Horizon 2020 Transport Advisory Group

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Foreword

This document presents the response of the Transport Advisory Group (TAG) to the 5 questions posed by the European Commission in view of the preparation of the H2020 Work programme 2018-2020 for Societal Challenge 5: Smart Green and Integrated Transport.

It is based on the rich and varied inputs provided by the TAG members in and between the three meetings that took place from end of February to early May 2016.

The report has 5 chapters:

1. **Background**, to highlight the extent to which the previous TAG report (June 2014) remains valid, but also point at important changes that have happened since, and how these reflect on the TAG remit;
2. **Challenges**, which are structured along the 3 EU strategic objectives for the transport sector: (i) Mobility for all, (ii) Resilience and sustainability, (iii) EU competitiveness and leadership;
3. **Innovation gaps and game changers**, which address 4 main innovation areas: (i) technologies and their integration in the transport system, (ii) efficiency and resilience of the transport system, (iii) economic performance and business models, (iv) accounting for the human;
4. **R&I Integration**, which aims to identify the needs and opportunities for cooperation with H2020 areas other than transport and (i) propose joint, interdisciplinary research with other thematic strands of the programme – both sectoral and "horizontal" and (ii) seek synergies to jointly address R&I governance issues that cut across themes and research communities;
5. **Research priorities**, where 16 R&I areas are listed and briefly described, to feed into the Work programme 2018-2020.

This structure, which was adopted to match the 5 initial questions, inherently entails that many of the issues discussed are addressed in more than one chapter, which may be perceived as redundant. This in fact deliberate, as the aim is (a) to allow for a self-standing reading of each chapter and, most importantly, (b) to ensure that all the possible angles of any given issue (challenges, innovation gaps, opportunities of synergies) are explicitly addressed.

In any instance, and in order to facilitate the reading of a document that inevitably reflects the very tight timing of its production, Chapter 5 provides systematic references that point to the specific sections of the report where the rationale behind each priority can be found, along with a more detailed discussion of the aims, scope and relevance.

As discussed in Chapter 1 Background, most of the substance of the previous H2020 Transport Work programmes remains valid. The TAG has therefore strived to identify R&I areas that are either novel or that require more and/or better focused attention. This contributes to explain why for a significant share of the proposed priorities the primary targeted innovation is not, or only indirectly, technological. Needless to say, this should not be construed as an under-representation of the technological dimension of the Transport R&I programme, which remains fundamental.

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1 Background

1.1 The last TAG recommendations and the transport priorities two years ago

The previous Transport Advisory Group (TAG) focussed on the Draft 2016-2017 Work Programme, and built its June 2014 response around the need to refresh the transport agenda, and adopt a disruptive rather than incremental approach. It proposed that transport paradigms were shifting with new emerging technologies, business environment and mobility patterns, as follows:

- Discontinuity in transport trends, including a 'mobility peak' and the freight-GDP decoupling;
- Technology revolutions within and outside the transport sector, and in trade;
- New and worsening mostly weather-related external threats, and uncertainties associated with saturated systems and just in time production;
- New business models and concepts such as collaboration and asset-sharing;
- Updated policy objectives of the 2011 Transport White paper;
- Changed life-styles related to demographic and health trends, and;
- New commercial opportunities emerging with Big Data and smart travel.

1.2 Today's socio economic context, and its impact on mobility patterns and Transport business.

Today much has stayed the same and the eight priority challenges remain relevant:

(i) Addressing the nexus of problems affecting urban transport (including congestion, pollution, accidents and inaccessibility);
(ii) Achieving the required level of climate change mitigation in the sector;
(iii) Managing the impact of demographic trends and, in particular, the ageing population;
(iv) Effectively harnessing new transport and related ICT technology;
(v) Making the transport system, and in particular infrastructure, capable to respond to new challenges
(vi) Making quantum improvements in safety levels across the transport system;
(vii) Improving energy efficiency and reducing transport's dependence on fossil fuels;
(viii) Redistributing passenger and freight traffic between transport modes on a large scale, primarily to ease environmental and congestion issues.

Still, there is a need for rethinking the challenges facing the transportation systems, and the approaches to be adopted. In the two short years since 2014, the socio-economic and strategic context has been substantially altered:

a) A slow growth world with uncertain perspective where the EU is not badly positioned yet not necessarily able to gain.

The economic outlook has settled on a slow growth path throughout the world, combined with continued declining ratio of international trade to GDP and resulting in an uncertain perspective for international trade and transport. While developing countries regained a reduced growth after the last financial turmoil, Asia and the emerging markets no longer serve as an economic driver, and representing a threat for sustaining the demand for European exports. Financial and economic prospects are relatively favourable in the US, and the EU with the adoption of a hawkish financial easing resulting in some depreciation of the Euro, favourable to exports. Welfare and equity gains of the last decades are at risk globally, and pressure on public budgets remain extreme. This mixed situation contributes to accumulated delayed maintenance of infrastructure and mass transit systems, with negative impacts on accessibility, congestion, safety and security, and the overall efficiency of transport systems. It is also poised to reduce trade and stiffen competition in traditional transportation and technology export markets.

b) The positive impact of the COP21 agreements, and the reality check of implementation.

The December 2015 adoption of the COP21, set a platform for climate change mitigation and GHG reduction. Most importantly, it cemented a success where the leadership of the European Union members was recognized, it injected a dose of optimism in the otherwise morose international context, and it signalled a turning point of effective engagement of the private sector. COP21 provides the Transportation industry with a clear agenda and mandate, and positions the EU favourably. The Volkswagen emission scandal that followed a few months later, exposed the limitation of leading EU policy impact, by revealing its enforcement weakness. The governance of the EU exemplary regulation was challenged, and the transportation industry is exposed in a controversy.

c) Security threats squarely targeting Europe and its logistic and strategic centres add to the mounting climate change and weather risks.

The horrific terrorist attacks in Paris and Brussels over the last year confirmed the continued and severe risks of manmade catastrophes, and exposed the permanent threats in particular to the major transportation nodes and mass transport systems. Preparedness and resilience to ever more frequent and powerful extreme events associated with climate change were established as a core transport sector agenda, and may provide some of the practices for security and safety. Still, terrorism threats permanently alter the way large infrastructure and public systems need to be managed,

challenge the governance and leadership of the transport sector, and add a layer of complexity and cost to transportation.

d) Lower oil price impact negatively many economic drivers, and set the transportation sector to dis-align with its environmental targets.

