks
Engine design	Advanced low emissions four stroke Spark Ignition (SI) engines; four stroke and two stroke Compression Ignition (CI) engines; small downsized engines for hybrid electric vehicles; rotary engine for range extender; waste heat recovery and new electric turbochargers or superchargers for CNG engines; ultra lean combustion; Liquefied Natural Gas (LNG), dual fuel engines or engines designed for running on biofuels for trucks; Waste heat recovery for hybrid trucks; 100% electrically turbocharged engines with new compressor blade designs; precise fuel metering; variable compression ratio engines; Simplified Internal Combustion Engine architecture for electrified powertrains; new ignition methods (microwave ignition, multi location ignition); variable engine cycles
Vehicle transmission	Intelligent automatic transmission for buses that can change shifting patterns in real time based on topography and vehicle occupancy; Transmissions for electric vehicles; Mass reduction, less friction losses of transmission
Systems	Mobility as a Service (MaaS); Cooperative Intelligent Transport Systems; Road Transport Management System and Road Side Units will be essential for the V2X communication and Coordinated Automated Road Transport; V2X and V2I communications for road users; Pilots for connected vehicles; Freight last mile logistics and overall logistics, of automated and connected vehicles; Platooning for euses could be a viable option for the future while highly automated urban euses with the ability to dock, charge and park will need to be developed; Coordinated Automated Road Transport (C-ART); Big data availability; Electrification of auxiliary systems in trucks

For the aviation sector aircraft design has been identified as the most dominant topic, with engine design and CAE in second place. Air traffic management, materials development and hybrid & electric propulsion ranked right below while, noise modelling and mitigation, alternative fuels and manufacturing processes were also technologies that will enable the sector. It needs to be noted that morphing concepts remain at an early development stage

and will require further mechanisms and materials in order to progress any further. The table below presents the aviation technology themes that have been researched by projects and literature in a more synoptic way.

<b>Aviation brief synopsis of technology themes</b>	
Aircraft design	Morphing concepts for wings, winglets, wingtips trailing edge, rotor blades can adapt their shape based on operational environment; Blended Wing Body (BWB) design; Super sonic aircraft designs
Computer Aided Engineering (CAE)	Computational fluid dynamics (CFD) and Finite Element Analysis (FEA) to model and simulate stress, physical and aerodynamic properties of sections, materials and engine design
Cabin	Windowless design, with cameras and screens substituting the view, light weight interior and inflight wireless and optical entertainment systems; Virtual Reality (VR) and Mixed Reality (MR) systems
Materials development	Polymer Matrix composites (PMCs), Ceramic Matrix Composites (CMCs), Carbon Fibre Reinforced Polymers (CFRPs), Glass-Fibre Reinforced Polymers (GFRPs), Aramid-Fibre reinforced Polymers (AFRPs); Hybrid alloys; Self actuated materials that can react to light, heat or electromagnetic fields for morphing; Nano materials; Icephobic materials
Manufacturing processes	Additive manufacturing and Out of Autoclave (OOA)
Alternative fuels	Hydro processed esters and fatty acids (HEFA), Fischer-Tropsch process syngas derived kerosene
Engine design	Advanced turbofans, Open rotor engines and geared turbofan engines; Ultra-high pressure ratio compressors, lean combustion and combustor design; Interaction between combustor and turbine; Hybrid electric propulsion; Combustors (variable flow splits, advanced combustors for low NO <sub>x</sub> emissions) and fans (zero hub, variable fan nozzle, high bypass ratio); Adaptive/variable cycle engines
Noise mitigation	Modelling and simulations of the emitted noise of CROR (Counter Rotating Open Rotor) engines; Interaction between combustor and turbine; plasma actuators at the engine's jet nozzle in order to reduce eddies formation; Nacelle liners, variable geometry chevrons, porous materials at nacelle surfaces
Aerodynamics	Air flow control methods for reducing turbulent flow, have been the most researched topic; Boundary layer separation point and shock waves' formation around aircraft structures; Controlling boundary layer and laminar flow control methods; Aerodynamic wingtip devices (sharklets, winglets) and high lift devices (variable camber trailing edges, dropped spoilers and hinge-less flaps); Increasing the aircrafts wing span through a truss braced design
Airports	Automation of the airport management; Automated baggage handling and robotic systems; Air ship type of airports; Inner city airport design; Emissions free taxing; Smart and secure cargo containers that would eliminate screening and tampering; Intermodality
Systems	Piezoelectric systems for morphing concepts; Advanced fly-by-wire, Fly-by-light and Wireless Flight Control Systems; Sensors and monitoring systems whether for structural integrity, noise, vibration, efficiency, health monitoring; Satellite Navigation; Optimisation of the future Air Traffic Management (ATM) system through modelling of Air Traffic Flow, better dynamic management of capacity and analysis of the impact that human behaviour has on ATM; Automated route management; 4-D trajectory; On-board Detect And-Avoid (DAA) systems for drones;

For the rail transport mode the most cited technology themes were satellite technologies and their integration with European Rail Traffic Management System and European Train Control System. Wagon design, non-destructive testing for infrastructure, CAE and future rail station design, including noise monitoring and mitigation solutions were all dominant themes. Fuel cells and use of hydrogen in rail were also identified as technologies that could find further applications in the near future. The table below presents the rail technology themes that have been researched by projects and literature in a more synoptic way.

<b>Rail transport brief synopsis of technology themes</b>	
Train design	Modular freight wagon designs for different types of materials and containers; New concept of coupling two trains together with a slave locomotive in the middle of the convoy; Freight lightweight wagons; Active suspensions running gear; Eddy current brakes; High speed lightweight passenger trains with new steering improvements (active, passive guiding), lateral and vertical suspension systems with independent wheel traction
Electrified & alternative fuel trains	Hybrid and electric propulsion; Hydrogen fuel cells propulsion; LNG usage;
Material development	Composite materials Fibre Reinforced Polymers (FRPs) for interior and exterior wagon parts or crossings switches; Coating solutions of axles and wheels are also identified as a viable solution to prevent fatigue cracking; lightweight materials, nanomaterials and self-lubricating parts are proposed with embed sensors that can monitor noise, vibration and health; Materials for rail tracks
Manufacturing processes	Additive manufacturing for coating rails track surfaces or wheel surfaces with special coatings;
Inspection and maintenance	Robotic systems with vision systems for tunnels and rail tracks; ultrasonic inspection such as Alternating Current Field Measurement (ACFM), Ultrasonic phased array and High Frequency Vibration; Eddy current sensor systems and Thermographic testing; Predictive maintenance systems and technologies;
Noise monitoring & mitigation	Accurately noise & vibration from running gears and wheels and how these interact wheels and tracks interact;
Systems	Biometric technologies for identification and verification of passengers in terms of safety/ security issues; Drones with infrared sensors for monitoring trespassers into secure rail areas; Train Control Management System-TCMS (ERTMS, ETCS, TCMS); Global Navigation Satellite System (GNSS) or European Global Navigation Satellite System (EGNSS) integrated with TCMS; Innovative cost-effective satellite-based train control speed supervision system; GNSS moving blocks, as new signalling train separation concepts; Telematic Applications for Freight (TAF)/Telematic Specifications for Interoperability (TSI) standards; ticketing mechanisms and technologies including collection of dynamic and static data; Infomodality

For the maritime transport mode the most dominant identified themes were electrified vessels followed by CAE, alternative fuels, multi-engine fuels, ship design, secondary energy converters and integrated emissions control. Autonomous ships and sensor technologies were also identified as potential future technologies for implementation. The table below presents the maritime transport technology themes that have been researched by projects and literature in a more synoptic way.

Maritime transport brief synopsis of technology themes	
Ship Design	Design for: recreational vehicles; CNG transport; inland water ways vessels; hull optimization for fuel consumption; future retrofitting technologies; holistic ship design methodologies; ship hull air lubrication;
Electrified vessels	Hydrofoil taxi; electric ferry; Hybrid propulsion
Autonomous ships	Autonomous ship merchant vessels
Computer Aided Engineering	Simulations for wave resistance; CAD and Computational Fluid Dynamic of for hull design; design procedures and CAD tools for Fibre Reinforced Polymer Ships; simulations for retrofitting technologies; software development for life cycle modelling; shipyard simulation; cavitation sound modelling
Inspection	Unmanned Aerial Vehicles (UAVs) for ship inspection and magnetic robots for hull inspection; Structural health monitoring sensors
Materials	Fibre Reinforced Polymers (FRP); advanced materials; composite patch repairs; nano materials; ship coating for antifouling
Manufacturing processes	New welding techniques and additive manufacturing
Exhaust after treatment	Selective catalytic reduction for high sulphur fuels; Diesel particulate filters; Exhaust gas recirculation; Electrostatic seawater scrubber (ESWS) for PM, SO <sub>2</sub> and water solubles; Non Thermal Plasma Reactor (NTPR) using Electron Beam and Microwave to remove NO <sub>x</sub> , Volatile Organic Compounds (VOC), CO; SO <sub>2</sub> dry and wet scrubbers; Combination of SCR and EGR
Resistance & propulsion	Trim monitoring control; Propeller design; Ship stability; Combinators; Pod propulsion
Multi-fuel engines	LNG/Diesel; Fuel flexible engines 2 stroke and 4 stroke engine; CNG) and/ or Liquefied Natural Gas (LNG) as an alternative hydrocarbon fuel to HFO; LNG-LPG/Diesel
Secondary energy converters	Electric motors; Electric heaters; Waste heat recovery systems; Hydrogen generators for auxiliary power; Fuel cells; Hybrid propulsion
Renewable energies	Kite and suction sail propulsion simulation; Wind assisted vessels with rotor sails; Photovoltaic (PV) systems for energy storage
Hydrodynamics	Pre-swirl stators and Boundary Layer Alignment Devices (BLAD); bulbous bows
Ports	Use of electricity and alternative fuels in cargo handling equipment; Alternative Maritime Power; Robotic systems for unloading cargo, automated vehicles and cranes; Internet of Things and big data analytics for monitoring of vessels, vehicles and equipment in real time; Intelligent holistic port managements systems that will cover all port aspects such as ships, cargo, passengers, workers and intermodal solutions offering connectivity with other transport modes
Systems	Sea traffic controls systems; High bandwidth networks and satellite communications will be required, allowing wireless connectivity or all the remote systems; decision support systems for crew/ passenger evacuations that will assist in the process during emergencies.

Transport research priorities at international level were treated through a brief review of the directions set by countries such as Russia, USA, India and China. The results are presented below.

Foresights from the Russian Government have identified a series of technologies such as: Computer-aided systems for monitoring of vehicles and transport infrastructure; Intelligent Transport Systems (ITS); New materials and advance manufacturing processes for vehicles and transport infrastructure including big data; Energy-efficient and safe vehicles and next generation transport systems; New materials and technologies for construction and operation of transport infrastructure in the Arctic and sub-Arctic areas; Energy efficient and environmental friendly means of transportation; Safety and security of infrastructure; Modernisation of rail infrastructure and rolling stock including better connectivity of the different Russian Federation regions; Ships building and relevant production technologies; navigation technologies for ships.

For the US, aviation, road and maritime transport technology priorities have been presented. For the US aviation some of the key concepts identified were: 1) support of existing flight simulation and modelling infrastructure like the FutureFlight Central, 2) New aircraft design, 3) Aircraft engine development and reduction of emissions including introduction of alternative fuels and electric propulsion in aircrafts, 4) Noise reduction, 5) Optimisation of air traffic flow, 6) Autonomous systems, 7) UAVs and 8) real time safety assurance systems. In addition, for the US road sector some of the priorities that were identified were autonomous self-driving vehicles for congestion reduction, connected vehicles advanced driver assistance systems and vehicle platooning including demonstrator projects that will test, evaluate and enable the aforementioned technologies. Interoperability standards of ITS and connected vehicles are also main priorities. Furthermore, the US Department Of Transport (USDOT) is carrying out research on big data, visualisation of collected data from mobility and other devices, traffic management and infomodality that will enable intermodal and seamless transport. Finally, in terms of the US maritime sector, some of the main priorities were: 1) innovation at port level to reduce environmental footprint, 2) introduction of alternative fuels on vessels, 3) environmentally friendly disposal of end of life ships, 4) Intelligent Transport System technologies for maritime/intermodal transportation, 5) door-to-door cargo tracking, 6) automation for vessels, ports and shipyards, 7) new ship designs.

For India the focus of transport priorities was based on making close collaboration between academia, government, research institutes and industry in order to create investments in EV indigenous vehicle manufacturing and research and electrification of road transport. In addition cluster groups for Battery Management Systems (BMS) and batteries, power, electronics and motors and testing infrastructure/HR/efficient technologies are expected to be created by this collaboration. In addition priorities are also set on buses and Bus Rapid Transport systems and investments in technology improvement of city bus systems. Focus on clean energy and environmentally friendly energy production will be required and will find usage in electromobility. Alternative fuels such as biobased fuels and hydrogen are also priorit topics for the Indian government. Pedestrian road safety has also been highlighted which will require technology assisted driver training systems in order to minimise fatalities. Integration of ICT systems and traffic management will be required to reduce road traffic congestion. Finally, modernisation of the rail infrastructure and high-speed rail freight corridors are also areas for development.

For China some of the main transport technology priorities that were identified were the following: 1) Investment in EV for passenger transport ranging from electric motors to battery development including fuel cells and charging/refuelling infrastructure 2) Development of the aviation sector through new aircraft concepts, new UAVs for logistics, hub airports and big data, additive manufacturing, improvements in aircraft aerodynamics and noise emissions 3) Development of high speed rail (for passenger and freight), new materials and intelligent manufacturing, maglev traffic control systems, autonomous train systems, 4) Electric and alternative fuel in ship propulsion, new smart vessel design including new manufacturing technologies, e-Navigation, port development and automation. 5) Environmental friendly and seamless logistics systems and access of sea-land between China, Japan and Korea.

Regarding Japan, the literature has indicated the following priorities. In the road sector autonomous vehicles and automated driving is required at local and highway level; Information and Communication Technologies (ICT) infrastructure that will enable autonomous vehicles such as radar, cameras, laser scanners, and vehicle technologies; advanced digital maps; V2V and V2I communication systems); truck platooning; MaaS; ultra small electric urban vehicles; fuel cell vehicles and hydrogen refuelling infrastructure; express tollways; innovative road based logistics; automated infrastructure inspection. In the waterborne sector the following priority areas are identified: Specialised tanker vessels for hydrogen and LNG transport; Increase of productivity in shipbuilding; efficient ships; use of CAE to eliminate testing; IoT and data from ship manufacturing; Satellite and communication systems; dual fuel engines; propulsion systems. For the aviation sector: air transport infrastructure; new aircraft concepts and quiet supersonic small passenger aircrafts; electric and hybrid propulsion; airframe technologies for better aerodynamics and noise reduction; green engine technologies for better efficiency and less noise; eco structural materials; air traffic management; radiation monitoring using UAVs; CAE.

## 1 Introduction

The overall objective of the INTEND project is to deliver an elaborated study of the research needs and priorities in the transport sector utilising a systematic data collection method. One of the main elements of the INTEND project is the review of pertinent literature (EU and international research projects including strategic research agendas, studies or roadmaps) in order to identify future technologies for each transport mode (road, aviation, rail, maritime) as well as infrastructure and transport systems which will be treated horizontally. The INTEND project will also review past forward looking projects and relevant recent studies in order to present future mobility concepts. Megatrends that will be affecting the future transport system will be identified using literature review. To ensure validity of the results, the Analytical Network Process (ANP) will be used to weight the megatrends, the influence of technological development trends as well as the one of political imperatives and derive reliable outcomes on the most predominant trends. Finally, INTEND will develop a transport agenda that would pave the way to an innovative and competitive European Transport sector. The project is driven by three main objectives:

- Define the transport research landscape
- Define the Megatrends and their impact on research needs
- Identify the main transport research needs and priorities

To enable a wide range of stakeholders to gain access to the results, INTEND will also develop an online platform, the INTEND Synopsis tool that will constitute a dynamic knowledge base repository on the major developments in the transport sector. This will provide a visualisation of main outcomes resulting from the already described ANP. The basis for the platform will be Transport Synopsis Tool which is already developed under the project RACE2050 coordinated by TUB. The repository will be updated and integrated into the INTEND website to provide a comprehensive picture of all forward looking studies focusing on technological developments, megatrends and policies.

### 1.1 D2.1 in the frame of INTEND work structure

Deliverable D 2.1 aims at providing an overview of the transport projects and future technologies. The current deliverable is based on “Task 2.1- Review and assessment of pertinent literature”, with the overall aim to gather, review and analyse relevant research documents from the European and international literature that has been produced through sponsored research projects, scientific publications, forward looking exercises, industry studies and strategic research agendas, with emphasis on transport. The aforementioned literature has been reviewed with the purpose of identifying technologies that require advancing or future technologies that will be used by the transport sector within a time horizon of 2020- 2035 thus enabling the sector to meet future demand and needs within the future context. The transport modes to be covered include road, aviation, rail, and maritime while transport systems and infrastructure are treated horizontally across the four modes. Figure 1 presents the structure of WP and the purpose of D 2.1 in the red circle.



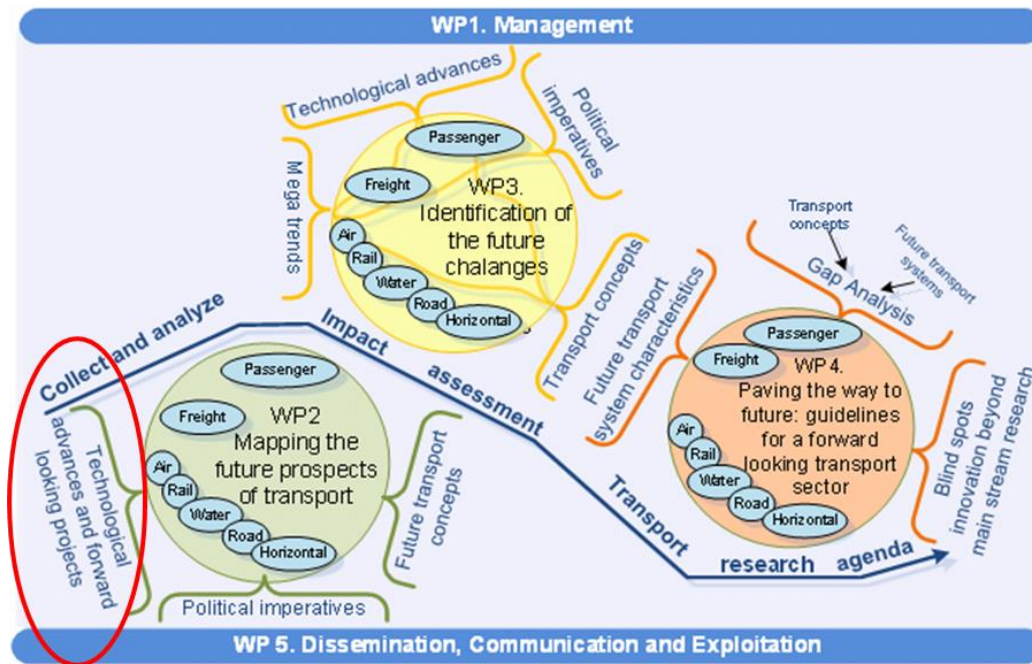


Figure 1. Overall structure of the WPs and role D 2.1

This approach will combine a backward looking exercise in terms of reviewing completed and ongoing research projects in order to extract the specific technologies that each project had researched or developed from 2010 and onwards, including relevant pertinent literature in order to identify technology trends and present the main technology themes of the reviewed sources. D 2.1 looked predominantly into EU FP7 and H2020 funded research projects with some additional international and national projects. This approach is suitable given the time horizon of 2020-2035 that INTEND is focusing on, because the technologies that have been researched from 2010 until the present time, it is likely that they will be available by 2035. Research projects calls in Europe at least, have largely been based on the requests of the EU transport stakeholder groups and roadmaps or visions that they have published over the years. Such examples are aviation calls that have stemmed from i.e.: ACARE's (2017) Flightpath 2050 targets (current and its previous versions), the Single European ATM Research (SESAR) programme and its aims to modernise European air traffic management, Shift2Rail (2015, 2017), WATERBORNE TP's vision 2030 or ERTRAC's and EGVI's research needs.

In addition technology news websites and forward looking reports have served as an supplementary net for capturing technologies that are more cutting edge, more recent and are purely based on private and industry initiatives. In many cases industry based research and product development does not always follow the same vision as academic research or that of the transport stakeholders. The proposed research needs and future technologies roadmaps, that technology platforms and transport stakeholders have produced have been also been reviewed and provide input to indicate future technology trends for the transport industry.

D 2.1 aims to deliver a list of dominant technology themes and the identified specific technologies that fit under these themes, thus providing feedback to "WP 3- Identification of



future challenges”. Specifically, the results of D 2.1 are to be used in “D 3.2- Megatrends validation and impact assessment” as feedback for an Analytical Network Process network which will cluster the future technologies, megatrends (D 3.1) and political imperatives (D 2.3) together in an effort to evaluate and prioritise all of the aforementioned information for the successful implementation of the key transport concepts of the future. In addition D 2.1 will provide input to “WP4 - Paving the way to future: guidelines for a forward looking transport sector” and specifically “Task 4.2 Gap Analysis” which will define streams of needed future researches in the fields of transport technologies, mobility concepts and research systems, etc., required to achieve the political goals (imperatives) that are to be associated with shared and long-term vision about the future of transport

## 2 Data collection methodology

The overall aim was to create a systematic data collection method that would enable the identification of the dominant transport technologies across the different transport modes within the outlook of 2020-2035. In addition to the four transport modes, technologies relevant to infrastructure and systems had to be captured. Figure 2 presents the approach that was used on reviewing each transport mode separately in terms of future technologies and how transport systems and infrastructure were horizontally incorporated into each mode.

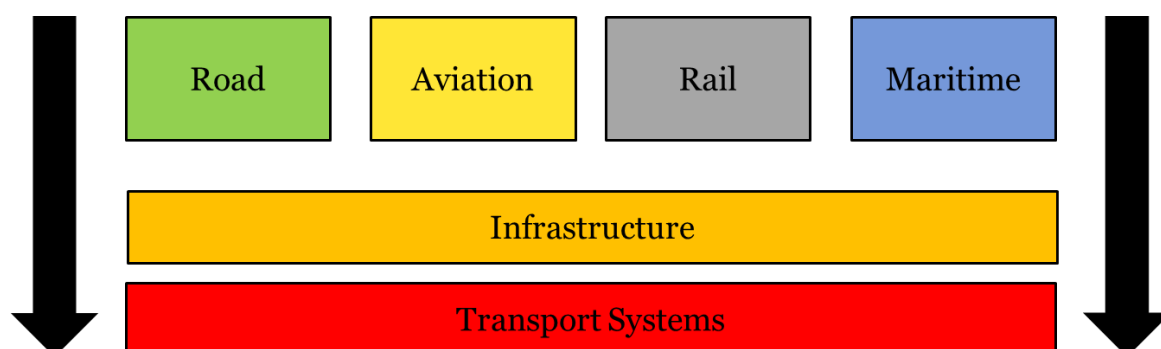


Figure 2 Review and assessment approach of literature

Figure 3 presents the main methodology steps that were followed in the completion of D 2.1.

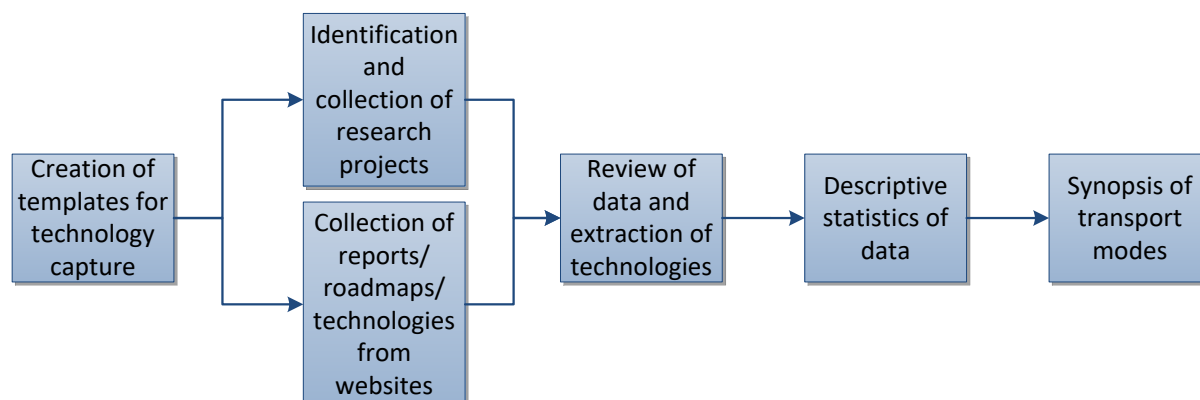


Figure 3. Methodology steps followed in D 2.1

## 2.1 The transport projects/ reports synopsis templates

A projects & report synopsis template (see Annex1) was created in MS Excel which was used as the main component of the repository. The template contains three spreadsheets per mode:

- 1) Reports spreadsheet: This spreadsheet was used for filing all the extracted information from reports/roadmaps/websites exclusively. This section of the template includes only information and technologies that have been identified by reviewing transport stakeholder roadmaps, future technology outlook reports, technology news websites and company websites. The main headings of the reports spreadsheet are shown below. The concept of thematic areas and clusters/subclusters is explained in the upcoming paragraphs.

Thematic Area	Cluster/Subcluster	Technology theme <sup>1</sup>	Technology identified <sup>2</sup>	Reference <sup>3</sup>	Sector <sup>4</sup>
---------------	--------------------	-------------------------------	------------------------------------	------------------------	---------------------

- 2) Projects spreadsheet: This spreadsheet was used for filing all the identified information and technologies what were researched exclusively by research projects. The main headings of the projects spreadsheets are shown below.

<sup>1</sup> The technology theme refers to the generic engineering theme that a technology belongs to i.e. computer aided engineering, vehicle design, engine design, materials development.

<sup>2</sup> The specific technology that has been identified in the source i.e. development of new composite materials, computational fluid dynamics and finite element analysis of ship propeller.

<sup>3</sup> The name of the report

<sup>4</sup> The sector that the identified technologies are applicable to: i.e. passenger, freight or both

Thematic Area	Cluster/Sub cluster	Subcluster Description	Technology theme	Technology researched	Project	Project brief results	Funding programme	Sector
---------------	---------------------	------------------------	------------------	-----------------------	---------	-----------------------	-------------------	--------

3) Projects acronyms spreadsheet: This spreadsheet was used only for storing the research project names for each mode and their acronyms. In addition it was used to summarise the thematic areas that each project covered, the funding scheme and the transport sector that the project was relevant to. The project acronyms spreadsheet main purpose was to be used internally to produce descriptive statistics later on in the project.

The next step for the creation of the templates was to create thematic areas where the identified technologies would be sorted out. Specifically, five thematic areas (to be referred as thematic areas from now on) were used: competitiveness, environment, energy, infrastructure and systems/safety.

The concept behind the division of the technologies into thematic areas, clusters and subclusters was based on the methodology followed by the MARPOS project (Boile et al., 2010) which reviewed a variety of EU maritime projects funded under FP5 to early FP7 in terms of technologies in order to identify future needs of the maritime transport research agenda. In addition the infrastructure and transport systems thematic areas were added to cover INTEND's specific needs.

In addition, the clusters and subclusters are thematic groups that help to create taxonomies of the projects and reports. Infrastructure and systems contained only clusters and had no subclusters. Clusters and subclusters although they were largely based on MARPOS project, they were tailored for each transport mode. The tailoring process and additional subclusters was done through other key documents such as roadmaps (IATA, 2013; ACARE, 2017; ERRAC, 2016; Shift2Rail, 2015, 2017), Strategic Research and Innovation Agendas (STRIAs) from TRIMIS website, and Technology platforms (WATERBORNE TP, 2016). The clusters and subclusters for each transport mode are given below.

**Table 1. Information clusters and subclusters per transport mode**

Road	Aviation
<b>Competitiveness</b> (thematic area)	<b>Competitiveness</b> (thematic area)
Competitive road transport (cluster) <ul style="list-style-type: none"> <li>Innovative road transport concepts/body structures (subcluster)</li> </ul>	Competitive aviation (cluster) <ul style="list-style-type: none"> <li>Innovative aircraft concepts/frames/structures (subcluster)</li> </ul>
Competitive road vehicle design <ul style="list-style-type: none"> <li>Design tools and simulation</li> <li>Cabin design &amp; interior</li> </ul>	Competitive aircraft design <ul style="list-style-type: none"> <li>Design tools for structural reliability</li> <li>Cabin</li> </ul>
Competitive production of road vehicles <ul style="list-style-type: none"> <li>Structural materials &amp; composites</li> <li>Manufacturing processes, production concepts</li> </ul>	Competitive aircraft production <ul style="list-style-type: none"> <li>Structural materials &amp; composites</li> <li>Manufacturing processes</li> </ul>
Competitive Life Cycle Services <ul style="list-style-type: none"> <li>Life cycle approaches</li> </ul>	Competitive Life Cycle Services <ul style="list-style-type: none"> <li>Inspection &amp; maintenance</li> <li>Repair, retrofit</li> </ul>
	Life cycle approaches

<b>Environment</b>	<b>Environment</b>
Reducing emissions <ul style="list-style-type: none"> <li>Alternative/conventional fuels</li> <li>Reducing noise &amp; vibration emissions</li> <li>After treatment of exhaust gases</li> </ul>	Reducing emissions <ul style="list-style-type: none"> <li>Alternative fuels</li> <li>Reducing noise emissions</li> </ul>
<b>Energy</b>	<b>Energy</b>
Optimising resistance and propulsion <ul style="list-style-type: none"> <li>Aerodynamics</li> <li>Engines / electric motors</li> <li>Transmissions, axles, tyres</li> <li>Batteries</li> </ul>	Optimising resistance and propulsion <ul style="list-style-type: none"> <li>Aerodynamics</li> <li>Engines</li> <li>Engine cycles</li> <li>Nacelles</li> </ul>
<b>Infrastructure</b>	<b>Infrastructure</b>
Intermodality Refuelling infrastructure for alternative fuels and innovative concepts Technologies for resilience	Airport safety/ security Innovative airport concepts Airport operations
<b>Systems</b>	<b>Systems</b>
Intelligent Transport System (ITS) Autonomous and connected vehicles and systems Big data Vehicle systems	Aircraft systems Air traffic Management
<b>Rail</b>	<b>Maritime</b>
<b>Competitiveness</b> (thematic area)	<b>Competitiveness</b> (thematic area)
Competitive rail (cluster) <ul style="list-style-type: none"> <li>Innovative rail concepts/ carriages/wagons (subcluster)</li> </ul> Competitive rail design <ul style="list-style-type: none"> <li>Design tools for structural reliability</li> <li>Cabin design</li> </ul> Competitive rail production <ul style="list-style-type: none"> <li>Structural materials &amp; composites</li> <li>Manufacturing processes</li> </ul> Competitive Life Cycle Services <ul style="list-style-type: none"> <li>Inspection &amp; maintenance</li> <li>Repair, retrofit</li> <li>Life cycle approaches</li> </ul>	Competitive maritime (cluster) <ul style="list-style-type: none"> <li>Innovative ship concepts (subcluster)</li> <li>Shipping operations and E-Maritime</li> </ul> Competitive ship design <ul style="list-style-type: none"> <li>Design tools for structural reliability and other functions</li> <li>Cabin design</li> </ul> Competitive ship production <ul style="list-style-type: none"> <li>Structural materials &amp; composites</li> <li>Production equipment and processes</li> </ul> Competitive Life Cycle Services <ul style="list-style-type: none"> <li>Inspection &amp; maintenance</li> <li>Repair, retrofit &amp; dismantling</li> </ul> Life cycle approaches
<b>Environment</b>	<b>Environment</b>
Reducing emissions <ul style="list-style-type: none"> <li>Alternative fuels</li> <li>Reducing noise emissions</li> <li>After treatment of exhaust gases</li> <li>Green train operations</li> </ul>	Reducing emissions <ul style="list-style-type: none"> <li>Alternative fuels</li> <li>After treatment of exhaust gases &amp; modelling techniques</li> </ul> Other emissions from waterborne transport <ul style="list-style-type: none"> <li>Reducing airborne and underwater noise</li> </ul> Reduced emissions by paints & cleaning, ballast water
<b>Energy</b>	<b>Energy</b>
Optimising resistance and propulsion <ul style="list-style-type: none"> <li>Aerodynamics</li> <li>Engines &amp; powerplants</li> </ul>	Optimising resistance and propulsion <ul style="list-style-type: none"> <li>Minimise resistance &amp; optimise propulsion</li> </ul>

	<ul style="list-style-type: none"> <li>• Ship powering</li> <li>• Energy management &amp; analytics for ship operations</li> </ul>
<b>Infrastructure</b>	<b>Infrastructure</b>
Station operations Rail safety/ security Intermodality Track systems Grid & energy	Smart and connected ports Intermodality Refuelling infrastructure for alternative fuels and innovative concepts Grid & energy
<b>Systems</b>	<b>Systems</b>
Rail systems	Maritime systems Safety

## 2.2 Data collection methodology

Figure 4 presents the collection process that was used to identify the relevant literature and research projects that were reviewed for the purpose of extracting possible future transport technologies.

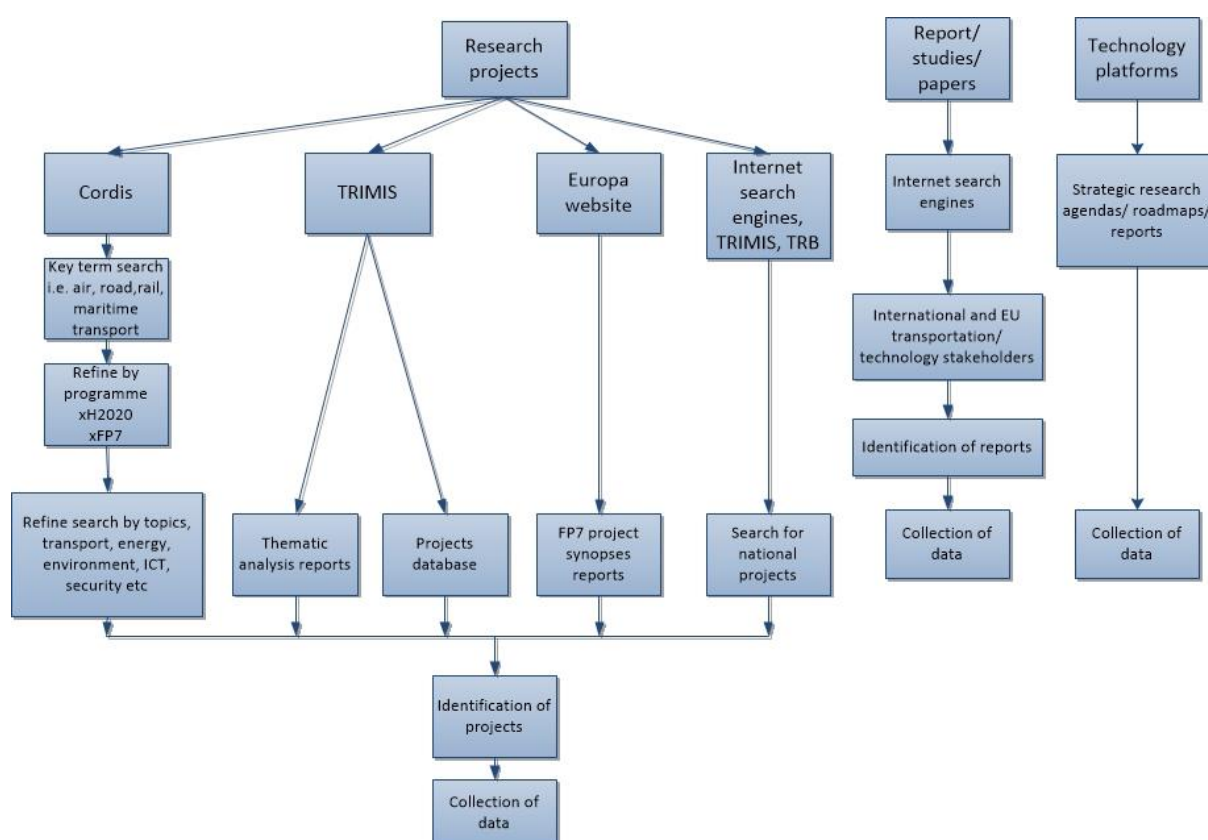


Figure 4. Data collection process for projects and reports

## **Selection of research projects**

### **Stage 1 – identifying research projects**

#### **EU research funded projects**

Databases such as Cordis<sup>5</sup> and TRIMIS (Transport Research and Innovation Monitoring and Information System)<sup>6</sup> were used as sources for identifying EU projects lists for each transport sector. Both websites offer a specific research projects section that was used.

Specifically, for FP7 projects, the following procedures were used in Cordis search: a) use of search terms for each transport mode i.e. road transport, air transport/aviation/ aeronautics, rail transport, maritime/water transport; b) further refinement of the search results using the “programme FP7- transport” filter; c) further refinement using “Project” filter, to identify only projects on the search list. For H2020 projects, the search filters were the same although the refinement was done using the “transport”, “energy”, “environment”, “infra”, “industrial leadership”, “security” filters due to the way the H2020 programme is structured and the Cordis search engine. The “transport” filter gave the most relevant results, although the rest of the topics were used to ensure wider search results and not missing projects that were relevant to transport but were funded by other calls.

The TRIMIS database was used in a slightly different manner. The website offers projects categorised by transport mode i.e. air, road, urban, rail, water and multimodal transport. After selecting each transport mode list, further refinement was done using the Framework programme filters i.e. FP7 and H2020.

After identifying the EU transport projects in each database the research projects template was populated. This methodology was used for each database in order to ensure that the majority of the available projects were captured by the process. The cross checks between Cordis and TRIMIS offered one final list of EU funded projects per transport mode. Crosschecks were also carried out using the Project synopses handbook for Sustainable Surface Transport Research (European Commission, 2014), the respective handbook for Aeronautics and Air Transport Research (European Commission, 2012) and EUCAR Projects Books (2015, 2016, 2017). In addition further selection criteria were applied to ensure that the most relevant projects were selected:

- FP7 projects funded under the last two calls from 2010-2013 were included
- Available projects from the beginning of the H2020 programme until the day of reviewing each transport sector between November 2017 and January 2018
- Projects that are relevant but have started before 2010 were left out regardless of ending after 2010.
- Only technology oriented projects were selected to be reviewed. No projects that covered topics such as transport methodologies, soft systems, business models, market research were selected for further review. The review included mainly Research and Innovation Actions or Innovation Actions rather than Coordination and Support Actions.

---

<sup>5</sup> [http://cordis.europa.eu/projects/home\\_en.html](http://cordis.europa.eu/projects/home_en.html)

<sup>6</sup> <https://trimis.ec.europa.eu/projects>

### **International/national/private funded projects**

The TRIMIS database was also used for identifying national research from EU countries. In many cases the projects identified under this search did not meet the aforementioned selection criteria with large numbers of national projects in the TRIMIS database being funded before 2010 or having a more theoretical approach than technology development.

For US funded projects the main database for projects was the Transport Research Board's Research in Progress (RiP) Database which contains information on completed and ongoing completed transportation research projects. RiP records are primarily projects funded by the U.S. Department of Transportation and State Departments of Transportation. University transportation research also is included in the database. In addition, the US Maritime Administration's' (MARAD) National Shipbuilding Research Program<sup>7</sup> offers a large number of projects relevant to manufacturing processes for shipbuilding. When searching the RiP database the main search filtering criteria that were used entailed projects that have been completed within the last 5 years or that are currently active. Also, the US transport research is not structured in the same manner as the European. The main transport mode areas in the RiP database that were used are divided into: aviation, highways, marine transportation, motor carriers, public transportation and railroads.

### **Stage 2- Selection of reports**

The selection process for the reports was simpler than the one used for projects. The main sources industry roadmaps, Strategic Research Agendas of the European Technology Platforms, future technology outlooks that have been produced by consultancy companies, transport companies, governments, and technology news websites or manufacturers' websites.

## **2.3 Review of research projects and pertinent literature**

The next step after creating the list of projects and filtering those that did not meet the selection criteria was the review process.

For EU projects the process was simple with Cordis serving as the main platform for searching project results. Once the project was identified on the Cordis database, the next step was to review the "result in brief section" that offers a brief synopsis of the project in order to get familiar with what the project was about. Furthermore, Cordis offers the final report summary of projects. These reports provide a good overall summary of the project. The information extracted for each project, entailed identifying the project results for each work package and the overall final results and inserting the data in the projects template. An example of the process is given below.

NEVERMOR project researched morphing concepts of various aircraft sections. Thus the general title of morphing concepts was used under the "technology theme" section. Under the "technology researched" section the specific technologies and the way they were performed were identified. NEVERMOR project designed morphing aircraft parts like nose wingtips and

---

<sup>7</sup> <https://www.nsrp.org/>



a joined wing shape design. In addition computational fluid dynamics and finite element analysis were used to carry out structural analysis using software tools. All of these technologies were filled out in the template in the form of: Design, CFD and FEM of drop nose wingtips with morphing camber. Finally, some brief results of those identified technologies were all added under the “project brief results” section. Some projects had researched more than one thematic area. For example the Hercules-C maritime project has carried out research on marine engines covering both developments on the engine itself as well as the exhaust after-treatment. In each case the project results had to be filled out in the respective sections under the energy and environment thematic areas. FP7 projects were the only projects that have been completed and offered final summary reports. In contrast H2020 due to having started the earlier after 2014, the majority did not have any available final reports yet. In this case periodic summary reports were used. For more recently funded H2020 project only a brief summary was available at the Cordis website which was simply enough to extract the project’s technology thematic area and an indication of what technologies the project will be researching. The reason for reviewing such projects despite the absence of results was that they assist in presenting trends of where EU funded research is heading.

The review process for the non-research projects related literature was simply based on identifying the technology themes, and the specific technology that has been proposed. Roadmaps contained the most credible information where the most relevant stakeholders propose the future outlook of the transport sector within a given timeline. In addition technology websites and other reports were used to collect addition future technologies and current technology initiatives that are carried out by the industry in order to identify technology trends.

## 2.4 Data analysis framework

Having completed the review process of both research projects and pertinent literature the next logical step was to provide a synopsis of what these two sources have researched or proposed in term of technologies. Section 3 offers a brief overview on the nature of technologies have been researched and how these technology themes are supported by the existing industry roadmaps. This approach is used to compare and contrast the most prominent technologies identified in the literature with the existing roadmaps.

Section 3 also briefly summarises in tables a) the technologies, for each transport mode, that have been researched, thus indicating the respective projects, b) the respective sector of the projects, c) the thematic areas they cover and d) their funding scheme. In addition descriptive statistics and graphs were provided in order to provide a visual representation of the findings



### 3 Future transport technologies

The following section provides the synopsis of project results and reports per transport mode offering a review of each thematic area. In addition the summary tables for the technologies identified are provided in the latter sections including descriptive statistics. Table 2 presents the number of EU and international/national projects that were reviewed under D 2.1. A grand total of 388 technology development/advancement projects were reviewed with the majority of those being EU funded. The full list of reviewed projects and report are available in Annex 2.

**Table 2. Number of reviewed technology development research projects**

Transport mode	EU funded	International/National/private funded
Road	120	7
Aviation	111	14
Rail	68	6
Maritime	55	7
	354	34
<b>Total</b>	<b>388</b>	

#### 3.1 Road transport

##### 3.1.1 Future road transport at a glance

##### **Road transport- Competitiveness**

The European Commission in 2011 released the White Paper on Transport introducing high standards for the road transport sector for 2020 and 2050. Specifically, reduction of greenhouse gas emissions (GHG) by 20%, increase of the share of renewables in the EU's energy mix to 20%, and 20% energy efficiency by 2020 (European Commission, 2011). The road transport sector, is facing congestions with more and more vehicles being introduced on the roads causing additional fuel consumption and more emissions as well as additional loss of time for road users. With the manufacturing industry focusing on Lean manufacturing and just-in-time process, road congestions will create additional cost to the manufacturers and the consumers. With decarbonisation and reducing oil dependency being some of the main driving forces for the automotive industry and governments, road transport will have to shift towards cleaner vehicles.

The shift towards introducing cleaner electric vehicles is evident by the number of projects that deal with this topic. Specifically, WIDE-MOB, ALIVE, AMBER-ULV, ELVA, EPSILON, SAFEV, URBAN-EV, BEHICLE, STEVE, DEMOBASE, RESOLVE, ESPRIT projects all carried out research in the development of lightweight small urban electric vehicles. ERTRAC et al. (2017) has identified that purpose built modular urban electric vehicles will be needed in the near future. Similarly, in the freight sector, the development of electric trucks and vans with modular structural architecture were the main themes (OPTIBODY, DELIVER, CONVENIENT, V-FEATHER). Further research on EVs and PHEVs is also envisaged in the EU FP9 programme by ERTRAC (2017b). Hybridisation of vehicles ranging from trucks, vans

and buses including demonstrator projects, was carried out by SMARTFUSION, HCV and CITY MOVE. Autonomous buses were demonstrated by the CITYMOBIL2 project. The electrification of buses and heavy duty vehicles including platooning demonstrators have also been suggested by ERTRAC (2018). Autonomous shuttle buses, taxis and shared autonomous vehicles have been identified as potential solutions for the city of Boston in the USA and NuTonomy, Optimus Ride and Aptiv Plc will undertake development of such autonomous applications for small passenger vehicles (Lang et al., 2017)

The application of fuel cells on vehicles such as buses, cars, taxis, vans and scooters in transport, has been the focus of numerous large scale demonstrator projects like H2ME, H2ME 2, HIGH V.LO-CITY, HYTRANSIT, HyTEC, CHIC and Project Portal. ERTRAC et al. (2017) supports the same concept by identifying that hydrogen powered buses and trucks will be required by 2020-2030 while hybrid electrification will be used in the short term before the wider introduction of hydrogen fuel cells into road transport. In addition based on ERTRAC's (2018) suggestions for the future EU FP9 programme, hydrogen fuel cells should also be considered, including their wider spread into other modes. Hence, Japan, as explained later in section 4.5 (see page 103), is pushing towards hydrogen mobility more than the rest of the countries due to the Fukushima disaster and their reliability on nuclear energy for power generation.

Computer Aided Engineering has also been a dominant theme in the road transport sector. Modelling tools have been developed to simulate EV components and vehicles in order to study and test their crashworthiness, structural mechanical properties, energy efficiency and other parameters (EBSF, HI-WI, ASTERICS, VENUS, MATISSE, POWERFUL, OBELICS, HiFi-ELEMENTS). The further development of precise numerical and real time modelling for internal combustion engines has been suggested by ERTRAC (2016). In addition, advanced magnetic modelling and Multiphysics tools have been developed that will be required in the future in order to simulate and test electric motors in virtual environments. Such tools will be used to measure Electromagnetic Compatibility (EMC) and health effects from electromagnetic fields (EMF) from EVs, a subject that has not yet received so much attention (DELIVER, EM-SAFETY).

Materials development is another technology theme that has been the subject of research from many projects. Projects like MAG-DRIVE and HI-WI have researched the topic of materials (nano-crystalline and amorphous NdFeB powders) for rare earth free permanent magnet electric motors. In addition the topic of lightweight materials for EVs was one of the most researched one. Projects like ALIVE, AMBER-ULV, E-LIGHT, PLUS-MOBY, EPSILON, BEHICLE and QUIET have studied the use of composite materials (Carbon Fibre Reinforced Polymer- CFRP, Fibre Reinforced Polymer-GFRP) or advanced metal materials (aluminium, magnesium, high strength steel). These combinations of materials are already being used by Audi on their latest A8 model offering less weight and 24% rigidity of the frame (Audi, 2017) ERTRAC (2106) has suggested that new materials will be required for ICE forced induction charging systems (i.e. turbochargers) and other engine moving parts, including anisotropic materials. An innovative concept for cabin interior materials has been suggested by JOSPEL where the interior of the car is used for resistive heating rather than heating the air around the passenger.

HI-WI, ALIVE and LOWFLIP are projects that have looked into specific manufacturing process for the automotive industry such as laser annealing for powder materials used on

electric motors, sand casting of magnesium alloys and Out of Autoclave processes for CFRP materials. Additive manufacturing will also play a considerable role in revolutionising the manufacturing industry and finding applications in the automotive industry with the potential of influencing freight logistics (Rand, 2018; Goulding and Morrell, 2014). EV battery recycling through pyrometallurgical, hydrometallurgical and physical routes, have been studied by EuroLiion and GreenLion projects. In addition ERTRAC et al (2017) and Malkin et al (2016) have suggested that end of life batteries from EVs instead of being recycled should be remanufactured or reused in second life applications such as stationary batteries

### **Road transport- Environment**

The environment thematic area of road transport is going to mainly be driven by reducing CO<sub>2</sub> emissions and minimizing fuel consumption. In this cluster the main technology themes that were identified for reducing emissions, were alternatives fuels and integrated emissions control.

The LNG Blue corridors project studied the development of freight corridors where trucks across Europe can refuel with LNG and developed a respective refuelling network. PHOTOFUEL studied the biocatalytic production of alternative liquid transportation fuels while project Portal is a cooperation project between Toyota and the Port of Los Angeles for the development of a fuel cell truck for drayage usage. In addition SMARTOP and CONVENIENT looked into the use of Photovoltaic (PV) systems on vehicles for reducing fuel consumption of auxiliary system.

CORE, HCV, EAGLE, GasOn and UPGRADE have studied the use of integrated emissions controls for reducing exhaust gas emissions. The methods that have been studied were: Advanced Selective Catalytic Reduction (SCR); Integration of the advanced SCR catalyst onto a diesel particulate filter substrate (SCR/DPF); AdBlue processors and ammonium nitrate additives into AdBlue to improve operating conditions; Gasoline particulate filters and 3 way catalysts without precious metals; Electrified Diesel Particulate Filters (DPF). ERTRAC (2016) has identified the way forward in terms of emissions control for each type of ICE. For the gasoline engine three way catalysts with new materials are proposed that can operate under lower temperatures and capable of particle filtration. ERTRAC (2017b) has suggested that reduction of catalyst materials could be a matter of further research in the upcoming Framework Programme. The use of SCR and Lean NO<sub>x</sub> traps (LNT) are also proposed while consideration will need to be given for controlling non-regulated pollutants like NH<sub>3</sub>. In terms of diesel engines, research will need to be carried out for trapping HC and NO<sub>x</sub> during cold start and making DPF operate under lower temperatures. In terms of Natural Gas engines new materials for catalytic converters and NO<sub>x</sub> conversion will be required. Companies like IAV (IAV, 2018) have developed a close coupled exhaust gas aftertreatment system for Diesel engines capable of operating at lower temperatures thus reducing emissions during cold start.

### **Road transport -Energy**

The energy thematic area is closely linked with the efforts of the automotive industry for electrification, cleaner ICEs and improvements of conventional vehicles in terms of aerodynamics and transmission.

Improvement of aerodynamic performance of vans and trucks was the main focus of research projects DELIVER, CONVENIENT, TRANSFORMERS, AEROFLEX. Project CONVENIENT studied the aerodynamic performance of different measures such as active grill shutters and wheel arch flow controls with side wings. An innovative concept of mission configurable aerodynamic design of a truck-trailer was studied by the TRANSFORMERS project.

Development of electric motors has been one of the most dominant themes of the Energy thematic area. Projects like Hi-Wi, EUNICE, PLUS-MOBY, SYRNEMO, MOTORBRAIN, ARMEVA and ReFreeDrive carried out research on improving and developing new electric motors either on a computational level or through actual prototypes. Magnet free Switched Reluctance Motors (SRM) and Permanent Magnet Assisted Synchronous Reluctance Motors that do not use rare earth material were developed by SYRNEMO, ARMEVA, ReFreeDrive and ModuLED.

In addition engine design and optimization of engines for better efficiency and fuel consumption have also been a main theme of this thematic area. Projects such as GASTone, CORE, LIBRALATO, POWERFUL, ORCA, EAGLE, GasOn, COLHD, HDGAS, REWARD, ECOCHAMPS and UPGRADE have all explored the development of cleaner engines. Some of the main themes studied were: advanced low emissions four stroke Spark Ignition (SI) engines, four stroke and two stroke Compression Ignition (CI) engines; small downsized engines for hybrid electric vehicles; rotary engine for range extender; waste heat recovery and new electric turbochargers or superchargers for CNG engines; ultra lean combustion; LNG, dual fuel engines or engines designed for running on biofuels for trucks; Waste heat recovery for hybrid trucks. ERTRAC (2016) has released a roadmap for ICE that explains all the short and long term developments that conventional engines will require in the future. To name a few: 100% electrically turbocharged engines with new compressor blade designs; precise fuel metering; variable compression ratio engines; Simplified ICE architecture for electrified powertrains; new ignition methods (microwave ignition, multi location ignition); waste heat recovery. Some of these concepts of variable compression ratio are already used by Infiniti in their sport engines while Mazda is to release their ground breaking Spark Controlled Compression Ignition (SPCCI) SKYACTIVE –X gasoline engine in 2019, which will incorporate both spark ignition and compression ignition element and offer diesel engine fuel consumption (Yamazaki *et al.*, 2015). Furthermore, the engine will be supercharged offering 10-30 % more torque than their current SKYACTIVE-G engine. A different approach ensuring that an ICE can offer performance or efficiency, has been implemented by automaker Infiniti and its Variable Compression turbo charged engine that uses a motor and an actuator arm to change the position of the crankshaft and thus the compression ratio<sup>8</sup>. Moreover, project CORE has studied the use of Miller cycle in conjunction with a Variable Valve Actuation (VVA) concept and a dual state turbo system. The use of Miller or Atkinson thermodynamic cycles in engine combustion with Variable Compression Ratio has also been suggested by ERTRAC (2016). Companies like Toyota use variable engine cycles Otto/Atkinson for performance/ fuel economy in their 1.2 L turbocharged aluminium block engine. More efficient ICE technologies and development of powerplants that have very low or near zero CO<sub>2</sub> well-to-wheel emissions will have to be further research in the upcoming EU FP9 programme (ERTRAC, 2017b).

---

<sup>8</sup> <https://www.infiniti-usa.com/about/technology/vc-turbo-engine.html>

Some other innovative concepts researched under the energy thematic area were relevant to transmission. Specifically, project LORRY will develop an innovative tire following a “Worn as good as New” technology where the tyre’s performance remains similar to as when it is new after many kms and has less wear compared to reference tyres. Project 3IBS has proposed an intelligent automatic transmission for buses that can change shifting patterns in real time based on topography and vehicle occupancy in order to reduce fuel consumption. ERTRAC (2016) has also proposed that advances will be needed in vehicle transmissions suggesting that manual transmissions will require reduction in mass and friction losses. Improvements in automatic transmissions will also need to be made by improving shifting patterns and optimising gears. Transmission for electric vehicles will also be required.

Finally, batteries were another cluster that received considerable attention and is closely related to electrification of vehicles. Projects such as GreenLion, OSTLER, SMARTBATT, HCV, DEMOBASE, ECAIMAN, iModBatt, EVERLASTING researched battery modularity and how the batteries should be integrated into the vehicle design rather the other way around that many manufacturers are currently doing; Development and improvement of Li-Ion batteries with new materials for cathodes and anodes; Battery cell ventilation and design; Use of supercapacitors. GreenLion, EUROLIS, EASYBAT, EuroLiion also developed new materials for future Li-Ion batteries. ERTRAC et al. (2017) in their electrification roadmap have suggested that optimisation of Li-Ion will be needed while new post Lithium batteries will be required for 2020 - 2030. Furthermore, the next generation of batteries will need to be modular, lightweight and should offer high energy capacity. Such batteries will be more suitable for buses and cars while combination of supercapacitors and supercharging will be used on trucks in the future (ERTRAC et al., 2017). The end of life batteries have been the subject of research for GreenLion and EuroLiion projects. According to ERTRAC (2017b) new advanced process will have to be devised to treat non-recyclable materials while vehicle batteries could find further use in stationary applications in houses or other locations.

### **Road transport- Infrastructure**

Infrastructure for road transport will be another major challenge for the road sector, related to the volumes of vehicles that will be in service in the future, the need for modal shift from road into other modes and thus the need for intermodal services. Furthermore, deployment of refuelling/ recharging infrastructure for new fuels and electric car and technologies for resilience are already a challenge that needs to be overcome.

In terms of intermodality only a limited number of projects dealt with this subject. AEROFLEX and TELLISYS where two projects that researched intermodal loading units that can be used for trucks and rail. I-TOUR developed an application for infomodality that allows the user to plan journeys and routes across different modes. Hence, the subjects of seamless intermodality using flexible interchanges and integrating innovative technologies that will enable such journeys have been suggested as subjects for further research by ERTRAC (2017b). Similarly, SOCIALCAR will provide a mobile phone platform for multimodal journey planning, booking and payment services.

The most popular cluster was refuelling infrastructure revolving around projects relevant to recharging of EVs or deployment of infrastructure that will assist the wider penetration of hydrogen into road transport. Projects such as FABRIC, FASTINCHARGE, UNPLUGGED, Green eMotion and ASSURED all dealt with the development of inductive charging

technologies ranging from slow charging up to rapid charging with 50 - 100 kW power. On road inductive charging research was also carried out by FABRIC. According to ERTRAC working group (2017) charging infrastructure will be required in the future with emphasis on automating the charging process for future EVs or autonomous vehicles thus allowing them to park automatically and charge without human intervention. Fast inductive charging for passenger cars and inductive charging for electric trucks is also suggested by ERTRAC et al (2017). Additionally, the same source suggests that electrification of roads will be required to allow trucks' further penetration.

H2ME, H2ME 2, HIGH V.LO-CITY, HYTRANSIT, HyTEC and CHIC project were part of the hydrogen fuel cell demonstrators and part of their research involved the rollout of hydrogen refuelling stations, including looking into sustainable hydrogen production processes. HIGH V.LO-CITY used renewable energies for the electrolytic production of hydrogen, as well as production of hydrogen from a local chlorine industry plant. Most of these projects also looked into ramping up production and refuelling rate of hydrogen on site. Finally, LNG BLUE CORRIDORS project rolled out 14 LNG stations across freight corridors in Europe. The ERTRACK working group (2017) suggests that refuelling infrastructure with alternative fuels will need to take in consideration local production of the fuels, especially in the case of hydrogen. Dedicated electricity networks for public transport will also need to be constructed, thus improving resilience and potential disruptions in case of network fails.

Goulding et al. (2014) have suggested that UAVs and sensor technologies could help in the predictive maintenance of road, bridges and other infrastructure. New materials for road could come from recycled materials such as plastic while self-healing materials could reduce the wear and tear of future roads (Rand, 2018; Goulding et al. 2014).

### **Road transport- Systems**

The road systems thematic area is closely related to technology themes that have been identified in the previous thematic areas. It refers to the systems that will enable future mobility concepts such as Mobility as a Service (MaaS), autonomous vehicles, ITS and ICT systems V2V and V2X connectivity.

Project STEVE studied the development of MaaS platform based on for electric quadricycles, while ELVITEN demonstrated a sharing system for EVs at different cities. In addition projects eCo-FEV and SMARTFUSION developed IT support platforms that can support users of electric cars and vans/trucks by providing routing services and energy management assist applications. Similarly, the ERTRAC working group (2017) and ERTRAC et al. (2017) support that MaaS platforms and their integration with public transport will be required in the future with inclusiveness of the elder people. Big data with infomodality applications will enable MaaS and other car sharing schemes while their application could find use in both passenger and freight (Rand, 2018). Further research on MaaS is also suggested by ERTRAC (2017b) in the upcoming EU FP9 programme. According to Raposo et al. (2017) Road Transport Management System and Road Side Units will be essential for the V2X communication and Coordinated Automated Road Transport.

V2X and V2I communications for road users are under research by SAFE STRIP and INTERACT. The first project deals with integrating CITS systems into integrated road strips while the latter will oversee the cooperative communication between autonomous vehicles and other road users. Project HIGHTS explores the issue of CITS and satellite service in

order to produce accurate services for road users, using additional data from wireless infrastructure and other communication networks for accurate geolocalisation of the vehicle. An innovative sensing technology that has the ability of converting fibre optic cables into virtual microphones that can detect and measure vehicle movement, is being developed by TomTom and Cisco, for supporting autonomous vehicles ([www.greencarcongress.com](http://www.greencarcongress.com)).

Advanced driver assistance systems (ADAS) have also been a key technology theme in terms of research projects. Projects such as COVEL, GENEVA, CITY MOVE, ERSEC, ADAS&ME, VI-DAS, ROBUSTSENSE, AutoMate, VIDAS and different projects of the USDOT on Automated Vehicle Research programme have looked into ADAS systems through by integrating EGNOS accurate satellite positioning for lane assistance and other usages; Collision avoidance for protection of vulnerable road users; ADAS systems for both rider/ driver for autonomous cars; ADAS systems with advanced sensors, machine learning features, computer vision and cloud data integration; vehicle platooning assisted by ADAS; merge/weave assist and speed harmonisation;

AutoNet2030, CITYMOBIL2, TAXISAT, L3Pilot, TrustVehicle, are projects that have studied the use of autonomous vehicles and automated driving. CITYMOBIL2 was one of the most well know trials of autonomous small buses and the development of the required infrastructure for the vehicle to operate. In addition these projects looked into the developing automated controls for the vehicles and system architecture. Pilots for connected vehicles are also underway at various US cities such as New York, Wyoming and Tampa. Hence, project companion studied the concept of vehicle platooning for trucks using on-board and off board systems. ERTRAC working group (2017) and ERTRAC (2017a; 2017b)) roadmaps suggest that demonstrators for freight last mile logistics and overall logistics, of automated and connected vehicles, will be needed in the near future. Such applications of vehicles can be used in waste collection as well as public transport. Driver behaviour of automated vehicles is an issue that will require further study through virtual human modelling of various situations that a driver might face during control handover, impairment or operator state (ERTRAC, 2017). Additionally, automated vehicles will require security measures to ensure that they are not vulnerable to cyber-attacks (ERTRAC, 2017; Raposo et al. 2017). ERTRAC et al. (2017) also indicated that multimodal platooning for ebuses could be a viable option for the future while highly automated urban ebuses with the ability to dock, charge and park will need to be developed. According to Raposo et al. Coordinated Automated Road Transport (C-ART) could be the *“extension of automated driving in which vehicles are not only able to move without human intervention (automated), but are also coordinated in order to maximize the overall efficiency of the transport system (connected and coordinated)”* (2017;4). This technology will require high level of automation of the vehicles and could be available with some small penetration by 2030. Vehicle sensors with multi-sensing components and capabilities in conjunction with infrastructure sensors will be required to enable Level 3+ automation of vehicles. Additionally big data can help study driving patterns and driver behaviour. Project UDRIVE created a data acquisition system from on-board devices in order to study driver behaviour. ERTRAC (2017a) and ERTRAC et al. (2017) suggest that big data will be required for EV fleet optimisation while data architectures will be needed to carry out this task. Big data availability will allow advances in ITS and Artificial intelligence (Lennert et al. 2016). Intel (2014) suggests that ADAS and autonomous driving will require development of on board systems with more computing power, centralised computing and low power semiconductors while ensuring the security and privacy of data.

In terms of vehicle systems projects like CONVENIENT and GASTone focused on electrifying truck auxiliary systems in order to minimise fuel consumption i.e. Electro-Hydraulic Power-Steering system (EHPS), Electric-driven Brake Air Compressor, electric water pump and electrical oil pump. ICE, QUIET, JOSPEL and CONVINIENT developed systems for heating and air-conditioning of vehicles with aim of reducing energy consumption. Other energy saving concepts for trucks were developed by CONVINIENT where the project created a predictive ECO-Driving Human Machine interface for speed control based on topography. The ERTRAC working group (2017) also suggests that more demonstrator projects should be carried out for promoting eco-driving and eco-routing and how they affect drivers behaviour.

### 3.1.2 Analysis of results in road transport technologies

The following section aims to analyse the results that were extracted from the projects and the dominant technology themes that were identified by both research projects and other literature. In the road transport sector 127 projects were reviewed with the majority of the projects addressing competitiveness, energy and systems. It needs to be noted that many projects addressed more than one thematic area (Figure 5). The fact that environment is the lowest in terms of coverage should not be taken literally i.e. that research does not address environmental issues. The environment thematic area addressed specific areas such as reducing emissions (air, noise, vibration) and use of alternative fuels. Tackling the issue of emissions is not always about reducing the product but reduction at source i.e. energy usage. Hence, the energy thematic area is the second most addressed area.

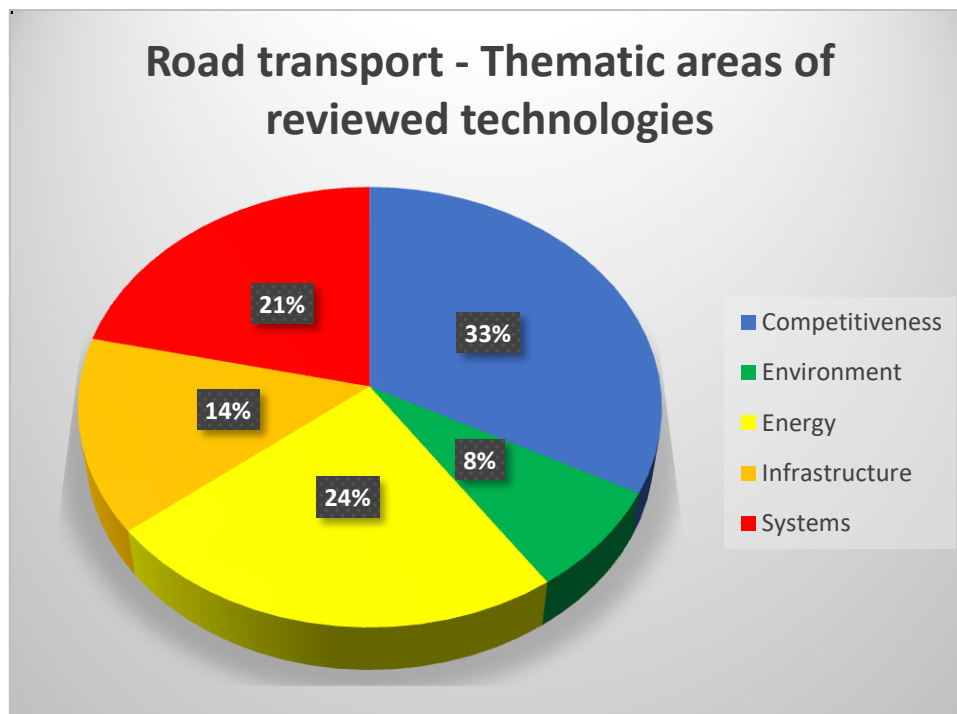


Figure 5. Road transport technology thematic areas of the reviewed research projects

Figure 6 presents the sector that the reviewed projects and their respective identified technologies were applicable to. Certain technologies were sector specific i.e. passenger or freight while others could be applied to both. According to the results 51% of the identified



technologies addressed the passenger sector, 16% were freight related while 33% could be applicable to both.

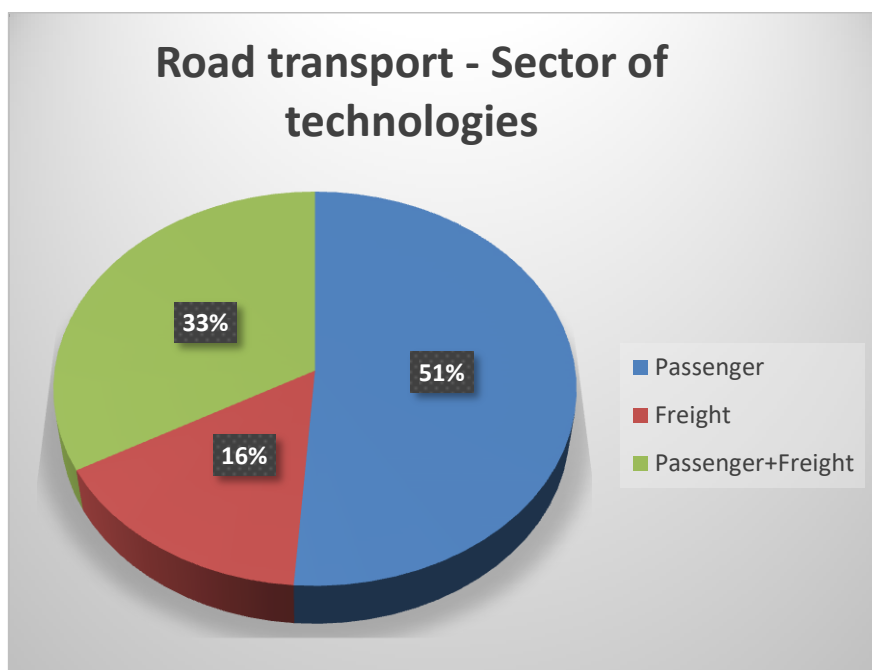


Figure 6. Road transport- applicable technology sector

Figure 7 presents the funding programmes of reviewed research projects. Other refers to national/international/private funded research projects.

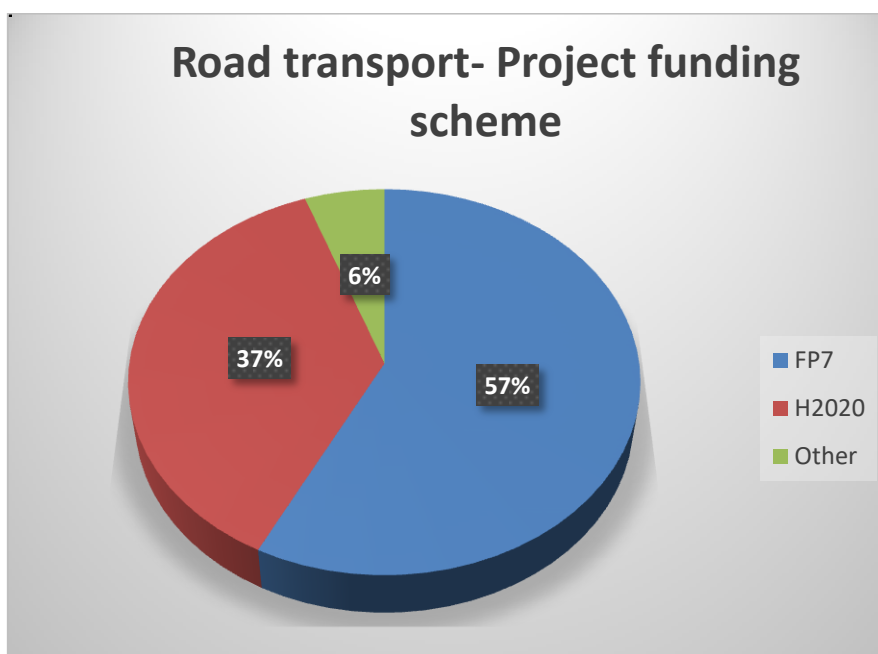


Figure 7. Road transport- Reviewed projects funding scheme

Figure 8 presents the dominant technology themes for road transport that were identified from the research projects and the pertinent literature based on citations. Specifically, electric

and hybrid electric vehicles seem to be identified as one of the main areas for research. Under this heading, EV design was included which although covers the specific theme of design it is part of the overall development of EV. Hence, this is the reason the heading of electric and hybrid vehicles has such a large difference compared to the other themes. EV demonstrators (bottom of graph) were projects that demonstrated the use of EVs and their main purpose was to purely study the application of EVs. For this reason it was decided not to be integrated with the rest the main heading. In addition autonomous vehicles came in second place which is well expected given their popularity in terms of projects that research this theme as well as the amount of roadmaps that identify them as future technology. Materials development for vehicles came in third place which is also predictable based on the amount of research projects that had as their main aim the development of light weight structural materials for EVs. Alternative fuels and engine design are perhaps technologies that will need wider usage/development in the short term before electric and fuel cell vehicles attract a larger share of the vehicle market. The alternative fuels & refuelling infrastructure theme has largely been affected by the amount of projects that have been working on development of hydrogen refuelling. Technologies like ADAS systems, fuel cell vehicles and CAE all shared the similar rankings. The fact that fuel cell vehicles were at a lower rank than alternative fuels refuelling can be attributed to the fact that some projects only looked at the hydrogen refuelling aspect than the vehicles. This is well justified considering the large cost for hydrogen refuelling stations and the safety aspects incorporated. ADAS, although it is a part of autonomous vehicles, it has been treated individually in order not to generalise this topic. CAE has already been explained that is crucial for future research and that further research into this field could help more modelling and simulations in the future. Integrated emissions control and charging infrastructure have ranked towards the middle of the graph. Development of electric motors could have received more attention although such research is most likely to be carried out by vehicle manufacturer's themselves. Battery modules, battery materials and end-of-life batteries are all different technology themes yet they fit under the umbrella of battery development. Technology themes with less than 2 citations were left out of the graph. This applies to the all the respective graphs of the transport modes that will follow.