   The positive impact of lower petroleum costs on consumption has not been substantial in Europe, although it should reduce its productivity disadvantage as an overall importer of oil. There is no prospect of global agreement on the opportunity cost of fossil fuels, their costing in the economic evaluation of investments, externalities and taxation. In the transport sector, low fuel cost has a major positive impact on the air transport industry, and brings relief to the auto industry. Yet, it weighs on alternative fuel research and development, leading to unwanted delays in the transition towards a carbon-free economy. Overall, low fuel prices make it harder to justify energy / emission saving measures in economic terms, and set the stage for a complacency adverse to long term competitiveness.

e) Large scale migration flows, impact border management, hamper mobility, increase costs, lower accessibility and enhances regional differences.

   The migration crisis is forcing member states to take ad hoc emergency measures that restrict mobility between states, and challenge the spirit of the Schengen agreements. Transport operators and infrastructures are caught in this crisis. Transport time and costs of security and immigration procedures have uneven accessibility impact across the union.

f) Increasing political uncertainty and volatility result in negative prospects for the transport sector.

   The long standing uncertainties related to Brexit, Grexit, growing anti-EU pressures in Poland and Hungary and separatist movements in Scotland, Catalonia etc - threaten EU-wide co-ordination of transport systems and operations, mobility and transport demand.

2 Challenges and Opportunities

2.1 Setting the scene

This chapter deals with the first of the five questions addressed to the Advisory Group:

What are the challenges in the field of Transport that require action under the Work Program 2018-2020?

And would they require an integrated approach across the societal challenges and leadership in enabling and industrial technologies?

The latter is also dealt with in Chapter 4.

The challenges and risks are organized around the three EU overall objectives in the field of transportation, i.e.

a) Ensuring mobility and access for all;

b) Developing a sustainable and resilient transport system, adapting to climate change and contributing its share to the EU environmental objectives, and;

c) Up keeping the competitiveness and leadership of the EU in the transportation arena.

In addition, two research needs run across the entire transport arena: Knowledge building, disseminating and application as the founding steps of research, and; Good and flexible governance conditions to ensure fair and effective research application. Although covered within each of the three challenges, and in chapter 4 as cross cutting issues, they are discussed separately at the end of the chapter.

The TAG mandates a five to seven years perspective for market deployment. For certain transport decisions, this is either too short or too long. Innovation, behaviour and markets impact one another and the transport system, each at a different speed. Effectiveness of research and innovation depends on timing, and the appropriate balancing the attention between the three areas of challenges.

2.2 Challenges related to Mobility and Access for All

"Mobility for all" may be specified as a "right" to accessibility to services and opportunities. It is associated with freedom of movement, democracy and self-reported happiness. Countries with lesser mobility are found to feature less security, poorer governance, and more unequal opportunities.

2.2.1 Changing demographic

The overall EU population is poised to remain mostly stable and crest just above 525 million in 2050. The challenge to achieving mobility for all, comes from the demographic wave change compounded by new emerging behaviours in cities and unforeseen migration patterns. The behavioural impact of the large and relatively affluent cohorts of baby boomers with individualistic life styles, advancing beyond 65 years of age, is uncertain. In particular, the strong correlation between age and disability points to a significant potential impact on the need for accessible transport services, and the economic and social consequences of mobility losses in that cohort are not fully understood. The transport system also needs substantial redesign to provide safe mobility for the older travellers.

2.2.2 Gender equality

Integrating the gender dimension in research and innovation content is one of the three objectives of gender equality in Horizon 2020. It concerns all parts of Horizon 2020 and it encompasses both research content and gender balance in research teams as part of the Horizon 2020 objectives in gender equality. Appropriate gender dimension of research enhances its societal relevance and improves market potential. It is necessary to devote resources to questioning gender norms and stereotypes, and addressing throughout the transport agenda, the evolving needs and social roles of women and men with an analysis of gender, sex or both. This is not a separate agenda since it runs through all aspect of research in transportation: it should be kept in mind and discussed when setting priorities.

2.2.3 Cultural megatrends

The emergence of a new urbanized and connected culture among the younger generations is challenging the traditional transport offer. New employment models are associated with precarious jobs, growing inequalities and unemployment. Issues of outright alienation and the migration crisis today intensify long standing social issues. For the transport system, this translates into affordability, accessibility and inclusion challenges. The reinforcing combination of poorer generations and new traveling and communication patterns results in a continued slow shift away from individual car owner use, to more car sharing, biking, real time "Uberized" transport service use in cities and car sharing for interurban travel. The regulation of emerging services, the competition with established businesses, and the synergy with infrastructure-based mass transit transport systems are an issue. Cities need more seamless, connected multi modal service systems allowing for individualized smart door to door trips. Efficiency in transport systems, and affordability, accessibility and inclusion require an interface between institutional transport and shared economy, and between local authorities, transport providers and internet based services. Transport research needs to establish the foundation for this horizontal coordination with appropriate analysis.

2.2.4 Risks

A variety of disruptive events are known to affect the transport system and bear significant impacts, notably on safety and health. They include (i) extreme weather episodes and geophysical catastrophes, (ii) manmade events including terrorist attacks, cyber-crime and industrial disputes, (iii) technical failures such as power outages or disrepair, and (iv) market transformations rendering a technology or service quickly obsolete. These risks may not be of comparable magnitude in their consequences, yet they are all highly disruptive and / or tremendously costly. They constitute separate agendas, yet it remains a research question whether they can all be addressed with generic risk management strategies. They demand revisited solutions beyond what is already "on the cards" to take into account all transport modes and to cover all the segments of trips, door to door. They require updated methodologies to cost benefits and to value lives saved. They need identical mind-sets, equal seamless coordination and cooperation between institutions, and the highest level centralized oversight. They call for cooperation and collaborative research across modes and beyond the transport sector, including for the identification of minimum networks, the development of common procedures, cross over experience sharing, joint emergency responses, and for the identification of further collaborative needs.

2.2.5 Safety: risks and opportunities with new technologies, aging and transitions

The ongoing revolution in vehicle technology and connectivity, the demand for more efficient use of space and the emerging changed behaviour, generate new and major safety risks and even more promising opportunities.

The greater safety risks may come from the many technological and behavioural transitions occurring simultaneously. Issues include the lack of safety standards of electro-mobility and for the introduction of automated vehicles, and other new technologies and practices. In freight technology, the platooning of trucks and the full automation of trucks, currently under trial in the US, requires further research. Vulnerable users face new risks with the growing use of bicycles, and the multiplying situation of walking and cycling in mixed traffic. Gender is an important dimension in all transition research since behaviours and needs may vary between men and women.

Another growing risk is associated with the aging of the population. There, the combination of more flexible legislation, regulations and enforcement of driving licences, forgiving infrastructure design, and vehicle updates will help to prolong the safe driving career of older people. Further research is also needed, for example, on the specific issue of dementia and driving, on promoting and encouraging a transition from driving to other transport alternatives and on the interaction between the three dimensions of safety, i.e. drivers, vehicles and the system in a mixed situation of transition towards automated vehicles. Addressing the needs of older people will result in a better transport system for all users, and in this respect it may represent an opportunity. The ergonomics of dummy for safety trials continue to be that of "average men", and it is urgent to introduce testing with dummies representative equally of women and men, as well as of elder people.

The greater safety opportunities may come from advanced Driver Assistance Systems. The pay back of research in that hugely promising arena is very quick and it should be given high priority. The perspective of safety improvement coming with automated vehicles is huge and should be supported with research: in fact it is so considerable that it may have a disruptive impact on the viability of conventional car insurance industry.

2.2.6 Health, an area of major underestimated threats

The impact of transport related pollution, and especially small particles emission has emerged as a huge underestimated health threat. The challenge is to redefine pollution exposure to take into account inhalation of airborne pollutants while in vehicles as well as outside. There is an urgent need to develop the capacity to monitor a traveller's exposure on a door to door basis across different transport modes and including walking, cycling and waiting times. At the same time, the status of regulation, enforcement and monitoring of air quality and vehicle pollution is in flux. At EU level, national and city levels, an abundance of initiatives are taken with many knowledge and standards gaps and lacking an established sequenced package of what to do at every level of decision making. We not only need research about "business model to manage the health impact of emission, with emphasis on small particles, and noise", but also about techniques and technology to produce less emission, particle and noise.

The health impact of public transport is believed to be substantial and yet remains under studied. The effects of non-motorized modes on health because of both exercise and reduced emissions needs to be revisited especially since multi modal trips are on the rise. At the same time, the upcoming impact of automated cars on reduced walking is unknown and should be researched.

Research has established noise as a significant nuisance and health hazard. There is a major lack of psycho-acoustical research to understand better the noise annoyance ad its social impact. Ministries responsible for transport and for health should coordinate to assert transport as a positive health driver. Research is also needed at the intersection between health and competitiveness, to provide the framework for a business model to manage the health impact of emissions, small particles, and noise.

2.3 Challenges related to Sustainable Mobility and Transport

2.3.1 Transport and the environment

Transport environmental impact and the environment impact on transport are global and local, urban, rural, fluvial and maritime, and concern a large spectrum of research arenas. The complex web of challenges organizes around local environmental effect, and global climate change impact. The local effect is mostly covered under the Health section. The transportation community faces extraordinary and diverse environmental challenges: establishing knowledge, developing new technologies and facilitating the transition to applications and commercialization, under updated and enabling policies and norms. Freight and air transport in particular, face the most complex technical challenges with longer term technology breakthrough yet with short term rewards expected from new business models. Climate change is a multiplier of risks for transport. It increases costs of investment and services, and it makes evaluation of costs more uncertain. The environmental dimension needs to be mainstreamed as part of the risks and the solutions throughout transportation activities.

2.3.2 Decarbonization

De-carbonization of transport and improved efficiency, is the core challenge in order to meet the 2050 targets. It focuses on advancing improved and alternative combustion (biofuels, electromobility) and other technologies enabling decarbonization. In air transport, alternative fuels will be the major way to decarbonization.

2.3.3 Making the most of technology development

Technology advancement is being pursued to reach the targets set by the EU and COP21. This calls for establishing the knowledge platform and standards, norms and regulations to measure the environmental impact of vehicles, equipment and systems, from the local clean air perspective and from the global climate change perspective; documenting and establishing consensus on performance targets, norms, monitoring and reporting. Targets include all surface modes, including maritime and fluvial, as well as air transport.

2.3.4 Synergy and Transition for sustainable mobility

Synergy should be built with the other interconnected fields: they include land use, urban and regional planning, climate science and ecology, business models and value chains, technology and innovations, and health. Merging efforts between the various sectors research and governance arenas, and using the UN's Sustainable Development Goals as a framework as needed, will ensure better progress and impact.

Managing the transition calls for effective enforcement, monitoring and transparency capacity of environmental decisions at all levels. The challenge has been recently illustrated with vehicle pollution norms and performance. For maritime and air transport, the transition needs to account for the international business practice, and affords the EU an opportunity to establish its technological leadership.

2.3.5 Smart greening of transportation

The smart greening of transportation starts with research for more energy efficient vehicles. Then it involves understanding, modelling, improving and documenting how each transport mode impacts the environment. More broadly, it requires to analyse how transport system choices lead to different climate footprint. Therefore, beyond the

transport systems, it entails the evaluation of land use and business models that condition transport demand. In cities, mitigation builds on a redesign of urban space for accessibility, liveability, re-allocation of road space and new patterns for street pace. Since there is no one model for cities, research and horizontal integration with all aspects of regional development are needed. For freight transport, reckoned to be one of the hardest sectors to decarbonize because of high rates of traffic growth forecast, short term progress may reside in new business models and changes in production and distribution models, while breakthrough in vehicle energy efficiency may take longer. Environmental mitigation for maritime transport and inland waterways focuses on technology advances such as automated ships/vessels. In all cases, the cost benefit of mitigation on local economies is under-researched.

2.3.6 Adaptation

Adaptation of transportation systems to climate change requires responsiveness and agility. The first challenge is the adaptation of construction and maintenance standards of infrastructure in response to the evolving temperature, pluviometry and humidity. With evolving climate conditions and innovation in transition, costing of infrastructure adaptation may be premature, yet research is needed on more efficient assets maintenance and management. Vehicles, equipment and services also need to be adapted, with special attention to extreme weather proofing for aircrafts, ships and vessels. Smart greening and operational performance of transport systems /services are the other more complex dimension of adaptation. In all cases, the horizontal considerations and appropriate interfaces with regional planning, urban management, the health sector, geologic and meteorological services, are critical.