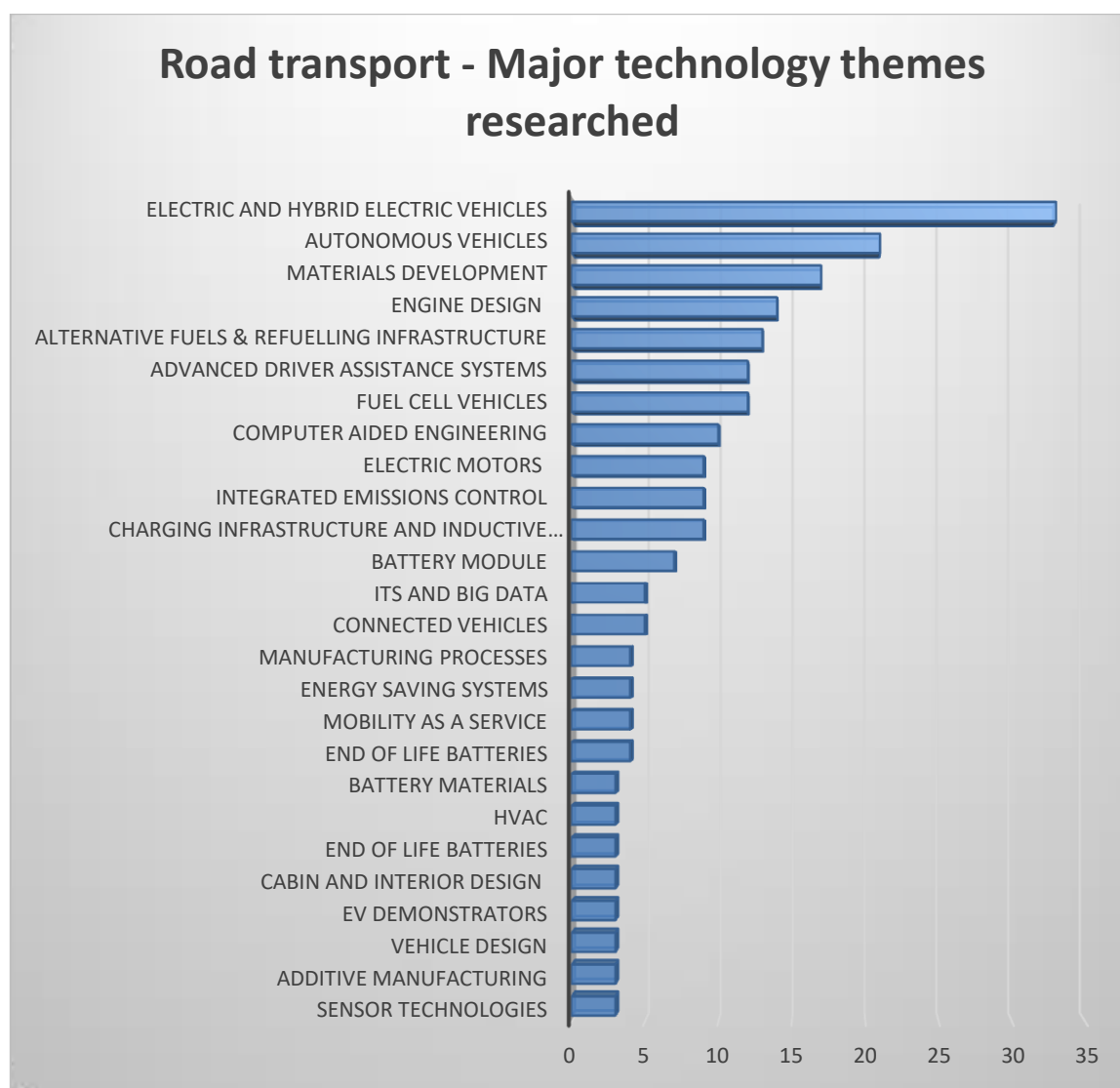


Figure 8. Road transport- dominant identified technology themes

### 3.1.3 Summaries of road transport technologies identified from projects

#### Competitiveness – Road research projects

Cluster: C1 Competitive road transport			
Subcluster: C1-1 Innovative road transport concepts/ body structures (future vehicle concepts, autonomous vehicles (non systems), platooning, swarms etc., fuel cell vehicles, EVs (freight/passenger), space frame construction, unibody frame, small urban vehicles, robot taxis, design for safety)			
Technology theme	Specific technology researched	Project	Sector
Vehicle design	1) CAD of external modular bus and design of coupling-decoupling system, 2) External modular bus concept that adjusts based on passenger demand	EBSF, 3IBS	Passenger
EV Vehicle design	1) Design, simulation and crash test of lightweight EVs, 2) 4 Seater electric	WIDE-MOB, ALIVE,	Passenger

	lightweight composite chassis electric vehicle, 3) Third generation passenger EV, 4) Safety of small EVs, 5) Urban EV between L and M category segment, 6) Low cost electric quadricycle, 7) Design of vehicles with battery system integration	AMBER-ULV, ELVA, EPSILON, SAFEDEV, URBAN-EV, BEHICLE, STEVE, DEMOBASE, RESOLVE, ESPRIT	
EV Vehicle design	1) Vehicle design using a modular structural architecture for electric light trucks or vans (ELTV's) focusing on the improvement of passive safety, 2) Design of an EV van using a sandwich chassis, 3) Hybrid electric truck using energy saving intelligent cruise control and electrified systems, 4) modular electric Light Delivery Van for lightweight, 24 hour operation and loading and unloading goods,	OPTIBODY, DELIVER, CONVENIEN, V-FEATHER	Freight
Autonomous vehicles	Design and real life pilot trial of an EV autonomous small bus	CITYMOBIL2	Passenger
Vehicle design	Design of super low-deck truck and trailer chassis design	TELLISYS	Freight
EV demonstrators	Demonstrations of electric buses, vans, cars	ZEEUS, Green eMotion, FREVUE	Passenger
Hybrid vehicles' demonstrators	1) Demonstration of hybrid diesel electric bus 2) Demonstration of hybrid diesel electric truck	HCV	Passenger + Freight
Vehicle platooning	1) Development of truck platooning concept and pilot trials using on board and off board systems, 2) Development of a truck platooning concept and demonstration of a Level 2 automation system	COMPANION, Project 0-6836	Freight
Hybrid and electric vehicles' demonstrators	Demonstration of electric/ hybrid trucks and vans with ICT support systems. 1) 3.5t electric van, 2) 26t hybrid diesel electric truck, 3) 7.5t full electric truck	SMARTFUSION	Freight
Hybrid vehicle design	Hybrid truck design for urban deliveries based on an integrated architecture using modular design concepts, reduced weight and fuel consumption, increased payload and electrification of auxiliaries	CITY MOVE	Freight
Electric vehicles	Demonstration of Electric light vehicles through a sharing platform	ELVITEN	Passenger
Fuel cell vehicles	Large scale demonstrators for fuel cell vehicles (buses, cars, vans, taxis, scooters)	H2ME, H2ME 2, HIGH V.LO-CITY, HYTRANSIT, HyTEC, CHIC, Project Portal	Passenger + Freight
<b>Cluster: C2 Competitive road vehicle design</b>			
<b>Subcluster: C2-1 Design tools and simulation (CAE, computation for virtual &amp; real advanced simulation and testing)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Project</b>	<b>Sector</b>

Computer Aided Engineering	1) Simulation tool development for passenger flow and accessibility of buses and bus line simulation, 2) Development of advanced magnetic modelling tools and multiphysics environment modelling tools , 3) Development of modelling and simulations for EV components, 4) Development of modelling and testing tools for of EV and their components in order to deliver more efficient vehicle designs faster, 5) Modelling and simulations tools for crashworthiness of Fibre Reinforced Polymers for future alternative fuel vehicles, 6) Development of simulation tools for powertrain integration, 7)Development of modelling and testing tools for of EV and their components in order to deliver more efficient vehicle designs faster, 8) Development of modelling and simulation tools for EV standard components and linkage between existing methods	EBSF, HI-WI, ASTERICS, VENUS, MATISSE, POWERFUL, OBELICS, HiFi-ELEMENTS	Passenger & Freight
Simulations and real life measurement of Electromagnetic Compatibility (EMC) and health effects from electromagnetic fields (EMF)	Measurements of EMC and EMF from an EV van using simulations and real life measurement in semi-anechoic shield chamber and a dynamometer	DELIVER	Freight
Simulations and measurements for electromagnetic fields	Design, simulations and real life measurements of electromagnetic fields (EMF)	EM-SAFETY	Passenger
<b>Subcluster: C2-2 Cabin design &amp; interior</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Project</b>	<b>Sector</b>
Ergonomic cabin design	1) Ergonomic workplace design for bus driver cabin, 2) Development of modelling and simulation tools for EV standard components and linkage between existing methods	EBSF, DELIVER	Passenger & Freight
Modular bus interior design	Modular bus interior design concept with sliding or folding seats that adapts to passenger demand	3IBS	Passenger
Energy efficiency of cabin	Optimization of the passenger compartments and their energy efficiency in EVs	DOMUS	Passenger
<b>Cluster: C3 Competitive production of road vehicles</b>			
<b>Subcluster: C3-1 Structural materials &amp; composites (lightweight materials, high strength steel, aluminium, magnesium, SAM2X5-630, plastics and composites)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Project</b>	<b>Sector</b>
Materials for permanent magnets of electric motors	1) Reduction of neodymium oxides in magnets for electric motors using nano-crystalline powders, 2) Development of an amorphous NdFeB powder	MAG-DRIVE, HI-WI	Passenger & Freight
Lightweight materials for Evs	1) Front vehicle structure made out of aluminium and a Cross member Subframe of die-casted and extrusion Aluminium, 2) Magnesium Strut rings 3)A -pillar and B-pillar made of hot formed high strength steel,	ALIVE, AMBER-ULV, E-LIGHT, PLUS-MOBY, EPSILON,	Passenger

	4)CRF roof, 5) Battery-Cover-Plate made of Thermoplastic GFRP has integrated Fixing Elements for the Seat Rail, 6) Doors made out of 5000 and 6000 Aluminium alloys, 7) Hybrid composite chassis using carbon fiber sillbeams with steel tubular trusses and folded metal sheets, 8) Carbon Fibre Reinforced Polymer materials for Body In White EV, 9) Aluminium parts for suspension system, 10) Magnesium sheets for enclosures of the rear compartment, 11) Novel plastometal bumper metal-plastic bumper structure (steel, low-density polyethylene (LLDPE) and polyurethane (PUR) elements combined together, 12) CFRP-aluminium body and interior, 13) CFRP-steel omega rear axle, 14) Lightweight multimaterial BiW with reinforced flat composite panels, high strength steel, structural aluminium joined and integrated under a bodywork in composite and polycarbonate glazing, 15) lightweight glasses and composites for windows and chassis, 16) light metal aluminium or magnesium seat components	BEHICLE, QUIET	
Materials for EV battery modules	Advanced pore morphology (APM) hybrid sandwich material and aluminium	SMARTBATT	Passenger
Materials for interior	Development of an innovative heating system based on resistive heating that uses the following materials 1) Rigid multilayer sheets in a thermoplastic matrix, 2) Fabrics with a heating coating in a thermoset resin.	JOSPEL	Passenger
Materials for cooling systems	Cooling system using Bi2Te3-based alloy materials	JOSPEL	Passenger
Brake system materials	Low environmental impact brake system	LOWBRASYS	Passenger + Freight
Materials for permanent magnets of electric motors	1) Reduction of neodymium oxides in magnets for electric motors using nano-crystalline powders, 2) Development of an amorphous NdFeB powder	MAG-DRIVE, HI-WI	Passenger & Freight
Lightweight materials for EVs	1) Front vehicle structure made out of aluminium and a Cross member Subframe of die-casted and extrusion Aluminium, 2) Magnesium Strut rings 3)A -pillar and B-pillar made of hot formed high strength steel, 4)CRF roof, 5) Battery-Cover-Plate made of Thermoplastic GFRP has integrated Fixing Elements for the Seat Rail, 6) Doors made out of 5000 and 6000 Aluminium alloys, 7) Hybrid composite chassis using carbon fiber sillbeams with steel tubular trusses and folded metal sheets, 8) Carbon Fibre Reinforced Polymer materials for Body In White EV, 9) Aluminium parts for suspension system, 10) Magnesium sheets for enclosures of the rear compartment, 11) Novel plastometal bumper metal-plastic bumper structure (steel, low-density polyethylene (LLDPE) and polyurethane (PUR) elements combined together, 12)	ALIVE, AMBER-ULV, E-LIGHT, PLUS-MOBY, EPSILON, BEHICLE, QUIET	Passenger

	CFRP-aluminium body and interior, 13) CFRP-steel omega rear axle, 14) Lightweight multimaterial BiW with reinforced flat composite panels, high strength steel, structural aluminium joined and integrated under a bodywork in composite and polycarbonate glazing, 15) lightweight glasses and composites for windows and chassis, 16) light metal aluminium or magnesium seat components		
Materials for EV battery modules	Advanced pore morphology (APM) hybrid sandwich material and aluminium	SMARTBATT	Passenger
Materials for interior	Development of an innovative heating system based on resistive heating that uses the following materials 1) Rigid multilayer sheets in a thermoplastic matrix, 2) Fabrics with a heating coating in a thermoset resin.	JOSPEL	Passenger
Subcluster: C3-2 Manufacturing processes, production concepts (Additive manufacturing, other possible processes, Factories of the Future)			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Project</b>	<b>Sector</b>
Assembly processes	Thermal bonding automated assembly process for EV batteries	GreenLion	Passenger & Freight
Manufacturing processes	1) Machine for laser annealing amorphous powder materials for electric motors, 2) Development of new sand casting manufacturing process for magnesium alloys with the use of electromagnetic pump to impulse the molten magnesium inside the sand mould. 3) Magnesium alloys with grain refiners to improve final microstructure, 4) Automated out of autoclave process for Carbon Fibre Reinforced Plastics	HI-WI, ALIVE, LOWFLIP	Passenger, Freight
Cluster: C4 Competitive Life Cycle Services			
Subcluster: C4-1 Life cycle approaches (End of life issues, life cycle concepts)			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Project</b>	<b>Sector</b>
Battery recycling	Hydrometallurgy treatments	GreenLion	Passenger & Freight
Battery recycling	Study of three recycling methods for EV batteries pyrometallurgical, a hydrometallurgical, and a physical route.	EuroLiion	Passenger & Freight
Tyres' lifecycle	NFC and RFID tags for complete lifecycle tracking of tyres	OnTrack	Passenger

## Environment – Road research projects

<b>Cluster: ENV1 Reducing emissions</b>			
<b>Subcluster: ENV 1 Alternative/conventional fuels (biofuels, alternative fuels, high octane gasoline)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Project</b>	<b>Sector</b>
Solar energy	Vehicle roof integrating solar cells, energy storage systems and auxiliaries as thermoelectric (TE) climatic control, electrochromic (EC) glazing, courtesy LEDs lighting and actuators	SMARTOP	Passenger

Solar energy	PV panel roof demonstrator for trucks	CONVENIENT	Freight
Alternative fuels	LNG demonstrator for trucks, technical specifications and roadmaps	LNG BLUE CORRIDORS	Freight
Alternative fuels	Proof of concept project for hydrogen fuel cell truck	Project Portal	Freight
Alternative fuels	Biocatalytic production of alternative liquid transportation fuels	PHOTOFUEL	Freight + Passenger
<b>Subcluster: ENV1-2</b> Reducing noise & vibration emissions (vehicle noise & vibration emissions)			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Project</b>	<b>Sector</b>
N/A	N/A	N/A	N/A
<b>Subcluster: ENV1-3</b> After treatment of exhaust gases (Diesel Oxidation Catalyst (DOC), Diesel Particulate Filter (DPF), NOx Storage Reduction (NSR) and Selective Catalytic Reduction (SCR), cold start trapping technologies, particle filtration (PF), new catalyst materials, catalysts for NGVs)			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Project</b>	<b>Sector</b>
Integrated Emissions control	1) Advanced Selective Catalytic Reduction (SCR) based on both mixed metal oxides and Cu-zeolite materials, 2) Integration of the advanced SCR catalyst materials onto a diesel particulate filter substrate (SCR/DPF) 3) Electrically heated device for complete vaporization and hydrolysis of the urea-water mixture in a small by-pass flow (AdBlue processor), 4) Ammonium nitrate addition to AdBlue to improve low-temperature performance of the SCR catalysts through optimization of operating conditions	CORE	Freight
Integrated Emissions control	Electrified Diesel Particulate Filter (DPF)	HCV	Passenger + Freight
Integrated Emissions control	1) NOX storage catalyst and 2) use of H2 as reducing agent for Selective Catalytic Reduction, 3) Development of a low precious metal content 3 way catalyst, 4) Gasoline Particulate Filter study and design	EAGLE, GasOn, UPGRADE,	Passenger
Emission Monitoring Systems	Nano-Particle Emission Measurement Systems	PEMS4NANO	Passenger + Freight

## **Energy – Road research projects**

<b>Cluster: ENE1</b> Optimising resistance and propulsion			
<b>Subcluster: ENE1-1</b> Aerodynamics (Aerodynamic issues of passenger and freight vehicles, platooning aerodynamics)			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Project</b>	<b>Sector</b>
Computer Aided Engineering	1) CFD simulations for aerodynamics of an EV van, 2) CFD simulations for a Active Grill Shutters combined with novel devices for wheel-arch flow-control on the tractor, together with proper aerodynamic fairings (which include side-wings, boat-tails and spoilers) for semi-trailer	DELIVER, CONVENIENT	Freight
Adaptable vehicle aerodynamics	Mission based adaptable vehicle aerodynamics	TRANSFORMERS	Freight



Optimised vehicle aerodynamics	Optimised adaptable vehicles and aerodynamics for drag reduction of trucks	AEROFLEX	Freight
<b>Subcluster: ENE1-2</b> Engines / electric motors (High efficiency light and heavy duty combustion engine technologies, hybridisation, downsizing, air management, efficient compressors and turbochargers, reduction of heat losses, waste heat recovery, Spark Controlled Compression Ignition (Mazda Skyactive X engine ), thermoelectric generators, nanocoolants)			
Technology theme	Specific technology researched	Project	Sector
Electric motors	1) Front and rear electric motors, 2) Electric in Wheel motor offering torque vectoring, 3) Synchronous reluctance motor (PMSyR) assisted by ferrite permanent magnets, 4) Permanent Magnet assisted Synchronous Reluctance Motor, 5) Development of a high efficiency electric motor, power converters and storage system with a modular design. 5) Novel design of the motor with topologies that use soft magnetic composites, power electronics and cooling with in-motor integration. 6) Microcontroller for intrinsic fail-safe of the power train	Hi-Wi, EUNICE, PLUS-MOBY, SYRNEMO, MOTORBRAIN	Passenger
Electric motors	1) Development of Switched Reluctance Motor (SRM), 2) Rare-earth magnet free brushless AC electrical motor design and manufacture	ARMEVA, ReFreeDrive	Passenger + Freight
Engine design	Installation of water cooled electric supercharge and electric turbocharger on a CNG engine. The energy for the electrified components came from a thermoelectric Generator	GASTone	Freight
Engine design	1) Down-speeding, 2) Two stage boosting using interstage cooling and variable asymmetric high pressure turbine, injection nozzles with high higher hydraulic flow, 3) optimised piston and rings	CORE	Freight
Secondary energy converters	Waste heat recovery system for hybrid drivetrain truck	NOWASTE	Freight
Range extender engine	Rotary engine range extender for an EV	OPTIMORE	Passenger
Computer Aided Engineering	Mechanical design and CFD thermal modelling of an Axial-flux Switched Reluctant Motor (AFSRM)	VENUS	Passenger + Freight
Engine design	Design, CFD and manufacture of a Libralato prototype engine (rotary engine)	LIBRALATO	Passenger
Engine design	Design, CFD and manufacture three engines: 1) advanced four-stroke Spark Ignition (SI) engine concept characterized by low-cost / low emissions, 2) Advanced four-stroke Compression Ignition (CI) engine concept able to run also on new tailored fuels and integrating the LTC (low temperature combustion), 3) An advanced two-stroke CI engine concept running on diesel fuel and integrating the LTHC (low thermal homogeneous combustion)	POWERFUL	Passenger
Electric motor and integration with drivetrain	A 30-50 kW electrical machine will be integrated with an efficient fully SiC drive and a gearbox within a powertrain traction module. Electric motor with dry rotor direct	DRIVEMODE	Passenger + Freight

	liquid cooling system integrated with the cooling system for the SiC drive.		
Electric motors	Development of an electric motor with buried-permanent magnet motor with reduced rare earth materials' use, and electric drivetrain for various configurations of Full and Hybrid Electric Vehicles	ModuLED	Passenger + Freight
Engine design	Downsizing concept for internal combustion engines in combination of hybridisation of buses and trucks	ORCA	Passenger + Freight
Engine design	1) Development of an ultra-lean Spark Ignition gasoline engine for electrified powertrains, 2) Smart coating to reduce thermal losses, 3) Hydrogen boosting for ultra lean combustion, 4) Close loop combustion control for extreme lean limit stabilisation, 5) Development of a super downsized CNG mono fuel engine that can meet post Euro 6 emissions, 2020+ CO2 targets under real driving emissions. The engine will use Variable Valve Actuation, Gaseous Direct Injection	EAGLE, GasOn	Passenger
Engine design	Engine design for running on biofuels	COLHD	Freight
Engine Design	LNG, dual-fuel and pure natural gas powertrain systems for heavy duty vehicles	HDGAS	Freight
Engine design	2 stroke and 4 stroke diesel engine concepts	REWARD	Passenger
Engine design	Efficient and compact hybrid powertrains	ECOCHAMPS	Passenger + Freight
Engine design	Downsized spark ignition gasoline engine design	UPGRADE	Passenger
<b>Subcluster: ENE1-3 Engine cycles (non-conventional thermodynamic cycles (Atkinson, Miller))</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Project</b>	<b>Sector</b>
Thermodynamic efficiency	Miller cycle in conjunction with a Variable Valve Actuation (VVA) concept and a dual state turbo system	CORE	Freight
<b>Subcluster: ENE1-4 Transmissions, axles, tyres (frictional losses minimisation, transmission mass reduction, transmission for EVs, dual clutch, automatic transmission, transmissions for hybridisation, transmission for autonomous, Heavy truck transmissions)</b>			
Tyre design	1) Worn as good as New" (i.e. WAGAN) technology tyre design, 2) Innovative nano-structures tire compounds	LORRY	Freight
Intelligent automatic bus transmission	Intelligent automatic transmission for buses that changes shifting program in real time based on topography and vehicle occupancy	3IBS	Passenger
Tyre design	Design of smaller dimension tyre for trucks	TELLISYS	Freight
Drivetrain	Direct drive, single stage and two stage switchable high speed gearbox for EV/ hybrid vehicles	DRIVEMODE	Passenger & Freight
<b>Subcluster: ENE1-5 Batteries</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Project</b>	<b>Sector</b>
Battery materials	1) Semiconductor nanowire materials for lithium-ion battery anodes, 2) new aqueous binder for Li-Ion battery electrodes, 3) ionic electrolyte components, 4) Lithium sulphur	GreenLion, EUROLIS	Passenger & Freight

	battery (LSB)		
Battery module	1) Lighter and green module using a prismatised pouch cell stacking design that has cell venting system, 2) Modular battery design, 3) New battery module concept to be part of the vehicle's structural body modelled, 4) Lithion Ion battery and supercapacitors energy storage systems, 5) Development of battery cells and digitalisation of the cell development process, 6) Electrolyte, Cathode and Anode improvements for next generation Lithium Ion Batteries, 7) Flexible modular lithium-ion battery pack, 8) Developed Li-ion batteries for EVS based on innovative silicon (Si) anode (negative electrode), novel low-cost salts, and a modified iron or manganese/nickel-based cathode (positive electrode)	GreenLion, OSTLER, SMARTBATT, HCV, DEMOBASE, ECAIMAN, iModBatt, EVERLASTING	Passenger & Freight
Battery swap concept	Design for interchangeable batteries and integration of generic battery designs into single design for battery swap	EASYBAT	Passenger & Freight
Battery materials	Developed Li-ion batteries for EVS based on innovative silicon (Si) anode (negative electrode), novel low-cost salts, and a modified iron or manganese/nickel-based cathode (positive electrode)	EuroLiion	Passenger & Freight

### **Infrastructure – Road research projects**

<b>Cluster: INF1 Intermodality</b> (Seamless interchange of freight and passengers, Synchro-modality over key transport corridor. Common data/information architectures)			
Technology theme	Specific technology researched	Project	Sector
Loading unit design	Design of Megaswapbox loading unit suitable for intermodal transport	TELLISYS	Freight
1) Info-Mobility, 2) software development	Development of a platform to support multimodal travelling and interoperability between modes and operators	I-TOUR	Passenger
Loading unit design	Adaptable loading units for trucks	AEROFLEX	Freight
Transport Demand management	Communication network for intelligent mobility	SOCIALCAR	Passenger
<b>Cluster: INF2 Refuelling</b> (infrastructure for alternative fuels and innovative concepts infrastructure for hydrogen, CNG /LNG, EV charging (charging points, inductive charging roads, pantographs), Smart grids)			
Technology theme	Specific technology researched	Project	Sector
Inductive charging	On road inductive charging solutions for Electric vehicles	FABRIC	Passenger + Freight
Inductive charging and power electronics	1) Development and simulations of Inductive Power Transfer Module (IPTM) with optimisable magnetic coupling 2) Power electronics for inductive charging, 3) Development of charging station, 4) Energy management system for charging station.	FASTINCHARGE	Passenger

Inductive charging	Development of two inductive charging stations one of 3,7 kW and a fast charger of 50 kW	UNPLUGGED	Passenger + Freight
Charging infrastructure	Minimum specifications for public charging infrastructure and development of ICT architecture to accompany connectivity between systems	Green eMotion	Passenger
Plug in and inductive charging	1) Modular high power electric vehicle supply equipment for Heavy duty, medium duty and light duty vehicles , 2) Development of inductive charging equipment capable of delivering 100 kW	ASSURED	Passenger + Freight
Alternative fuels refuelling infrastructure	Rollout of 14 LNG station across road freight corridors	LNG BLUE CORRIDORS	Freight
Alternative fuels refuelling infrastructure	Hydrogen refuelling infrastructure deployment. The hydrogen production will be done through an electrolytic process	H2ME 2, H2ME	Passenger + Freight
Alternative fuels refuelling infrastructure	Compression and buffering module (CBM) for hydrogen refuelling stations which will increase dispensing capacity	H2Ref	Passenger
Alternative fuels refuelling infrastructure	Technologies that will scale up the output and throughput of hydrogen refuelling stations for buses	NewBusFuel	Passenger
Alternative fuels refuelling infrastructure	1) Rollout of hydrogen refuelling stations for the 3 demonstrators. 2)The H2 used in one of the stations comes from a local chlorine industry, 3) Integration of renewable energies for electricity generation that is to be used for H2 production	HIGH V.LO-CITY	Passenger
Alternative fuels refuelling infrastructure	1) Rollout of a hydrogen refuelling station using ionic compressors for faster refuelling. 2) On site hydrogen production using an electrolyser system	HYTRANSIT	Passenger
Alternative fuels refuelling infrastructure	1) Rollout of a hydrogen refuelling stations capable of 350 & 700 bar fuelling, 2) Study of different supply concepts: partial on site hydrogen production and hydrogen delivery	HyTEC	Passenger
Alternative fuels refuelling infrastructure	Rollout of hydrogen refuelling stations to support the demonstration of FCEV buses	CHIC	Passenger
<b>Cluster: INF3 Technologies for resilience ("sensors, monitoring strength, stability and security of assets, radar and microradars")</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Project</b>	<b>Sector</b>
New pavement materials	1) Nanotechnology based Carbon black modified bitumen, 2) Asphalt Concrete (AC), Porous Asphalt (PA) and Very Thin Layer Asphalt Concrete (BBTM) made of industrial by products, Reclaimed Asphalt Pavements (RAP) and other additives	DURABROADS	Passenger + Freight
Non Destructive Testing (NDT)	NDE tomograph (3D-scanner) for concrete bridges	COBRI	Passenger + Freight

**Systems – Road research projects**

<b>Cluster: SYS1 Intelligent Transport System (ITS) (V2V, V2I systems)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Project</b>	<b>Sector</b>
IT based systems for Evs	IT platform that enables the connection and information exchanges between multiple infrastructure systems that are relevant to the FEV such as road IT infrastructure, EV backend infrastructure and EV charging infrastructure	eCo-FEV	Passenger
ICT support systems for vehicles	ICT support system for drivers of electric and hybrid freight vehicles offering electric battery management, satellite navigation routing and battery charging linked to zoning management system	SMARTFUSION	Freight
Mobility as a Service (MaaS)	Electro-Mobility-as-a-Service platform for electric quadricycles	STEVE	Passenger
ICT support systems for vehicles	Development of various applications to support a shared ELV service 1) Brokering and a Booking service for EL-Vs and charge points, 2) EL-V fleet monitoring tool and 3) Eco-Drive app,	ELVITEN	Passenger
Satellite services	Use of satellite systems in conjunction with on-board sensing and infrastructure-based wireless communication technologies (e.g., Wi-Fi, ITS-G5, UWB tracking, Zigbee, Bluetooth, LTE...) to produce advanced, highly-accurate positioning technologies for Cooperative-Intelligent Transport System (C-ITS).	HIGHTS	Passenger & Freight
V2I communication	C-ITS apps embedded in integrated strips on the road	SAFE STRIP	Passenger + Freight
V2X communication	Cooperative interaction of Autonomous Vehicles with other road users in mixed traffic environments	INTERACT	Passenger
Loading unit design	Design of Megaswapbox loading unit suitable for intermodal transport	TELLISYS	Freight
1) Info-Mobility, 2) software development	Development of a platform to support multimodal travelling and interoperability between modes and operators	I-TOUR	Passenger
Loading unit design	Adaptable loading units for trucks	AEROFLEX	Freight
Transport Demand management	Communication network for intelligent mobility	SOCIALCAR	Passenger
<b>Cluster: SYS2 Autonomous and connected vehicles and systems (Lidars, sensors, vision systems etc., V2V (ADAS, braking, collision alerts), V2I, V2X-communication to support safety and traffic management, self-learning systems)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Project</b>	<b>Sector</b>
Autonomous vehicles and V2I infrastructure	Design and real life pilot trial of an EV autonomous bus including all required infrastructure systems	CITYMOBIL2	Passenger

Vehicle automation systems	Advanced automation combination of sensors such as ultrasonic cameras, radars and laser scanners	ADAPTIVE	Passenger + Freight
Automated driving and co-operative systems	1) Specifications of V2X messages for automated driving, also feeding ETSI ITS standardization 2) Development of manoeuvring control algorithms for cooperative automation 3) Development of cost-effective on-board architecture for integrated sensing and communications	AutoNet2030	Passenger & Freight
Advanced driver assistance systems	1) Lane Navigation Assistance based on EGNOS satellite positioning, 2) EGNOS based ADAS applications with high precision, 3) Advanced ADAS for anti-roll over, collision avoidance and protection for Urban Vulnerable Road Users (VRU) , 4) ADAS system using EGNOS- GNSS accuracy Collision Avoidance System, 5) Development of ADAS system with an integrated driver/rider state monitoring system, able to both be utilized in and be supported by vehicle automation of Levels 1 to 4., 5) Development of ADAS system and automated driving platform	COVEL, GENEVA, CITY MOVE , ERSEC, ADAS&ME, VI-DAS, ROBUSTSENSE	Passenger & Freight
Advanced driver assistance systems	Design of an ADAS system using: 1)Sensor and Communication Platform, 2) Probabilistic Driver Modelling and Learning; 3) Probabilistic Vehicle and Situation Modelling; 4) Adaptive Driving Manoeuvre Planning, Execution and Learning; 5)Human Machine Interface	AutoMate	Passenger
Advanced driver assistance systems	Development of a 1) next-gen 720° connected ADAS. 2) Advances in sensors, computer vision, data fusion, machine learning and user feedback. 3) Cloud	VI-DAS	Passenger
Advanced driver assistance systems	EGNOS based ADAS applications with high precision	GENEVA	Passenger
Geolocation and fleet management	EGNOS based precision geolocation of asphalt construction fleets and fleet management applications	ASPHALT	Freight
Advanced driver assistance systems	USDOT automated vehicle research programme that deals with various topics of automation relative to ADAS and human in the loop interaction such as: Cooperative adaptive cruise control, platooning, merge/weave assist, speed harmonization, and eco-approach/departure. 2) Concepts, testing and evaluation of first-mile/last-mile prototypes	Automated Vehicle Research programme 1, 2 of the USDOT	Passenger + Freight
Vehicle platooning control systems and ADAS	On board system for platooning control of the vehicles, off board platform for V2I communication using 3G network and V2V communication system	COMPANION	Freight



Autonomous vehicles	Development GNSS based taxi application	TAXISAT	Passenger
Connected measuring system	EGNOS-GNSS bases measuring system for vehicles that will be used for pinpointing objects and the vehicle's position on the map	ERSEC	Passenger & Freight
Satellite based services and software development	Insurance software system based on EGNOS-GNSS data	GNSSMETER	Passenger & Freight
Automated driving	Pilot, test, and evaluation of automated driving functions and connected automation	L3Pilot	Passenger
Autonomous vehicles	1) Design of controllers and sensor fusion systems for automated vehicles, capable of dealing with complex, uncertain and variable road scenarios to enhance road safety 2) Intuitive human machine interface for automated vehicles	TrustVehicle	Passenger
Safety systems	Vulnerable road users' protection systems	PROSPECT	Passenger
Connected vehicles	Development of a connected vehicles system for New York	CVDP - NYC CONNECTED VEHICLES PROJECT	Passenger + Freight
Connected vehicles	Development of a connected vehicles system for Wyoming	CVDP- WYOMING Connected Vehicles Pilot	Passenger + Freight
Connected vehicles	Development of a connected vehicles system for Tampa	CVPDP -TAMPA CONNECTED VEHICLES PILOT	Passenger + Freight
Vehicle platooning control systems and ADAS	Level 2 automation system for truck platooning with On board systems for vehicle control & monitoring, sensory equipment for machine vision, GPS and an ADAS	Project 0-6836	Freight
<b>Cluster: SYS3 Big data</b> (big data from IoT and connected systems)			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Project</b>	<b>Sector</b>
Data collection, monitoring and analysis from vehicles	Data acquisition system from onboard vehicles devices that record driver behaviour	UDRIVE	Passenger + Freight
<b>Cluster: SYS4 Vehicle systems</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Project</b>	<b>Sector</b>
Handling support system	Optical guidance system for buses to assist at docking	EBSF	Passenger + Freight
Inductive charging vehicle side systems	Electro mechanical system for inductive charging on vehicle side	FASTINCHARGE	Passenger
Energy saving systems	1) Predictive Eco-Driving Human Machine Interface (HMI) for controlling truck speed based on topography, 2) Electric Air Conditioning system, featuring a high-voltage electric compressor, supplied by the high energy battery for energy saving while	CONVENIENT	Freight

	the truck is parked		
Cooling system and simulation	Dual Level Cooling System design and simulation	CONVENIENT	Freight
Electrification of auxiliary systems and simulations	Electrification of auxiliary systems Electro-Hydraulic Power-Steering system (EHPS), Electric-driven Brake Air Compressor,	CONVENIENT	Freight
Electrification of auxiliary systems and simulations	Electrification of auxiliary systems: electric water pump and electrical oil pump	GASTone	Freight
Energy saving systems	Belt driven start stop generator	GASTone	Freight
Energy saving systems	Hybrid-on-Demand (HoD) feature. This feature integrates regenerative braking, supplementary propulsion and intelligent energy controls on a truck	TRANSFORMERS	Freight
HVAC	Magneto caloric refrigeration system for Evs	ICE	Passenger
Driving behaviour	Systems for assessing driver's behaviour such as mobile phone location services, mobile phone applications, telematics devices, built-in data loggers, dash cameras and enhanced dash cameras, wearable technologies, compound systems, and eye trackers	UDRIVE	Passenger & Freight
HVAC	Development of 1) refrigerant for cooling, combined with an energy-saving heat pump operation for heating, 2) advanced thermal storages based on phase change materials, powerfilms for infrared radiative heating	QUIET	Passenger
HVAC	1) Heating system that does not heat the air in the cabin but instead the surfaces surrounding the passenger. 2) Cooling unit with low weight materials and lead free	JOSPEL	Passenger
Vehicle's health monitoring system	IoT based application for monitoring vehicle's condition	JAM	Passenger

## 3.2 Aviation transport

### 3.2.1 Future aviation transport at a glance

#### **Aviation- Competitiveness**

Future aviation in terms of competitiveness is going to be shaped by growth in passenger travel demand from countries with growing economies such as India, China, Middle East and other Asia Pacific countries (Deloitte, 2017). Further demand is expected by business, leisure, visiting friend and high value freight travel demand (ACARE, 2017).



The main concepts in terms of aircraft design research are focused on morphing sections of the aircraft, new aircraft designs for: hybrid and electric propulsion, supersonic speeds, composite materials and personalized transport (MYCOPTER).

The morphing concepts' idea is that certain sections of the wings, winglets, wingtips trailing edge, even rotor blades can adapt their shape based on operational environment when made through innovative materials and actuated by mechanisms or electricity alone (NEVEMOR, SARISTU, SABRE). The overall aim is to reduce drag and thus energy efficiency. In addition, Blended Wing Body (BWB) (aka hybrid wing body) aircraft design is identified as a promising concept for hybrid and electric propulsion. The concepts of hybrid or electric propulsion in aircrafts are already being developed by Airbus (E-Fan and Vahana), Boeing, NASA, Rolls-Royce and Siemens. Advances in tape laying manufacturing processes (tow steering) will also allow composite wings to be designed differently thus allowing weight reduction and improvements in fuel efficiency (Science Daily, 2017). Overall aircraft design has been a major technology theme of research (ALaSCA, AHEAD, ATLLAS II, HEXAFLY-INT, DIspURSAL, Ce-Liner, WASIS, NASA X-plane project). Private companies are also trying to revive supersonic flight with the Spike S-512 Supersonic Jet, the Aerion AS2 business jet BOOM XB-1 supersonic demonstrator while Japan Aerospace Exploration Agency (JAXA) is also working on quiet supersonic jets (D Send programme). Hence,, the concept of air to air refuelling for passenger aircrafts has been proposed by RECREATE project Finally, JAXA is working on the development of a rotary wing airfoil airplane (helicopter) that could be used for emergency operations in Japan.

CAE methods such as computational fluid dynamics (CFD) and Finite Element Analysis (FEA) are all commonly used tools used in conjunction with Computer Aided Design (CAD) to model and simulate stress, physical and aerodynamic properties of sections and materials (IDIHOM, MAAXIMUS, EXTREME, AEROGUST, DAEDALOS, ECO-COMPASS, JAXA project for rotary airfoil airplane). Such tools will require further development in order to offer more accuracy close to physical tests. Such design tools will automate the design process and will also provide accurate visualization of the design.

According to IATA (2013) cabin interior technologies, such as windowless design, with cameras and screens substituting the view, light weight interior and inflight wireless and optical entertainment systems, will become mainstream. According to Airbus future vision cabin classes will be replaced by zones that cover individual needs. In flight Virtual Reality (VR) and Mixed Reality (MR) systems could potentially become part of future in cabin entertainment systems (VR-HYPERSPACE).

Materials development will also enable future aircraft designs to become reality. According to IATA (2013) composite materials will be used for fuselage and wings. Examples are Polymer Matrix composites (PMCs), Ceramic Matrix Composites (CMCs), Fibre Reinforced Polymers (CFRPs), Glass-Fibre Reinforced Polymers (GFRPs), Aramid-Fibre reinforced Polymers (AFRPs). In addition hybrid alloys (sandwiched sheets of metal with other polymer fibres) and advance alloy metal will also be required. Self-actuated materials that can react to light, heat or electromagnetic fields will also be prerequisite for morphing concepts. Nano materials will find applications in structural health monitoring applications (SARISTU). Other projects that have developed materials for various applications are ELECTRICAL, CERFAC, ATLLAS II, HEXAFLY-INT, ALMAGIC, TICOAJÓ, NHYTE, ECO-COMPASS, aFJR) Also, high temperature materials are also envisaged and they will enable supersonic flight of Mach 5-7

(HEXAFLY-INT). Adhered/jointed aircraft sections will find further usage on wing sections. Such topics have been studied by CERFAC, TICOAJO. Finally, icephobic materials can also play considerable role in avoiding ice formation on wing sections. Manufacturing processes such as additive manufacturing and Out of Autoclave (OOA) methods are mostly cited in terms of research. Additive manufacturing (MERLIN, Bionic Aircraft, AMOS, MMTech, AMATHO, EMUSIC) will enable weight minimization of various components while also it can be used for repairs at a lower price. The out of autoclave process can potentially reduce manufacturing times and cost of fibre polymer sections without the need of expensive autoclaves, while the process can also be used for repairing such materials. According to ACARE (2017) digitization of the entire supply chain will be needed in the future while VR simulation of production and assembly planning can also be used by aerospace manufacturing companies (SIMFAL project).

Furthermore, development of Non Destructive Testing (NDT) inspection methods will be required in the aviation industry (ENCOMB, DOTNAC, LOCOMACHS, ComBoNDT, Bionic Aircraft). New materials and processes will require new NDT methods that will be able to detect defects in composite materials, adhered sections with hybrid materials and bonds as well as components made by additive manufacturing. Finally, recycling of additive layer manufacturing materials, overall re-use of thermoplastic composite parts and recycling of aircraft components from end of life vehicles will need to be considered, given the large life cycle aircrafts have. Such aspects will be required to become part of the design process of an aircraft through methods such as Design for Environment (DFE) which already exists since the 90s. Another technology that could help businesses is Software as a Service where companies can offer cloud based computing power and other software services to businesses without the latter requiring physical hardware installations (Martin, 2018). Finally, new predictive maintenance software are becoming available by companies such as GE (*PREDIX<sup>9</sup>*) and Honeywell (*GoDirect<sup>TM</sup> Connected Maintenance*) (Honeywell Aerospace, 2018) that enable the airline company to monitor online the health status and operational hours of certain aircraft components i.e. Auxiliary power units, Environmental control systems Inertial reference systems, Wheels and brakes, Mechanical components or landing gear.

### **Aviation – Environment**

Improving aviation's environmental performance and efficiency is possibly the main driving force and challenge in this industry. Environmental issues such as reduction of CO<sub>2</sub>, NO<sub>x</sub>, and noise are the main driving forces behind any measurable performance improvement in the aviation industry. ACARE's (2017) Flightpath 2050 vision has set targets for 75% CO<sub>2</sub> emissions reduction (per passenger kilometre) and 90% reduction in NO<sub>x</sub> emissions, to be achieved by 2050. In addition ACARE (2017) has also set a reduction by 65% for perceived noise emission of flying aircrafts. All the aforementioned targets use as a baseline the capabilities of typical new aircrafts in 2000. These targets will drive improvements in noise emissions of engines and wider usage of biofuels in aviation. Aviation companies are already undergoing trials for biofuels in an effort to reduce exhaust emissions and trials have been performed in passenger flights.

---

<sup>9</sup> [https://d154rjc49kgakj.cloudfront.net/Case%20Studies/Case%20Study\\_Landing%20Gear\\_FINAL.pdf](https://d154rjc49kgakj.cloudfront.net/Case%20Studies/Case%20Study_Landing%20Gear_FINAL.pdf)

Based on the research projects and reports that have been reviewed the dominant technology themes identified were the following: alternative fuels and noise emissions mitigation and control methods.

In terms of alternative fuels both research projects (SOLAR-JET, 2G-CSAFE, ITAKA, JETSCREEN, Federal Aviation Administration' (FAA) CLEEN programme) and the aviation industry are working on the introduction and further usage of 2<sup>nd</sup> generation biofuels and alternative fuels in general. Sources such as Hydroprocessed esters and fatty acids (HEFA) are already used in commercial flights and have been identified as a viable emissions reduction technology compared to conventional fuels (Takriti et al., 2017; IATA, 2013). Biofuels mixed with kerosene are also viable option studied by DLR and Lufthansa Technik (DLR, 2017) as well as Fischer-Tropsch process syngas derived kerosene (IATA, 2013).

Noise control and mitigation has also been covered extensively by research projects through various approaches (NINHA, ORINOCO, RECORD, ENOVAL, ARTEM, IMAGE, Federal Aviation Administration's CLEEN programme, FQUROH). Open rotor engines (see energy section) that are being researched and have been proposed as a future technology due to their inherent design will require further noise reduction. Projects like NINHA and FAA's CLEEN programme have carried out computational modelling, simulations and testing of the emitted noise of CROR (Counter Rotating Open Rotor) engines. Other projects like RECORD have looked into how engine sections interact together such as the combustor and turbine. Another technology that has been identified and remains at an experimental stage was the use of plasma actuators at the engine's jet nozzle in order to reduce eddies formation (ORINOCO, IMAGE). Finally the use of liners, variable geometry chevrons (used by Boeing) (IATA, 2013) and porous materials at nacelle surfaces have also been identified as noise emissions reduction methods. An interesting concept has been developed by JAXA's FQUROH project where a phased array microphone system has been developed in order to localise noise sources while the aircraft is flying above the measuring system.

### **Aviation – Energy**

Aviation energy is closely linked to the environment sector and the aforementioned targets that have been set about exhaust gas emissions. To achieve these targets, engine design and new innovative propulsion concepts (Open rotor engines, advanced turbofan engines, or hybrid/ electric propulsion) will be required to reduce energy consumption and improve engine efficiency aviation. Aerodynamics are also interrelated to the energy consumption of an aircraft. Aerodynamics have been improving continuously and research is focusing making more slender, flexible wings, active flow control methods and reducing the formation of turbulent flow around aircraft sections. (The morphing concepts that have previously been mentioned are also part of the competitiveness)

In terms of technology themes in the aerodynamics subcluster, air flow control methods for reducing turbulent flow, have been the most researched topic from research projects (MARS, AFDAR, TFAST, DRAGY). The use of plasma actuators for controlling downstream flow and creation of eddies have been studied by project MARS. Turbulent boundary layer control methods have also been investigated by project DRAGY, while the interaction of boundary layer separation point and shock waves' formation around aircraft structures has been studied to further understand the phenomenon. These technology themes about controlling boundary layer and laminar flow control methods are also identified as solutions for

improving aerodynamic performance by IATA (2013). Advancement of computational prediction tools for studying the transition from laminar to turbulent flow has also been researched (RECEPT) which will be vital for future aircraft design in order to create better aerodynamic performing structures. The use of more aerodynamic wingtip devices (sharklets, winglets) and high lift devices (variable camber trailing edges, dropped spoilers and hinge-less flaps) are also suggested by IATA (2013). Increasing the aircraft's wing span through a truss braced design is also being studied by a NASA-Boeing project (NASA X project).

Engine and engine components design is one of the most researched topics within the energy and thematic area and overall as a technology theme in the aviation mode. Projects like LEMCOTEC, FACTOR, IMPACT-AE, SOPRANO, ULTIMATE, SHEFAE 2, DREAM, FACTOR, LEMCOTEC, FIRST, aFJR, and FAA's CLEEN programme have all researched engine design issues through various technologies. To name a few, ultra-high pressure ratio compressors, lean combustion and combustor design are some of the topics that could help reduce exhaust emissions and improve performance. Interaction between combustor and turbine has also been studied. In addition hybrid electric propulsion has also been studied by projects like MAHEPA, AHEAD, ASuMED, DISPURSAL and FEATHER. Integration of electrical propulsion systems into powerplants are being researched by different engine manufacturers and electric driven fan aircrafts [Airbus E-fan programme (Airbus, 2017), NASA X-57 programme (NASA, 2016)] are in development. According to IATA (2013) the main engine design architectures that will be required beyond 2020 are advanced turbofan and open rotor engines while geared turbofan engines could be available before 2020. Rolls Royce and Safran Group/ General Electric are already in the testing process of open rotor engines. Furthermore, advancements in combustors (variable flow splits, advanced combustors for low NO<sub>x</sub> emissions) and fans (zero hub, variable fan nozzle, high bypass ratio) are viable technologies according to IATA (2013). In addition, adaptive/variable cycle engines that can automatically alternate between high-thrust mode for maximum power and high-efficiency mode for optimum fuel savings are in development by General Electric, Rolls Royce and Pratt & Whitney.

### **Aviation-Infrastructure**

The main elements for aviation infrastructure that remain crucial are: 1) The growth of the aviation sector; 2) The consequent need of an improved use of the existing infrastructures; 3) A better allocation of resources (with reduced costs and emissions) and a smoother service for the customers (both in passenger and freight).

Many efforts are put in the automation of the airport management, management which is usually time consuming, labour intensive and considered a burden by the customers. Such an automation process will assume the form of passenger's profiling, e.g. making use of the data already existing in order to reduce redundant requests and speed up the procedures. But the overall goal is even wider, that is rethinking the whole procedure management. In this vein, there are many indications of foreseen radical changes in the airport organisation which vary from automated check-in to new mind-sets of automation in border control (ABC4EU). For instance, the baggage handling is considered very problematic and an encumbrance both for the operators and for the passengers. Robotic systems for automated check ins and baggage handling have been introduced like SITA's system at the Geneva Airport in Switzerland (Sita, 2016; International airport review, 2017). New, radical and disruptive approaches to the service (and in revolutionising the baggage handling) have been

suggested by PASSME. Concepts like the single token mean that passenger's identity is verified and authenticated by matching their passport and biometric data only once throughout a travel journey. The single token can be produced for a passenger in a smart phone, in a secure and trusted application, or at an airport kiosk. Once the single token is produced the passenger's identification can later be verified only through his/her biometrics (IATA,u.d.). IATA (2018) has created the One ID initiative based on this principle in order to bring together airports, airlines and government together to implement this concept. Airport like Aruba, Schiphol, Changi and Helsinki are already trialling or implementing such systems.

New concepts for redefining airports have been defined by MAAT and CentAirStation where the concepts of air ships outside cities or in-city small intermodal airports have been introduced. Part of airport improvements are also envisaged by introducing green operations. Emissions free taxing has been suggested both by ACARE (2017) and IATA (2013). Such systems are already in use through electric tugs like the TaxiBot (Taxibot, 2018) which is used by Lufthansa. More environmentally friendly chemicals for de-icing are also suggested by ACARE (2017) in order to minimise the environmental impact of airports.

About safety and security, it seems that the same approach is followed. CITRIMACC project offered a solution for smart and secure cargo containers that would eliminate screening and tampering. Finally, about inter-modality, the current trend is a consolidated transit service for airport, so to reduce personalized arrival and departure for passengers (DORA).

### **Aviation-Systems**

Two main technology clusters were evident in the systems thematic area: Aircraft systems and air traffic management.

Generally speaking aircraft systems are those that will enable the different technologies on board the aircraft. This would include systems for aircraft flight control & instrumentation, morphing of the aircraft sections, monitoring and sensing. Projects like FUTUREWINGS and SMS have developed piezoelectric systems that would actuate morphing wing aerofoil sections. IATA (2013) also suggests the need for developing actuation systems for morphing wings. The trend of improving the human-machine connection is one of the main concepts under development by better defining guidance, navigation and control technologies, which have better interface with the personnel in charge of the activities (MYCOPTER, RECREATE, AMOR, LAPARTS, AEROGLOSS, VISION). The subject of flight control has been studied through various approaches by systems for high speed (HEXAFLY-INT) that can assist air to air refuelling of passenger aircrafts (RECREATE), automatic remotely configurable controls (INCEPTION) and collision avoidance (AMOR). The need for Advanced fly-by-wire, Fly-by-light and Wireless Flight Control Systems is also supported by IATA (2013). Development of sensors and monitoring systems whether for structural integrity, noise, vibration, efficiency, health monitoring etc will gradually become prerequisites of future aircrafts (VIBRATION, EXTREME, ACASIAS). Such sensors may have to be powered by energy saving systems as suggested by IATA (2013) in addition, to other devices that may improve energy consumption such as electric in-wheel motors for taxing, Auxiliary Power Units and zonal dryers for reducing cabin air conditioning energy. Systems projects for de-icing of the aircraft like NO-ICE-ROTOR, PHOBIC2ICE, SEaSiDE will tackle the issue of ice formation on aircrafts through innovative concepts.

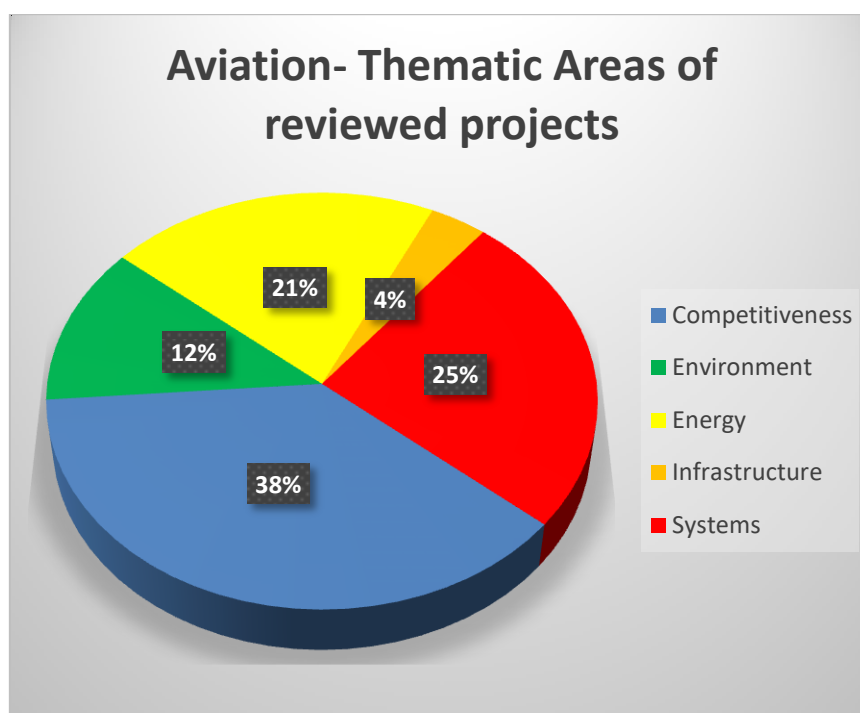
There are also more disruptive innovations at the horizon, like the use of Maglev systems that will substitute the traditional take-off and landing process (Gabriel) and electric actuators which will replace hydraulic systems assisting in aircraft operations and minimising aircraft mass (ACTUATION2015).

In terms of air traffic management, the vast majority of projects studied the themes of air traffic control. Satellite Navigation is already offered by the US-Federal Aviation Authority and offers more accuracy, availability, and integrity which is needed to support continuous all-weather use of GPS as a primary means of navigation. Optimisation of the future Air Traffic Management (ATM) system through modelling of Air Traffic Flow, better dynamic management of capacity and analysis of the impact that human behaviour has on ATM, have been carried out by projects like OptiFrame, PARTAKE and BigData4ATM).

Automated route management (PARTAKE), via improved and quicker response to human commands, but also through an automated recognition of human commands (Malorca), so to make the latter immediately able to activate machine's response (RETINA, Vision) have been researched by the aforementioned projects. However, while the human-machine interaction can be defined as an incremental efficiency trend, the development of better machine-to-machine connections is a promising (and more future oriented) part of the research field (SVETLANA, TBO-Met, COPTRA, AMOR). In this latter case, the air traffic management should be ready to deal with new challenges, including the massive development of drones and their impact in business-as-usual air management. On-board Detect And-Avoid (DAA) systems will be prerequisites for drones in the future to avoid collisions with other airspace users (European Commission, 2017). Innovative trajectory planning based on environmental impact has been suggested by ATM4E, while ACARE (2017) has indicated that 4-D trajectory management will have to become standard in the future. IATA's roadmap (2013) has also indicated a variety of guidance, navigation & control technologies that will enable future aviation ranging from satellite navigation and augmentation systems, ground based augmentation, GPS landing to automatic surveillance systems.

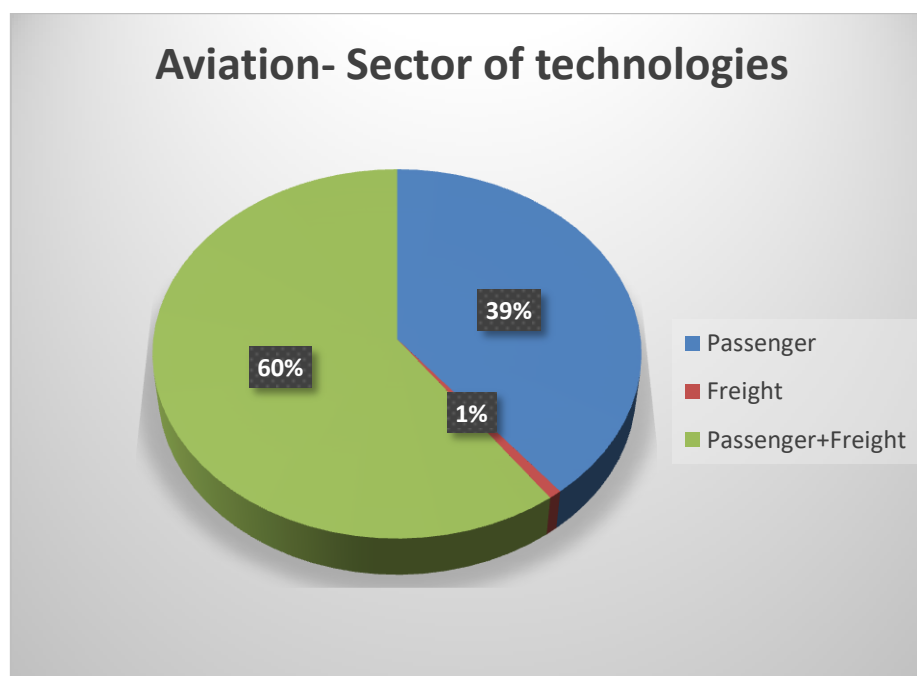
### **3.2.2 Analysis of results in aviation transport technologies**

Figure 9 presents the thematic areas covered by the 125 aviation projects that were reviewed. Competitiveness, systems and energy are once again the main fields of research. The fact that environment is at the fourth place does not mean that projects did not address this topic. In the aviation mode the main subclusters under this category were alternative fuels and reducing noise emissions. The aspect of exhaust emission is directly addressed at source i.e. the powerplants that belong to the energy thematic area.



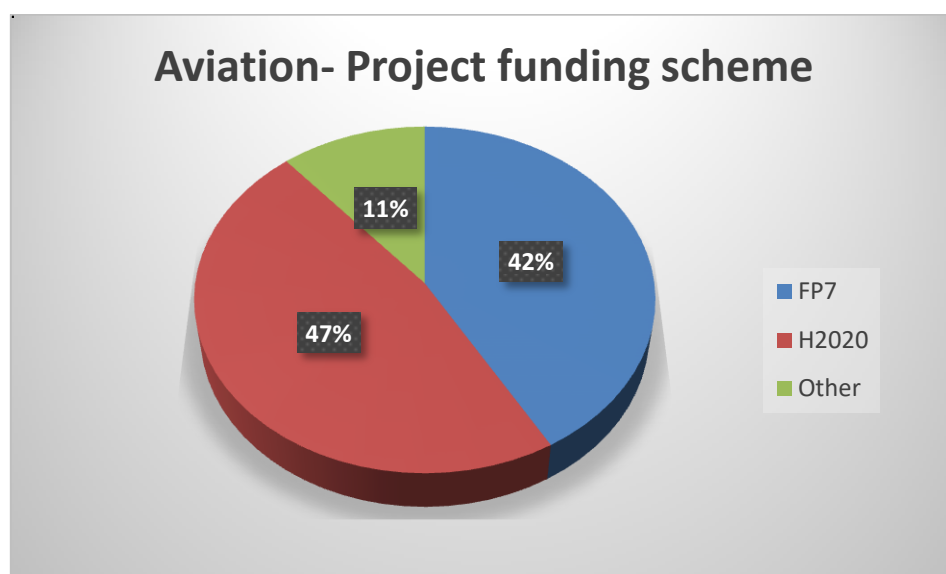
**Figure 9. Aviation- technology thematic areas of the reviewed research projects**

Figure 10 presents the sector of the identified technologies from the aviation research projects. The majority of the technologies (60%) that were researched were applicable to both passenger and freight sector. A 39% of the projects addressed technologies that were only relevant to passenger transport and hence were counted on the passenger statistics. Only 1 project was relevant to the freight sector exclusively and specifically about airports.



**Figure 10. Aviation- applicable technology sector**

Figure 11 presents the funding scheme of the reviewed projects.



**Figure 11. Aviation- Reviewed projects funding scheme**

Figure 12 presents the research technology themes that were identified during the review of the aviation sector both from research projects and literature. Aircraft design was the most research/cited technology, with engine design, CAE taking the second place while air traffic management, materials development and electric & hybrid propulsion were ranked at the 3rd place. The results are justified based on the importance of the thematic areas where these technologies belong to have on the overall growth of the aviation industry. With competitiveness, systems and energy being the dominant areas for research both aircraft & engine design, CAE, materials development and electrified propulsion will be responsible for the overall design of the future aircraft as well reducing traffic congestion through new air traffic management and control methods. Noise modelling, manufacturing process and alternative fuels are also popular technology themes. CAE, especially, in the aviation industry will enable further cost reduction in the development of future aircrafts both in the design and production phase. Hybrid propulsion and electrification of propulsion is still in development and will require further attention given the potential energy savings it can offer to this sector. Additive manufacturing although is technically a manufacturing process, it was treated individually due to its special characteristics and disruptive potential. Also morphing concepts relates both to design and system aspects and was treated individually due to its innovative nature.



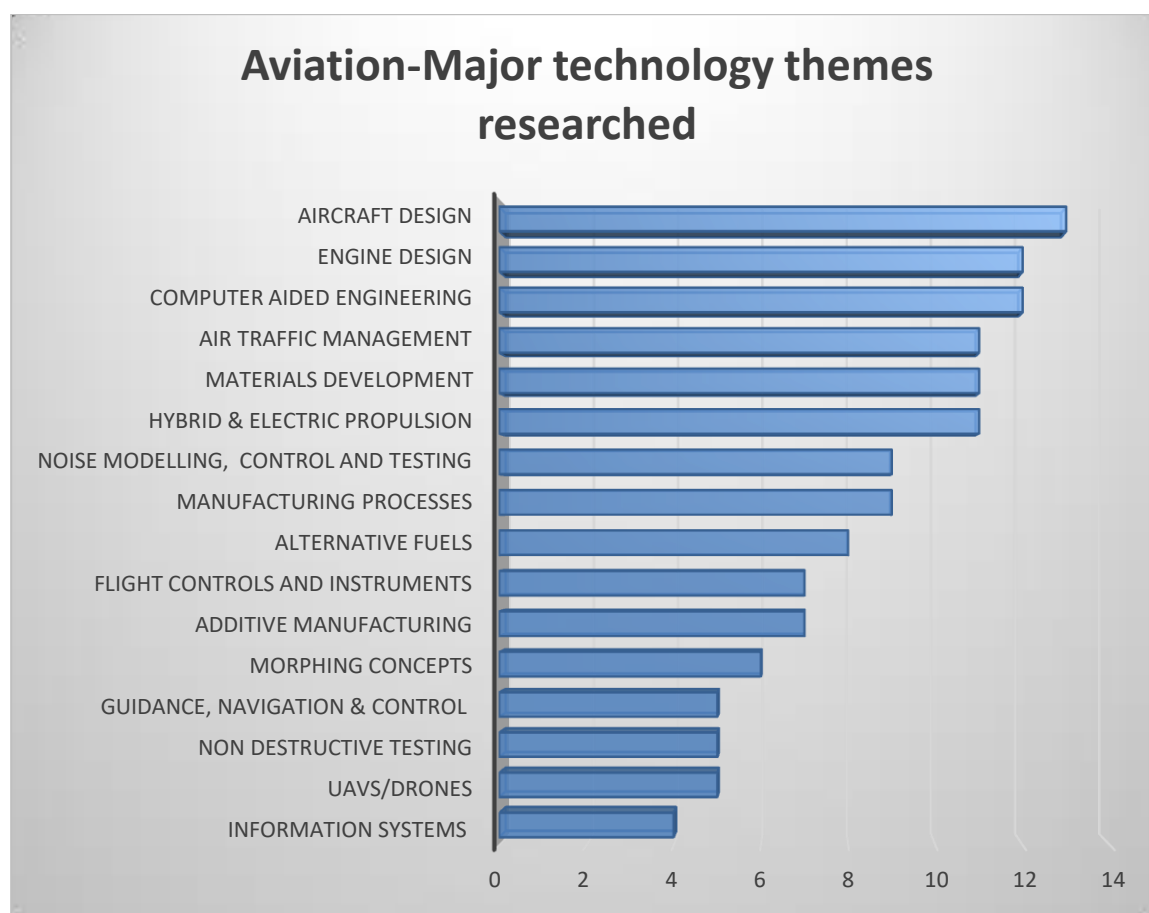


Figure 12. Aviation- dominant identified technology themes

### 3.2.3 Summaries of aviation transport technologies identified from projects

#### **Competitiveness – Aviation research projects**

<b>Cluster: C1 Competitive aviation</b>			
<b>Subcluster: C1-1 Innovative aircraft concepts/ frames/structures (Strut / truss braced wings, hybrid wing body, morphing airframes, low noise configurations, Personalized and individualized transportation to/from and within airport and during air travel, Small on-demand aircraft)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Project</b>	<b>Sector</b>
Morphing concepts	1) Design, CFD and FEM of morphing drop nose wingtips, morphing camber 2) Design and CFD of variable planform and sweep (joined wing aircraft) 3) Morphing technologies for wing leading edge, trailing edge and winglets, 4) Design, modelling and testing of helicopter blade morphing technologies	NEVEMOR, SARISTU, SABRE	Passenger
Aircraft design	1) Pro lattice barrel fuselage design, 2) Blended Wing Body (BWB) using hybrid propulsion, 3) Design of a hypersonic aircraft capable of 5 Mach speed, 4) Design of a hypersonic aircraft capable of	ALaSCA, AHEAD, ATLLAS II, HEXAFLY-INT, DIspURSAL, Ce-Liner, WASIS,	Passenger

	7 Mach, 5) Design of hybrid wing body with multiple BLI fans on the upper side of the fuselage, 6) C- wing design concept of an electrically propelled aircraft, 7) Composite fuselage section using a lattice structure with joints and openings incorporated into the design, 8) Design of Rotary airfoil airplane	Future type rotary-airfoil airplane	
Aircraft design	3 aircraft designs to for subsonic flight: 1) purpose built aircraft, 2) Hybrid wing blended wing body design, 3) truss braced wing aircraft	NASA X-plane project	Passenger + Freight
Personal aerial transportation system	Vertical take of landing personal aerial vehicle	MYCOPTER	Passenger
Air to air refuelling concept	Air to air refuelling for civil aircraft	RECREATE	Passenger + Freight
Aircraft design	Supersonic jet at 1.6 Mach	Spike S-512 Supersonic Jet	Passenger
Aircraft design	Supersonic Jet at 1.4 Mach	Aerion Mach 1.4 AS2 business jet	Passenger
Aircraft design	Supersonic Jet	BOOM XB-1 SUPERSONIC DEMONSTRATOR	Passenger
Aircraft design	Quiet supersonic jet	D Send programme	Passenger
<b>Cluster: C2 Competitive aircraft design</b>			
<b>Subcluster: C2-1 Design tools for structural reliability (CAE + other tools, computation for virtual &amp; real advanced simulation and testing)</b>			
Technology theme	Specific technology researched	Project	Sector
Structural loads	Computational FEA dynamic loading of an aircraft and validation through testing (buckling, material damping, mechanical hysteresis)	DAEDALOS	Passenger
Computer Aided Engineering	1) Improvement of high order methods for computational fluid dynamics for modelling airflows, 2) Predictive virtual testing of composite structures up to failure, 3) Damage models for composite materials, 4) CFD and FEA modelling of gust loads, 5) modelling and simulation tools for biomaterials, 6) Development of CFD tools for rotary-airfoil aircraft	IDIHOM, MAAXIMUS, EXTREME, AEROGUST, ECO-COMPASS, Future type rotary-airfoil airplane system technology project	Passenger + Freight
<b>Subcluster: C2-2 Cabin (Windowless designs, Differentiation of flight cabin classes and zones according to individual needs, modular cabin design, Wide scale deployment of in-flight communication for passengers (mobile phone, Wi-Fi), Virtual reality in-flight entertainment)</b>			
Technology theme	Specific technology researched	Project	Sector
Passenger comfort	In flight Virtual reality (VR) and Mixed Reality (MR) systems	VR-HYPERSPACE	Passenger
Cabin and cockpit noise	Instrumentation of a cabin and cockpit to evaluate noise system	CANOBLE	Passenger
Cabin design	Futuristic passenger-centered cabin design	FUCAM	Passenger
<b>Cluster: C3 Competitive aircraft production</b>			
<b>Subcluster: C3-1 Structural materials &amp; composites (Composites, Al-Li alloys, nanomaterials)</b>			

Technology theme	Specific technology researched	Project	Sector
Materials development: Nanomaterials	1) Nanoreinforced carbon based composites, 2) Nanomaterials for structural health monitoring	ELECTRICAL, SARISTU	Passenger
Materials development: Joints for fastened & adhered sections	1) Butt strap applications 2) H- Junctions, 3) Reversible bonding, 4) Titanium composite adhesive joints	CERFAC, TICOAJÓ	Passenger
Materials development: Composite materials	1) Titanium matrix composites (TMC), 2) Hollow sphere Structures, Tube Stacking Structures, 3) Ultra High Temperatures Ceramics, 4) Ceramic Matrix composites (CMC)	ATLLAS II	Passenger
Materials development: High temperature materials	High temperature structural materials for Mach 7	HEXAFLY-INT	Passenger
Materials development: New materials	1) New high strength aluminium materials for ALM parts, 2) PEEK-Carbon Fiber Prepreg with addition of amorphous (PEI) films, 3) Super-Icephobic surfaces to prevent ice formation on aircrafts, 4) Alternatives to chromium coatings for corrosion protection for Magnesium-Aluminium alloys, 5) Combination of recycled carbon fibres and bio-fibres in a hybrid non-woven and development of bio-based epoxy resins, 6) Ceramic matrix composite fan blades for engine	Bionic Aircraft, NHYTE, PHOBIC2ICE, ALMAGIC, ECO-COMPASS, aFJR	Passenger + Freight
<b>Subcluster: C3-2 Manufacturing processes (Additive manufacturing, other possible processes)</b>			
Technology theme	Specific technology researched	Project	Sector
Additive Manufacturing	1) Selective Laser Melting (SLM), 2) Laser Metal Deposition (LMD) 3) Adaptive manufacturing processes and Rapid Manufacture for Gamma Titanium Aluminides ( $\gamma$ -TiAl), 4) Electron Beam Melting - EBM, 5) Stress build up in structures created with AM	MERLIN, Bionic Aircraft, AMOS, MMTech, AMATHO, EMUSIC	Passenger + Freight
Manufacturing processes	1) Gravity and centrifugal casting of large titanium alloy components, 2) Out of Autoclave Liquid Resin Infusion (OOA LRI), 3) Asymmetric incremental sheet metal forming for Ti alloys, 4) Near Net Shape Hot Isostatic Pressing (NNSHIPping), 5) Investment casting for Ti alloys <sup>1</sup>	COLTS, LOCOMACHS, INMA, LOWFLIP, EMUSIC	Passenger + Freight
Computer Aided Engineering	1) Simulation of wing box manufacture and assemble using Lean production principles, 2) Virtual reality simulation for production and assembly planning	LOCOMACHS, SIMFAL	Passenger + Freight
Assembly process automation	Reduction of assembly time of large composite aircraft sections through heavy automation	MAAXIMUS	Passenger + Freight
<b>Cluster: C4 Competitive Life Cycle Services</b>			
<b>Subcluster: C4-1 Inspection &amp; maintenance (inspection &amp; maintenance new methods)</b>			

Technology theme	Specific technology researched	Project	Sector
Non-destructive testing (NDT)	1) NDT for CFRP structures and bonds, 2) Use of pulsed and continuous Terahertz systems for NDT of composites, 3) Acousto-Ultrasonic Tomography, 4) Air Coupled Ultrasound Inspection, 5) New NDT and repair methods for ALM parts	ENCOMB, DOTNAC, LOCOMACHS, ComBoNDT, Bionic Aircraft	Passenger + Freight
<b>Subcluster: C4-2 Repair, retrofit (repair and retrofitting new methods)</b>			
Technology theme	Specific technology researched	Project	Sector
Repair processes and equipment	Novel Processes and Equipment in Composite Repair Technology	NEWCORT	Passenger + Freight
<b>Subcluster: C4-3 Life cycle approaches (Aircraft Life Cycle)</b>			
Technology theme	Specific technology researched	Project	Sector
Recycling of materials	1) Recycling of Additive Layer Manufacturing materials, 2) Re-use of Thermoplastic Composites from dismantled aircrafts	Bionic Aircraft, RESET	Passenger + Freight

## **Environment – Aviation research projects**

<b>Cluster: ENV1 Reducing emissions</b>			
<b>Subcluster: ENV 1-1 Alternative fuels (alternative fuels, biofuels)</b>			
Technology theme	Specific technology researched	Project	Sector
Production of synthetic fuels	Production of kerosene using Fischer-Tropsch method from synthetic gas	SOLAR-JET	Passenger + Freight
2nd generation biofuels	1) Testing of biofuels (alcohols, methyl esters, ethyl esters, valerates, furanics, branched hydrocarbons, in relation to synthetic jet fuels), 2) Demonstration of blended biokerosene with conventional fuels (camelina and cooking oil), 3) Testing of paraffinic kerosene, Farnesane paraffin, synthetic paraffinic kerosene, Hydrotreated Depolymerized Cellulosic Jet and Sasol Iso-paraffinic kerosene for negative effects on engine performance	2G-CSAFE, ITAKA, CLEEN	Passenger + Freight
Alternative fuels	Design tools and experiments for risk assessment of alternative fuels	JETSCREEN	Passenger + Freight
<b>Subcluster: ENV 1-2 Reducing noise emissions (engine/aircraft noise emissions)</b>			
Technology theme	Specific technology researched	Project	Sector
Noise modelling, control and testing	1) Noise modelling and measurements for Counter Rotating Open Rotor aircraft, 2) Noise control by using plasma actuators and simulation, 3) Engine core noise measurements from interaction between combustor and turbine, 4) Liners for nacelles and fan modules of Ultra High	NINHA, ORINOCO, RECORD, ENOVAL, ARTEM, IMAGE, , IMAGE, ASCENT No. 007, D-SEND, FQUROH	Passenger + Freight

	Bypass Ratio (UHBR) engines, 5) Large low pressure ratio fan module and a novel intermediate case, 6) Innovative technologies for the reduction of aircraft noise at the source, 7) Simulation methodologies and investigation of plasma actuation, turbulence screens and innovative porous materials as noise mitigation methods, 8) Sonic boom N wave modelling, 9) Serrated leading edge slats, 10) perforated landing gear fairings, 11) phased array microphone system for localising noise sources		
Software tools for quieter design of engines	1) Aeroacoustic design and prediction tools related to fan broadband (BB) noise emissions from aircraft nacelle intakes + exhaust nozzles, 2) Methodologies and tools to mitigate the impact of aviation noise	TurboNoiseBB, ANIMA	Passenger + Freight

### **Energy – Aviation research projects**

<b>Cluster:</b> ENE1 Optimising resistance and propulsion			
<b>Subcluster:</b> ENE 1-1 Aerodynamics (High lift devices, drag reductions coatings, winglets, riblets, laminar flow, boundary layer, wingtip devices.)			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Project</b>	<b>Sector</b>
Surface protection system	Active and passive multi-functional surface protection systems for wings	AEROMUCO	Passenger + Freight
Air Flow control methods	1) Active flow control and interrelations with Reynolds stress, 2) Particle Image Velocimetry (PIV) for measuring flow field, 3) Interaction between shock waves and boundary layer separation points, 4) Turbulent Boundary Layer Control (TBLC) for skin-friction drag	MARS, AFDAR, TFAST, DRAGY	Passenger + Freight
Computer Aided Engineering	1) Improvement of transition-prediction tools for future laminar flow aircraft,	RECEPT	Passenger
High speed aerodynamics	Aerodynamic balance at Mach 7	HEXAFLY-INT	Passenger
Wing design	Design and scaled wind tunnel test of light weight, low drag truss braced wings	NASA-Boeing based project	Passenger
<b>Subcluster:</b> ENE 1-2 Engines (Advanced and open geared Turbofan, open rotor engines, electric propulsion, fans, engine cooling technologies, hybrid propulsion, distributed propulsion, combustors, compressors, low noise configurations)			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Project</b>	<b>Sector</b>
Engine design	1) Ultra-high pressure ratio compressors, 2) Lean combustion for ultra-high Overall Pressure Ratio (OPR), 3) Combustor-turbine flow interaction for high pressure turbines (HPT), 4) Novel combustor design architectures	LEMCOTEC, FACTOR, IMPACT-AE	Passenger
Turbine materials	Superalloys for turbine blades (Nb/Nb5Si3 and SiN4/MoSi2)	HYSOP	Passenger + Freight

Hybrid propulsion	1) Serial-hybrid-electric propulsion architecture for aircraft, 2) Hybrid engine using shrouded contra-rotating fans, bleed cooling, dual hybrid combustion system (biofuel and hydrogen), 3) Design of superconductive Hybrid-electric distributed propulsion (DP) , 4) Basic research for hybrid electric powertrain using High Temperature Super conducting motors	MAHEPA, AHEAD, ASuMED, DIspURSAL	Passenger + Freight
Alternative propulsion	Pulse Detonation Combustor (PDC) demonstrator as replacement of the turbine in a turboengine	TIDE	Passenger
Engine design	1) Alternative designs of engine combustion systems for reduced non-volatile PMs, 2) Research for optimum turbofan engine design, 3) New concepts for heat exchangers, 4) Engine compartments for a rotorcraft, 5) Flow field interactions between combustor and High Pressure Turbine (HPT), 6) High performance light weight High Pressure Compressor (HPC) guide vane and the Cooled HPC exit cone , 7) CFD of fuel spray behaviour and soot formation	SOPRANO, ULTIMATE, SHEFA E 2, , DREAM, FACTOR, LEMCOTEC, FIRST	Passenger + Freight
Engine control	Electronic Control unit for diesel aviation engines	EDEC	Passenger
Blade design	Blade design, FEA and testing of Counter Rotating Open Rotor Engine blades	BLADEOUT	Passenger + Freight
Turboprop mechatronics	Electrical power management of Turboprop engine	ACHIEVE	Passenger
Electric propulsion	Electric motor for small glider airplane	JAXA	Passenger
<b>Subcluster: ENE1-3 Engine cycles</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Project</b>	<b>Sector</b>
N/A	N/A	N/A	N/A
<b>Subcluster: ENE1-4 Nacelles (buried engines, reduced weight nacelles)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Project</b>	<b>Sector</b>
Morphing nacelles	Morphing nacelle lip CFD and FEA	MORPHELLE	Passenger
Nacelle design	Increased nacelle length to reduce nacelle drag	BALANCE	Passenger

### **Infrastructure – Aviation research projects**

<b>Cluster: INF1 Airport safety/ security (Airport safety/ security procedures, Integrated security approach “no borders”)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Project</b>	<b>Sector</b>
Secure cargo containers	Smart secure cargo container to eliminate screening and tampering	CITRIMACC	Freight
Automated border control gates (ABC)	Enhancement of the Automated Border Control gates system	ABC4EU	Passenger
<b>Cluster: INF2 Innovative airport concepts (Central airport and inner-city air transport concepts)</b>			



Technology theme	Specific technology researched	Project	Sector
Airship concepts	Multibody airship	MAAT	Passenger + Freight
Airport concepts	Design of an inner city airport	CentAirStation	Passenger + Freight
<b>Cluster: INF3 Airport operations (full automation of passenger baggage processes)</b>			
Technology theme	Specific technology researched	Project	Sector
Information systems	Travel time optimization systems	PASSME	Passenger
<b>Cluster: INF4 Intermodality (Improved performance and integration with other modes)</b>			
Technology theme	Specific technology researched	Project	Sector
Information systems	Information system for travel time optimization	DORA	Passenger

### **Systems – Aviation research projects**

<b>Cluster: SYS1 Aircraft systems (Flight control systems, System Health Monitoring - diagnostic and prognostic, Flying communication networks)</b>			
Technology theme	Specific technology researched	Project	Sector
Flight safety	Aircraft-pilot-couplings and rotorcraft-pilot-couplings (A/RPCs)	ARISTOTEL	Passenger + Freight
Personal aerial transportation systems & flight controls	1) Human machine interface for controlling and augmentation 2) Automation and navigation	MYCOPTER	Passenger
High speed flight control	High speed flight control	HEXAFLY-INT	Passenger
Structural monitoring and simulation	In flight structural health monitoring based on modelling	VIBRATION	Passenger
Automatic flight control and simulations	Preliminary design of automatic flight controls and human machine interface for air to air refuelling	RECREATE	Passenger + Freight
Morphing wings	Piezoelectric systems for morphing aerofoil sections	FUTUREWINGS	Passenger
Morphing concepts	Piezoelectric systems for morphing aerofoil sections combined with vibro acoustics sensors	SMS	Passenger + Freight
Sensor technologies	High speed fibre optic sensors and piezosensor networks for dynamic loading monitoring	EXTREME	Passenger + Freight
Energy Storage	Energy Storage and Regenerative System (ESRS)	ESTEEM	Passenger + Freight
Integrated sensors	Integrated sensors for structural components	ACASIAS	Passenger + Freight
Anti-icing and de-icing systems	Development and test of a heater layer for tilt rotorcrafts	NO-ICE-ROTOR	Passenger
Flight control systems	Automatic flight control systems supported by sensor based control laws	INCEPTION	Passenger + Freight
Flight control systems	Collision avoidance system	AMOR	Passenger
Mitigating ice formation	Simulation and modelling of ice formation	PHOBIC2ICE	Passenger + Freight

Cockpit design and flight controls	Reliable touch screen control panel	LAPARTS	Passenger
Flight instruments	Augmented reality headset for pilots	AEROGLASS	Passenger + Freight
Guidance, Navigation & Control technologies	Validation of Guidance, Navigation & Control technologies	VISION	Passenger + Freight
<b>Cluster: SYS2 Air traffic Management (Future Air traffic management &amp; control, airport procedures)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Project</b>	<b>Sector</b>
Air Traffic Management	Mathematical modelling and optimisation of Trajectory Based Operations	OptiFrame	Passenger + Freight
Satellite Navigation	Satellite based positioning, navigation and timing (PNT)	FAA Satellite Navigation	Passenger + Freight
Air Traffic Control	Air Traffic Flow and Capacity Management (ATFCM) decision support tool	PARTAKE	Passenger + Freight
Aircraft systems	Modelling and development of Electro-Mechanical Actuators (EMAs)	ACTUATION2015	Passenger + Freight
Take-off and landing	Magnetic-levitation take-off and landing (maglev TOL) system	Gabriel	Passenger + Freight
Big data analytics and ATM	Translation of big data analytics from passenger-centric spatio-temporal data in order to plan and manage an ATM system	BigData4ATM	Passenger
Air Traffic Control	Automation of air traffic controller's commands to pilots through automatic speech recognition	Malorca	Passenger + Freight

### 3.3 Rail transport

#### 3.3.1 Future rail transport at a glance

##### **Rail transport– Competitiveness**

In 2011 the European Commission introduced its White Paper on Transport (European Commission, 2011) with related goals to rail, focusing on 1) tripling the highspeed passenger rail network by 2030; 2) offering connectivity between rail, airports and ports; 3) shifting 30% of road freight towards rail or waterborne; 4) doubling ton-kms for rail freight and establishing a European multimodal transport information, management and payment system. In order to achieve such targets, rail sector competitiveness needs to improve product attractiveness to customers, reduce life cycle costs by introducing: modern technologies in rolling stock, maintenance procedures, ticketing and infrastructure (Amoore and Jaiswall, 2013).

In the competitiveness thematic area the main themes of research are related to wagon and running gear design, braking systems, new freight train concepts, non-destructive testing of infrastructure and trains, composite materials and manufacturing process including additive manufacturing, and preventive maintenance/ condition monitoring.

Wagon design for freight trains has been the focus of projects like CAPACITY4RAIL, VIWAS, HERMES and VEL-WAGON, proposing their own design concepts for modular wagons or wagons that are designed for different types of containers or granular materials. An innovative concept has been offered by project MARATHON that proposed the coupling of



two trains together with a slave locomotive in the middle of the convoy, which resulted to fuel savings. High performance freight lightweight wagons, or active suspensions running gear and the use of eddy current brakes were also part of the topics researched. These concepts are also supported by Shift2Rail (2017, 2015) future roadmaps that indicate that the rail sector will need new high speed lightweight passenger trains with new steering improvements (active, passive guiding), lateral and vertical suspension systems with independent wheel traction. Modular light weight wagon for freight trains are also suggested while trials for autonomous freight trains are already underway by the Rio Tinto Mining Company. Introduction of fuel cell concepts and hydrogen electric hybridisation is also being tested in real life. Quieter cabin interiors with modular adaptive design based on occupancy could potentially be part of future trains according to ERRAC (2016). Similar concepts have been studied by project MAT4RAIL focusing on more ergonomic cabin and cockpit design.

Composite materials Fibre Reinforced Polymers (FRPs) for interior and exterior wagon parts or crossings switches have been studied by project like MAT4RAIL, S-CODE. Coating solutions of axles and wheels are also identified as a viable solution to prevent fatigue cracking (EURAXLES, smaRtAIL). Furthermore, additive manufacturing also seems to be finding applications in the rail industry either for components, coating rails track surfaces or wheel surfaces with special coatings (RUN2RAIL, Mobile 3D Printing of Rail Track Surface for Rapid Repairment, smaRtAIL). The aforementioned technology themes are also proposed by Shift2Rail (2015, 2017) where the introduction of lightweight materials, nanomaterials and self-lubricating parts are proposed with embed sensors that can monitor noise, vibration and health.

The most researched technology theme within the competitiveness thematic area was non-destructive testing. Projects like ACEM-Rail, ROBO-SPECT, SAFTInspect, DTD SYSTEM 2, SAFT, INTERAIL proposed various concepts for inspecting infrastructure i.e. robotic systems with vision systems for tunnels and rail tracks; ultrasonic inspection such as Alternating Current Field Measurement (ACFM), Ultrasonic phased array and High Frequency Vibration; eddy current sensor systems and Thermographic testing. Similar methods based mostly on ultrasonic testing were proposed by EURAXLES, DTRT13-G-UTC59 and RAAI for inspecting train components. Predictive maintenance systems and technologies were researched as well. MAXBE, AUTOMAIN, DIAG-PANTOGRAPH, WARNTAK, INNOWAG all looked into developing solutions that can monitor health/ condition of train components. A more holistic approach is suggested by Shift2Rail (2015) where an end-to-end solution is proposed, covering all processes and data analytics for locomotives and wagons. Finally, Shift2Rail (2015) also suggests that the ageing heavy diesel shunting locomotive fleets will need to be replaced by hybrid electric solutions using Li-Ion batteries.

### **Rail transport- Environment**

The European Railway has an important role to play in minimising its impact on the environment through managing its exhaust emissions and securing continuity of supply of services while utilizing the available resources in a highly effective and efficient manner (ERRAC, 2016). Noise emissions of rail transport and exhaust gas emissions are the principal areas of focus in the cluster while wider penetration of alternative fuels is also considered.

Projects like QUIET-TRACK, RUN2RAIL, FFL4E, FINE1 and RIVAS have studied technologies related to reducing noise emissions: either by monitoring on board noise and vibration with the aim of identifying rail track sections that require maintenance; Noise prediction modelling of systems and subsystems; Simulations of how noise is transmitted and what possible mitigation measures could be used on tracks such as soil stiffening, open trenches with noise-absorbent materials. Project CARGOVIBES studied vibrations caused by freight trains and how these are perceived by people in term of annoyance. Similarly, Shift2Rail (2015) has proposed that computational methods will need to be furthered developed in order to predict more accurately noise & vibration from running gears and wheels and how these interact together. Also, noise skirts for wheels have been suggested (Shift2Rail, 2015). According to ERRAC (2016), silent brake blocks could reduce noise emissions in the future.

In terms of the wider penetration of alternative fuels into the rail mode, ARUP (2014) has indicated the integration of LNG and hydrogen (at a later stage) as viable options for reducing exhaust gas emissions from trains. Such endeavours remain to be evaluated in terms of exhaust emissions performance, especially in the use of renewable diesel as an alternative to conventional diesel (NCDOT project 2018-09). Energy regeneration/recuperation technologies either from braking system or from other devices have been the subjects of research for projects like ETALON and FFL4E. Such regenerative systems are available by Hitachi (2012).