2.3.7 Resilience

Weather related extreme events are expected to become continuously more frequent and more ferocious in the future, and to produce significant disruptions in transportation. Like all challenges, it is an occasion for service improvement and an opportunity for excellence. Resilience has two parameters: ability to withstand disruption, and ability to recover. All systems, all locations, all times need to be combed and reviewed for their resilience. While much attention may be given to withstanding extreme events, because of their self-contained focus, the ability to recover and re-bound is equally if not more important. There, flexibility is key and demand coordination across the transport network, across transport modes, and horizontally with local governments, communities and business. Research is needed across the board on all aspects of resilience.

2.4 Competitiveness and Leadership in Transportation

Keeping pace with skills development and the exponential growth of knowledge and technology is critical. There is a broad sense however, that “Europe is losing its competitiveness” because of its smaller scale, lesser investment in research and development, lesser vertical integration than its major competitors, and less supportive environment for new market entrants with innovative products and services. There is a need for cooperative research to identify and work on new challenges. There is also a need to adopt a strategy between preserving EU technological leadership, or whether to accept, selectively, the role of follower in areas where others, for example the USA, are more advanced. Imitation also supports growth and competitiveness, and in many ways imitation represents incremental innovation where there may be an advantage. In any event a clear strategy about leadership may be of value in core research areas.

2.4.1 Technology and Innovation

Many technology and manufacturing processes need specific research input in the transport industry, such as integrated non-destructive evaluation, processes for new materials, robotics, augmented reality, 3D printing, etc... One example is the exploitation of big data to support manufacturing and maintenance. Cyber-physical systems (CPS) allow to detect, locate, and remediate degraded components of connected automated vehicle or equipment. Current automotive systems lack a systematic approach and infrastructure to support post-market runtime diagnostics for control software. Today no standard diagnostic targets the ECU software even though systems such as stability, cruise, and traction control are critical for vehicle safety. A novel cloud environment responsible to store and manage the data is necessary. There is also a need to address the development of common-standard HW-SW platforms that could allow the remote monitoring of the critical parameters and the update of the software. This would have a considerable impact on the design of new architectures and on security. The roll out of these technologies in automated vehicles, for private use, commercial fleets or public transport, will be of increasing value as the content of electronics and software expands.

2.4.2 Congestion and infrastructure use

Congestion imposes crippling costs on the economy and the welfare of people. Aging commuter and mass transit systems have not kept up with urban growth. Passenger transport systems are no longer optimal for new travel patterns. Freight transport is expected to continue a rapid growth competing for road capacity. As a consequence, reliability has become an issue for surface transport. At the same time, the surface infrastructure is mostly not used to capacity. In air transport, airport congestion is a limiting factor. Seamless intermodality and redundancies between systems are needed to improve reliability. New business models for the optimization of infrastructure usage to alleviate congestion and secure resilience is an open field for research.

2.4.3 Security

There is a need to advance not only in all the elements entering into the transport security challenge, but also to develop the capacity to link the dots between each of them. Security systems need to take into account all threats, natural or manmade, including terrorisms, cyber-crime, and technical failures. The security needs to cover the passengers and operators, the infrastructure, including the transport nodes and their surrounding and access, as well as equipment and vehicles. The efficient traffic flows of vehicles or passengers needs to be preserved with new technologies and collaborations. Non-intrusive security checks, user profiling and face screening technologies such as Passenger Name Record (PNR) require appropriate governance to manage the compromise between privacy and convenience. The same balancing act between speed and security scrutiny emerges not just in Air transport but for all modes, in particular mass transit. It does not only concern passengers but also private and fleet vehicles, and freight in all modes, for example in securing the movement of deep sea containers. Ultimately, the economics of data privacy policies need to be better understood. Abnormal behaviour recognition (notably in crowds) is another technology required, and the pre-suicide behaviour on rail platform, now successfully applied in the UK, is an example of the technologies to be developed and applied to all transport modes across the EU. Cheap, remotely controlled, ubiquitous drones have carved a huge and sudden security gap for transportation, in particular the High Speed Rail network, large commercial aircrafts, and strategic transport nodes. This requires urgent

and mode-specific attention. Automation, connectivity and on line payment require cyber security, which is treated below as a self-standing issue with Big Data. All the research needs emerging from this broad agenda cannot be imported and must be developed for EU specificity.

2.4.4 Regulatory frameworks supportive of innovations

Taking full advantage of technological change requires that regulatory frameworks keep evolving in ways that support the introduction to market of innovative transport products and services. In certain areas, this means avoiding overregulation and ensuring that regulations are not used as barriers to block new entrants. In other areas, particularly when it comes to introduction of disruptive technologies, it means fast, flexible, and transparent creation of new regulations that remove regulatory and legal uncertainty and give clarity to innovators and investors as to what exact products and services they have the right to sell in the market.

2.4.5 Supporting new entrants commercializing innovative technologies

The EU transport industry continues to be globally competitive overall. However, there are signs that this position may be eroding, as we have entered an era when much of the market disruption in transport comes from new, technology-based companies. In particular, Europe is starting to fall significantly behind the US, where a vibrant and fast-growing ecosystem of transport focused start-ups is emerging, particularly in Silicon Valley. The key barrier to the emergence and growth of a comparable ecosystem in Europe is a major lack of financing for science- and R&D-based companies. As a result, many of them are forced to move to the US relatively early on.

2.4.6 New Business models

New business models in transportation are contributing to reinvent production of goods, delivery, risk sharing, pricing and financing. Today new service-mobility providers are poised to manufacture affordable vehicles meeting the large and growing demand for more sustainable urban mobility of people and goods. OTTO is offering to retrofit lorries into driverless mode. UBER and others are creating modern transportation services, based on connectivity and linking individual demand with a transport offer. TESLA is building the market while actually developing the product; it received a record 200,000 first day pre-orders for its US$35,000 cars under development. There is a recognition that Tesla type solutions are needed, with shorter than 15 years product development schemes. The transition from vehicle ownership to user-ship for individuals and households, and from production to fleet management for the industry, represents a challenge for the vehicle manufacturers who are losing their most valuable asset: their direct relationship with the end user. The development of battery charging stations by TESLA for electric vehicles, is another example of new business model, where the private sector finances the bulk of the infrastructure. It raises governance issues for the cooperation and sharing of risks and costs between public authority, infrastructure and energy companies. Charging while running is being experimented and raises the need for new contractual arrangement pre-requisites. The governance arrangement for supercharger network in the EU is missing and requires optimizing the mobility and convenience, sustainability and competitiveness of the system to come.

2.4.7 Keeping the means of production within Europe

Planning novel manufacturing programmes is essential for European producers of all mobility means. Local production of urban electro-mobility equipment by local companies entering into partnership with local governments may be an avenue to

impulse flexible and tailored urban and suburban transport. There is a need to implement new approaches of Pan-European collaborative production (hardware and software), procurement and services, through the development of innovative Smart and Secure Electric Mobility Value Chains. European re-industrialisation can be encouraged by providing the conditions for EU regions to produce similar vehicles and services by sharing customer needs, technologies and solutions while addressing their specific regional/local needs.

2.5 Cross cutting Challenges Knowledge and Governance

2.5.1 Knowledge

There is a critical need to renew the evidence base with state of the art data processing techniques, travel and behavioural surveys, studies documenting the socio economic mega trends, understanding them and building the knowledge to address its issues and respond to its needs with appropriate policies and incentives. Empirical evidence is needed to produce estimates of elasticities, reliability metrics, comfort indicators robust values of time. New research is making major improvements to our understanding but there are more gaps than conclusive results. Most current modelling exercises are based on knowledge that is outdated and insufficient using sometimes obsolete estimates. Collecting empirical evidence is often labour intensive but much can collected by students under supervision as part of their research projects, but only if such research is funded. This need runs across all areas of transport from environmental sustainability to safety & health, yet it represents a focus area of its own. The efficient sharing of knowledge, updating of the repository of data and promotion of its use in policy making, also constitutes a research governance agenda.

2.5.2 Governance

2.5.2.1 Governance at the sector level

Governance is a self-standing agenda. It is related to context, and appropriate institutions may be especially important during the many transitions through which the sector is evolving. At the sector level, a fundamental discussion needs to be held on the role of national and local governments, with respect to ethics, privacy, safety and security, and on the social premises on which transport decisions are taken. This includes the management of urban space, access and inclusion, technological changes, mega-data and privacy. It requires an array of stakeholder's participation to manage the disruptions from new technologies and the resistance of established interests. It builds on establishing indicators of urban space use, and the valuation of mobility against social and economic utilisation of street space. It seeks to adapt public spaces, help users adopt ICT technologies and prevent quasi monopoles emergence and abuse. The resulting pricing and policies should be set at the lowest possible level. It is also necessary to build a vision and a consensus on where we want to be on matters of governance and privacy ten, twenty and fifty years from now.

2.5.2.2 Governance at the project level

On a project per project basis, participatory governance, consisting of the interaction between users and producers is necessary for quality design and timely adoption of new services and products. The development of intrusive products, such as drones, also raises governance issues, since it is difficult to retroactively regulate this booming innovation. It is necessary also to enable behaviour changes associated with such innovations. Finally situations of *de facto* monopolies emerging and addressed *ex post*

by regulations are an issue. This is particularly the case with Big Data. Simultaneously, if unsure of the prospects and potential applications, regulation may be restrictive.

2.5.2.3 Governance of transitions

The management of unchartered transitions should be documented and analysed for lessons, especially regarding mixed road traffics of automated and non-automated vehicles, on highways, and including pedestrians and two wheelers in urban areas. Learning from other sectors, such as manufacturing, or transport modes where automated vehicles have been introduced, such as port and metros, may also prove beneficial. Example of ongoing transitions with governance questions abound: Automated fleets may alter the relative cost of operation of public transport, and public transport financing principles may need to be revisited? More flexibility in governance is required to broaden the testing of driverless cars currently limited to the UK, Germany and Sweden and selected urban areas, leading to some EU tests being carried out in the US. Regarding freight transport, control and governance issues arise with the responsibility for home deliveries on the so-called 'last mile' switching from the shopper to the e-retailer, with outsourcing of the delivery to local carriers and often involving agencies to act as local collection points for delivery.

2.5.2.4 Governance and Big Data security

Data related to the mobility, identity, activity, security or safety of individuals, shared and controlled by third parties, are a major casualty of transport services. Research is needed to develop solutions for this issue, as new systems are defined by the access to data. The trade-offs between companies' performance disclosure, enforcement of regulations and privacy, are equally challenging. Every stakeholder needs access to its respective data, yet such data as on environmental or energy performance represent an asset that can make or break competitiveness. When regulators demand transparency for fair competition and good governance, companies seek to preserve their competitiveness, and they may hide or fake data to protect themselves: the existence of web sites that provide guidance on how to fake one's data is an evidence of this practice.

2.5.3 International cooperation

2.5.3.1 Cooperation with developing countries for trade and security

Cooperation with selected developing countries is an avenue whereby good governance practices are shared and exported in order to address security gaps and to ensure EU security. It is also necessary to have reciprocal and compatible regulations for trade, for example to export automated vehicles. Rules for users of automated vehicles need to be standardized, in the same way as the UN oversaw the Traffic signal standardization through the Vienna Convention. WTO, International Telecom Union (ITU) need to be involved and ITU possibly reinforced. EU may serve as a catalyst for international governance since it has credibility. The new governance allows a framework to be put in place smoothly, and serve to settle conflicts and differences.

2.5.3.2 Cooperation to keep up with the global state of research

It is necessary to remain aware of the global state of research: in particular regarding strategic areas of research among our larger partners US and China. To gain some measure of proximity to that unknown strategic research, there is scope for selected international cooperation and the Commission may facilitate rapid links and other engagement ways with China and US.

3 Innovation Gaps and Game Changers

3.1 A new innovation landscape

This chapter addresses the question of innovation gaps (science and technology, innovation, markets, policy) and potential game changers, including the role of the public sector, in accelerating changes. It also covers how Europe is positioned regarding innovation in the transport sector, and other transport related arenas.

The issues raised by the search for innovation gaps and game changers have to be reviewed in the framework of the EU research and innovation policies, as announced last year by the Research Commissioner Carlos Moedas. They emphasized promoting an innovation strategy that is not only seeking to fulfil existing needs, but that also aims at creating "disruptive markets". This innovation strategy generated strong feedback regarding the existing gaps to the current support for disruptive innovations and their scaling up, and the need for support for strategic innovation champions at EU level. To substantiate this strategy the Commission has started a debate on the "how" and "what" innovation to foster.