Furthermore, in terms of exhaust emissions and after treatment of exhaust gases the only project that has been identified was NCDOT Project 2018-09, which proposes the use of a Blended After Treatment System that uses a Compact Selective Catalytic Reduction (CSCR) with a Urea storage and an injection circuit.

### **Rail transport- Energy**

The rail energy cluster is closely linked to the environment and competitiveness. The rail sector will require a more holistic approach looking into energy management, traction energy, which predominates, but also energy used for all the other railway functions (these are treated in the infrastructure cluster).

In terms of propulsion technologies hybrid and electric propulsion have been proposed by project FFL4E. The electric propulsion will be used for last mile propulsion into urban areas with the use of Li-Ion batteries. Electrified propulsion using fuel cells is currently being tested by Alstom (Alstom, 2017) and their Coradia iLint regional train in addition, Siemens and Ballard Power systems are working on a new fuel cell drive system for the Siemens Mireo train platform (Railway Technology, 2018). The use of hydrogen fuel cell electric propulsion is supported by ERRAC (2016) as well. Furthermore, Hitachi (2012) has carried out research on electric motors that require less maintenance through more efficient design using improved air flow and auxiliary cooling fans.

### **Rail transport- Infrastructure**

The rail infrastructure is asked to overcome several challenges in the future, which includes, shift towards better station design in accordance to changing passenger needs and aspirations, improvement in safety and security includes security measures, authorization

and certification of track and track side elements, interoperability and enhancement of new track components.

In other words these innovations might be clustered in group of (1) application of advanced technologies and processes and group of (2) improvement or new devices that enable new traffic management, control and communications between mobile and stable features and sustainability of the track subsystems and environment.

New technical solutions and life-saving technologies of how to design new terminals, stations will improve station security and people movement during emergencies (GATEWAY, FAIR Stations). SECURESTATION also researched the safety and resilience aspects of future stations during incident and simulated human behaviour. The direction of these projects is supported by Shift2Rail (2017) roadmap that suggests that crowd management will be required in the future including better accessibility of the platform and better safety management. Design and development of mega hub freight villages for comodality and long-distance transportation (ERRAC, 2016) will most likely support the shift of transported goods from other modes into rail. These mega hubs will need to be equipped with green logistics technologies and autonomous freight handling systems. Intelligent video gate terminal systems and data management will allow faster and more reliable tracking of incoming and outgoing assets (Shift2Rail, 2017). Internet of Things and availability of big data will pave the way for multimodal transport solutions (ARUP, 2014) while infomodality applications will be required to enable seamless travels (CSDIP)

Advances in railway infrastructure safety in particular application of new technologies such as automatic track warning system (ALARP), tailored specification for secure modern rail design (CYRILs), may lead to systematize innovative technologies for safety. Integration of the automatic train detection with UOZ-2, deterring devices have numerous application and support completely new safety management systems (SAFE TRAIN). Biometric technologies could allow identification and verification of passengers in terms of safety/ security issues, while drones with infrared sensors could play a role in monitoring for trespassers into secure rail areas (ERRAC, 2016).

Interoperable technologies for international transport focuses on developing technical systems for international use, analysing technical specifications for interoperability and making recommendations for new systems and devices such truck/train container system (SAFE-CTS) or MegaSwapBoxes (TelliSys).

Developments in design of new rail track elements (switches, bainitic steel rail, etc.) will drastically improve the performance of all railway networks, reduce a LCC of track maintenance and renewal and changing the potential offering a service. Some examples of projects are: VERT, WRIST and SUSTRAIL. Shift2Rail (2017) also suggests that re-use of recycled materials as well as new materials for track applications, will help reduce cost of infrastructure.

### **Rail transport - systems**

In the rail sector, considerable research effort was reported into the creation of innovative technologies for traffic control and management systems, technical specifications of interoperability, telematics applications for passenger/freight, mobility as a service and automatic train operations. All these technologies allowing much improved information to be

made available both within the rail industry (allowing better routing of empty wagons, provision of the most suitable wagons for work, understanding maintenance status, etc) and to customers, allowing better information on traffic status and estimated time of arrival.

TCMS (ERTMS, ETCS, TCMS) will play a greater role in the smart control of the flow of information regarding position of train, train operation, traffic management and communications, etc (SMART RAIL). But there are many difficulties in enhancing information in a timely manner. GNSS or EGNSS integrated with TCMS, as technology advances, create holistic coherent rail information management system that integrates major railway subsystems. Development of innovative cost-effective satellite-based train control speed supervision system (SATLOC), as well as fail- safe train location system allows the extension of ERTMS/ETCM systems to rail low density lines (GRAIL-2) (Shift2Rail, 2017).

Looking further ahead, improving network management is to increase efficiency and focuses on more advanced level of ETCS that allow moving blocks. In moving blocks, a safe zone is defined around each train as it moves. By applying GNSS moving blocks, as new signalling train separation concept, will be based on the train self location (X2RAIL-2, ASTRail).

Over the years, national rail networks have developed different technical specifications for infrastructure. Different gauge widths, electrification standards, and safety and signalling systems, all make it more difficult and more costly to run a train from one country to another. EU transport policy promotes interoperability and particularly TSI to overcome such differences while preserving safety levels. These are new technical specifications for communication between vehicle and track (MISTRAL), vehicle and signalling system (TREND), for multiple data exchange and formats (ST4RT). Shift2Rail (2017) suggests that telematics applications and electrification built on TAF/TSI standards will be required in the future and will allow real monitoring and tracking of cargo.

Development of telematics transport systems represents a new technological approach to solving transportation problems. Innovative and practical solutions for a sustainable wagonload transport (VIWAS) as well as smart machine-vision based cargo counting module (MARVIN) are technological advances that drastically improve freight transport performance and raise competitiveness of rail service. Machine to Machine (M2M) technology and sensors will additionally enable automation of tasks and real-time monitoring (ARUP, 2014)

Innovation technologies that address multimodal travel such as mobility-as-a-service platforms (SMaRTE) require research on set of quantified factors influencing rail usability, and recommendations on how to decrease the cognitive effort and onward mobility for rail journeys through a “Smart Journey Vision” and rail map of measures. Multimodality will require further ticketing mechanisms and technologies including collection of dynamic and static data. Travel companion mobile application with geolocation (Shift2Rail, 2017) will also assist users in their multimodal journey planning.

Last but not least automatic freight train operation (SMART) as innovative technology increase the quality of rail freight, as well as its effectiveness and capacity, through the contribution to automation of railway cargo haul at European railways, while ICT systems for information services for wagonload traffic could help scheduling operations (XRAIL).

### 3.3.2 Analysis of results in rail transport technologies

Figure 13 presents the thematic areas covered by the 72 rail transport projects that were reviewed. Competitiveness (36%), systems (27%) and infrastructure (25%) were the main thematic areas for the rail transport mode. A shift towards environment is observed in this mode compared to the other modes mainly attributed to noise mitigation projects. The systems thematic area is also justified being in the second position because of the importance that rail system technologies especially ERTMS, ETCS etc have on this mode. Hence, infrastructure has also been the field of research for a considerable amount of research projects given the nature of the rail vehicles that are track based.

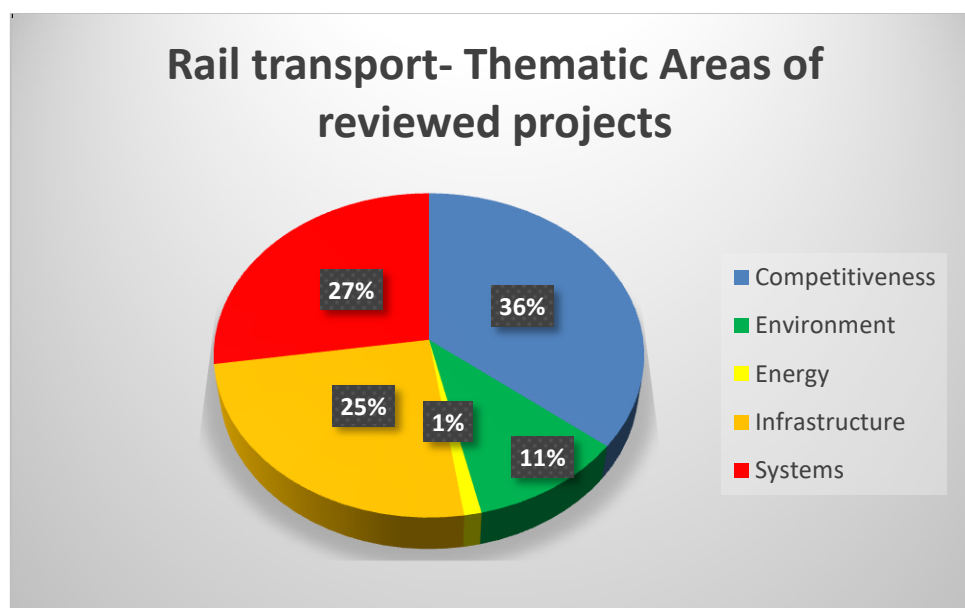
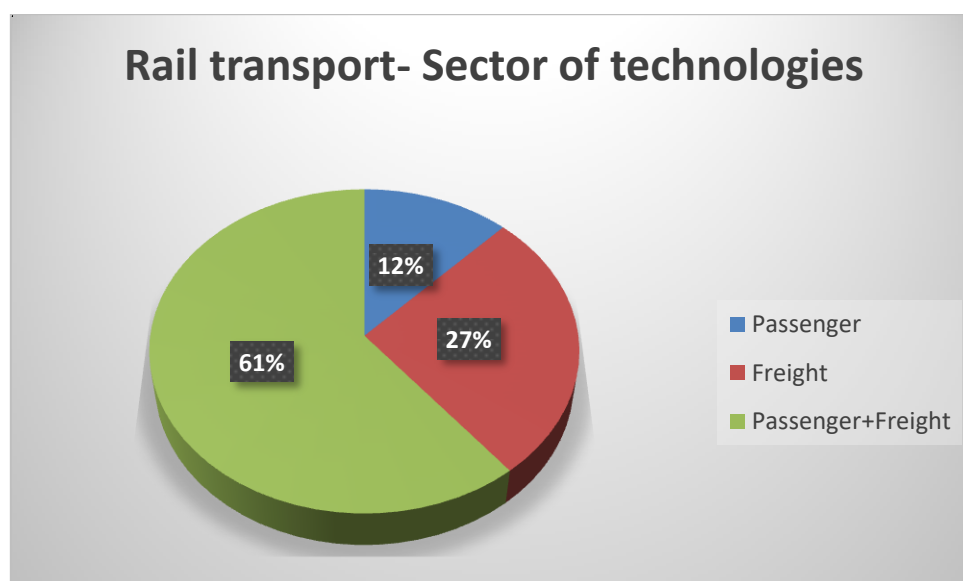


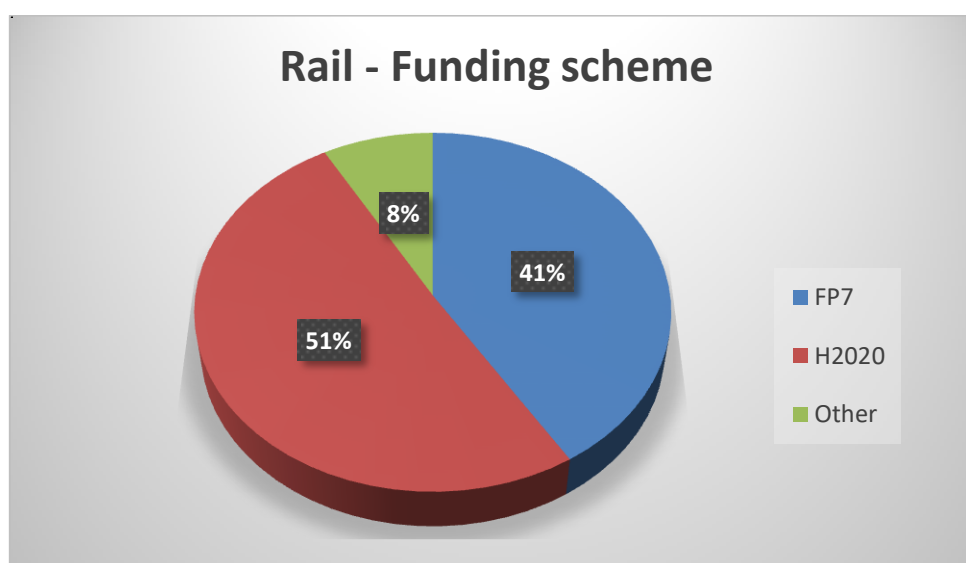
Figure 13. Rail transport- technology thematic areas of the reviewed research projects

Figure 14 presents the sector that the identified technologies from the rail transport research projects belong. The majority of the technologies (61%) that were researched were applicable to both passenger and freight sector. A 27% of the technologies were relevant to freight transport while 12% were about passenger transport exclusively.



**Figure 14. Rail transport- applicable technology sector**

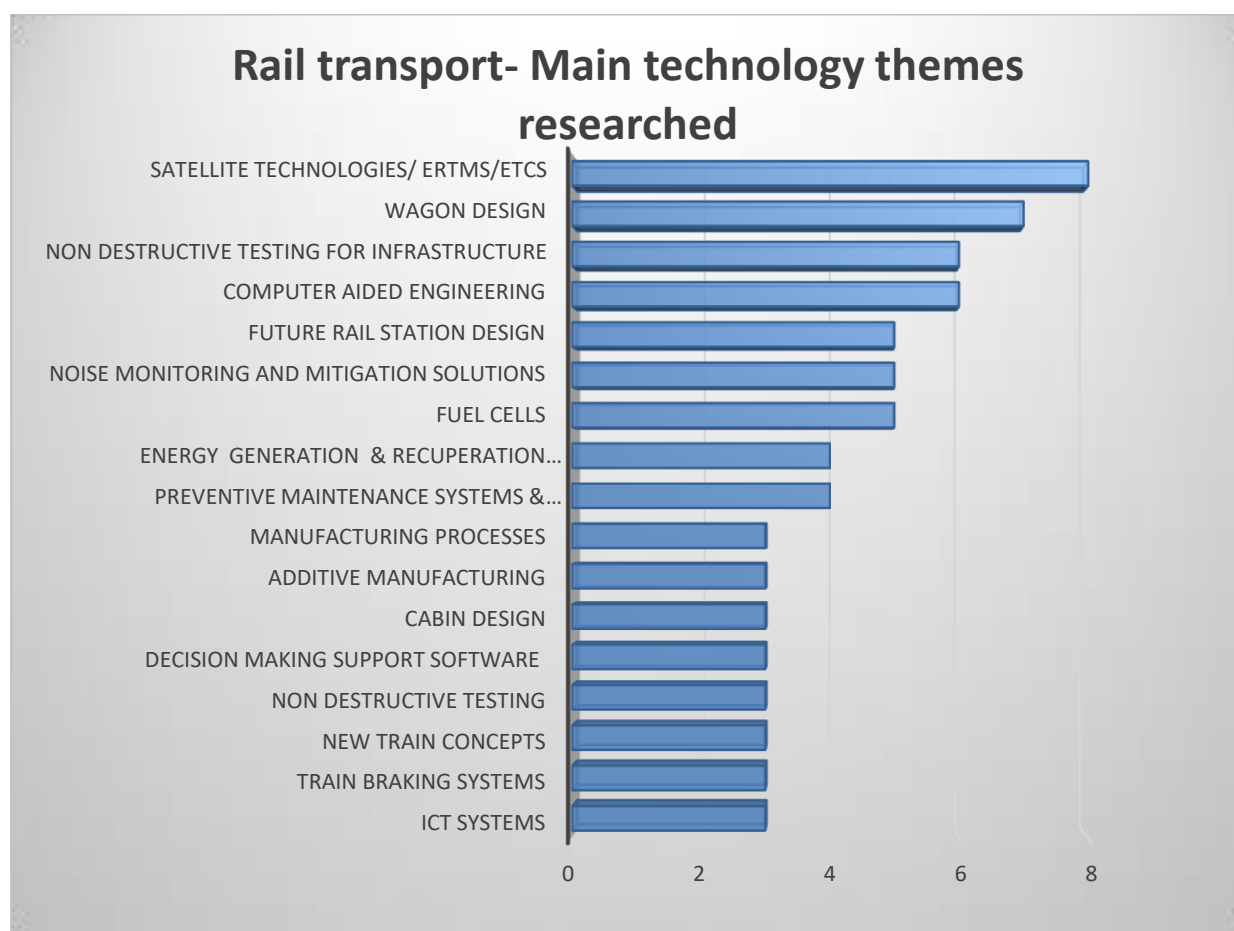
In terms of funding scheme of the reviewed research projects, 51% of those were H2020 funded while, 41% were from FP7 (Figure 15). Only a small proportion (8%) of international research projects were reviewed.



**Figure 15. Rail transport- Reviewed projects funding scheme**

Figure 16 presents the research technology themes that were identified during the review of the rail transport sector both from research projects and literature. The integration of satellite technologies into ERTMS and ETCS was one of the most dominant themes which will enable further automation of the sector. Wagon design in this case was mostly applicable to the freight sector and was the second most dominant technology theme. Non-destructive testing was split into two categories one for infrastructure and another for the vehicles. The NDT for infrastructure has proven to be more dominant and hence it was considered that they should be displayed individually because they refer to a different aspect. Hence, if both headings were added together the results would show that this technology was one of the most significant themes. Although NDT is very important for the rail mode, it would be difficult to

justify that it is the most dominant technology. CAE follows the same trend identified in the previous transport modes. CAE can play a considerable role in virtual acoustic certification and noise modelling of the vehicles, inducing the design manufacture and production process. Therefore, its position is well justified. Noise mitigation whether at source or through the infrastructure is also important, while energy saving operation on board the vehicles have been identified as equally needed. Hydrogen fuel cells also seem to be picking up momentum in the rail industry and their application could soon be seen in passenger transport. Preventive maintenance solutions are also perhaps an innovative concept that could reduce down time of trains. Manufacturing processes and additive manufacturing have been treated in the same manner as already discussed in the previous modes and have been presented separately, with both technology themes showing that rail transport mode will require further advancements in this field. It needs to be noted that technology themes with less than or equal to 2 citations, did not make it to the graph. Examples are themes like fuel cells or composite materials that despite being important technologies they had received small number of citations in the review project and literature.



**Figure 16. Rail transport - dominant identified technology themes**

### 3.3.3 Summaries of rail transport technologies identified from projects

#### Competitiveness – Rail research projects

<b>Cluster: C1 Competitive rail</b>			
<b>Subcluster: C1-1 Innovative rail concepts</b> (Traction systems, high speed carbody, wagon, bogies, eddy current brake systems, train modularity, Personal Rapid Transit (PRT) and Hyperloop)			
Technology theme	Specific technology researched	Project	Sector
Wagon design	1) New carrier wagon design for different container types, 2) Modular wagon design concepts, 3) Smart and flexible wagons for improved transport of granular multimaterials, 4) Simulation technics combined with cost estimation of introduction of new wagon	CAPACITY4RAIL, VIWAS, HERMES, VEL-WAGON	Freight
Wagon design	1) Design of metro vehicles for security 2) Finite Element Analysis for blast simulation and real life blast test	SECUREMETRO	Passenger
New train concept	Design and real life testing of coupling two trains together and having the slave locomotive in the middle of the convoy	MARATHON	Freight
Train braking systems	Design, Finite Elements Analysis, Eddy current brakes,	ECUC	Passenger + Freight
Bogie design	New bogie design using several features based on the Y25 type bogie	SUSTRAIL	Freight
Running gear design	New running gear concept with active suspensions	RUN2RAIL	Passenger+ Freight
Freight train design	Design concept for a high-performance freight train (lightweight freight wagon, a vehicle bogie for enhanced ride features, a power conversion unit to provide power to refrigerated containers, and a city logistics freight handling system)	SPECTRUM	Freight
New train concept	Special pods travelling at high speeds in near-vacuum conditioned tubes.	HYPERLOOP ONE	Passenger
<b>Cluster: C2 Competitive rail design</b>			
<b>Subcluster: C2-1 Design tools for structural reliability</b> (Computer Aided Engineering + other tools)			
Technology theme	Specific technology researched	Project	Sector
Acoustic certification modelling	Virtual modelling for acoustic certification of trains after design	ACOUTRAIN	Passenger+ Freight
<b>Subcluster: C2-2 Cabin design</b> (Inclusive train design, modular trains and cabins to flexibly adapt to passenger needs)			
Technology theme	Specific technology researched	Project	Sector
Cabin and cockpit design	New ultralight and flexible cabin seat concepts and ergonomic modular train cockpit design	MAT4RAIL	Passenger
<b>Cluster: C3 Competitive rail production</b>			
<b>Subcluster: C3-1 Structural materials &amp; composites</b> (Materials & composites)			
Technology theme	Specific technology researched	Project	Sector
Coating solutions	1 ) New coating solutions for axles to prevent fatigue cracks 2) Smart coatings for railway wheels	EURAXLES, smaRtAIL	Passenger +Freight



Composite materials	1) Replacement of interior and exterior metal parts with Fibre Reinforced Polymers (FRPs), 2) New advanced composite materials (fusion of hybrid Fiber Reinforced Polymers and concrete) for switches and crossings	MAT4RAIL, S-CODE	Passenger +Freight
Materials and manufacturing processes for rail tracks	Development of rail - bainitic steels and development of aluminothermic and orbital friction welding processes	WRIST	Passenger +Freight
<b>Subcluster:</b> C3-2 Manufacturing processes (new manufacturing process, additive manufacturing, 3D printing)			
Technology theme	Specific technology researched	Project	Sector
Additive manufacturing	1) 3D printing mobile solutions for rail track surfaces, 2) Advanced low energy Laser Metal Deposition Technology (LMD) for bogie wheels smart coating materials	Mobile 3D Printing of Rail Track Surface for Rapid Repairment, smaRtAIL	Passenger +Freight
Manufacturing processes	Manufacturing processes running gear: 3D metal printing, automated tape layering of composite materials	RUN2RAIL	Passenger +Freight
<b>Cluster:</b> C4 Competitive Life Cycle Services			
<b>Subcluster:</b> C4-1 Inspection & maintenance (inspection & maintenance new methods (vehicles and tracks))			
Technology theme	Specific technology researched	Project	Sector
Preventive maintenance systems and maintenance operations	1) Condition monitoring system for axle bearing health status, 2) Transfer of lean manufacturing principles to maintenance, 3) Diagnostic pantograph, 4) Rail track vibration monitoring system	MAXBE, AUTOMAIN, DIAG-PANTOGRAPH, WARNTRAK	Passenger + Freight
3D modelling and switch control inspection	Development of lightweight laser based trolley for scanning switches and crosses	AUTOMAIN	Passenger + Freight
Computer Aided Engineering	Finite element Analysis and modelling of axles for fatigue testing	EURAXLES	Passenger + Freight
Non destructive testing	1) Non destructive testing methods for continuous monitoring of axles using an adhesive plug and electrochemical techniques, 2) Ultrasonic Tomography (UST), 3) Phased array ultrasonic testing for corrosion assessment and crack detection of component, 4) Reliability software for high cycle variable amplitude corrosion fatigue of rail axles.	EURAXLES, DTRT13-G-UTC59, RAAI	Passenger + Freight
Non-destructive testing for infrastructure	1)Eddy current sensor system, 2) Hollow shaft acoustic sensor, 3) Thermographic testing system, 4) Laser profiler and inertial pack, 5) Fuzzy ultrasonic testing system, 6) Brillouin Fiber optics for structural health monitoring, 7) Robotic vehicle for tunnel inspections using remote controls, robotic arm, crane and vision system, 8) Ultrasonic inspection system for high manganese steel crossings, 9) Railway and rolling stock condition monitoring system, 10) Synthetic Aperture Focusing Technique (SAFT) combined with advanced processing algorithms to offer an	ACEM-Rail, ROBO-SPECT, SAFTInspect, DTD SYSTEM 2, SAFT, INTERAIL	Passenger + Freight

	ultrasonic inspection technique with enhanced Signal to Noise Ratio, 11) Development of Alternating Current Field Measurement (ACFM), Ultrasonic phased array and High Frequency Vibration methods for semi-automated high speed inspection of tracks		
Decision making support software system	Information system for infrastructure management from measurement to maintenance	INFRAALERT	Passenger + Freight
Predictive maintenance	Health monitoring sensors and systems for trains	INNOWAG	Freight
<b>Subcluster: C4-2 Repair, retrofit (repair and retrofitting new methods)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Project</b>	<b>Sector</b>
N/A	N/A	N/A	N/A
<b>Subcluster: C 4-3 Life cycle approaches (train life cycle)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Project</b>	<b>Sector</b>
N/A	N/A	N/A	N/A

### Environment – Rail research projects

<b>Cluster: ENV1 Reducing emissions</b>			
<b>Subcluster: ENV 1-1 Alternative fuels (alternative fuels, biofuels)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Project</b>	<b>Sector</b>
Renewable diesel	Emissions evaluation of renewable diesel in rail	NCDOT Research Project Number: 2018-09	Passenger
<b>Subcluster: ENV 1-2 Reducing noise emissions (Noise &amp; vibration)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Project</b>	<b>Sector</b>
Noise monitoring and mitigation solutions	1) Development of an onboard noise monitoring system for noise emitted by tracks, 2) Methodologies for noise and vibration prediction, 3) Low noise running gear for future locomotive, 4) Tools for noise prediction and measurement of trains and subsystems 5) New technologies as active windows for noise protection and new ways of communicating about noise performance of trains, 6) Noise transmission path computer simulations and mitigations measures like soil stiffening and sheet pile walls close to the track, open trenches and trenches filled either with soft or stiff materials. Designs of wide sleepers in combination with soft under sleeper pads and of rail fastening systems with soft under rail pads	QUIET-TRACK, RUN2RAIL, FFL4E, FINE1, RIVAS	Passenger+ Freight
Vibration mitigation	Computational vibration measurements and influence on human health and annoyance	CARGOVIBES	Freight
<b>Subcluster: ENV 1-3 After treatment of exhaust gases (After treatment of diesel powerplant exhaust)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Project</b>	<b>Sector</b>

After Treatment System	Blended After Treatment System (BATS)	NCDOT Research Project Number: 2018-09	Passenger
<b>Subcluster:</b> ENV 1-4 Green train operations (Regenerative energy storage systems, Battery technologies and onboard energy storage systems)			
Technology theme	Specific technology researched	Project	Sector
Energy generation solutions	1) Energy generation and harvesting solutions for onboard train integrity radio communication systems, 2) Recuperation of braking energy	ETALON, FFL4E	Freight

### **Energy – Rail research projects**

<b>Cluster:</b> ENE1 Optimising resistance and propulsion			
<b>Subcluster:</b> ENE 1-1 Aerodynamics (train aerodynamics)			
Technology theme	Specific technology researched	Project	Sector
N/A	N/A	N/A	N/A
<b>Subcluster:</b> ENE 1-2 Engines & powerplants (hybrid systems, engine advances etc, diesel powerplant)			
Technology theme	Specific technology researched	Project	Sector
Hybrid or electric propulsion	Electricity usage and storage for last mile propulsion	FFL4E	Freight

### **Infrastructure– Rail research projects**

<b>Cluster:</b> INF1 Station operations (future stations, station design, improved train platform interface, novel terminal, hubs)			
Technology theme	Specific technology researched	Project	Sector
Future rail station design	1) User flow modelling, 2) station design algorithm that optimises passenger flow, 3) Engineering design of a train and/or platform based mechanism, 4) VR demonstrator station design, 5) Development of an Intelligent Active Dynamic Signage System (IADSS) to support railway station security during emergencies	FAIR Stations, GATEWAY	Passenger
Energy efficiency & Information systems	Information systems-energy efficient solutions	FR8HUB	Freight
Infrastructure management and Information systems	Software based Decision Support Tools for infrastructure management	DESTination RAIL	Freight + Passenger
<b>Cluster:</b> INF2 Rail safety/security			
Technology theme	Specific technology researched	Project	Sector
Track side worker safety	Track-side train presence alert device (TPAD) and wearable device wireless mobile terminals (MT)	ALARP	Passenger +Freight
Simulation and	1) Analysis of station building structural and	SECUREST ATION	Passenger +Freight

tools for resilient stations	physical resilience during an incident 2) Simulation of human behaviour and movement during emergencies for safe evacuation		
Artificial Intelligence, big data management and Decision support frameworks	AI and safety of rail infrastructure	SAFE-10-T	Passenger +Freight
Safety monitoring systems	1) Development of fault finding monitoring systems for wayside and onboard vehicle, 2) Autonomous system for automatic train detection that will be integrated with a UOZ-2 animal deterring device.	D-RAIL	Passenger +Freight
Passenger Information Systems	The project developed a system that provides real time information about the railway timetable to passengers, which is also visualized at selected stations	CSDIP	Passenger
<b>Cluster: INF3 Intermodality (connectivity with other modes of transport)</b>			
Technology theme	Specific technology researched	Project	Sector
Multimodal terminal design & simulation	Simulation and design tools for the design of multimodal terminal infrastructure	INTERMODE L EU	Freight
Intermodal freight logistics	1) Intermodal truck/train container transfer system (CTS technology, 2) intelligent intermodal, modular volume-optimised and traceable MegaSwapBoxes (MSB)	SAFE-CTS, TelliSys	Freight
<b>Cluster: INF 4 Track systems</b>			
Technology theme	Specific technology researched	Project	Sector
Track design	New slab track concept design	Capacity4Rail	Freight
Decision making software	Infrastructure Subsystems Management (ISM) software tool	ACEM-Rail	Passenger +Freight
Materials and manufacturing processes for rail tracks	Development of rail - bainitic steels and development of aluminothermic and orbital friction welding processes	WRIST	Passenger +Freight
Rails switches	Innovative rail switches for winter conditions	VERT	Passenger + Freight
Track components	Innovations in the track components (for higher reliability and reduced maintenance) combined with innovations in rolling stock and freight vehicles (with a targeted increased in speed and axle-load)	SUSTRAIL	Freight
<b>Cluster: INF5 Grid &amp; energy (smart power supply)</b>			
Technology theme	Specific technology researched	Project	Sector
Energy management system and software	1) Development of a railway energy management system software for grid and onboard systems, 2) Cloud-based open data management platform (ODM) for energy and asset management	MERLIN, IN2DREAMS	Passenger + Freight
Railway power grid	Development of a railway smart grid	IN2STEMPO	Passenger + Freight

Energy harvesting solutions	Energy harvesting solutions for trackside object controllers	ETALON	Freight
-----------------------------	--	--------	---------

### **Systems – Rail research projects**

<b>Cluster:</b> SYS1 Rail systems (Traffic control & management systems (TCMS), automatic train operations, Driverless freight trains, Machine to Machine technologies (M2M), TAP/TAF TSI Telematics applications for passenger/freight Technical specifications of interoperability, Ticketless technologies travel, mobility as a service, intelligent trains)			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Project</b>	<b>Sector</b>
Condition monitoring	On board and wayside sensor condition monitoring system	MAXBE	Freight
Systems to allow coupling of trains	Remote radio controls, antennas, intelligent computerized interface and brake system for the slave locomotive connected to the vehicle control	MARATHON	Freight
Wagon telematics	Single wagon monitoring telematics using GPS, GSM and loading sensors and development of visualisation software	VIWAS	Freight
Computer Aided Engineering	1) Fuzzy rule based models for railway infrastructure and components as well as maintenance and traffic processes, 2) Design of real time decision support tool for yard managers	OPTIRAIL, OPTIYARD	Passenger + Freight
Electromagnetic interference	Modelling and testing of electromagnetic interference with a spot signalling system (BTM), DC track circuit, GSM-R and broadcasting services (which include TV, radio, Freight RFID, WFI and GSM)	TREND	Passenger + Freight
Satellite technologies/ERT MS/ETCS	1) EGNSS application on railway to assist ERTMS and ETCS systems, 2) Demonstrator to improve standardisation and integration of Traffic Management processes with the aim to achieve flexibility and scalability within the choice of functional service module managed by TMS., 3) Standardisation and integration of Traffic management , 4) Development of a new sophisticated interface in the train cabin and braking system and second a common and interoperable train-to-ground (T2G) communication system, 5) TCS (European Train Control System) and CBTC (Communications-based train control) architectures 6) Architecture for future GNSS positioning system, 7) Laboratory for on board testing systems for ETCS 8) Smart train positioning system , 9) GNSS based ETCS prototype/application in Rail Low Density Lines	STARS, X2RAIL-2, CONNECTA, NGTC, EATS, GRAIL-2	Passenger + Freight
Smart sensors	Smart sensors and smart running gear components for self diagnosis	RUN2RAIL	Passenger + Freight
LED Signals	Self De-Icing LED Signals	TPF-5(351)	Passenger + Freight
Signalling and Automation Systems	Satellite-based Signalling and Automation Systems on railways	ASTRail	Passenger + Freight
Design and Implementation of Interoperability	Demonstrator tool that will provide ontology-based transformations between different standards and protocols	ST4RT	Passenger
Living labs	Development of 3 living labs for a) dedicated services; wagonload trains, b) control tower for	Smart-Rail	Freight

	long distance rail freight, c) Reliability of rail and (unexpected) obstructions on the track		
Time table planning with IT decision support tool	Software for time table construction that can handle major perturbations	ON-TIME	Passenger+ Freight
Rail communication systems	Technical Specification of the future communication system railway to replace GSM-R	MISTRAL	Passenger + Freight
Automated train operations	Development of: 1) prototype solution for obstacle detection and initiation of long distance forward-looking braking, 2) short distance wagon recognition for shunting onto buffers which can be integrated, 3) a real-time marshalling yard management system integrated into an IT platform	SMART	Freight
Vision systems	Smart Machine-Vision scanner for handling and counting of neo-bulk cargo	MARVIN	Freight
ICT systems	Xrail project will enhance the competitiveness of wagonload traffic in Europe, by developing ICT systems to provide enhanced information to the users like delay alerts, next-day-arrival messages and international transport schedules.	XRAIL	Freight

### 3.4 Waterborne transport

#### 3.4.1 Future waterborne transport at a glance

##### **Waterborne transport- Competitiveness**

Population growth in Africa, Asia and South America during the next decade and urbanisation will create demand for tailored and specific type of waterborne services which will also require upgrade for infrastructure (Waterborne Technology Platform, 2016).

The EU's maritime industry remains competitive offering high value added products, rapid innovation, high safety standards and a leading position in terms of green technologies (Waterborne Technology Platform, 2016).

In terms of research, competitiveness of the maritime sector seems to revolve around the following themes:

Electric vessels, Autonomous ships, integration of fuel cells in maritime vessels, ship design tools and development of computer aided engineering software, composite and advanced metal materials for ship structures, robotic inspection for hull, welding automations for shipbuilding and design for life cycle.

The aforementioned topics identified in the funded research projects are also supported by a series of direction that technology platforms and the industry studies indicate. Smart and autonomous or remotely operated cargoships are already being investigated by the industry companies such as Yara and Kongsberg companies (the Yara Birkeland vessel) (Paris, 2017), Rolls Royce (2017) with the (Svitzer Hermod vessel) or the, as well as the research

community with the MUNIN project. Such vessels will require smart sensors, vessel situational awareness and satellite positioning systems to allow real time tracking while ship monitoring systems will allow shipping companies to monitor vessel parameters and optimize operations remotely from shore. Vessels for inland waterways will also be required offering modal shift from other modes of transport thus creating demand for new vessel designs for this operations or new logistics concepts. New ships will also have to be redesigned using modular design concepts that will also allow retrofitability of future technologies (IfM Education and Consultancy et al., 2015). Specialised vessels for use in arctic routes are also envisaged (IfM Education and Consultancy et al., 2015).

Hybrid or fully electric vessels and their design will be required in order to enable autonomous ships or fill in the gap for short sea shipping. Fully electric vessels so far are only envisaged for recreational purposes and taxiboats (SEABUBBLE, BB Green, GFF projects) or small ferries (E-Ferry project). Hybridisation is also expected to occur through the combination of LNG and electricity with LNG and CNG bunkering vessels also requiring redesign.

Robotics will also to play a significant role in the future maritime sector. Robot applications can be incorporated into a) automating and increasing production speed of the vessel, b) inspection and maintenance of the hull (welding robots or UAVs) (SMARTYARDS and MINOAS projects). Structural health monitoring sensors on the ship will offer preventive maintenance and will offer less downtime of the vessel.

The design, manufacture and assembly of ships will also require change. New Computer Aided Engineering software (CAD, Computational Fluid Dynamics and Finite Element Analysis, shipyard production and assembly simulation) will have to be created to assist engineers with the design process and more accurately predicting behaviour of materials and design prior to testing. New welding techniques and additive manufacturing both on their way will allow redesign of components and design freedom. Holistic ship design (HOLISHIP project) incorporating cradle to grave concepts will be required ranging from software that will carry out this work to sensors that will improve the life span of the ship through preventive maintenance (Lloyd's register, 2015; WaterborneTP, 2016). The advancement of new lightweight materials either metals or polymers, nano materials, bio inspired or self-healing materials will be required thus allowing weight reduction of the ship, better manufacturability, less fuel consumption and better corrosion resistance. (Lloyd's register, 2015; WaterborneTP, 2016; IfM Education and Consultancy et al. (2015)).

### **Waterborne transport- Environment**

Based on the literature review of research projects the most prominent technologies for the Maritime Environment theme are the following:

Use of alternative fuels, integrated emissions control methods (exhaust gas aftertreatment), computational modelling for underwater noise (cavitation) and antifouling methods.

The use of alternative fuels will play a considerable role in maritime transport. LNG has been identified as a primary fuel for short sea shipping as well as for mega container ships. According to Lloyd's register (2015), LNG, methanol, Bio-diesel, Fuel cells (with hydrogen or methanol) or even nuclear energy will become the primary fuels. LNG retrofitting will also require development of plans and conversion kits that can easily be installed on ship. The

use of photovoltaic systems on board ships has also been studied and simulated for providing energy to auxiliary systems and minimizing primary fuel usage (INOMANS<sup>2</sup>HIP, JOULS projects). Biodiesel blends derived from algae or other biomass streams could become more mainstream although their impact on emissions and engine components remains under research.

After treatment of exhaust gases is possibly the most researched area of the Environment technologies theme. The research carried out is based on 2<sup>nd</sup> generation scrubbers (dry or wet) for reducing SO<sub>2</sub> and Particulate Matter (DEECON, RETROFIT, TEFLES, META 4 projects) other methods include the use of Selective Catalytic Reduction (SCR) and Diesel Particulate Filters (DPF) (HERCULES-C, HERCULES-2, JOULES projects). An innovative method was tested by DEECON project with the use of a Non Thermal Plasma Reactor and Electrostatic seawater scrubber for reducing PMs, SO<sub>2</sub>, NOx, VOCs and CO promising results in terms for percentage reduction of NO and PMs although both devices did not manage to run at the same time. Retrofitting kits and methods of such integrated emissions control methods will also be required in the future. Finally, computational modelling for simulating exhaust after treatment technologies can also be viable through accurate modelling and tools.

Underwater noise caused by cavitation is also a subject that has been researched through computational modelling (SONIC, AQUO). This effect can be tackled either through real time monitoring devices and adjusting ship parameters based on the regions that the ships are passing through and the aquatic life present or through propeller design changes and wake formation.

Fouling of the ship's hull is also an issue that causes downtime for maintenance and increases fuel consumption due to increasing friction. In addition fouling can introduce invasive species into local marine environments. Technological solutions vary ranging from new innovative paints that contain immobilised biocides, ultrasonic solutions and other onboard cleaning solutions (FOUL-X-SPEL, BIOECOMARINE, FLIPER). Ballast water management has also been studied with new innovative solutions that will purify the water with microfluidic technology thus avoiding chemicals. (TRILO-BWTS).

### **Waterborne transport- Energy**

Energy optimization and minimization in the maritime sector is one of the most researched thematic areas with the aim of reducing fuel usage and thus carbon emissions. The main research technologies in this thematic area are: 1) propeller design and positioning of the propeller, 2) hull design, 3) trim optimization, 4) engine optimization through advanced concepts, 5) hybridization of propulsion and electrification of secondary energy converters, 6) propulsion assist through renewable energies, 7) dual fuel engines, 8) new materials for engine components, 9) turbocharging of engines, 10) ship energy modelling, 11) and energy management of ship and systems

Computational modelling through computational fluid dynamics and other CAE tools of the propellers or hull sections is currently the dominant method for simulating the energy efficiency, hydrodynamics, wake formation and other parameters crucial for evaluating if a design is viable on a vessel. The main technologies researched in terms of ship propulsion were various propeller designs and either tested through simulations or in real life. Such designs include variable pitch propellers (combinators) (TEFLES project), counter rotating



propellers driven by electric motors (podded motors) or contracted and loaded tips (TRIPOD project). Other propeller concepts included Large Area Propulsion (STREAMLINE project) where the propeller is situated far behind the ship in order to lower the vessel's speed and reduce cavitation noise. Devices like pre-swirl stators and Boundary Layer Alignment Devices (BLAD) also showed promising results in terms of ship hydrodynamics (GRIP, TARGETS project). An innovative concept of ship hull air lubrication has been identified by the TARGETS project and was only simulated showing significant benefits for bulkers and tankers. The above concepts are also supported by the Waterborne TP which suggests that new computational methods and validation processes will be required for future advanced propulsors while concepts of reducing friction either through hydrophobic materials or air bubble techniques will be required.

In terms of ship powering the main concepts of research and future engine improvements and optimization are relevant to injections systems, advanced engine control and combustion, materials and engines capable of running on various fuels. Specifically, many of the projects have looked into the aspect of multifuel or bi-fuel engines replacing Heavy Fuel Oil with CNG or LNG and LNG/ Diesel combinations (JOULES, RETROFIT). Two stroke low speed engines were also part of the concept of slow sea shipping in order to improve fuel consumption (HELIOS, MUNIN, RETROFIT). Turbochargers and waste heat recovery are also technologies that different projects have developed and could work in combination with other engine optimisations thus offering increased power and reduced emissions (HERCULES-C, INOMANS<sup>2</sup>HIP, MUNIN). Secondary energy converters using either hydrogen or other alternative fuels will play a considerable role in electrifying auxiliary systems. Secondary energy converters are auxiliary systems that can replace conventional systems i.e. power generators, heaters, with electric systems in order to minimise energy consumption on board a ship (i.e. electric motors, electric heaters, fuel cell systems for energy generation). Another technology concept that has been covered by various project was the use of wind power to assist in ship propulsion through different methods i.e. kite assisted vessels or vertical wind turbines generating energy (JOULES, ULYSSES, RotorDEMO, TARGETS, SeagateSail). The latter concept is already available by Norsepower. Research on engine materials and use of new manufacturing processes is also carried out by HERCULES-2 project. WaterborneTP (2017) has indicated that multifuel maritime engines will be required for the future, including engine optimization as well as new engine materials and components. Multifuel engines with health monitoring sensors and intelligent electronic control is also indicated by Lloyd's register (2017). The use of hydrogen fuel cells has already been carried out by ABB for secondary energy converters while CMB has already produced a small passenger vessel with hydrogen power (world maritime news, 2017).

Finally, energy management systems and modelling systems will play a significant role in the future thus providing the ability to the owners and the crew to make decisions based on real time performance monitoring (REFRESH, INOMANS<sup>2</sup>HIP, TARGETS projects). Systems will also need to be developed that model and simulate energy consumption of the whole ship and its components (SEAHUB, SCOUT projects). These technologies have also been identified by the Waterborne TP and Lloyd's (2015) and in conjunction with monitoring sensors of engines and other components such systems will aim at better overall efficiency of ships.

Computer Aided engineering is once more dominant in all of the aforementioned themes either through computational fluid dynamics, component simulations, CAD or Finite Element Analysis.

### **Waterborne transport- Infrastructure**

Maritime infrastructure will require further technological advancements in order to cope with the increase of freight demand and connectivity with other modes of transport or inland waterways. Improving port efficiency and throughput with automation and energy efficiency will become vital. The main technological trends in terms of research projects are focused around port automation, infrastructure required for autonomous vessels, energy efficiency of ports and port equipment. In addition refuelling infrastructure for alternative fuels and ship to shore refuelling will be required. Projects like RETROFIT, INOMANS<sup>2</sup>HIP, TEFLES studied the use of cold ironing for supplying energy to ships while at berth.

Electrification of terminal equipment is currently already happening in various ports globally and will continue to increase and improve. Apart from electrified Rubber Tired Gantry Cranes (RTGs) (GREENCRANES project) terminal handling equipment can also be converted to run on alternative fuels such as CNG/LNG or even in hybrid setup. Electric tractors are finding more and more applications for drayage in ports such as Port of Los Angeles, Port of Valencia, Port of Long Beach to name a few. According to Waterborne TP (2017) smart connected ports using automated solutions for terminals will be required. Such solutions could be robotic systems for unloading cargo, automated vehicles and cranes. Internet of Things will play a considerable role while big data analytics will enable the monitoring of the vessels, vehicles and equipment in real time. A digital pilot is already in usage at the Port of Los Angeles where a system is used to provide digitisation of the cargo flows and its movement within the supply chain. In addition, intelligent holistic port managements systems will be required in the future, covering all port aspects such as ships, cargo, passengers, workers and intermodal solutions offering connectivity with other transport modes (Waterborne TP).

Refuelling infrastructure for providing ship to shore energy is probably the most dominant technology researched in this field. Solutions such as Alternative Maritime Power (also known as “cold ironing”) are identified as the main method for minimizing fuel usage of the ships while at birth thus reducing emissions. The method includes the electrification of the ship while at birth through the electricity grid. More innovative methods have also been implemented. Specifically, an LNG hybrid barge named ‘Hummel’ is already operating at the port of Hamburg and provides LNG generated electricity to cruise ships at such a typical example as it can supply 7.5 MW of LNG generated electricity to cruise ships. This barge is being located and can thus be regarded as a floating power plant (Hybrid Port Energy, 2017). Hydrogen refuelling, and production infrastructure is also something envisaged within the maritime concept. Specifically, generating hydrogen from electricity generated by renewable energies (H2OCEAN project) or in general hydrogen refuelling infrastructure at ports for the fuelling of Fuel cell vehicles at the port (MARANDA) or other equipment. The latter has been introduced at the Port of Honolulu where fuel cells power reefer containers at the port. Finally, liquefied hydrogen arriving by tanker ships in specialised large tank containers will require special equipment to unload and load such containers. Such research is carried out by the Japan Ship Technology Association.

### **Waterborne Transport-Systems & Safety**

Maritime systems will be those that will enable autonomous maritime vessels and while create connections between the V2V and V2I. Smart systems with sensors and software will be required for the future maritime sector and will allow the connection between intelligent control/health monitoring systems within the ships structure and subsystems (Waterborne TP, 2017; IfM Education and Consultancy et al. (2015)). Sensor technologies will also find usage in detecting and avoiding large mammals in order to ensure that they are not disturbed (IfM Education and Consultancy et al., 2015). Further development of sensors, high bandwidth networks and satellite communications will be required, allowing wireless connectivity or all the remote systems. Such sensors will be characterized by low energy, consumption, fault tolerance, self-calibration abilities and fault proofness (Lloyd's register, 2015). Big data analytics will also enable the analysis of the ships performance and control thus allowing visualisation and monitoring of fleets and cargo under operations. Stakeholders will also be able to have 3D video and live audio from the ships (Lloyd's register, 2015). In addition, connectivity of the ship navigation systems, vessel traffic services and Search and Rescues services and the European maritime digital highway will be required. Cybersecurity of the aforementioned systems will be vital. In the short term simulation platforms and software that will model, simulate and visualize the navigation of autonomous ships will be required. Such systems are already being developed by Transas Technology company (Marinet.org, 2018).

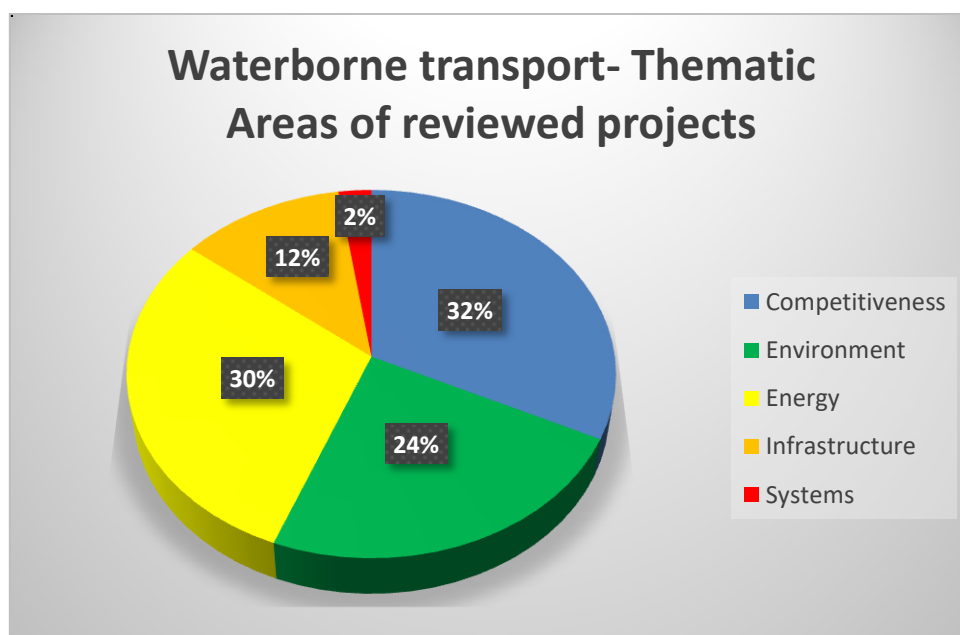
Safety of the future ships according to the technology roadmap of WaterborneTP (2017) will require sea traffic controls systems equivalent to those of the aviation sector. Human machine interface will need to be improved allowing onboard crew to have situational awareness. Ships will be required to have better fire resistance and monitoring including decision support systems for crew/ passenger evacuations that will assist in the process during emergencies. Safety systems such as stability management is envisaged for accident conditions including new lifeboats and launch and recovery systems.

The main research project covering this thematic area was MUNIN which looked into developing software and modules for deep sea navigation, control and manoeuvring and collision avoidance systems, including operational systems for extreme weather.

#### **3.4.2 Analysis of results in waterborne transport technologies**

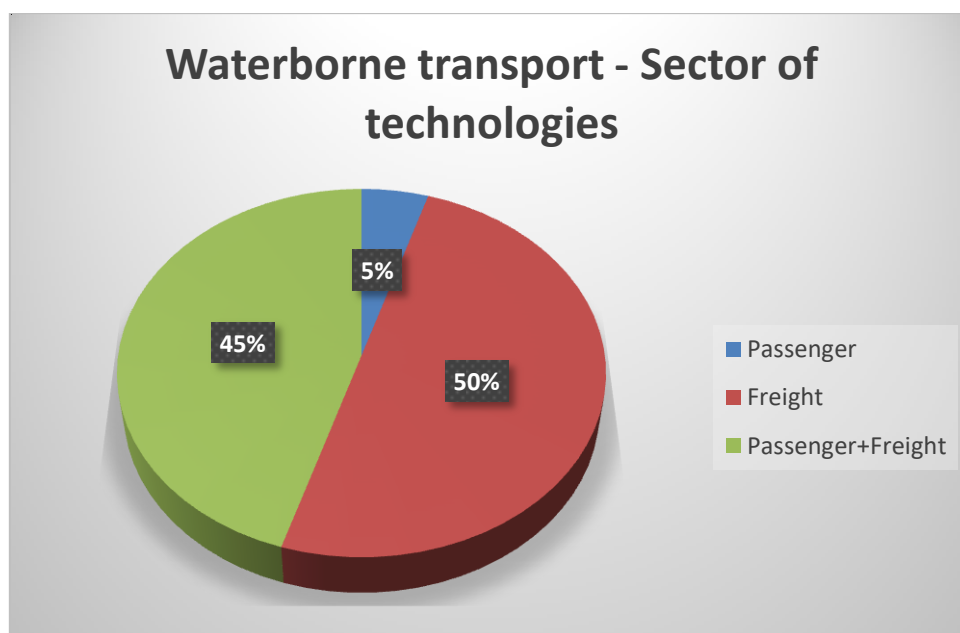
The following section aims to analyse the results that were extracted from the maritime transport projects and the dominant technology themes that were identified by both research projects and other literature. In the maritime transport sector 62 projects were reviewed with the majority of the projects addressing competitiveness, energy and environment (Figure 17). These results are well expected based on the importance of these three thematic areas for the maritime mode. Competitiveness of the maritime sector is one of the outmost priorities for EU sector that the majority of the reviewed projects are relevant to. In addition, the energy area was second place. This is due to two factors: 1) larger amount of energy subclusters for the maritime mode compared to other modes, 2) the importance that these subclusters (i.e.

minimising resistance & optimising propulsion, ship powering, have for this mode of transport.



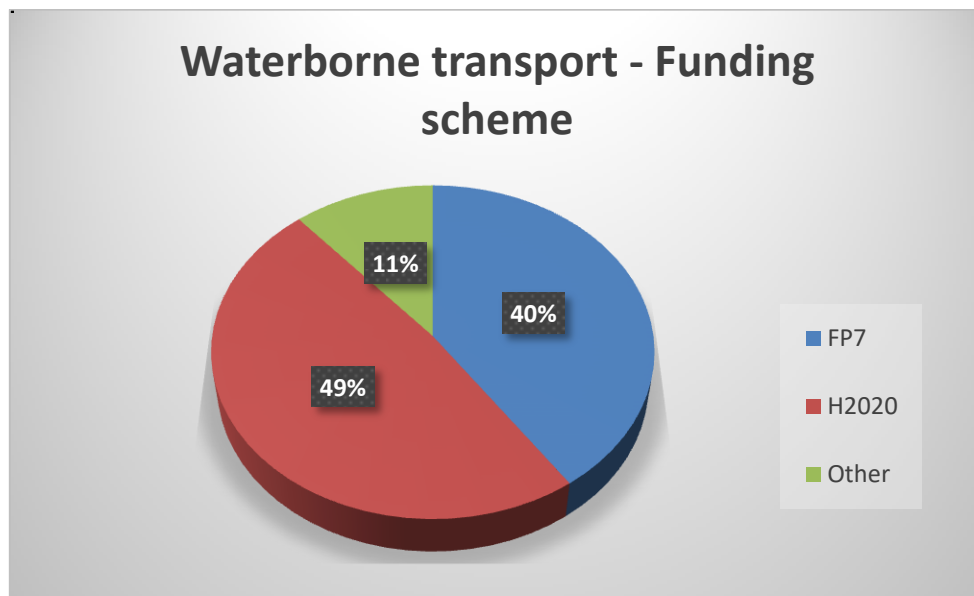
**Figure 17. Waterborne transport- technology thematic areas of the reviewed research projects**

Figure 18 presents the sector that the identified technologies from the projects belong to in the maritime transport mode. Specifically, 50% of the identified technologies addressed the freight sector, 45 % where applicable to both passenger & freight while only 5 % of those where only passenger sector specific.



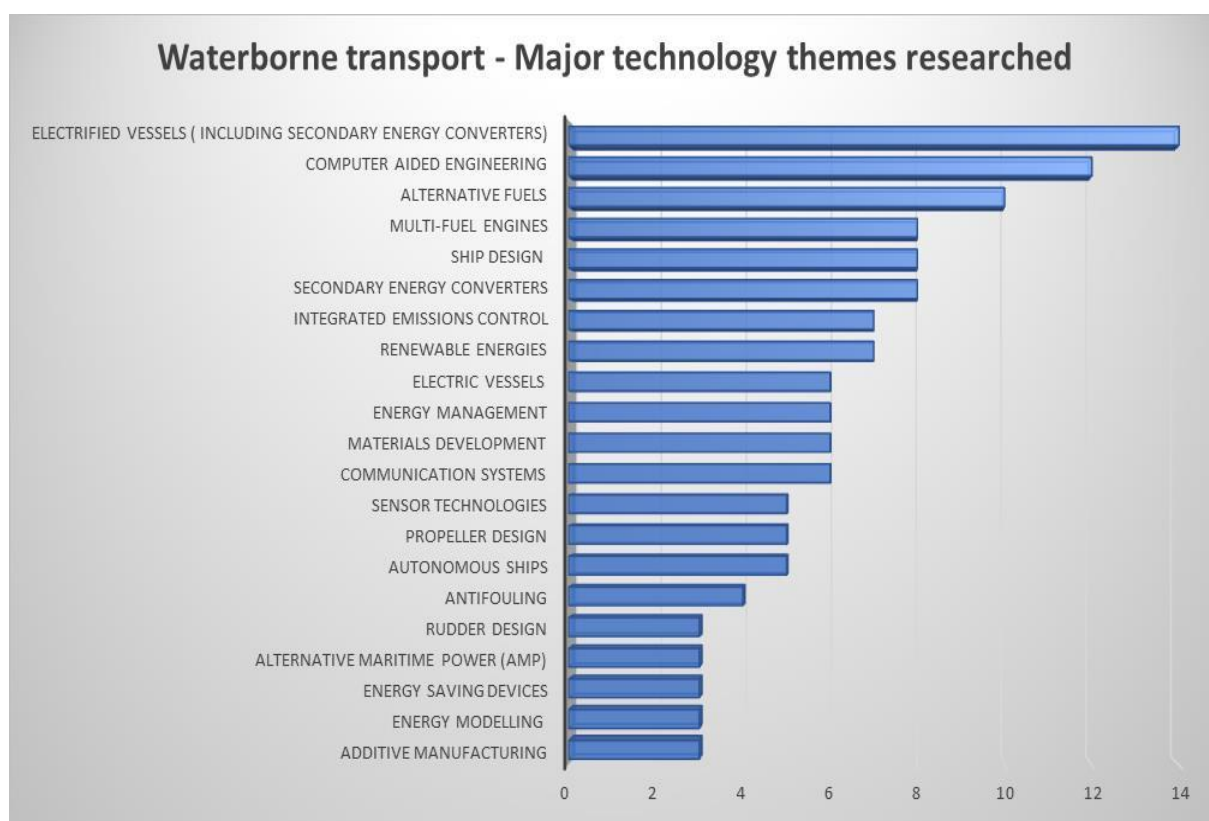
**Figure 18. Waterborne transport- applicable technology sector**

In terms of funding of the reviewed projects, 49% belonged to H2020 and 40 % to FP7. The remaining 11% were some German national, US MARAD and Japanese funded projects.



**Figure 19. Maritime transport- Reviewed projects funding scheme**

Figure 20 presents the most dominant identified technologies that were extracted from research projects and literature. Electrified vessels have been identified as a dominant technology theme based on adding other themes that were relevant to electrification of ships such as electric vessels and secondary energy converters. The second most dominant technology theme was CAE. In the maritime sector many projects have developed CAE tools in order to model and more accurately simulate ship design and the effect that design decision have on better hydrodynamics. CAE may also find applications in modelling of underwater-noise, propulsion, ship energy, shipyard simulations, even modelling of retrofitting energy saving devices which is currently done in very crude ways of reverse engineering ship sections. If such off-the-self tools exist that can accurately virtually model all of the aforementioned functions then the sector will benefit from significant cost savings. Alternative fuels and Multifuel engines have also been identified in 3<sup>rd</sup> and 4<sup>th</sup> position. The latter is the effect of using alternative fuels and the changes that will be required in engine development to accommodate the use of alternative fuels. The use of renewable energies for supplying power or for additional propulsion (wind assisted propulsion) in maritime has been researched and mentioned by various sources including actual prototypes in the maritime mode. Integrated emissions control in 5<sup>th</sup> position is justifiable given the significance that exhaust emissions control has for maritime and the push from more regulatory changes. Although important technologies such as communication systems, materials development, autonomous ships, sensor technologies and AMP did not receive large amount of citations or projects this does not mean that they will not be required for enabling the future of maritime transport. Sensor technologies are quite important and will enable the connectivity of energy and health monitoring of structures and components. AMP (aka cold ironing) is already being used or trialled in many ports globally and will require further integration into the maritime mode in an effort to minimise emissions at berth. Communication systems will enable autonomous vessels, and both will play a role in the future. Finally, additive manufacturing could play a significant role in the waterborne sector where spare parts can be printed on board the ship thus reducing downtime.



**Figure 20. Waterborne transport - dominant identified technology themes**

### 3.4.3 Summaries of waterborne transport technologies identified from projects

#### **Competitiveness – Waterborne research projects**

<b>Cluster: C1 Competitive maritime</b>			
<b>Subcluster: C1-1 Innovative ship concepts (inland waterway vessels, crafts for coastal and offshore, automated and autonomous vessels)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Project</b>	<b>Sector</b>
Vessel speed	Ultras slow speed ships	ULYSSES	Freight
Battery powered Air Supported Vessel (ASV)	ASV electric mono hull design and testing of the vessel	BB GREEN, GFF	Passenger
Autonomous ships	Autonomous ship merchant concept	MUNIN	Freight
Electric vessels	1) Electric hydrofoil taxi, 2)100% electrically powered ferry	SEABUBBLE, E-FERRY	Passenger
Fuel cell electric vessels	Hydrogen fuel cell powered high speed electric ferry	META 2	Passenger
Ship design	Hull design for recreational and work boats	S.D.S.	Passenger

Ship design	1) Ship design for Compressed Natural Gas (CNG) transportation, 2) Re-design of a standard inland ship hull	GASVESSEL, NEWS	Freight
Folding containers	Folding containers enabling the reduction of empty movements.	4FOLD PHASE 2	Freight
Integrated logistics system	An adapted logistics and supply system for the respective demands of market in the catchment area; Enlargement of the European inland waterway system for container transport	NEWS	Freight
Improved hull design	hull-form optimisation a significant reduction in fuel consumption	MOVEIT	Freight
Cargo system for perishable food liquids	Aseptic, temperature controlled, quality monitoring, self-loading cargo system	AgroHighway	Freight
<b>Cluster: C2 Competitive ship design</b>			
<b>Subcluster: C2-1 Design tools for structural reliability and other functions (CAE + other tools, computation for virtual &amp; real advanced simulation and testing)</b>			
Technology theme	Specific technology researched	Project	Sector
Ship design	Ship design for future retrofitting of technologies	RETROFIT	Freight
Computer Aided Engineering	1) Simulations for wave added ship resistance, 2) CAD and CFD tools for hull shape design, 3) CAD software for 3D hull arrangement and a 3D ship stability, 4) Design procedures and software tools for FRP ships	PerSEE, No-Welle, SMARTYARDS, FIBRESHIP	Passenger+ Freight
Digital education tools	Ship-handling simulators for education, training and examination purposes and develop digital tools for cargo handling, ship stability and energy-efficient navigation.	PROMINENT	Freight
<b>Cluster: C3 Competitive ship production</b>			
<b>Subcluster: C3-1 Structural materials &amp; composites (maritime vessel materials)</b>			
Technology theme	Specific technology researched	Project	Sector
Composite materials	Fibre Reinforced Polymers (FRP) for ships	FIBRESHIP	Freight
Advanced materials for vessels	Advanced material solutions for efficient ships	RAMSSES	Freight + Passenger
<b>Subcluster: C3-2 Production equipment and processes (manufacturing and production process, Virtual and Augmented Reality Techniques, Measurement and Reverse Engineering Methods, additive manufacturing)</b>			
Technology theme	Specific technology researched	Project	Sector
Computer Aided Engineering	CAE shipyard simulation software	SMARTYARDS	Passenger+ Freight
Manufacturing process	Laser-Arc Hybrid Welding	Practical method of Laser-Arc Hybrid Welding for Thick Plates	Passenger+ Freight
Computer Aided Engineering	CAE shipyard process monitoring system	visualization system in	Passenger+ Freight



		shipyard	
<b>Cluster: C4 Competitive Life Cycle Services</b>			
<b>Subcluster: C4-1 Inspection &amp; maintenance (New inspection &amp; maintenance methods)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Project</b>	<b>Sector</b>
Inspection robotic systems	1) Modified an Unmanned Aerial Vehicle (UAV) for ship inspection 2) Development of Lightweight and heavyweight magnetic inspection robots	MINOAS	Passenger+ Freight
<b>Subcluster: C4-2 Repair, retrofit &amp; dismantling (repair and retrofitting new methods, Smart solutions for outfitting, repair, retrofit, end-of-life)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Project</b>	<b>Sector</b>
Computer Aided Engineering	Simulation toolkit for retrofitting ships with new technologies	RETROFIT	Freight
Reverse engineering	Photogrammetry and photo-modelling used for reverse engineering equipment	RETROFIT	Freight
Welding automation	Design of a robot for welding process automation	SMARTYARDS	Passenger+ Freight
Repair of structures	Composite patch repair technology	Co-PATCH	Passenger+ Freight
<b>Subcluster: C4-3 Life cycle approaches [Life Cycle Performance Assessment Methods and Tools, Integrated Maritime Design (for Life cycle) Environment]</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Project</b>	<b>Sector</b>
Ship design & Computer Aided Engineering	Software for ship lifecycle modelling	SHIPLYS	Freight
Ship design	Innovative holistic ship design methodologies	HOLISHIP	Passenger + Freight

### **Environment- Waterborne research projects**

<b>Cluster: ENV 1 Reducing emissions</b>			
<b>Subcluster: ENV1-1 Alternative fuels ( biofuels &amp; alternative fuels usage)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Project</b>	<b>Sector</b>
Solar energy	Photovoltaic modules on board ships	INOMANS <sup>2</sup> HIP, JOULS	Passenger + Freight
Alternative fuels	1) Tested algae derived biofuel diesel blends, 2) Liquefied Natural Gas conversions, 3) Adjustable diesel-/gas-/LNG-electric energy- and propulsion system	META 1, META 3, NEWS	Passenger + Freight
Fuel additives	Fuel modifiers	GREENDRIVE	Freight
<b>Subcluster: ENV1-2 After treatment of exhaust gases &amp; modelling techniques (2nd generation Post treatment technologies (scrubbers etc), Modelling techniques for emissions reduction)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Project</b>	<b>Sector</b>
Integrated Emissions control	1)SCR (selective catalytic reduction) for high sulphur fuels , 2) Diesel particulate filter (DPF), 3) EGR (exhaust gas recirculation), 4) Electrostatic seawater scrubber (ESWS) for PM, SO2 and water solubles, 5) Non Thermal	HERCULES-C, DEECON, RETROFIT, JOULES, HERCULES-2, META 4	Passenger+ Freight



	Plasma Reactor (NTPR) using Electron Beam and Microwave to remove NO <sub>x</sub> , VOC, CO, 6) SO <sub>2</sub> dry and wet scrubbers, 7) Combination of SCR and EGR 8) Methane and ethane abatement technology into lean burn 4-stroke gas engines		
Certification and monitoring	Evaluate options for certification procedures for new engines and retrofit solutions for vessel operators to comply with stricter emission limits	PROMINENT	Freight
<b>Cluster:</b> ENV 2 other emissions from waterborne transport			
<b>Subcluster:</b> ENV2-1 Reducing airborne and underwater noise			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Project</b>	<b>Sector</b>
Computational noise modelling	Development of computational modelling and measurement techniques for underwater noise caused by cavitation	SONIC, AQUO	Passenger + Freight
<b>Subcluster:</b> ENV2-2 Reduced emissions by paints & cleaning, ballast water			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Project</b>	<b>Sector</b>
Antifouling	1) Polyurethane-based paint containing immobilised biocides (Econea & Irgarol) and silicone based paint containing immobilised (Econea), 2) On-board automatic cleaning system, 3) Ultrasonic technology that provides vessels full AF prevention	FOUL-X-SPEL, FLIPER, BIOECOMARINE	Passenger + Freight
Ballast Water Management	Microfluidic technology for the purification of ballast water	TRILO-BWTS	Freight

### **Energy- Waterborne research projects**

<b>Cluster:</b> ENE 1 Optimising resistance and propulsion			
<b>Subcluster:</b> ENE1-1 Minimise resistance & optimise propulsion (Friction reduction techniques, Delivered power in operational conditions (wind, waves), Dedicated developments for advanced propulsors)			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Project</b>	<b>Sector</b>
Ship stability	Trim monitoring control	RETROFIT	Freight
Energy Saving Devices	1) CFD real life test of a Pre-Swirl Stator , 2) CFD of a BLAD– Boundary Layer Alignment Device	GRIP, TARGETS	Freight
Combinators	Computational modelling of Combinator mode for controllable pitch propellers	TEFLES	Freight
Propeller design	1) Design & testing of contracted and loaded tip (CLT) propellers, and counter-rotating propellers (CRP) for electric driven pod propulsors, 2) Simulation of propeller designs: Wageningen B, Meridian and Upgraded Meridian Series	TRIPOD, TARGETS	Freight
Propeller, rudder and energy saving devices design	1) Design and CFD of Large Area Propulsion, 2) Design and CFD of Advanced Screw Propeller System with the use of twisted rudder design or inflow improving devices	STREAMLINE	Freight

Ship design	1) CFD modelling for bulbous bow, 2) Ship hull air lubrication	TARGETS	Freight
Rudder design	Rudder design optimisation designs	MOVEIT	Freight
<b>Subcluster: ENE1-2 Ship powering (Improved engine design, new engine components and materials, multi-fuel engines, Zero emission propulsion techniques (wind propulsion, nuclear, electric))</b>			
Technology theme	Specific technology researched	Project	Sector
Advanced combustion and computer aided combustion optimisation, Injection systems, Integrated emissions technologies, adaptive engine control, new engine materials	1) Direct injection gas combustion system 2) Multi-fuel engine efficiency optimisation and fuel switching 3) Cool combustion 4) Computer aided combustion optimisation 5) Computational fluid dynamics & experiments for fuel injectors 6) Advanced turbocharging combined with integrated emissions control systems 7) Development and testing of emissions control systems for 2 and 4 stroke engines 8) Advanced bearing and combustion chamber technology 9) Advanced control for Diesel-electric hybrid engine system	HERCULES-C	Passenger+ Freight
Multi-fuel engines	1) Dual fuel engines (LNG/Diesel), 2) Fuel flexible engines (dimethyl ether, propane, diesel) 2 stroke and 4 stroke engine, 3) Two-stroke low speed marine diesel engine that operates on high-pressure Compressed Natural Gas (CNG) and/ or Liquefied Natural Gas (LNG) as an alternative hydrocarbon fuel to HFO, 4) dual fuel engines (LNG-LPG/Diesel)	RETROFIT, JOULES, HELIOS, HERCULES-2	Passenger+ Freight
Energy Storage	1) Battery Storage System (BSS), 2) Battery Storage System and supercapacitors	INOMANS <sup>2</sup> HIP, JOULES	Passenger+ Freight
Secondary energy converters	1) Electric motors, electric heaters, WHRS, Organic Rankine Cycle, 2) Waste Heat Recovery System (WHRs) model, 3) Hydrogen generator for electricity generation, 4) Fuel cells using hydrogen or methanol as auxiliary energy generation, 5) Computational modelling of batteries for hybrid propulsion, 6) Hybrid drive for hybrid propulsion, 7) Hydrogen fuelled PEMFC based hybrid powertrain system	JOULES, INOMANS <sup>2</sup> HIP, H2MOVE, TARGETS, TEFLES, Auxilia, MARANDA	Passenger+ Freight
Renewable energies	1) Kite and suction sail propulsion simulation, 2) Wind assisted vessels, 3) Wind assisted propulsion using the Magnus effect with a rotor sail technology	ULYSSES, JOULES, SeagateSail, TARGETS, RotorDEMO	Passenger+ Freight
Electric propulsion	CFD of Contra Rotating Pod (CRP) and Integrated Contra rotating Pod (ICP) propulsion units	STREAMLINE	Freight
Engine design for autonomous vessels	Two stroke low speed turbocharged crosshead diesel engine and pump jet	MUNIN	Freight
New advanced engine materials and component design	1) Cast and powder metallurgy processed materials 2) new design of cylinder heads	HERCULES-2	Passenger+ Freight
Adaptive powerplant control	1) Systems and processes allowing a continuous optimized performance of the	HERCULES-2	Passenger+ Freight

and performance	power plant throughout its lifetime 2) Engine operation optimisation through cylinder cut out		
New power system configurations	Power configurations and assessing how these configurations match the ship's operational profile.	MOVEIT	Freight
<b>Subcluster:</b> ENE1-3 Energy management & analytics for ship operations (Energy Data acquisition and management systems, Analysis and decision making (tools), Dynamic modelling and simulation tools)			
Technology theme	Specific technology researched	Project	Sector
Energy Modelling	1) Dynamic Energy modelling (DEM) of ships components, 2) General Energy Systems (GES) simulation tool, 3) Dynamic Energy Model (DEM) of ships components	REFRESH, INOMANS <sup>2</sup> HIP, TARGETS	Freight
Energy Management	1) Heat recovery for cooling systems, 2) Energy monitoring of medium-weight vessels, 3) Real time energy monitoring of fleet	EEECMS-2, SCOUT, SEAHUB	Passenger+ Freight

### Infrastructure- Waterborne research projects

<b>Cluster:</b> INF1 Smart and connected ports			
<b>Subcluster:</b> N/A (Integration of national single windows with trade portals and port community systems, Development of Intelligent holistic solutions for the efficient management of ships in ports for freight, passengers and workers, integrated with Urban Mobility Plans and solutions. Development of digital infrastructure, ICT innovation, and automation: Robotics, automation, and autonomous vehicles)			
Technology theme	Specific technology researched	Project	Sector
Autonomous systems	Shore Control Centre for autonomous vessel	MUNIN	Freight
Alternative fuels and port equipment	1) LNG powered terminal tractors, reach stackers and RTGS .2) Electrified Rubber Tired Gantry Cranes (RTGs), 3) Energy monitoring system for ports	GREENCRANES	Freight
Port of the future	Defining the vision for the Port of the Future concept	DocksTheFuture	Freight
Integrated logistics system	New river ports infrastructure concepts	NEWS	Freight
Port security system	Security sensors for next generation port solutions; Security communications infrastructure.	SUPPORT	Passenger+ Freight
<b>Cluster:</b> INF2 Port intermodality			
<b>Subcluster:</b> N/A (Improved interoperability of existing port related systems and the integration between transport modes, Improved interconnectivity and integration between transport modes and established systems, such as: Maritime national Single Windows, RIS, e-Customs, TAF, ERTMS and rail one stop shop, "access points", "data pipelines";)			
Technology theme	Specific technology researched	Project	Sector
N/A	N/A	N/A	N/A
<b>Cluster:</b> INF3 Refuelling infrastructure for alternative fuels and innovative concepts			
<b>Subcluster:</b> N/A (cold ironing, infrastructure to accommodate alternative fuels in shipping)			
Technology theme	Specific technology researched	Project	Sector

Alternative Maritime Power (AMP)	1) Cold Ironing with electricity produced at harbour via LNG generator, 2) Cold ironing modelled	RETROFIT, INOMANS <sup>2</sup> HIP, TEFLES	Freight
Hydrogen refuelling & production	1) Offshore floating platform for hydrogen refueling and production, 2) Hydrogen refuelling infrastructure	H2OCEAN, MARANDA	Passenger+ Freight
Hydrogen refuelling	Cargo loading / unloading system for liquefied hydrogen at port	Development of cargo loading / unloading system for liquefied hydrogen and the relevant rules for operation	Freight

### **Systems & Safety- Waterborne research projects**

<b>Cluster: SYS1 Maritime systems</b>			
<b>Subcluster: N/A</b> (Integration of ship navigational and communication facilities aboard ships, including the bridge systems, other ships, VTS and SAR, into a European marine digital highway information system. Integration of navigation technologies with shore based data networks and centres: (SafeSeaNet, (AIS, LRIT), GNSS, National Single Window, VTS, route planning etc.). Ship to shore communications)			
Technology theme	Specific technology researched	Project	Sector
Autonomous Systems	1) Developed Deep Sea Navigation System, Collision Avoidance Module, Harsh Weather Operation Module, Strategic Harsh Weather Route Planning Module and Remote Manoeuvring Support Systems, 2) Autonomous engine monitoring and control system	MUNIN	Freight
<b>Cluster: SYS 2 Safety</b>			
<b>Subcluster: N/A</b> (Safe automation and autonomy, accident prevention, fire resistance)			
Technology theme	Specific technology researched	Project	Sector
Implementation of resilience engineering	Develop and validate a multi-level resilience model and virtual platform	SEAHORSE	Freight

## **4 Technology themes in the international scene**

Given the fact that research and technology priorities for different continents vary and the structure of research and funding is also different compared to the EU, transport priorities of countries like the USA, Russia and India will be presented in this section.

### **4.1 Russia**

Transport can play an important role in promoting growth, diversification and regional convergence. However, with insufficient investment and incomplete structural reforms, Russia faces very large challenges in modernising its large transport system. Urban transport

problems are intensifying, because of weak policy coordination and inadequate traffic management. Promoting competition in the transport sector is essential (Kolik et.al., 2015). Substantial investments in the aging roadway infrastructure have been made in Russia, while further investments are also predicted in the midterm future (Ecola et al., 2014)

In 2014 the Ministry of Education and Science of the Russian Federation prepared a Science and Technology foresight with an outlook of 2030, which presents the priorities that Russia has set on specific research areas including transport and aerospace (Sokolov and Chulok, 2014; Ministry of Education and Science of the Russian Federation et. al., 2014):

- Models of transport-economic balance and smart transportation systems with the use of supercomputing resources at the exaflop level.
- Increased requirements for hardware elements of on-board electronics, radio equipment, space instrument engineering. Increase of demand for intelligent on-board systems.
- Transition to new materials and technologies for construction and operation of transport infrastructure and vehicles.
- Computer-aided systems for monitoring of vehicles and transport infrastructure.
- Large-scale use of light alloys and polymers in manufacturing of vehicles. To succeed in this target there is a need for cooperation with foreign players due to the creation of a partner network (EY, 2014).
- Technologies to reduce the harmful impact of transport on the environment: The environmental impact of road transport in Russia is substantial. Its share in all the emissions in Russia is about 40% and in transport emissions about 80%. The main factor for this situation is the motorisation boom in Russia. Car ownership has doubled since 2000 (Kolik et al., 2015). There is a need for transition to green transport and especially to hybrid vehicles and development of hydro- and aerodynamic flow control theory
- Increasing the safety standards for infrastructure, vehicle and transport systems. Road traffic mortality in Russia is five times higher than in several European Union countries, about twice higher than in the United States and significantly higher than in other advanced transition economies. The main reasons for this situation are the bad state of the roads, the sharp decline in road police personnel, as well as drunk driving (Kolik et.al., 2015). There is a need for technologies to ensure safe travel in difficult conditions, such as intelligent on-board systems
- The shipbuilding industry gives priority to include drilling and operating platforms, shipping terminals, various types of ships to extract hydrocarbons, ice-breakers, tugboats, ships with a high ice class (including tankers and gas carriers), scientific research vessels (to study the oil and gas potential of the continental shelf, provide hydrometeorological support, and monitor the environment), and environmental safety vessels (Dekhtyaruk et. al., 2014)
- Creation of small spacecraft clusters with a rocket engine with increased thrust
- Systems for wireless energy transmission to transport and space equipment
- Systems of autonomous landing of aircrafts and autonomous navigation of land and water vehicles
- Materials for the extreme conditions of high – speed travel in terrestrial and aquatic environments

In 2016 the Russian Federation has published the Strategy for The Scientific and Technological Development of The Russian Federation (SNTR, 2016). The document set out the aims and basic objectives for the scientific and technological development in the country, including policies and outcomes of its the implementation. In general science and technology is seen as priority area for the Russian Federation especially since early 2000 where the country has shifted towards an innovation driven economy with substantial increase in science funding. According to this strategy, Russia will need to focus, for the next 10-15 years, into technologies that will allow innovative development of the domestic market of products and services, while ensuring that a stable position is retained for Russia in the foreign markets. Such transport related technology development will provide for (SNTR, 2016):

- Transition to advanced digital and intelligent production technologies (robotic systems, new materials and design methods, processing of big data, machine learning and artificial intelligence)
- Environmentally friendly and resource saving energy including means of transportation and storing of power
- Safety against any type of threats or terrorism that can disrupt society, economy and the state (these can potential disrupt transport systems and infrastructure resilience)
- Connectivity of the different territories of the Russian Federation using intelligent transport and telecommunications. This includes retaining a position in the international market of transport and logistics systems. Reference to the air, space, world ocean, Arctic and Antarctic Regions is also made.

An efficient modern transportation system can become a “locomotive” of the Russian economy and promote the country’s innovation-based development. However, creating it requires significant financial resources, which cannot be obtained exclusively from the federal budget. Therefore, the key economic challenge for the transport sector is to increase its investment attractiveness – which can be achieved by reducing costs, increase efficiency of construction and maintenance of infrastructure and increase productivity (Sokolov and Chulok, 2014).