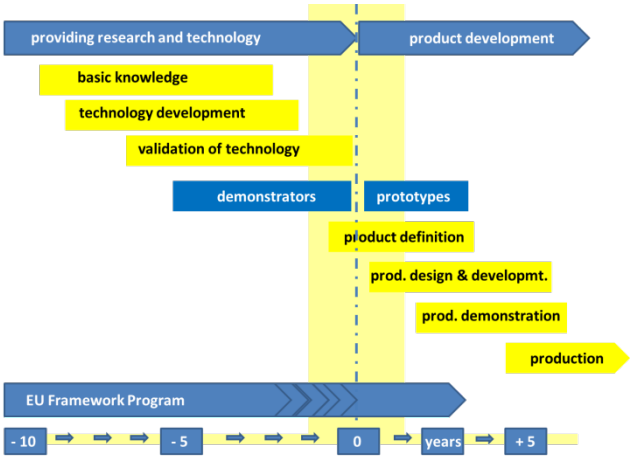

Figure: Chain of Research and Innovation in the Engineering and Technology Sciences © DLR 2010

From a mobility and transport perspective, noteworthy issues in the debate are whether to continue to cover the entire chain of research and innovation with EU funding, and how this could be achieved (Figure 1). The debate is very much driven with a technology oriented mind-set, leaving out areas of upmost importance in the transportation field, such as: organizational innovation which includes innovation via new business models; the interaction with the user and the consideration of user's needs and preconditions for innovation acceptance; changes in the overall political, economic and societal framework. While the strategic line of "societal relevance" was already stressed by the Transport Advisory Group (TAG) during the 2014/2015 term and has been applied to transport research funding within the current Horizon 2020 period, this approach needs to be deepened so that the technology oriented mind-set of research and innovation can be superseded by a broader set of research and innovation dimensions, notably:

- Technologies and their interface with the transport system;
- Efficiency, resilience and effectiveness of the transport system;

- Economic and commercial competitiveness, business models and markets;
- Accounting for the human: demand, needs and behaviours; inclusion and access.

In addition, research and innovation will need to consider the complexities emerging, for each of these dimensions, from the extreme differences in the speed of innovation across the physical elements of the transport system (vehicles and infrastructures, built environment) and the business models. Business models may change rapidly and cause disruptions in the system when new opportunities emerge with digitalization, and when potential new actors enter from other non-transport sectors. The speed of many of the recent changes in the transport business is unprecedented in the sector.

3.2 Technologies and their interface with the transport system

Unlike only some years ago, technologies that are relevant to the transport sector are increasingly developed in areas that lie outside the direct transportation arena. This is true in particular of digital technologies and sensor systems that enable automation. Innovation in vehicles, engines and propulsion systems that are specifically designed for transportation remain obviously relevant for the improvement of the transport system performance. Current developments, however, continue to show that important changes do not occur through technological innovation alone, but as a result of its combination with the dynamic of individuals or corporate users generating new mobility options and new business models.

3.2.1 Automation

3.2.1.1 Vehicle automation and its consequences for (road) safety.

Vehicle automation has turned into a hot topic within only a very few years. It is expected, specifically when it comes to road vehicle automation, that it will become a major game changer leading to a profound reorganisation of the overall transport system. Car and truck makers and their supplying industries have engaged in extensive R&D activities as the automated cars and trucks now compete to bring to the market the first passenger fully automated vehicles at speeds of up to 120 km/h on European highways by the year 2020. Automation of trucks comes in combination with platooning. Innovation in the different fields of automation is therefore in full swing, and European car and truck makers and suppliers are expected to play a leading role in this race. To enter the market smoothly, vehicle automation needs to demonstrate and prove its positive impact on transport safety not only for car users, but for all road users. This is all the more relevant as mixed use of road infrastructure by all modes – soft and motorized – is expected to increase in the next years.

3.2.1.2 Automation in the freight sector – trucks and drones.

Today trucks and light commercial vehicles make up 13 % of the vehicle stock in Europe, and they are estimated to generate about one third of kilometres driven on European roads. Automation in the freight sector is not receiving the same level of attention and analysis as in the personal vehicle sector, although it represents an important area of innovation, especially with the added combination of automation and platooning. Given the favourable commercial impact of technology development of truck automation, and the level of competition in the trucking industry, it should be expected that innovation in this area will be implemented even faster than for passenger cars. This is also true for drones: they will be able to serve specific transport and

delivery needs for which demand is ever more increasing. So far the use of drones is a white spot on the European transport R&I map. The assessment of environmental and social impacts from drone use will need to go hand in hand with developing a plan for drone certification and drone operation regulation.

3.2.1.3 Automation in the rail sector.

There are ongoing R&D activities to develop higher levels of automation by implementing the Automatic Train Operation (ATO) in all rail market segments (high speed, mainline, urban, regional, and freight). ATO operation will enable further increases in safety, as well as improvements in operational and energy efficiencies. The use of satellite positioning and smart, radio-connected intelligent wayside objects as well as the development of a modern train integrity solution will ease maintenance efforts, improve operational efficiencies, and open new functional possibilities for railway network information management and control. Within the rail freight sector, modern solutions for automatic coupling of wagons and automation progress in terminals and marshalling yards are needed to increase handling speed on the last mile, and enhance rail competitiveness. Higher automation within rail mode will require unified approval procedures, common operational rules and improved automation of testing processes.

3.2.1.4 Automation in public transport.

Automation is a strong challenge for public transport, and may turn into either a big chance or a big threat. A key critical consideration is the improvement of the performance and competitiveness of public transport by road vehicle automation. So far, uncertainty exists regarding the economics of large-scale delivery in public transport, the design of the policy framework for accountability, and the public attitudes conditioning the extent and speed of deployment. There are currently no complete tests, or deployments from which to conclude implementation best practice.

3.2.1.5 Transition from conventional road transport to vehicle automation.

There is a broad consensus that successful transition pathways from self-driving to fully automated driving are crucial for innovation in road transport automation. Although fully automated vehicles are expected to manage any situation, research is needed into the requirements of “mixed” traffic, and the behaviour of soft modes users vis-à-vis automated traffic. One important issue will be whether the interaction of fully automated road vehicles and non-automated road users should be supported by technologies to guarantee the best possible safety for all. Is there a need to get pedestrians and cyclists “connected”? Filling this innovation gap will become even more urgent if expectations about an accelerated roll-out of automated road transport prove true. It is absolutely necessary that research in this field includes the ethical dimension.