Furthermore, the Russian Railways have created a strategy relevant to the development of their rail infrastructure where the main priorities are laid down (Russian Railways, 2018). These priorities involve the modernisation of existing rail infrastructure and construction of new rail routes by 2030. Hence, acquiring new rolling stock with a bit more emphasis on the passenger cars is also envisaged, in order to replace old locomotives and wagons. Expansion of the high speed lines is also part of their strategy in order to accelerate long distance passenger travel more than 700km using the new generation rolling stock. Upgrade of existing lines between regional centres will also be required to facilitate high speed travel. In addition, super speed routes operating at 350 km/h along selected corridors. Finally, new lines will need to be built to accommodate transport of industrial products and mineral deposits.

Russian Institutes that deal with rail transport research such as the JSC Railway Research Institute (VNIIZHT<sup>10</sup>) specialise in technology topics that can also reflect the overall needs of

---

<sup>10</sup> <http://www.vniizht.ru/>

the Russian railways. Specifically, the topics cover (Rail-research, 2018): 1) Increase in mass and weight of freight trains, 2) Development of technical means for increasing car and axle loading, 3) means for increasing car and axle loading, 4) high speed rail and traffic, 5) track and rolling stock interaction, 6) saving fuel, energy, material resources, 7) operational efficiency of rolling stock, 8) rail related environmental issues, 9) certification, standardisation and metrology, 10) safety and tests of rolling stock, 11) improvement of labour efficiency.

In the waterborne sector the Russian Federation seems to focus its maritime technological priorities on (Dekhtyaruk et al. 2014): 1) production technologies, 2) Ship construction 3) Navigation and telecommunications, 4) Steering and control, 5) Engines and mechanisms, 6) Safety and security, 7) New materials, 8) ecology and environmental protection. These priorities are shown in Figure 21 below.

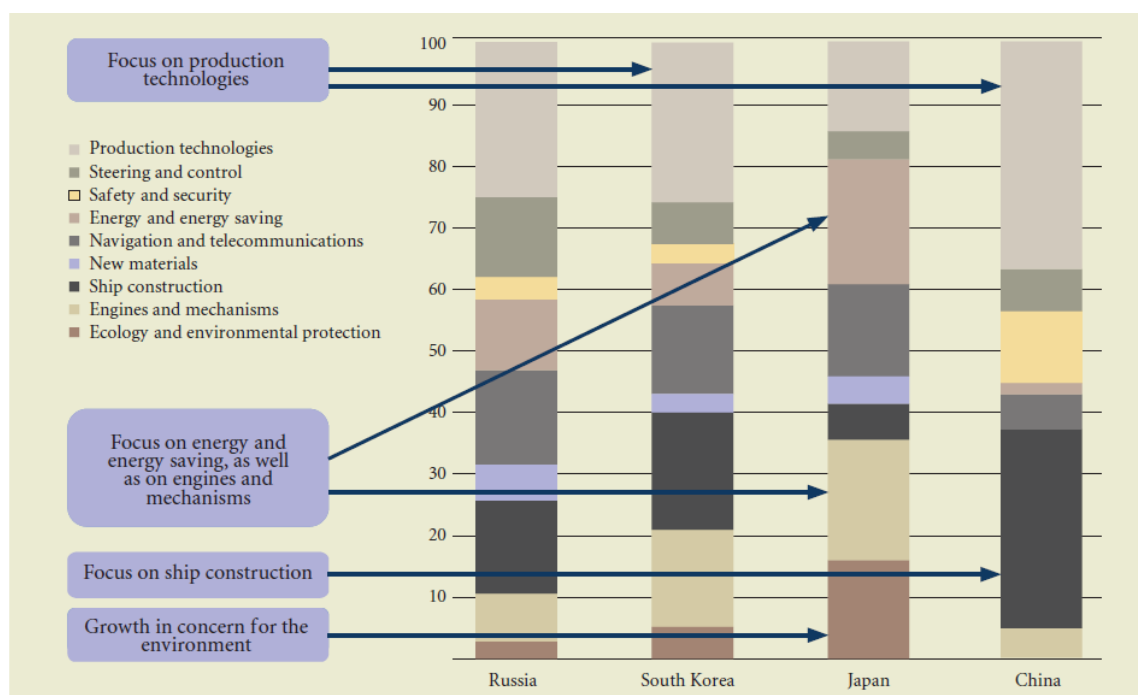


Figure 21: National technological priorities (percentage of total number of technologies).

Source (Dekhtyaruk et al. 2014;36)

## 4.2 USA

This section identifies technology priorities and future directions set by the US government and key stakeholders from the U.S.

In the aviation sector, NASA (National Aeronautics and Space Administration) in its strategic implementation plan identifies that priority is given to the operation of the FutureFlight Central<sup>11</sup>, a simulation facility, with the purpose of development, validation and application of advanced modelling, simulation and testing capabilities to assess future aviation system concepts and architectures.

<sup>11</sup> <https://www.aviationsystemsdivision.arc.nasa.gov/facilities/ffc/index.shtml>



Specifically, priority is given to the following research themes (NASA, 2017): 1) Advanced Operational Concepts, Technologies, and Automation (Dynamic Fully Autonomous Trajectory Services), 2) Safety Management for Emergent Risks, 3) Integrated Modeling, Simulation and Testing (Future Flight Central is one of the simulation facilities which used for integrated testing of new tools designed to improve gate-to-gate air traffic flow), 3) Airspace Operations Performance Requirements, 4) Understanding and Measuring Community Response to Sonic Booms, 5) Integrated Design Solutions for Revolutionary High-speed Aircraft, which will fly with supersonic speed and its propulsion system and its shape are combined to achieve a lower target decibel level, 6) Minimizing the Airport Community Noise Impact of High-speed Aircraft, 7) Increasing Cruise Efficiency and Reducing or Eliminating the Impact of High-altitude Emissions, 8) Advanced Ultra-efficient Airframes (The airplane builders try to design planes with smaller tails, which would reduce weight, drag and fuel use), 9) Advanced Ultra-efficient Propulsion, 10) Advanced Airframe-engine Integration, 11) Clean and Efficient Rotorcraft Propulsion, 12) Safe and Certifiable Vertical Take-off and Landing (VTOL) Technologies, 13) Advanced Component Noise Reduction, 14) Characterization and Integration of Alternative Fuels, 15) Scalable Alternative Propulsion Systems (such as novel “turbo-electric distributed propulsion” concept in which power is electrically distributed from wing-tip gas generators to a series of embedded fans to substantially increase propulsive efficiency and lead to dramatic reductions in fuel consumption, noise, and emissions), 16) System-wide Data Analysis for Understanding Safety Events, 17) Improved Performance of Detection, Analysis and Prognostic Tools, 18) Integrated Threat Prognosis, Alerting and Guidance, 19) Techniques for Real-time Safety Assurance, 20) Real-time System-wide Safety Assurance Demonstration, 21) Unmanned Aircraft Systems Integration, 22) Design and Analysis of Autonomous Systems.

Regarding the road sector, the U.S. Department of Transportation (DOT) has calculated that 94 percent of crashes can be tied to a human choice or error, and many observers believe that automated vehicle technologies could reduce or eliminate these errors. For example, technologies that automatically slow or stop a vehicle when it predicts a forward collision can mitigate accidents due to inattentive driving and save lives. Further, fully self-driving vehicles could reduce traffic congestion through more efficient operations or make time in the car less onerous by freeing drivers from some or all driving responsibilities. Moreover, people with physical limitations that prevent them from operating a vehicle may find that driverless vehicles provide them with greater mobility. The US DOT has stated that automated vehicle technologies, including fully self-driving cars, may prove to be the greatest personal transportation revolution since the popularization of the personal automobile a century ago. Automakers and technology firms are investing heavily to develop and deploy automated vehicles. Already, automated technologies are changing cars and light trucks, as well as other vehicles (GAO, 2017). The automated vehicle research programme of the USDOT (2018a) carries out research that involves two main technology themes 1) advanced driver assistance systems and 2) autonomous vehicles. In the first case the programme includes development, testing and demonstration of research related to human in the loop interaction such as: Cooperative adaptive cruise control, platooning, merge/weave assist, speed harmonization, and eco-approach/departure. The second path includes research relevant to developing, testing and evaluation of concepts and prototype autonomous vehicles. Demonstrators of connected vehicles research are also underway by the US DOT with examples in New York, Wyoming and Tampa cities (for further info see Annex 1.1 and 2.1).



In addition the US DOT also has an ITS standards programme to enable the interoperability of connected vehicle and ITS services with a multimodal transport network both vehicles and infrastructure. The programme involves the development of standards and protocols (US DOT, 2018b). The US DOT also offers research on Enterprise Data and connected cities on topics such as: 1) visualisation techniques of big data and mobility, 2) traffic analysis and management and 3) infomodality for intermodal transport

The main target for the U.S. maritime system is to enhance America's multimodal mobility and to ensure national and economic security in an increasingly globalized world. For this goal MARAD (Maritime Administration), which is the agency within the U.S. Department of Transportation (DOT) and supports the United States maritime industry, has sets six strategic goals which their implementation will be achieved through concrete actions. More specifically, the first strategic goal is to support U.S. Maritime Capabilities and this goal includes the following actions: 1. Secure maximum preference cargo for U.S.-flag vessels, 2. Seek to reduce U.S.-Flag operating costs, 3. Improve support programs for domestic shipbuilding/repair capability, 4. Continue to ensure ready availability of ships, training billets, crews, and strategic ports (MARAD, 2017).

The third strategic goal is to improve, expand and protect waterborne transportation. For the implementation of this goal the following actions will be needed: 1. DOT funding and financial resources to assist in reducing national landside port congestion, 2. Establish marine highway services to certain congested large urban port areas and along major freight corridors, 3. Leverage DOT resources to enable additional U.S. ports to have landside facilities that can accommodate fully-loaded containerships of up to 24,000 TEU capacity, 4. Leverage DOT resources to enable additional U.S. ports to have landside facilities that can accommodate fully-loaded containerships of up to 16,000 TEU capacity, 5. Leverage DOT resources to enable additional U.S. ports to have landside facilities that can accommodate dry bulk and tanker vessels of 50 feet in draft (MARAD, 2017).

The fourth strategic goal is to minimize environmental impacts and this will be achieved through these actions: 1. Collaborate with public and private entities to expand carriage of cargo by water, to reduce pollution and congestion in other transportation modes, 2. Support research, testing and innovation to enable ports to minimize their environmental footprint through improved technology and practices, 3. Support research, development and demonstration of alternative non-carbon energy sources and cleaner burning carbon based fuels and technology that will enhance vessel energy efficiency, reduce pollution and lower costs, 4. Dispose of government-owned merchant-type ships in an efficient and environmentally responsible manner in domestic shipyards (MARAD, 2017).

The fifth strategic goal is the maritime innovation. This goal includes the following actions: 1. ITS technologies and innovations and applications to benefit maritime/intermodal transportation, 2. Use of technologies to improve information flow for secure door-to-door tracking of cargoes including movements of cargoes on vessels, through ports, and on connecting surface transportations systems, 3. Development of innovative ship designs and business processes suitable for U.S. domestic carriers and shipyards, 4. Sustain progress in research, innovation, and deployment, including advanced technology for automation, ship design, shipyards, ports, and carriers and 5. Position the USMMA as a leader and partner in maritime research and innovation (MARAD, 2017).

### 4.3 India

India is currently the fourth largest emitter of greenhouse gases (GHG) in the world. The transport sector accounts for 13% of India's energy related CO<sub>2</sub> emissions. Opportunities exist to mitigate GHG emissions and make India's transport growth more sustainable and climate compatible by aligning development and climate change agendas. For this reason it is necessary to design an urban transport planning which will address numerous challenges such as: deteriorating air quality, rising greenhouse gas emissions, and adverse rising energy security risks. In this planning electric vehicles have a core role, because they offer alternate mobility options that can help to redress the previous adverse impacts (Shukla et.al., 2014).

The government of India has set some targets such as enhancing national energy security, mitigating the adverse impact of vehicles on environment and growth of domestic manufacturing capabilities. All these targets are mentioned in the National Electric Mobility Mission Plan 2020 (NEMMP) which was created and announced by the government and its key points are the following (Shukla et.al., 2014):

- Investments in R&D and electric vehicle infrastructure by the private sector and the Indian government.
- Joint government-industry investment in R&D, power infrastructure and fuel procurement for power generation
- 6-7 million units of new vehicle sales of the full range of electric vehicles, along with resultant liquid fuel savings of 2.2 – 2.5 million tonnes can be achieved.
- Substantial lowering of vehicular emissions and decrease in carbon dioxide emissions by 1.3%-1.5% in 2020 as compared to the status quo scenario.
- Phase-wise strategy for R&D, demand and supply incentives, manufacturing and infrastructure upgrade
- Development of indigenous products and manufacturing capabilities. 25-30% of EV products sourced locally. This includes plans for export to foreign markets

All these points will be achieved based on the collaborative approach between academia, research institutes, industries and government. The last will give priority to the development of industry for the production of indigenous EV products sourced locally. Three subgroups in the areas of Battery Management Systems (BMS) and batteries, power, electronics and motors and testing infrastructure/HR/efficient technologies are expected to be created by this collaboration.

Regarding the predictions about the future of mobility in India, it is considered possible that the planning will give priority to buses and Bus Rapid Transport systems are expected in all cities with more than a million inhabitants. The government of India will invest in technology improvement of city bus systems and in particular will give priority to the following areas: 1) Basic computerization: computerization of all departments and training to be provided to staff with responsibility of data entry, 2) GPS inn buses – Vehicle tracking: all buses to be fitted with GPS and integrated with tracking, 3) Electronic ticketing machines (ETMs): procurement of ETMs and transition from offline ticketing machines to online in all buses, 4) Closed-circuit television (CCTV) : Installation of CCTV cameras at buses, terminals and bus stops, 5) Passenger Information Systems (PIS): Installation of PIS boards at key bus stops, terminals and buses. Installation of voice announcement system with internal PIS boards, 6) On-Bus

Diagnostics System (OBD): Conduct the feasibility study to integrate OBD with old and new buses and 7) Bus Fleet Management System (BFMS): Process mapping of all depot activities.

Moreover electric buses, electric bicycles and electric scooters and motorcycles are expected have a much larger battery, bigger payload capacity and a longer driving range. This situation will require a smart grid with the use of renewables, so it is important to have substantial investments (Shukla et.al., 2014).

Some more generic priorities for R&D in India, yet relevant to transport and energy, are the following according to Mission Innovation (2018): 1) environmentally friendly, clean energy technologies including renewable energies, 2) clean fossil fuel technologies, 3) electric grid technologies and advanced transportation systems and fuels (bio-based) and other crosscutting technologies, 4) hydrogen and fuel cells. These priorities will take place through the collaboration and investments made by Public Private Sector, National Laboratories, Universities and International Partners.

Finally, Technology Information, Forecasting and Assessment Council-TIFAC (2015) presents transport related technology innovations that will contribute to making Indian transport cost effective and provide quality services to the citizen by 2035. These technologies are presented in Figure 22. In addition to these priorities, the roadmap (TIFAC, 2015) suggests that mandatory technology assisted driver training will assist achieving zero pedestrian fatalities. High quality infrastructure, road transportation technologies and traffic management systems will have to be integrated including ICT systems that will tackle traffic congestion. Dedicated high speed rail freight corridors will enable multimodality for goods and services. Development and production of powertrain for an indigenous transport aircraft will create challenges for the Indian government.

INTELLIGENT TRANSPORTATION SYSTEM	●	●	●	
ALTERNATE FUEL BASED TRANSPORTATION	●	●	●	
ADVANCED POWERTRAIN TECHNOLOGIES	●	●	●	
AFFORDABLE ENERGY STORAGE AND INFRASTRUCTURE FOR FAST CHARGING	●	●	●	
ACTIVE AERODYNAMICS	●	●	●	
HEAT RECOVERY SYSTEMS	●	●	●	
INTELLIGENT ROADS	●	●	●	
LONG LIFE, LOW MAINTENANCE ROADS AND STRUCTURES	●	●	●	
SELF HEALING ROADS	●	●	●	●
FOG VISION SYSTEM FOR ROAD AND RAIL	●	●	●	
ACTIVE AND PASSIVE SAFETY TECHNOLOGY	●	●	●	
MAGNETIC LEVITATION TECHNOLOGY	●	●	●	
TILTING TRAIN TECHNOLOGY	●	●	●	
AUTONOMOUS VEHICLES	●	●	●	
NOVEL MODES OF TRANSPORT (e.g. EVACUATED TUBE TRANSPORT, HYPERLOOP )	●	●	●	
AMPHIBIAN AND FLYING VEHICLES	●	●	●	
BIOMIMETICS DESIGN FOR SHIP	●	●	●	

Technologies, concepts and approaches relating to safe and speedy mobility that–

- are readily deployable
- needs to be moved from Lab to Field
- require targeted research
- are still in the imagination

Figure 22: Technology developments required by the Indian Government.

Source: TIFAC (2015; 63)

## 4.4 China

In 2017, the Chinese Ministry of Transport and Ministry of Science and Technology have released 13<sup>th</sup> Five-year Special Plan for Science and Technology Innovation in the Transportation Sector with an outlook up to 2020 and onwards. This document was released in Chinese and the following sections are based on google translation of key areas of the document.

China has set a target to invest on more environmental-friendly aviation. Specifically, future air traffic management needs to take account of new technologies, to deliver more air space capacity while reducing emissions and protecting the environment (European Commission, 2017). In this sector the government has focused its interests on the specific research areas, such as: 1) New aircraft technologies (light aircraft, amphibious aircraft, electric aircraft with electric propulsion system), 2) New concepts of UAVs, 3) Design of new types of large hub airports, 4) Use of big data for safe operation simulation platform, 5) UAVs in logistics, 6)

New flight control technology based on high-precision aeronautical meteorological forecast (Ministry of Transport and Ministry of Science and Technology, 2017).

Regarding the rail sector there is a focus on the following themes: 1) Adaptation of key technologies for improving overall efficiency and safety in rail (new materials, new energy sources) 2) Use of Internet to enhance the intelligent manufacture and operation of rail transit equipment, 3) New types of high-speed passenger and freight trains, 4) Design of new Maglev traffic control systems, 5) Develop low-cost unmanned-oriented train system technology, 6) New support technologies based on information integration of the sky and sky vehicles, 7) Distributed intelligent power supply technology, 8) Enhance support to the rail transit system as the most suitable way to cover green environmental sustainability needs (Ministry of Transport and Ministry of Science and Technology, 2017).

For the Chinese road sector, in the next the ten years, the promotion of electric vehicle technologies targeting green transportation will be required. According to Du and Ouyang (2013) the priorities given in this field are the following:

- 1) Progress on traction batteries. China is one of the world's major battery producers. BYD, BAK and Lishen battery companies, amongst others, produce most of the lithium-ion batteries for consumer electronics, particularly for mobile phones and computers. Today, a great deal of research is underway regarding battery development for the automotive sector. For this reason the Chinese government has placed great importance on the advanced battery R&D.
- 2) Progress on electric motors for EVs. Based on the advantages of electric motor, there are two kind of key technologies in China: the widely used Permanent magnet synchronous motors and the AC asynchronous motors. The former was usually applied by electric car due to its high power density, and the later was adopted by electric bus due to its lower cost.
- 3) Progress on electric vehicles. Developing electric vehicles (EVs) has been chosen as national strategy as solution to energy security and urban air pollution by China. In past 15 years, the EVs technologies have improved greatly, and in the public serving field, the electric vehicle were used in large-scale. Nowadays companies in China mainly focus on small to compact electric sedan
- 4) Progress on fuel cell technologies. China is facing urgent energy security and urban air pollution problems. Today China mainly focuses on PEM fuel cell technology.
- 5) New business models for EV promotion in China. In order to mitigate the barriers of EV mass penetration, such as high upfront cost, limited serving life of batteries, immature infrastructure, limited range, inconvenient charging, etc., the new business model to promote EVs were tried and tested in China, including battery swapping, fast charging, battery leasing, electric car leasing by month, day or hour, finance leasing
- 6) Focus on EV, electric powertrain and fuel cell electric vehicle. The core technologies include energy storage, electric motor assembly and electronic control.

Moreover, China, Japan and Korea participate in a trilateral cooperation between the countries. The NEAL-NET<sup>12</sup> is a transnational, non-profit mechanism for logistics information exchange. The fields of cooperation between the three countries cover logistics information systems and standards technologies including promotion of technological exchange and training. Within this framework of cooperation the three countries will endeavour to realize seamless logistics systems and access of sea-land inter-modal trailer chassis in the future with China and Korea facilitating access to the trailer chassis and Japan with Korea will carry out pilot projects (MLIT, 2016). Other priorities include the promotion of environmentally friendly logistics between the three governments and the private sector to move forward related projects. Studies for capacity and efficient development of container terminal and ports have also been suggested by the three governments.

In the Aviation sector, the EU and China have participated in joint research in FP6, FP7 and H2020 programme. Projects like ECO-COMPASS, EMUSIC, DRAGY, COLTS, MARS and IMAGE. These projects have dealt with topics such as improvement of manufacturing projects, aerodynamics and drag reduction, noise reduction of structures and engines.

Regarding the waterborne sector there is a focus on the following themes: 1) Green ship design (total optimized utilization of marine power system, LNG electric propulsion, noise reduction technology), 2) Advanced propulsion technology (design and optimization of ship propulsion system, operation and management technology of ship smart grid), 3) Smart ship technologies (Research on intelligent ship design and manufacturing technology, intelligent ship simulation technology, intelligent cabin, intelligent design and manufacturing of system equipment, e-Navigation ship technology), 4) Efficient port construction technology (Research on port surveillance and control of video traffic control technology, automated yard operations machinery, automated shore operations machinery, automated horizontal transport machinery and automation control system integration technology, large port hub infrastructure construction and transformation, navigation support technologies) 5) Intelligent port and terminal operation management technology (Research on Decision Support Technology, automated container terminal operations) (Ministry of Transport and Ministry of Science and Technology, 2017). According to Dekhtyaruk et al. (2014) as presented at Figure 21 China seems to focus predominantly on production technologies and ship construction for the maritime sector, while Safety and security, Steering and control of vessels, Engines and mechanisms and energy saving seem to be of lesser importance.

Some more generic priorities for R&D in China, yet relevant to transport and energy, are the following according to Mission Innovation (2018): 1) vehicles & other transportation, 2) solar, wind & other renewables, 3) hydrogen & fuel cells, 4) cleaner fossil energy, 5) CO<sub>2</sub> capture and storage methods, 6) electricity grid, 7) energy storage.

---

<sup>12</sup> <http://www.nealnet.org/>

## 4.5 Japan

The Japanese Ministry of Land, Infrastructure, Transport and Tourism (MLIT, 2016b) has produced the White Paper On Land, Infrastructure, Transport And Tourism In Japan, that describes different research priority areas and current developments in transport. This document presents at an abstract level various projects and fields of interest relevant to transport where Japan wants to improve the productivity of the overall transport system whether through new technologies or optimization of the existing stock.

The MLIT (2016b) productivity revolution projects are summarized below:

- Traffic congestion and expansion of rail and road networks
- Maritime productivity: Two main initiatives exist in this field
  - I. i-Shipping: an initiative that seeks to increase the productivity of the shipbuilding industry and reduce fuel waste and eliminate accidents in shipping operations. This initiative includes CFD of replace water tank tests, IoT and big data during manufacturing of the ships,
  - II. j-Ocean: an initiative that seeks to enable Japanese maritime industry to build a larger share in the ocean development market
- Intelligent use of expressways and toll structures
- Productivity of logistics and innovation in road-based logistics. This effort includes the overseas expansion of Japanese logistics by promoting international standardization of Japan's logistics systems.
- Infrastructure maintenance including road tunnel robotic inspection technologies
- Rail productivity
- Air transport infrastructure
- Promotion of construction using ICT systems (ICT systems in dredging, road construction and bridge construction)
- ICT use in automotive for the realization of autonomous driving (R&D in i.e. radar, cameras, laser scanners, and vehicle technologies; advanced digital maps; V2V and V2I communication systems)
- Truck platooning between Tokyo and Osaka with the use of unmanned vehicles following a manned vehicle at the beginning of the convoy
- Unmanned automated transport service (last-mile autonomous driving, terminal-based traffic system)
- Car sharing and ride matching initiatives
- Ultra small mobility using small electric vehicles for cities, rentals in mountainous and remote island areas or tourist resorts

In Japan the Public-Private ITS Initiative has created roadmaps for the development of Intelligent Transport Systems in the country. This initiative has led to the sharing of the future direction among ITS-related ministries, agencies, and private companies (IT Strategic Headquarters, 2016). Japan has updated the 2015 version of the roadmap giving emphasis on collaboration with other developed countries about automated driving by developed countries. In the ITS/ Automation roadmap emphasis is given on creating a society with the world's safest road transport by 2020 while setting the target for safest and smoothest road transport by 2030. These targets are linked in the effort of the Japanese government to reduce fatalities from road accidents. From an industrial perspective Japan aims to expand the export of ITS- related vehicles and infrastructure using public-private collaborations with the aim of becoming a global hub of innovation relevant to automated driving systems after



2020 (IT Strategic Headquarters, 2016). According to the same ITS roadmap autonomous vehicle deployment is seen at highway level and on local roads. The main priorities for autonomous vehicles are presented in Figure 23.

<b><u>Advanced autonomous cars</u></b>	
a.	Automated driving systems that can contribute to the enhancement of international competitiveness in the global market
<b>Passenger Cars</b>	
-	<u>Commercialization of autonomous cars (semi-autopilot) on highways (by 2020)</u>
-	<u>Commercialization of autonomous cars (equivalent to Level 2) on local roads (by 2020)</u>
-	<u>Commercialization of automated valet parking in parking lots</u>
<b>Trucks</b>	
-	<u>Realization of truck platooning on highways</u>
<b><u>Regional public transportation services</u></b>	
b.	Regional public transportation systems equipped with automated driving functions
-	<u>Realization of ART (Advanced Rapid Transit: equivalent to Level 2) (2020 Tokyo Olympics and Paralympics)</u>
c.	Regional community-type small automated driving systems
-	<u>Provision of unmanned autonomous driving transport services in limited areas (by 2020)</u>
-	<u>Commercialization of automated valet parking in parking lots (aforementioned)</u>

**Figure 23. Expected timing for the realisation of commercialisation and servicing of automated driving systems**

**Source: IT Strategic Headquarters (2016; 24)**

In addition, the IT Strategic Headquarters (2016) roadmap also presents Driving Safety Support Systems that will be required in the future. The main technologies identified are: 1) collision-mitigation support systems, 2) automatic accident report systems and in cabin vehicle video recorders and data recorders that evaluate the accident conditions, 3) Safety Information services for the driver, 4) R& D for sensors that support pedestrians, (mobile support systems, infrastructure radar systems and systems that use road-to-vehicle communications and mobile phone networks), 5) estimation techniques for road fatalities, 5) CO2 emissions visualisation and 6) building of dynamic maps to enable automation. Trilateral cooperation for ITS systems exist between the Japanese government, USA and Europe highlighting the importance of ITS systems for all three nations (MLIT, n.d.). Initiatives that have been presented by the Japanese Ministry of Land, Infrastructure, Transport and Tourism (n.d) related to ITS include the deployment of “ITS spot” a car navigation system that offers Dynamic Route Guidance, Safety driving support and Electronic Toll Collection (ETC). Other sustainable transport initiatives in Japan focus on improving 1) air quality by reducing vehicle air emissions, 2) road traffic and pedestrian safety, 3) promotion of public transport, 4) improving Bus Rapid Transit and Light Rail Transit including better interconnectivity between transport modes, 5) cycle sharing scheme, 6) promotion of electric vehicles (Ministry of Environment and MLIT, 2010)

The Japanese government has introduced in 2013 the Basic Plan on Ocean policy (MLIT, 2013) where priority topics are introduced for the competitiveness of the Japanese maritime sector. The efforts are focused in making Japanese shipbuilding and ship machinery industries competitive by making efforts towards reducing CO<sub>2</sub>, NO<sub>x</sub> and SO<sub>x</sub> emissions and



other pollutants from ships in order to be compliant with environmental regulations while ensuring ship safety. Maritime pollution from the effect of shipping is also raised as an issue. The Basic Plan also gives emphasis on collaborations between the industry, academia and government sectors in order to create technologically development for high- value- added vessels that will help the Japanese industry to compete internationally.

Other priority areas of interest for the Japanese Ministry of Land, Infrastructure, Transport and Tourism (MLIT) related to the waterborne sector is the application of Big Data and IoT in the sector (Mori, 2016). Specifically, development of satellite systems and communication technology such as Very Small Aperture Terminals (VSATs) which can be used for satellite communications and tracking of operations in real time using IoT and big data. Applications can be found in voyage planning based on weather conditions, ship condition and cargo monitoring (Mori, 2016). Regarding the reduction of CO<sub>2</sub> emissions Japan is working on research for emissions reduction technologies such engine systems (i.e. waste heat recovery), dual fuel gas engines, propulsion systems (i.e. controllable pitch propellers), hull low friction coatings. Hydrogen fuel cell energy is also a major priority area for Japan which includes both the waterborne and the road sector. Emphasis is given in reducing the cost of hydrogen supply infrastructure and making FCVs more competitive than Hybrids EVs. Plans for the roll out of a hydrogen supply chain look into the creation of full scale H<sub>2</sub> power plants as well as imports from overseas by 2030, while integration of renewables into the production of CO<sub>2</sub> free H<sub>2</sub> are envisaged after 2040 (Mori, 2016). The hydrogen supply chain part also includes construction of maritime vessels for the transport of the fuel as well as ship-to shore loading system for cryogenic liquid hydrogen. Moreover, Japan is looking to develop offshore technologies that will help in the storage or extraction of offshore utilities. Examples are a Floating Liquefied Natural Gas Facility and an Ultra Deepwater Drilling Platform. Based on Figure 21 regarding the maritime technological priorities, according to (Dekhtyaruk et al. 2014), Japan has as main its main focus on: 1) Energy and Energy saving, 2) Engines and mechanisms, 3) Production technologies, 4) Ecology and environmental protection, 5) Navigation and telecommunications, 6) Ship construction, 7) New materials and 8) steering and control of vessels.

After the Fukushima disaster, due the dramatic drop of electricity production in the country, Japan has pushed towards the use of hydrogen ranging from use in vehicles, houses and power stations. In fact the government believes that the 2020 Tokyo Olympics will leave a hydrogen society as their legacy. Kawasaki Heavy Industries are developing a supply chain for hydrogen with the help of the Norwegian company Nel Hydrogen where liquefied hydrogen will be produced using renewable energy and will be delivered in Japan on tankers (Karagiannopolos et al., 2017). Furthermore, 11 companies including automakers Toyota, Nissan and Honda have formed Japan H<sub>2</sub> Mobility, LLC (JHyM) in February 2018 with the aim of developing hydrogen stations for FCVs in Japan. The plan is to establish 80 hydrogen refuelling stations by fiscal year 2021 in an effort to smoothly increase the number of FCVs in Japan (Toyota Motors Corporation, 2018). A Basic Hydrogen Strategy document has been released by the Ministry of Economy, Trade and Industry (METI) outlining initial strategies for the deployment, applications and production of hydrogen in Japan.

Some more generic Japanese R&D priorities, yet relevant to transport and energy, are the following according to Mission Innovation (2018): 1) Innovative production process, 2) Ultra-lightweight and heat-resistant structural materials, 3) Next-generation batteries, 4) Production, storage and utilization of hydrogen, 5) Next-generation photovoltaics, 6) Next-generation

geothermal power generation, 7) Fixing and utilizing CO<sub>2</sub>, 8) System infrastructure technologies: AI, Big Data and IoT and core technologies for the next generation power electronics, innovative sensors and superconductivity.

## 5 Conclusions

D 2.1 serves the role of identifying key transport technologies with an outlook of 2020-2035 across the four transport modes including infrastructure and transport system which were treated horizontally. The approach used to carry out this research, was based on the review of a 374 research projects covering predominantly EU funded projects and a small number of international and national projects, to identify technology trends in research. Furthermore, pertinent literature such as transport technology roadmaps, future visions of transport and technology news were used to identify further technologies that will be required by transport.

In the road transport sector it has been identified that the most dominant technologies in terms of research were: electric and hybrid vehicles; autonomous vehicles; materials development; internal combustion engine design; alternative fuels and refuelling infrastructure; ADAS; CAE; Fuel cell vehicles; electric motor design and battery development. An interesting trend in terms of automotive research that has been identified is the development of small lightweight electric urban vehicles. This focus is not necessarily in line with the direction that the automakers are currently taking with their current models especially when the market of mid sized cars is shrinking and the SUV is growing. Perhaps such vehicles will become more widely used when combined with MaaS and localised in large urban cities. This does not mean though that such vehicles may not become more popular in the near future after 2020.

Table 3 below presents the road technology themes that have been researched by projects and literature in a more synoptic way.

In the road transport sector, it has been identified that the most dominant technologies in terms of research were: electric and hybrid vehicles; autonomous vehicles; materials development; internal combustion engine design; alternative fuels and refuelling infrastructure; ADAS; CAE; Fuel cell vehicles; electric motor design and battery development.

**Table 3. Road transport brief synopsis of technology themes**

Road transport brief synopsis of technology themes	
Electric Vehicle Design	Light weight small urban electric vehicles (EVs) with modular design
Electric Vehicles Batteries	Battery module design and materials for anodes and cathodes; battery recyclability
Electric motor design	Magnet free Switched Reluctance Motors (SRM) and Permanent Magnet Assisted Synchronous Reluctance Motors that do not use rare earth material
Electric Vehicles and fuel cell vehicles	EV and FCV demonstrators and required refuelling/ recharging infrastructure
Computer Aided	CAE tool for crashworthiness; better engine design; electric motors and accurate

Engineering	EV modelling and simulations; Multiphysics tools for modelling Electromagnetic Compatibility (EMC) and health effects from electromagnetic fields (EMF) from EVs
Materials development	lightweight materials for EVs, Fibre Reinforced Polymers (CFRPs), Glass-Fibre Reinforced Polymers (GFRPs) or advanced metal materials (aluminium, magnesium, high strength steel)
Automated driving	Demonstrators of autonomous and ADAS systems;
Hybrid vehicles	Hybridisation of vehicles trucks buses and vans
Integrated emissions control	Advanced Selective Catalytic SCR; SCR integration with Diesel Particulate Filters (SCR/DPF); AdBlue processors and ammonium nitrate additives into AdBlue to improve operating conditions; Gasoline particulate filters and 3 way catalysts without precious metals; Electrified Diesel Particulate Filters (DPF); SCR and Lean NOx traps (LNT); Trapping Hydro Carbons ((HC) and NOx during cold start and making DPF operate under lower temperatures; New materials for catalytic converters and NOX conversion for natural gas engines
Aerodynamics	Aerodynamic improvement for vans and trucks
Engine design	Advanced low emissions four stroke Spark Ignition (SI) engines; four stroke and two stroke Compression Ignition (CI) engines; small downsized engines for hybrid electric vehicles; rotary engine for range extender; waste heat recovery and new electric turbochargers or superchargers for CNG engines; ultra lean combustion; Liquefied Natural Gas (LNG), dual fuel engines or engines designed for running on biofuels for trucks; Waste heat recovery for hybrid trucks; 100% electrically turbocharged engines with new compressor blade designs; precise fuel metering; variable compression ratio engines; Simplified Internal Combustion Engine architecture for electrified powertrains; new ignition methods (microwave ignition, multi location ignition); variable engine cycles
Vehicle transmission	Intelligent automatic transmission for buses that can change shifting patterns in real time based on topography and vehicle occupancy; Transmissions for electric vehicles; Mass reduction, less friction losses of transmission
Systems	Mobility as a Service (MaaS); Cooperative Intelligent Transport Systems; Road Transport Management System and Road Side Units will be essential for the V2X communication and Coordinated Automated Road Transport; V2X and V2I communications for road users; Pilots for connected vehicles; Freight last mile logistics and overall logistics, of automated and connected vehicles; Platooning for e buses could be a viable option for the future while highly automated urban e buses with the ability to dock, charge and park will need to be developed; Coordinated Automated Road Transport (C-ART); Big data availability; Electrification of auxiliary systems in trucks

For the aviation sector aircraft design has been identified as the most dominant topic, with engine design and CAE in second place. Air traffic management, materials development and hybrid & electric propulsion ranked right below while, noise modelling and mitigation, alternative fuels and manufacturing processes were also technologies that will enable the sector. It needs to be noted that morphing concepts remain at an early development stage and will require further mechanisms and materials in order to progress any further. The table below presents the aviation technology themes that have been researched by projects and literature in a more synoptic way.

Table 4 presents the technology themes for the aviation mode that have been researched by projects and literature in a more synoptic way.

**Table 4. Aviation brief synopsis of technology themes**

<b>Aviation brief synopsis of technology themes</b>	
Aircraft design	Morphing concepts for wings, winglets, wingtips trailing edge, rotor blades can adapt their shape based on operational environment; Blended Wing Body (BWB) design; Super sonic aircraft designs
Computer Aided Engineering	Computational fluid dynamics (CFD) and Finite Element Analysis (FEA) to model and simulate stress, physical and aerodynamic properties of sections, materials and engine design
Cabin	Windowless design, with cameras and screens substituting the view, light weight interior and inflight wireless and optical entertainment systems; Virtual Reality (VR) and Mixed Reality (MR) systems
Materials development	Polymer Matrix composites (PMCs), Ceramic Matrix Composites (CMCs), Carbon Fibre Reinforced Polymers (CFRPs), Glass-Fibre Reinforced Polymers (GFRPs), Aramid-Fibre reinforced Polymers (AFRPs); Hybrid alloys; Self actuated materials that can react to light, heat or electromagnetic fields for morphing; Nano materials; Icephobic materials
Manufacturing processes	Additive manufacturing and Out of Autoclave (OOA)
Alternative fuels	Hydro processed esters and fatty acids (HEFA), Fischer-Tropsch process syngas derived kerosene
Engine design	Advanced turbofans, Open rotor engines and geared turbofan engines; Ultra-high pressure ratio compressors, lean combustion and combustor design; Interaction between combustor and turbine; Hybrid electric propulsion; Combustors (variable flow splits, advanced combustors for low NO <sub>x</sub> emissions) and fans (zero hub, variable fan nozzle, high bypass ratio); Adaptive/variable cycle engines
Noise mitigation	Modelling and simulations of the emitted noise of CROR (Counter Rotating Open Rotor) engines; Interaction between combustor and turbine; plasma actuators at the engine's jet nozzle in order to reduce eddies formation; Nacelle liners, variable geometry chevrons, porous materials at nacelle surfaces
Aerodynamics	Air flow control methods for reducing turbulent flow, have been the most researched topic; Boundary layer separation point and shock waves' formation around aircraft structures; Controlling boundary layer and laminar flow control methods; Aerodynamic wingtip devices (sharklets, winglets) and high lift devices (variable camber trailing edges, dropped spoilers and hinge-less flaps); Increasing the aircrafts wing span through a truss braced design
Airports	Automation of the airport management; Automated baggage handling and robotic systems; Air ship type of airports; Inner city airport design; Emissions free taxing; Smart and secure cargo containers that would eliminate screening and tampering; Intermodality
Systems	Piezoelectric systems for morphing concepts; Advanced fly-by-wire, Fly-by-light and Wireless Flight Control Systems; Sensors and monitoring systems whether for structural integrity, noise, vibration, efficiency, health monitoring; Satellite Navigation; Optimisation of the future Air Traffic Management (ATM) system through modelling of Air Traffic Flow, better dynamic management of capacity and analysis of the impact that human behaviour has on ATM; Automated route management; 4-D trajectory; On-board Detect And-Avoid (DAA) systems for drones;

For the rail transport mode the most cited technology themes were satellite technologies and their integration with ERTMS and ETCS. Wagon design, non-destructive testing for infrastructure, CAE and future rail station design, including noise monitoring and mitigation solutions were all dominant themes. Table 5 presents the rail technology themes that have been researched by projects and literature in a more synoptic way.

**Table 5. Rail transport brief synopsis of technology themes**

<b>Rail transport brief synopsis of technology themes</b>	
Train design	Modular freight wagon designs for different types of materials and containers; New concept of coupling two trains together with a slave locomotive in the middle of the convoy; Freight lightweight wagons; Active suspensions running gear; Eddy current brakes; High speed lightweight passenger trains with new steering improvements (active, passive guiding), lateral and vertical suspension systems with independent wheel traction
Electrified & alternative fuel trains	Hybrid and electric propulsion; Hydrogen fuel cells propulsion; LNG usage;
Material development	Composite materials Fibre Reinforced Polymers (FRPs) for interior and exterior wagon parts or crossings switches; Coating solutions of axles and wheels are also identified as a viable solution to prevent fatigue cracking; lightweight materials, nanomaterials and self-lubricating parts are proposed with embed sensors that can monitor noise, vibration and health; Materials for rail tracks
Manufacturing processes	Additive manufacturing for coating rails track surfaces or wheel surfaces with special coatings;
Inspection and maintenance	Robotic systems with vision systems for tunnels and rail tracks; ultrasonic inspection such as Alternating Current Field Measurement (ACFM), Ultrasonic phased array and High Frequency Vibration; Eddy current sensor systems and Thermographic testing; Predictive maintenance systems and technologies;
Noise monitoring & mitigation	Accurately noise & vibration from running gears and wheels and how these interact wheels and tracks interact;
Systems	Biometric technologies for identification and verification of passengers in terms of safety/ security issues; Drones with infrared sensors for monitoring trespassers into secure rail areas; Train Control Management System-TCMS (ERTMS, ETCS, TCMS); Global Navigation Satellite System (GNSS) or European Global Navigation Satellite System (EGNSS) integrated with TCMS; Innovative cost-effective satellite-based train control speed supervision system; GNSS moving blocks, as new signalling train separation concepts; Telematic Applications for Freight (TAF)/Telematic Specifications for Interoperability (TSI) standards; ticketing mechanisms and technologies including collection of dynamic and static data; Infomodality

For the maritime transport mode the most dominant identified themes were electrified vessels followed by CAE, alternative fuels, multi-engine fuels, ship design, secondary energy converters and integrated emissions control. Autonomous ships and sensor technologies were also identified as potential future technologies for implementation. Table 6 presents the maritime technology themes that have been researched by projects and literature in a more synoptic way.

**Table 6. Maritime transport brief synopsis of technology themes**

<b>Maritime transport brief synopsis of technology themes</b>	
Ship Design	Design for: recreational vehicles; CNG transport; inland water ways vessels; hull optimization for fuel consumption; future retrofitting technologies; holistic ship design methodologies; ship hull air lubrication;
Electrified vessels	Hydrofoil taxi; electric ferry; Hybrid propulsion
Autonomous ships	Autonomous ship merchant vessels
Computer Aided Engineering	Simulations for wave resistance; CAD and Computational Fluid Dynamic of for hull design; design procedures and CAD tools for Fibre Reinforced Polymer Ships; simulations for retrofitting technologies; software development for life cycle modelling; shipyard simulation; cavitation sound modelling
Inspection	Unmanned Aerial Vehicles for ship inspection and magnetic robots for hull inspection; Structural health monitoring sensors
Materials	Fibre Reinforced Polymers (FRP); advanced materials; composite patch repairs; nano materials; ship coating for antifouling
Manufacturing processes	New welding techniques and additive manufacturing
Exhaust after treatment	Selective catalytic reduction for high sulphur fuels; Diesel particulate filters; Exhaust gas recirculation; Electrostatic seawater scrubber (ESWS) for PM, SO <sub>2</sub> and water solubles; Non Thermal Plasma Reactor (NTPR) using Electron Beam and Microwave to remove NO <sub>x</sub> , Volatile Organic Compounds (VOC), CO; SO <sub>2</sub> dry and wet scrubbers; Combination of SCR and EGR
Resistance & propulsion	Trim monitoring control; Propeller design; Ship stability; Combinators; Pod propulsion
Multi-fuel engines	LNG/Diesel; Fuel flexible engines 2 stroke and 4 stroke engine; CNG) and/ or Liquefied Natural Gas (LNG) as an alternative hydrocarbon fuel to HFO; LNG-LPG/Diesel
Secondary energy converters	Electric motors; Electric heaters; Waste heat recovery systems; Hydrogen generators for auxiliary power; Fuel cells; Hybrid propulsion
Renewable energies	Kite and suction sail propulsion simulation; Wind assisted vessels with rotor sails; Photovoltaic (PV) systems for energy storage
Hydrodynamic s	Pre-swirl stators and Boundary Layer Alignment Devices (BLAD); bulbous bow
Ports	Use of electricity and alternative fuels in cargo handling equipment; Alternative Maritime Power; Robotic systems for unloading cargo, automated vehicles and cranes; Internet of Things and big data analytics for monitoring of vessels, vehicles and equipment in real time; Intelligent holistic port managements systems that will cover all port aspects such as ships, cargo, passengers, workers and intermodal solutions offering connectivity with other transport modes
Systems	Sea traffic controls systems; High bandwidth networks and satellite communications will be required, allowing wireless connectivity or all the remote systems; decision support systems for crew/ passenger evacuations that will assist in the process during emergencies.

In terms of international and national research projects, 34 projects were reviewed due to the fact that more time and effort was consumed by the amount of EU research projects available. The technology needs of other international countries such as Russia, USA, China

India and Japan have briefly been covered through technology roadmaps, studies and websites.

Foresights from the Russian Government have identified a series of technologies such as: Computer-aided systems for monitoring of vehicles and transport infrastructure; ITS; New materials and advance manufacturing processes for vehicles and transport infrastructure including big data; Energy-efficient and safe vehicles and next generation transport systems; New materials and technologies for construction and operation of transport infrastructure in the Arctic and sub-Arctic areas; Energy efficient and environmental friendly means of transportation; Safety and security of infrastructure; Modernisation of rail infrastructure and rolling stock including better connectivity of the different Russian Federation regions; Ships building and relevant production technologies; navigation technologies for ships.

For the US, aviation, road and maritime transport technology priorities have been presented. For the US aviation some of the key concepts identified were: 1) support of existing flight simulation and modelling infrastructure like the FutureFlight Central, 2) New aircraft design, 3) Aircraft engine development and reduction of emissions including introduction of alternative fuels and electric propulsion in aircrafts, 4) Noise reduction, 5) Optimisation of air traffic flow, 6) Autonomous systems, 7) UAVs and 8) real time safety assurance systems. In addition, for the US road sector some of the priorities that were identified were autonomous self-driving vehicles for congestion reduction, connected vehicles advanced driver assistance systems and vehicle platooning including demonstrator projects that will test, evaluate and enable the aforementioned technologies. Interoperability standards of ITS and connected vehicles are also main priorities. Furthermore, the USDOT is carrying out research on big data, visualisation of collected data from mobility and other devices, traffic management and infomodality that will enable intermodal and seamless transport. Finally, in terms of the US maritime sector, some of the main priorities were: 1) innovation at port level to reduce environmental footprint, 2) introduction of alternative fuels on vessels, 3) environmentally friendly disposal of end of life ships, 4) ITS technologies for maritime/intermodal transportation, 5) door-to-door cargo tracking, 6) automation for vessels, ports and shipyards, 7) new ship designs.

For India the focus of transport priorities was based on making close collaboration between academia, government, research institutes and industry in order to create investments in EV indigenous vehicle manufacturing and research and electrification of road transport. In addition cluster groups for Battery Management Systems (BMS) and batteries, power, electronics and motors and testing infrastructure/HR/efficient technologies are expected to be created by this collaboration. In addition priorities are also set on buses and Bus Rapid Transport systems and investments in technology improvement of city bus systems. Focus on clean energy and environmentally friendly energy production will be required and will find usage in electromobility. Alternative fuels such as biobased fuels and hydrogen are also priority topics for the Indian government. Pedestrian road safety has also been highlighted which will require technology assisted driver training systems in order to minimise fatalities. Integration of ICT systems and traffic management will be required to reduce road traffic congestion. Finally, modernisation of the rail infrastructure and high speed rail freight corridors are also areas for development.

For China some of the main transport technology priorities that were identified were the following: 1) Investment in EV for passenger transport ranging from electric motors to battery

development including fuel cells and charging/refuelling infrastructure 2) Development of the aviation sector through new aircraft concepts, new UAVs for logistics, hub airports and big data, additive manufacturing, improvements in aircraft aerodynamics and noise emissions 3) Development of high speed rail (for passenger and freight), new materials and intelligent manufacturing, maglev traffic control systems, autonomous train systems, 4) Electric and alternative fuel in ship propulsion, new smart vessel design including new manufacturing technologies, e-Navigation, port development and automation. 5) Environmental friendly and seamless logistics systems and access of sea-land between China, Japan and Korea.

Regarding Japan, the literature has indicated the following priorities. In the road sector autonomous vehicles and automated driving is required at local and highway level; ICT infrastructure that will enable autonomous vehicles such as radar, cameras, laser scanners, and vehicle technologies; advanced digital maps; V2V and V2I communication systems; truck platooning; MaaS; ultra small electric urban vehicles; fuel cell vehicles and hydrogen refuelling infrastructure; express tollways; innovative road based logistics; automated infrastructure inspection. In the waterborne sector the following priority areas are identified: Specialised tanker vessels for hydrogen and LNG transport; Increase of productivity in shipbuilding; efficient ships; use of CAE to eliminate testing; IoT and data from ship manufacturing; Satellite and communication systems; dual fuel engines; propulsion systems. For the aviation sector: air transport infrastructure; new aircraft concepts and quiet supersonic small passenger aircrafts; electric and hybrid propulsion; airframe technologies for better aerodynamics and noise reduction; green engine technologies for better efficiency and less noise; eco structural materials; air traffic management; radiation monitoring using UAVs; CAE.

## References

- ACARE (2017), *Strategic Research & Innovation Agenda*, 2017 Update | Volume 1, <http://www.acare4europe.org/sria> assessed online 21/01/2018
- AIRBUS (2017), *Airbus, Rolls-Royce, and Siemens team up for electric future Partnership launches E-Fan X hybrid-electric flight demonstrator*, <http://www.airbus.com/newsroom/press-releases/en/2017/11/airbus--rolls-royce--and-siemens-team-up-for-electric-future-par.html> assessed online 10/02/2018
- Alstom (2017), *Coradia iLint regional train*, Alstom website, <http://www.alstom.com/products-services/product-catalogue/rail-systems/trains/products/coradia-ilint-regional-train/> assessed online 11/02/2018
- Amoore J., Jaiswall J., (2013) *ERRAC Work Package 05: Strengthening Competitiveness*, <http://www.errac.org/wp-content/uploads/2013/07/WP05-FINAL-ROADMAP-REPORTv6-3.pdf>
- ARUP (2014), *Future of rail 2050*, <https://www.arup.com/publications/research/section/future-of-rail-2050> , accessed online 15/02/2018



Audi (2017), *Looking ahead to the new Audi A8: Space Frame with a unique mix of materials*, <https://www.audi-mediacycenter.com/en/press-releases/looking-ahead-to-the-new-audi-a8-space-frame-with-a-unique-mix-of-materials-7567> accessed online 12/02/2018

Bian M. Z., Sasaki T. T., Suh B. C., Nakata T., Kamado S., Hono K., (2017), A heat-treatable Mg–Al–Ca–Mn–Zn sheet alloy with good room temperature formability”, *Scripta Materialia* Vol. 138, pp151-155, <http://doi.org/10.1016/j.scriptamat.2017.05.034>

Boile M., Sdoukopoulos L., Gagatsi E. (2010), *D2.3- Inventory of EU funded maritime transport research projects, analysis of research outcomes. Draft publication with the achievements recommendations – assessment of the results of FP5/FP6/FP7 maritime projects*, MARitime POLicy Support- MARPOS project.

CargoCap, <http://www.cargocap.com/>

Dekhtyaruk Y., Karyshev I., Korableva M., Velikanova N., Edelkina A., Karasev O., Klubova M., Bogomolova A., Dyshkant N. (2014) *Foresight in Civil Shipbuilding — 2030. Foresight-Russia*, vol. 8, no 2, pp. 30–45, <https://ideas.repec.org/a/hig/fsight/v8y2014i2p30-45.html>, accessed online 09/02/2018

Deloitte, (2017), *2017 Global aerospace and defence industry outlook- Growth prospects remain upbeat*, <https://www2.deloitte.com/global/en/pages/manufacturing/articles/global-a-and-d-outlook.html> , assessed online 21/01/2018

DLR (2017), *DLR and Lufthansa Technik investigate biofuels in new study*, DLR website, [http://www.dlr.de/dlr/en/desktopdefault.aspx/tabid-10176/372\\_read-22563/#/gallery/27096](http://www.dlr.de/dlr/en/desktopdefault.aspx/tabid-10176/372_read-22563/#/gallery/27096), assessed online 9/02/2018

Du J. And Ouyang M. (2013) Review of electric vehicle technologies progress and development prospect in China. Paper presented at the 27th international electric vehicle symposium and exhibition, Barcelona, 17–20 November 2013. <http://ieeexplore.ieee.org/abstract/document/6914849/?reload=true> accessed online 21/01/2018

Ecola L., Charlene Rohr C., Zmud J., Kuhnimhof T., , Phleps P., (2014), *The Future of Driving in Developing Countries*, Rand Corporation, [https://www.rand.org/pubs/research\\_reports/RR636.html](https://www.rand.org/pubs/research_reports/RR636.html) accessed online 23/03/2018.

ERRAC (2016), *Research and Innovation –Advancing the European Railway: Future of Surface Transport Research Rail, Technology and Innovation Roadmaps*, [http://www.errac.org/wp-content/uploads/2016/04/CER\\_FosterRail\\_publication\\_2016\\_DEF.pdf](http://www.errac.org/wp-content/uploads/2016/04/CER_FosterRail_publication_2016_DEF.pdf) accessed online 10/02/2018.

ERTRAC, (2016), *Future Light and Heavy Duty ICE Powertrain Technologies*, [http://www.ertrac.org/uploads/documentsearch/id42/2016-06-09\\_Future%20ICE\\_Powertrain\\_Technologies\\_final.pdf](http://www.ertrac.org/uploads/documentsearch/id42/2016-06-09_Future%20ICE_Powertrain_Technologies_final.pdf) , assessed online 22/02/2018.

ERTRAC (2017a), *Automated Driving Roadmap*, ERTRAC Working Group “Connectivity and Automated Driving,

[http://www.ertrac.org/uploads/images/ERTRAC\\_Automated\\_Driving\\_2017.pdf](http://www.ertrac.org/uploads/images/ERTRAC_Automated_Driving_2017.pdf) accessed online 31/01/2018, accessed online 14/02/2018

ERTRAC (2017b), *Strategic Research Agenda, Input to 9<sup>th</sup> EU Framework Programme*. <http://www.ertrac.org/uploads/documentsearch/id51/Draft-ERTRAC-SRA-for-%20FP9-%20version-for-public-consultation.pdf> accessed online 5/4/2018.

ERTRAC (2018), *ERTRAC recommendations on the next EU R&D Programme (FP9)*,

ERTRAC working group (2017) *Integrated Urban Mobility Roadmap*, <http://www.ertrac.org/uploads/documentsearch/id45/2017%20ERTRAC%20Urban%20Mobility%20Roadmap%20-%20web.pdf>

ERTRAC, EPoSS and ETIP SNET (2017), *European Roadmap Electrification of Road Transport*, [http://www.ertrac.org/uploads/documentsearch/id50/ERTRAC\\_ElectrificationRoadmap2017.pdf](http://www.ertrac.org/uploads/documentsearch/id50/ERTRAC_ElectrificationRoadmap2017.pdf) accessed online 12/02/2018

European Commission (2011), *White Paper- Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system*, COM(2011) 144 final , Brussels, <http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0144&from=EN> accessed online 10/02/2018.

European Commission (2012), *Aeronautics and Air Transport Research Project Synopses - 7th Framework Programme 2007-2013*, Volume 2 Calls 2010 & 2011, Directorate-General for Research and Innovation Cooperation/Transport (including Aeronautics).

European Commission (2014), *Sustainable Surface Transport Research 7th Framework Programme 2007-2013, Project Synopses - Volume 2*, Calls 2010 to 2013, Directorate-General for Research and Innovation Cooperation/Transport (including Aeronautics), Brussels.

European Commission, (2017), *Connected and Automated Transport* <https://ec.europa.eu/programmes/horizon2020/en/news/connected-and-automated-transport-expert-group-report>

EUCAR, (2015), *Projects Book 2015–2016*, [http://www.eucar.be/wp-content/uploads/2015/11/EUCAR\\_Projects\\_Book\\_2015\\_2016.pdf](http://www.eucar.be/wp-content/uploads/2015/11/EUCAR_Projects_Book_2015_2016.pdf) accessed online 31/01/2018.

EUCAR, (2016), *Project Book 2017*, [http://www.eucar.be/wp-content/uploads/2016/12/Projectbook\\_2017\\_WEB.pdf](http://www.eucar.be/wp-content/uploads/2016/12/Projectbook_2017_WEB.pdf), accessed online 31/01/2018

EUCAR (2017), *Project Book 2018*, [http://www.eucar.be/wp-content/uploads/2017/11/PROJECTBOOK\\_2018.pdf](http://www.eucar.be/wp-content/uploads/2017/11/PROJECTBOOK_2018.pdf) ,accessed online 31/01/2018

EY (2014), *The road to 2030: a survey of infrastructure development in Russia*. EYG no. AU2325. EYGM Limited, [http://www.ey.com/Publication/vwLUAssets/EY-russia-infrastructure-survey-2014-eng/\\$FILE/EY-russia-infrastructure-survey-2014-eng.pdf](http://www.ey.com/Publication/vwLUAssets/EY-russia-infrastructure-survey-2014-eng/$FILE/EY-russia-infrastructure-survey-2014-eng.pdf), accessed online 05/02/2018

GAO (2017) Automated Vehicles: Comprehensive Plan Could Help DOT Address Challenges, GAO-18-132 (Washington, D.C.: November 2017). <https://www.gao.gov/assets/690/689234.pdf> accessed online 06/02/2018

Goulding and Morell M. (2014), *Future of Highways*, ARUP, <http://www.driversofchange.com/projects/future-of-highways/> accessed online 30/03/2014

Hitachi (2012), *Future Railway Technologies for Satisfying Social Needs*, Hitachi Review, Vol. 61, No.6, [http://www.hitachi.com/rev/archive/2012/r2012\\_07.html](http://www.hitachi.com/rev/archive/2012/r2012_07.html) accessed online 27/12/2017

Honeywell Aerospace (2018), *Connected Maintenance For A Connected World*, <https://aerospace.honeywell.com/en/products/auxiliary-power-and-thermal/godirect-connected-maintenance-for-apus> accessed online 17/04/2018.

Hybrid Port Energy (2017), *LNG Hybrid Barge*, available from: [http://www.lng-hybrid.com/2\\_about\\_hpe/about\\_hpe.html](http://www.lng-hybrid.com/2_about_hpe/about_hpe.html) assessed online 18/01/2018.

IATA, (2013), *Technology Roadmap*, 4<sup>th</sup> edition, <https://www.iata.org/whatwedo/environment/Documents/technology-roadmap-2013.pdf> assessed online 21/01/2018

IATA (u.d.), *Why governments and the aviation industry have to prepare together for the next golden age of air travel*, <https://www.iata.org/whatwedo/workgroups/Documents/single-token-pax-facilitation.pdf> accessed online 4/4/2018

IATA (2018), *One ID concept paper*, Version 1, [http://www.iata.org/whatwedo/passenger/Documents/OneID\\_Concept\\_Paper-Version1-January2018.pdf](http://www.iata.org/whatwedo/passenger/Documents/OneID_Concept_Paper-Version1-January2018.pdf) accessed online 4/4/2018

IAV, (2018), <https://www.iav.com/us>

ICAO (2011), *Review: Sustainable alternative fuels for aviation*, International Civil Aviation Organisation, Canada, [www.icao.int](http://www.icao.int)

IfM Eduction and Consultancy Services Limited and University of Cambridge, (2015), *UK Marine Industries Technology Roadmap 2015*, [http://www.ukmarinealliance.co.uk/sites/default/files/UKMIA%20Roadmap%202015\\_0.pdf](http://www.ukmarinealliance.co.uk/sites/default/files/UKMIA%20Roadmap%202015_0.pdf) accessed online 12/04/2018.

Intel (2014), *Technology and Computing Requirements for Self-Driving Cars*, <http://les-svc.org/wp-content/uploads/2015/06/2016-05-18-Intel-automotive-autonomous-driving-vision-paper.pdf> , accessed online 14/02/2018

International Airport (2017), *The future of aviation: a definitive guide to the next 20 years* <https://www.internationalairportreview.com/article/34859/future-aviation-next-20-years/> ,accessed online 19/02/2018.

IT Strategic Headquarters (2016), *Public-Private ITS Initiative/Roadmaps 2016.: Toward the Realization of Automated Driving on Highways and Unmanned Autonomous Driving Transport Services in Limited Regions by 2020*,

[https://japan.kantei.go.jp/policy/it/2016/itsinitiative\\_roadmaps2016.pdf](https://japan.kantei.go.jp/policy/it/2016/itsinitiative_roadmaps2016.pdf) accessed online 29/03/2018

Karagiannopoulos L., Sonali P., Sheldrick A. (2017), Norway races Australia to fulfil Japan's hydrogen society dream, Reuters website, <https://www.reuters.com/article/us-japan-hydrogen-race/norway-races-australia-to-fulfill-japans-hydrogen-society-dream-idUSKBN17U1QA> accessed online 12/04/2018

Kolik, A., A. Radziwill and N. Turdyeva (2015), "Improving Transport Infrastructure in Russia", *OECD Economics Department Working Papers*, No. 1193, OECD Publishing, Paris. <http://dx.doi.org/10.1787/5js4hmcs3mxp-en> , accessed online 14/02/2018

Lang . N., Rüßmann M., Chua J., Doubara, X., (2017), *Making Autonomous Vehicles a Reality: Lessons from Boston and Beyond*, [http://image-src.bcg.com/Images/BCG-Making-Autonomous-Vehicles-a-Reality-Oct-2017\\_tcm9-173687.pdf](http://image-src.bcg.com/Images/BCG-Making-Autonomous-Vehicles-a-Reality-Oct-2017_tcm9-173687.pdf)

Lennert F, Macharis C., (VUB Brussels), van Acker V., Neckermann L. (2017), *Smart Mobility and services- Expert group report*, <http://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetailDoc&id=34596&no=1> accessed online 14/02/2018

Linerberger R., Hussain A., Mehra S., Pankratz D., (2018), *Elevating the future of mobility- Passenger drones and flying cars*, [https://www2.deloitte.com/content/dam/insights/us/articles/4339\\_Elevating-the-future-of-mobility/DI\\_Elevating-the-future-of-mobility.pdf](https://www2.deloitte.com/content/dam/insights/us/articles/4339_Elevating-the-future-of-mobility/DI_Elevating-the-future-of-mobility.pdf), accessed online 4/4/2018

Lloyd's register, (2015), *Global Marine Technology Trends 2030*, Lloyd's Register, QinetiQ and University of Southampton

Lloyd's register, (2017), *Global Marine Technology Trends 2030 Autonomous Systems*, Lloyd's Register Group Ltd, QinetiQ and University of Southampton.

Malkin P., Bisagni C., Golinska P., Schmitt D., Peter van den Bossche P., Salvato F., (2017) *Vehicle Design & Manufacturing*, Expert group report, <http://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetailDoc&id=34594&no=1> 12/02/2018

MARAD (2017), *Maritime Administration Strategic Plan: Navigating the Future 2017 – 2021*, <https://www.marad.dot.gov/wp-content/uploads/pdf/MARAD-Strategic-Plan-2017-2021-20170119-Final-signed.pdf> accessed online 01/02/2018

Martin M. (2018), *Four Commercial Trends Hitting Aviation in 2018*, Aviation Today Website , <http://www.aviationtoday.com/2018/01/01/digital-twins-ai-mobile-apps-drones-4-tech-developments-set-hit-commercial-aviation-2018/> accessed online 17/04/2018

Marinet.org (2018), Technological platform to develop the unmanned navigation systems based on computer simulation in virtual environment, <https://marinet.org/technological-platform-to-develop-the-unmanned-navigation-systems-based-on-computer-simulation-in-virtual-environment/> assessed 20/01/2018.

Ministry of Education and Science of the Russian Federation, National Research University and Institute for Statistical Studies and Economics of Knowledge (2014) *Russia 2030*:

*Science and Technology Foresight* - Moscow: HSE, 2016. – 232 p. – 300 copies. – ISBN 978-5-7598-1351-4, <https://issek.hse.ru/en/news/172190256.html>, accessed online 03/02/2018

METI, (2018), Basic Hydrogen Strategy, [http://www.meti.go.jp/english/press/2017/1226\\_003.html](http://www.meti.go.jp/english/press/2017/1226_003.html)

Ministry of Environment, MLIT (2010), Environmentally Sustainable Transport Initiative in Japan, presentation, <http://www.uncrd.or.jp/content/documents/5EST-B1G204.pdf> , accessed online 30/03/2018

MLIT (Ministry of Land, Infrastructure, Transport and Tourism) (n.d.), *Future directions for the trilateral ITS cooperation*, Presentation, <http://www.mlit.go.jp/road/ITS/pdf/FuturedirectionsforthetrilateralITScooperation.pdf> accessed online 30/03/2018.

MLIT (Ministry of Land, Infrastructure, Transport and Tourism), (2013), *Basic Plan on Ocean Policy*, [https://www.kantei.go.jp/jp/singi/kaiyou/kihonkeikaku/130426kihonkeikaku\\_e.pdf](https://www.kantei.go.jp/jp/singi/kaiyou/kihonkeikaku/130426kihonkeikaku_e.pdf) accessed online 12/04/2018

MLIT (Ministry of Land, Infrastructure, Transport and Tourism), (2016a), *Joint Statement of The 6th China-Japan-Korea Ministerial Conference on Transport And Logistic*, <http://www.mlit.go.jp/common/001140429.pdf>, accessed online 4/4/2018

MLIT (Ministry of Land, Infrastructure, Transport and Tourism), (2016b), White Paper On Land, Infrastructure, Transport And Tourism In Japan, 2016, <http://www.mlit.go.jp/en/statistics/white-paper-mlit-2016.html> accessed online 13/04/2018

Mori H., (2016), Japanese Policies in Maritime Industry, Future technology and Finance on maritime sector in Japan and Norway, presentation, 12<sup>th</sup> February, <http://www.mlit.go.jp/common/001121368.pdf> accessed online 12/04/2018.

NASA (2016), *NASA Electric Research Plane Gets X Number, New Name*, <https://www.nasa.gov/press-release/nasa-electric-research-plane-gets-x-number-new-name> , assessed online 10/02/2018.

NASA (2017) NASA Aeronautics: Strategic Implementation Plan. 2017 Update. Washington, DC 20546, NP-2017-01-2352-HQ. <https://www.nasa.gov/sites/default/files/atoms/files/sip-2017-03-23-17-high.pdf> accessed online 04/02/2018

Paris C., (2017), Norway Takes Lead in Race to Build Autonomous Cargo Ships, The Wall Street Journal website, [www.wsj.com](http://www.wsj.com) assessed online 16/01/2018

Rand (2018), Examining Future Transport Scenarios to Drive Innovation in the UK, <https://www.rand.org/randeurope/research/projects/future-transport-scenarios.html> , accessed online 17/04/2018.

Raponso A., Ciuffo B., Makridis, M. and Thiel, C., (2017), *The r-evolution of driving: from Connected Vehicles to Coordinated Automated Road Transport (C-ART)*, Joint Research Centre (JRC), [http://publications.jrc.ec.europa.eu/repository/bitstream/JRC106565/art\\_science\\_for\\_policy\\_report\\_1-soa\\_final\\_tobepublished\\_online.pdf](http://publications.jrc.ec.europa.eu/repository/bitstream/JRC106565/art_science_for_policy_report_1-soa_final_tobepublished_online.pdf) assessed online 14/02/2018.



Railway Technology (2018), Siemens and Ballard to develop new generation of fuel cells for trains, Railway technology website, 27 February 2018, <https://www.railway-technology.com/news/siemens-ballard-develop-new-generation-fuel-cells-trains/>, accessed online 18/04/2018.

Rail-research.org website (2018), JSC Railway Research Institute (VNIIZHT), <http://www.railway-research.org/JSC-Railway-Research-Institute> , accessed online 5/4/2018.

Rolls Royce (2017), *Rolls-Royce demonstrates world's first remotely operated commercial vessel*, [www.rolls-royce.com](http://www.rolls-royce.com) , accessed online 16/01/2018

Russian Railways website (2018), Strategy, [http://eng.rzd.ru/statice/public/en?STRUCTURE\\_ID=7](http://eng.rzd.ru/statice/public/en?STRUCTURE_ID=7) , accessed online 5/4/2018.

Science Daily, (2017), Designing the fuel-efficient aircraft of the future, <https://www.sciencedaily.com/releases/2017/03/170307100430.htm> assessed online 21/01/2018

SHAKTI (Shakti Sustainable Energy Foundation) and DIMTS (Delhi Intergrated Multi – Modal Transit System Limited) (2016) Roadmap for improving City Bus Systems in India. Final Report. <https://smartnet.niua.org/sites/default/files/webform/Roadmap%20for%20improving%20City%20Bus%20Systems%20in%20India.pdf> accessed online 20/01/2018

Shift2Rail (2015), Multi-Annual Action Plan, [http://www.shift2rail.org/wp-content/uploads/2013/07/MAAP-final\\_final.pdf](http://www.shift2rail.org/wp-content/uploads/2013/07/MAAP-final_final.pdf) , accessed online 27/12/2017

Shift2Rail (2017), Multi-Annual Action Plan- executive view, Part A, <https://shift2rail.org/about-shift2rail/reference-documents/> accessed online 27/12/2017

Shukla, P.R., Dhar, S., Pathak, M. And Bhaskar, K., (2014) Promoting Low Carbon Transport in India. Electric Vehicles Scenarios and a Roadmap for India. . UNEP DTU Partnership, Indian Institute of Management, CEPT University. ISBN: 978-87-93130-22-7. <http://www.forskningsdatabasen.dk/en/catalog/2262326728> accessed online 20/01/2018

SITA (2016) SITA's baggage robot lends passengers a hand at Geneva Airport, <https://www.sita.aero/pressroom/news-releases/sitas-baggage-robot-lends-passengers-a-hand-at-geneva-airport> accessed online 19/02/2018

SNTR (2016), *Strategy For The Scientific And Technological Development Of The Russian Federation*, [http://sntr-rf.ru/media/Strategy%20STD%20RF\(eng\).pdf](http://sntr-rf.ru/media/Strategy%20STD%20RF(eng).pdf) accessed online 14/04/2018

Sokolov, A. And Chulok, A. (2014). *Russian S&T foresight 2030: looking for new drivers of growth. In: Shaping Innovation Systems: Using the Future for Shaping STI Policies*. JRC. [https://ec.europa.eu/jrc/sites/jrcsh/files/fta2014-t1Practice\\_177.pdf](https://ec.europa.eu/jrc/sites/jrcsh/files/fta2014-t1Practice_177.pdf) , accessed online 07/02/2018

Takriti E.S., Pavlenko N., and Searle S. (2017), Mitigating International Aviation Emissions Risks And Opportunities For Alternative Jet Fuels, The International Council on Clean Transportation(ICCT), White Paper

Taxibot, <http://www.taxibot-international.com/> accessed online 19/02/2018

TIFAC (Technology Information, Forecasting and Assessment Council) (2015), Technology Vision 2035, <http://planning.kar.nic.in/docs/SDG/Technology%20Vision%202035.pdf> accessed 16/04/2018.

Toyota Motor Corporation (2018), *Japan H2 Mobility, LLC established by eleven companies to accelerate deployment of hydrogen stations in Japan*, Toyota newsroom, [https://newsroom.toyota.co.jp/en/corporate/21322195.html?adid=aq478\\_mail&padid=aq478\\_mail](https://newsroom.toyota.co.jp/en/corporate/21322195.html?adid=aq478_mail&padid=aq478_mail) accessed online 4/12/2018

US DOT (2018a), *Automated Vehicle Research*, [https://www.its.dot.gov/automated\\_vehicle/avr\\_plan.htm](https://www.its.dot.gov/automated_vehicle/avr_plan.htm) accessed online 26/03/2018

US DOT (2018b), *ITS Research 2015-2019 Interoperability*, Office of the Assistant Secretary for Research and Technology, [https://www.its.dot.gov/research\\_areas/interoperability.htm](https://www.its.dot.gov/research_areas/interoperability.htm) , accessed online 23/03/2018.

Voegelé T., Godziejewski B., Grand-Perret S., Rødseth Ø.J., Merat N., van Schijndel-de Nooij M., (2016), *STRIA Roadmap, Connected And Automated Transport (CAT)*, <https://trimis.ec.europa.eu/sites/default/files/roadmaps/STRIA%20Roadmap%20-%20Cooperative%20C%20connected%20and%20automated%20transport.pdf>

Waterborne TP (2016), *Waterborne Strategic Research And Innovation Agenda*, <https://www.waterborne.eu/principal-documents/waterborne-strategic-research-and-innovation-agenda/> assessed online 22/02/2018.

World maritime news, (2017), *CMB Shows Off Its Hydrogen-Powered Vessel*, <https://worldmaritimeneeds.com/archives/236641/cmb-shows-off-its-hydrogen-powered-vessel/> assessed online 17/01/2018.

Yamasaki, Y., Umahashi, S., Uesugi, Y., Ma, Q. *et al.* (2015) "Development of Dynamic Models for an HCCI Engine with Exhaust Gas Rebreathing System," SAE Technical Paper 2015-01-1803 doi: [10.4271/2015-01-1803](https://doi.org/10.4271/2015-01-1803)

Ministry of Transport and Ministry of Science and Technology (2017), *Special Plan for Science and Technology Innovation in the Field of Transport for the Thirteenth Five-year Plan*. In Chinese [http://zizhan.mot.gov.cn/zfxxgk/bnssj/kjs/201706/t20170607\\_2215134.html](http://zizhan.mot.gov.cn/zfxxgk/bnssj/kjs/201706/t20170607_2215134.html) accessed online 01/02/2018

## Annex 1- Templates

### 1. Road transport technologies projects & reports synopsis template

#### Research projects template

Thematic Area		Cluster/Subcluster	Subcluster Description	Technology theme	Technology researched	Project	Project brief results	Funding programme	Sector
<b>Competitiveness</b>	<b>C1</b>	<b>Competitive road transport</b>							
	C1-1	Innovative road transport concepts/ body structures/	future vehicle concepts, autonomous vehicles(non systems), platooning, swarms etc, fuel cell vehicles, Evs (freight/passenger), space frame construction, unibody frame, small urban vehicles, robot taxis, design for safety						
	<b>C2</b>	<b>Competitive road vehicle design</b>							
	C2-1	Design tools and simulation	CAE, computation for virtual & real advanced simulation and testing						
	C2-2	Cabin design & interior							
	<b>C3</b>	<b>Competitive production of road vehicles</b>							
	C3-1	Structural materials & composites	lightweight materials, high strength steel, aluminium, magnesium, SAM2X5-630, plastics and composites						



	<b>C4</b>	<b>Competitive Life Cycle Services</b>							
	C4-1	Life cycle approaches	End of life issues, life cycle concepts						
<b>Environment</b>	<b>ENV1</b>	<b>Reducing emissions</b>							
	ENV1-1	Alternative/conventional fuels	biofuels, alternative fuels, high octane gasoline						
	ENV1-2	Reducing noise & vibration emissions	vehicle noise & vibration emissions						
	ENV1-3	After treatment of exhaust gases	Diesel Oxidation Catalyst (DOC), Diesel Particulate Filter (DPF), NOx Storage Reduction (NSR) and Selective Catalytic Reduction (SCR), cold start trapping technologies, particle filtration (PF), new catalyst materials, catalysts for NGVs						
<b>Energy</b>	<b>ENE1</b>	<b>Optimising resistance and propulsion</b>							
	ENE1-1	Aerodynamics	Aerodynamic issues of passenger and freight vehicles, platooning aerodynamics						

## D 2.1 Transport projects & future technologies synopses handbook

	ENE1-2	Engines / electric motors	High efficiency light and heavy duty combustion engine technologies, hybridisation, downsizing, air management, efficient compressors and turbochargers, reduction of heat losses, waste heat recovery, Spark Controlled Compression Ignition (Mazda Skyactive X engine ), thermoelectric generators, nanocoolants,						
	ENE1-3	Engine cycles	non conventional thermodynamic cycles (Atkinson, Miller)						
	ENE1-4	Transmissions, axles, tyres	frictional losses minimisation, transmission mass reduction, transmission for Evs, dual clutch, automatic transmission, transmissions for hybridisation, transmission for autonomous, Heavy truck transmissions						
	ENE1-5	Batteries							
<b>Infrastructure</b>	<b>INF1</b>	<b>Intermodality</b>							
	<b>INF3</b>	<b>Technologies for resilience</b>	sensors, monitoring strength, stability and security of assets, radar and microradars						
<b>Systems</b>	<b>SYS1</b>	<b>Intelligent Transport System (ITS)</b>	V2V, V2I systems						

	<b>SYS3</b>	<b>Big data</b>	big data from IoT and connected systems						
	<b>SYS4</b>	<b>Vehicle systems</b>							

### Road reports template

Thematic Area		Cluster/Subcluster	Technology theme	Technology identified	Reference	Sector
<b>Competitiveness</b>	<b>C1</b>	<b>Competitive road transport</b>				
	C1-1	Innovative road transport concepts/ body structures/				
	<b>C2</b>	<b>Competitive road vehicle design</b>				
	C2-1	Design tools and simulation				
	C2-2	Cabin design				
	<b>C3</b>	<b>Competitive production of road vehicles and batteries</b>				
	C3-1	Structural materials & composites				
	C3-2	Manufacturing processes, production concepts				
	<b>C4</b>	<b>Competitive Life Cycle Services</b>				
	C4-1	Life cycle approaches				
<b>Environment</b>	<b>ENV1</b>	<b>Reducing emissions</b>				
	ENV1-1	Alternative/conventional fuels				
	ENV1-2	Reducing noise & vibration emissions				
	ENV1-3	After treatment of exhaust gases				
<b>Energy</b>	<b>ENE1</b>	<b>Optimising resistance and propulsion</b>				
	ENE1-1	Aerodynamics				
	ENE1-2	Engines / electric motors				
	ENE1-3	Engine cycles				

	ENE1-4	Transmissions, axles, tyres				
	ENE1-5	Batteries				
<b>Infrastructure</b>	<b>INF1</b>	<b>Intermodality</b>				
	<b>INF2</b>	<b>Refuelling infrastrurcture for alternative fuels and innovative concepts</b>				
	<b>INF3</b>	<b>Technologies for resilience</b>				
<b>Systems</b>	<b>SYS1</b>	<b>Intelligent Transport System (ITS)</b>				
	<b>SYS2</b>	<b>Autonomous and connected vehicles and systems</b>				
	<b>SYS3</b>	<b>Big data</b>				
	<b>SYS4</b>	<b>Vehicle systems</b>				

## 2. Aviation transport technologies projects & reports synopsis template

### Aviation research projects template

Thematic Area		Cluster/Subcluster	Subcluster Description	Technology theme	Technology researched	Project	Project brief results	Funding programme	Sector
<b>Competitiveness</b>	<b>C1</b>	<b>Competitive aviation</b>							
	C1-1	Innovative aircraft concepts/ frames/structures	Strut / truss braced wings, hybrid wing body, morphing airframes, low noise configurations, Personalized and individualized transportation to/from and within airport and during air travel, Small						

## D 2.1 Transport projects &amp; future technologies synopses handbook

			on-demand aircraft						
	<b>C2</b>	<b>Competitive aircraft design</b>							
	C2-1	Design tools for structural reliability	CAE + other tools, computation for virtual & real advanced simulation and testing						
	C2-2	Cabin	Windowless designs, Differentiation of flight cabin classes and zones according to individual needs, modular cabin design, Wide scale deployment of in-flight communication for passengers (mobile phone, Wi-Fi), Virtual reality in-flight entertainment						
	<b>C3</b>	<b>Competitive aircraft production</b>							
	C3-1	Structural materials & composites	Composites, Al-Li alloys, nanomaterials						
	C3-2	Manufacturing processes	Additive manufacturing, other possible processes						
	<b>C4</b>	<b>Competitive Life Cycle Services</b>							
	C4-1	Inspection & maintenance	inspection & maintenance new methods						
	C4-2	Repair, retrofit	repair and retrofitting new methods						
	C4-3	Life cycle approaches	Aircraft Life cycle						
<b>Environment</b>	<b>ENV1</b>	<b>Reducing emissions</b>							
	ENV1-1	Alternative fuels	biofuels, alternative fuels						
	ENV1-2	Reducing noise emissions	engine/aircraft noise emissions						
<b>Energy</b>	<b>ENE1</b>	<b>Optimising resistance</b>							

## D 2.1 Transport projects &amp; future technologies synopses handbook

		and propulsion							
	ENE1-1	Aerodynamics	High lift devices, drag reductions coatings, winglets, riblets, laminar flow, boundary layer, wingtip devices,						
	ENE1-2	Engines	Advanced and open geared Turbofan, open rotor engines, electric propulsion, fans, engine cooling technologies, hybrid propulsion, distributed propulsion, combustors, compressors, low noise configurations						
	ENE1-3	Engine cycles	engine cycles						
	ENE1-4	Nacelles	buried engines, reduced weight nacelles						
Infrastructure	INF1	Airport safety/ security	Airport safety/ security procedures, Integrated security approach "no borders"						
	INF2	Innovative airport concepts	Central airport and inner-city air transport concepts,						
	INF3	Airport operations	full automation of passenger baggage processes						
	INF4	Intermodality	Improved performance and integration with other modes						
Systems	SYS1	Aircraft systems	Flight control systems, System Health Monitoring - diagnostic and prognostic, Flying communication networks						

	<b>SYS2</b>	<b>Air traffic Management</b>	Future Air traffic management & control, airport procedures						
--	-------------	-------------------------------	---	--	--	--	--	--	--

### Aviation reports template

Thematic Area		Cluster/Subcluster	Technology theme	Technology identified	Reference	Sector
<b>Competitiveness</b>	<b>C1</b>	<b>Competitive aviation</b>				
	C1-1	Innovative aircraft concepts/ frames/structures				
	<b>C2</b>	<b>Competitive aircraft design</b>				
	C2-1	Design tools for structural reliability				
	C2-2	Cabin				
	<b>C3</b>	<b>Competitive aircraft production</b>				
	C3-1	Structural materials & composites				
	C3-2	Manufacturing processes & production				
	<b>C4</b>	<b>Competitive Life Cycle Services</b>				
	C4-1	Inspection & maintenance				
	C4-2	Repair, retrofit				
	C4-3	Life cycle approaches				
<b>Environment</b>	<b>ENV1</b>	<b>Reducing emissions</b>				
	ENV1-1	Alternative fuels				
	ENV1-2	Reducing noise emissions				
<b>Energy</b>	<b>ENE1</b>	<b>Optimising resistance and propulsion</b>				
	ENE1-1	Aerodynamics				
	ENE1-2	Engines				
	ENE1-3	Engine cycles				
	ENE1-4	Nacelles				
<b>Infrastructure</b>	<b>INF1</b>	<b>Airport safety/ security</b>				

	INF2	Innovative airport concepts				
	INF3	Airport operations				
	INF4	Intermodality				
Systems	SYS1	Aircraft systems				
	SYS2	Air traffic Management				

### 3. Rail transport technologies projects & reports synopsis template

#### Rail research projects template

Thematic Area		Cluster/Subcluster	Subcluster Description	Technology theme	Technology researched	Project brief results	Project	Funding programme	Sector
Competitiveness	C1	Competitive rail							
	C1-1	Innovative rail concepts/ carbodies/wagons	Traction systems, high speed carbody, wagon, bogies, eddy current brake systems, train modularity, Personal Rapid Transit (PRT) and Hyperloop,						
	C2	Competitive rail design							
	C2-1	Design tools for structural reliability	CAE + other tools						
	C2-2	Cabin design	Inclusive train design, modular trains and cabins to flexibly adapt to passenger needs						
	C3	Competitive rail production							
	C3-1	Structural materials & composites	materials & composites						
	C3-2	Manufacturing processes	new manufacturing process, additive manufacturing, 3D printing						
	C4	Competitive Life Cycle Services							



## D 2.1 Transport projects &amp; future technologies synopses handbook

	C4-1	Inspection & maintenance	inspection & maintenance new methods (vehicles and tracks)						
	C4-2	Repair, retrofit	repair and retrofitting new methods						
	C4-3	Life cycle approaches	train life cycle						
<b>Environment</b>	<b>ENV1</b>	<b>Reducing emissions</b>							
	ENV1-1	Alternative fuels	biofuels,						
	ENV1-2	Reducing noise emissions	Noise & vibration						
	ENV1-3	After treatment of exhaust gases	After treatment of diesel powerplant exhaust						
	ENV1-4	Green train operations	Regenerative energy storage systems, Battery technologies and onboard energy storage systems						
<b>Energy</b>	<b>ENE1</b>	<b>Optimising resistance and propulsion</b>							
	ENE1-1	Aerodynamics	train aerodynamics						
	ENE1-2	Engines & powerplants	hybrid systems, engine advances etc, diesel powerplant						
<b>Infrastructure</b>	<b>INF1</b>	<b>Station operations</b>	future stations, station design, improved train platform interface, novel terminal, hubs						
	<b>INF2</b>	<b>Rail safety/ security</b>							
	<b>INF3</b>	<b>Intermodality</b>	connectivity with other modes of transport						
	<b>INF4</b>	<b>Track systems</b>	new generation track system						
	<b>INF5</b>	<b>Grid &amp; energy</b>	smart power supply						

<b>Systems</b>	<b>SYS1</b>	<b>Rail systems</b>	Traffic control & management systems (TCMS), automatic train operations, Driverless freight trains, Machine to Machine technologies (M2M), TAP/TAF TSI Telematics applications for passenger/freight Technical specifications of interoperability, Ticketless technologies travel, mobility as a service, intelligent trains						
----------------	-------------	---------------------	--	--	--	--	--	--	--

### Rail reports template

Thematic Area		Cluster/Subcluster	Technology theme	Technology identified	Report name	Sector
<b>Competitiveness</b>	<b>C1</b>	<b>Competitive rail</b>				
	C1-1	Innovative rail concepts/ carbodies/wagons				
	<b>C2</b>	<b>Competitive rail design</b>				
	C2-1	Design tools for structural reliability				
	C2-2	Cabin design				
	<b>C3</b>	<b>Competitive rail production</b>				
	C3-1	Structural materials & composites				
	C3-2	Manufacturing processes				
	<b>C4</b>	<b>Competitive Life Cycle Services</b>				
	C4-1	Inspection & maintenance				

	C4-2	Repair, retrofit				
	C4-3	Life cycle approaches				
<b>Environment</b>	<b>ENV1</b>	<b>Reducing emissions</b>				
	ENV1-1	Alternative fuels				
	ENV1-2	Reducing noise emissions				
	ENV1-3	After treatment of exhaust gases				
	ENV1-4	Green train operations				
<b>Energy</b>	<b>ENE1</b>	<b>Optimising resistance and propulsion</b>				
	ENE1-1	Aerodynamics				
	ENE1-2	Engines & powerplants				
<b>Infrastructure</b>	<b>INF1</b>	<b>Station operations</b>				
	<b>INF2</b>	<b>Rail safety/ security</b>				
	<b>INF3</b>	<b>Intermodality</b>				
	<b>INF4</b>	<b>Track systems</b>				
	<b>INF5</b>	<b>Grid &amp; energy</b>				
<b>Systems</b>	<b>SYS1</b>	<b>Rail systems</b>				

#### 4. Waterborne transport technologies projects & reports synopsis template

##### Waterborne transport projects template

Thematic Area		Cluster/Subcluster	Subcluster Description	Technology theme	Technology researched	Project	Project brief results	Funding programme	Sector
<b>Competitiveness</b>	<b>C1</b>	<b>Competitive maritime</b>							
	C1-1	Innovative ship concepts	inland waterway vessels, crafts for coastal and offshore, automated						

## D 2.1 Transport projects & future technologies synopses handbook

			and autonomous vessels,						
	C1-2	Shipping operations and E-Maritime	Open and integrated data networks protected from cybersecurity risks enabling new innovative ship functions and easy integration with shore services.						
	<b>C2</b>	<b>Competitive ship design</b>							
	C2-1	Design tools for structural reliability and other functions	CAE + other tools, computation for virtual & real advanced simulation and testing						
	<b>C3</b>	<b>Competitive ship production</b>							
	C3-1	Structural materials & composites	maritime materials						
	C3-2	Production equipment and processes	Advanced welding and multi-material joining processes, New production processes, Strategies and technologies for automation of complex one-off processes, Virtual and Augmented Reality Techniques, Measurement and Reverse Engineering Methods, additive manufacturing						
	<b>C4</b>	<b>Competitive Life Cycle Services</b>							
	C4-1	Inspection & maintenance	inspection & maintenance new						

## D 2.1 Transport projects &amp; future technologies synopses handbook

			methods						
	C4-2	Repair, retrofit & dismantling	repair and retrofitting new methods, Smart solutions for outfitting, repair, retrofit, end-of-life						
	C4-3	Life cycle approaches	Life Cycle Performance Assessment Methods and Tools, Integrated Maritime Design (for Life cycle) Environment						
<b>Environment</b>	<b>ENV1</b>	<b>Reducing emissions</b>							
	ENV1-1	Alternative fuels	biofuels & alternative fuels usage						
	ENV1-2	After treatment of exhaust gases & modelling techniques	2nd generation Post treatment technologies (scrubbers etc), Modelling techniques for emissions reduction						
	<b>ENV2</b>	<b>other emissions from waterborne transport</b>							
	ENV2-1	Reducing airborne and underwater noise							
	ENV2-2	Reduced emissions by paints & cleaning, ballast water							
<b>Energy</b>	<b>ENE1</b>	<b>Optimising resistance and propulsion</b>							

## D 2.1 Transport projects & future technologies synopses handbook

	ENE1 -1	Minimise resistance & optimise propulsion	Friction reduction techniques, Life-cycle considerations, Full scale validation of advanced prediction methods, Delivered power in operational conditions (wind, waves), Dedicated developments for advanced propulsors,						
	ENE1 -2	Ship powering	Improved engine design, new engine components and materials, multi-fuel engines, Zero emission propulsion techniques (wind propulsion, nuclear, electric						
	ENE1 -3	Energy management & analytics for ship operations	Energy Data acquisition and management systems, Analysis and decision making (tools), Dynamic modelling and simulation tools,						

Infrastructure	INF1	Smart and connected ports	Integration of national single windows with trade portals and port community systems, Development of Intelligent holistic solutions for the efficient management of ships in ports for freight, passengers and workers, integrated with Urban Mobility Plans and solutions. Development of digital infrastructure, ICT innovation, and automation: Robotics, automation, and autonomous vehicles;						
	INF2	Intermodality	Improved interoperability of existing port related systems and the integration between transport modes, Improved interconnectivity and integration between transport modes and established systems, such as: Maritime national Single Windows, RIS, e-Customs, TAF, ERTMS and						

			rail one stop shop, "access points", "data pipelines";						
	INF3	Refuelling infrastructure for alternative fuels and innovative concepts	cold ironing, infrastructure to accommodate alternative fuels in shipping						
Systems & safety	SYS1	Maritime systems	Integration of ship navigational and communication facilities aboard ships, including the bridge systems, other ships, VTS and SAR, into a European marine digital highway information system. Integration of navigation technologies with shore based data networks and centres: (SafeSeaNet, (AIS, LRIT), GNSS, National Single Window, VTS, route planning etc.). Ship to shore communications						
	SYS2	Safety	Safe automation and autonomy, accident prevention,						



			fire resistance						
--	--	--	-----------------	--	--	--	--	--	--

### Waterborne transport reports template

Thematic Area		Cluster/Subcluster	Technology theme	Technology identified	Reference	Sector
<b>Competitiveness</b>	<b>C1</b>	<b>Competitive maritime</b>				
	C1-1	Innovative ship concepts				
	C1-2	Shipping operations and E-Maritime				
	<b>C2</b>	<b>Competitive ship design</b>				
	C2-1	Design tools for structural reliability				
	<b>C3</b>	<b>Competitive ship production</b>				
	C3-1	Structural materials & composites				
	C3-3	Production equipment and processes				
	<b>C4</b>	<b>Competitive Life Cycle Services</b>				
	C4-1	Inspection & maintenance				
	C4-2	Repair, retrofit & dismantling				
	C4-3	Life cycle approaches				
<b>Environment</b>	<b>ENV1</b>	<b>Reducing emissions</b>				
	ENV1-1	Alternative fuels				
	ENV1-2	After treatment of exhaust gases & modelling techniques				
	<b>ENV2</b>	<b>other emissions from waterborne transport</b>				
	ENV2-1	Reducing airborne and underwater noise				
	ENV2-2	Reduced emissions by paints & cleaning, ballast water				
<b>Energy</b>	<b>ENE1</b>	<b>Optimising resistance and propulsion</b>				

## D 2.1 Transport projects & future technologies synopses handbook

	ENE1-1	Minimise resistance & optimise propulsion				
	ENE1-2	Ship powering				
	ENE1-3	Energy management & analytics for ship operations				
<b>Infrastructure</b>	<b>INF1</b>	<b>Smart and connected ports</b>				
	<b>INF2</b>	<b>Intermodality</b>				
	<b>INF3</b>	<b>Refuelling infrastructure for alternative fuels and innovative concepts</b>				
<b>Systems &amp; safety</b>	<b>SYS1</b>	<b>Maritime systems</b>				
	<b>SYS2</b>	<b>Safety</b>				

## Annex 2- Results from reviewed projects and reports

### 2.1 Road transport reports

#### Competitiveness – Road reports

<b>Cluster: C1 Competitive road transport</b>			
<b>Subcluster: C1-1 Innovative road transport concepts/ body structures (future vehicle concepts, autonomous vehicles(non systems), platooning, swarms etc., fuel cell vehicles, Evs (freight/passenger), space frame construction, unibody frame, small urban vehicles, robot taxis, design for safety)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
Logistics planning demonstrators	Large-scale demonstrators on logistics planning for urban city planners showing the impact of concepts, tools and innovations	ERTRAC working group (2017b)	Freight
Electric vehicles	Lightweight electric vehicle concepts with modular designs for customisation to user needs	ERTRAC, EPoSS and ETIP SNET (2017)	Passenger
Electric vehicles	Commercial and purpose design Evs for urban use		Passenger
Hybrid electric vehicles	Next generation PHEV		Passenger
Fuel cell vehicles	Hydrogen powered electric buses		Passenger
Fuel cell vehicles	Hydrogen powered fuel cell trucks (2020-2030)		Freight
Fuel cell vehicles	Fuel cell range extenders for e-trucks (2025 perspective)		Freight
Electric hybrid vehicles	Electric hybrid drivetrains for trucks (short term)		Freight
Electric vehicles	Hermes to deploy 1500 Mercedes-Benz Sprinter and Vito electric vans by 2020 including pilot project in 2018	Hermes to deploy 1500 Mercedes-Benz Sprinter and Vito electric vans by 2020; pilot project in 2018, <a href="http://www.greencarcongress.com">www.greencarcongress.com</a>	Freight
Electric vehicles	The state of California has will use 23 class 8 and 5 electric trucks from BYD in freight and rail yards	First of 27 electric trucks coming to Southern California freight and rail yards, <a href="http://www.arb.ca.gov">www.arb.ca.gov</a>	Freight
Electric vehicles	Japan Post and Honda to create electric motorcycles for postal deliveries	Japan Post and Honda Enter	Freight

		Discussions on Collaboration Toward the Establishment of Social Infrastructure, <a href="http://www.hondanews.info">http://www.hondanews.info</a>	
Autonomous vehicles	Volvo Construction Equipment has developed a concept for an autonomous electric loader the HX2 and an electric hybrid wheel loader the LX1	Volvo CE unveils the next generation of its electric load carrier concept, <a href="http://www.volvoce.com">www.volvoce.com</a>	Freight
Autonomous vehicles	Autonomous shuttle buses, taxis and shared autonomous vehicles identified as potential solutions for the city of Boston. Trials for Avs under the cooperation of the city of Boston and private companies such are NuTonomy, Optimus Ride and Aptiv Plc will have been agreed in 2017	Lang et al. (2017)	Passenger
Fuel cell vehicles and hybrid electric vehicles	Kenworth is developing a Class 8 prototype truck and using hydrogen fuel cells. A second hybrid truck is being developed with CNG engine and an electric motor. The trucks will be used at the Port of Los Angeles	Kenworth Advances Low - Zero Emission Prototype Projects on T680 Day Cab Drayage Trucks for Southern California Ports, <a href="http://www.kenworth.com">www.kenworth.com</a>	Freight
Fuel cell vehicles	UPS is developing a hydrogen fuel cell class 6 delivery trucks. The truck uses 32 kW fuel cell coupled to 45 kWh of battery storage and 10 kg of hydrogen fuel with a range of about 200kms	UPS Unveils First Extended Range Fuel Cell Electric Delivery Vehicle, <a href="http://www.pressroom.ups.com">www.pressroom.ups.com</a>	Freight
Electric vehicles	Cummins has unveiled an electric Class 7 EV urban hauler demonstrator which is fitted with a 140 kWh battery pack and an electric powertrain with range between 160- 480 km based on battery package. The vehicle is to be released by 2022 and will include a natural gas range extender with 50 % less fuel consumption than today's hybrids	Cummins Unveils Next Generation of Energy-Diverse Products and Technology Solutions, <a href="http://www.cummins.com">www.cummins.com</a>	Freight
Electric vehicles	NTU Singapore and BlueSG have developed an ultra-fast charging electric shuttle. Equipped with supercapacitors, it is capable of charging in 20 seconds and of travelling 2 kms on a single charge, with additional backup power of 30kms. It does not require costly infrastructure and a whole line can be deployed in a matter of weeks. Also	NTU Singapore and BlueSG launch ultra-fast charging electric tram; 20-second recharge , <a href="http://www.greencarcongress.com">http://www.greencarcongress.com</a>	Passenger

	special charging stations have been built in the area where the road trials will take place.		
Electric vehicles	Electric vehicles identified as a technology for further research in the FP9 programme and will help achieve carbon neutral transport	ERTRAC (2017b)	Passenger + Freight
Fuel cell vehicles	Further research on hydrogen fuel cell vehicles will be required in the EU FP9 programme	ERTRAC (2017b)	Passenger + Freight
Electric and hybrid vehicles	Increased uptake of PHEV and BEV by improving their range and efficiency. Fully electric buses and electrified heavy duty vehicles. These technologies have been identified as research topics for the the EU FP9 research programme	ERTRAC (2017b)	Passenger
Autonomous vehicles	Google's driverless vehicles	ARUP (2014)	Passenger
Fuel cell vehicles	Cars equipped with hydrogen fuel cells are capable of long journeys of up to 640 km and can be refuelled in minutes.	ARUP (2014)	Passenger + Freight
<b>Cluster: C2 Competitive road vehicle design</b>			
<b>Subcluster: C2-1 Design tools and simulation (CAE, computation for virtual &amp; real advanced simulation and testing)</b>			
Technology theme	Specific technology researched	Reference	Sector
Computer aided engineering	Precise numerical and real time modelling of engine gas management system and controls, fuel system, engine core system, engine combustion and emissions,	ERTRAC (2016)	Passenger + Freight
Testing facilities	Development of strategic testing facilities	Malkin et al (2016)	Passenger+ Freight
<b>Subcluster: C2-2 Cabin design &amp; interior</b>			
Technology theme	Specific technology researched	Reference	Sector
N/A	N/A	N/A	N/A
<b>Cluster: C3 Competitive production of road vehicles</b>			
<b>Subcluster: C3-1 Structural materials &amp; composites (lightweight materials, high strength steel, aluminium, magnesium, SAM2X5-630, plastics and composites)</b>			
Technology theme	Specific technology researched	Reference	Sector
Materials development: new materials	New materials for engine forced induction charging systems, lightweight materials for housing and moving parts, use of anisotropic materials	ERTRAC (2016)	Passenger + Freight

Materials development: advanced materials	SAM2X5-630 is an amorphous steel that can respond to shock loading and can withstand extreme conditions hence it can be processed successfully under extreme conditions. This type of steel could find its usage in the automotive industry	SAM2X5-630: The steel industry fights back!, <a href="http://writingaboutcars.com">http://writingaboutcars.com</a>	Passenger
Materials development: advanced materials	An aluminium, steel, magnesium and carbon fiber-reinforced polymer (CFRP) have been used for the first time in Audi's Space Frame in the new A8. The combination of materials offers 24% better rigidity of the frame	Looking ahead to the new Audi A8: Space Frame with a unique mix of materials , <a href="https://www.audi-mediacycenter.com">https://www.audi-mediacycenter.com</a>	Passenger
Materials development: advanced materials	NIMS and Nagaoka University of Technology developed a high-strength magnesium sheet alloy (Mg-1.1Al-0.3Ca-0.2Mn-0.3Zn) that has excellent room-temperature formability comparable to that of the aluminium sheet metal currently. The material AXMZ1000 can find applications on body panels of some automobiles and is 1.5 to 2 times stronger than aluminium alloy	Bian et al. (2017)	Passenger + Freight
Materials development: advanced materials	Buderus Guss has developed the iDisc, a brake disc that generates up to 90% less brake dust than a conventional brake disc. The iDisc is coated tungsten-carbide coating, it has similar performance to ceramic brakes and is wear resistant and corrosion free	Bosch subsidiary Buderus Guss introduces brake disc that generates up to 90% less brake dust, <a href="http://www.greencarcongress.com">http://www.greencarcongress.com</a>	Passenger + Freight
Materials development: advanced materials	Aluminium, carbon-fibre composites, high-strength steel will be used to reduce weight of vehicles and improve fuel efficiency	Goulding and Morrell (2014)	Passenger + Freight
Subcluster: C3-2 Manufacturing processes, production concepts (Additive manufacturing, other possible processes, Factories of the Future)			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
Manufacturing processes	New processes for engine forced induction charging systems	ERTRAC (2016)	Passenger + Freight
Manufacturing processes	Remote laser welding for use with aluminium sheet panels for cars. The process offers exact positioning of the laser beam and reduces the risk of hot cracking	Looking ahead to the new Audi A8: Space Frame with a unique mix of materials ,	Passenger

	during the production process. In addition the laser depth penetration can be precisely controlled by means of the heat input	<a href="https://www.audi-mediacycenter.com">https://www.audi-mediacycenter.com</a>	
Additive manufacturing	3D printing identified as method that can improve manufacturing processes and could have the ability to influence freight travel.	Examining Future Transport Scenarios to Drive Innovation in the UK, <a href="http://www.rand.org">www.rand.org</a>	Freight
Additive manufacturing	"3D printing, or additive manufacturing, is being hailed as a breakthrough technology which could lead to a new industrial revolution. The technology could have a dramatic effect on the vehicle manufacturing industry"	Goulding and Morrell (2014)	Passenger + Freight
Additive manufacturing	3D printing identified as a research topic for delivering goods to customers for FP9 research programme	ERTRAC (2017b)	Freight
Cluster: C4 Competitive Life Cycle Services			
Subcluster: C4-1 Life cycle approaches (End of life issues, life cycle concepts)			
Technology theme	Specific technology researched	Reference	Sector
End of life batteries	2nd use of batteries with consideration of Total cost of ownership	ERTRAC, EPoSS and ETIP SNET (2017)	Passenger
End of life batteries	Research on innovative End-of-Life recovery options (shift from traditional recycling to more energy efficient remanufacturing) and new second life applications	Malkin et al (2016)	Passenger + Freight
End of life batteries	Energy-efficient regeneration of Li-ion battery's cathode materials, by hydrothermal treatment of cycled electrode particles followed by short annealing. This approach can be used to recycle and regenerate LiCO <sub>2</sub> cathodes on a large scale and can be potentially applied to other types of cathode materials in Li-ion batteries.	"Researchers develop energy-efficient process to recycle Li-ion battery cathodes", <a href="http://www.greencarcongress.com">www.greencarcongress.com</a>	Passenger + Freight
End of life batteries	EV batteries need to be dismantled and have high potential for reuse of materials. These will have the chance to be re-used as stationary batteries for other purposes.	ERTRAC (2017b)	Passenger + Freight

**Environment – Road Reports**

<b>Cluster:</b> ENV1 Reducing emissions			
<b>Subcluster:</b> ENV 1 Alternative/conventional fuels (biofuels, alternative fuels, high octane gasoline)			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
Alternative fuels	Hydrogen usage for e-buses and e-trucks	ERTRAC, EPoSS and ETIP SNET (2017)	Passenger + Freight
<b>Subcluster:</b> ENV1-2 Reducing noise & vibration emissions (vehicle noise & vibration emissions)			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
N/A	N/A	N/A	N/A
<b>Subcluster:</b> ENV1-3 After treatment of exhaust gases (Diesel Oxidation Catalyst (DOC), Diesel Particulate Filter (DPF), NOx Storage Reduction (NSR) and Selective Catalytic Reduction (SCR), cold start trapping technologies, particle filtration (PF), new catalyst materials, catalysts for NGVs)			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
Integrated emissions control	Gasoline engine: Three way catalyst (TWC) new materials. Operation under lower temperatures for TWC and Particle Filtration. Use of Selective Catalytic Reduction and Lean Nox Traps (LNT). Integration of Exhaust After Treatment (EAT) systems and considerations for non regulated pollutants like NH3	ERTRAC (2016)	Passenger + Freight
Integrated emissions control	Diesel engines: Cold start trapping of HC and Nox. Lower operating temperatures for Diesel Oxidation Catalyst and Diesel Particulate Filter. Study of effect of biodiesel of DPF. Usage of SCR and LNT technologies. Study for the effect of EAT on real driving emissions and fuel consumption		Passenger + Freight
Integrated emissions control	Natural gas engines: new materials for catalytic converters for NG vehicles, new materials NOX conversion		Passenger + Freight
Emissions monitoring systems	Exhaust emissions monitoring for each vehicle through roadside gas measuring device and automatic plate recognition system	Ricardo exhibits real-world driving emissions testing at Air Quality show, <a href="http://www.ricardo.com">www.ricardo.com</a>	Passenger + Freight
Integrated emissions control	IAV has developed a closed-coupled exhaust gas aftertreatment which allows Diesel Oxidation Catalyst and Diesel Particulate Filter /Selective Catalytic Reduction to reach optimum working temperature more quickly which, even when driving in the low-load range, significantly cuts emissions.	Innovative Close-Coupled Exhaust Gas Aftertreatment, <a href="http://www.iav.com">www.iav.com</a>	Passenger



Integrated emissions control	Reduction of catalyst materials identified as research topic for the FP9 research programme	ERTRAC (2017b)	Passenger
------------------------------	---	----------------	-----------

### **Energy – Road Reports**

<b>Cluster:</b> ENE1 Optimising resistance and propulsion			
<b>Subcluster:</b> ENE1-1 Aerodynamics (Aerodynamic issues of passenger and freight vehicles, platooning aerodynamics)			
Technology theme	Specific technology researched	Reference	Sector
N/A	N/A	N/A	N/A
<b>Subcluster:</b> ENE1-2 Engines / electric motors (High efficiency light and heavy duty combustion engine technologies, hybridisation, downsizing, air management, efficient compressors and turbochargers, reduction of heat losses, waste heat recovery, Spark Controlled Compression Ignition (Mazda Skyactive X engine ), thermoelectric generators, nanocoolants)			
Technology theme	Specific technology researched	Reference	Sector
Engine design	ICE: Improved aerodynamics of compressors and turbines and flexible machinery for variable flow rates and improved pressure ratios of turbochargers. Internally cooled compressors. 100% of future engines equipped with induction charging systems. Turbocompounding with new turbine blade designs and electric turbochargers	ERTRAC (2016)	Passenger + Freight
Engine design	Dedicated preparation (rate of mass flow, increased & variable pressure, temperature, spray pattern)) and precise metering of the fuel. Oxidation of each fuel molecule generating a maximum of heat energy		Passenger + Freight
Engine design	Variable or flexible compression ratio engines		Passenger + Freight
Engine design	Simplified engine architectures for electrified powertrains		Passenger + Freight
Engine design	ICE: Gasoline high Lambda, lean concepts, e.g. with pre-chamber ignition Innovative ignition, e.g. microwave ignition, simultaneous ignition at multiple locations	ERTRAC (2016)	Passenger + Freight
Engine design	ICE: More sophisticated and more detailed physical models embedded in control units. Simple & accurate & robust nonlinear embedded plant models and control		Passenger + Freight
Secondary energy converters	Waste heat recovery: Improvements on organic Rankine cycle efficiency and materials advancement. Improvement of energy recovery efficiency, durability and cost of thermoelectric generators. Back-pressures and pumping losses due to turbocompounding systems		Passenger + Freight
Engine design	ICE: Engine encapsulation		Passenger + Freight

Engine design	ICE: Usage of thermoelectric generators		Passenger + Freight
Engine design	ICE: Usage of Organic Rankine Cycle		Passenger + Freight
Engine design	Powertrain thermal management: flexible pump control, electric thermostat, coolant heat storage flask, engine encapsulation, oil heat storage, variable flow lubrication, heat to oil		Passenger + Freight
Engine design	Optimised energy management efficient and air cooled EV powertrains	ERTRAC, EPoSS and ETIP SNET (2017)	Passenger
Electrified powertrains retrofitting	Efficient retrofit electrified powertrains for conventional vehicles		Passenger
Engine design	Mazda is to release the SKYACTIVE X engine in the next years, the first commercial gasoline engine to use compression ignition and uses a proprietary combustion method called Spark Controlled Compression Ignition (SPCCI). It combines the advantages of gasoline and diesel engines to optimize environmental performance, power and acceleration performance. The engine will be equipped with a supercharger offering 10-30% more torque than the current Mazda engine Skyactive G engine.	Yamasaki et al (2015)	Passenger
Engine design	New efficient ICE technologies with very low/ near zero well to wheel CO2 emissions, identified as research topic by ERTRAC for the FP9 research programme	ERTRAC (2017b)	Passenger
<b>Subcluster: ENE1-3 Engine cycles (non-conventional thermodynamic cycles (Atkinson, Miller))</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
Engine cycles	Atkinson or Miller thermodynamic cycles can improve efficiency at medium to high engine load with the combination of Variable Compression Ratio (VCR) and advanced valve train systems	ERTRAC (2016)	Passenger
<b>Subcluster: ENE1-4 Transmissions, axles, tyres (frictional losses minimisation, transmission mass reduction, transmission for Evs, dual clutch, automatic transmission, transmissions for hybridisation, transmission for autonomous, Heavy truck transmissions)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
Transmission developments	Further development: of Automated manual transmission (gear selection strategies, optimisation of the actuation system), manual transmission (mass reduction and friction losses), dual clutch transmission (minimise parasitic energy losses), automatic transmission (improve losses, optimise gears and shifting), transmission for electric vehicles	ERTRAC (2016)	Passenger + Freight
<b>Subcluster: ENE1-5 Batteries</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
Battery module	Optimisation of Li-ion Cell technology for short term and post-lithium batteries for 2020-2030	ERTRAC, EPoSS	Passenger

Battery module	Modular battery systems and lightweight next generation high energy density batteries for electric passenger cars and buses	and ETIP SNET (2017)	Passenger
Supercapacitors	Advanced dual electric storage concept for trucks: supercapacitors and supercharging for high energy and power		Freight
Battery module	Light and affordable batteries with Batteries with better tolerances to extremes of temperature will be needed, as identified by ERTRAC as a research topic for the FP9 research programme	ERTRAC (2017b)	Passenger + Freight

### **Infrastructure – Road reports**

<b>Cluster: INF1 Intermodality</b> (Seamless interchange of freight and passengers, Synchro-modality over key transport corridor. Common data/information architectures)			
Technology theme	Specific technology researched	Reference	Sector
Smart stations	The organisation of “smart” stations where this refuelling is organised: > Transfer stations from individual (private or shared) means to public transport; > Public transport interchanges (from electric bus to rail modes); > Depots or garages for (electric) buses and/or tram/light rail; link to the smart (cities) grids;	ERTRAC working group (2017b)	Passenger
Smart stations	Bus depot and bus stop automation, automated accessibility solutions for impaired and elderly users should be addressed	ERTRAC working group (2017a)	Passenger
Seamless intermodality	Flexible and upgradeable interchanges easily integrating innovative technologies is suggested by ERTRAC as an FP9 research topic	ERTRAC (2017b)	Passenger
<b>Cluster: INF2 Refuelling</b> (infrastructure for alternative fuels and innovative concepts infrastructure for hydrogen, CNG /LNG, EV charging (charging points, inductive charging roads, pantographs), Smart grids)			
Technology theme	Specific technology researched	Reference	Sector
Alternative fuels refuelling infrastructure, Charging infrastructure	Refuelling capabilities and origin of energy: - local production (generators); dedicated electricity network for public transport (e.g. in case of metro system); city grid...;	ERTRAC working group (2017)	Passenger
Charging infrastructure	Charging station automation		Passenger
Charging infrastructure	Automated charging for Evs, interoperability with respect to	ERTRAC, EPoSS and ETIP SNET	Passenger

	parking/charging infrastructure for Evs, real time charging info and Vehicle to Grid connectivity	(2017)	
Inductive charging	Fast inductive charging for passenger cars		Passenger
Inductive charging	Inductive charging for trucks during stop overs		Freight
Charging infrastructure	Electric Road Systems for trucks (2025)		Freight
Charging infrastructure	Wuhan will develop core technology of hydrogen production, storage and transport. The city will build 20 hydrogen fuelling stations by 2020, to support the running of 3000 hydrogen fuel-cell vehicles and 30-100 by 2025.	""Hydrogen city" to be built in central China", www.xinhuanet.com	Passenger + Freight
Inductive charging	In road inductive charging will be used in the future to power electric vehicles	Goulding and Morrell (2014)	Passenger
Charging infrastructure	Ultra high speed charging stations	ERTRAC (2018)	Passenger
Inductive charging	Wireless inductive charging for buses.	ARUP (2014)	Passenger
Inductive charging	North Carolina University has developed new technology and techniques to enable wireless charging to moving vehicles	ARUP (2014)	Passenger + Freight
<b>Cluster: INF3 Technologies for resilience ("sensors, monitoring strength, stability and security of assets, radar and microradars")</b>			
Technology theme	Specific technology researched	Reference	Sector
Materials and sensors	Novel materials and production methods for infrastructure across the transport network, which could reduce damage and wear-and-tear of road surfaces or automatically repair ruptures or abrasions	Examining Future Transport Scenarios to Drive Innovation in the UK , www.rand.org	Passenger + Freight
Sensor technologies	Wireless sensor networks combined and ultra low power sensor will be used in the future to monitor structural integrity of bridges and tunnels	Goulding and Morrell (2014)	Passenger + Freight
Underground roadways	Underground roadways for non autonomous vehicles	Goulding and Morrell (2014)	Passenger
Materials for roadways	Roads made out of recycled plastic	Goulding and Morrell (2014)	Passenger + Freight

### Systems – Road Reports

<b>Cluster: SYS1 Intelligent Transport System (ITS) (V2V, V2I systems)</b>			
Technology theme	Specific technology researched	Reference	Sector

Mobility as a Service	Provide a network of public transport with efficient services and to exploit potential benefits of Mobility as a Service (MaaS) to help older people to stay active	ERTRAC working group (2017)	Passenger
ICT infrastructure	Connecting the different (ICT- and non-ICT) infrastructures to better allow for operational optimisation, whilst taking into account aspects like privacy and security		Passenger
Sensor technologies	Physical and digital infrastructures for higher-level automation. Digital oriented infrastructure like off-board sensors in urban environments to act as infrastructural sensing aiding in critical situations during autonomous driving.	ERTRAC (2017a)	Passenger
Mobility as a Service	Sharing platforms for EVs and MaaS	ERTRAC, EPoSS and ETIP SNET (2017)	Passenger
V2X communication	V2X connectivity (mostly V2I) will be essential in Coordinated Automated Road Transport as AVs will need to communicate with the Road Transport Management System and Road Side Units	Raposo et al (2017)	Passenger + Freight
Acoustic sensing for vehicle positioning	TomTom, in partnership with Cisco, is developing ultra-fast lane level traffic technology supporting autonomous driving and smarter mobility. The Distributed Acoustic Sensing (DAS) technology, will have the ability to convert a fiber optic cable into an array of virtual microphones that detect and measure vehicle movements. DAS technology promises to be significantly cheaper to set up and maintain than traditional inductive loop sensors	TomTom and Cisco developing ultra-fast lane level traffic technology supporting autonomous driving; acoustic sensing, <a href="http://www.greencarcongress.com">www.greencarcongress.com</a>	Passenger + Freight
ICT support systems for vehicles	ICT enabled user navigation, routing, booking and ticketing applications	Lennert et al (2017)	Passenger
Autonomous vehicles sharing services	Car sharing schemes for electric or future electric autonomous vehicles		Passenger
Mobility as a Service	MaaS and mobility on demand for urban transport		Passenger
ICT systems	Next generation of ICT telecommunication technologies will be required for various applications	Examining Future Transport Scenarios to Drive Innovation in the UK ,	Passenger

		www.rand.org	
Internet of things	IoT identified as enabling technology that will influence logistics and freight in the future	Examining Future Transport Scenarios to Drive Innovation in the UK , www.rand.org	Freight
Mobility as a Service	MaaS identified by ERTRAC as research topic for the FP9 research programme	ERTRAC (2017b)	Passenger
<b>Cluster: SYS2 Autonomous and connected vehicles and systems (Lidars, sensors, vision systems etc., V2V (ADAS, braking, collision alerts), V2I, V2X-communication to support safety and traffic management, self-learning systems)</b>			
Technology theme	Specific technology researched	Reference	Sector
Connected and automated vehicles demonstrators	Efficient and safe Connected and Automated heavy-duty vehicles in real logistics operations. Efficient and resilient hub-to-hub long-distance connected and automated enhanced freight logistics operation on public roads in mixed traffic and at terminal logistics sites	ERTRAC working group (2017)	Freight
Connected vehicles	Connected vehicles will broadcast their speed and direction to other vehicles, offering warnings for safety warnings	Goulding and Morrell (2014)	Passenger + Freight
Connected and automated vehicles	Connected and automated driving identified as a key technology for the future that will require further research in the FP9 programme and will help achieve zero fatalities	ERTRAC (2017b)	Passenger + Freight
Automated vehicles	Automated concepts for safe and efficient last-mile urban logistics. Research and innovation of end-to-end automated urban logistics solutions, waste collection, last-mile delivery, goods-on-vehicle consolidation and consolidation centres.	ERTRAC (2017a)	Freight
Automated vehicles	Automated Public Transport		Passenger
Computer aided engineering	Automated vehicle driver behaviour modelling. Virtual human modelling for driver/operator behaviour and readiness as well as impact evaluations considering also driver control handover, driver/operator state and impairment.		Passenger
Security for automated vehicles	Security methods to protect automated driving. Need for a holistic approach to protect the electronics architecture and vulnerable communications channels between vehicle and driver, with specific reference to automation	ERTRAC (2017a)	Passenger + Freight

Automated charging & parking	Automated parking and charging systems	ERTRAC, EPoSS and ETIP SNET (2017)	Passenger
Autonomous vehicles and Mobility as a Service	Autonomous fleets of Evs for MaaS		Passenger
Automated vehicles	Highly automated urban e-buses with abilities to dock, charge and park		Passenger
Vehicle platooning	Multimodal platooning for e-buses		Passenger
Automated vehicles	Automated e-shuttle buses		Passenger
Advanced driver assistance systems	Technologies to enable ADAS and self-driving: 1) greater computing power offering the capability of processing approximately 1 GB of data per second. 2) Centralized approach as opposed to the current distributed-computing approach. 3) Low-power semiconductors with high processing capabilities, 5) Robust security and privacy requirements for data transmissions.	Intel (2014)	Passenger + Freight
Advanced driver assistance systems	ADAS: Machine Learning (ML) advances and development of algorithms for perception and decision making in complex environments	Raposo et al (2017)	Passenger + Freight
Coordinated Automated Road Transport (C-ART)	Highly automated driving technologies are necessary in Coordinated-Automated Road Transport (starting at level 3 but preferably level 4 and level 5 automation systems).	Raposo et al (2017)	Passenger + Freight
Coordinated Automated Road Transport (C-ART)	C-ART: Dedicated in-vehicle interface that passengers can use for non-driving related activities		Passenger + Freight
Coordinated Automated Road Transport (C-ART)	C-ART: Outside Human Machine Interface of vehicle and pedestrians or		Passenger
Security for automated vehicles	Data privacy and data security between the different stakeholders and vehicle communication networks that enable C-ART		Passenger + Freight
Autonomous vehicles	Autonomous fleets for urban logistics and smart systems for autonomous trucks	Lennert et al (2016)	Freight

Sensor technologies	Need for robust, affordable sensors including multi-sensing components and (dynamic) out-of-vehicle sensors that will enable levels of automation (level3+)	European Commission (2017)	Passenger + Freight
Vehicle platooning	Platooning for trucks over short distances	ERTRAC (2017b)	Freight
Autonomous vehicles	Autonomous vehicles identified as future transport technologies that will impact transport networks	Examining Future Transport Scenarios to Drive Innovation in the UK, <a href="http://www.rand.org">www.rand.org</a>	Passenger
Autonomous vehicles	Autonomous vehicles identified as a future technology that will increase road safety and relieve congestion	Goulding and Morrell (2014)	Passenger
<b>Cluster: SYS3 Big data (big data from IoT and connected systems)</b>			
Technology theme	Specific technology researched	Reference	Sector
ITS and big data	Smart solutions using ITS and big data to tackle growing demand without substantial investment into infrastructure. More research is needed to investigate the actual efficiency benefits of such technologies and to what extent they can replace infrastructure development	ERTRAC working group (2017)	Passenger + Freight
Big data	Data architectures for automated driving enabling safe off-board and on-board inter-operability	ERTRAC (2017a)	Passenger
Big data	Big data for optimisation of EV fleet management	ERTRAC, EPoSS and ETIP SNET (2017)	Passenger
ITS and big data	Big data availability and advances in artificial intelligence to allow to enable ITS applications	Lennert et al (2016)	Passenger + Freight
Big data	Big data in conjunction with user applications will allow personalised information and will enable new mobility services, car sharing schemes seamless transport, efficient freight transport	Examining Future Transport Scenarios to Drive Innovation in the UK, <a href="http://www.rand.org">www.rand.org</a>	Passenger+ Freight
<b>Cluster: SYS4 Vehicle systems</b>			
Technology theme	Specific technology researched	Reference	Sector
Driving behaviour	Promote of eco-driving and eco-routing by study to change drivers behaviour through demo projects	ERTRAC working group (2017)	Passenger + Freight
HVAC	Intelligent (pre-) conditioning & climate controlling	ERTRAC, EPoSS and ETIP SNET (2017)	Passenger
Pedestrian safety systems	Safety of pedestrian in presence of small noise free EVs		Passenger
Electrification of	Electrified auxiliaries for trucks		Freight



auxiliary systems and simulations		
-----------------------------------	--	--

## 2.2 Aviation reports

### Competitiveness – Aviation Reports

<b>Cluster: C1 Competitive aviation</b>			
<b>Subcluster: C1-1 Innovative aircraft concepts/ frames/structures (Strut / truss braced wings, hybrid wing body, morphing airframes, low noise configurations, Personalized and individualized transportation to/from and within airport and during air travel, Small on-demand aircraft)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
Morphing concepts	Morphing fuselage and wing	IATA (2013)	Passenger+ Freight
Aircraft design	Hybrid wing body		
Aircraft design	Cruise efficient STOL		
Aircraft design	Flying without landing gear		
Electric aircrafts	Electrically propelled aircrafts		
Electric and hybrid aircrafts	Electrically propelled aircrafts or hybrid systems for thrust generations and on board functions	ACARE (2017)	Passenger+ Freight
Aircraft design	Use of rotorcrafts for both densely and sparsely populated areas		
Aircraft design	Composite wing designs that take advantage of the advances of tow steering available by automatic fibre placement machines. With this method composites can be placed in various complex curves creating the tow-steered composite wings. Tow-steered composite wings reduce the weight and improve the fuel efficiency of the aircraft in comparison to conventional composite designs.	"Designing the fuel-efficient aircraft of the future" , sciencedaily.com	Passenger+ Freight
Electric and hybrid aircrafts	Hybrid electric aircrafts: Znum Aero is developing a regional hybrid-electric aircraft that will deliver 80% lower emissions and a 75% drop in community noise. It will, at the same time, improve travel times and travel fares in regional air transport.	Boeing and Jet Blue back Znum Aero, startup developing hybrid electric aircraft; focus on regional airports, greencarcongress.com	Passenger
Electric and hybrid aircrafts	Airbus, Rolls-Royce and Siemens have formed a partnership to develop a hybrid-electric aircraft. Their goal is to mature the technology, performance, safety and reliability enabling quick progress on the hybrid electric	"Airbus, Rolls-Royce, Siemens partner on hybrid-electric aircraft; E-Fan X series hybrid to	Passenger

	technology on aircrafts.	fly in 2020", greencarcongre ss.com	
Autonomous aircrafts	Autonomous passenger aircrafts: A3 and AUVSI are cooperating to develop, with the contribution of regulatory bodies and industry leaders, standards for self-piloted aircrafts and regulatory pathways to make automated passenger flight possible in urban areas. A3 is also developing a self-piloted flying vehicle platform for individual passenger and cargo transport.	"A3 by Airbus and AUVSI call for cooperation in developing industry standards for urban air mobility", greencarcongre ss.com	Passenger+ Freight
Morphing concepts	Morphing wings: NASA has tested a new morphing wing technology that allows an aircraft to seamlessly extend its flaps, leaving no drag-inducing, noise-enhancing gaps for air to flow through.	"These Eight Green Technologies Could Save Airlines \$225 Billion", alwaysinmotion. sae.org	Passenger+ Freight
UAVs	Drones for short range urban deliveries	Lennert et al (2016)	Freight
Electric aircrafts	Electrification of aircrafts with fewer than 100 seats	Malkin et al (2016)	Passenger
UAVs	Fleets of drones to be used for deliveries to rural areas	Goulding and Morrell (2014)	Freight
Passenger drones	Passenger drones and flying cars identified as potential future technologies	Lineberger et al. (2018)	Passenger
UAVs	Drones for automated aircraft inspections	"Four Commercial Trends Hitting Aviation in 2018", www.aviationtoday.com	Passenger + Freight
Electric aircrafts	Vahana is a self piloted VTOL passenger aircraft	Vahana, the Self-Piloted, eVTOL aircraft from A <sup>3</sup> by Airbus, Successfully Completes First Full-Scale Test Flight, www.airbus.com	Passenger
<b>Cluster: C2 Competitive aircraft design</b>			
<b>Subcluster: C2-1 Design tools for structural reliability (CAE + other tools, computation for virtual &amp; real advanced simulation and testing)</b>			
Technology theme	Specific technology researched	Reference	Sector
Virtual reality, Computer Aided Engineering	Full use and development of virtualisation technologies and cyber-physical systems for simulations that will provide reliable data results as the physical tests	ACARE (2017)	Passenger+ Freight
Computer Aided Engineering	New design tools and software for vehicle design and automations of the	Malkin et al (2016)	Passenger+ Freight

	design process		
Testing infrastructure	Development of strategic testing facilities		
Subcluster: C2-2 Cabin (Windowless designs, Differentiation of flight cabin classes and zones according to individual needs, modular cabin design, Wide scale deployment of in-flight communication for passengers (mobile phone, Wi-Fi), Virtual reality in-flight entertainment)			
Technology theme	Specific technology researched	Reference	Sector
Cabin design	Light weight cabin interiors	IATA (2013)	Passenger+ Freight
Cabin design	Windowless design		
Cabin design	Wireless/Optical connections for Inflight-Entertainment		
Cabin design	In Airbus' future cabin concept First, Business and Economy class will be replaced by zones that target more individual needs. Relaxing, playing games, or even interacting with other passengers or holding business meetings with people on the ground will be possible. This concept is for beyond 2040	The airbus concept cabin www.airbus.com	Passenger
Cluster: C3 Competitive aircraft production			
Subcluster: C3-1 Structural materials & composites (Composites, Al-Li alloys, nanomaterials)			
Technology theme	Specific technology researched	Reference	Sector
Materials development: Composite materials	Composites for wings and fuselage, composite primary and secondary structures ( Polymer matrix composites (PMCs), Ceramic Matric Composites (CMCs), Fibre Reinforced Polymers (CFRPs), Glass-Fibre Reinforced Polymers (CFRPs), Aramid-Fibre reinforced Polymers (AFRPs)	IATA (2013)	Passenger+ Freight
Materials development: Morphing materials	Self-actuated materials from external stimuli (light, heat, electromagnetic fields)		
Materials development: Alloy materials	Advanced alloys for structural components: Aluminium- Lithium, Advanced Titanium, Aluminium- Magnesium-Scandium )		
Materials development: Hybrid Alloy materials	Hybrid Alloys- hybrids of metal and high performance fibres : Aluminium sheets with Glare (glass-fibre-reinforced) or ARALL (aramid-fibre-reinforced), CentraAL ( fibre metal laminate sandwiched between layers of advanced aluminium alloys)		
Subcluster: C3-2 Manufacturing processes (Additive manufacturing, other possible processes)			
Technology theme	Specific technology researched	Reference	Sector
Manufacturing processes	Laser Beam Welding and Friction Stir Welding	IATA (2013)	Passenger+ Freight
Manufacturing processes	High-value manufacturing technologies and embedded digitalisation of the	ACARE (2017)	Passenger+ Freight

	entire supply chain, facilitating a data-driven material conversion and manufacturing process		
Virtual reality, Computer Aided Engineering	Full use and development of virtualisation technologies and cyber-physical systems for simulations that will provide reliable data results as the physical tests		
Manufacturing processes	Meltless titanium alloy powder manufacturing technology developed by joint venture between Allegheny Technologies Incorporated (ATI) and GE Aviation	"ATI and GE Aviation form meltless titanium JV", greencarcongress.com	Passenger+ Freight
Manufacturing processes	NASA has developed a new process for stitching together large sections of lightweight composite materials, resulting in damage-tolerant structures that could be used in creating uniquely shaped future aircrafts. These aircrafts will be 20% lighter than an all-metal aircraft.	"These Eight Green Technologies Could Save Airlines \$225 Billion" , alwaysinmotion.sae.org	Passenger+ Freight
<b>Cluster: C4 Competitive Life Cycle Services</b>			
<b>Subcluster: C4-1 Inspection &amp; maintenance (inspection &amp; maintenance new methods)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
N/A	N/A	N/A	N/A
<b>Subcluster: C4-2 Repair, retrofit (repair and retrofitting new methods)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
N/A	N/A	N/A	N/A
<b>Subcluster: C4-3 Life cycle approaches (Aircraft Life Cycle)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
Design for Environment	Ecodesign of the aircrafts using materials and processes with low impact on the environment, and able to be recycled. Life-cycle assessment incorporated into the design process	ACARE (2017)	Passenger+ Freight
Recycling of materials	Recycling and re-use of materials and smart logistics networks for collecting recyclable materials from the entire aircraft's product lifecycle		

### **Environment – Aviation Reports**

<b>Cluster: ENV1 Reducing emissions</b>			
<b>Subcluster: ENV 1-1 Alternative fuels (alternative fuels, biofuels)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
Alternative fuels	Kerosene derived by syngas made from Fischer-Tropsch process.	IATA (2013)	Passenger+ Freight

Alternative fuels	Hydroprocessed Renewable Jet fuels	Takriti et al. (2017)	Passenger+ Freight
Alternative fuels	Alternative jet fuels from sugar canes, syngas, Farnesene. AJF from sugar and starch feedstocks deliver only a small GHG benefit		
Alternative fuels	Hydroprocessed esters and fatty acids ( HEFA), such as derived from feedstocks such as, camelina, jatropha, algae, and cooking oil waste, are already permitted for use on commercial flights. Only Alternative Jet Fuels from lignocellulosic energy crops, agricultural residues and waste feedstocks are shown to provide substantial emission reductions compared to conventional jet fuel		
Alternative fuels	Biofuel blends: Biofuels mixed with conventional kerosene lead to improved carbon footprint and reduced emissions of pollutants, according to experiments conducted by DLR and Lufthansa Technik. They are a step towards the concept of fuels with optimal properties in terms of environmental and technical characteristics.	"DLR and Lufthansa Technik investigate biofuels in new study", <a href="http://www.DLR.de">www.DLR.de</a>	Passenger+ Freight
Alternative fuels	The SBRC a consortium consisting of Boeing, Etihad and UOP Honeywell as founding members are working on new methods of creating alternative aviation fuels coming from biomass that has been grown using seawater and natural fertilizer from aquaculture. The derived fuel will be tested by Etihad airlines	"Etihad Airways and Boeing check on aviation biofuel progress at Masdar", <a href="http://greencarcongress.com">greencarcongress.com</a>	Passenger+ Freight
<b>Subcluster: ENV 1-2 Reducing noise emissions (engine/aircraft noise emissions)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
Aircraft design	Variable geometry chevron at the nacelle trailing edge	IATA (2013)	Passenger+ Freight

### Engines – Aviation Reports

<b>Cluster: ENE1 Optimising resistance and propulsion</b>			
<b>Subcluster: ENE 1-1 Aerodynamics (High lift devices, drag reductions coatings, winglets, riblets, laminar flow, boundary layer, wingtip devices.)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
Air Flow control methods	Laminar flow control technologies(natural and hybrid)	IATA (2013)	Passenger+ Freight
Wing design	Variable camber and control surfaces		
Wing design	Wingtip devices: wingtip fence, blended winglet/sharklets, ranked wingtip, split winglets with scimitar tips, Spiroid wingtip		
Wing design	High lift devices: High lift/ low noise devices, Variable camber trailing edge, Dropped spoiler, Hinge-less flap		
Air Flow control methods	Coatings: Drag reduction coatings, Turbulent flow drag coatings, aircraft graphic films		

Air Flow control methods	Morphing wing		
Air Flow control methods	Boundary layer Ingesting Inlet		Passenger
Wing design	High aspect ratio wings: the University of Michigan has designed an aircraft utilizing wings with longer wingspan to reduce air resistance and improve fuel efficiency. Boeing is currently building a prototype based on this concept	"Designing the fuel-efficient aircraft of the future", sciencedaily.com	Freight + Passenger
<b>Subcluster: ENE 1-2 Engines (Advanced and open geared Turbofan, open rotor engines, electric propulsion, fans, engine cooling technologies, hybrid propulsion, distributed propulsion, combustors, compressors, low noise configurations)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
Engine design	Geared turbofan, Advanced turbofan and Open rotor engines, Counter rotating fan	IATA (2013)	Passenger+ Freight
Engine design	Fans: Zero hub, very high bypass ratio, variable fan nozzle		
Engine design	Combustors: variable flow splits, ultra compact low emission combustors, advanced combustors for low NOX emissions		
Engine design	Thermal barrier coatings for improved combustion efficiency		
Engine design	New titanium alloys and advanced nickel based super alloys for engine components		
Engine design	Ultrahigh bypass ratio engines with high speed gearbox	ACARE (2017)	Passenger+ Freight
Engine design	Pulse detonation	IATA (2013)	Passenger
<b>Subcluster: ENE1-3 Engine cycles</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
Engine cycles	Adaptive cycles	IATA (2013)	Passenger+ Freight
<b>Subcluster: ENE1-4 Nacelles (buried engines, reduced weight nacelles)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
Aircraft design	Buried engines	IATA (2013)	Passenger+ Freight
Aircraft design	Reduced nacelle weight		

### **Infrastructure – Aviation Reports**

<b>Cluster: INF1 Airport safety/ security (Airport safety/ security procedures, Integrated security approach "no borders")</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
Automated luggage service	Robotics: Artificial intelligence and robotics technologies have already been implemented in some airports around the globe. From automated check-in kiosks to concierge robots	"A definitive guide to what will change in aviation over the next 20 years	Passenger

	that greet passengers, robotics improve both the efficiency of the airport operations and the user's experience.	(5-1)", internationalairportreview.com	
Cluster: INF2 Innovative airport concepts (Central airport and inner-city air transport concepts)			
Technology theme	Specific technology researched	Reference	Sector
N/A	N/A	N/A	N/A
Cluster: INF3 Airport operations (full automation of passenger baggage processes)			
Technology theme	Specific technology researched	Reference	Sector
Airport green operations	Taxing using electric tugs (i.e. Taxi Bot)	IATA (2013)	Passenger+ Freight
Airport green operations	Emissions free taxing	ACARE (2017)	Passenger+ Freight
Airport green operations	Environmentally friendly chemicals for aircraft de-icing		
Cluster: INF4 Intermodality (Improved performance and integration with other modes)			
Technology theme	Specific technology researched	Reference	Sector
ICNS	Requirement for information infrastructure, including the integration of Integrated Communications, Navigation, and Surveillance (ICNS), to address inter-modality and performance	Voege et al. (2016)	Passenger + Freight

### **Systems – Aviation Reports**

<b>Cluster: SYS1 Aircraft systems (Flight control systems, System Health Monitoring - diagnostic and prognostic, Flying communication networks)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
Sensor technologies	Structural health monitoring	IATA (2013)	Passenger+ Freight
Flight control systems	Flight control system: Advanced fly-by-wire, Fly-by-light, Wireless Flight Control System		
Morphing concepts	Smart wing technologies with smart actuators		
Aircraft green operations	Electric Landing Gear drive (Wheel Tug system)		
Aircraft green operations	Energy harvesting devices for sensors and cabin switches		
Aircraft green operations	Zonal dryer system for reducing cabin moisture and reducing aircraft weight		
APUs	Efficient Auxiliary Power Units: Proton Exchange, Solide Oxide, Solid Acide Fuel Cells	IATA (2013)	Passenger+ Freight
Aircraft communications	Aeronautical Telecommunications Network: Communications Protocol for Communications		



	Management		
Aircraft communications	FANS-1/A Communications Protocol: Oceanic Data Link Communications using SATCOM		
Aircraft communications	Aircraft Communications and Reporting System: VHF/HF/SATCOM		
Virtual reality	Augmented reality and Virtual Reality: AR and VR could aid the pilots during flights, improve the passenger experience through personalised offers and could present a means for revenue generation for the airport itself too.	"A definitive guide to what will change in aviation over the next 20 years   (11-15)", internationalairportreview.com	Passenger+ Freight
<b>Cluster: SYS2 Air traffic Management (Future Air traffic management &amp; control, airport procedures)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
Guidance, Navigation & Control technologies	Global Navigation Satellite System: e.g. GPS, Galileo, GLONASS, etc.	IATA (2013)	Passenger+ Freight
Guidance, Navigation & Control technologies	Satellite Based Augmentation System: e.g. WAAS		
Guidance, Navigation & Control technologies	Ground Based Augmentation System e.g. LAAS		
Guidance, Navigation & Control technologies	GPS Landing Systems		
Guidance, Navigation & Control technologies	Flight Management Systems		
Guidance, Navigation & Control technologies	Automatic Dependent Surveillance Broadcast: ADS-B IN		
Guidance, Navigation & Control technologies	Automatic Dependent Surveillance Broadcast: ADS-B OUT		
Guidance, Navigation & Control technologies	Automatic Dependent Surveillance Contract: ADS-C		
Guidance, Navigation & Control technologies	Flight Information Service-Broadcast		
Guidance, Navigation & Control technologies	Traffic Information Service – Broadcast		
Guidance, Navigation & Control technologies	Satellite based augmentation system (SBAS): SBAS can supplement GPS and other satellite navigation systems and is used for landing aircrafts. It provides an innovative alternative to	"A first in Germany as aircraft lands using only	Passenger



	the conventional instrument landing system (ILS) and can also be used in poor weather conditions. It improves the position accuracy of GPS from 10-20 metres to 1-3 meters and it does not require ground infrastructure that is expensive to operate and maintain.	satellite navigation", internationalairportreview.com	
Guidance, Navigation & Control technologies	Optimised trajectories and reduced fuel-burn per flight in accordance with FP2050 goals	ACARE (2017)	Passenger+ Freight
Guidance, Navigation & Control technologies	4-D trajectory management should be standard		
System Wide Information Management	System-wide information management (SWIM) principles of data exchange protocols and open service-oriented architecture (SOA). This can enable remote virtualisation of ATM, flight, distribution and management data.	Moving towards virtualisation www.sesarju.eu	Passenger+ Freight
Guidance, Navigation & Control technologies	Remote tower control already offered by Frequentis through their SmartVISION solution. Advanced panoramic IR (infrared) cameras designed for mission-critical ground and air surveillance will be installed at Saarbrücken Airport with the control centre being located at Leipzig	DFS selects remote tower technology from Frequentis www.dfs.de	Passenger+ Freight
Guidance, Navigation & Control technologies	WSI Fusion: This application is a global flight operations management solution for commercial airlines. It provides early insight into changing flight, airport, and airspace conditions to optimise operations, mitigate the impacts of disruptive events, improve weather prediction and the airlines' reaction to adverse conditions.	"A definitive guide to what will change in aviation over the next 20 years   (11-15)", internationalairportreview.com	Passenger
System Wide Information Management	The automation of the future aviation sector will take advantage of the System-Wide Information management (SWIM) system. Big data internet of air will allow the players in the industry to supply and use each other's data	Voegel et al. (2016)	Passenger + Freight
Drones	On-board Detect And-Avoid (DAA) systems will be required in the future allowing small drones to avoid collisions with other airspace users		

## 2.3 Rail transport reports

### Competitiveness – Rail Reports

<b>Cluster:</b> C1 Competitive rail			
<b>Subcluster:</b> C1-1 Innovative rail concepts (Traction systems, high speed carbody, wagon, bogies, eddy current brake systems, train modularity, Personal Rapid Transit (PRT) and Hyperloop)			
Technology theme	Specific technology researched	Reference	Sector
Running gear design	Independent wheel traction	Shift2Rail (2015)	Passenger
Power electronics	New power electronics for vehicles		
Wagon design	High speed Composite-hybrid carbodyshell		

Running gear design	Steering (auto, passive and active guiding) including mechatronic systems		Passenger + Freight
Running gear design	Lateral suspension (semi active & active). Vertical suspension (semi-active & active)		
Train braking systems	Linear eddy current brakes, magnetic track brakes and adhesion-independent brakes. In addition Pneumatic systems for high speed trains, regional trains, metros and freight applications. Hydraulic solution for light weight vehicles		
Running gear design	Lightweight, low noise, high speed and track friendly running gear		
Wagon design	Modular lightweight aerodynamic wagon design with increased payload and platform wagon frame		
Pipeline freight	Freight pipelines concept to shift transport of goods from other modes to rail in congested urban areas	<a href="http://www.cargocap.com">http://www.cargocap.com</a>	Freight
Autonomous trains	Autonomous freight train trialed by mining company Rio Tinto and underwent a fully autonomous journey in Australia	<a href="http://www.riotinto.com/">http://www.riotinto.com/</a>	Freight
Running gear design	Mechatronics for running gear	ERRAC (2016)	Passenger + Freight
Freight train design	Faster flexible freight trains performing like passenger trains (especially operation and speed)		Freight
Wagon design	New techniques and vehicles for urban freight delivery		
Fuel cell hybrid vehicles	World's first hybrid electric tram powered mainly by hydrogen and equipped with a super-capacitor has started running in Tangshan.	"First hydrogen hybrid tram put into operation", <a href="http://www.intelligenttransport.com">www.intelligenttransport.com</a>	Passenger
Fuel cell vehicles	Croningen and Friesland plan to start testing a train running on hydrogen. It will be the first hydrogen train in Netherlands. The provinces hope that it will be a cheap and sustainable alternative to the diesel trains currently running between Leeuwarden and Groningen.	"Groningen, Friesland To Test Netherlands' First Hydrogen Train Next Year", <a href="http://www.nltimes.nl">www.nltimes.nl</a>	Passenger
Cluster: C2 Competitive rail design			
Subcluster: C2-1 Design tools for structural reliability (Computer Aided Engineering + other tools)			
Technology theme	Specific technology researched	Project	Sector
Computer aided engineering	Virtual certification of traction	Shift2Rail (2017)	Passenger + Freight
Computer aided engineering	Simulation of all subsystems of the train allowing remote and distributed testing including hardware in-the-loop through heterogeneous communication networks		
Computer aided engineering	New design tools and software for vehicle design and automations of the design process	Malkin et al (2016)	Passenger+ Freight
Testing infrastructure	Development of strategic testing facilities		
Subcluster: C2-2 Cabin design (Inclusive train design, modular trains and cabins to flexibly adapt to passenger needs)			
Technology theme	Specific technology researched	Project	Sector

Cabin design	Modular interiors allowing the operator to adapt the layout based on occupancy to improve passenger flow and capacity	Shift2Rail (2015)	Passenger
Cabin design	LED interior lighting	Hitachi (2012)	Passenger
Cabin design	Improvement of interior acoustic comfort for passenger	ERRAC (2016)	Passenger
Cabin design	Adaptive interiors configuration for different types of users e.g. family activities, mobile office and group travel		
Cluster: C3 Competitive rail production			
Subcluster: C3-1 Structural materials & composites (Materials & composites)			
Technology theme	Specific technology researched	Reference	Sector
Materials development: Composite materials	New materials for bogies & light weight bodyshell concepts with integrated sensing for health, vibration and noise. Use of carbon fiber reinforced polymers, honeycomb and aluminium sheet doors.	Shift2Rail (2017)	Passenger
Materials development: nanomaterials	New materials (nano material, self-healing/ lubricating) for S&C and enhanced control, monitoring and sensor systems		Passenger + Freight
Subcluster: C3-2 Manufacturing processes (new manufacturing process, additive manufacturing, 3D printing)			
Technology theme	Specific technology researched	Reference	Sector
Manufacturing processes	Joining technologies and manufacturing process for lightweight bodyshells	Shift2Rail (2015)	Passenger
Additive manufacturing	3D printing is expected to revolutionise the supply chain, reducing the need for mass-produced manufacturing, transportation and storage	ARUP (2014)	Passenger+ Freight
Cluster: C4 Competitive Life Cycle Services			
Subcluster: C4-1 Inspection & maintenance (inspection & maintenance new methods (vehicles and tracks))			
Technology theme	Specific technology researched	Reference	Sector
Predictive maintenance	Development of end-to-end solutions for predictive maintenance, including processes, data handling, analytics, dashboards, for locomotives and wagons	Shift2Rail (2015)	Freight
Non-destructive testing for infrastructure	SONAR, LIDAR, hyperspectral and ultrasonic techniques, inspection by robots, UAVs, hybrid air vehicles and satellites or service trains for regular track inspections	ERRAC (2016)	Passenger +Freight
Subcluster: C4-2 Repair, retrofit (repair and retrofitting new methods)			
Technology theme	Specific technology researched	Reference	Sector
Retrofitting of engines	Retrofitting of the ageing heavy diesel shunting locomotive class with new hybrid engine and powerful Li-Ion batteries	Shift2Rail (2015)	Freight
Subcluster: C 4-3 Life cycle approaches (train life cycle)			
Technology theme	Specific technology researched	Reference	Sector
N/A	N/A	N/A	N/A

**Environment – Rail Reports**

<b>Cluster: ENV1 Reducing emissions</b>			
<b>Subcluster: ENV 1-1 Alternative fuels (alternative fuels, biofuels)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
Alternative fuels	Integration of LNG and hydrogen (at later stage ) in rail transport	ARUP (2014)	Passenger + Freight
<b>Subcluster: ENV 1-2 Reducing noise emissions (Noise &amp; vibration)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
Computer aided engineering	Acoustic noise reduction through software development for noise & vibration simulation for running gear and wheel/rail contact. Prediction methods for ground vibrations	Shift2Rail (2015)	Freight
Noise mitigation	Exterior noise skirts for wheel part		Passenger
Computer aided engineering	Tools for evaluating the effect of different configurations of mechatronic bogies regarding curve squeal as well as interior noise		Passenger + Freight
Train braking systems	Technologies for silent brake blocks. Acoustic reprofiling and grinding of wheels	ERRAC (2016)	Passenger + Freight
<b>Subcluster: ENV 1-3 After treatment of exhaust gases (After treatment of diesel powerplant exhaust)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
N/A	N/A	N/A	N/A
<b>Subcluster: ENV 1-4 Green train operations (Regenerative energy storage systems, Battery technologies and onboard energy storage systems)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
Energy generation solutions	Efficient autonomous power generator for freight wagon electrification attached to bogie's axle bearing in combination with energy management and battery system	Shift2Rail (2015)	Freight
Energy recuperation	Regenerative braking system for electrified and non-electrified railway lines available for hybrid diesel passenger trains by Hitachi	Hitachi (2012)	Passenger
Energy recuperation	Regenerative braking systems and on board battery equipment for non electrified parts of the network	ERRAC (2016)	Passenger + freight

**Energy – Rail Reports**

<b>Cluster: ENE1 Optimising resistance and propulsion</b>			
<b>Subcluster: ENE 1-1 Aerodynamics (train aerodynamics)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
N/A	N/A	N/A	N/A
<b>Subcluster: ENE 1-2 Engines &amp; powerplants (hybrid systems, engine advances etc, diesel powerplant)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
Fuel cells	Hydrogen fuel cell electric propulsion passenger train from Alstom. The Coradia iLint	www.Alstom.com	Passenger
Electric motor design	More efficient fully enclosed electric motors that require less maintenance with improved air flow cooling ducts and auxiliary fan for cooling efficiency of the bearings	Hitachi (2012)	Passenger

Materials for powerpacks	Silicon carbide used in inverters		
Materials for powerpacks	Silicon carbide used in semiconductors	ERRAC (2016)	Passenger + freight
Fuel cells	Hydrogen fuel cell electric propulsion		
Fuel cells	Siemens and Ballard Power Systems have announced plans to jointly develop a fuel cell drive for the Siemens Mireo train platform		Passenger

Siemens and Ballard to develop new generation of fuel cells for trains, [www.railway-technology.com](http://www.railway-technology.com)

### **Infrastructure – Rail Reports**

Cluster: INF1 Station operations (future stations, station design, improved train platform interface, novel terminal, hubs)			
Technology theme	Specific technology researched	Reference	Sector
Future rail station design	Crowd management, improved station design and components, improved accessibility to train platform and safety management in public areas	Shift2Rail (2017)	Passenger
ICT systems	Intelligent Video Gate Terminals including data management to enable fast and reliable detection of incoming and outgoing assets		Freight
Future rail station design	Energy harvesting floors for railway stations	ARUP (2014)	Passenger
Future rail station design	Design of mega hub freight villages for comodality and long distance transportation. In addition urban green logistics technologies for mega hubs	ERRAC (2016)	Freight
ICT systems	Innovation to expand the throughput of freight terminals, especially exploiting autonomous and intelligent freight handling systems		
Cluster: INF2 Rail safety/security			
Technology theme	Specific technology researched	Reference	Sector
Drones	Monitoring drones with infrared sensors can be used for checking trespassers	ARUP (2014)	Passenger + Freight
Safety systems	Detection Systems - No intrusive sensors and no time spent in security check	ERRAC (2016)	Passenger
Safety systems	Technologies for safety of future Intelligent Transport Systems and safety approach into entire logistic chain		Passenger + Freight
Safety systems	Biometric technologies for identification and verification		Passenger
Safety systems	5G networks for future communication platforms and technologies for cyber security		Passenger + Freight
IT systems resilience	Self-sustaining networks as parallel networks in addition to public internet		Passenger + Freight
Cluster: INF3 Intermodality (connectivity with other modes of transport)			
Technology theme	Specific technology researched	Reference	Sector

IoT	Internet of Things and big data will pave the way for integrated and multimodal transport solutions	ARUP (2014)	Passenger + Freight
<b>Cluster: INF 4 Track systems</b>			
Technology theme	Specific technology researched	Reference	Sector
Computer aided engineering	Enhanced switches & crossings (S&C) whole system modelling, simulation and design.	Shift2Rail (2017)	Passenger + Freight
Noise mitigation	High performance N&V isolation systems		
Dynamic Rail Information Management System (DRIMS)	Dynamic Rail Information Management System (DRIMS) concepts		
Recyclability of tracks	Large scale introduction of re-used recyclable materials and new tailored material for track applications.		
ICT systems	Railway Integrated Measuring and Monitoring System (RIMMS) concepts		
Drones	Monitoring drones with infrared sensors can check switch point heating systems	ARUP (2014)	Passenger + Freight
<b>Cluster: INF5 Grid &amp; energy (smart power supply)</b>			
Technology theme	Specific technology researched	Reference	Sector
Smart grids	Smart electrical monitoring including smart control and protection	Shift2Rail (2017)	Passenger + Freight
Smart grids	Energy distribution systems for Pan European SMART Grid technology		

### **Systems – Rail Reports**

<b>Cluster: SYS1 Rail systems</b> (Traffic control & management systems (TCMS), automatic train operations, Driverless freight trains, Machine to Machine technologies (M2M), TAP/TAF TSI Telematics applications for passenger/freight Technical specifications of interoperability, Ticketless technologies travel, mobility as a service, intelligent trains)			
Technology theme	Specific technology researched	Reference	Sector
Traffic Control and Management System	Wireless, data driven and modular Traffic Control and Management System	Shift2Rail (2017)	Passenger + Freight
Computer aided engineering	Simulation of all subsystems of the train allowing remote and distributed testing including hardware in-the-loop through heterogeneous communication networks		Passenger + Freight
Satellite technologies	Fail safe train positioning including GNSS technologies		Passenger + Freight
Ticketing technologies	Ticketing mechanisms for multimodal journeys including collection of dynamic and static data		Passenger
ICT systems	Travel companion mobile applications for geo navigation functions and device tapping functions. These applications will require cloud based platforms.		Passenger
Mobility as a Service	Mobility as a service incorporating user centric ecosystem, comodality	Shift2Rail (2015)	Passenger
Automatic coupling and decoupling	Automatic coupling and decoupling including power, air and data connectivity, which will		Freight

	serve electrification for condition monitoring of wagon and goods.		
TAF/TSI	Telematics applications and electrification built on TAF TSI standards enabling real time monitoring and tracking of cargo for logistic purposes. Automatic train set-up functionalities and information to the driver including real time conditioned monitoring for goods		
Sensor technologies	Machine-to-machine (M2M) technology for efficiency using sensors embedded in a wide array of objects and systems to automate tasks and deliver real-time analysis and monitoring	ARUP (2014)	Passenger + Freight
Advanced train administration and communications system	Advanced train administration and communications system (ATACS) that use space-wave radio transmission	Hitachi (2012)	Passenger
ICT systems	Integrated information systems handling the whole journey across modes and different mobility providers	ERRAC (2016)	Passenger
Automatic Train Operation	Automatic Train Operation		Passenger + Freight
Satellite positioning technologies	Satellite based rail positioning		Passenger + Freight
Automatic coupling and decoupling	Technologies to allow virtual coupling and development of moving block signalling		Freight
Automatic coupling and decoupling	Automatic coupling and decoupling		Freight

## 2.4 Waterborne transport reports

### Competitiveness – Maritime Reports

Cluster: C1 Competitive maritime			
Subcluster: C1-1 Innovative ship concepts (inland waterway vessels, crafts for coastal and offshore, automated and autonomous vessels)			
Technology theme	Specific technology researched	Reference	Sector
Hybrid vessels	New hybrid tug designs: Wärtsilä has introduced new tug designs featuring hybrid propulsion systems	“Wärtsilä introducing portfolio of hybrid tug designs”, <a href="http://greencarcongress.com">greencarcongress.com</a>	Freight
Autonomous ships	Smart and autonomous vessels using sensor, situational awareness and AI technologies, fully automated vessels could significantly reduce fuel and crew costs and cargo travel times. Real time collection of ship parameters, with automated information management that will enable big data analysis.	Lloyd's register (2015)	Freight

Autonomous ships	Rolls-Royce and Svitzer have tested the worlds first remotely operated commercial vessel: The vessel safely conducted a number of remotely controlled manoeuvres through a Remote Operating Centre. A Dynamic Positioning System and a range of advanced sensors enabled the remote controlled system	Rolls-Royce demonstrates world's first remotely operated commercial vessel, <a href="http://www.rolls-royce.com">www.rolls-royce.com</a>	Freight
Autonomous ships	Autonomous self docking crewless cargo ships	Lennert et al (2016)	Freight
Hybrid vessels	Hybrid electric propulsion with LNG	Malkin et al (2016)	Passenger
Hybrid vessels	Port of Rotterdam put into operation a new efficient, hybrid patrol vessel, equipped with a special wing profile to reduce vessel wake and an aluminium hull, resulting in reduced fuel consumption.	"Port of Rotterdam Authority puts hybrid vessel into operation", <a href="http://www.greencarcongress.com">www.greencarcongress.com</a>	Freight + Passenger
Ship design	Modular ship design capable of retrofit	IfM Education and Consultancy Services Limited, University of Cambridge (2015)	Freight + Passenger
Ship design	Non ballast water ship design		Freight + Passenger
Ship design	Design for range of speeds and not optimised to single speed		Freight + Passenger
Ship design	Ship design for arctic routes		Freight
Autonomous ships	Autonomous vessels with minimum intervention and unmanned vessels in later stage		Freight + Passenger
Electric vessels	Electric vessels required for the future maritime sector		Freight + Passenger
Subcluster: C1-2 Shipping operations and E-Maritime			
Technology theme	Specific technology researched	Reference	Sector
Automated nautical operations	Development of automated decision support tools for safer and more automated nautical operation of ships including remote control from shore	Waterborne Strategic Research and Innovation Agenda. <a href="http://www.waterborne.eu">www.waterborne.eu</a>	Passenger +Freight
Virtual transport corridors	Improved interoperability of port systems and integration between transport modes. Implementation of virtual transport corridors. Intermodal logistic chain management systems		
E-maritime	Digitalisation of transport documents to assist intermodality		
Cluster: C2 Competitive ship design			



<b>Subcluster: C2-1 Design tools for structural reliability and other functions (CAE + other tools, computation for virtual &amp; real advanced simulation and testing)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
Computer Aided Engineering	Development of design tools for modelling new material and process	Waterborne Strategic Research and Innovation Agenda. www.waterborne.eu	Passenger +Freight
Computer Aided Engineering	Virtual and augmented reality in large newbuild yards. Reengineering in retrofit		
High Performance Computing	ICT infrastructure for big data analysis and high performance computing		
Computer Aided Engineering	New design tools and software for vehicle design and automations of the design process	Malkin et al (2016)	Passenger+ Freight
Testing infrastructure	Development of strategic testing facilities		
Computer Aided Engineering	Virtualisation and standardisation enabling system in the loop intergration at any design stage, maintaining design intent with full visibility	IfM Education and Consultancy Services Limited, University of Cambridge (2015)	Passenger+ Freight
<b>Cluster: C3 Competitive ship production</b>			
<b>Subcluster: C3-1 Structural materials &amp; composites (maritime vessel materials)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
Materials development: Composite materials	Advanced composite materials (fire retardant), advanced thin sheet structures	Waterborne Strategic Research and Innovation Agenda. www.waterborne.eu	Passenger +Freight
Materials development: Composite materials	Composite Materials: Polymer matrix composites which can offer lightweight, strong and corrosion resistant materials.	Lloyd's register (2015)	Freight and Passenger
Materials development: Nano materials	Microscale and Nano- scale fine-tuned materials offering the enhanced characteristics produced by adjusting their structures at microscale or nano-scale. Such materials will lead to stronger metals and alloys with high malleability and corrosion resistance and new anti-corrosion coatings. i.e. Graphene-doped anti-corrosion coating		
Materials development: Nano materials	Self healing material, metal nano composites and materials for Electromagnetic shielding	IfM Education and Consultancy Services Limited, University of Cambridge (2015)	Passenger +Freight
<b>Subcluster: C3-2 Production equipment and processes (manufacturing and production process, Virtual and Augmented Reality Techniques, Measurement and Reverse Engineering Methods, additive manufacturing)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
Manufacturing process	Advanced welding processes for constructing lightweight metallic structures and friction stir welding of steel. Adhesive bonding for non metallic materials and mechanical joining for material combinations	Waterborne Strategic Research and Innovation Agenda. www.waterborne.eu	Passenger +Freight
Manufacturing automation	Smart automation in smaller yards, new assembly processes, autonomous and intelligent equipment, process re-		

	engineering. Automated coating and outfitting, human machine interaction		
Additive manufacturing	Additive manufacturing for spare parts in short term, with AM produced critical components in long term. AM and other processes combined to make larger parts		
Computer Aided Engineering	Wider use of advanced planning simulation tools from yards and simulation of supply chain. Integrated tools with real life data feedback from cradle to grave		
Additive manufacturing	Additive manufacturing will provide greater design freedom and will enable architects to manufacture objects with complex geometry	Lloyd's register (2015)	Passenger +Freight
Manufacturing process	Steel-Cutting and Piping Installation using advanced laser technologies will speed up the cutting process while embedded sensors will be fitted to the piping at an early stage		
Cluster: C4 Competitive Life Cycle Services			
Subcluster: C4-1 Inspection & maintenance (New inspection & maintenance methods)			
Technology theme	Specific technology researched	Reference	Sector
Preventive maintenance	Improved maintenance systems and remote monitoring of ships allowing preventive maintenance and repair of the ship. The aim is for zero defects during voyage	Waterborne Strategic Research and Innovation Agenda. www.waterborne.eu	Passenger +Freight
Sensor technologies	Electronic tagging and new sensor technologies. Every part of the engine room will be electronically tagged, providing valuable information for maintenance and repair purposes. It will help control stock and spare parts onboard and the new generation of sensors will provide valuable information regarding the vessel's condition. This information will be crucial for the inspection procedures and inspection times and effort will significantly drop.	Lloyd's register (2015)	Freight
Inspection robotic systems	Autonomous robotics and remote-controlled robots. Three new types of robots will be used, the learning robot, the practical robot (which can handle an asset) and the mini-robot useful for inspections in harsh environments. These robots will either be fixed to the ship structure, wearable or be offboard the vessel and will perform from building ,firefighting and maintenance activities to housekeeping tasks and mini surveillance		Passenger +Freight
Additive manufacturing	Additive manufacturing for low cost tooling and components	IfM Education and Consultancy Services Limited, University of Cambridge (2015)	Passenger +Freight
Manufacturing process	Automation of manufacturing and assembly processes	IfM Education and Consultancy Services Limited, University of	Passenger +Freight