3.2.1.6 Testing of vehicle automation.

Innovation in road transport, in particular for driver assistance and fuel efficiency, has been supported over the last several years, by Field Operational Test sites (FOT) in Europe. Testing of automation, however, has two different dimensions which can be covered by FOT only in parts: (i) Testing is an absolute prerequisite to get the permission for bringing vehicles and their specific functionalities to the market; carmakers have to guarantee the safety of the system and its components. In the case of conventional cars this means testing by driving them for many millions of kilometres.

Since existing testing procedures prove vehicle safety only partly, there is an urgent need to investigate and implement new methodologies and procedures. (ii) Exploring the acceptability of fully automated vehicles and supporting their acceptance will need tangibility, i.e. testing sites need to allow the public to get in contact with the new technology. This includes a proof of safety that covers all road users, including those who are not "connected".

3.2.1.7 Assessment of automation effects.

While automation is the "big promise" in terms of road safety and enhanced mobility for all, credible insights into its cost to users (individuals and firms, public transport operators and freight transport providers) and to the public sector, are still missing. Elements that need to be taken into account include, among others: ICT infrastructure that has to be established as an enabler of automation; the optimization of transport systems in terms of service provision and energy consumption; the redesign of physical infrastructures, and also; the social and economic cost of data privacy. One important area will be the impact of automation on the logistics and freight sector, as automation, together with platooning, are expected to lead to major cost savings in the road transport, thus affecting considerably the competition between road and rail. An integral part of the assessment should be the analysis of interaction between technology and human mobility that will help to capitalise on the positive and reduce the negative impacts.

3.2.2 New aerial vehicles

3.2.2.1 Drones and personal aerial vehicles.

Advances in technologies and materials are ushering a new era of small aerial vehicles for both personal and commercial use. This wave originally started with a fast advent of unmanned aerial vehicles, including drones. However, technologies developed for this segment, such as advanced autonomous flight capabilities, are increasingly seeping through toward vehicles carrying people, such as personal point-to-point vehicles. Aside from technological challenges, a wider introduction of products based on and around these technologies will create opportunities and challenges all the way to the systemic level, including in areas such as access to and management of aerial traffic.

3.2.2.2 Using drones for improvements in the maritime sector.

Ships' stable container platforms can easily accommodate on-board drones. Studies of how to use drone technologies to improve maritime navigation, safety and security (piracy and smuggling of people), would allow to define appropriate rules and regulation framework at the EU and global level.

In the shipbuilding sector, drones can considerably improve inspections and safety of shipbuilding structures. This opens new possibilities for the integration of shipbuilding industries with the ICT sector. It could create new types of services which can offer both regular and emergency inspection of ship structures and equipment while the ship is sailing or when emergencies occur. Research is needed to deepen the knowledge about the positive and potential negative impacts of drone use in the shipbuilding sector and the operation of ships.

3.2.3 Electromobility

3.2.3.1 Fast and massive diffusion of electromobility.

Electromobility is on the way to move from a more technological realm to implementation. Research and innovation needed in this area concern notably (i) the charging infrastructure (private, semi-public and public) needed to accelerate the diffusion of electric vehicles including technologies to charge while running, and (ii) improvement in battery performance, i.e. batteries' capability to store electricity in a better, lighter and more efficient way, while offering at the same time the best possible safety standards. Innovation in this area should draw from the experience of existing regulation as it exists in countries like Japan and the US where electromobility is more advanced. Small electric vehicles represent important niches in urban transport and may help foster the diffusion of electromobility: their research and development represents a valuable and specific strand of innovation in the field of electromobility.

3.2.3.2 Pushing innovation in the electromobility field by combination with automation.

So far electromobility is "stigmatized" by a lack of convenience for everyday use (also for commercial purposes), because of the need for frequent refuelling. Better battery capacity will be one strand of improvement, needed in particular to allow for long distance trips; automation will be another strand that enables the vehicle to run with optimal efficiency and best possible balance of operation and loading sequences. This calls for research on energy harvesting technologies for road vehicles, as well as energy storage and ubiquitous energy provisioning. It may be expected that acceptance of both electromobility and automation will significantly benefit from their combination.

3.3 Efficiency, resilience and effectiveness of the transport system

Efficiency and effectiveness of the transport system clearly depend on the performance of both infrastructure and vehicles. This does not only include motorised road and rail vehicles and their respective infrastructures, but also active modes like the bicycle and walking. There are considerable knowledge gaps concerning the exchangeability of different modes for everyday and long distance travel in both the passenger and the freight arena. If efficiency and effectiveness are defined by exchangeability, this will automatically include an increase in resilience of the overall system. Innovation in this area may come from several directions: infrastructure providing easy digital and physical access to a broad range of transport means, and / or; transport services, including micro infrastructures such as bike boxes, and; vehicles that can be used flexibly depending of situations and needs.

3.3.1 Efficiency of the transport system

Efficiency includes economic, social and environmental dimensions. Achieving higher efficiency in the transport system requires knowledge about the life cycle cost of the system's components, the costs of the system maintenance and those arising from transportation's external effects. Innovation in the design of vehicles and transport systems, should take into account optimal life-time performances. From a social perspective efficiency of the transport system is heavily dependent on social external costs, notably in the field of health. The environmental dimension is concerned with greening transport via technological, organizational or regulatory interventions and improvements. It also includes interaction with alternative use of space, above all street space in urban environment, and takes into account all sizes of cities or villages as well

as concepts of urban redesign. To increase the liveability of cities, valuing of mobility versus social and economic utilisation of street space is needed, using indicators of broadly defined "urban" space use. This calls for the integrated study of transport and alternative urban forms.