		Cambridge (2015)	
Manufacturing process	New welding technologies and cutting methods	IfM Education and Consultancy Services Limited, University of Cambridge (2015)	Passenger +Freight
<b>Subcluster:</b> C4-2 Repair, retrofit & dismantling (repair and retrofiting new methods, Smart solutions for outfitting, repair, retrofit, end-of-life)			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
N/A	N/A	N/A	N/A
<b>Subcluster:</b> C4-3 Life cycle approaches [Life Cycle Performance Assessment Methods and Tools, Integrated Maritime Design (for Life cycle) Environment]			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
Computer Aided Engineering	Life Cycle Performance Assessment tools developed into software, commercialisation of such tools and integration into design and decision support tools	Waterborne Strategic Research and Innovation Agenda. <a href="http://www.waterborne.eu">www.waterborne.eu</a>	Passenger +Freight
Sensor technologies	New generation of sensors: This technology will provide top-quality data, that will help optimise and extend each vessel's life cycle, by improving its efficiency, safety and maintenance. It will also improve the life cycle of the equipment during the vessel's life span.	Lloyd's register (2015)	Freight
End of life solutions	End of life recycling solutions for materials	IfM Education and Consultancy Services Limited, University of Cambridge (2015)	Passenger +Freight

### **Environment – Waterborne transport Reports**

<b>Cluster:</b> ENV 1 Reducing emissions			
<b>Subcluster:</b> ENV1-1 Alternative fuels ( biofuels & alternative fuels usage)			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
Alternative fuels	LNG fuelled mega containership designed by MOL and SHI: This LNG powered containership design features an optimal retrofit plan for conventionally powered existing vessels, a suitable LNG fuel supply to ensure maximum power output and dual fuel engine systems.	"LNG-Fuelled Mega Container Ship Design Approved", <a href="http://maritime-executive.com">maritime-executive.com</a>	Freight
Alternative fuels	LNG will be the main fuel, with uptake first on short-sea ships operating in areas with developed gas bunkering infrastructure.	Waterborne Strategic Research and Innovation Agenda. <a href="http://www.waterborne.eu">www.waterborne.eu</a> , Lloyd's register (2015)	Freight
Alternative fuels	Hydrogen and Methanol. Methanol has good compatibility with dual fuel engines. However, it is not expected to appear in any considerable quantities in the maritime industry by 2030 due to the fact that it is not a cost-effective solution yet		

Alternative fuels	LNG vessels required	IfM Education and Consultancy Services Limited, University of Cambridge (2015)	Passenger +Freight
<b>Subcluster:</b> ENV1-2 After treatment of exhaust gases & modelling techniques (2nd generation Post treatment technologies (scrubbers etc), Modelling techniques for emissions reduction)			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
Integrated emissions control	2nd generation scrubbers as a post treatment technology	Waterborne Strategic Research and Innovation Agenda. <a href="http://www.waterborne.eu">www.waterborne.eu</a>	Passenger +Freight
<b>Cluster:</b> ENV 2 other emissions from waterborne transport			
<b>Subcluster:</b> ENV2-1 Reducing airborne and underwater noise			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
N/A	N/A	N/A	N/A
<b>Subcluster:</b> ENV2-2 Reduced emissions by paints & cleaning, ballast water			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
Coatings	Bio-inspired and Bio-Based materials that will exhibit chemical and physical attributes to protect the surfaces from external challenges (icing, abrasion etc.)	Lloyd's register (2015)	Passenger +Freight
Coatings	Friction reduction techniques through hydrophobic surfaces and air bubble techniques	Waterborne Strategic Research and Innovation Agenda. <a href="http://www.waterborne.eu">www.waterborne.eu</a>	Passenger +Freight
Antifouling	Hybrid coating materials	IfM Education and Consultancy Services Limited, University of Cambridge (2015)	Passenger +Freight

### **Energy – Waterborne transport Reports**

<b>Cluster:</b> ENE 1 Optimising resistance and propulsion			
<b>Subcluster:</b> ENE1-1 Minimise resistance & optimise propulsion (Friction reduction techniques, Delivered power in operational conditions (wind, waves), Dedicated developments for advanced propulsors)			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
Propulsors	Computational design, validation and development of advanced propulsors	Waterborne Strategic Research and Innovation Agenda. <a href="http://www.waterborne.eu">www.waterborne.eu</a>	Passenger +Freight
Rudder design	Two-stage rudders: Either by utilizing two rows of rudders or by using a multi-section rudder that rotates on a main kingpin, -both with leading and trailing sections- this technology would increase smooth water flow over the shadow	"The Option of a Two-Stage Rudder", maritime-executive.com	Freight and Passenger

	surface of the rudder and improve vessel steering. This could enable large ships to sail through small channels without tug assistance. It could also expand the application of kinetic ferries, by improving their propulsive power.		
<b>Subcluster: ENE1-2 Ship powering (Improved engine design, new engine components and materials, multi-fuel engines, Zero emission propulsion techniques (wind propulsion, nuclear, electric))</b>			
Technology theme	Specific technology researched	Reference	Sector
Engine design	Improved engine design for operation in "off-design"	Waterborne Strategic Research and Innovation Agenda. <a href="http://www.waterborne.eu">www.waterborne.eu</a>	Passenger +Freight
Engine design	New engine components and materials		
Multi-fuel engines	Multi-fuel engines		
Hybrid propulsion	Hybrid propulsion systems for fish farming ships: Wärtsilä is designing the first hybrid propulsion system ever to be put on a fish farming ship.	"Wärtsilä designing first hybrid propulsion system for fish farming ship", <a href="http://greencarcongress.com">greencarcongress.com</a>	Freight
Multi-fuel engines	Dual-fuel engines: The current dual-fuel engines market portfolio will increase with Dist-Meth, Dist-Eth and Dist-Gly pairs. These engines will be fully electronically controlled, incorporating a network of control modules and sensors, able to manage the engine under different load and fuel conditions.	Lloyd's register (2015)	Freight
Fuel cell electric vessels	Hydrogen fuel cell for cruise ships: ABB will deliver the first hydrogen fuel cell system ever to be fitted in a cruise ship	"ABB to deliver first fuel cell system for Royal Caribbean; Ballard Fcvelocity", <a href="http://greencarcongress.com">greencarcongress.com</a>	Passenger
Fuel cell electric vessels	Hydrogen-powered passenger ferries: Sandia Labs has conducted research on the application of hydrogen as a fuel in passenger ferries and has found that a high speed, hydrogen-fuelled passenger ferry is feasible.	"Sandia researchers take study of hydrogen-powered passenger ferries to next level; optimizing design", <a href="http://greencarcongress.com">greencarcongress.com</a>	Passenger
Fuel cell electric vessels	CMB has launched a new hydrogen-powered passenger vessel. Both of these have next to zero CO <sub>2</sub> , atmospheric particulate matter and sulphur oxide emissions.	CMB Shows Off Its Hydrogen-Powered Vessel, <a href="http://worldmaritimenews.com">worldmaritimenews.com</a>	Passenger
Hybrid and electric propulsion	Hybrid and electric propulsion: A technology that will be used in ECAs or ports, achieving ultra low or zero emissions. Locally operating vessels will be fully electric and others will have hybrid propulsion systems, utilizing wind and solar energy.	Waterborne Strategic Research and Innovation Agenda. <a href="http://www.waterborne.eu">www.waterborne.eu</a>	Freight
Fuel cell vessels	Hydrogen fuel cells	IfM Education and Consultancy Services Limited,	Passenger +Freight

		University of Cambridge (2015)	
Secondary energy converters	Waste heat recovery systems	IfM Education and Consultancy Services Limited, University of Cambridge (2015)	Passenger +Freight
Hybrid propulsion	Hybrid propulsion systems	IfM Education and Consultancy Services Limited, University of Cambridge (2015)	Passenger +Freight
<b>Subcluster: ENE1-3 Energy management &amp; analytics for ship operations (Energy Data acquisition and management systems, Analysis and decision making (tools), Dynamic modelling and simulation tools)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
Energy management	Electronic performance tools for energy efficiency and optimum efficiency of ship during voyage	Waterborne Strategic Research and Innovation Agenda. www.waterborne.eu	Passenger +Freight
Energy management	Computational methods for optimising power for operational conditions (wind, waves, shallow or restricted water)		
Energy management	Optimisation of energy distribution, storage and peak smoothing		
Sensor technologies	New generation of sensors and Big Data Analytics: The development of new types of sensors will allow better and easier monitoring and management of the energy usage of the vessel. This new technology combined with the Big Data Analytics technology will enable real-time performance monitoring of the vessel and will lead ,eventually, to a more efficient energy management.	Lloyd's register (2015)	Freight

### **Infrastructure – Waterborne transport Reports**

<b>Cluster: INF1 Smart and connected ports</b>			
<b>Subcluster: N/A (Integration of national single windows with trade portals and port community systems, Development of Intelligent holistic solutions for the efficient management of ships in ports for freight, passengers and workers, integrated with Urban Mobility Plans and solutions. Development of digital infrastructure, ICT innovation, and automation: Robotics, automation, and autonomous vehicles)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
Smart & connected ports	Smart conected port automation solutions for terminals (robotics, automated vehicles and cranes) including cyber security. IoT and big data analytics for port services aided with VR and augmented reality systems.	Waterborne Strategic Research and Innovation Agenda. www.waterborne.eu	Passenger +Freight
Port management solutions	Intelligent hollistic port management solutions covering ship, freight, passengers, workers and urban mobility plans		



Port management solutions	Digital pilot at the port of LA. The latter and GE have launched a digital pilot improve cargo flows through the port. The pilot has been very successful and there are plans to expand the program to include all container terminals and shipping lines at the Port. It is estimated that ,from this expansion, there will be efficiency gains of between 8% and 12%.	"Port of Los Angeles and GE Transportation expanding digital pilot throughout Port", <a href="http://greencarcongress.com">greencarcongress.com</a>	Freight
Port automation	Automated robotic systems for cargo	Lennert et al (2016)	Freight
<b>Cluster: INF2 Port intermodality</b>			
<b>Subcluster: N/A</b> (Improved interoperability of existing port related systems and the integration between transport modes, Improved interconnectivity and integration between transport modes and established systems, such as: Maritime national Single Windows, RIS, e-Customs, TAF, ERTMS and rail one stop shop, "access points", "data pipelines";)			
Technology theme	Specific technology researched	Reference	Sector
Intermodality	Improved interoperability of port systems and integration between transport modes	Waterborne Strategic Research and Innovation Agenda. <a href="http://www.waterborne.eu">www.waterborne.eu</a>	Passenger +Freight
<b>Cluster: INF3 Refuelling infrastructure for alternative fuels and innovative concepts</b>			
<b>Subcluster: N/A</b> (cold ironing, infrastructure to accommodate alternative fuels in shipping)			
Technology theme	Specific technology researched	Reference	Sector
Alternative fuels refuelling infrastructure	LNG hybrid barge that offers cold ironing services to cruise ship from LNG generated electricity	Hybrid Port Energy (2017)	Passenger
Alternative fuels	Hydrogen fuel cells used to power reefer containers at the port of Honolulu	Hydrogen Fuel Cell Project at Honolulu Harbor, <a href="http://energy.sandia.gov">http://energy.sandia.gov</a>	Freight

### System – Waterborne transport Reports

<b>Cluster: SYS1 Maritime systems</b>			
<b>Subcluster: N/A</b> (Integration of ship navigational and communication facilities aboard ships, including the bridge systems, other ships, VTS and SAR, into a European marine digital highway information system. Integration of navigation technologies with shore based data networks and centres: (SafeSeaNet, (AIS, LRIT), GNSS, National Single Window, VTS, route planning etc.). Ship to shore communications)			
Technology theme	Specific technology researched	Reference	Sector
Communication systems	Smart systems and software for ship to ship and ship to infrastructure connectivity. Including cyber security of systems	Waterborne Strategic Research and Innovation Agenda. <a href="http://www.waterborne.eu">www.waterborne.eu</a>	Passenger +Freight
Sensor technologies	New sensors and real time collection of ship parameters with automated information management and surveillance that will enable the use of big data applications. Big data will allow analysis of ship performance		

	and control optimisation under operations		
Communication systems	Improved communication systems utilising high bandwidth services, extending 5G networks to sea, easier data sharing and promoting the IoT concept on board the vessel. Improved communication systems will provide a wide range of operational and convenience services to both the crew and the passengers. Stakeholders will be able to monitor the condition of the vessel and all data related to its operation, easier with live audio and high definition video collected onboard.	Lloyd's register (2015)	Passenger +Freight
Remote navigation systems for autonomous vessels	Technological platform for unmanned navigation systems: Transas Technology is developing a platform for unmanned navigation systems based on computer simulation in virtual environment. It is the first solution to offer a full-scale model of an autonomous ship and this model includes a ship navigation model, a ship remote control model, 3d ship & environment visualization model and other simulation models to achieve successful unmanned navigation.	"Technological platform to develop the unmanned navigation systems based on computer simulation in virtual environment", marinet.org	Freight
Communication systems	Interfacing of ship navigation systems with other ships, Vessel Traffic Service and Search and Rescue services, and the European maritime digital highway system	Waterborne Strategic Research and Innovation Agenda. www.waterborne.eu	Passenger +Freight
Communication systems	Integrated navigation technologies allowing communication with shore-based data networks		
Communication systems	New interfaces between for cooperative navigation between ship to ship and to shore allowing autonomous ship operations		
Big data	Big data analytics will enable real-time performance monitoring and alert systems leading to a well- informed decision- making process. It will also contribute to an early recognition of hazards, and higher customer satisfaction levels. The impact of better communication systems will be major to the realization of this technology	Lloyd's register (2015)	Passenger +Freight
Sensor technologies	New generation of sensors: Wireless sensor technology and mirco- and nano-mechanical sensors will revolutionise the environmental monitoring and data collection. The development of sensor technologies will be key factor for other developments like the autonomous vessels, big data analytics and robotics		Freight



<b>Cluster: SYS 2 Safety</b>			
<b>Subcluster: N/A (Safe automation and autonomy, accident prevention, fire resistance)</b>			
<b>Technology theme</b>	<b>Specific technology researched</b>	<b>Reference</b>	<b>Sector</b>
Sea traffic control	Development of sea traffic control system similar to aviation's	Waterborne Strategic Research and Innovation Agenda. <a href="http://www.waterborne.eu">www.waterborne.eu</a>	Passenger +Freight
Human machine interface	Improve the Human Machine Interface to help situational awareness		
UAVs	Use of drones to ensure overboard person		
Ship stability	Stability management and systems for accident conditions		
Safety decision support systems	Fire resistance monitoring and extinguish system aided by fire accident evacuation software and decision support systems		
Emergency recovery systems	Launch and recovery systems for lifeboats. New design and concepts of lifeboats for large vessels		
Sensor technologies	Mamal avoidance and detection systems	IfM Education and Consultancy Services Limited, University of Cambridge (2015)	Passenger +Freight
Sensor technologies	Wireless onboard sensors for data gathering and vessel health monitoring	IfM Education and Consultancy Services Limited, University of Cambridge (2015)	Passenger +Freight
Communication systems	V2V and V2I communication systems	IfM Education and Consultancy Services Limited, University of Cambridge (2015)	Passenger +Freight

## 2.5 Road transport projects

### Competitiveness – Road projects

Cluster: C1 Competitive road transport					
Subcluster: C1-1 Innovative road transport concepts/ body structures (future vehicle concepts, autonomous vehicles(non systems), platooning, swarms etc, fuel cell vehicles, EVs (freight/passenger), space frame construction, unibody frame, small urban vehicles, robot taxis, design for safety)					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Vehicle design	CAD of external modular bus and design of coupling-decoupling system	EBSF - European Bus System of the Future	The study considered an articulated bus with a modular structure in order to permit a complete flexibility. The whole vehicle system is composed by one tractor and two trailers with two axles and is provided with a steering system, acting on all the wheels - for the tractor – and, on the rear wheels for the trailer	FP7	Passenger & Freight
CAE and real life crash tests	Design, crash simulations and real life simulation of an lightweight body designed for EV powertrain	WIDE-MOB - Building blocks concepts for efficient and safe multiuse urban electrical vehicles	WIDE-MOB designed building block concepts for future EVs based on lightweight architecture, distributed drivetrains and low aerodynamic drag. The design was tested by a prototype for crash worthiness	FP7	Passenger
EV Vehicle design	Design, simulation and crash test of lightweight EV	ALIVE - "Advanced High Volume Affordable Lightweighting for Future Electric Vehicles"	ALIVE designed and manufactured an vehicle frame in order to be lightweight and for high volume production	FP7	Passenger
EV Vehicle design	Vehicle design using a modular structural architecture for electric light trucks or vans (ELTV's) focusing on the improvement of passive safety	OPTIBODY - Optimized Structural components and add-ons to improve passive safety in new Electric Light Trucks and Vans (ELTVs)	OPTIBODY developed new structural concept of ELTVs which is composed of a chassis, a cabin and a number of specific add-ons focusing on new market segments	FP7	Freight

## D 2.1 Transport projects & future technologies synopses handbook

Vehicle design	1) Vehicle design and development of a 4 seater small lightweight hybrid metal composite chassis electric vehicle. 2) Hybrid composite chassis using carbon fiber sillbeams with steel tubular trusses and folded metal sheets	AMBER-ULV - Automotive Mechatronic Baseline for Electric Resilient Ultra Light Vehicle	AMBER-ULV project aimed to close the gap between heavy quadricycles and M1 category vehicles in terms of safety and performances, while maintaining a convenient and affordable price to quality ratio by designing a prototype 4 WD EV	FP7	Passenger
Vehicle design	Design of an EV van using a sandwich chassis	DELIVER - "Design of Electric Light Vans for Environment-impact Reduction"	DELIVER designed and constructed of an EV van for lower environmental impact	FP7	Freight
Vehicle hybridization	Hybrid electric truck using energy saving intelligent cruise control and electrified systems	CONVENIENT -Complete Vehicle Energy-saving Technologies for Heavy-Trucks	CONVENIENT demonstrated on 2 prototypes trucks the use of hybrid powertrains for long haul usage including 40 ton trailer	FP7	Freight
Autonomous vehicles	Design and real life pilot trial of an EV autonomous small bus	CITYMOBIL2 - Cities demonstrating cybernetic mobility	CITYMOBIL2 designed and tested in real life an autonomous small bus without driver and capacity of 10 people capable of speeds up to 20kmh	FP7	Passenger
EV design	Design of a modular electric Light Delivery Van for lightweight, 24 hour operation and loading and unloading goods	V-FEATHER - InnoVative Flexible Electric Transport	V-FEATHER designed a modular light weight light commercial vehicle that would be capable of running 24 hours either through on road charging or fast charging based on a in-hub electric motor concept. The concept also envisages battery size reduction and longer range due to modularity, lower mass and other intelligent controls	FP7	Freight
EV design	Design and modelling of third generation passenger EV	ELVA - Advanced Electric Vehicle Architectures	ELVA evaluated criteria that third generation Evs should have and based on a public contest design and a secondary ELVA vehicle design sketched and modelled an EV that met these requirements	FP7	Passenger
EV design	Design and FEA of passenger EV	EPSILON - Small Electric Passenger vehicle with maximized Safety and Integrating a Lightweight Oriented Novel body architecture	Design and FEA of a lightweight four wheeler EV with 600kg weight is supposed to close the gap between two-wheelers, ultra-light vehicles (L7e) and conventional passenger cars (M1) vehicle categories	FP7	Passenger

## D 2.1 Transport projects & future technologies synopses handbook

CAE	Design aspects, modelling and simulation of safe small Evs	SAFEV - Safe Small Electric Vehicles through Advanced Simulation Methodologies	SAFEV researched the safety design aspects of future small electric vehicles and how safe they are for pedestrian impact and for the passenger as well	FP7	Passenger
CAE	Design, modelling, simulation and manufacture of a safe small Evs	URBAN-EV - Super Light Architectures for Safe and Affordable Urban Electric Vehicles	URBAN-EV aims to design, model and manufacture a lightweight EV that will be safe for both passengers and pedestrians with a target weight of 400kg	FP7	Passenger
Vehicle design	External modular bus concept that adjusts based on passenger demand	3IBS – “The Intelligent, Innovative, Integrated Bus Systems	3IBS explored the concepts of External modularity which describes concepts that offer a variable capacity by coupling and uncoupling single buses or trailers to buses. The modularity can be adjusted during peak or off peak times where there is more or less demand	FP7	Passenger
Vehicle design	Design of super low-deck truck and trailer chassis design	TELLISYS - Intelligent Transport System for Innovative Intermodal Freight Transport	TELLISYS designed and tested a three axle truck with an extremely low fifth wheel height of 850 mm. For this reason new chassis and suspension have been designed. A trailer chassis with a Tara weight to be less than four tons and a coupling height of 850 mm with a gooseneck tunnel was also designed and tested. The trailer was designed to be compatible with standard ISO containers	FP7	Freight
EV Vehicle design	Design and manufacture of low weight modular safe car to fit the market between L and M category	BEHICLE - BEst in class veHICLE: Safe urban mobility in a sustainable transport value-chain (BEHICLE)	BEHICLE designed and manufactured four small lightweight passenger cars that were designed based on modular sections and had to be proven safe and crashworthy. The vehicle was designed without B pillars and incorporated four point seatbelts	FP7	Passenger
Electric vehicles	Demonstration of electric buses	ZEEUS - Zero Emission bUs Systems	ZEEUS demonstrated the concept of electrification of public transport with the use of full-electric battery-based busses in five locations (Barcelona, Bonn, Muenster, Plzen and Rome), whereas plug-in hybrid or range-extender type of power-trains were demonstrated in three sites (London, Glasgow and Stockholm). Statistical data were collected to demonstrate the effectiveness of the demonstrators as well as feedback to OEMs of future electric buses	FP7	Passenger
Hybrid vehicles	1) Demonstration of hybrid diesel electric bus 2) Demonstration of hybrid diesel electric truck	HCV - Hybrid Commercial Vehicle	1) HCV demonstrated a 2nd generation hybrid bus offering 35% less fuel consumption, lower weight, lower air and noise emissions. 2) The project also demonstrated an IVECO Daily hybrid bus using supercapacitors and electric air conditioning unit	FP7	Passenger & Freight

## D 2.1 Transport projects & future technologies synopses handbook

Vehicle platooning	Development of truck platooning concept and pilot trials using on board and off board systems	COMPANION - Cooperative dynamic formation of platoons for safe and energy-optimized goods transportation	COMPANION created a semi-autonomous system to enable truck platooning using pilot trials	FP7	Freight
Vehicle platooning	Development of a truck platooning concept and demonstration of a Level 2 automation system	Project 0-6836	Project 0-6836 developed and demonstrated a the proof of concept for level 2 automation for trucks in the state of Texas. The trials were performed in a test track under specific conditions with success	USA-Texas Department of transport	Freight
EV demonstrators	EV demonstrators across various cities in Europe	Green eMotion - Development and demonstration of a unique and user-friendly framework for green electromobility in Europe	Green eMotion aimed at the promotion of electromobility in Europe through demonstrators of electric vehicles in various cities as well as actions based on infrastructure development to business models	FP7	Passenger
Hybrid and electric vehicles' demonstrators	Demonstration of electric/hybrid trucks and vans with ICT support systems. 1) 3.5t electric van, 2) 26t hybrid diesel electric truck, 3) 7.5t full electric truck	SMARTFUSION - Smart Urban Freight Solutions	SMARTFUSION developed and demonstrated a series of pilot trials using electric and hybrid vans or trucks. The demonstrators took place in Italy, UK and Germany. The vehicles were installed with an ICT routing or satellite navigation system. The systems also included considerations for battery charging	FP7	Freight
Hybrid vehicle design	Hybrid truck design for urban deliveries based on an integrated architecture using modular design concepts, reduced weight and fuel consumption, increased payload and electrification of auxiliaries	CITY MOVE - City multi-Role Optimized Vehicle	CITY MOVE designed a hybrid truck based on an architecture suitable for urban deliveries in order to improve fuel consumption, weight and operational suitability of the vehicle. The vehicles is supported by ADAS systems and electrified auxiliaries	FP7	Freight
Electric vehicle design	Development and production of a low cost electric quadricycle	STEVE - Smart-Taylored L-category Electric Vehicle demonstration in hEterogeneous urbanuse-cases	STEVE aims to develop and produce a low cost electric quadricycle to be used as part of electric mobility as a service mobility platform	FP7	Passenger
Electric vehicle design	Design of light-weight EV chassis including suspension system with an integrated battery pack into the design and other energy saving optimizations	DEMOBASE - DDesign and MOdelling for improved BAattery Safety and Efficiency	No further information at this stage	H2020	Passenger

## D 2.1 Transport projects & future technologies synopses handbook

Electric vehicles	Demonstration of Electric light vehicles through a sharing platform	ELVITEN - Electrified L-category Vehicles Integrated into Transport and Electricity Networks	ELVITEN will demonstrate a sharing system of ELVs at different cities	H2020	Passenger
Fuel cell vehicles	Large scale demonstrator for fuel cell vehicles	H2ME 2 - Hydrogen Mobility Europe 2	H2ME 2 aims to create a large scale test for hydrogen mobility for passenger and freight sector by demonstrating the FCEVs from different manufacturers. The project also aims to roll out hydrogen refuelling infrastructure to assist in the deployment of the vehicles	H2020	Passenger + Freight
Fuel cell vehicles	Large scale demonstrator for fuel cell vehicles	H2ME - Hydrogen Mobility Europe	H2ME will deploy 200 OEM FCEVs (Daimler and Hyundai) and 125 fuel cell range-extended vans (Symbio FCell collaborating with Renault) to be studied and used in daily operations for passenger and freight usages	H2020	Passenger + Freight
EV Vehicle design	Design of Electric L-category Vehicles (ELVs) and low cost components and systems for the vehicle	RESOLVE - Range of Electric Solutions for L-category Vehicles	RESOLVE will design two electric tilting four wheelers demonstrator ELVs (L2e and L6e category)	H2020	Passenger
Fuel cell vehicles	Demonstration of fuel cell hybrid buses in three EU regions	HIGH V.LO-CITY - Cities speeding up the integration of hydrogen buses in public fleets	HIGH V.LO-CITY is a demonstrator project of 14 H2 hybrid FC commercial public buses that will assess the application of the technology on public transport. Hydrogen production facilities were also rolled out for the purposes of the project	FP7	Passenger
Fuel cell vehicles	1) Demonstration of fuel cell hybrid buses in Scotland, 2) Concept design of first hybrid fuel cell coach for long route application	HYTRANSIT - European Hydrogen Transit Buses in Scotland	HYTRANSIT is a demonstrator project for hydrogen mobility in Scotland with the use of hydrogen fuel cell hybrid buses and the design of a hybrid fuel cell coach. Development of refuelling infrastructure is also part of the project's objective	FP7	Passenger
Fuel cell vehicles	Deployment of fuel cell vehicles taxi, scooters and passenger cars	HyTEC - Hydrogen Transport in European Cities	Demonstrator project for the deployment of fuel cell passenger vehicles in London and Copenhagen. Five taxis and 19 passenger cars were used. Hydrogen refuelling infrastructure was also deployed to support the vehicles	FP7	Passenger
Fuel cell vehicles	Hydrogen Fuel Cell truck	Project Portal	Toyota's proof of concept for hydrogen fuel cell Class 8 truck in cooperation with the port of Los Angeles. The truck is used for drayage purposes. The truck has 670 horsepower and 1,325 pound feet of torque from two Mirai fuel cell stacks and a 12kWh battery with an estimated driving range is more than 200 miles	US-Private	Freight

## D 2.1 Transport projects & future technologies synopses handbook

EV Vehicle design	Stackable electric vehicle design	ESPRIT - Easily diStributed Personal Rapld Transit	ESPRIT will develop a light weight electric vehicle that can be stacked together to gain space. It will also design a system to charge an eight ESPRIT vehicle road train at a time.	H2020	Passenger
EV demonstrators	Demonstration of the application of Evs in last mile logistics with urban freight vehicles	FREVUE - FREVUE VALIDATING FREIGHT ELECTRIC VEHICLES IN URBAN EUROPE	Demonstrator project of last mile logistics with Evs suign light commercial vehicles and trucks in Amsterdam, Lisbon, London, Madrid, Milan, Oslo, Rotterdam and Stockholm	FP7	Freight
Fuel cell vehicles	Large scale demonstrator for fuel cell buses	CHIC - Clean Hydrogen in European Cities	CHIC is a demonstrator project of 26 H2FC buses in medium sized fleets in normal city bus operation. The project included the roll out of hydrogen refuelling infrastructure	H2020	Passenger
<b>Cluster:</b> C2 Competitive road vehicle design					
<b>Subcluster:</b> C2-1 Design tools and simulation (CAE, computation for virtual & real advanced simulation and testing)					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Computer Aided modelling and simulation	Simulation tool development for passenger flow and accessibility of buses and bus line simulation	EBSF - European Bus System of the Future	EBSF developed a 2D and 3D simulation tool for buses in order to simulate accessibility of people, passenger behaviour at bus stops, including validation with real life pilot	FP7	Passenger & Freight
CAE	Development of advanced magnetic modelling tools and multiphysics environment modelling tool modelling tools	HI-WI - Materials and drives for High & Wide efficiency electric powertrains	1) Hi-Wi developed an EV powertrain modelling tool capable of simulating e-motor, power electronics inverter, DC-DC converter, battery, and on-board vehicle power network, etc., with different levels of fidelity and abstraction. 2) Developed new modelling and simulation tools for power systems and magnetic materials.	FP7	Passenger
CAE and simulations	Development of modelling and simulations for EV components	ASTERICS - Ageing and efficiency Simulation & TEsting under Real world conditions for Innovative electric vehicle Components and Systems	ASTERICS incorporated real world driving cycles for Evs in order to develop simulation and modelling tools that were used to assess performance of Evs and their components	FP7	Passenger & Freight

## D 2.1 Transport projects & future technologies synopses handbook

Simulations and real life measurement of Electromagnetic Compatibility (EMC) and health effects from electromagnetic fields (EMF)	Measurements of EMC and EMF from an EV van using simulations and real life measurement in semi-anechoic shield chamber and a dynamometer	DELIVER - Design of Electric Light Vans for Environment-impact Reduction	DELIVER evaluated EMC and EMF emissions from an EV Van coming from the powertrains, batteries and inverter. Simulations showed very close accuracy between real life measurements. EMF measurements and simulations has also been identified as potentially important to be integrated into future EV design	FP7	Freight
CAE	Development of electromagnetic design and calculation tools for electric motors	VENUS - Switched/Synchronous Reluctance Magnet-free Motors for Electric Vehicles	VENUS project developed design and calculation tools for electromagnetic design of future electric motors	FP7	Passenger
Simulations and measurements for electromagnetic fields	Design, simulations and real life measurements of electromagnetic fields (EMF)	EM-SAFETY - EM safety and Hazards Mitigation by proper EV design	Designs, simulations and measurement in order to reduce minimize exposure of passengers to electromagnetic fields	FP7	Passenger
CAE	Modelling and simulations tools for crashworthiness of Fibre Reinforced Polymers for future alternative fuel vehicles	MATISSE - Modelling And Testing for Improved Safety of key composite Structures in alternatively powered vehicles	MATISSE investigated the crashworthiness of FRP vehicle structures from future cars especially those using alternative fuels in order to provide advanced capabilities and tools that allow OEM car designers to model, simulate and test the safety aspects of such vehicles in the same way as they can currently analyse and assess pressed steel bodies	FP7	Passenger
Simulation tools	Development of simulation tools for powertrain integration	POWERFUL - POWERtrain for FUTURE Light-duty vehicles	POWERFUL developed computer models for simulation of engines, which can be integrated to larger environments for simulation of powertrains and vehicles. These models must be capable to predict engine characteristics under real world driving conditions	FP7	Passenger
Simulation tools	Development of modelling and testing tools for of EV and their components in order to deliver more efficient vehicle designs faster	OBELICS - Optimization of scalable real-time models and functional testing for e-drive Concepts	No further information at this stage	H2020	Passenger
Simulation tools	Development of modelling and simulation tools for EV standard components and linkage between existing methods	HiFi-ELEMENTS - High Fidelity Electric Modelling and Testing	The project will standardize model interfaces for common e-drive components (e-machine, inverter, battery, DC/DC converter, thermal management system). In addition the project will create seamless workflow by linking extended versions of existing tools—a model/data management tool and a co-simulation tool for MiL and HiL environments—augmented with effort-saving automated	H2020	Passenger



			methods for model parameterization		
<b>Subcluster: C2-2 Cabin design &amp; interior</b>					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Ergonomic cabin design	Ergonomic workplace design for bus driver cabin	EBSF - European Bus System of the Future	EBSF developed and mock up design of a bus driver workspace offering improved safety and service performance as well as intuitive driving style	FP7	Passenger & Freight
Ergonomic cabin design	Ergonomic workplace design for EV van driver cabin	DELIVER - Design of Electric Light Vans for Environment-impact Reduction	DELIVER investigated through simulations and modelling the ergonomics, accessibility and visibility that a driver has in EV van that was designed by the project	FP7	Freight
Modular bus interior design	Modular bus interior design concept with sliding or folding seats that adapts to passenger demand	3IBS - The Intelligent, Innovative, Integrated Bus Systems	3IBS although the project did not develop a modular interior it did research through case studies the concept of interior modularity on buses where seats are folded or slide to adjust bus capacity based on demand during the day	FP7	Passenger
Energy efficiency of cabin	Optimization of the passenger compartments and their energy efficiency in EVs	DOMUS - Design Optimisation for efficient electric vehicles based on a User-centric approach	DOMUS will develop a validated framework to optimize the energy efficiency of the passenger compartments in EVs. It will develop solutions for glazing, seats, insulation and radiant panels, along with controllers to optimize their performance and a prototype vehicle to demonstrate these features.	H2020	Passenger
<b>Cluster: C3 Competitive production of road vehicles</b>					
<b>Subcluster: C3-1 Structural materials &amp; composites (lightweight materials, high strength steel, aluminium, magnesium, SAM2X5-630, plastics and composites)</b>					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Materials for permanent magnets of electric motors	Reduction of neodymium oxides in magnets for electric motors using nanon-crystalline powders	MAG-DRIVE - New permanent magnets for electric-vehicle drive applications	MAG-DRIVE aimed at developing new powder magnetic materials for permanent electric motors for EVs in order to reduce the use of rare earth materials	FP7	Passenger & Freight

## D 2.1 Transport projects & future technologies synopses handbook

Materials for permanent magnets of electric motors	Development of an amorphous NdFeB powder	HI-WI - Materials and drives for High & Wide efficiency electric powertrains	Hi-Wi developed a new amorphous NdFeB powder for reducing rare earth materials for magnets of electric motors	FP7	Passenger & Freight
Lightweight materials for Evs	1) Front vehicle structure made out of aluminium and a Cross member Subframe of die-casted and extrusion Aluminum, 2) Magnesium Strut rings 3)A -pillar and B-pillar are made of hot formed high strength steel, 4)CRF roof, 5) Battery-Cover-Plate made of Thermoplastic GFRP has integrated Fixing Elements for the Seat Rail, 6) Doors made out of 5000 and 6000 Aluminum alloys	ALIVE - Advanced High Volume Affordable Lightweighting for Future Electric Vehicles	ALIVE has identified, designed and produced a Body in White and chassis for an EV using specific lightweight materials with the aim of reducing weight at least 7 kilos through these specifications	FP7	Passenger
Lightweight materials for Evs	Hybrid composite chassis using carbon fiber sillbeams with steel tubular trusses and folded metal sheets	AMBER-ULV - Automotive Mechatronic Baseline for Electric Resilient Ultra Light Vehicle	AMBER-ULV created a ultralight chassis for a small 4 seater EV demonstrating high potential passenger safety and battery protection	FP7	Passenger
Lightweight materials for Evs	Carbon Fibre Reinforced Polymer materials for Body In White EV	E-LIGHT - Advanced Structural Light-Weight Architectures for Electric Vehicles	E-LIGHT designed and modelled a CFRP BiW as suitable material for a lightweight EV	FP7	Passenger
Lightweight materials for Evs	1) Aluminium parts for suspension system 2)magnesium sheets for enclosures of the rear compartment, 3) Novel plastometal bumper metal-plastic bumper structure (steel, low-density polyethylene (LLDPE) and polyurethane (PUR) elements combined together	PLUS-MOBY - Premium Low weight Urban Sustainable e-MOBility	PLUS-MOBY identified, simulated and modelled potential materials for a lightweight EV	FP7	Passenger

## D 2.1 Transport projects & future technologies synopses handbook

Materials for EV battery modules	Advanced pore morphology (APM) hybrid sandwich material and aluminium	SMARTBATT - Smart and Safe Integration of Batteries in Electric Vehicles	SMARTBATT identified the materials for battery housing of future EVs that is part of the underbody. Innovative materials were used, for example advanced pore morphology (APM) hybrid sandwich material for the cover and cast aluminium for the tunnel	FP7	Passenger
Lightweight materials for Evs	1) CFRP-aluminium body and interior 2) CFRP-steel omega rear axle	EPSILON - small Electric Passenger vehicle with maximized Safety and Integrating a Lightweight Oriented Novel body architecture	EPSILON designed and identified as suitable materials through FEA, a CFRP-aluminium combination for body and interior, a novel rear axle made of CFRP-steel	FP7	Passenger
Lightweight materials for Evs	Lightweight multimaterial BiW with reinforced flat composite panels, high strength steel, structural aluminium joined and integrated under a bodywork in composite and polycarbonate glazing	BEHICLE - BEst in class vehicle: Safe urban mobility in a sustainable transport value-chain (BEHICLE)	BEHICLE designed and manufactured four Evs using the identified lightweight materials	FP7	Passenger
Lightweight materials for Evs	1) lightweight glasses and composites for windows and chassis 2) light metal aluminium or magnesium seat components	QUIET - QUalifying and Implementing a user-centric designed and Efficient electric vehicle	QUIET envisage to reduce EV weight by 20% from vehicle components e.g. doors, windshields, seats, heating and air conditioning	H2020	Passenger
Materials for interior	Development of an innovative heating system based on resistive heating that uses the following materials 1) Rigid multilayer sheets in a thermoplastic matrix, 2) Fabrics with a heating coating in a thermoset resin.	JOSPEL - Low energy passenger comfort systems based on the joule and peltier effects	JOSPEL reconsidered the concept of traditional heating of the cabin. Instead the heating system is based on resistive heating which consists of heating the surroundings of the passenger instead of the air in order to reduce energy usage	H2020	Passenger
Materials for cooling systems	Cooling system using Bi2Te3-based alloy materials	JOSPEL- Low energy passenger comfort systems based on the joule and peltier effects	Jospel developed a Thermoelectric device with the following characteristics in order to reduce weight and energy efficiency: small size, high cooling performance, low electrical consumption, reliable and Pb-free	H2020	Passenger
Brake system materials	Low environmental impact brake system	LOWBRASYS - a LOW environmental impact BRAke SYStem	The project will develop a novel and low environmental impact brake system that will reduce micro and nanoparticles emissions, it will aim at measuring and understanding the micrometer-sized and ultrafine particles and it will also provide recommendations to	H2020	Passenger + Freight

			policy makers.		
<b>Subcluster:</b> Manufacturing processes, production concepts (Additive manufacturing, other possible processes, Factories of the Future)					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Assembly processes	Thermal bonding automated assembly process for EV batteries	GreenLion - Advanced manufacturing processes for Low Cost Greener Li-Ion batteries	The project developed a Li-ion module/battery pack automated assembly process using thermal bonding	FP7	Passenger & Freight
Manufacturing processes	Machine for laser annealing amorphous powder materials for electric motors	Hi-Wi - Materials and drives for High & Wide efficiency electric powertrains	Hi-Wi developed a machine and manufacturing process for producing laser annealed amorphous powders to be used in magnets of Evs	FP7	Passenger
Manufacturing processes	1) Development of new sand casting manufacturing process for magnesium alloys with the use of electromagnetic pump to impulse the molten magnesium inside the sand mould. 2) Magnesium alloys with grain refiners to improve final microstructure	ALIVE - Advanced High Volume Affordable Lightweighting for Future Electric Vehicles	ALIVE developed a new process for sand casting magnesium offering no oxides or gas porosity in the final parts. This process overcame current the drawbacks of current methods of sand casting ( low volume and high melt oxidation) or high pressure die casting (gas porosity due to high volumes). In addition the project improved the quality of the material through better material microstructure. Overall the process offered high productivity and low cost tooling since the sand moulding process is automated	FP7	Passenger
Manufacturing processes	Automated out of autoclave process for Carbon Fibre Reinforced Plastics	LOWFLIP - Low cost flexible integrated composite process	LOWFLIP developed a manufacturing process suitable for various transport sectors. A demonstrator relevant to automotive was carried out with a novel automated production process with large tapes that produced the wall that shields the driver's cabin from the trailer	FP7	Passenger + Freight
<b>Cluster:</b> C4 Competitive Life Cycle Services					
<b>Subcluster:</b> C4-1 Life cycle approaches (End of life issues, life cycle concepts)					

Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Battery recycling	Hydrometallurgy treatments	GreenLion - Advanced manufacturing processes for Low Cost Greener Li-Ion batteries	Processes for recycling battery components using hydrometallurgy treatments. These processes will recover the battery constituents both in metallic and solution form	FP7	Passenger & Freight
Battery recycling	Study of three recycling methods for EV batteries pyrometallurgical, a hydrometallurgical, and a physical route.	EuroLiion - High energy density Li-ion cells for traction	EuroLiion considered three recycling processes for the Li-ion batteries developed under the project. The 1st method gives basically a slag containing a Li product that is incorporated in e.g. construction materials, the 2nd one uses a separation technique from where components are recovered via dissolution/precipitation reactions. The 3rd route includes almost full dismantling of the cell so as to recover as much materials as possible.	FP7	Passenger & Freight
	NFC and RFID tags for complete lifecycle tracking of tyres	OnTrack - Development of a commercial manufacturing process for embeddable RFID and NFC Tags for complete lifecycle tracking of tyres	The project will develop UHF/NFC RFID tags to embed directly into tyres so that each one has a unique ID, enabling complete lifecycle tracking. These tags can store various data regarding the tyre's history, making it easier for FOs to plan and execute their tyre re-treads and removing the logistical burden of re-treading.	H2020	Passenger

### Environment – Road Projects

<b>Cluster:</b> ENV1 Reducing emissions					
<b>Subcluster:</b> ENV1-1      Alternative/conventional fuels (biofuels, alternative fuels, high octane gasoline)					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Solar energy	Vehicle roof integrating solar cells, energy storage systems and auxiliaries as thermoelectric (TE) climatic control, electrochromic (EC) glazing, courtesy LEDs lighting and actuators	SMARTOP - Self powered vehicle roof for on-board comfort and energy saving	SMARTOP aimed to develop a smart roof for both conventional and electric vehicles in order to minimise the energy consumption of auxiliary needs of the vehicles by harvesting solar energy	FP7	Passenger

## D 2.1 Transport projects & future technologies synopses handbook

Solar energy	PV panel roof demonstrator for trucks	CONVENIENT - Complete Vehicle Energy-saving Technologies for Heavy-Trucks	CONVENIENT developed and integrated on a truck demonstrator a roof of high performances PV panels in terms of lightweight, flexibility and efficiency	FP7	Freight
Alternative fuels	LNG demonstrator for trucks, technical specifications and roadmaps	LNG BLUE CORRIDORS - LNG-BC: Liquefied Natural Gas Blue Corridors	LNG BLUE corridors aimed to develop strategies and roadmaps for LNG usage on trucks. The fuel was used by a fleet of vehicles and the overall performance was assessed	FP7	Freight
Alternative fuels	Proof of concept project for hydrogen fuel cell truck	Project Portal	Proof of concept project between Toyota and Port of Los Angeles	US-Private	Freight
Alternative fuels	Biocatalytic production of alternative liquid transportation fuels	PHOTOFUEL - Biocatalytic solar fuels for sustainable mobility in Europe	The project aims to study and advance the biocatalytic production of alternative liquid fuels, which require only sunlight, CO <sub>2</sub> and water. It will develop microbial cells to directly excrete hydrocarbon and long chain alcohol fuel compounds to the medium, from which they can be separated without the need to harvest biomass.	H2020	Freight + Passenger
<b>Subcluster: ENV1-2</b> Reducing noise & vibration emissions (vehicle noise & vibration emissions)					
<b>Technology theme</b>	<b>Technology identified</b>	<b>Project</b>	<b>Project brief results</b>	<b>Funding programme</b>	<b>Sector</b>
Noise Reduction	Noise Barrier based on different frequencies	Design of Noise Barrier based on Different Frequencies	The project will develop designs for noise barriers based on different frequencies. A Low frequency based Noise Barrier (<200Hz), a middle frequency based Noise Barrier (200-1k Hz) and a high frequency based Noise Barrier (1k-20k Hz).	India-CSIR	Passenger + Freight
<b>Subcluster: ENV1-3</b> After treatment of exhaust gases (Diesel Oxidation Catalyst (DOC), Diesel Particulate Filter (DPF), NO <sub>x</sub> Storage Reduction (NSR) and Selective Catalytic Reduction (SCR), cold start trapping technologies, particle filtration (PF), new catalyst materials, catalysts for NGVs)					
<b>Technology theme</b>	<b>Technology identified</b>	<b>Project</b>	<b>Project brief results</b>	<b>Funding programme</b>	<b>Sector</b>

## D 2.1 Transport projects & future technologies synopses handbook

Integrated Emissions control	1) Advanced Selective Catalytic Reduction (SCR) based on both mixed metal oxides and Cu-zeolite materials, 2) Integration of the advanced SCR catalyst materials onto a diesel particulate filter substrate (SCR/DPF) 3) Electrically heated device for complete vaporization and hydrolysis of the urea-water mixture in a small by-pass flow (AdBlue processor), 4) Ammonium nitrate addition to AdBlue to improve low-temperature performance of the SCR catalysts through optimization of operating conditions	CORE - CO2 REduction for long distance transport	CORE tested and simulated a series of SCR strategies and materials concluding to a 3rd generation Cu-SCR catalyst (Gen3) technology that improved Nox conversion	FP7	Freight
Integrated Emissions control	Electrified Diesel Particulate Filter (DPF)	HCV - Hybrid Commercial Vehicle	HCV developed an e-DPF prototype. No further info is available on the device or results	FP7	Passenger + Freight
Integrated Emissions control	1) NOX storage catalyst and 2) use of H2 as reducing agent for Selective Catalytic Reduction	EAGLE - Efficient Additivated Gasoline Lean Engine	EAGLE will develop an ultra-lean Spark Ignition gasoline engine, adapted to future electrified powertrains. In addition the project will explore Nox reduction mechanisms and the use of Hydrogen for reducing emissions	H2020	Passenger
Integrated Emissions control	1) NOX storage catalyst and 2) use of H2 as reducing agent for Selective Catalytic Reduction	EAGLE - Efficient Additivated Gasoline Lean Engine	EAGLE will develop an ultra-lean Spark Ignition gasoline engine, adapted to future electrified powertrains. In addition the project will explore Nox reduction mechanisms and the use of Hydrogen for reducing emissions	H2020	Passenger
Integrated Emissions control	Development of a low precious metal content 3 way catalyst	GasOn - Gas-Only internal combustion engines	GasOn developed a 3 way catalyst to be used by a downsized CNG engine in order to meet post Euro 6 emissions standards	H2020	Passenger
Emission Monitoring Systems	Nano-Particle Emission Measurement Systems	PEMS4NANO - Portable Nano-Particle Emission Measurement System	The project will develop two nano-particle emission measurement systems capable of measurement procedures down to 10nm. One optimized for use in the development laboratory and another optimized for mobile testing.	H2020	Passenger + Freight

Integrated Emissions control	Gasoline Particulate Filter study and design	UPGRADE - High efficient Particulate free Gasoline Engines	UPGRADE will study and design a Gasoline Particulate Filter for a small downsized Spark ignition stoichiometric engine	H2020	Passenger
------------------------------	--	--	--	-------	-----------

### **Energy – Road Projects**

<b>Cluster:</b> ENE1 Optimising resistance and propulsion					
<b>Subcluster:</b> ENE1-1      Aerodynamics      (Aerodynamic issues of passenger and freight vehicles, platooning aerodynamics)					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Computational Fluid Dynamics simulation	CFD simulations for aerodynamics of an EV van	DELIVER	DELIVER carried out CFD simulations to evaluate aerodynamic efficiency of their designed EV van. Results showed that some of the ergonomic design aspects at the front of the vehicle created disadvantages although these were overcome with design measures at the rear of the vehicle	FP7	Freight
Computational Fluid Dynamics simulation	CFD simulations for a Active Grill Shutters combined with novel devices for wheel-arch flow-control on the tractor, together with proper aerodynamic fairings (which include side-wings, boat-tails and spoilers) for semi-trailer	CONVENIENT	CONVENIENT developed simulations in order to evaluate a series of measures identified for reducing aerodynamic cooling drag, wheel drag and reduce flow separation at cab corners	FP7	Freight
Adaptable vehicle aerodynamics	Mission based adaptable vehicle aerodynamics	TRANSFORMERS	TRANSFORMERS developed a mission configurable aerodynamic design for a truck-trailer including movable roofs	FP7	Freight
Optimised vehicle aerodynamics	Optimised adaptable vehicles and aerodynamics for drag reduction of trucks	AEROFLEX	No further information at this stage	FP7	Freight



<b>Subcluster: ENE1-2</b> Engines / electric motors (High efficiency light and heavy duty combustion engine technologies, hybridisation, downsizing, air management, efficient compressors and turbochargers, reduction of heat losses, waste heat recovery, Spark Controlled Compression Ignition (Mazda Skyactive X engine ), thermoelectric generators, nanocoolants)					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Electric motors & power electronics	Front and rear electric motors	Hi-Wi - Materials and drives for High & Wide efficiency electric powertrains	Hi-Wi developed and carried out system tests for front and rear electric motors including development of the power electronics required	FP7	Passenger
Electric motors	Development of Switched Reluctance Motor (SRM)	ARMEVA - Advanced Reluctance Motors for Electric Vehicle Applications	ARMEVA studied different reluctance motor technologies suitable for EV concluding to the development of an SRM including its mechanical, electrical and thermal design. This type of electric motor benefits from magnet free design and no use of rare earth materials, weight reduction as well as optimised design for manufacturing and dismantling	FP7	Passenger + Freight
Electric motors	Electric in Wheel motor offering torque vectoring	EUNICE - Eco-design and Validation of In-Wheel Concept for Electric Vehicles	EUNICE designed, modelled and validated in real life a concept of electric in wheel motors for each wheel of the vehicle. This solution offered torque vectoring for better cornering through a dedicated Engine Control Unit. A new suspension design was also used had to accommodate the added wheel weight	FP7	Passenger
CNG engine and electrified induction charging components	Installation of water cooled electric supercharge and electric turbocharger on a CNG engine. The energy for the electrified components came from a thermoelectric Generator	GASTone - New powertrain concept based on the integration of energy recovery, storage and re-use system with engine system and control strategies	GASTone simulated and installed on a test bench CNG power pack, an electric supercharger and turbocharger with the aim of increasing power and efficiency through electrified components. The electric turbocharger showed high potential for energy recuperation however it caused too much backpressure on the engine side	FP7	Freight
Optimisation of engine and components	1) Down-speeding, 2) Two stage boosting using interstage cooling and variable asymmetric high pressure turbine, injection nozzles with high higher hydraulic flow, 3) optimised piston and rings	CORE - CO <sub>2</sub> REDuction for long distance transport	CORE developed studied and tested a series of added components and optimisation measures on a domestic long distance hybrid truck. The measures provided a 12.9% fuel efficiency in the test cell	FP7	Freight

## D 2.1 Transport projects &amp; future technologies synopses handbook

Secondary energy converters	Waste heat recovery system for hybrid drivetrain truck	NOWASTE - Engine Waste Heat Recovery and Re-Use	NOWASTE simulated and developed a waste heat recovery system consisting of : Exhaust gas heat exchanger, expander (+generator), pump, and the condenser. The mechanical energy produced by the expander machine can be directly used as powertrain power or it can be transformed into electrical energy	FP7	Freight
Electric motors	Synchronous reluctance motor (PMSyR) assisted by ferrite permanent magnets	PLUS-MOBY - Premium Low weight Urban Sustainable e-MOBility	PLUS-MOBY designed, modelled, simulated and developed a synchronous reluctance motor (PMSyR) assisted by ferrite permanent magnets of 7.5 kW rated power, 94% efficiency over the NEDC cycle, diameter 200mm, length 249mm for a lightweight EV	FP7	Passenger
Range extender engine	Rotary engine range extender for an EV	OPTIMORE - Optimised Modular Range Extender for every day Customer Usage	OPTIMORE explored the concept of range extended EVs with the use of a modular EV design based on an existing Volvo vehicle and the use of a rotary range extender including control systems and emissions control for the extender.	FP7	Passenger
CAE	Mechanical design and CFD thermal modelling of an Axial-flux Switched Reluctant Motor (AFSRM)	VENUS - Switched/Synchronous Reluctance Magnet-free Motors for Electric Vehicles	VENUS designed, manufactured and tested an Axial-flux Switched Reluctant Motor (AFSRM) for use in EVs. This included thermal analysis and modelling of the cooling performance of the motor. The stator assembly of the VENUS AFSR motor is very different from existing industrial motors, due to each of the actuators of the stator being an independent workpiece. One motor was manufactured and tested in a light commercial vehicle while a second motor with a similar setup was designed for an L class vehicle	FP7	Passenger + Freight
Electric motors	Permanent Magnet assisted SYNchronous Reluctance Motor	SYRNEMO - Synchronous Reluctance Next Generation Efficient Motors for Electric Vehicles	SYRNEMO designed and manufactured prototype Permanent Magnet assisted SYNchronous Reluctance Motors. These motors offer higher power density and higher driving cycle efficiency at lower cost than the current state-of-the-art Permanent Magnet (PM) synchronous motors while they do not require rare earth materials. Two motor variants have been prototyped with the liquid cooled offering much better performance than the air cooled motor	FP7	Passenger
Electric motors and nanoelectronics	1) Development of a high efficiency electric motor, power converters and storage system with a modular design. 2) Novel design of the motor with topologies that use soft magnetic composites, power electronics and cooling with in-motor integration. 3)	MOTORBRAIN - Nanoelectronics for Electric Vehicles Intelligent Failsafe PowerTrain	MOTORBRAIN designed an EV motor incorporating modular systems within the motor as well as microcontrollers for ensuring overall reliability and safety of the motor	FP7	Passenger

## D 2.1 Transport projects & future technologies synopses handbook

	Microcontroller for intrinsic fail safe of the power train				
Engine design	Design, CFD and manufacture of a Libralato prototype engine (rotary engine)	LIBRALATO - Libralato Engine Prototype	Libralato designed, manufactured and tested a Libralato engine which is a rotary engine design based on an invention 20 years ago but is not associated with the problems of Wenkel engines. The engine is suitable for hybrid or plug in hybrid vehicles offering aggressive downsizing. The prototype proved to be an initial step towards learning about the engine and creating initial designs and prototypes. The engine's efficiency remains unproven	FP7	Passenger
Engine design	Design, CFD and manufacture three engines: 1) advanced four-stroke Spark Ignition (SI) engine concept characterized by low-cost / low emissions, 2) Advanced four-stroke Compression Ignition (CI) engine concept able to run also on new tailored fuels and integrating the LTC (low temperature combustion), 3) An advanced two-stroke CI engine concept running on diesel fuel and integrating the LTHC (low thermal homogeneous combustion)	POWERFUL - POWERtrain for FUture Light-duty vehicles	POWERFUL developed 3 different engines exploring optimisation and improvement of current engines. The first engine offered a 10% fuel saving potential in real life. The second engine is a less common variation of a diesel 4 stroke engine into 2 stroke which is more common in maritime applications. The result is that certain modifications are required for this engine to operate although significant CO2 reductions were achieved. The third engine required further calibration	FP7	Passenger
Electric motor and integration with drivetrain	A 30-50 kW electrical machine will be integrated with an efficient fully SiC drive and a gearbox within a powertrain traction module. Electric motor with dry rotor direct liquid cooling system integrated with the cooling system for the SiC drive.	DRIVEMODE - Integrated Modular Distributed Drivetrain for Electric/Hybrid Vehicles	No further information at this stage	H2020	Passenger + Freight
Electric motors	Development of an electric motor with buried-permanent magnet motor with reduced rare earth materials' use, and electric drivetrain for various configurations of Full and Hybrid Electric Vehicles	ModuLED - Modular Electric Drivetrains	ModuLED will develop a buried permanent magnet motor that reduces the usage of rare earth materials and will be integrate with an inverter for power electronics, advanced control with higher fault tolerance, advanced cooling features, with reduced sizing and higher efficiency. The motor will be demonstrated in an existing EV	H2020	Passenger + Freight

## D 2.1 Transport projects & future technologies synopses handbook

Engine design	Downsizing concept for internal combustion engines in combination of hybridisation of buses and trucks	ORCA - Optimised Real-world Cost-Competitive Modular Hybrid Architecture for Heavy Duty Vehicles	No further information at this stage	H2020	Passenger + Freight
Engine design	1) Development of an ultra-lean Spark Ignition gasoline engine for electrified powertrains, 2) Smart coating to reduce thermal losses, 3) Hydrogen boosting for ultra-lean combustion, 4) Close loop combustion control for extreme lean limit stabilisation	EAGLE - Efficient Additivated Gasoline Lean Engine	EAGLE aims to develop an ultra lean spark ignition engine (gasoline) that will be used in hybrid drivetrains in order to reduce emissions	H2020	Passenger
Engine design	Development of a CNG mono fuel engine that can meet post Euro 6 emissions, 2020+ CO2 targets under real driving emissions	GasOn - Gas-Only internal combustion engines	GasOn aims to develop a CNG engine that will offer low emissions under various driving cycles including real life conditions. No further information at this stage	H2020	Passenger
Engine design	Engine design for running on biofuels	COLHD - Commercial vehicles using Optimised Liquid biofuels and HVO Drivetrains	COLHD will optimize and further develop 3 DDF powertrains running on biogas (LBM or LBP) and 2nd generation biofuels (HVO).	H2020	Freight
Engine Design	LNG, dual-fuel and pure natural gas powertrain systems for heavy duty vehicles	HDGAS - Heavy Duty Gas Engines integrated into Vehicles	HDGAS will develop advanced powertrain concepts for LNG, dual-fuel and for pure natural gas engines as well as aftertreatment systems. It will integrate them into heavy duty vehicles and confirm achievement of Euro VI emissions standards, in-use compliance under real-world driving conditions and CO2 or greenhouse gas targets currently under definition. It will develop three engines and new fuel systems that will be integrated into three demonstration vehicles.	H2020	Freight
Engine design	2 stroke and 4 stroke diesel engine concepts	REWARD - REal World Advanced technologies for Diesel engines	The project will develop for Diesel engined cars friction and wear reduction measures, exhaust gas treatment concepts, fuel-efficient 2-stroke and 4-stroke Diesel engine concepts at TRL 6 or TRL 7 levels , integrate them in three demonstration vehicles and assess them.	H2020	Passenger
Engine design	Efficient and compact hybrid powertrains	ECOCHAMPS - European COmpetitiveness in Commercial	The project will introduce efficient, compact, low weight, robust and cost effective hybrid powertrains for both passenger cars and commercial vehicles. It will also propose a modular system and standardisation	H2020	Passenger + Freight

## D 2.1 Transport projects &amp; future technologies synopses handbook

		Hybrid and AutoMotive PowertrainS	framework for hybrid electric powertrains and will deliver 5 demonstrator hybrid vehicles.		
Electric motors	Rare-earth magnet free brushless AC electrical motor design and manufacture	ReFreeDrive - Rare Earth Free e-Drives featuring low cost manufacturing	The project will develop two rare-earth magnet free solutions for the power traction system of EVs. An induction machine with fabricated and copper die-cast rotor (IM) and synchronous reluctance (SynRel) machine. Both are brushless AC electrical machines.	H2020	Passenger + Freight
Engine design	Downsized spark ignition gasoline engine design	UPGRADE - High efficient Particulate free Gasoline Engines	UPGRADE will develop powertrain system solutions based the on Spark Ignited GDI approach and new Gasoline Particulate Filter technologies, to create particulate free gasoline engines. It will demonstrate one B-segment vehicle, equipped with a small downsized stoichiometric engine, and one D/E vehicle equipped with a medium size lean-burn engine.	H2020	passenger
<b>Subcluster: ENE1-3</b> Engine cycles (non-conventional thermodynamic cycles (Atkinson, Miller))					
<b>Technology theme</b>	<b>Technology identified</b>	<b>Project</b>	<b>Project brief results</b>	<b>Funding programme</b>	<b>Sector</b>
Thermodynamic efficiency	Miller cycle in conjunction with a Variable Valve Actuation (VVA) concept and a dual state turbo system	CORE - CO2 REduction for long distance transport	CORE developed an engine concept for high efficiency Diesel engine for long haul using the Miller cycle obtainable through a VVA concept	FP7	Freight
<b>Subcluster: ENE1-4</b> Transmissions, axles, tyres (frictional losses minimisation, transmission mass reduction, transmission for Evs, dual clutch, automatic transmission, transmissions for hybridisation, transmission for autonomous, Heavy truck transmissions)					
<b>Technology theme</b>	<b>Technology identified</b>	<b>Project</b>	<b>Project brief results</b>	<b>Funding programme</b>	<b>Sector</b>
Tyre design	1) Worn as good as New" (i.e. WAGAN) technology tyre design, 2) Innovative nano-structures tyre compounds	LORRY - Development of an innovative low rolling resistance truck tyre concept in combination with a full scale simulation tool box for tyre performance in function of material and road parameters	LORRY developed, modelled and teste in real life tests on trucks new innovative tyre concepts that have low rolling resistance and perform as good as new after many miles. The results showed that after 170.000 showed less wear compared to the reference test tyres while the reduction of rolling resistance was too difficult to evaluate in real life through the tests.	FP7	Freight

## D 2.1 Transport projects &amp; future technologies synopses handbook

Intelligent automatic bus transmission	Intelligent automatic transmission for buses that changes shifting program in real time based on topography and vehicle occupancy	3IBS - The Intelligent, Innovative, Integrated Bus Systems	3IBS studied the effect of an intelligent automatic system which can change the gear program in real time based on topography and occupancy with results presenting fuel savings of 13.7 % for 10 m buses and 17.2 % for 12 m. The results were taken from trials in Italy	FP7	Passenger
Tyre design	Design of smaller dimension tyre for trucks	TELLISYS - Intelligent Transport System for Innovative Intermodal Freight Transport	TELLISYS had to design a smaller dimensions tyre compared to standard truck tyres to meet TelliSys super low deck truck requirements in terms of "tyre space box"	FP7	Freight
Drivetrain	Direct drive, single stage and two stage switchable high speed gearbox for EV/ hybrid vehicles	DRIVEMODE - Integrated Modular Distributed Drivetrain for Electric/Hybrid Vehicles	DRIVEMODE will explore the feasibility of Direct drive, single stage and two stage switchable high speed gearbox for EV/ hybrid vehicles. No further information at this stage	H2020	Passenger & Freight
<b>Subcluster: ENE1-5 Batteries</b>					
<b>Technology theme</b>	<b>Technology identified</b>	<b>Project</b>	<b>Project brief results</b>	<b>Funding programme</b>	<b>Sector</b>
Battery materials	1) Semiconductor nanowire materials for lithium-ion battery anodes, 2) new aqueous binder for Li-Ion battery electrodes, 3) ionic electrolyte components	GreenLion - Advanced manufacturing processes for Low Cost Greener Li-Ion batteries	1) GreenLion developed new high capacity group iv lithium alloying materials for replacing graphitic anode active materials in Li-ion batteries.2) In addition toxic and environmentally hazardous binders for greener Li-ion electrodes were replaced by a newly developed aqueous binder. 3) Development of non-flammable lithium-ion battery electrolyte components (ionic liquids) to replace flammable solvents with chemically inert ionic liquids	FP7	Passenger & Freight
Battery module	Lighter and green module using a prismatic pouch cell stacking design that has cell venting system	GreenLion - Advanced manufacturing processes for Low Cost Greener Li-Ion batteries	Development of a lightweight stackable Li-ion module batter pack with a venting system to prevent explosion from cell runaway	FP7	Passenger & Freight
Battery swap concept	Design for interchangeable batteries and integration of generic battery designs into single design for battery swap	EASYBAT - Models and generic interfaces for easy and safe Battery insertion and removal in electric vehicles	EASYBAT explored the concept of battery swap and designed mechanisms and models to help integrate generic battery design into swappable battery modules	FP7	Passenger & Freight

## D 2.1 Transport projects & future technologies synopses handbook

Battery module	Modular battery design	OSTLER - Optimised storage integration for the electric car	OSTLER designed and tested a battery pack to be designed modular and standardised so it can easily be adapted to different EVs. Safety and crashworthiness tests were also carried out	FP7	Passenger
Battery module	New battery module concept to be part of the vehicle's structural body modelled	SMARTBATT -Smart and Safe Integration of Batteries in Electric Vehicles	SMARTBATT concept is that the battery case is no longer a separate supplement to be considered for the design of the bodywork but a fully integrated and basic structural component of the vehicle body (e.g. vehicle underbody). CAD models were built based on a two types of battery cells and mechanical, thermal and crashworthiness tests were simulated. Materials	FP7	Passenger
Battery materials	Lithium sulphur battery (LSB)	EUROLIS - Advanced European lithium sulphur cells for automotive applications	EUROLIS developed, modelled and tested a battery for Evs based on lithium sulphur identifying materials for membranes, electrodes, cathode and liquids	FP7	Passenger & Freight
Battery materials	Developed Li-ion batteries for EVS based on innovative silicon (Si) anode (negative electrode), novel low-cost salts, and a modified iron or manganese/nickel-based cathode (positive electrode)	EuroLiion - High energy density Li-ion cells for traction	EuroLiion developed a new Li-ion cell to offer high energy density of at least 200 Wh/kg have low costs i.e., a maximum of 150 Euro/kWh and improved safety. Life cycle considerations were also researched	FP7	Passenger & Freight
Battery module	1) Lithion Ion battery and 2) supercapacitors energy storage systems	HCV - Hybrid Commercial Vehicle	HCV developed and demonstrated the use of Li-Ion batteries on a hybrid bus and the use of supercapacitors on a hybrid truck	FP7	Passenger & Freight
Battery module	Development of battery cells and digitalisation of the cell development process	DEMOBASE - DEsign and MOdelling for improved BAttery Safety and Efficiency	No further information at this stage	H2020	Passenger
Battery Energy Management	Battery energy management and sensors for more accurate monitoring of energy levels combining road, vehicle and driver data	EVERLASTING - Electric Vehicle Enhanced Range, Lifetime And Safety Through INGenious battery management	EVERLASTING aims to develop better battery energy management and sensory monitoring of the battery cells of EVs. This will help decrease range anxiety and also provide better thermal and load management for the battery	H2020	Passenger + Freight
Battery module	Electrolyte, Cathode and Anode improvements dor next generation Lithium Ion Batteries	ECAIMAN - Electrolyte, Cathode and Anode Improvements for Market-near Next-	The project will develop a powerful lithium-ion battery by improving individual components and technologies to result in overall improvement of the cell. It will include a 5V high- voltage spinel, a high- capacity composite	H2020	Freight + Passenger

		generation Lithium Ion Batteries	anode, and a stable high- voltage electrolyte		
Battery module	Flexible modular lithium-ion battery pack	IModBatt - Industrial Modular Battery Pack Concept Addressing High Energy Density, Environmental Friendliness, Flexibility and Cost Efficiency for Automotive Applications	The project will design and manufacture a modular lithium ion battery pack with high energy density to be used in automotive and small stationary applications. It will be suitable for industrial automated assembly with an easy disassembly design.	H2020	Freight + Passenger

### **Infrastructure – Road Projects**

<b>Cluster: INF1</b> Intermodality (Seamless interchange of freight and passengers, Synchro-modality over key transport corridor. Common data/information architectures)					
<b>Technology theme</b>	<b>Technology identified</b>	<b>Project</b>	<b>Project brief results</b>	<b>Funding programme</b>	<b>Sector</b>
Loading unit design	Design of Megaswapbox loading unit suitable for intermodal transport	TELLISYS - Intelligent Transport System for Innovative Intermodal Freight Transport	TELLISYS designed the Megaswapbox, a loading unit with two openable long- and one openable rear side. The roof can be slid and lifted to enable optimal loading from 4 sides. The unit is not stackable and is handled via grapple pockets.	FP7	Freight
1) Info-Mobility, 2) software development	Development of a platform to support multimodal travelling and interoperability between modes and operators	I-TOUR - intelligent Transport system for Optimized URban trips	I-TOUR developed applications to support infomobility that allows the user multimodal journey planning and routing	FP7	Passenger
Loading unit design	Adaptable loading units for trucks	AEROFLEX - Aerodynamic and Flexible Trucks for Next Generation of Long Distance Road Transport	No further information at this stage	H2020	Freight
Transport Demand management	Communication network for intelligent mobility	SOCIALCAR - Open social transport network for urban approach to carpooling	SocialCar will develop an IT platform to provide planning, booking and payment services for multimodal and multiservice trips via a mobile app. The project will try to match travel requests with the integrated public-private transport supply by developing powerful data processing flows and algorithms.	H2020	Passenger



## D 2.1 Transport projects & future technologies synopses handbook

<b>Cluster: INF2 Refuelling infrastructure for alternative fuels and innovative concepts (infrastructure for hydrogen, CNG /LNG, EV charging (charging points, inductive charging roads, pantographs), Smart grids)</b>					
<b>Technology theme</b>	<b>Technology identified</b>	<b>Project</b>	<b>Project brief results</b>	<b>Funding programme</b>	<b>Sector</b>
Inductive charging	On road inductive charging solutions for Electric vehicles	FABRIC - FeAsiBility analysis and development of on-Road charging solutions for future electric vehiCles	FABRIC developed and tested an inductive charging system for on road usage. Pilot trials were carried out at three different roads	FP7	Passenger & Freight
Inductive charging and power electronics	1) Development and simulations of Inductive Power Transfer Module (IPTM) with optimisable magnetic coupling 2) Power electronics for inductive charging, 3) Development of charging station, 4) Energy management system for charging station.	FASTINCHARGE - Innovative fast inductive charging solution for electric vehicles	The project developed an IPTM module which was validated showing contactless transfer of energy in static and dynamic mode at 35kW input power level and up to 9cm distance between the coils, with an efficiency of 92% at a 30kW output power with no misalignment between the coils and safe electromagnetic field exposure. The IPTM module can be used for on route charging. In addition the project developed a charging station for inductive charging. Finally, an energy management system was developed to allow monitoring, control and decision making for the inductive charging station	FP7	Passenger
Inductive charging	Development of two inductive charging stations one of 3,7 kW and a fast charger of 50 kW	UNPLUGGED - Wireless charging for Electric Vehicles	UNPLUGGED developed 2 prototype charging stations for low and high power for Evs. En-route inductive charging was also studied but not demonstrated. Communication modules were also built	FP7	Passenger & Freight
Charging infrastructure	Minimum specifications for public charging infrastructure and development of ICT architecture to accompany connectivity between systems	Green eMotion - Development and demonstration of a unique and user-friendly framework for green electromobility in Europe	Green eMotion researched the requirements and available methods for public charging across European countries in order to created minimum specifications. In addition the required ICT infrastructure architecture for connectivity of the charging infrastructure was developed	FP7	Passenger
Plug in and inductive charging	1) Modular high power electric vehicle supply equipment for Heavy duty, medium duty and light duty vehicles , 2) Development of inductive charging equipment capable of delivering 100 kW	ASSURED - fAst and Smart charging solutions for full size URban hEavy Duty applications	ASSURED aims to develop plug in and inductive electric vehicle supply equipment for buses and vans. The most interesting part is the development of the 100 kW inductive charger	H2020	Passenger & Freight

## D 2.1 Transport projects & future technologies synopses handbook

Alternative fuels refuelling infrastructure	Rollout of 14 LNG station across road freight corridors	LNG BLUE CORRIDORS - LNG-BC: Liquefied Natural Gas Blue Corridors	LNG BLUE corridors aimed to develop strategies and roadmaps for LNG usage on trucks and roll out stations to be used by a demonstrator fleet of LNG trucks	FP7	Freight
Alternative fuels refuelling infrastructure	Hydrogen refuelling infrastructure deployment. The hydrogen production will be done through an electrolytic process	H2ME 2 - Hydrogen Mobility Europe 2	H2ME 2 will develop and rollout a number of hydrogen refuelling stations that will assist in the project's demonstrators of FCEVs	H2020	Passenger + Freight
Alternative fuels refuelling infrastructure	Hydrogen refuelling infrastructure deployment	H2ME - Hydrogen Mobility Europe	H2ME will deploy 29 hydrogen refuelling stations that will be used to assist the deployment of the fuel cell vehicles' demonstrators. Data from the performance of the stations will be analysed and will provide input from early adaptors for policy maker	H2020	Passenger + Freight
Alternative fuels refuelling infrastructure	Compression and buffering module (CBM) for hydrogen refuelling stations which will increase dispensing capacity	H2Ref - Development of a cost effective and reliable hydrogen fuel cell vehicle refuelling system	H2Ref aims to bring from TRL 3 to 6 a CBM module that will improve dispensing capacity of refuelling hydrogen stations for refuelling of 70 MPA passenger vehicles	H2020	Passenger
Alternative fuels refuelling infrastructure	Technologies that will scale up the output and throughput of hydrogen refuelling stations for buses	NewBusFuel - New Bus ReFuelling for European Hydrogen Bus Depots	NewBusFuel will research technologies that will help hydrogen refuelling stations for buses to improve capacity and refuelling time. No further information at the moment	H2020	Passenger
Alternative fuels refuelling infrastructure	1) Rollout of hydrogen refuelling stations for the 3 demonstrators. 2)The H2 used in one of the stations comes from a local chlorine industry, 3) Integration of renewable energies for electricity generation that is to be used for H2 production	HIGH V.LO-CITY - Cities speeding up the integration of hydrogen buses in public fleets	Apart from the demonstration of Hydrogen Fuel Cell Hybrid buses across 3 EU regions, HIGH V.LO-CITY, established H2 refuelling infrastructure that incorporated by product H2 from local chlorine production industry, or renewable energies for H2 production	H2020	Passenger
Alternative fuels refuelling infrastructure	1) Rollout of a hydrogen refuelling station using ionic compressors for faster refuelling. 2) On site hydrogen production using an electrolyser system	HYTRANSIT - European Hydrogen Transit Buses in Scotland	HYTRANSIT rolled out a hydrogen refuelling station to support the demonstrator of the hybrid hydrogen fuel cell buses in Scotland.	FP7	Passenger
Alternative fuels refuelling infrastructure	1) Rollout of a hydrogen refuelling stations capable of 350 & 700 bar fuelling, 2) 2) Study of different supply concepts: partial on site hydrogen production and hydrogen delivery	HyTEC - Hydrogen Transport in European Cities	HyTEC rolled out hydrogen refuelling stations in London and Copenhagen to support the deployment of the fuel cell vehicles that were demonstrated during the project. Hydrogen supply paths were also studied	FP7	Passenger

## D 2.1 Transport projects & future technologies synopses handbook

Alternative fuels refuelling infrastructure	Rollout of hydrogen refuelling stations to support the demonstration of FCEV buses	CHIC - Clean Hydrogen in European Cities	CHIC is a demonstrator project of 26 H2FC buses in medium sized fleets in normal city bus operation. The project included the roll out of hydrogen refuelling infrastructure	H2020	Passenger
<b>Cluster: INF3</b> Technologies for resilience (sensors, monitoring strength, stability and security of assets, radar and microradars)					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
New pavement materials	1) Nanotechnology based Carbon black modified bitumen, 2) Asphalt Concrete (AC), Porous Asphalt (PA) and Very Thin Layer Asphalt Concrete (BBTM) made of industrial by products, Reclaimed Asphalt Pavements (RAP) and other additives	DURABROADS - Cost-effective DURABLE ROADS by green optimized construction and maintenance	DURABROADS developed new materials for asphalt pavements that are more resilient, sustainable and cost efficient. The Carbon black modified bitumen behaves better to ageing resistance than conventional PMB. In addition the developed pavements require less maintenance and rehabilitation costs. Less energy is also required for their construction due to the use of reclaimed materials	FP7	Passenger + Freight
Non Destructive Testing (NDT)	NDE tomograph (3D-scanner) for concrete bridges	COBRI - Ultrasound NDE tomograph. Design and construction of a portable 3D ultrasound scanner for non-destructive testing and evaluation (NDT and NDE) of concrete in bridges and other building structures	COBRI will develop an NDT 3D scanner that will be able to inspect concrete structures on bridges 10 times faster than the current state of the art instrument and with better resolution	H2020	Passenger + Freight

### Systems – Road Projects

<b>Cluster: SYS1</b> Intelligent Transport System (ITS) (V2V, V2I systems)					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector

## D 2.1 Transport projects & future technologies synopses handbook

IT based systems for Evs	IT platform that enables the connection and information exchanges between multiple infrastructure systems that are relevant to the FEV such as road IT infrastructure, EV backend infrastructure and EV charging infrastructure	eCo-FEV - efficient Cooperative infrastructure for Fully Electric Vehicles	eCo-FEV developed and demonstrated a platform offering multiple advanced electric mobility services for EV users to improve the energy management efficiency and usability of their vehicles	FP7	Passenger
ICT support systems for vehicles	ICT support system for drivers of electric and hybrid freight vehicles offering electric battery management, satellite navigation routing and battery charging linked to zoning management system	SMARTFUSION - Smart Urban Freight Solutions	SMARTFUSION developed electric and hybrid vehicle truck and van demonstrators that were used in conjunction with ICT support systems to route the vehicles for freight deliveries and assist in charging and energy management	FP7	Freight
Mobility as a Service (MaaS)	Electro-Mobility-as-a-Service platform for electric quadricycles	STEVE - Smart-Tailored L-category Electric Vehicle demonstration in heterogeneous urban use-cases	STEVE will provide Low-cost and financially sustainable ELV solutions and "gamified" services, to enhance users' awareness, engagement and vehicle energy efficiency	FP7	Passenger
ICT support systems for vehicles	Development of various applications to support a shared ELV service 1) Brokering and a Booking service for EL-Vs and charge points, 2) EL-V fleet monitoring tool and 3) Eco-Drive app,	ELVITEN - Electrified L-category Vehicles Integrated into Transport and Electricity Networks	ELVITEN will demonstrate a sharing system of ELVs at different cities and will create various support ICT applications	H2020	Passenger
Satellite services	Use of satellite systems in conjunction with on-board sensing and infrastructure-based wireless communication technologies (e.g., Wi-Fi, ITS-G5, UWB tracking, Zigbee, Bluetooth, LTE...) to produce advanced, highly-accurate positioning technologies for Cooperative-Intelligent Transport System (C-ITS).	HIGHTS - High precision positioning for cooperative ITS applications	HIGHTS developed an innovative concept in order to support accurate positioning required by C-ITS systems with the use of satellite technology aided by other on board systems like wireless communications or sensors	H2020	Passenger & Freight

## D 2.1 Transport projects & future technologies synopses handbook

V2I communication	C-ITS apps embedded in integrated strips on the road	SAFE STRIP - Safe and green Sensor Technologies for self-explaining and forgiving Road Interactive aPplications	SAFE STRIP will introduce a technology to embed C-ITS applications in existing road infrastructure, including novel I2V and V2I, as well as VMS/VSL functions into low-cost, integrated road strips, to make roads self-explanatory and forgiving for all road users and all vehicle generations.	H2020	Passenger + Freight
V2X communication	Cooperative interaction of Autonomous Vehicles with other road users in mixed traffic environments	INTERACT - Designing cooperative interaction of automated vehicles with other road users in mixed traffic environments	INTERACT will develop novel software and HMI hardware components for reliable and user-centric communication between an AV, its users and other road users. The project will also focus on intention recognition and behaviour prediction of surrounding road users.	H2020	Passenger
Connected vehicles	Development of a connected vehicles system for New York	CVDP - NYC CONNECTED VEHICLE PROJECT - CONNECTED VEHICLE PILOT DEPLOYMENT PROGRAM- NYC CONNECTED VEHICLE PROJECT	The project will develop safety applications based on V2V, V2I and IVP communications. These applications will provide drivers with alerts so as to avoid a crash or reduce the severity of injuries or damage to vehicles and infrastructure. The project will utilize a Traffic Management Center and relevant software, Aftermarket Safety Devices for Vehicles and two pedestrian oriented apps. It will deploy numerous Roadside Units (RSUs) to enable the aforementioned communications.	US DOT	Passenger + Freight
Connected vehicles	Development of a connected vehicles system for Wyoming	CVDP- WYOMING Connected Vehicle Pilot - CONNECTED VEHICLE PILOT DEPLOYMENT PROGRAM- WYDOT Connected Vehicle Pilot	The project will use dedicated short-range communications (DSRC) based applications that leverage V2V and V2I connectivity, to provide a range of services such as advisories, roadside alerts, and dynamic travel guidance for freight and passenger travel in I-80. It will deploy a Forward Collision Warning , an I2V Situational Awareness, a Work Zone Warning, a Spot Weather Impact Warning and a Distress Notification application on 400 participating vehicles with onboard units and will also deploy 75 Roadside Units (RSUs) to enable the aforementioned communications	US DOT	Passenger + Freight
Connected vehicles	Development of a connected vehicles system for Tampa	CVPDP -TAMPA CONNECTED VEHICLE PILOT - CONNECTED VEHICLE PILOT DEPLOYMENT PROGRAM -TAMPA CONNECTED VEHICLE PILOT	The project will develop V2V and V2I based applications that will improve safety and traffic conditions in downtown Tampa. It will develop a Curve Speed Warning, an Emergency Electronic Brake Light, a Forward Collision Warning, an Intersection Movement Assist, a Pedestrian in a Signalized Crosswalk, a Pedestrian Mobility, an Intelligent Traffic Signal System, a Vehicle Data for Traffic Operations, a Transit Signal	US DOT	Passenger + Freight

## D 2.1 Transport projects & future technologies synopses handbook

			Priority, a Vehicle Turning Right in Front of a Transit Vehicle and a Red Light Violation Warning application. It will also deploy numerous RSUs to enable the aforementioned communications.		
<b>Cluster:</b> SYS2 Autonomous and connected vehicles and systems (Lidars, sensors, vision systems etc, V2V (ADAS, braking, collision alerts), V2I, V2X-communication to support safety and traffic management, self-learning systems)					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Autonomous vehicles and V2I infrastructure	Design and real life pilot trial of an EV autonomous bus including all required infrastructure systems	CITYMOBIL2 - Cities demonstrating cybernetic mobility	CITYMOBIL2 created all the systems required to allow the autonomous navigation of a small driverless EV bus. A pilot was performed at the city of Trikala, Greece	FP7	Passenger
Vehicle automation systems	Advanced automation combination of sensors such as ultrasonic cameras, radars and laser scanners	ADAPTIVE - Automated Driving Applications & Technologies for Intelligent Vehicles	ADAPTIVE advanced the technical side of vehicle automation by testing combinations of sensors and created step by step guides on vehicle automation for future projects	FP7	Passenger & Freight
Automated driving and co-operative systems	1) Specifications of V2X messages for automated driving, also feeding ETSI ITS standardization 2) Development of maneuvering control algorithms for cooperative automation 3) Development of cost-effective on-board architecture for integrated sensing and communications	AutoNet2030 - Co-operative Systems in Support of Networked Automated Driving by 2030	AutoNet2030 aimed to research and validate procedures and algorithms for interaction control among co-operative vehicles, including both automated and manually driven vehicles	FP7	Passenger & Freight
Advanced driver assistance systems	Lane Navigation Assistance based on EGNOS satellite positioning	COVEL - Cooperative Vehicle Localization for Safe and Sustainable Mobility	COVEL developed a Lane Navigation Assistant (LNA) – an in-vehicle device which enables lane-level navigation and lane-level traffic management based on EGNOS satellite data positioning which can be obtained by EGNOS Data Access Service (EDAS)	FP7	Passenger & Freight
Advanced driver assistance systems	EGNOS based ADAS applications with high precision	GENEVA - Galileo / EGNOS Enhanced Driver Assistance	GENEVA developed EGNOS based ADAS application for urban assist. Not much information is available for the project	FP7	Passenger

## D 2.1 Transport projects & future technologies synopses handbook

Geolocation and fleet management	EGNOS based precision geolocation of asphalt construction fleets and fleet management applications	ASPHALT - ASPHALT, Advance Galileo navigation System for asPHALT's fleet machines	ASPHALT developed an EGNOS based geolocation system to be used by asphalt laying equipment and fleets. In addition the project developed a fleet management application	FP7	Freight
Vehicle platooning control systems and ADAS	On board system for platooning control of the vehicles, off board platform for V2I communication using 3G network and V2V communication system	COMPANION - Cooperative dynamic formation of platoons for safe and energy-optimized goods transportation	COMPANION developed a semi-autonomous platooning system for truck with the aim of fuel saving. The system included GPS antennas and GNSS devices, cameras for driver behaviour, data loggers and a human machine interface that provided instructions to the driver	FP7	Freight
Autonomous vehicles	Development GNSS based taxi application	TAXISAT - A new TAXI application guided by SATellite	TAXISAT explored the development of GNSS based driverless taxi application capable of 1m positioning accuracy within any topography	FP7	Passenger
Advanced driver assistance systems	Advanced ADAS for anti-roll over, collision avoidance and protection for Urban Vulnerable Road Users (VRU)	CITY MOVE - City multi-Role Optimized Vehicle	CITY MOVE developed architecture for a city logistics truck that was supported by an ADAS system. Not much information available	FP7	Freight
Advanced driver assistance systems	ADAS system using EGNOS-GNSS accuracy Collision Avoidance System	ERSEC - Enhanced Road Safety by integrating Egnos-Galileo data with on-board Control system	ERSEC developed ADAS prototype system for collision avoidance with the aim of evaluating the impact of EGNOS-GNSS data availability and overall accuracy of the system	FP7	Passenger & Freight
Connected measuring system	EGNOS-GNSS bases measuring system for vehicles that will be used for pinpointing objects and the vehicle's position on the map	ERSEC - Enhanced Road Safety by integrating Egnos-Galileo data with on-board Control system	ERSEC developed a system to be used for measuring the position of the vehicle on the map as well as any other object with high accuracy using EGNOS-GNSS	FP7	Passenger & Freight
Satellite based services and software development	Insurance software system based on EGNOS-GNSS data	GNSSMETER - GNSS-based metering for vehicle applications and value added road services	GNSSMETER developed a software and equipment to be used to calculate position, velocity and time in order to offer insurance services for vehicles based on data from EGNOS	FP7	Passenger & Freight
Automated driving	Pilot, test, and evaluation of automated driving functions and connected automation	L3Pilot - Piloting Automated Driving on European Roads	The project will focus on large-scale piloting of SAE Level 3 functions, with additional assessment of some Level 4 functions	H2020	Passenger

## D 2.1 Transport projects & future technologies synopses handbook

Advanced driver assistance systems	Design of an ADAS system using: 1)Sensor and Communication Platform, 2) Probabilistic Driver Modelling and Learning; 3) Probabilistic Vehicle and Situation Modelling; 4) Adaptive Driving Manoeuvre Planning, Execution and Learning; 5)Human Machine Interface	AutoMate - Automation as accepted and trustful teamMate to enhance traffic safety and efficiency	AutoMate will develop an ADAS system that will be created based on the cooperation of the system and the driver as a team to go from A to B safely	H2020	Passenger
Autonomous vehicles	1) Design of controllers and sensor fusion systems for automated vehicles, capable of dealing with complex, uncertain and variable road scenarios to enhance road safety 2) Intuitive human machine interface for automated vehicles	TrustVehicle - Improved trustworthiness and weather-independence of conditional automated vehicles in mixed traffic scenarios	TrustVehicle is a demonstrator project for automated vehicles that aims to develop systems that will ensure safety under uncertain conditions	H2020	Passenger
Advanced driver assistance systems	Development of ADAS system with an integrated driver/rider state monitoring system, able to both be utilized in and be supported by vehicle automation of Levels 1 to 4.	ADAS&ME - Adaptive ADAS to support incapacitated drivers Mitigate Effectively risks through tailor made HMI under automation	ADAS&ME will develop and ADAS drover/ rider state monitoring system such as fatigue, sleepiness, stress, inattention and impairing emotions, employing existing and novel sensing technologies and also incorporating weather conditions through V2X networks	H2020	Passenger + Freight
Advanced driver assistance systems	Development of a 1) next-gen 720° connected ADAS. 2) Advances in sensors, computer vision, data fusion, machine learning and user feedback. 3) Cloud	VI-DAS - Vision Inspired Driver Assistance Systems	VI-DAS will develop an next gen ADAS system for scene analysis and driver status. The system will provide the capability to better understand driver, vehicle and scene context, facilitating a significant step along the road towards truly semi-autonomous vehicles	H2020	Passenger
Safety systems	Vulnerable road users' protection systems	PROSPECT - PROactive Safety for PEdestrians and CyclisTs	PROSPECT will improve the vulnerable road users' (VRU) protection systems. It focusses on active safety solutions, where vehicle-based sensors survey the vehicle surroundings and the system acts actively in case of a critical situation with a VRU.	H2020	Passenger
Advanced driver assistance systems	Development of ADAS system and automated driving platform	ROBUSTSENSE - Robust and Reliable Environment Sensing and Situation Prediction for Advanced Driver Assistance Systems and Automated Driving	The project will introduce reliable and secure sensors and software aiming at automated and safe mobility under real world conditions. It will also develop metrics to measure sensor system reliability on every level of assistance.	H2020	Passenger



## D 2.1 Transport projects &amp; future technologies synopses handbook

Autonomous vehicles	Limited Driverless Vehicle Operations	Automated vehicle research programme 2 USDOT	USDOT automated vehicle research programme that deals with automation of the vehicles such as: developing concepts, testing and evaluation of first-mile/last-mile prototypes	USDOT	Passenger + Freight
<b>Cluster: SYS3 Big data (big data from IoT and connected systems)</b>					
<b>Technology theme</b>	<b>Technology identified</b>	<b>Project</b>	<b>Project brief results</b>	<b>Funding programme</b>	<b>Sector</b>
Data collection, monitoring and analysis from vehicles	Data acquisition system from onboard vehicles devices that record driver behaviour	UDRIVE - eEuropean naturalistic Driving and Riding for Infrastructure & Vehicle safety and Environment	UDRIVE developed a state of the art Data acquisition System that was used for collecting data from cameras, data loggers and sensors that were recording natural driving behaviour of different drivers across six EU countries. A monitoring tool was also developed and statistical data were compared between countries	FP7	Passenger + Freight
<b>Cluster: SYS4 Vehicle systems</b>					
<b>Technology theme</b>	<b>Technology identified</b>	<b>Project</b>	<b>Project brief results</b>	<b>Funding programme</b>	<b>Sector</b>
Handling support system	Optical guidance system for buses to assist at docking	EBSF - European Bus System of the Future	EBSF developed an optical guidance system for docking at the bus stops using a suspension softening system and a device with infrared sensors located near the doors	FP7	Passenger + Freight
Inductive charging vehicle side systems	Electro mechanical system for inductive charging on vehicle side	FASTINCHARGE - Innovative fast inductive charging solution for electric vehicles	The project developed a secondary coil to be used on the vehicle side in order to allow inductive charging between infrastructure and vehicle	FP7	Passenger
Energy saving systems	Predictive Eco-Driving Human Machine Interface (HMI) for controlling truck speed based on topography	CONVENIENT - Complete Vehicle Energy-saving Technologies for Heavy-Trucks	CONVENIENT created a demonstrator for an E-Horizon (intelligent cruise control) system that intelligently controls the vehicle speed depending on the topographical data fed onto the system	FP7	Freight

## D 2.1 Transport projects & future technologies synopses handbook

Cooling system and simulation	Dual Level Cooling System design and simulation	CONVENIENT - Complete Vehicle Energy-saving Technologies for Heavy-Trucks	CONVENIENT designed and simulated an integrated thermal management system for ICE, hybrid motor, battery, e-auxiliaries and HVAC. In addition to this, new flat heat exchangers have been developed for the secondary cooling circuit that could substitute the conventional heat exchangers only for secondary cooling circuit in dual loop circuit.	FP7	Freight
Energy saving systems	Electric Air Conditioning system, featuring a high-voltage electric compressor, supplied by the high energy battery for energy saving while the truck is parked	CONVENIENT - Complete Vehicle Energy-saving Technologies for Heavy-Trucks	CONVENIENT developed, simulated and installed an Electric AC unit with an electric compressor offering autonomy up to 8-10 hours that can provide cooling to the driver while the truck is parked	FP7	Freight
Electrification of auxiliary systems and simulations	Electrification of auxiliary systems Electro-Hydraulic Power-Steering system (EHPS), Electric-driven Brake Air Compressor,	CONVENIENT - Complete Vehicle Energy-saving Technologies for Heavy-Trucks	CONVENIENT studied, designed and simulated the electrification of auxiliary components such as power steering systems and brake air compressor. The first system was simulated and demonstrated in a pilot trials on a truck while the second system was proven too complex to be demonstrated and was only simulated. The electrified steering system was overall equally or even better evaluated than the conventional one	FP7	Freight
Electrification of auxiliary systems and simulations	Electrification of auxiliary systems: electric water pump and electrical oil pump	GASTone - New powertrain concept based on the integration of energy recovery, storage and re-use system with engine system and control strategies	GASTone simulated the possibility of electrifying truck auxiliary systems such as the water pump and oil pump but concluded that only the oil pump showed potential energy saving benefits	FP7	Freight
Energy saving systems	Belt driven start stop generator	GASTone - New powertrain concept based on the integration of energy recovery, storage and re-use system with engine system and control strategies	GASTone had integrated a belt driven start stop generator that showed promising energy saving potential on a test bench truck engine	FP7	Freight
Energy saving systems	Hybrid-on-Demand (HoD) feature. This feature integrates regenerative braking, supplementary propulsion and intelligent energy controls on a truck	TRANSFORMERS - Configurable and Adaptable Trucks and Trailers for Optimal Transport Efficiency	TRANSFORMERS developed, tested and installed on truck the HoD system. The latter works by recapturing braking energy in heavy traffic or when it is necessary to restrict the vehicle's speed when descending hills. Unlike a conventional hybrid driveline, the diesel engine is on the tractor, while the supporting electric driveline	FP7	Freight

## D 2.1 Transport projects & future technologies synopses handbook

			is on the trailer		
HVAC	Magneto caloric refrigeration system for Evs	ICE - MagnetoCaloric Refrigeration for Efficient Electric Air Conditioning	ICE designed an efficient air conditioning and heating system based on a MagnetoCaloric heat pumps and a new system architecture to fulfil the thermal comfort and energy requirements of Fully Electric Vehicles (FEVs)	FP7	Passenger
Driving behaviour	Systems for assessing driver's behaviour such as mobile phone location services, mobile phone applications, telematics devices, built-in data loggers, dash cameras and enhanced dash cameras, wearable technologies, compound systems, and eye trackers	UDRIVE - eUropean naturalistic Driving and Riding for Infrastructure & Vehicle safety and Environment	UDRIVE used a series of available technologies to record and assess natural driving behaviour across 6 EU countries and create a European Naturalistic Driving database	FP7	Passenger & Freight
HVAC	Development of 1) refrigerant for cooling, combined with an energy-saving heat pump operation for heating, 2) advanced thermal storages based on phase change materials, powerfilms for infrared radiative heating	QUIET - QUalifying and Implementing a user-centric designed and Efficient electric vehicle	QUIET is to reduce the energy needed for cooling and heating the cabin of an electric vehicle under different driving conditions, by at least 30 %	H2020	Passenger
HVAC	1) Heating system that does not heat the air in the cabin but instead the surfaces surrounding the passenger. 2) Cooling unit with low weight materials and lead free	JOSPEL - Low energy passenger comfort systems based on the joule and peltier effects	JOSPEL created a new heating and cooling system for energy reduction of EVS	H2020	Passenger
Vehicle platooning control systems and ADAS	Level 2 automation system for truck platooning with On board systems for vehicle control & monitoring, sensory equipment for machine vision, GPS and an ADAS	Project 0-6836 - Commercial Truck Platooning Level 2 Automation	Project 0-6836 demonstrated the proof of concept for a level 2 automated vehicle platooning at the State of Texas. The platooning system consisted of a series of subsystems for controlling the vehicles, Human Machine Interface, sensors, cameras, fail safe mechanisms and an ADAS	USA-Texas Department of transport	Freight
Vehicle's health monitoring system	IoT based application for monitoring vehicle's condition	JAM - vehicle predictive maintenance through Artificial Intelligence	JAM will produce an IoT solution, connected to the vehicle's interface for OBD that will constantly monitor the vehicle's health. It will collect data from all vehicle sensors, and will detect risks before malfunctions occur	H2020	Passenger

			using state of the art AI.		
--	--	--	----------------------------	--	--

## 2.6 Aviation projects results

### Competitiveness – Aviation Projects

<b>Cluster:</b> C1 Competitive aviation					
<b>Subcluster:</b> C1-1 Innovative aircraft concepts/ frames/structures (Strut / truss braced wings, hybrid wing body, morphing airframes, low noise configurations, Personalized and individualized transportation to/from and within airport and during air travel, Small on-demand aircraft)					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Morphing concepts	1) Design, CFD and FEM of morphing drop nose wingtips, morphing camber 2) Design and CFD of variable planform and sweep (joined wing aircraft)	NEVEMOR - Novel Air Vehicles Configurations: From Fluttering Wings to Morphing Flight	The project designed, simulated, and evaluated various morphing wingtip configurations, skin materials and actuators to allow the morphing to take place. The wind tunnel test of the drop nose wingtips on a reference regional jet seemed to help the aerodynamic effectiveness. The morphing devices seemed to have more effectiveness in the joined wing aircraft.	FP7	Passenger
Airframes	Pro lattice barrel fuselage design	ALaSCA - Advanced Lattice Structures for Composite Airframes	The barrel design using tape laying processes has indicated a 10% reduction of primary structure weight	FP7	Passenger
Morphing concepts	Morphing technologies for wing leading edge, trailing edge and winglets.	SARISTU - Smart Intelligent Aircraft Structures	SARISTU designed, manufactured and tested morphing wing components	FP7	Passenger

## D 2.1 Transport projects & future technologies synopses handbook

Composite airframes	Composite fuselage section using a lattice structure with joints and openings incorporated into the design	WASIS - Composite Fuselage Section Wafer-design Approach for Increasing Safety in Worst-case Situations and Minimising Joints	WASIS designed a fuselage lattice section with the aim of replacing aluminium and reducing weight. The design incorporated joints and openings so manufacture would require fewer cuts	FP7	Passenger
Aircraft design	Blended Wing Body (BWB) using hybrid propulsion	AHEAD - Advanced Hybrid Engines for Aircraft Development	AHEAD conceptually designed a Blended Wing Body that can use hybrid propulsion	FP7	Passenger
Aircraft design	Design of a hypersonic aircraft capable of 5 Mach speed	ATLLAS II - Aero-thermodynamic Loads on Lightweight Advanced Structures II	Conceptual structural and thermal design, CFD and wind tunnel tests of a hypersonic aircraft design	FP7	Passenger
Personal aerial transportation system	Vertical take off and landing personal aerial vehicle	MYCOPTER - Enabling Technologies for Personal Air-transport Systems	MYCOPTER conceptualized a personal VTOL personal aerial vehicle with the aim of creating flight control and automations for the pilot	FP7	Passenger
Aircraft design	Design of a hypersonic aircraft capable of 7 Mach	HEXAFLY-INT - High-Speed Experimental Fly Vehicles - International	The project will design and demonstrate a 3 m vehicle capable of 7 Mach	FP7	Passenger
Air to air refuelling concept	Air to air refuelling for civil aircraft	RECREATE - Research on a Cruiser-enabled Air Transport Environment	RECREATE studied the feasibility of air to air refuelling with cruiser and feeder aircrafts	FP7	Passenger+F reight
Aircraft design	Design of hybrid wing body with multiple BLI fans on the upper side of the fuselage	DiSPURSAL - Distributed Propulsion and Ultra-high By-pass Rotor Study at Aircraft Level	Pre-design study of a Hybrid Wing-Body aircraft morphology comprising an airframe made from CFRP structure and installation of Riblets on its skin	FP7	Passenger
Morphing concepts	Design, modelling and testing of helicopter blade morphing technologies	SABRE - Shape Adaptive Blades for Rotorcraft Efficiency	SABRE aims to study and test shape adaptive blades which can morph their shape to optimize performance in all conditions.	H2020	Passenger
Aircraft design	C- wing design concept of an electrically propelled aircraft	Ce-Liner	CE-Liner is a concept study from Bauhaus Luftfahrt for a passenger aircraft for 2035 that will have a C wing design, using high temperature superconducting electric motors	German	Passenger

## D 2.1 Transport projects & future technologies synopses handbook

Aircraft design	3 aircraft designs to for subsonic flight: 1) purpose built aircraft, 2) Hybrid wing blended wing body design, 3) truss braced wing aircraft	NASA X-plane project	NASA will be reviving the X-plane project by	US-NASA	Passenger+ Freight
Aircraft design	Supersonic jet at 1.6 Mach	Spike S-512 Supersonic Jet	Spike S-512 Supersonic Jet will be able to fly at Mach 1.6 supersonic speed without creating a disturbing sonic boom. It will have a fuel efficient design, a range of 6200 nmi and modern cabin design capable of carrying up to 18 passengers.	PRIVATE	Passenger
Aircraft design	Supersonic Jet at 1.4 Mach	Aerion Mach 1.4 AS2 business jet	Aerion will develop a supersonic business jet able to cruise at Mach 1.4 or to cruise without a sonic boom at 1.1-1.2 Mach. It will feature advanced aerodynamics and cabin design.	PRIVATE	Passenger
Aircraft design	Supersonic Jet	BOOM XB-1 SUPERSONIC DEMONSTRATOR	Boom is developing a supersonic jet that will be able to hit Mach 2.2. It will be built from durable carbon composites. It will feature an area-ruled fuselage, a chine, and a refined delta wing in terms of aerodynamics and it will be powered by three turbojet engines equipped with variable geometry nozzle systems. It will be a one-third scale demonstrator of the BOOM passenger airliner.	PRIVATE	Passenger
Aircraft design	Quiet supersonic jet	D SEND programme	D send is JAXA programme for the design of supersonic passenger jet which will create a smaller sonic boom. The design is tested by dropping a 2 separate model designs from a high altitude and measuring the noise effect	JAXA	Passenger
Aircraft design	Rotary-wing airplane	Future type rotary-airfoil airplane system technology	This project aims to design a rotary-airfoil aircraft (helicopter) that can be used for emergency purposes. The aircraft will have no tail rotor while fixed wings and propellers will be added thus drastically improving about 1.8 times its maximum flying speed.	JAXA	Passenger
<b>Cluster:</b> C2 Competitive aircraft design					
<b>Subcluster:</b> C2-1 Design tools for structural reliability (CAE + other tools, computation for virtual & real advanced simulation and testing)					
<b>Technology theme</b>	<b>Technology identified</b>	<b>Project</b>	<b>Project brief results</b>	<b>Funding programme</b>	<b>Sector</b>

## D 2.1 Transport projects & future technologies synopses handbook

Structural loads	Computational FEA dynamic loading of an aircraft and validation through testing (buckling, material damping, mechanical hysteresis)	DAEDALOS - Dynamics in Aircraft Engineering Design and Analysis for Light Optimised Structures	The project designed a business regional jet for applying dynamic loading through FEA and verifying the results in real life tests on manufactured structural components. The computational results came close to the lab tests	FP7	Passenger
Computational Fluid Dynamics	Improvement of high order methods for computational fluid dynamics for modelling airflows	IDIHOM - Industrialisation of High-order Methods – A Top-down Approach	The project studied advanced turbulence models and the efficiency improvement of solution algorithms for the nonlinear discrete systems for both steady and time-accurate applications.	FP7	Passenger+ Freight
CAE	Predictive virtual testing of composite structures up to failure	MAAXIMUS - More Affordable Aircraft structure through eXtended, Integrated, and Mature nUmerical Sizing	MAAXIMUS created a predictive virtual platform for testing composite sections thus reducing time and cost of testing and changes to design	FP7	Passenger + Freight
Simulation tools for materials	Damage models for composite materials	EXTREME - EXTREME Dynamic Loading - Pushing the Boundaries of Aerospace Composite Material Structures	EXTREME developed new damage and meso-scale models to describe materials behaviour under dynamic loading. The material model able to describe shock wave formation and propagation in composites with long fibre	H2020	Passenger + Freight
CAE	CFD and FEA modelling of gust loads	AEROGUST - Aeroelastic Gust Modelling	AEROGUST will develop CFD and FEA models of gust loads on aircraft thus reducing the need for wind tunnel testing of these loads	H2020	Passenger + Freight
CAE	Modelling and simulation tools for bio-materials	ECO-COMPASS	ECO-COMPASS will develop modelling and simulation tools for biomaterials (bio-fibres and bio-resin) and multifunctional materials	H2020 EU-CHINA	Passenger
CAE	Development of CFD tools for rotary wing aircraft	Future type rotary-airfoil airplane system technology project	This project aims to design CFD tools that will help create a rotary-airfoil aircraft (helicopter) that can be used for emergency purposes. The software will determine wake flows corresponding to future rotary-wing aircraft, aerodynamic resistance and noise, and steering technology to be provided in the blade	JAXA	Passenger
CAE	Modelling and simulation tools for bio-materials	ECO-COMPASS	ECO-COMPASS will develop modelling and simulation tools for biomaterials (bio-fibres and bio-resin) and multifunctional materials	H2020 EU-CHINA	Passenger

## D 2.1 Transport projects & future technologies synopses handbook

CAE	Development of CFD tools for rotary wing aircraft	Future type rotary-airfoil airplane system technology project	This project aims to design CFD tools that will help create a rotary-airfoil aircraft (helicopter) that can be used for emergency purposes. The software will determine wake flows corresponding to future rotary-wing aircraft, aerodynamic resistance and noise, and steering technology to be provided in the blade	JAXA	Passenger
<b>Subcluster:</b> C2-2 Cabin (Windowless designs, Differentiation of flight cabin classes and zones according to individual needs, modular cabin design, Wide scale deployment of in-flight communication for passengers (mobile phone, Wi-Fi), Virtual reality in-flight entertainment)					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Passenger comfort	In flight Virtual reality (VR) and Mixed Reality (MR) systems	VR-HYPERSPACE - The innovative use of virtual and mixed reality to increase human comfort by changing the perception of self and space	The project tested VR and MR as ways of improving passenger comfort and creating positive illusions regardless of the cabin interior	FP7	Passenger
Cabin and cockpit noise	Instrumentation of a cabin and cockpit to evaluate noise	CANOBLE - CABin NOise from Boundary Layer Excitation	CANOBLE aims to manufacture, install instrumentation and test mock up sections of cabin and cockpit for analysing aero/vibro acoustics caused by external turbulent boundary layer	H2020	Passenger
Cabin design	Futuristic passenger-centered cabin design	FUCAM - FUTURE Cabin for the Asian Market	The project will develop a 2025+ conceptual cabin design devoted to the Asian market, for short and medium range aircrafts.	H2020	Passenger
<b>Cluster:</b> C3 Competitive aircraft production					
<b>Subcluster:</b> C3-1 Structural materials & composites					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector



## D 2.1 Transport projects & future technologies synopses handbook

Conductive nanomaterials	Nanoreinforced carbon based composites	ELECTRICAL - Novel Aeronautical Multifunctional Composite Structures with Bulk Electrical Conductivity and Self-sensing Capabilities	The project tested the electrical conductivity of composite structures in order to meet requirements for electrical static discharge and other electrical interferences. In addition the main aim was to create nanoreinforced CFRP materials with dielectric mounted sensors that will be used for non-invasively quality assessment monitoring	FP7	Passenger
Joints for fastened sections	1) Butt strap applications 2) H-Junctions, 3) Reversible bonding	CERFAC - Cost-effective Reinforcement of Fastener Areas in Composites	The project investigated joints such as 1) compressed moulded patches, 2) epoxy resins for H elements, 3) Stainless steel mesh with adhesive film, 4) thin ply reinforcements, 5) braided and tailored fiber placement reinforcements	FP7	Passenger
Nanomaterials	Nanomaterials for structural health monitoring	SARISTU - Smart Intelligent Aircraft Structures	SARISTU also designed, manufactured and tested a damage detecting self-sensing fuselage section demonstrator	FP7	Passenger
Composite materials	1) Titanium matrix composites (TMC), 2) Hollow sphere Structures, Tube Stacking Structures, 3) Ultra High Temperatures Ceramics, 4) Ceramic Matrix composites (CMC)	ATLLAS II - Aero-thermodynamic Loads on Lightweight Advanced Structures II	ATLLAS tested through FEA and operational testing various composite components for high thermal and structural loads. These materials were chosen as potential candidates for a highspeed aircraft capable of 5 Mach	FP7	Passenger
High temperature materials	High temperature structural materials for Mach 7	HEXAFLY-INT - High-Speed Experimental Fly Vehicles - International	The project will investigate materials capable of withstanding high temperature for Mach 7	FP7	Passenger
Material substitution	Alternatives to chromium coatings as corrosion protection for Magnesium-Aluminium alloys	ALMAGIC - Aluminium and Magnesium Alloys Green Innovative Coatings	ALMAGIC will seek for alternative of hexavalent chromium a known carcinogenic material used for corrosion treatment of Mg-Al alloys	H2020	Passenger + Freight
Joints for adhered sections	Titanium composite adhesive joints	TICOAJO - Titanium Composite Adhesive Joints	TICOAJO will investigate hybrid joining of titanium and CFRP sections through destructive testing and different environmental conditions	H2020	Passenger + Freight

## D 2.1 Transport projects &amp; future technologies synopses handbook

New materials	New high strength aluminium materials for ALM parts	Bionic Aircraft - Increasing resource efficiency of aviation through implementation of ALM technology and bionic design in all stages of an aircraft life cycle	The project will research new light weight aluminium materials capable of high strength for application in ALM	H2020	Passenger + Freight
New materials	PEEK-Carbon Fiber Prepreg with addition of amorphous (PEI) films	NHYTE - New Hybrid Thermoplastic Composite Aerostructures manufactured by Out of Autoclave Continuous Automated Technologies	NHYTE will develop new hybrid thermoplastic matrix composite materials with multifunctional capabilities which benefits from not requiring a curing phase in an autoclave thus lowering manufacturing energy costs	H2020	Passenger + Freight
New materials	Super-Icephobic surfaces to prevent ice formation on aircrafts	PHOBIC2ICE - Super-IcePhobic Surfaces to Prevent Ice Formation on Aircraft	PHOBIC2ICE will design and fabricate polymeric, metallic and hybrid coatings using different deposition methods. Laser treated and anodized surfaces will be prepared to study ice prevention methods on aircraft parts	H2020	Passenger + Freight
New materials	Development of lightweight ceramic matrix composites (CMC)	aFJR	Under the aFJR project, JAXA is developing lightweight heat resistant ceramic- matrix composites fan blades	JAXA	Passenger + Freight
New materials	Development of combining recycled carbon fibres and bio-fibres in a hybrid non-woven and bio-based epoxy resins	ECO-COMPASS	ECO-COMPASS will develop new biomaterials in a cooperation project between CHINA and the EU	H2020 EU-CHINA	Passenger
<b>Subcluster:</b> C3-2 Manufacturing processes (Additive manufacturing, other possible processes)					
<b>Technology theme</b>	<b>Technology identified</b>	<b>Project</b>	<b>Project brief results</b>	<b>Funding programme</b>	<b>Sector</b>
Additive Manufacturing	Selective Laser Melting (SLM) and Laser Metal Deposition (LMD) processes	MERLIN - Development of Aero-engine Component Manufacture using Laser-additive Manufacturing	MERLIN investigated the use of SLM and LMD in the manufacturing of engine components covering the design and manufacture of the components, integrated NDT into the process, productivity study and reduction of cycle time for these processes	FP7	Passenger

## D 2.1 Transport projects & future technologies synopses handbook

Casting	Gravity and centrifugal casting of large titanium alloy components	COLTS - Casting of Large Ti Structures	COLTS investigated the use of gravity and centrifugal casting processes for making Ti6Al4V alloy casts. Mould designs and coatings were modelled and tested to identify best results. Electron beam welding was also used as a manufacturing processes for welding thin large Ti sections	FP7	Passenger
Production simulation	Simulation of wingbox manufacture and assemble using Lean production principles	LOCOMACHS - Low COst Manufacturing and Assembly of Composite and Hybrid Structures	LOCOMACHS carried out a virtual lean production flow simulation of manufacturing and assembly of a complete wingbox	FP7	Passenger
Manufacturing processes	Out of Autoclave Liquid Resin Infusion (OOA LRI)	LOCOMACHS - Low COst Manufacturing and Assembly of Composite and Hybrid Structures	LOCOMACHS used the OOA LRI method for manufacturing composite aerostructures instead of using an autoclave that is an extremely expensive equipment	FP7	Passenger
Manufacturing processes	Asymmetric incremental sheet metal forming for Ti alloys	INMA - Innovative Manufacturing of Complex Ti Sheet Aeronautical Components	The project used 2 technology demonstrators for manufacturing Ti6Al4V components under hot and cold forming conditions. The results offered good geometric accuracy and overall quality	FP7	Passenger + Freight
Assembly process automation	Reduction of assembly time of large composite aircraft sections through heavy automation	MAAXIMUS - More Affordable Aircraft structure through eXtended, Integrated, and Mature nUmerical Sizing	MAAXIMUS objective was to reduce assembly time of large composite structures of the fuselage by using robotics and tolerance management	FP7	Passenger + Freight
Manufacturing processes	Adaptive manufacturing processes and Rapid Manufacture for Gamma Titanium Aluminides ( $\gamma$ -TiAl)	MMTech - New aerospace advanced cost effective materials and rapid manufacturing technologies	MMTECH will develop methods for creating consistent powder batches of $\gamma$ -TiAl and investigate adaptive manufacturing techniques which can automatically vary deposition and machining parameters based on information gained during manufacture. It will look into softening the material with lasers to reduce cracking during manufacturing. Such metal powders have the potential of reducing costs is the entire life cycle of the component	H2020	Passenger + Freight

## D 2.1 Transport projects & future technologies synopses handbook

Additive Manufacturing	Additive Layer Manufacturing (ALM)	Bionic Aircraft - Increasing resource efficiency of aviation through implementation of ALM technology and bionic design in all stages of an aircraft life cycle	The project aims to develop automated ALM design process to significantly reduce time and costs for bionic lightweight design. In addition it will create energy efficient and highly productive ALM process with innovative beam shaping optics to lower costs of manufacturing and reduce emissions during manufacturing. An integrity system will be added into the manufacturing process ensuring the integrity of the manufactured components. The ALM method will be used for Airbus' future biomimetic design concepts of aircrafts	H2020	Passenger + Freight
Additive Manufacturing	Direct Energy Deposition (DED) Additive Manufacturing (AM)	AMOS - Additive Manufacturing Optimization and Simulation Platform for repairing and re-manufacturing of aerospace components	AMOS will conduct fundamental research to understand the material integrity through chosen DED AM processes, the accuracy and limitations of these deposition processes, defect identification and automated and hybrid DED combined with post-deposition machining strategies	H2020	Passenger + Freight
Simulation tools	Virtual reality simulation for production and assembly planning	SIMFAL - Assembly Planning and Simulation of an Aircraft Final Assembly Line	SIMFAL will develop a VR simulation tool that can help aircraft manufacturers to visualize the effect that alternative actions have on planning and assembly. The tool will provide information about the current assembly strategy, the current state of the system (logistics, machine equipment) and maintenance information	H2020	Passenger + Freight
Additive Manufacturing	Direct Laser Deposition - DLD, Selective Laser Melting - SLM and Electron Beam Melting - EBM	AMATHO - Additive Manufacturing for Tiltrotor HO using	AMATHO aims to design, assess and manufacture a novel tiltrotor drive system housing exploiting the features of additive manufacturing techniques. powder feed direct energy deposition techniques (Direct Laser Deposition - DLD) and powder bed fusion techniques (Selective Laser Melting - SLM and Electron Beam Melting - EBM) are investigated. In addition various metals are assessed for particles' granulometry, morphology, material properties and compatibility for these AM methods	H2020	Passenger
Manufacturing processes	Automated out of autoclave process for Carbon Fibre Reinforced Plastics	LOWFLIP - Low cost flexible integrated composite process	LOWFLIP developed a manufacturing process suitable for various transport sectors. A demonstrator relevant to aviation was carried out by producing a typical stiffened skin panel from a tail cone section. The double-curved skin is stiffened with T-stringers, which have to be preshaped in a separate forming step and joined with the skin by co-curing both elements	FP7	Passenger + Freight

## D 2.1 Transport projects &amp; future technologies synopses handbook

Additive Manufacturing/ Advanced manufacturing process	1) Additive manufacturing, 2) Near Net Shape Hot Isostatic Pressing (NNSHIPping), 3) Investment casting for Ti alloys	EMUSIC	EMUSIC project is a cooperation project between EU and CHINA with the objective of developing manufacturing process. The main aims are to 1) the build rate and the build up of stresses during AM; 2) the reproducibility of products, the characteristics of the powder and the development of reusable and/or low cost tooling for NNSHIP; (3) issues caused by inconsistent microstructures; (4) improving the strength of wax patterns and optimising welding of investment cast products	H2020 EU-CHINA	Passenger + Freight
<b>Cluster:</b> C4 Competitive Life Cycle Services					
<b>Subcluster:</b> C4-1 Inspection & maintenance (inspection & maintenance new methods)					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Non-destructive testing (NDT)	Extended NDT for CFRP structures and bonds	ENCOMB - Extended Non-Destructive Testing of Composite Bonds	The project tested various NDT methods such as laser scanning vibrometry, active thermography. Sensor-based techniques such as embedded optical fibre sensors or electrochemical impedance spectroscopy were also tested as well as laser-excited and non-linear ultrasonic techniques.	FP7	Passenger
Non-destructive testing (NDT)	Use of pulsed and continuous Terahertz systems for NDT of composites	DOTNAC - Development and Optimisation of THz NDT on Aeronautic Composite Multilayered Structures	Pulsed and continuous terahertz systems were tested on 2D scanner for inspecting aircraft components. The technique was able to detect delaminations on glass fibre laminates as well as defects in bonds of sandwich structures like fibre reinforced plastics	FP7	Passenger
Non-destructive testing (NDT)	1) Acousto-Ultrasonic Tomography and 2) Air Coupled Ultrasound Inspection	LOCOMACHS - LOW COst Manufacturing and Assembly of Composite and Hybrid Structures	1) Novel capacitive and piezoelectric transducers with innovative focusing capabilities were developed, including control electronics, 2) Novel probes for contact generation and detection of plate waves in the 100-200 kHz range were developed and manufactured	FP7	Passenger + Freight
Non-destructive testing (NDT)	Extended NDT for CFRP bondlines	ComBoNDT - Quality assurance concepts for adhesive bonding of aircraft composite structures by extended NDT	ComBoNDT seeks to identify non destructive testing techniques for testing adhesive bonded CFRP sections	H2020	Passenger + Freight

## D 2.1 Transport projects & future technologies synopses handbook

Non-destructive testing (NDT) and repairing	New NDT and repair methods for ALM parts	Bionic Aircraft - Increasing resource efficiency of aviation through implementation of ALM technology and bionic design in all stages of an aircraft life cycle	The project will develop new innovative NDT and repairs methods for ALM part in order to reduce costs and component service life	H2020	Passenger + Freight
<b>Subcluster: C4-2 Repair, retrofit (repair and retrofitting new methods)</b>					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Repair processes and equipment	Novel Processes and Equipment in Composite Repair Technology	NEWCORT - Novel Processes and Equipment in Composite Repair Technology	The project will develop and validate novel processes and equipment for the repair of composite airframes.	H2020	Passenger + Freight
<b>Subcluster: C4-3 Life cycle approaches (Aircraft Life cycle)</b>					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Recycling of materials	Re-use of Thermoplastic Composites from dismantled aircrafts	RESET - Re-use of Thermoplastic Composite	The project aims to bring a second life to thermoplastic composites from dismantled aircrafts, to the carbon fibre recovery by means of polymer pyrolysis or to energetic recovery. These composites will be used to obtain new, reinforced thermoplastic composites. The project will also evaluate their properties to ensure suitability regarding their final application in the aviation industry.	H2020	Passenger + Freight
Recycling of materials	Recycling of Additive Layer Manufacturing materials	Bionic Aircraft - Increasing resource efficiency of aviation through implementation of ALM technology and bionic design in all stages of an aircraft life cycle	Bionic Aircraft project will develop recycling method for ALM parts to avoid disposal	H2020	Passenger + Freight

**Environment – Aviation Projects**

<b>Cluster: ENV1 Reducing emissions</b>					
<b>Subcluster: ENV1-1 Alternative fuels (biofuels, alternative fuels)</b>					
<b>Technology theme</b>	<b>Technology identified</b>	<b>Project</b>	<b>Project brief results</b>	<b>Funding programme</b>	<b>Sector</b>
Production of synthetic fuels	Production of kerosene using Fischer-Tropsch method from synthetic gas	SOLAR-JET - Solar Chemical Reactor Demonstration and Optimisation for Long-term Availability of Renewable Jet Fuel	SOLAR-JET demonstrated the entire production chain of renewable kerosene obtained from solar energy, water and carbon monoxide for use in the aviation industry	FP7	Passenger + Freight
2nd generation biofuels	Testing of biofuels (alcohols, methyl esters, ethyl esters, valerates, furanics, branched hydrocarbons, in relation to synthetic jet fuels)	2G-CSAFE - Combustion of Sustainable Alternative Fuels for Engines used in aeronautics and automotives	2G-CSAFE tested pollutants formation from oxidation /combustion of biofuels and blends in experimental reactors and sampling cones. The results showed that biofuels lead to increased formation of pollutants	FP7	Passenger + Freight
2nd generation biofuels	Demonstration of blended biokerosene with conventional fuels (camelina and cooking oil)	ITAKA - Initiative Towards sustainable Kerosene for Aviation	Two demonstrators of biofuels usage at Oslo Gardermoen and Los Angeles Airports	FP7	Passenger + Freight
Alternative fuels	Design tools and experiments for risk assessment of alternative fuels	JETSCREEN - JET Fuel SCREENing and Optimization	JETSCREEN will design a screening and optimisation platform that integrates design tools and experiments with the aim of optimising alternative fuels for maximum energy per kilogram of fuel and lower emissions in the combustion system	H2020	Passenger + Freight
Alternative fuels	Tests of various alternative fuels (paraffinic kerosene, Farnesane paraffin, synthetic paraffinic kerosene, Hydrotreated Depolymerized Cellulosic Jet and Sasol Iso-paraffinic kerosene for effect in engine components and performance	CLEEN programme	Under the CLEEN programme Boeing tested the effect of paraffinic kerosene on non metallic engine components with the results varying based on the materials that these non metallic components were made of. In addition Pratt & Whitney tested different fuel blends (separately) of synthetic paraffinic kerosene, Hydrotreated Depolymerized Cellulosic Jet and Sasol Iso-paraffinic kerosene with aviation fuel in order to investigate any negative effects on engine performance. No negative effects were observed	FAA- Private	Passenger

<b>Subcluster: ENV1-2</b> Reducing noise emissions (engine/aircraft noise emissions)					
<b>Technology theme</b>	<b>Technology identified</b>	<b>Project</b>	<b>Project brief results</b>	<b>Funding programme</b>	<b>Sector</b>
Noise modelling	Noise modelling and measurements for Counter Rotating Open Rotor aircraft	NINHA - Noise Impact of Aircraft with Novel Engine Configurations in Mid-to-High Altitude Operations	NINHA used various noise modelling and computational simulation techniques to simulate noise levels from a CROR engine while en route and near field	FP7	Passenger
Engine noise control and simulation	Simulation of noise control by using plasma actuators	ORINOCO - Co-operation with Russia in the Field of Advanced Engine Noise Control based on Plasma Actuators	Numerical simulations were used to measure near field noise of shear level of the jet with or without actuators. Further studies were carried out in a lab using six plasma actuators in a circular jet nozzle	FP7	Passenger + Freight
Noise modelling and testing	Engine core noise measurements from interaction between combustor and turbine	RECORD - Research on Core Noise Reduction	RECORD used prediction methods for core noise, ranging from low-order modelling approaches to high-fidelity compressible large eddy simulations (LESs). In addition the project developed test rigs that can measure combustion noise in transonic high pressure turbines	FP7	Passenger + Freight
Noise reduction and testing	1) Liners for nacelles and fan modules of Ultra High Bypass Ratio (UHBR) engines, 2) Large low pressure ratio fan module and a novel intermediate case	ENOVAL - Engine Module Validators	1) Prototype electrodynamic panel designed, manufactured and tested on a test rig, 2) CFD and FEA of optimum fan designs and manufacturing simulation of the components	FP7	Passenger + Freight
Software tools for quieter design of engines	Aeroacoustic design and prediction tools related to fan broadband (BB) noise emissions from aircraft nacelle intakes + exhaust nozzles	TurboNoiseBB - Validation of improved turbomachinery noise prediction models and development of novel design methods for fan stages with reduced broadband noise	TurboNoiseBB will create aeroacoustic design prediction tools with the aim of designing a novel low BB fan system incorporating nacelle intakes & exhaust nozzles noise emissions	H2020	Passenger + Freight
Noise reduction and testing	Innovative technologies for the reduction of aircraft noise at the source	ARTEM - Aircraft noise Reduction Technologies and related Environmental iM pact	Noise reduction studies looking at various components together rather than isolated sources. In addition ARTEM will explore efficient noise damping of engine noise and other sources through investigation of dissipative surface materials and liners. These technologies will be coupled to the modelling of future aircraft configuration such as blended wing body	H2020	Passenger + Freight



## D 2.1 Transport projects & future technologies synopses handbook

Noise management	Methodologies and tools to mitigate the impact of aviation noise	ANIMA - Aviation Noise Impact Management through Novel Approaches	The project will review and assess noise management practices to establish best practice guidelines, create a platform gathering tools and best practices and ensuring exploitation of the results, assess new methodologies for reducing community annoyance and it will develop a 24/7 Noise Management Toolset, to manage and mitigate the impact of aviation noise.	H2020	Passenger + Freight
Noise reduction methods	Simulation methodologies and investigation of plasma actuation, turbulence screens and innovative porous materials as noise mitigation methods	IMAGE - Innovative Methodologies and technologies for reducing Aircraft noise Generation and Emission	The project's purpose is to investigate experimentally and numerically innovative airframe and engine noise-reduction technologies and to develop robust methodologies of addressing these technologies. The research involves the use of plasma actuation, turbulence screens and innovative porous materials.	H2020	Passenger + Freight
Noise modelling & testing	Computational fluid dynamics (CFD), computational aero-acoustics (CAA) for open rotor engine	CLEEN programme	Under the CLEEN programme, computational fluid dynamics (CFD), computational aero-acoustics (CAA), and rig scale testing were carried out to the design of open rotor engines with the aim of reducing the noise emissions. Gust/forcing, blade response, near field acoustics and farfield acoustics were tested. Different rotor blade designs and configurations were modelled with the final design offering 26% noise reduction due to lower fuel burn alone	FAA- Private	Passenger
Noise modelling	Computational fluid dynamics for evaluating N wave sonic boom noise	ASCENT project No. 007	ASCENT project 007 aims to advance the understanding of N wave sonic boom noise from supersonic aircrafts. So far the following studied have been carried out: 1) The assessment of low boom acoustic signatures and the causes of variability. 2) The evaluation of the appropriateness of metrics for use in noise certification, as assessed for wide range of sonic boom signatures. 3) An exploratory review of social media monitoring as potential supplemental means to gauge the overall community reaction to a community noise test.	FAA- Private	Passenger
Noise measurements	Noise measurements of N waves from sonic boom noise	D SEND programme	D send is JAXA programme for the design of supersonic passenger jet which will create a smaller sonic boom. The design is tested by dropping a 2 separate model designs from a high altitude and measuring the noise effect	JAXA	Passenger
Noise reduction methods & modelling	Noise mitigation technologies 1) Serrated slat, 2) brake system perforated fairing, 3) flyover noise source measurements	FQUROH	The FQUROH project aims to reduce noise emissions of aircrafts by studying different mitigation methods such as: 1) a separated lower part of the slat (cusp) at the leading edge of the wing instead of conventional slat that creates	JAXA	Passenger + Freight

			swirling shear flow; 2) A streamlined perforated fairing system that is attached to the wheels and reduces vortical flow; 3) Development of a phased array microphone system that can capture and localise noise source while the aircraft is flying above the measuring system.		
--	--	--	--	--	--

### **Energy – Aviation Projects**

<b>Cluster:</b> ENE1 Optimising resistance and propulsion					
<b>Subcluster:</b> ENE1-1 Aerodynamics (High lift devices, drag reductions coatings, winglets, riblets, laminar flow, boundary layer, wingtip devices)					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Surface protection system	Active and passive multi-functional surface protection systems for wings	AEROMUCO - Aerodynamic Surfaces by Advanced Multifunctional Coatings	Development and testing of novel coatings for preventing ice build up, rain erosion, abrasion and kinetic assessment of enzyme	FP7	Passenger + Freight
Separation control and drag reduction	Active flow control and interrelations with Reynolds stress	MARS - Manipulation of Reynolds Stress for Separation Control and Drag Reduction	MARS simulated and tested a variety of actuators. The use plasma actuators for controlling downstream flow and affecting the development of Reynolds stresses	FP7	Passenger + Freight
Computational modelling	Improvement of transition-prediction tools for future laminar flow aircraft	RECEPT - Receptivity and amplitude-based transition prediction	RECEPT aimed to improve transition-prediction tools that can identify when the air flow changes from a laminar state to a turbulent one in order to help future aircraft designs	FP7	Passenger
Advanced flow diagnostics	Particle Image Velocimetry (PIV) for measuring flow field	AFDAR - Advanced Flow Diagnostics for Aeronautical Research	AFDAR used PIV to achieve 3D volumetric measurements over wings and aerofoils and gain understanding of turbulence physics	FP7	Passenger + Freight
High speed aerodynamics	Aerodynamic balance at Mach 7	HEXAFLY-INT - High-Speed Experimental Fly Vehicles - International	The project will investigate high speed aerodynamics	FP7	Passenger

## D 2.1 Transport projects & future technologies synopses handbook

Air Flow control methods	Interaction between shock waves and boundary layer separation points	TFast - Transition Location Effect on Shock Wave Boundary Layer Interaction	The project will identify shock wave on aircraft structures and components and will identify flow control methods for transition induction methods	FP7	Passenger
Air Flow control methods	Turbulent Boundary Layer Control (TBLC) for skin-friction drag	DRAGY - Drag Reduction in Turbulent Boundary Layer via Flow Control	DRAGY will investigate the application of active and passive control turbulent skin-friction drag reduction methods from a TRL 1 to TRL 2-3	H2020	Passenger +Freight
Wing design	Design and scaled wind tunnel test of light weight, low drag truss braced wings	NASA-Boeing based project	NASA and Boeing have been working together to design a longer, thinner and lighter wing for commercial transport aircraft that requires a brace, or truss, to provide the wing extra support and will be able to reduce carbon emissions by 50%	USA-NASA-Private	Passenger
<b>Subcluster: ENE1-2</b> Engines (Advanced and open geared Turbofan, open rotor engines, electric propulsion, fans, engine cooling technologies, hybrid propulsion, distributed propulsion, combustors, compressors, low noise configurations)					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Engine compressors	Ultra-high pressure ratio compressors	LEMCOTEC - Low-emissions Core-engine Technologies	Development and manufacture of Ultra-high pressure ratio compressors for a small regional turbofan engine. The architecture integrated lean burn technology for Nox targets	FP7	Passenger
Combustors	Lean combustion for ultra high Overall Pressure Ratio (OPR)	LEMCOTEC - Low-emissions Core-engine Technologies	Design and manufacture of a lean combustion chamber for ultra high OPR along with fuel injection and control system	FP7	Passenger
Engine thermal management & structures	High performance light weight High Pressure Compressor (HPC) guide vane and the Cooled HPC exit cone	LEMCOTEC - Low-emissions Core-engine Technologies	Design and manufacture of components and structures to allow high stiffness compressors including testing of cast components	FP7	Passenger + Freight
Combustor- turbine design efficiency	Combustor-turbine flow interaction for high pressure turbines (HPT)	FACTOR - Full Aero-thermal Combustor-turbine Interaction Research	Design and manufacture of engine components as well as test rig to study the flow interaction of the combustor and turbine	FP7	Passenger + Freight

## D 2.1 Transport projects & future technologies synopses handbook

CFD of fuel injectors	CFD of fuel spray behaviour and soot formation	FIRST - Fuel Injector Research for Sustainable Transport	Development, fine-tuning and validation of CFD models to accurately describe the atomisation process and soot formation in a combustor	FP7	Passenger + Freight
Turbine materials	Superalloys for turbine blades (Nb/Nb5Si3 and SiN4/MoSi2)	HYSOP - Hybrid Silicide-based Lightweight Components for Turbine and Energy Applications	HYSOP identified Nb/Nb5Si3 and SiN4/MoSi2 as potential materials for turbines blades for their properties of withstanding high temperatures. The project design and tested various manufacturing processes for making these blades	FP7	Passenger + Freight
Combustors	Novel combustor design architectures	IMPACT-AE - Intelligent Design Methodologies for Low-pollutant Combustors for Aero-engines	IMPACT-AE designed, modelled and validated combustor architectures with the aim of reducing CO and NOX emissions. The results offered a 50% reduction in NOX emissions	FP7	Passenger + Freight
Hybrid propulsion	Hybrid engine using shrouded contra-rotating fans, bleed cooling, dual hybrid combustion system (biofuel and hydrogen)	AHEAD - Advanced Hybrid Engines for Aircraft Development	AHEAD designed and tested the concept of a hybrid engine with innovative technologies using LNG and hydrogen. The engine was designed to be used on Multifuel Blended Wing Body	FP7	Passenger + Freight
Powerplant optimisation	Flow field interactions between combustor and High Pressure Turbine (HPT)	FACTOR - Full Aero-thermal Combustor-Turbine interaction Research	Designed, manufactured and tested a combustor outlet / turbine inlet to investigate interaction of the two components as one unit and reduce specific fuel consumption	FP7	Passenger + Freight
Hybrid propulsion	Design of superconductive Hybrid-electric distributed propulsion (DP)	ASuMED - Advanced Superconducting Motor Experimental Demonstrator	ASuMED will design, develop and demonstrate a high temperature superconductive stator with an integrated cryogenic cooling system that will be used for aircraft hybrid propulsion	H2020	Passenger
Hybrid propulsion	Basic research for hybrid electric powertrain using High Temperature Superconducting motors	DIspURSAL - Distributed Propulsion and Ultra-high By-pass Rotor Study at Aircraft Level	Hybrid-electric power-train that requires basic research regarding hybrid-electric systems architecture and behaviour of associated components, such as High-Temperature Super-conducting (HTS) motors, generators, gear system, converter/controller, Solid State Power Controllers (SSPC), cryo-cooler and HTS transmission system	FP7	Passenger
Alternative propulsion	Pulse Detonation Combustor (PDC) demonstrator as replacement of the turbine in a turboengine	TIDE - Tangential Impulse Detonation Engine	TIDE designed, manufactured a PDC demonstrator as an alternative engine part for future high speed aviation transport. The project included CFD simulations	FP7	Passenger

## D 2.1 Transport projects & future technologies synopses handbook

Engine design and emissions	Alternative designs of engine combustion systems for reduced non-volatile PMs	SOPRANO - Soot Processes and Radiation in Aeronautical inNOvative combustors	SOPRANO will deliver more accurate experimental and numerical methodologies for predicting the soot emissions in combustion systems	H2020	Passenger +Freight
Engine design and emissions	Research for optimum turbofan engine design	ULTIMATE - Ultra Low emission Technology Innovations for Mid-century Aircraft Turbine Engines	ULTIMATE will explore the major loss sources at current turbofan engine and will explore synergies of breakthrough technologies that can be used in the future in order to create engines with ultralow CO2, NOX and noise emissions	H2020	Passenger + Freight
Engine heat exchangers	New concepts for heat exchangers	SHEFAE 2 - Surface Heat Exchangers For Aero Engines 2	SHEFAE2 aims to develop, design and manufacture High Length to depth ratio Surface Air Cooled Oil Coolers and mounting systems as well as High efficiency Fuel Oil Heat Exchanger	H2020 EU-JAPAN	Passenger+ Freight
Hybrid propulsion	Serial-hybrid-electric propulsion architecture for aircraft	MAHEPA - Modular Approach to Hybrid Electric Propulsion Architecture	MAHEPA will bridge the gap between research and product stage for hybrid propulsion system. The latter consists of a hydrocarbon fuelled internal combustion engine and an electric generator as primary power source, while in the second source is a hydrogen fuel cell that will produce power showcasing the flexibility of the architecture	H2020	Passenger+ Freight
Engine control	Electronic Control unit for diesel aviation engines	EDEC - Enhanced Diesel Engine Control	EDEC will develop an Electronic Control Unit for a 6 cylinder diesel engine used for general aviation	H2020	Passenger
Blade design	Blade design, FEA and testing of Counter Rotating Open Rotor Engine blades	BLADEOUT - CROR Blade-Out Impact Simulations and Sample Manufacturing	BLADEOUT will design and test blades for CROR engines with the aim of ensuring their safety mandated by aviation regulations in case of a blade-out failure due to the specific design of the CROR engine and its blades than may cause impact to the fuselage	H2020	Passenger + Freight
Engine design	Engine compartments for a rotorcraft	DREAM - Design and Realization of equipped engine compartments including cowling for a fast compound rotorcraft	The project will cover the design and manufacturing of the engine compartments for a fast compound rotorcraft. It will also cover the flightworthiness substantiation.	H2020	Passenger
Turboprop mechatronics	Electrical power management of Turboprop engine	ACHIEVE - Advanced mechatronics devices for a novel turboprop Electric starter-generator and health monitoring system	The project will develop a multi-functional, compact and engine-integrated mechatronics device, for better, more efficient and greener turboprops. The device will be able to perform functions like motoring, generating, power transmission, health monitoring and communication.	H2020	Passenger

## D 2.1 Transport projects &amp; future technologies synopses handbook

Combustors	Combustor design for lower emissions and efficiency	CLEEN programme	Under the CLEEN programme General Electric tested a lean burn combustor system the TAPS II (Twin Annular Premixing Swirler) with aim of improving NOX emissions and particulate emissions below the CAEP/6 requirements and apply the TAPS technology to narrow body applications including demonstration of the system on a core engine.	FAA- Private	Passenger
Electric propulsion	Electric propulsion system for light aircraft	FEATHER	Under the FEATHER project, JAXA has developed an aircraft-use 60 kw electric motor system for a small glider aircraft. The motor delivers high levels of output per unit weight, has excellent efficiency, and offers regenerative power during descent procedures to charge its battery.	JAXA	Passenger
Engine design	Ultra-high bypass fan jet engine	Advanced Fan Jet Research (aFJR) project	The aFJR is a project for improving turbofan engines by increasing engine bypass ratio. The increase of bypass ratio will require larger fan diameter which will be manufactured by lightweight materials.	JAXA	Passenger + Freight
<b>Subcluster: ENE1-3</b> Engine cycles					
<b>Technology theme</b>	<b>Technology identified</b>	<b>Project</b>	<b>Project brief results</b>	<b>Funding programme</b>	<b>Sector</b>
N/A	N/A	N/A	N/A	N/A	N/A
<b>Subcluster: ENE1-4</b> Nacelles (buried engines, reduced weight nacelles)					
<b>Technology theme</b>	<b>Technology identified</b>	<b>Project</b>	<b>Project brief results</b>	<b>Funding programme</b>	<b>Sector</b>
Morphing nacelles	Morphing nacelle lip CFD and FEA	MORPHELLE - Morphing Enabling Technologies for Propulsion System Nacelles	MORPHELLE developed a concept of a morphing nacelle lip that can change its geometry according for take off and landing in order to reduce fuel consumption and noise emissions	FP7	Passenger
Nacelle design	Increased nacelle length to reduce nacelle drag	BALANCE - Business Aviation Laminar Nacelle	The project aims to provide technologies that enable reduction of the drag of the business jet nacelle by 1%, by increasing the laminar surface to 30-40% of the nacelle length.	H2020	Passenger

**Infrastructure – Aviation Projects**

<b>Cluster: INF1</b> Airport safety/ security (Airport safety/ security procedures, Integrated security approach “no borders”)					
<b>Technology theme</b>	<b>Technology identified</b>	<b>Project</b>	<b>Project brief results</b>	<b>Funding programme</b>	<b>Sector</b>
Secure cargo containers	Smart secure cargo container to eliminate screening and tampering	CITRIMACC - Circulation Pilot with Continuous Control of Multi-Modal Air Cargo Containers	CITRIMACC's concept is a smart cargo container and information exchange platform with the aim of reducing screening costs and eliminate tampering risks by combining composite materials, electronic documentation, GPS, GPRS and RFID technologies for real time monitoring	H2020	Freight
Automated border control gates (ABC)	Enhancement of the Automated Border Control gates system	ABC4EU - ABC GATES FOR EUROPE	The project will enhance the workflow and functionalities of the ABC Gates. It will identify the requirements for an integrated, interoperable and citizen's rights respectful ABC system and It will focus in the need for harmonization in the design and operational features of ABC Gates.	FP7	Passenger
<b>Cluster: INF2</b> Innovative airport concepts (Central airport and inner-city air transport concepts)					
<b>Technology theme</b>	<b>Technology identified</b>	<b>Project</b>	<b>Project brief results</b>	<b>Funding programme</b>	<b>Sector</b>
Airship concepts	Multibody airship	MAAT - Multibody Advanced Airship for Transport	MAAT conceptualized a flying airship system based on the cruiser / feeder principle offering a flexible shuttle service for long and middle range air transport	FP7	Passenger+ Freight
Airport concepts	Design of an inner city airport	CentAirStation	Bau Bauhaus Luftfahrt in collaboration with Glasgow School of Art investigated and design the concept of an inner city airport for aircrafts operating regionally between these new inner-city airports and conventional airports. The concept will contribute to solve major air transport challenges in 2040 and beyond. High noise protection and intermodality connections are envisaged in the concept design.	German	Passenger+ Freight
<b>Cluster: INF3</b> Airport operations (full automation of passenger baggage processes)					

Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Information systems	Travel time optimization systems	PASSME - Personalised Airport Systems for Seamless Mobility and Experience	The project will develop a real-time system for managing passenger flows, a passenger independent system for managing luggage flows, passenger-centric airport and airplane interior designs and a personalized application that will provide personalized information, for reduced travel times, seamless and less stressful journeys.	H2020	Passenger
<b>Cluster: INF4</b> Intermodality (Improved performance and integration with other modes)					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Information systems	Information system for travel time optimization	DORA - Door to Door Information for Airports and Airlines	The project will develop an information system to reduce time needed for transportation to, from and within the airport and provide fast alternatives to the passengers. At the time being the project has completed the requirements and components specification phase, a project evaluation plan has been developed and preparation for trials has started.	H2020	Passenger

### Systems – Aviation Projects

<b>Cluster: SYS1</b> Aircraft systems (Flight control systems, System Health Monitoring - diagnostic and prognostic, Flying communication networks)					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Flight safety	Aircraft-pilot-couplings and rotorcraft-pilot-couplings (A/RPCs)	ARISTOTEL - Aircraft and Rotorcraft Pilot Couplings – Tools and Techniques for Alleviation and Detection	ARISTOTEL developed different pilot-vehicle models that can simulate aircraft behaviour under operation and assist the pilot thus improving flight safety	FP7	Passenger + Freight
Personal aerial transportation systems & flight controls	1) Human machine interface for controlling and augmentation 2) Automation and navigation	MYCOPTER - Enabling Technologies for Personal Air-transport Systems	1) Development of a prototype human-machine interface (HMI) for personal aerial vehicle with the combination of a haptic shared control framework and a Highway-in-the-Sky display. 2) Developed navigation systems and simulated collision avoidance	FP7	Passenger



## D 2.1 Transport projects & future technologies synopses handbook

High speed flight control	High speed flight control	HEXAFLY-INT - High-Speed Experimental Fly Vehicles - International	The project will investigate high speed flight control systems	FP7	Passenger
Structural monitoring and simulation	In flight structural health monitoring based on modelling	VIBRATION - Global in flight health monitoring platform for composite aerostructures based on advanced VIBRATION based methods	VIBRATION created a structural health monitoring platform that can estimate the damage to a composite structure during flight. Numerical modelling was used to predict the threshold between a healthy and damaged part	FP7	Passenger
Automatic flight control and simulations	Preliminary design of automatic flight controls and human machine interface for air to air refuelling	RECREATE - Research on a Cruiser-enabled Air Transport Environment	RECREATE did the preliminary design and human machine interface that would enable air to air refuelling of civil aircrafts	FP7	Passenger + Freight
Morphing concepts	Piezoelectric systems for morphing aerofoil sections	FUTUREWINGS - Wings of the future	FUTUREWINGS looked into systems required to allow morphing of aerofoil section. Theoretical models and CFD of components were carried out to evaluate the concept. Small aerofoils were manufactured and tested	FP7	Passenger
Morphing concepts	Piezoelectric systems for morphing aerofoil sections combined with vibro acoustics sensors	SMS - Smart Morphing and Sensing	SMS will develop a system for a morphing flap with the aim of changing shape based on real time vibro acoustic sensory data	H2020	Passenger + Freight
Sensor technologies	High speed fibre optic sensors and piezosensor networks for dynamic loading monitoring	EXTREME - EXTREME Dynamic Loading - Pushing the Boundaries of Aerospace Composite Material Structures	EXTREME developed smart impact high fibre optic sensors and piezosensors that can help in real time monitoring of dynamic loading thus finding applicability by the manufacturers seeking intelligent structural components	H2020	Passenger + Freight
Energy Storage	Energy Storage and Regenerative System (ESRS)	ESTEEM - Advanced Energy STORAGE and Regeneration System for Enhanced Energy Management	ESTEEM will develop a Energy Storage and Regenerative System ESRS with embedded supercapacitors Energy Storage Device (ESD) for smart energy management of a regenerative Electro-Mechanical Actuator (EMA) emulator	H2020	Passenger + Freight
Integrated sensors	Integrated sensors for structural components	ACASIAS - Advanced Concepts for Aero-Structures with Integrated Antennas and Sensors	ACASIAS will develop integrated sensors for monitoring noise, and communications in fuselage, winglets, and structural panels	H2020	Passenger + Freight

## D 2.1 Transport projects & future technologies synopses handbook

Anti-icing and de-icing systems	Development and test of a heater layer for tilt rotorcrafts	NO-ICE-ROTOR - Development and demonstration of materials and manufacturing process for ultra high reliability electric Anti-ice/De-ice thermal layers for high strain rotor blades and helicopter airframe sections	The project aims to design, develop and test an anti-icing and de-icing system for advanced tilt rotorcrafts	H2020	Passenger
Flight control systems	Automatic flight control systems supported by sensor based control laws	INCEPTION - Incremental Nonlinear flight Control supplemented with Envelope Protection techniques	INCEPTION aims to design of automatic flight control systems, supported by sensor-based control laws that will be able to be configured online in case of a failure -emergency scenario	H2020	Passenger + Freight
Flight control systems	Collision avoidance system	AMOR - A Mile Of Runway	AMOR will develop an Electronic Detection and Avoid (ED&A) system assisting small aircraft pilots to navigate safely without interfering with civil aircraft operations	H2020	Passenger
Anti-icing and de-icing systems	Simulation and modelling of ice formation	PHOBIC2ICE - Super-IcePhobic Surfaces to Prevent Ice Formation on Aircraft	The project will develop technologies and predictive simulation tools to prevent ice formation on aircrafts. It will enable the design and fabrication of icephobic surfaces and coatings with improved functionalities.	H2020	Passenger + Freight
Anti-icing and de-icing systems	Innovative compact and low cost "Hybrid Electro-Expulsive De-Icing System"	SEaSiDE - SEaSiDE (Smart Electro-expulsive System for SAT Aircrafts De-Icing)	To analyse, design, develop, test in an Ice Wind Tunnel Test (IWT) and deliver to the Topic Manager a prototype of Hybrid (thermal and electro-expulsive) De-Icing system having a continuous Power demand for meter on wingspan of 0.6KW. Project under development.	H2020	Passenger + Freight
Cockpit design and flight controls	Reliable touch screen control panel	LAPARTS - LARge Passenger Aircraft Reliable Touch Screen.	The project will develop a very reliable and ergonomic Touch Screen Control Panel (TSCP) system that will host all functionalities currently hosted on the Overhead Control Panel (OCP).	H2020	Passenger
Flight instruments	Augmented reality headset for pilots	AEROGLOSS - Augmented reality aerial navigation for a safer and more effective aviation	The project will developed a product able to assist pilots in aerial navigation by visualizing instrument data and flight conditions on an augmented reality head-mounted display. Four databases to feed global data to Aero Glass have already been specified, the VFR and IFR applications have been completed and the head tracking function of the glasses has been upgraded	H2020	Passenger + Freight

## D 2.1 Transport projects & future technologies synopses handbook

Guidance, Navigation & Control technologies	Validation of Guidance, Navigation & Control technologies	VISION - Validation of Integrated Safety-enhanced Intelligent flight cONtrol	VISION will validate smarter technologies for aircraft Guidance, Navigation and Control (GN&C) by including: 1) vision-based systems 2) advanced detection and resilient methods.	H2020	Passenger + Freight
Aircraft systems	Modelling and development of Electro-Mechanical Actuators (EMAs)	ACTUATION2015 - Modular Electro Mechanical Actuators for ACARE 2020 Aircraft and Helicopters	ACTUATION2015 developed and modelled EMAs that will eliminate hydraulic circuits, pumps and reservoirs in aircrafts. Four actuators for permanent and transient applications on commercial aircraft have been selected: aileron, spoiler, High Lift and braking actuators have then been designed, manufactured and tested. Main Landing Gear and Main Landing Gear Door extension/retraction and locking, as well as primary flight control for regional and business jet have only been modelled	FP7	Passenger + Freight
Take-off and landing	Magnetic-levitation take-off and landing (maglev TOL) system	Gabriel - Integrated Ground and Onboard System for Support of the Aircraft's Safe Take-off and Landing	The GABRIEL project studied the development a revolutionary new operational concept using ground-based power system with magnetic levitation technology to assist the aircraft's take-off and landing.	FP7	Passenger + Freight
<b>Cluster: SYS2 Air traffic Management (Future Air traffic management &amp; control, airport procedures)</b>					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Air Traffic Management	Mathematical modelling and optimization of Trajectory Based Operations	OptiFrame - An Optimization Framework for Trajectory Based Operations	OptiFrame will carry out mathematical modelling and algorithmic optimisation to support future Air Traffic Flow and Capacity Management (ATFCM)	H2020	Passenger + Freight
Satellite Navigation	Satellite based positioning, navigation and timing (PNT)	FAA Satellite Navigation	FAA Satellite Navigation Team provides satellite (GPS) based positioning, navigation, and timing (PNT) services in the United States to enable performance-based (RNP/RNAV) operations for all phases of flight from en route, terminal, approach, and surface navigation	US-FAA	Passenger+ Freight
Air Traffic Control	Air Traffic Flow and Capacity Management (ATFCM) decision support tool	PARTAKE - cooperative depArtuRes for a competitive ATM network sERVICE.	PARTAKE focuses on improving the air traffic dynamic demand capacity balance by using means of the prompt identification of proximate events at network level, the re-adjustment of take-off times within the assigned nominal Calculated-Take-Off-Time (CTOT) margins and the rearrangement of departing sequence of aircraft at the involved airports to minimize the amount of ATC	H2020	Passenger+ Freight

			interventions		
Big data analytics and ATM	Translation of big data analytics from passenger-centric spatio-temporal data in order to plan and manage an ATM system	BigData4ATM - Passenger-centric Big Data Sources for Socio-economic and Behavioural Research in ATM	BigData4ATM aims to evaluate the potential applications of the new data sources, data analytics techniques and theoretical models through a number of case studies relevant for the European ATM system, including the development of passenger-centric door-to-door delay metrics, the improvement of air traffic forecasting models, the analysis of intra-airport passenger behaviour and its impact on ATM, and the assessment of the socioeconomic impact of ATM disruptions.	H2020	Passenger
Air Traffic Control	Automation of air traffic controller's commands to pilots through automatic speech recognition	Malorca - Machine Learning of Speech Recognition Models for Controller Assistance	Malorca aims to develop a system that will automate manually given commands to the ATC system through automatic speech recognition. This system will assist air traffic controllers in decreasing flight time by giving faster commands	H2020	Passenger + Freight
Air Traffic Control	Synthetic Vision (SV) and Augmented Reality (AR) technologies	RETINA - Resilient Synthetic Vision for Advanced Control Tower Air Navigation Service Provision	RETINA's proposed solution will allow Secondary Surveillance Radar (SSR) equipped aircraft to operate at synthetic vision equipped airports thus improving the overall air traffic system capacity and, indirectly, alleviating congestion on nearby airports. Complex airports will benefit from the implementation of such technology by preserving airport capacity level in all weather conditions, even when Low Visibility Procedures apply. This will result in substantial financial savings for carriers and larger incomes for Air Navigation Service Providers.	H2020	Passenger + Freight
Air Traffic Control	Safety (and maintenance) improvement Through automated flight data Analysis	SVETLANA - Safety (and maintenance) Improvement through Automated Flight-data Analysis	SVETLANA project developed a new analysis cycle process based on a 2 steps approach: first an automated detection process based on data-mining techniques and then a human expertise feedback loop to assess smart maintenance and flight safety improvement. In the frame of the project, a common basis for the processing of all available flight data and anomaly detection in real-time has been designed. Several data-mining algorithms (two patents applied) were developed, based on the most recent research outcome in the field of anomaly detection, they are fully data-driven and not base on threshold exceedence anymore.	FP7	Passenger + Freight

## D 2.1 Transport projects & future technologies synopses handbook

Air Traffic Control	Analysing and quantifying the effects of meteorological uncertainty in Trajectory Based Operations	TBO-Met - Meteorological Uncertainty Management for Trajectory Based Operations	TBO-Met's main objective is to improve the predictability of aircraft trajectories when subject to meteorological uncertainty keeping acceptable levels of efficiency, both at the pre-tactical level (up to three hours before departure) and at the tactical level (during the flight). To reach this goal, a methodology based on the use of stochastic trajectory control algorithms optimization will be used, which will be evaluated and assessed using advanced air traffic simulation facilities. At the sector scale, the main objective is to increase the accuracy of the prediction of sector demand when meteorological uncertainty is taken into account. To achieve this objective, a methodology will be developed to measure the uncertainty of sector demand (probabilistic sector loading), based on the uncertainty of the individual trajectories.	H2020	Passenger + Freight
Air Traffic Control	Smarter technologies for aircraft Guidance, Navigation and Control (GN&C) by including 1/ vision-based systems 2/ advanced detection and resilient methods.	Vision - Validation of Integrated Safety-enhanced Intelligent flight cONtrol	VISION aims to create: 1. a vision-based control surface monitoring system, which provides additional information or confirmation, and will be fused with the more classical Fault Detection and Diagnosis techniques. 2. investigate vision-aided local precision navigation systems which covers poor Global Navigation Satellite System (GNSS) integrity.	H2020	Passenger + Freight
Air Traffic Control	Building probabilistic traffic forecasts on the basis of flight trajectory predictions.	COPTRA - COmbining Probable TRAjectories	COPTRA aims to: 1) Build probabilistic trajectories (Arbitrary Polynomial Chaos Expansion has been used to quantify aircraft trajectory prediction uncertainty). 2) Combining probabilistic trajectories in probabilistic traffic forecasts (Queue Network Model (QNM) enables the identification of stochastic parametrisation of the ATM network as to be able to predict the behaviour of the network under disturbances). 3) Application of probabilistic traffic prediction to ATC planning.	H2020	Passenger + Freight
Air Traffic Control	Innovative, spherical, self-supporting radome that can operate at 26 GHz.	RADOME - SPHERICAL MULTILAYER "RADAR DOME"	The Pilot Trials confirmed that in the frequency range of interest (25.5 GHz-27 GHz), radomes based on new technology are superior than those based on metal infrastructure in terms of hydrophobicity (higher), transmission loss (lower), power reflected and dissipated (lower), while providing at the same time a high resistance to severe weather conditions.	H2020	Passenger + Freight
Air Traffic Control	Electronic Detection and Avoid (ED&A) system, providing small aircraft with "electronic eyes".	AMOR - A Mile Of Runway	Offering a fully operational ED&A set-up that, within five years, can be implemented in approx. 0.5% of the current GA market (300k aircraft) with an affordable, independent system at a market price of €20k. The system will be distributed through tier 1 and tier 2 co-developers who are	H2020	Passenger + Freight

			already engaged in the project.		
Air Traffic Control	Reduction of air traffic environmental impacts Reduction of air traffic environmental impacts in European airspace on climate, air quality, and noise through optimization of air traffic operations.	ATM4E - Air Traffic Management for environment	The concept of calculating Environmental Change Functions in order to account for the environmental impact of aircraft operations on the local level (air Quality and noise) extends the boundaries of the current state of the art. Full integration of local air quality and noise metrics in the study is still at an early stage but the preparatory work undergone in the first few months for establishing a standard methodology shows promising results.	H2020	Passenger + Freight

## 2.7 Rail transport projects results

### Competitiveness – Rail Projects

Cluster: C1 Competitive rail					
Subcluster: C1-1 Innovative rail concepts/ carriages/wagons (Traction systems, high speed carriage, wagon, bogies, eddy current brake systems, train modularity, Personal Rapid Transit (PRT) and Hyperloop)					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Wagon design	New carrier wagon design for different container types	CAPACITY4RAIL - Increasing Capacity 4 Rail networks through enhanced infrastructure and optimised operations	C4R designed and evaluated different bodies and axles designs for reducing cost without increasing train length and by being able to carry different types of containers	FP7	Freight
New train concept	Design and real life testing of coupling two trains together and having the slave locomotive in the middle of the convoy	MARATHON - Make Rail The Hope for protecting Nature	MARATHON developed a concept for coupling two trains together and using the second locomotive as a slave thus creating a 1500m trains, by incorporating radio controls and new braking system to provide stability. The new concept was tested in real life and saw energy consumption reduction by 10%	FP7	Freight

## D 2.1 Transport projects & future technologies synopses handbook

Train braking systems	Design, Finite Elements Analysis, Eddy current brakes,	ECUC - Eddy Current Brake Compatibility	ECUC designed, modelled, tested and evaluated the use of eddy current brakes on rail. The results showed that eddy current brakes cannot be used as a stand alone system and need to be used in conjunction with electro-dynamic brakes or friction brakes. In addition restriction due to heating of the rails and the system could be imposed.	FP7	Passenger + Freight
Wagon design	Modular wagon design concepts (Flex Freight Car, Timber Cassette 2.0, Container Loading Adapter)	VIWAS - Viable Wagonload production Schemes	VIWAS developed and manufactured 3 new modular wagon design concepts. 1) Flex freight car: a new type of wagon that meets the requirements for loading and unloading containers in sidings was developed. The wagons' floor is filled in with iron grids making it modular and allowing different parts of the grid to be removed. 2) Timber cassette 2.0: first flex freight unit for timber transports which is also stackable (up to 6 empty cassettes) for empty runs. 3) Container Loading Adapter: consists of three separate 6 m modules which can be put on any Sgns or Sgnss container wagon. The platform allows loading and unloading of containers with forklifts	FP7	Freight
Bogie design	New bogie design using several features based on the Y25 type bogie	SUSTRAIL - The sustainable freight railway: Designing the freight vehicle – track system for higher delivered tonnage with improved availability at reduced cost	SUSTRAIL designed a new bogie concept using a Lenoir link primary suspension, longitudinal linkages (providing stiffness between axle boxes using a radial arm), a centre pivot secondary suspension. In addition axle coating was chose for corrosion resistance, friction modifiers and a braking system. The designed addressed sustainable materials, design for maintenance, modularity and lightweight concepts. Manufacturing and testing of the design were also carried out	FP7	Freight
Wagon design	1) Design of metro vehicles for security 2) Finite Element Analysis for blast simulation and real life blast test	SECUREMETRO - Inherently secure blast resistant and fire safe metro vehicles	SECUREMETRO designed and tested secure metro vehicles against blasts and fire by incorporating more resilient design, special windows to prevent breakage and fire resistance barriers. In addition resistance ceiling panels were used in order for the ceiling not to collapse on the passengers in case of a blast. LEDs lights were also incorporated	FP7	Passenger

## D 2.1 Transport projects & future technologies synopses handbook

Running gear design	New running gear concept with active suspensions	RUN2RAIL - Innovative RUNning gear soluTiOns for new dependable, sustainable, intelligent and comfortable RAIL vehicles	RUN2Rail will design running gear with active suspensions to enable non- conventional concepts	H2020	Passenger +Freight
Wagon design and optimisation	Development of smart and flexible wagons for improved transport of granular multimaterials	HERMES - Development Of Smart And Flexible Freight Wagons And Facilities For Improved Transport Of Granular Multimaterials	The project aims to optimize rail freight transportation, it will holistically address the aspects that may improve freight wagon performance: enhanced logistics, improved multimodal operative, higher load capacity, optimized filling/emptying time and flexibility to transport multi-products.	H2020	Freight
Wagon design	Simulation technics combined with cost estimation of introduction of new wagon	VEL-WAGON - Versatile, Efficient and Longer Wagon for European Transportation	The project examine the limits of light wagon construction and the future infrastructure response to the everyday-more-challenging railway traffic. The investigation is initiated with concrete wagon concepts to be examined, namely, 4-axle rigid platforms of 80 to 90 feet length. The outcome is a compromised solution between economic aspects and technical constraints- innovative freight wagon as well as ITU.	FP7	Freight
Freight train design	Design concept for a high-performance freight train (lightweight freight wagon, a vehicle bogie for enhanced ride features, a power conversion unit to provide power to refrigerated containers, and a city logistics freight handling system)	SPECTRUM	SPECTRUM designed a freight train aiming for lightwightness and functioning of a passenger train in terms of power, speed, and acceleration and braking. It will also operate across domestic, national and international lines and routes with little restriction, and be capable of accommodating the required types of freight container units.	FP7	Freight
New train concept	Special pods travelling at high speeds in near-vacuum conditioned tubes.	HYPERLOOP ONE	Hyperloop one is developing a system of transport that would see pods or containers travel at high speeds through overground or underground tubes that have been pumped into a near-vacuum. With so little friction in the tunnel, the pods would be able to travel at immense speeds with a projected top speeds of 760mph.	International	Passenger +Freight



<b>Cluster:</b> C2 Competitive rail design					
<b>Subcluster:</b> C2-1 Design tools for structural reliability (CAE + other tools)					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Acoustic certification modelling	Virtual modelling for acoustic certification of trains after design	ACOUTRAIN - Virtual certification of acoustic performance for freight and passenger trains	ACOUTRAIN investigated the acoustic modelling of train noise in order to evaluate noise performance and provide virtual certification for train designs. This approach required methods to distinguish noise sources from the train	FP7	Passenger +Freight
<b>Subcluster:</b> C2-2 Cabin design (Inclusive train design, modular trains and cabins to flexibly adapt to passenger needs)					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Cabin and cockpit design	New ultralight and flexible cabin seat concepts and ergonomic modular train cockpit design	MAT4RAIL	MAT4RAIL aims to address train interior Design and shortcomings of current rolling stock in terms of modularity in use, to meet the changing passenger demand during the 30-40 years of an in-service operating life-cycle of a train	H2020	Passenger
<b>Cluster:</b> C3 Competitive rail production					
<b>Subcluster:</b> C3-1 Structural materials & composites (materials & composites)					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Coating solutions	New coating solutions for axles to prevent fatigue cracks	EURAXLES - Minimizing the risk of fatigue failure of railway axles	Innovative coatings to ensure fatigue resistance of axles	FP7	Passenger +Freight

## D 2.1 Transport projects & future technologies synopses handbook

Coating solutions	Smart coatings for railway wheels	SmaRtAIL - Smart protective coatings on classic materials for a new generation of ecologically sustainable 'green' railway vehicles	smaRtAIL project aims to develop an innovative and validated technology consisting of the application of protective layers called smart coating, onto railway wheels working surface .Innovative laser technology reconstruction extend the durability of wheels .	H2020	Passenger + freight
Composite materials	Replacement of interior and exterior metal parts with Fibre Reinforced Polymers (FRPs)	MAT4RAIL	MAT4RAIL results are usage of new material in railway environment regarding Fire, Smoke and Toxicity, mechanical performance and cost effective manufacturing	H2020	Passenger
Composite materials	New advanced composite materials (fusion of hybrid Fiber Reinforced Polymers and concrete) for switches and crossings	S-CODE - Switch and Crossing Optimal Design and Evaluation	S-CODE proposed new materials for improved performance for S&C based around new operating concepts (e.g. super-fast switching, self-healing switch). The project proposed a new design proposed based on fusing hybrid FRP - concrete beam as a rail sleeper. The hybrid system consists of a Rectangular Hollow Section (RHS) pultruded profile filled with geo-polymer concrete. It was found that the proposed composite beam satisfied the minimum flexural requirements for composite railway sleepers	H2020	Passenger +Freight
<b>Subcluster:</b> C3-2 Manufacturing processes (new manufacturing process, additive manufacturing, 3D printing)					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Additive manufacturing	3D printing mobile solutions for rail track surfaces	Mobile 3D Printing of Rail Track Surface for Rapid Repairment	The US DOT project aims to develop a 3D metal/composite printing technology for fixing railway surface damage on site, which includes: (1) Mobile 3D printer system design; (2) Rapid surface cleaning of rail track; (3) 3D printing rail track surface on site; and (4) Trueing surface to achieve precise dimension and surface finish.	US-DOT	Passenger +Freight
Additive manufacturing	Advanced low energy Laser Metal Deposition Technology (LMD) for bogie wheels smart coating materials	SmaRtAIL - Smart protective coatings on classic materials for a new	smaRtAIL will develop an innovative laser metal deposition technology for reconstruction and extending the durability of wheels with smart coatings	H2020	Passenger+F reight

## D 2.1 Transport projects & future technologies synopses handbook

		generation of ecologically sustainable 'green' railway vehicles			
Manufacturing processes	Manufacturing processes running gear: 3D metal printing, automated tape layering of composite materials	RUN2RAIL - Innovative RUNning gear soluTiOns for new dependable, sustainable, intelligent and comfortable RAIL vehicles	RUN2Rail will investigate 3D metal printing and automated tape laying as potential processes for producing running gear	H2020	Passenger +Freight
<b>Cluster:</b> C4 Competitive Life Cycle Services					
<b>Subcluster:</b> C4-1 Inspection & maintenance (inspection & maintenance new methods (vehicles and tracks))					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Preventive maintenance system	Condition monitoring system for axle bearing health status	MAXBE - Interoperable Monitoring, Diagnosis And Maintenance Strategies For Axle Bearings	MAXBE developed a system that can contribute to early detection of axle bearing failures	FP7	Freight
Maintenance operations planning	Transfer of lean manufacturing principles to maintenance	AUTOMAIN - Augmented Usage of Track by Optimisation of Maintenance, Allocation and Inspection of railway Networks	AUTOMAIN investigated the transfer of lean manufacturing principles into rail maintenance in order to reduce down time and incorporated value stream mapping into the process	FP7	Passenger+ Freight
3D modelling and switch control inspection	Development of lightweight laser based trolley for scanning switches and crosses	AUTOMAIN - Augmented Usage of Track by Optimisation of Maintenance,	AUTOMAIN developed a lightweight laser based trolley to accurately assess switches and crosses against standards and inspect their condition	FP7	Passenger+ Freight

## D 2.1 Transport projects & future technologies synopses handbook

		Allocation and Inspection of railway Networks			
CAE	Finite element Analysis and modelling of axles	EURAXLES - Minimizing the risk of fatigue failure of railway axles	EURAXLES carried out FEA and modelling of axles to determine fatigue and fretting fatigue limits of the components.	FP7	Passenger+ Freight
Non-destructive testing	Non-destructive testing methods for continuous monitoring of axles using an adhesive plug and electrochemical techniques	EURAXLES - Minimizing the risk of fatigue failure of railway axles	EURAXLES investigated a continuous monitoring NDT method for assessing axle corrosion and cracking fatigue of axles by monitoring elastoresistive behaviours of an adhesive plug	FP7	Passenger+ Freight
Non-destructive testing for infrastructure	1)Eddy current sensor system, 2) Hollow shaft acoustic sensor, 3) Thermographic testing system, 4) laser profiler and inertial pack, 5) Fuzzy ultrasonic testing system, 6) Brillouin Fiber optics	ACEM-Rail - Automated and cost effective maintenance for railway	ACEM-Rail developed 5 NDT systems embarked on trains and 1 fiber optics systems laid along the tracks for automated track inspections. All methods have proven to detect defects on rail tracks although some such as the thermographic system had speed constraints and require special testing trains.	FP7	Passenger + Freight
Inspection for infrastructure	Robotic vehicle for tunnel inspections using remote controls, robotic arm, crane and vision system	ROBO-SPECT - ROBotic System with Intelligent Vision and Control for Tunnel Structural INSPECTION and Evaluation	ROBO-SPECT has developed a robotic vehicle for inspecting rail tunnels that can detect with a high resolution multi-view camera system able to detect tunnel anomalies (corrosion, delamination, calcium leakages, opening joints and other surface defects that could affect the tunnel structural integrity) and able to take precise measurements using ultrasonic fiber-optic sensors with accuracies of up to 0.1mm. A ground control station (GCS) was also established for controlling the robot	FP7	Passenger + Freight
Decision making support software system	Information system for infrastructure management from measurement to maintenance	INFRALERT - Linear Infrastructure Efficiency Improvement By Automated Learning And Optimised Predictive Maintenance Techniques	INFRALERT aims to develop an expert-based information system to support and automate infrastructure management from measurement to maintenance. This will include the collection, storage and analysis of inspection data, to determine maintenance	H2020	Passenger + Freight

## D 2.1 Transport projects & future technologies synopses handbook

Non Destructive Testing	Ultrasonic Tomography (UST)	DTRT13-G-UTC59 - Ultrasonic Tomography for Infrastructure Inspection	Ultrasonic Tomography (UST) to examine the interior of wooden beams and cross ties as well as railroad tunnel linings on-site.	UTCRS	Passenger + Freight
Wagon design	Diagnostic pantograph	DIAG-PANTOGRAPH - Train Pantograph equipped with diagnostic system for reduction of faults and maintenance cost	DIAG-PANTOGRAPH will develop a pantograph for low speed trains offering diagnostic and control features, coupled with a new design of the contact strip and electronic monitoring technologies for the reduction of faults and maintenance costs.	H2020	Passenger
Non-destructive testing for infrastructure	Railway and rolling stock condition monitoring system	DTD SYSTEM 2 - A disruptive innovation for the minimisation of railway maintenance costs	DTD System is capable of detecting with high precision wheel defects at the onset of deterioration, and using this information to design a predictive maintenance plan both for the railway and the rolling stock	H2020	Passenger + Freight
Predictive maintenance for infrastructure	Rail track vibration monitoring system	WARNTRAK - Rail track monitoring system - Wireless Autonomous On-Board System measuring vibration with continuous reporting to reduce maintenance costs and enhance reliability and safety	The project will develop a rail track wireless and autonomous on-board monitoring system, measuring vibration, via axle box mounted vibration sensors, with continuous reporting to reduce maintenance costs and enhance reliability and safety	H2020	Passenger + Freight
Non-destructive testing for infrastructure	Ultrasonic inspection system for high manganese steel crossings	SAFTInspect - Ultrasonic inspection solution for railway crossing points	SAFTInspect developed and manufactured a complete automated ultrasonic inspection prototype system for inspection of sub-surface flaws in high manganese steel railway crossings.	FP7	Passenger + Freight
Non Destructive Testing	1) Phased array ultrasonic testing for corrosion assessment and crack detection of component, 2) Reliability software for high cycle variable amplitude corrosion fatigue of rail axles.	RAAI - Whole Life Rail Axle Assessment and Improvement Using Ultrasonic Phased array and Corrosion Inspection Systems	RAAI aims to develop two novel methods: 1) corrosion assessment 2) phased array ultrasonic. The first method assesses the effect of corrosion on high-cycle fatigued component such as the axle and evaluates its remnant life thereby improving the sentencing of corroded axles. The second method is specifically for hollow axles of high speed trains and aims to improve	H2020	Passenger+ Freight

## D 2.1 Transport projects & future technologies synopses handbook

			the speed of the inspection (by 75%) and improve crack detection reliability (almost 100% with a crack of 2-3 mm depth) without dismantling the wheel-set and with minimum time of inspection.		
Non destructive testing for infrastructure	Synthetic Aperture Focusing Technique (SAFT) combined with advanced processing algorithms to offer an ultrasonic inspection technique with enhanced Signal to Noise Ratio	SAFT - Ultrasonic Inspection Solution for railway crossing points	SAFT developed a novel array transducer working in a synthetic aperture focusing technique (SAFT). This novel design enables efficient acquisition of data for SAFT processing. SAFT post-processing generate 2 and 3D reconstructions of the ultrasonic volumetric image to produce a simple pass or fail indication for the user	H2020	Passenger+ Freight
Non destructive testing for infrastructure	Development of ACFM Alternating Current Field Measurement (ACFM), Ultrasonic phased array and High Frequency Vibration methods for semi automated high speed inspection of tracks	INTERAIL - Development of a Novel Integrated Inspection System for the Accurate Evaluation of the Structural Integrity of Rail Tracks	INTERAIL developed Alternating Current Field Measurement (ACFM) sensors, inspection systems based on conventional ultrasonics probes as the main rail evaluation method, railway automated on-line inspection prototype system	FP7	Passenger
Predictive maintenance	Health monitoring sensors and systems for trains	INNOWAG - INNOvative monitoring and predictive maintenance solutions on lightweight WAGon	INNOWAG will develop an effective health monitoring technologies, and predictive maintenance models for sustainable and attractive European rail freight	H2020	Freight
<b>Subcluster:</b> C4-2 Repair, retrofit (repair and retrofitting new methods)					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
N/A	N/A	N/A	N/A	N/A	N/A
<b>Subcluster:</b> C4-3 Life cycle approaches (train life cycle)					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector

N/A	N/A	N/A	N/A	N/A	N/A
-----	-----	-----	-----	-----	-----

**Environment – Rail Projects**

<b>Cluster:</b> ENV1 Reducing emissions					
<b>Subcluster:</b> ENV1-1 Alternative/conventional fuels (biofuels, alternative fuels, high octane gasoline)					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Renewable diesel	Emissions evaluation of renewable diesel in rail	NCDOT Research Project Number: 2018-09 - Managing Energy and Emissions for Rail Operations	NCDOT is currently to evaluate real life emissions of renewable emissions in locomotives	NC DOT	Passenger
<b>Subcluster:</b> ENV1-2 Reducing noise emissions (Noise & vibration)					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Noise monitoring and mitigation solutions	Development of an onboard noise monitoring system for noise emitted by tracks	QUIET-TRACK - Quiet Tracks for Sustainable Railway Infrastructures	QUIET-TRACK developed an on-board monitoring systems based on noise measurement system and location sensors that continuously monitor rail roughness values, track decay rate values and wear. The system can help identify track maintenance locations or locations where noise mitigating solutions have to be applied.	FP7	Passenger+ Freight
Noise monitoring and mitigation solutions	Methodologies for noise and vibration prediction	RUN2RAIL - Innovative RUNning gear soluTiOns for new dependable, sustainable, intelligent and comfortable RAIL vehicles	RUN2RAIL will development of a novel and comprehensive methodology for predicting the transmission of noise and vibration from the running gear to the car body. No further information at this stage.	H2020	Passenger+ Freight

## D 2.1 Transport projects & future technologies synopses handbook

Noise mitigation	Low noise running gear for future locomotive	FFL4E - Future Freight Loco for Europe	FFL4E will design low noise running gear for future freight locomotive	H2020	Passenger
Vibration mitigation	Computational vibration measurements and influence on human health and annoyance	CARGOVIBES - Attenuation of ground-borne vibration affecting residents near freight railway lines	CARGOVIBES's purpose was to determine mechanisms that explain the differences in people's responses to vibrations from freight trains	FP7	Freight
Vibration mitigation	Noise transmission path computer simulations and mitigations measures like soil stiffening and sheet pile walls close to the track, open trenches and trenches filled either with soft or stiff materials. Designs of wide sleepers in combination with soft under sleeper pads and of rail fastening systems with soft under rail pads have been proposed.	RIVAS - Railway Induced Vibration Abatement Solutions	RIVAS has studied the influence of vehicle parameters like e.g. wheel set mass, axle distances, and properties of primary and secondary suspension has been quantified in a combination of state-of-the-art numerical modelling using train-track-soil models and the analysis of measurements	FP7	Passenger+ Freight
Vibration mitigation	New concrete technology for continuously supported embedded rail and reducing vibration of the vehicles	eco-railjacket - Total Full Ecologic Embedded Railways Jacket System	Eco-railjacket New embedded railways jacket system designed by Prefarails is used to reduce the vibration of the vehicles, minimize the road and housing noise and vibrations around the tramways or trains, improve the passengers comfort and minimize the environment impacts.	H2020	Passenger
Noise monitoring and mitigation solutions	1) Tools for noise prediction and measurement of trains and subsystems 2) New technologies as active windows for noise protection and new	FINE1 - Future Improvement for Energy and Noise	FINE1 , S2R Technical Demonstrator (TD) project will develop a methodology and know-how to enable development of low noise and low energy TDs	H2020	Passenger + Freight



## D 2.1 Transport projects & future technologies synopses handbook

	ways of communicating about noise performance of trains				
<b>Subcluster: ENV1-3</b> After treatment of exhaust gases (After treatment of diesel powerplant exhaust)					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
After Treatment System	Blended After Treatment System (BATS)	NCDOT Research Project Number: 2018-09 - Managing Energy and Emissions for Rail Operations	NCDOT is currently conducting a pilot study to retrofit a Blended After Treatment System (BATS) on a number of locomotives to reduce NOx and PM emissions	NC DOT	Passenger
<b>Subcluster: ENV1-4</b> Green train operations (Regenerative energy storage systems, Battery technologies and onboard energy storage systems)					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Energy generation solutions	Energy generation and harvesting solutions for onboard train integrity radio communication systems	ETALON - Energy harvesting for signalling and communication systems	ETALON will develop energy generation solutions for on board train integrity radio communication systems. Not enough available information at this stage.	H2020	Freight
Energy recuperation	Recuperation of braking energy	FFL4E - Future Freight Loco for Europe	FFL4E aims to create a braking energy recuperation system where the energy will be stored and used during peak times. No further information at this moment.	H2020	Freight

### Energy – Rail Projects

**Cluster: ENE1** Optimising resistance and propulsion

<b>Subcluster: ENE1-1</b> Aerodynamics (train aerodynamics)					
<b>Technology theme</b>	<b>Technology identified</b>	<b>Project</b>	<b>Project brief results</b>	<b>Funding programme</b>	<b>Sector</b>
N/A	N/A	N/A	N/A	N/A	N/A
<b>Subcluster: ENE1-2</b> Engines & powerplants (hybrid systems, engine advances etc., diesel powerplant)					
<b>Technology theme</b>	<b>Technology identified</b>	<b>Project</b>	<b>Project brief results</b>	<b>Funding programme</b>	<b>Sector</b>
Hybrid or electric propulsion	Electricity usage and storage for last mile propulsion	FFL4E - Future Freight Loco for Europe	FFL4E offers limited information at the moment but the aim is to store energy for last mile propulsion capabilities for Li-Ion batteries	H2020	Freight

### Infrastructure – Rail Projects

<b>Cluster: INF1</b> Station operations (future stations, station design, improved train platform interface, novel terminal, hubs)					
<b>Technology theme</b>	<b>Technology identified</b>	<b>Project</b>	<b>Project brief results</b>	<b>Funding programme</b>	<b>Sector</b>
Future rail station design	1) User flow modelling, 2) station design algorithm that optimises passenger flow, 3) Engineering design of a train and/or platform based mechanism, 4) VR demonstrator of the design	FAIR Stations - Future Secure and Accessible Rail Stations	FAIR Stations will create a design for a future rail station with the aim of ensuring security, safety, baggage handling, ticketing, design for accessibility, information & signage, and climatology	H2020	Passenger +Freight
Energy efficiency & Information systems	Information systems-energy efficient solutions	FR8HUB - Real time information applications and energy efficient solutions for rail freight	The project will develop real-time information applications and energy efficient solutions for hubs, nodes and terminals.	H2020	Freight

## D 2.1 Transport projects & future technologies synopses handbook

Infrastructure management and Information systems	Software based Decision Support Tools for infrastructure management	DESTination RAIL - Decision Support Tool for Rail Infrastructure Managers	The project will develop a decision support tool based on scientific principles for risk assessment using real performance measurements and other vital data stored in an Information Management System, to help make rational investment choices.	H2020	Freight + Passenger
Future rail station design	Development of an Intelligent Active Dynamic Signage System (IADSS) to support railway station security during emergencies	GETAWAY - Generating simulations to Enable Testing of Alternative routes to improve WAYinding in evacuation of over-ground and underground terminals	GETAWAY designed and development of an Intelligent Active Dynamic Signage System (IADSS). Active Dynamic Signage System will be linked to an automated system utilizing evacuation simulation, CCTV footage and Fire Detection System information to determine the optimal evacuation route as the fire develops, bringing Intelligence to the ADSS.	FP7	Passenger
Combustors	Combustor design for lower emissions and efficiency	CLEEN programme	Under the CLEEN programme General Electric tested a lean burn combustor system the TAPS II (Twin Annular Premixing Swirler) with aim of improving NOX emissions and particulate emissions below the CAEP/6 requirements and apply the TAPS technology to narrow body applications including demonstration of the system on a core engine.	FAA- Private	Passenger
<b>Subcluster: INF2 Rail safety/ security</b>					
<b>Project brief results</b>	<b>Project brief results</b>	<b>Project brief results</b>	<b>Project brief results</b>	<b>Project brief results</b>	<b>Project brief results</b>
Track side worker safety	Track-side train presence alert device (TPAD) and wearable device wireless mobile terminals (MT)	ALARP - A railway automatic track warning system based on distributed personal mobile terminals	ALARP created 2 devices with the purpose of ensuring the safety of track side workers when train are approaching. 1) TPAD, able to sense an approaching train on the interested track without interfering with the signalling system. 2) A wearable MT to inform the workers about possible approaching trains and/or other events that could put at risk their safety	FP7	Passenger +Freight
Simulation and tools for resilient stations	1) Analysis of station building structural and physical resilience during an incident 2) Simulation of human behaviour and movement during emergencies	SECURESTATION - Passenger station and terminal design for safety, security and resilience to terrorist	Securestation developed: 1) advanced predictive tools for physical and functional resilience of stations during emergencies. 2) Simulated pedestrian behaviour and movement in emergencies	FP7	Passenger +Freight

## D 2.1 Transport projects & future technologies synopses handbook

	for safe evacuation	attack			
Artificial Intelligence, big data management and Decision support frameworks	AI and safety of rail infrastructure	SAFE-10-T - Safety of Transport Infrastructure on the TEN-T Network	The project will develop a Safety Framework to ensure high safety performance while allowing longer life-cycles for critical infrastructure. It will incorporate remote monitoring, algorithms to enable machine learning and will lead to intelligent objects that communicate their safety condition during extreme events to eradicate sudden failures.	H2020	Passenger +Freight
Safety monitoring systems	Development of fault finding monitoring systems for wayside and onboard vehicle	D-RAIL - Development of the Future Rail Freight System to Reduce the Occurrences and Impact of Derailment	D-RAIL will develop new monitoring systems for wayside and onboard the vehicle capable of fault finding that could cause derailment	FP7	Passenger +Freight
Safety monitoring systems	Autonomous system for automatic train detection that will be integrated with a UOZ-2 animal deterring device.	SafeTrain - Piloting and industrial validation of autonomous and sustainable animal deterring system for the rail transport	The project will result in a device based on an intelligent mechanism of listening for an approaching train, originally developed for the application in level crossing warning system. Wireless data transfer between UOZ- 2 devices is built on a new generation of single-board computer and comprises state-of-the-art communication modules and software.	H2020	Passenger +Freight
<b>Subcluster:</b> INF3 Intermodality (connectivity with other modes of transport)					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Multimodal terminal design & simulation	Simulation and design tools for the design of multimodal terminal infrastructure	INTERMODEL EU - Simulation using Building Information Modelling Methodology of Multimodal, Multipurpose and Multiproduct Freight Railway Terminals Infrastructures	The project will develop a methodology and ICT tools for the simulation of intermodal railway logistics platform models to support tasks related to the design and planning phases of the railway's terminal infrastructure.	H2020	Freight

## D 2.1 Transport projects &amp; future technologies synopses handbook

Intermodal freight logistics	Intermodal truck/train container transfer system (CTS technology)	SAFE-CTS	The project will demonstrate an efficient and cost-effective freight logistics system based on multimodal transport as an alternative to road-based freight transport	H2020	Freight
Intermodal freight logistics	Intelligent intermodal, modular volume-optimised and traceable MegaSwapBoxes (MSB)	TelliSys	TelliSys developed a new MSB based on the unique selling propositions like stackability, three openable sides, three meters loading height, trimodality, pallet wide and cargo security.	FP7	Freight
<b>Subcluster: INF4 Track systems (new generation track system)</b>					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Track design	New slab track concept design	Capacity4Rail - Increasing Capacity 4 Rail networks through enhanced infrastructure and optimised operations	Development and design of low maintenance and modular designs of slab tracks for mixed traffic up to very high speed traffic	FP7	Freight
Decision making software	Infrastructure Subsystems Management (ISM) software tool	ACEM-Rail - Automated and cost effective maintenance for railway	Development of an intelligent Infrastructure Subsystem Management (ISM) tool which integrates and manage all data and provides Decision Support Tools (especially those in charge of the estimation of track degradation and of the optimization of maintenance scheduling)	FP7	Passenger +Freight
Materials and manufacturing processes for rail tracks	Development of rail - bainitic steels and development of aluminothermic and orbital friction welding processes	WRIST - Innovative Welding Processes for New Rail Infrastructures	WRIST will aim to significantly reduce cost in maintenance of the track, also freeing up more capacity for rail traffic. These innovations will enable the use of bainitic rail steels which will deliver an increased reliability, permit the achievement of lower life cycle costs for track maintenance and renewal by eliminating the source of higher dynamic forces at "cupped" or irregular geometry welds that are responsible for the more rapid loss of track geometry and necessitate expensive maintenance tamping intervention	H2020	Passenger + freight
Rails switches	Innovative rail switches for winter conditions	VERT - Vertex switch – the foundation for a more sustainable and reliable	VERT will develop an Innovative Vertex switch for guiding the train by moving the switch blades vertically instead of horizontally which eliminates the area where snow and ice can land. Vertex offers a reliable switch that works	H2020	Passenger+ Freight

## D 2.1 Transport projects &amp; future technologies synopses handbook

		railway transport system	well in all weather conditions, eliminates the need for manual snow clearance, provides measurable cost and energy savings and has potential to significantly reduce the numbers of delayed hours.		
Track components	Innovations in the track components (for higher reliability and reduced maintenance) combined with innovations in rolling stock and freight vehicles (with a targeted increased in speed and axle-load)	SUSTRAIL - The sustainable freight railway: Designing the freight vehicle – track system for higher delivered tonnage with improved availability at reduced cost	SUSTRAIL investigated a sustainable track design, intended to yield a low-maintenance track concept. By project was defined a set of critical parameters to help determine the track modifications necessary for new freight vehicles and increased freight traffic. Following a failure mode and effects analysis, a set of track innovations was selected	H2020	Freight
<b>Subcluster: INF5 Grid &amp; energy (smart power supply)</b>					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Energy management system and software	Development of a railway energy management system software for grid and onboard systems	MERLIN - Sustainable and intelligent management of energy for smarter railway systems in Europe: an integrated optimisation approach	MERLIN developed a REMS software that visualised and monitored energy consumption of different railway subsystems and their components. In addition a Dynamic Onboard Energy Manager was developed for inside the train usage	FP7	Passenger+ Freight
Railway power grid	Development of a railway smart grid	IN2STEMPO - Innovative Solutions in Future Stations, Energy Metering and Power Supply	IN2STEMPO will contribute to the development of a new railway network that will integrate smart metering, innovative power electronic components, energy management and energy storage systems	FP7	Passenger+ Freight
Energy management system and software	Cloud-based open data management platform (ODM) for energy and asset management	IN2DREAMS - Intelligent solutions toward the Development of Railway Energy and Asset Management Systems in Europe	IN2DREAMS will develop a modular cloud-based open data management platform (ODM) facilitating ubiquitous support of both energy and asset services providing energy metering services through a dynamically reconfigurable platform for the entire railway system	H2020	Passenger+ Freight

## D 2.1 Transport projects & future technologies synopses handbook

Energy harvesting solutions	Energy harvesting solutions for trackside object controllers	ETALON - Energy harvesting for signalling and communication systems	ETALON will develop energy harvesting solutions for trackside object controller. Not enough available information at this stage.	H2020	Freight
-----------------------------	--	---	--	-------	---------

### Systems –Rail Projects

<b>Cluster:</b> SYS1 Rail systems (Traffic control & management systems (TCMS), automatic train operations, Driverless freight trains, Machine to Machine technologies (M2M), TAP/TAF TSI Telematics applications for passenger/freight Technical specifications of interoperability, Ticketless technologies travel, mobility as a service, intelligent trains)					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Condition monitoring	Onboard and wayside sensor condition monitoring system	MAXBE - Interoperable Monitoring, Diagnosis And Maintenance Strategies For Axle Bearings	MAXBE developed a condition monitoring system consisting of strain gauges, high frequency accelerometers, temperature and acoustic emission sensors.	FP7	Freight
Systems to allow coupling of trains	Remote radio controls, antennas, intelligent computerized interface and brake system for the slave locomotive connected to the vehicle control	MARATHON - Make Rail The Hope for protecting Nature	The MARATHON kit was a series of developed systems that would allow the concept of coupling two trains together with the second locomotive as a slave drive	FP7	Freight
Wagon telematics	Single wagon monitoring telematics using GPS, GSM and loading sensors and development of visualisation software	VIWAS - Viable Wagonload production Schemes	VIWAS developed the aJourOnline telematics IT platform incorporating a monitoring system for individual wagon monitoring	FP7	Freight
Modelling	Fuzzy rule based models for railway infrastructure and components as well as maintenance and traffic processes	OPTIRAIL - Development Of A Smart Framework Based On Knowledge To Support Infrastructure Maintenance Decisions In Railway Corridors	OPTIRAIL developed fuzzy rule-based systems (FRBS) to assist decision making through modelling of infrastructure, components and maintenance processes	FP7	Passenger + Freight
Electromagnetic interference	Modelling and testing of electromagnetic interference with a spot signalling system	TREND - Test of Rolling Stock Electromagnetic Compatibility for	TREND studied, designed the specified test sites and test setups that enables harmonising freight and passenger rolling stock approval tests for	FP7	Passenger + Freight

## D 2.1 Transport projects & future technologies synopses handbook

	(BTM), DC track circuit, GSM-R and broadcasting services (which include TV, radio, Freight RFID, WFI and GSM)	cross-Domain interoperability	EMC focusing on interferences with communication and railway signalling systems		
New train control system	1) TCS (European Train Control System) and CBTC (Communications-based train control) architectures 2) Architecture for future GNSS positioning system	NGTC - Next Generation Train Control	NGTC delivered final architectures and functional allocation to subsystems for a future train control system. Hence, the project delivered specifications for IT Security, IP-Rules, external Interfaces, multisector Architecture for train communications In addition it also created the procedures for GNSS-based positioning performance assessment	FP7	Passenger + Freight
Software design and decision support tools	Design of real time decision support tool for yard managers	OPTIYARD - Optimised Real-time Yard and Network Management	OptiYard will facilitate real-time interaction between yard and relevant network IT systems that allow for software based planning and ultimately optimisation of single wagonload and blocktrain operational processes.	H2020	Passenger + Freight
Satellite technologies/ERTMS/ETCS	EGNSS application on railway to assist ERTMS and ETCS systems	STARS - Satellite Technology for Advanced Railway Signalling	STARS developed a universal equipment setup and measurement procedures describing how to measure the achievable GNSS performance in a railway environment, with the focus on safety critical applications	H2020	Passenger + Freight
European Train Control Systems	1) Progressed laboratory on board testing systems for ETCS 2) Created equipment for smart train positioning system	EATS - ETCS Advanced Testing and Smart Train Positioning System	EATS developed an on-board ETCS model to reduce time and effort needed in the verification and certification procedure. Similarly a STPS system was developed with its testing equipment	FP7	Passenger + Freight
Smart sensors	Smart sensors and smart running gear components for self diagnosis	RUN2RAIL - Innovative RUNning gear soluTiOns for new dependable, sustainable, intelligent and comfortable RAIL vehicles	RUN2Rail will develop smart sensors and smart running gear components with self-diagnosing capability. No further info at this stage	H2020	Passenger + Freight
European Train Control System component (ETCS)	1) Fail-Safe Train Positioning using GNSS and multisensors 2) New signalling train separation concepts	X2RAIL-2 - Enhancing railway signalling systems based on train satellite positioning, on-board safe train	1) Demonstrator to reduce traditional train detection systems by means of using multisensors and GNSS. Shift2Rail project 2) Demonstrator for on board train integrity though	H2020	Passenger + Freight



## D 2.1 Transport projects & future technologies synopses handbook

		integrity, formal methods approach and standard interfaces, enhancing Traffic Management System functions	moving block or virtual block based train self localisation		
European Rail Traffic Management	Standardisation and integration of Traffic management	X2RAIL-2 - Enhancing railway signalling systems based on train satellite positioning, on-board safe train integrity, formal methods approach and standard interfaces, enhancing Traffic Management System functions	Demonstrator to improve standardisation and integration of Traffic Management processes with the aim to achieve flexibility and scalability within the choice of functional service module managed by TMS.	H2020	Passenger + Freight
LED Signals	Self De-Icing LED Signals	TPF-5(351) - Self De-Icing LED Signals	The project developed multiple prototypes of a new type of self de-icing light-emitting diodes (LED) signals for highway signalized intersections and railroad signalling applications and validated them using the field tests.	Various DOTs US	Passenger + Freight
Signalling and Automation Systems	Satellite-based Signalling and Automation Systems on railways	ASTRail - SATellite-based Signalling and Automation SysTems on Railways along with Formal Method and Moving Block validation	The project will enhance satellite-based signalling and automation systems by searching innovative solutions and technologies from other sectors and assessing their reusability in the railway field with particular care for safety and performance.	H2020	Passenger + Freight
Design and Implementation of Interoperability	Demonstrator tool that will provide ontology-based transformations between different standards and protocols	ST4RT - Semantic Transformations for Rail Transportation	ST4RT will provide the transformation technology which is necessary to assure that technical interoperability can be deployed effectively and cost-efficiently by market actors in order to create service offerings that substantially improve mobility. Such transformation technology is a powerful tool that enhances semantic interoperability between disparate, heterogeneous legacy systems	H2020	Passenger
Living labs	Development of 3 living labs for a) dedicated services; wagonload trains, b) control tower for long distance rail	Smart-Rail - Smart Supply Chain Oriented Rail Freight Services – Smart-Rail	Smart-Rail aims to deliver three living labs. The purpose of the Living Labs is to test and improve the innovative measures in a real life situation.	H2020	Freight

## D 2.1 Transport projects & future technologies synopses handbook

	freight, c) Reliability of rail and (unexpected) obstructions on the track				
Next generation of TCMS	Development of a new sophisticated interface in the train cabin and braking system and second a common and interoperable train-to-ground (T2G) communication system	CONNECTA - Cost-efficient and reliable trains, including high-capacity trains and high-speed trains	CONNECTA aims to deliver next generation of TCMS architectures and components with wireless capabilities as well as the next generation of electronic braking systems. They proposed new technological concepts, standard specifications and architectures for train control and monitoring, with specific applications in train-to-ground communications and high safety electronic control of brakes	H2020	passenger
Time table planning with IT decision support tool	Software for time table construction that can handle major perturbations	ON-TIME - Optimal Networks for Train Integration Management across Europe	ON TIME created methods for timetable construction that are robust to perturbations and resilient to statistical variations in operations, standardized, interoperable approaches for the communication and presentation of information to drivers and controllers in order to present the right information at the right time in a clear and consistent form	H2020	Passenger+ Freight
Rail communication systems	Technical Specification of the future communication system railway to replace GSM-R	MISTRAL - Communication Systems for Next-generation Railways	MISTRAL will develop technical specifications for a new rail radio system which will leverage the broadband capacity of IP-based wireless communication to enhance signalling but also to make possible innovative services for both users and train automation/control.	H2020	Passenger+ Freight
Automated train operations	Development of: 1) prototype solution for obstacle detection and initiation of long distance forward-looking braking, 2) short distance wagon recognition for shunting onto buffers which can be integrated, 3) a real-time marshalling yard management system	SMART - Smart Automation of Rail Transport	SMART will develop a prototype solution for obstacle detection as well as standardized interfaces for integration into Autonomous Train Operation (ATO) module. In addition the system will use night vision technologies - thermal camera and image intensifier with multi-stereo vision system and laser scanners. The system will be able to detect obstacles up to 1km and will be able to provide support for shunting operations within +/- 5 cm distance estimation	H2020	Freight

## D 2.1 Transport projects & future technologies synopses handbook

	integrated into an IT platform		tolerance. Finally, the yard management system will provide real time data about resources available over open and TAF/TSI standard data formats.		
Satellite technologies/ERTMS/ETCS	GNSS based ETCS prototype/application in Rail Low Density Lines	GRAIL-2 - GNSS-based ATP System for Railway Low Density Lines	GRAIL-2 will develop a full on-board localization system of the train, thus reducing or eliminating the trackside equipment for localization (balises). The GNSS based ETCS prototype/application enables "positive train detection" that allows a future implementation of "moving block" systems (future ETCS level 3)	FP7	Passenger+ Freight
Vision systems	Smart Machine-Vision scanner for handling and counting of neo-bulk cargo	MARVIN - Independent Smart Machine-Vision Based Cargo Counting Module	MARVIN will develop a machine vision based solution has very high accuracy and does not depend on additional labelling (barcode) or sensors (RFID) that need investments and arrangement within the whole logistics chain.	H2020	Freight
ICT systems	Information services for wagonload traffic	Xrail project will enhance the competitiveness of wagonload traffic in Europe, by developing ICT systems to provide enhanced information to the users like delay alerts, next-day-arrival messages and international transport schedules.	XRAIL	Private	Freight

## 2.8 Waterborne transport project results

### Competitiveness – Waterborne transport Projects

Cluster: C1 Competitive maritime					
Subcluster: C1-1 Innovative ship concepts (inland waterway vessels, crafts for coastal and offshore, automated and autonomous vessels)					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Vessel speed	Ultras low speed ships	ULYSSES - Ultra Slow Ships	The project defined the requirements for ultra-slow ships, including technical, economic, safety and environmental factors	FP7	Freight
Battery powered Air Supported Vessel (ASV)	ASV electric mono hull design	BB GREEN - Battery powered Boats, providing Greening, Resistance reduction, Electric, Efficient and Novelty	Designed and tested a composite material mono hull that uses an air cushion for reducing hull friction and electric propulsion	FP7	Passenger
Battery powered Air Supported Vessel (ASV)	Testing of an ASV electric mono hull vessel	GFF - Green Fast Ferry - the world's first 30 knots battery powered Air Supported commuter ferry	Real life demonstration of the vessel developed in BB GREEN project. The first 30 knots electric ASV vessel	H2020	Passenger
Autonomous ships	Autonomous ship merchant concept	MUNIN - Maritime Unmanned Navigation through Intelligence in Networks	Developed the architecture, systems and procedures for an autonomous cargo ship that can be continuously monitored and controlled by a shore control. Developed systems for an autonomous bridge and engine room	FP7	Freight

## D 2.1 Transport projects & future technologies synopses handbook

Electric vessels	Electric hydrofoil taxi	SEABUBBLE - Fast-Forwarding to the Future of On-Demand Urban Water Transportation	The project wants to explore the feasibility of an electric hydrofoil taxi for 4 passengers and driver for rivers and inland waterways	H2020	Passenger
Fuel cell electric vessels	Hydrogen fuel cell powered high speed electric ferry	META 2 - Maritime Environmental and Technical Assistance (META) Program	Technical feasibility study of the a hydrogen power fuel cell fast speed passenger ferry name SF-BREEZE	US-MARAD	Passenger
Electric vessels	100% electrically powered ferry	E-FERRY - Prototype and full-scale demonstration of next generation 100% electrically powered ferry for passengers and vehicles	The project will develop a 100% electrically powered, emission free and medium sized ferry with reduced weight and high power capacity. Its electric drivetrain has already passed the Factory Acceptance Test and the hull construction has initiated.	H2020	Passenger
Ship design	Hull design for recreational and work boats	S.D.S. - an innovative system for building hulls for recreational and work boats	The project introduces a new hull design, which consists of a thin exoskeleton cedar that follows the force lines acting on the hull, enclosed within two "skins" of vacuum impregnated carbon or fibreglass, increasing safety, strength and rigidity of the boat and reducing consumption and emissions.	H2020	Passenger
Ship design	Ship design for Compressed Natural Gas (CNG) transportation	GASVESSEL - Compressed Natural Gas Transport System	The project will examine the feasibility of a new offshore and onshore compressed natural gas transportation system. It aims to present new methods to exploit stranded and unused gas and supply natural gas to places where it is not yet part of the energy supply.	H2020	Freight
Folding containers	Folding containers enabling the reduction of empty movements.	4FOLD PHASE 2 - 4FOLD Reduction of the International Transport of Empty Containers by Folding	The project has developed a technology with which 4 containers can be stacked taking the space of just one container. Phase 2 aims to catalyse the uptake of the 4FOLD container and convince the logistics sector of its value, through a large scale demonstration.	H2020	Freight

## D 2.1 Transport projects & future technologies synopses handbook

Design of Inland Waterway Ships	Re-design of a standard inland ship hull	NEWS - Development of a Next generation European Inland Waterway Ship and logistics system	Increasing transport capacity (cargo hold is designed to carry four containers in a row and three stacked, special purpose cargo, bulk cargo and cars)	FP7	Freight
Integrated logistics system	An adapted logistics and supply system for the respective demands of market in the catchment area; Enlargement of the European inland waterway system for container transport; New river ports infrastructure concepts; Re-evaluation of multimodal activities.	NEWS - Development of a Next generation European Inland Waterway Ship and logistics system	Adapted logistics & supply system for market demands (possibility to use the ship in a liner service on two routes: Western route (Enns - Rotterdam) and Eastern route (Enns - Constanta)	FP7	Freight
Improved hull design	hull-form optimisation a significant reduction in fuel consumption	MOVEIT - Modernisation of Vessels for Inland waterway freight Transport	Several safe structural solutions, performing almost equally with respect to kinetic energy absorption and time to full energy absorption, are available: ADN steel double hull; λ-shape steel double hull; Y-shape steel double hull, whereby the λ-shape or Y-shape steel double hulls indicate the potential to minimise the double hull width, offering bigger cargo-holds and higher economic efficiency	FP7	Freight
New, innovative mode of transport for perishable food liquids	Aseptic, temperature controlled, quality monitoring, self-loading cargo system	AgroHighway - Demonstration of an Innovative concept for high quality Transport of Perishable Agro Food Liquids inducing a Modal shift to Short Sea and River transport	Provide a flexible, maritime transport solution for perishable agro food liquids; reduce costs for transport over middle to long distances; increase the maximum transport distance and capacity; optimize the supply chains.	FP7	Freight
<b>Subcluster:</b> C1-2 Shipping operations and E-Maritime (Open and integrated data networks protected from cybersecurity risks enabling new innovative ship functions and easy integration with shore services.)					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
N/A	N/A	N/A	N/A	N/A	N/A

<b>Cluster: C2 Competitive ship design</b>					
<b>Subcluster: C2-1 Design tools for structural reliability and other functions (CAE + other tools, computation for virtual &amp; real advanced simulation and testing)</b>					
<b>Technology theme</b>	<b>Technology identified</b>	<b>Project</b>	<b>Project brief results</b>	<b>Funding programme</b>	<b>Sector</b>
Ship design	Ship design for future retrofitting of technologies	RETROFIT - RETROFITting ships with new technologies for improved overall environmental footprint	Identified design tools for retrofitability of future ships with newer technologies	FP7	Freight
Ship design	Design procedures and software tools for FRP ships	FIBRESHIP - Engineering, production and life - cycle management for the complete construction of large - length FIBRE - based SHIPS	The project will deliver new design procedures and guidelines supported on new validated software analysis tools	H2020	Freight
Computer Aided Modelling	Simulations for wave added ship resistance	PerSEE - Performance of ships in seaway	Determination of wave added resistance for any wave chosen wave direction and determination of propulsion losses	German Federal Ministry of Economic Affairs and Energy (BMWi)	Passenger+ Freight
Computer Aided Engineering	CAD and CFD tools for hull shape design	No-Welle - Numerical Optimisation of ships with high wave resistance	Hull wave resistance design tools using CAD and CFD	German Federal Ministry of Economic Affairs and Energy (BMWi)	Passenger+ Freight
Computer Aided Engineering	CAD software for 3D hull arrangement and a 3D ship stability	SMARTYARDS - Developing Smart Technologies for Productivity Improvement of European Small and Medium Sized Shipyards	Designed CAD software for 3D design and stability aspects that allows two way data exchange between the 2 software packages and the designers thus offering time savings and error reduction.	FP7	Passenger+ Freight

## D 2.1 Transport projects &amp; future technologies synopses handbook

Digital education tools	Ship-handling simulators for education, training and examination purposes and develop digital tools for cargo handling, ship stability and energy-efficient navigation.	PROMINENT - Promoting Innovation in the Inland Waterways Transport Sector	PROMINENT will design a digital education tool	H2020	Freight
<b>Cluster:</b> C3 Competitive ship production					
<b>Subcluster:</b> C3-1 Structural materials & composites (maritime materials)					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Composite materials	Fibre Reinforced Polymers (FRP) for ships	FIBRESHIP - Engineering, production and life - cycle management for the complete construction of large - length FIBRE - based SHIPs	The project aims to introduce FRP	H2020	Freight
Advanced materials for vessels	Advanced material solutions for efficient ships	RAMSSES - Realisation and Demonstration of Advanced Material Solutions for Sustainable and Efficient Ships	The project will demonstrate the benefits of advanced materials, from components through equipment and ship integration to repair. In cooperation with other initiatives, it will create a maritime materials innovation platform for continuous technology transfer between the industry's sectors.	H2020	Freight + Passenger
<b>Subcluster:</b> C3-2 Production equipment and processes (Advanced welding and multi-material joining processes, New production processes, Strategies and technologies for automation of complex one-off processes, Virtual and Augmented Reality Techniques, Measurement and Reverse Engineering Methods, additive manufacturing)					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector



## D 2.1 Transport projects &amp; future technologies synopses handbook

Computer Aided Engineering	CAE shipyard simulation software	SMARTYARDS - Developing Smart Technologies for Productivity Improvement of European Small and Medium Sized Shipyards	Developed a prototype software for simulation of shipyard activities that optimised the use of available resources and offered the ability to simulate the consequences of different changes in the assembly process.	FP7	Passenger+ Freight
Manufacturing process	Laser-Arc Hybrid Welding	Practical method of Laser-Arc Hybrid Welding for Thick Plates	JSTRA has carried out R&D for automatic weld seam tracking technology for welding and laser-arc hybrid welding technology to complete hybrid welding.	Japan Ship Technology Association	Passenger+ Freight
Computer Aided Engineering	CAE shipyard process monitoring system	visualization system in shipyard	JSTRA has created a visualisation systems that can identify and record working processes at a shipyard using a video images, and also data from WI-Fi wavelength strength, GPS, acceleration sensors and RFID	Japan Ship Technology Association	Passenger+ Freight
<b>Cluster:</b> C4 Competitive Life Cycle Services					
<b>Subcluster:</b> C4-1 Inspection & maintenance (inspection & maintenance new methods)					
<b>Technology theme</b>	<b>Technology identified</b>	<b>Project</b>	<b>Project brief results</b>	<b>Funding programme</b>	<b>Sector</b>
Inspection robotic systems	1) Modified an Unmanned Aerial Vehicle (UAV). 2) Development of Lightweight and heavyweight magnetic inspection robots	MINOAS - Marine INspection rObotic Assistant System	1) Used a UAV for visual inspection.2) Developed a lightweight crawler inspection robot with neodymium magnets to be used on ship walls for visual inspection and marking defective areas. Developed a heavyweight magnetic crawler with two robotic arms for Non Destructive Testing capabilities	FP7	Passenger+ Freight
<b>Subcluster:</b> C4-2 Repair, retrofit & dismantling (repair and retrofitting new methods, Smart solutions for outfitting, repair, retrofit, end-of-life)					
<b>Technology theme</b>	<b>Technology identified</b>	<b>Project</b>	<b>Project brief results</b>	<b>Funding programme</b>	<b>Sector</b>

## D 2.1 Transport projects & future technologies synopses handbook

Simulation tools for retrofitting	Simulation toolkit for retrofitting ships with new technologies	RETROFIT - RETROFITting ships with new technologies for improved overall environmental footprint	Developed a simulation/ planning tool for retrofitting lead time reduction	FP7	Freight
Reverse engineering	Photogrammetry and photo-modelling used for reverse engineering equipment	RETROFIT - RETROFITting ships with new technologies for improved overall environmental footprint	Used reverse engineering methods to acquire geometrical data of equipment and input them into CAD	FP7	Freight
Welding automation	Design of a robot for welding process automation	SMARTYARDS - Developing Smart Technologies for Productivity Improvement of European Small and Medium Sized Shipyards	Designed a mobile and flexible welding robot for automating the welding process of large flat panels thus increasing productivity and quality	FP7	Passenger+ Freight
Repair of structures	Composite patch repair technology	Co-PATCH - Composite Patch Repair For Marine And Civil Engineering Infrastructure Applications	The project explored with success the use of applying composite patches for repairing small cracks in steel structures on marine vessels	FP7	Passenger+ Freight
<b>Subcluster:</b> C4-3 Life cycle approaches (Life Cycle Performance Assessment Methods and Tools, Integrated Maritime Design (for Life cycle) Environment)					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Ship design & computational modelling	Software for ship lifecycle modelling	SHIPLYS - Ship Lifecycle Software Solutions	The project aims to produce a vessel's lifecycle modelling technique for better decision-making and integrate data from different design stages, through virtual prototyping, so as to lower the costs and improve the shipbuilding process.	H2020	Freight
Ship design	Innovative holistic ship	HOLISHIP -	The project will develop design methodologies	H2020	Passenger +

	design methodologies.	HOListic optimisation of SHIP design and operation for life cycle	integrating design requirements, constraints and performance indicators, so as to reduce both design costs and the overall vessel's life cycle costs. It will create an integrated software platform for the multi-objective ship design and operation, coupling existing tools, to reduce design development time.		Freight
--	-----------------------	---	---	--	---------

### **Environment – Waterborne transport Projects**

<b>Cluster: ENV1 Reducing emissions</b>					
<b>Subcluster: ENV1-1 Alternative fuels (biofuels &amp; alternative fuels usage)</b>					
<b>Technology theme</b>	<b>Technology identified</b>	<b>Project</b>	<b>Project brief results</b>	<b>Funding programme</b>	<b>Sector</b>
Solar energy	Photovoltaic modules on board ships	INOMANS <sup>2</sup> HIP - INOvative Energy MANagement System for Cargo SHIP	PV systems identified through simulations as potential energy sources for systems	FP7	Freight
Solar energy	Photovoltaic solar cells	JOULES - Joint Operation for Ultra Low Emission Shipping	Identified PV cells as a future trend through technology evaluation	FP7	Passenger+ Freight
Alternative fuels	Tested algae derived biofuel diesel blends	META 1 - Maritime Environmental and Technical Assistance (META) Program	Under the MATE program the Maritime Administration carried out trials of hydrotreated algae-derived biodiesel blends with Ultra Low Sulphur Diesel (50/50) and pure 100% renewable diesel. The tests presented emissions reductions while engine components were also tested for any detrimental effects of the fuel blend	USA-MARAD	Passenger+ Freight
Alternative fuels	Liquefied Natural Gas conversions	META 3 - Maritime Environmental and Technical Assistance (META) Program	The MARAD program has funded 2 demonstration projects for converting vessels to LNG powered. 1 RORO and 1 tug vessel	USA-MARAD	Freight

## D 2.1 Transport projects & future technologies synopses handbook

Alternative fuels	Adjustable diesel-/gas-/LNG-electric energy- and propulsion system	NEWS - Development of a Next generation European Inland Waterway Ship and logistics system	Reducing fuel costs and emission (Liquefied Natural Gas (LNG) is appr. 20% cheaper than diesel. Additionally, LNG provides a reduction of greenhouse gas emissions and other pollutants. The redundant energy and propulsion system with two propellers is optimized for shallow water)	FP7	Freight
Fuel additives	Fuel modifiers	GREENDRIVE - A molecular fuel modifier for ships able to reduce the costs related to fuel and maintenance for fleet operators	The project has developed a molecular fuel modifier device which, by applying electric fields to the fuel mix, reduces emissions, fuel consumption maintenance costs.	H2020	Freight
<b>Subcluster:</b> ENV1-2 emissions reduction) After treatment of exhaust gases & modelling techniques (2nd generation Post treatment technologies (scrubbers etc), Modelling techniques for					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Integrated Emissions control	1) Development of sequential SCR (selective catalytic reduction) for high sulphur fuels , 2) Diesel particulate filter (DPF)	HERCULES-C - Higher Efficiency, Reduced Emissions, Increased Reliability and Lifetime, Engines for Ships	Achieved reductions of emissions up to 80% (PM 50%, THC 50%, NOx 80%)	FP7	Passenger+ Freight
Integrated Emissions control	1) Electrostatic seawater scrubber (ESWS) for PM, SO2 and water solubles 2) Non Thermal Plasma Reactor (NTPR) using Electron Beam and Microwave to remove Nox, VOC, CO	DEECON - Innovative After-Treatment System for Marine Diesel Engine Emission Control	1) Built a retrofit system unit. The ESWS demonstrated significant reduction of SO2 and PMs. 2) A prototype NTPR system achieved almost 100% NO reduction over short periods of time(10mins) and 50% PM reduction. 3) Both systems could not run at the same time during the pilot testing	FP7	Freight
Integrated Emissions control	SO2 dry and wet scrubbers	RETROFIT - RETROFITting ships with new technologies for improved	Retrofitting scrubbers identified as SO2 reduction mechanisms	FP7	Freight

## D 2.1 Transport projects &amp; future technologies synopses handbook

		overall environmental footprint			
Integrated Emissions control	SCR and PM filters	JOULES - Joint Operation for Ultra Low Emission Shipping	Identified SCR and PM filters as potential technologies for 2025 through technology evaluation	FP7	Passenger+ Freight
Computmodelling of Integrated Emissions Control	Dry scrubbing and Selective Catalytic Reduction	TEFLES - Technologies and scenarios For Low Emissions Shipping	The technology was identified through simulation as potential energy saver for RORO ships , when used in conjunction with Combinator mode, batteries for hybrid systems and refrigeration system	FP7	Freight
Integrated Emissions control	Use of scrubbers for controlling black carbon emissions	META 4 - Maritime Environmental and Technical Assistance (META) Program	The project tested in real life the application of scurbbers for controlling black carbon although without presenting any reduction results	USA-MARAD	Passenger+ Freight
Integrated Emissions control	1) High pressure SCR on Diesel PM filters on Miller cycle 4 stroke engine 2) Combination of SCR and EGR 3) Methane and ethane abatement technology into lean burn 4-stroke gas engines	HERCULES-2 - Fuel Flexible, Near - Zero Emissions, Adaptive Performance Marine Engine	The project will develop the following solutions: 1) Combined on-engine aftertreatment solutions for 4-stroke diesel engines, 2) SCR reduction agent injection solutions, 3) Methane and ethane abatement technology with gas engines, 4) Emission measurement systems for integrated after treatment technologies	H2020	Passenger+ Freight
Certification and monitoring	Evaluate options for certification procedures for new engines and retrofit solutions for vessel operators to comply with stricter emission limits	PROMINENT - Promoting Innovation in the Inland Waterways Transport Sector	PROMINENT will evaluate certification procedures for new engine emissions limits	H2020	Freight
<b>Cluster:</b> ENV2 other emissions from waterborne transport					
<b>Subcluster:</b> ENV2-1 Reducing airborne and underwater noise					

Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Computational noise modelling	Development of computational modelling and measurement techniques for underwater noise caused by cavitation	SONIC - Suppression Of underwater Noise Induced by Cavitation	SONIC designed tools and mitigation measures for reducing noise without reducing propulsion efficiency that can help in ship design. The developed tools also help in the implementation of Maritime Strategy Framework Directive.	FP7	Passenger+ Freight
Computational noise modelling	Development of computational modelling and measurement techniques for underwater noise caused by cavitation and interactions with ship hull (wake, vibro-acoustic response)	AQUO - Achieve Quieter Oceans by shipping noise footprint reduction	The project to validated and improved models and methods to predict underwater noise radiated by the propeller, including cavitation effects, and interactions with ship hull (wake, vibro-acoustic response). The feasibility of a low-cost system real time noise monitoring system has been addressed.	FP7	Passenger+ Freight
Antifouling	Polyurethane-based paint containing immobilised biocides (Econea & Irgarol) and silicone based paint containing immobilised (Econea)	FOUL-X-SPEL - Environmentally Friendly Antifouling Technology to Optimise the Energy Efficiency of Ships	In particular, efforts are focussed on the improvement of the knowledge of cavitation noise phenomena and in the development of predictive models for the propeller noise radiation (including validation with measurements).	FP7	Passenger+ Freight
<b>Subcluster:</b> ENV2-2 Reduced emissions by paints & cleaning					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Antifouling	Polyurethane-based paint containing immobilised biocides (Econea & Irgarol) and silicone based paint containing immobilised (Econea)	FOUL-X-SPEL - Environmentally Friendly Antifouling Technology to Optimise the Energy Efficiency of Ships	In particular, efforts are focussed on the improvement of the knowledge of cavitation noise phenomena and in the development of predictive models for the propeller noise radiation (including validation with measurements).	FP7	Passenger+ Freight

## D 2.1 Transport projects & future technologies synopses handbook

Antifouling	On-board automatic cleaning system	FLIpER - The first on-board automatic ship hull management cleaning system for hull fouling prevention towards maritime eco-efficiency	Cliin has developed the first on-board automatic cleaning system "FLIpPER" that enables at any given time and location cleaning of the hull. Estimated 20% less fuel consumption of the ship over 5 years.	H2020	Passenger+ Freight
Antifouling	Ultrasonic technology that provides vessels full AF prevention	BIOECOMARINE - New Ultrasonic Cost-Effective Equipment as Anti-Fouling System for Vessels	The project will develop an ultrasonic based antifouling (AF) solution that can be adapted to all types of vessels. It will increase AF Coating efficiency and durability. Operational cost savings are estimated between 15-20%	H2020	Passenger+ Freight
Ballast Management	Water Microfluidic technology for the purification of ballast water	TRILO-BWTS - Disruptive and patented microfluidic technology purification for ship ballast water, being maintenance free, eliminating clogging of filters and providing significant life-cycle cost savings	The project introduces a new ballast water purification system based on microfluidic technology for the removal of microorganisms, avoiding the clogging of filters and the use of chemicals.	H2020	Freight

### Energy – Waterborne transport Projects

<b>Cluster:</b> ENE1 Optimising resistance and propulsion					
<b>Subcluster:</b> ENE1-1 Minimise resistance & optimise propulsion ("Friction reduction techniques, Life-cycle considerations, Full scale validation of advanced prediction methods, Delivered power in operational conditions (wind, waves), Dedicated developments for advanced propulsors,")					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Ship stability	Trim monitoring control	RETROFIT - RETROFITting ships	Developed a computer based decision support system to a TRL 8	FP7	Freight

## D 2.1 Transport projects & future technologies synopses handbook

		with new technologies for improved overall environmental footprint			
Energy Saving Devices and computational fluid dynamics (CFD)	CFD real life test of a Pre-Swirl Stator	GRIP - Green Retrofitting through Improved Propulsion	Evaluated the performance gains of using a pre-swirl stator, initially through Computational fluid dynamics and later through pilot testing on bulk carrier. The results were a gain of speed by 0.3 knots at the same propulsion power	FP7	Freight
Combinator optimising and computational modelling	Computational modelling of Combinator mode for controllable pitch propellers	TEFLES - TEchnologies and scenarios For Low Emissions Shipping	The technology was identified through simulation as potential energy saver for RORO ships, when used in conjunction with batteries for hybrid systems, Cold ironing, After treatment and refrigeration system	FP7	Freight
Propeller design	Design & testing of contracted and loaded tip (CLT) propellers, and counter-rotating propellers (CRP) for electric driven pod propulsors	TRIPOD - TRIPLE Energy Saving by Use of CRP, CLT and PODded Propulsion	The project designed & tested combinations of propeller designs used by electric podded motors. The CLT propellers offered better efficiency	FP7	Freight
Propeller, rudder and inflow devices design	1) Design and CFD of Large Area Propulsion, 2) Design and CFD of Advanced Screw Propeller System with the use of twisted rudder design or inflow improving devices	STREAMLINE - Strategic Research For Innovative Marine Propulsion Concepts	1) Design and CFD of LAP a concept of placing the propeller far behind the ships, so the size of the propeller can be increased dramatically while lowering its speed. The LAP was almost cavitation noise free. 2) Design and CFD of Advanced screw propellers with different geometries which were tested with twisted rudders and showed promising results. Propeller inflow improving devices were also tested in their ability to improve inflow.	FP7	Freight
Ship design & computational modelling	CFD modelling for bulbous bow	TARGETS - Targeted Advanced Research for Global Efficiency of Transportation Shipping	Carried out CFD modelling of a bulbous bow as a friction resistance reduction method	FP7	Freight



## D 2.1 Transport projects & future technologies synopses handbook

Ship design & computational modelling	Ship hull air lubrication	TARGETS - Targeted Advanced Research for Global Efficiency of Transportation Shipping	Numerical simulation for validation of the ship hull air lubrication concept. Results indicated that full ships such as bulkers or tankers show significant benefits, while for slender hull forms the benefit is negligible	FP7	Freight
Propeller design and computational simulation	Simulation of propeller designs: Wageningen B, Meridian and Upgraded Meridian Series	TARGETS - Targeted Advanced Research for Global Efficiency of Transportation Shipping	Tested various propeller designs through simulation	FP7	Freight
Energy Saving Devices and computational fluid dynamics (CFD)	CFD of a BLAD–Boundary Layer Alignment Device	TARGETS - Targeted Advanced Research for Global Efficiency of Transportation Shipping	The BLAD device helps reduce axial inflow deficiency into the propeller and harmonises inflow conditions. In addition, it helps create additional thrust by creating a swirl against propeller inflow	FP7	Freight
Rudder design	Rudder design optimisation designs	MOVEIT - Modernisation of Vessels for Inland waterway freight Transport	Using new rudder designs, fuel savings around 8 per cent can be achieved, and the manoeuvring capabilities may remain still satisfactory; Removal of flanking rudders can result in reduced fuel consumption; Ship lengthening in association with constant payload, as well as constant draught can be beneficial with respect to the relative fuel consumption of a vessel, resulting in a decreased , however, still sufficient manoeuvrability;	FP7	Freight
<b>Subcluster: ENE1-2</b> Ship powering (Improved engine design for operation in “off-design”, Optimisation of energy distribution, storage and peak smoothing ,new engine components and materials, multi-fuel engines, life-cycle cost and impact assessment, Zero emission propulsion techniques (wind propulsion, nuclear, electric))					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Advanced combustion and computer aided combustion optimisation, Injection systems, Integrated emissions technologies, adaptive engine control, new materials	1) Direct injection gas combustion system 2) Multifuel engine efficiency optimisation and fuel switching 3)Cool combustion 4) Computer aided combustion optimisation 5) Computational fluid	HERCULES-C - Higher Efficiency, Reduced Emissions, Increased Reliability and Lifetime, Engines for Ships	Reductions of fuel consumption by 3%. Also achieved high performance over powerplant lifetime	FP7	Passenger+ Freight

## D 2.1 Transport projects & future technologies synopses handbook

	<p>dynamics &amp; experiments for fuel injectors 6) Advanced turbocharging combined with integrated emissions control systems and EGR (exhaust gas recirculation) 7) Development and testing of emissions control systems for 2 and 4 stroke engines 8)Advanced bearing and combustion chamber technology 9)Advanced control for Diesel-electric hybrid engine system</p>				
Multi-fuel engines, Advanced combustion, Injection systems, new materials	Two-stroke low speed marine diesel engine that operates on high-pressure Compressed Natural Gas (CNG) and/ or Liquefied Natural Gas (LNG) as an alternative hydrocarbon fuel to HFO	HELIOS - High Pressure Electronically controlled gas injection for marine two-stroke diesel engines	HELIOS developed a new two stroke gas engine available to the maritime market offering low emissions and very high efficiency	FP7	Passenger+ Freight
Multi-fuel engines	Dual fuel engine (LNG/Diesel)	RETROFIT - RETROFITting ships with new technologies for improved overall environmental footprint	LNG/Diesel dual fuel engines identified as a viable efficient technology	FP7	Freight
Energy Storage modelling	Battery Storage System (BSS)	INOMANS <sup>2</sup> HIP - INOvative Energy MANagement System for Cargo SHIP	Simulated the use of a Battery Storage system where the stored power is used to drive the thrusters and the shaft generators as motors	FP7	Freight

## D 2.1 Transport projects & future technologies synopses handbook

Energy Storage	Battery Storage System and supercapacitors	JOULES - Joint Operation for Ultra Low Emission Shipping	Identified BSS and supercapacitors through technology evaluation	FP7	Passenger+ Freight
Secondary energy converters	Waste Heat Recovery System (WHRS) model	INOMANS <sup>2</sup> HIP - INOvative Energy MANAgement System for Cargo SHIP	Modelled WHRS as a potential method of recovering energy	FP7	Freight
Renewable energies	Wind assisted vessels	JOULES - Joint Operation for Ultra Low Emission Shipping	Identified wind assisted vessels as a future trend through technology evaluation	FP7	Passenger+ Freight
Secondary energy converters	Electric motors, electric heaters, WHRS, Organic Rankine Cycle	JOULES - Joint Operation for Ultra Low Emission Shipping	Identified the rising trend of secondary converters on ships by 2025 through technology evaluation. ORC technology used in a demonstrator.	FP7	Passenger+ Freight
Multi-fuel engines	Dual fuel gas engines and diesel engines	JOULES - Joint Operation for Ultra Low Emission Shipping	Identified a shift towards dual fuel gas engines for ships in 2025 although diesel engines will still be used	FP7	Passenger+ Freight
Secondary energy converters and computational modelling	Computational modelling of batteries for hybrid propulsion	TEFLES - TEchnologies and scenarios For Low Emissions Shipping	The technology was identified through simulation as potential energy saver for RORO ships , when used in conjunction with Combinator mode, Cold ironing, After treatment and refrigeration system	FP7	Freight
Renewable energies	Kite and suction sail propulsion simulation	ULYSSES - Ultra Slow Ships	Kite and suction sail propulsion simulated to predict power and ship behaviour using auxiliary wind propulsion systems	FP7	Freight
Podded propulsion units	CFD of Contra Rotating Pod (CRP) and Integrated Contra rotating Pod (ICP) propulsion units	STREAMLINE - Strategic Research For Innovative Marine Propulsion Concepts	Conventional propeller and pod working together offer improved propulsive efficiency, enhanced manoeuvrability, redundancy and flexibility with respect to the changing operating conditions. CRP is considered to be much more realistic and practicable, cost effective and more reliable than ICP, while the latter is more suitable for the long term	FP7	Freight

## D 2.1 Transport projects & future technologies synopses handbook

Engine design for autonomous vessels	Two stroke low speed turbocharged crosshead diesel engine and pump jet	MUNIN - Maritime Unmanned Navigation through Intelligence in Networks	The project identified the use of a two-stroke low speed turbocharged crosshead Diesel engine with a directly coupled fixed pitch propeller as main propulsion system. Additionally, a pump jet was installed as fall-back solution for the non-redundant main engine.	FP7	Freight
Renewable energies	Wind assisted propulsion using the Magnus effect with a rotor sail technology	RotorDEMO - Norsepower Rotor Sail Solution demonstration project	Full scale demonstration of Norsepower Rotor Sails on RoPax vessel offering potential 30% fuel savings	H2020	Freight
Secondary energy converters and computational modelling	Fuel cells using hydrogen or methanol as auxiliary energy generation	TARGETS - Targeted Advanced Research for Global Efficiency of Transportation Shipping	Developed a complex component model to describe fuel cells in the context of the overall dynamic energy model of freight vessels	FP7	Freight
Renewable energies and computational simulation	Wind assisted vessels	TARGETS - Targeted Advanced Research for Global Efficiency of Transportation Shipping	Simulated the potential power gain of using a Dyna rig wind sail arrangement	FP7	Freight
Secondary energy converters	Hydrogen generator for electricity generation	H2MOVE - Hydrogen generator for higher fuel efficiency and lower carbon emissions in maritime transport	Aris Pump Ltd. developed H2MOVE, safe small footprint hydrogen generator to be used with diesel marine engines for energy production	H2020	Passenger+ Freight
Renewable energies	Wind assisted vessels	SeagateSail - 20% fuel saving for commercial vessels through a hybrid wind plus motor cruise mode	Seagate is developing an innovative collapsible-automatic-retrofittable delta wing sail allowing the vessel to reduce fuel consumption by 20%	H2020	Freight
Secondary energy converters	Hydrogen fuelled PEMFC based hybrid powertrain system	MARANDA - Marine application of a new fuel cell powertrain validated in demanding arctic conditions	Development of an emission-free hydrogen fuelled PEMFC based hybrid powertrain system is developed for marine applications and validated both in test benches and on board the research vessel Aranda	H2020	Passenger+ Freight

## D 2.1 Transport projects & future technologies synopses handbook

Fuel flexible engines	1) Fuel flexible engine (dimethyl ether, propane, diesel) 2 stroke and 4 stroke engine, 2) Fuel flexible injection system	HERCULES-2 - Fuel Flexible, Near -Zero Emissions, Adaptive Performance Marine Engine	The project will develop a fuel injection system for multi fuel purposes that can switch between fuels while the engine is operating. Demonstration of fuel flexible engine operation	H2020	Passenger+ Freight
Dual fuel engines and computational fluid dynamics	Computational fluid dynamics of combustion in dual fuel engines (LNG-LPG/Diesel)	HERCULES-2 - Fuel Flexible, Near -Zero Emissions, Adaptive Performance Marine Engine	The project will study the CFD of combustion of multifuels. In addition use of high speed cameras in combustion chamber to validate CFD data	H2020	Passenger+ Freight
New advanced engine materials and component design	1) Cast and powder metallurgy processed materials 2) new design of cylinder heads	HERCULES-2 - Fuel Flexible, Near -Zero Emissions, Adaptive Performance Marine Engine	1) The project will test cast engine components and powder metallurgy turbocharger turbine casings 2) New design for cylinder heads to reduce thermomechanical cycle resistance	H2020	Passenger+ Freight
Adaptive powerplant control and performance	1) Systems and processes allowing a continuous optimized performance of the power plant throughout its lifetime 2) Engine operation optimisation through cylinder cut out	HERCULES-2 - Fuel Flexible, Near -Zero Emissions, Adaptive Performance Marine Engine	1) The project will develop optimized control methods and adaptive lubrication system for powerplants, 2) The project aims to control and optimise marine engines with cylinder cut out under low load operations	H2020	Passenger+ Freight
Secondary energy converters	Hybrid drive for hybrid propulsion	Auxilia - Hybrid Drive for Commercial Ships and Yachts	Auxilia is an easy to fit, compact plug and play hybrid drive for smaller sized commercial ships and yachts with diesel engines up to 2000 kW. Auxilia reduces fuel consumption and main engine maintenance and improves manoeuvring.	H2020	Passenger+ Freight
New power system configurations	Power configurations and assessing how these configurations match the ship's operational profile.	MOVEIT - Modernisation of Vessels for Inland waterway freight Transport	The future new build vessels will be more constructed with the gas power configurations while the current vessels will have to install after treatment devices to meet the future requirements	FP7	Freight
Energy system and drivetrain solutions	Low energy and near to zero emissions ships	LEANSHIPS - Low Energy And Near to zero emissions Ships	The project will develop engine, fuel, drive train, hull, propulsor, and energy system technologies for efficient, less polluting new or retrofitted vessels. It will display combinations of these technologies in 8 demonstration actions.	H2020	Freight + Passenger

## D 2.1 Transport projects & future technologies synopses handbook

<b>Subcluster:</b> ENE1-3    Energy management & analytics for ship operations (Energy Data acquisition and management systems, Analysis and decision making (tools), Dynamic modelling and simulation tools)					
<b>Technology theme</b>	<b>Technology identified</b>	<b>Project</b>	<b>Project brief results</b>	<b>Funding programme</b>	<b>Sector</b>
Energy Modelling	Dynamic Energy modelling (DEM) of ships components	REFRESH - Green Retrofitting of Existing Ships	A DEM system was built and tested in conjunction with decision support tool in order to assist the crew to make decisions for optimal energy management on-board the ship	FP7	Freight
Energy Modelling	Used the General Energy Systems (GES) simulation tool	INOMANS <sup>2</sup> HIP - INOvative Energy MANagement System for Cargo SHIP	The project used GES to model all the global energy systems on-board a ship and added new models for alternative energy sources.	FP7	Freight
Energy Modelling	Dynamic Energy Model (DEM) of ships components	TARGETS - Targeted Advanced Research for Global Efficiency of Transportation Shipping	A DEM software was developed that captures holistically the transfer, conversion and storage of energy onboard a ship as a function of its operational profile and over long periods of time or during its commercial life-cycle	FP7	Freight
Energy Management	Real time energy monitoring of fleet	SEAHUB - Real-time Fleet Performance Center (FPC) to optimize energy efficiency in Maritime Transport to reduce fuel consumption and harmful emissions	The project will develop a Real-time Fleet Performance Center (FPC) that will collect energy monitoring data across a fleet	H2020	Freight
Energy Management	Heat recovery for cooling systems	EEEC <sup>SM</sup> -2 - Energy and Environmentally Efficient Cooling System for Maritime use	The project will develop a technology to harness unused heat onboard the vessel for cooling purposes.	H2020	Passenger+ Freight

## D 2.1 Transport projects & future technologies synopses handbook

Energy Management	Energy monitoring of medium-weight vessels	SCOUT - Smart Monitoring Control and User interactive ecosystem for improving energy efficiency and economic maintenance of Medium-Weight Ships	The project is developing a smart monitoring and control system for medium-weight vessels to improve the engine's performance, provide advanced consuming knowledge and achieve longer ship life with reduced operational costs.	H2O20	Freight
-------------------	--	---	--	-------	---------

### Infrastructure – Waterborne transport Projects

**Cluster:** INF1 Smart and connected ports (Integration of national single windows with trade portals and port community systems, Development of Intelligent holistic solutions for the efficient management of ships in ports for freight, passengers and workers, integrated with Urban Mobility Plans and solutions. Development of digital infrastructure, ICT innovation, and automation: Robotics, automation, and autonomous vehicles)

Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Autonomous systems	Shore Control Centre for autonomous vessel	MUNIN - Maritime Unmanned Navigation through Intelligence in Networks	Developed a software for onshore control and monitoring of autonomous vessels	FP7	Freight
Alternative fuels and port equipment	1) LNG powered terminal tractors, reach stackers and RTGS .2) Electrified Rubber Tired Gantry Cranes (RTGs), 3) Energy monitoring system for ports	GREENCRANES - Green technologies and eco-efficient alternatives for cranes & operations at port container terminals	The project carried out pilot testing and trials of Electric	TEN-T	Freight
Port of the future	Defining the vision for the Port of the Future concept	DocksTheFuture - Developing the methodology for a coordinated approach to the clustering, monitoring and evaluation of results of actions under the Ports of the Future topic	The project aims to develop a methodology for a coordinated approach to the clustering, monitoring and evaluation of results of actions under the Ports of the Future topic. It will lead to the Port of Future Road Map for 2030 that will include R&D and policy recommendations and several other exploitation elements.	H2020	Freight

## D 2.1 Transport projects &amp; future technologies synopses handbook

Integrated logistics system	New river ports infrastructure concepts	NEWS - Development of a Next generation European Inland Waterway Ship and logistics system	Adapted logistics & supply system for market demands (possibility to use the ship in a liner service on two routes: Western route (Enns - Rotterdam) and Eastern route (Enns - Constanta)	FP7	Freight
Port security system	Security sensors for next generation port solutions; Security communications infrastructure.	SUPPORT - Security UPgrade for PORTs	The project identified port security upgrade solutions encompassing legal, organisational, technology and human factor perspectives. These solutions should provide substantial improvements in the performance, reliability, speed and cost of European port security.	FP7	Passenger+ Freight
<b>Cluster:</b> INF2 Intermodality (Improved interoperability of existing port related systems and the integration between transport modes, Improved interconnectivity and integration between transport modes and established systems, such as: Maritime national Single Windows, RIS, e-Customs, TAF, ERTMS and rail one stop shop, "access points", "data pipelines")					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
N/A	N/A	N/A	N/A	N/A	N/A
<b>Cluster:</b> INF3 Refuelling infrasturcture for alternative fuels and innovative concepts (cold ironing, infrastructure to accommodate alternative fuels in shipping)					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Alternative Maritime Power (AMP)	Cold Ironing with electricity produced at harbour via LNG generator	RETROFIT - RETROFITting ships with new technologies for improved overall environmental footprint	Cold ironing with LNG generator identified as energy saving solution	FP7	Freight
Alternative Maritime Power (AMP)	Cold ironing modelled	INOMANS <sup>2</sup> HIP - INOvative Energy MANagement System for Cargo SHIP	Cold ironing identified as potential energy saving solution	FP7	Freight



## D 2.1 Transport projects & future technologies synopses handbook

Alternative Maritime Power (AMP) and computational modelling	Cold ironing modelled	TEFLES - Technologies and scenarios For Low Emissions Shipping	The technology was identified through simulation as potential energy saver for RORO ships , when used in conjunction with Combinator mode, batteries for hybrid systems, After treatment and refrigeration system	FP7	Freight
Hydrogen refuelling & production	Offshore floating platform for hydrogen refuelling and production	H2OCEAN - Development of a wind-wave power open-sea platform equipped for hydrogen generation with support for multiple users of energy	The project produced design specification and simulation of an offshore hydrogen refuelling platform that could can also produce hydrogen through electrolysis using wind and wave energy	FP7	Passenger+ Freight
Hydrogen refuelling	Hydrogen refuelling infrastructure	MARANDA - Marine application of a new fuel cell powertrain validated in demanding arctic conditions	Development of a mobile hydrogen storage container capable for 350bar	H2020	Passenger+ Freight
Hydrogen refuelling	Cargo loading / unloading system for liquefied hydrogen at port	Development of cargo loading / unloading system for liquefied hydrogen and the relevant rules for operation	JSTRA is working on the development of a liquefied hydrogen loading system from ships that deliver fuel to a port	Japan Ship Technology Association	Freight

**Systems – Waterborne transport Projects**

<b>Cluster: SYS1 Maritime systems</b> (Integration of ship navigational and communication facilities aboard ships, including the bridge systems, other ships, VTS and SAR, into a European marine digital highway information system. Integration of navigation technologies with shore based data networks and centres: (SafeSeaNet, (AIS, LRIT), GNSS, National Single Window, VTS, route planning etc.). Ship to shore communications)					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Autonomous Systems	Developed Deep Sea Navigation System, Collision Avoidance Module, Harsh Weather Operation Module, Strategic Harsh Weather Route Planning Module and Remote Manoeuvring Support Systems	MUNIN - Maritime Unmanned Navigation through Intelligence in Networks	Developed software prototypes for autonomous bridge concept	FP7	Freight
Autonomous systems	Autonomous engine monitoring and control system	MUNIN - Maritime Unmanned Navigation through Intelligence in Networks	Developed software prototypes for autonomous engine monitoring and control and engine efficiency system	FP7	Freight
<b>Cluster: SYS2 Safety</b> (Safe automation and autonomy, accident prevention, fire resistance)					
Technology theme	Technology identified	Project	Project brief results	Funding programme	Sector
Implementation of resilience engineering	Develop and validate a multi-level resilience model and virtual platform	SEAHORSE - Safety Enhancements in transport by Achieving Human Orientated Resilient Shipping Environment	The SEAHORSE project clearly demonstrated that different transport modes can and should work together to share the best practices with practical impact on safety.	FP7	Freight