3.3.2 Resilience of the transport system to potential disruptions.

Resilience of the transport systems (infrastructure and services) to potential disruptions that result from man-made or natural disasters, is measured in terms of response time to the disruption, minimization of economic and operational impacts, and time for returning to normal operations. The robustness of transport systems needs to be reviewed and should include viable alternative service solutions as appropriate, for the situation of disruption. This applies also to the transport of goods, as disruption may cause negative impacts on the activities of firms and the supply to consumers. Specific knowledge gaps with respect to resilience concern the robustness of the transport system and its subsystems, and the possibilities to adapt to dynamic changes in the environment and to react to previously unforeseen situations. Innovation should combine technical and organisational aspects and go for solutions that respond to a variety of problematic situations. Major gaps concern the avoidance of events that lead to a breakdown of the transport system or one of its subsystems. Critical infrastructure resilience should be addressed on various levels: European, national, regional, urban. Urgent innovation should come from automated detection systems that will also be of great utility in the area of traffic management.

3.3.3 Increasing the effectiveness of the transport system

Europe has a long lasting and far reaching experience with respect to alternative modes to the private car: public transport, new sharing based mobility concepts, bicycle and feet. Innovation should focus on enhancing the set of options provided to individuals and firms to use co-modal mobility that optimally serves their needs and operates at a high level of environmental performance. When it comes to multimodality a thorough reconsideration of the travel time concept will be needed and balanced against other positive effects of environment friendly modes, but also against other desired characteristics of the transport system like accessibility, reliability or timeliness. The study of travel time will also be important to anticipate the potential impact of automated vehicles that allow for seamless door-to-door transport and may drastically change the current use of effective transport systems or the concept, and value, of travel time.

3.3.3.1 Effectiveness and security of the transport system.

Wholesome transport system security is a basic prerequisite to the demand of people and firms. It is basic to warrant the freedom of movement which is also a basic right in Europe's democratic political system. Against the background of increased threats to the transport system, new approaches need to be developed to ensure its secure access, operation and use. Research should develop new, non-intrusive, identification means (e.g. face recognition or recognition of dubious behaviour) to be implemented not only on a mode specific basis (so far mainly in public transport), but also seamlessly across travel modes. Innovation will have to meet people's and firms' specific needs to maintain the effectiveness of travel, i.e. traveling or transporting with a minimum of additional disruptions for security checks.

3.3.3.2 *Effectiveness and efficiency of infrastructures vis-à-vis changes in demand.*

Infrastructure is built to meet an actual or expected demand at a certain moment in time. Given the spatial redistribution of population and economic activities in several parts in Europe, a reassessment of the value of infrastructure assets has to be carried out, defining further need of infrastructure in terms of up- or downgrading. Therefore research is needed to characterise infrastructure with respect to its ability to be upgraded and to serve future needs. This will allow for informed decisions on the re-use, adaptation or upgrading of infrastructure. In addition assessment must take into account new service requirements due to present or future changes in technology, and must provide adequate approaches to combine infrastructure maintenance with improvement. This should go hand in hand with the creation of new business models under low or uneven growth conditions, and as public funding of infrastructure is reaching its limits: these new business models would provide the funding and financing of low cost or remote maintenance and upgrading of infrastructure.

3.3.3.3 *Ex ante exploration of effectiveness and efficiency of policies and technologies.*

When innovation occurs it is often introduced and implemented without a clear vision of its potential impact, which makes the risk of the real impact poorly predictable, and possible rebound effects easily overlooked. To better forecast the desired degree of effectiveness and efficiency of policies and technologies, two analyses must be enhanced and improved; firstly the empirical evidence of human innovative technologies use and reaction to regulations, incentive and policies, and; secondly, the respective modelling toolbox for prospective assessment. One particular topic should be the impact of the combined digitalisation and automation on the current transport system and its reorganization. Research on this should start early in the process and explicitly investigate rebound effects that may emerge from the new technologies and services. Model-based forward looking activities are needed to anticipate the impact and use of technology and should address both short and long term impacts.

3.4 Economic and commercial competitiveness, business models and markets

Economic and commercial competitiveness are increasingly linked to the combination of product distribution and service provision. In this context digitalization, and its respective actors, are the essential game changers, offering more convenient and valuable services to both passenger and freight transport.

3.4.1 New business models based on the exploitation of Big Data

The importance of data, originating from the delivery and use of products and services, will increase considerably. Study is needed on how these data will allow for new business models, and how they can be used to optimise the overall transport system. The potential value propositions of Big Data are multiple and relevant for all modes in personal travel as well as freight.

3.4.2 (Big) Data security as a key to innovation

Big Data is expected to be one of the key innovation in the transport sector over the coming years. The use of the data, however, requires solutions that share data and make it available and accessible on the one hand, while also guaranteeing security and privacy of individuals or companies information. Both companies and the public sector will be dependent of these solutions which need to be found within a narrow time frame. This

is another area where intensive horizontal integration should be applied considering that cyber data security is also crucial for sectors like health or finance. At the same time, ethics of cyber data needs to be developed from a multisectoral perspective.

3.4.3 New markets for travel, including freight

New markets at the regional, national and international level may arise as a result of the redistribution of European population through internal migration. These migrations occur from remote to urban areas and internationally mostly from countries under pressure because of armed conflicts or deteriorated living conditions. Research is needed to better understand and serve these markets in appropriate ways. At the regional and national level, this should include co-modal solutions that allow for a high degree of sustainability. Important gaps concern the knowledge on how solutions that have been developed for an urban clientele, such as sharing transport assets, can meet the needs of "new arrivals". In the freight sector, innovation will be spurred in new markets in particular where low emission solutions are needed for densifying areas. Solutions could come through technology as well as through the re-organisation of distribution logistics and the use of alternative delivery modes. Knowledge and innovation gaps exist with respect to new "last mile" solutions, such as unattended delivery (e.g. reception boxes and locker blanks) and crowd-shipping.

3.5 Accounting for the human: demand, needs and behaviours; inclusion and access.

The "human element" within the transport system is represented by individuals who need travel for themselves (or for goods they are responsible for), and use transport to fulfil the needs and wishes they conceive in their daily lives. The other side of the coin are persons that are impacted by their co-citizens' travel and transport needs. Research and innovation that address demand, needs and behaviour therefore always should take into account action and impact. At the same time, research and innovation need to integrate the gender dimension, devote resources to questioning gender norms and stereotypes, carry out analysis of gender, sex and both, and address the evolving needs and social roles of women and men.

Besides the need to gain knowledge on the demand and behaviour of humans, addressing the human factor as such creates the condition to grasp the consequences of people and firms responding simultaneously as actors and users; people and firms interact with the transport system, but also with work places, with everyday consumption activities across a wide array of economic sectors and social services. These complex interactions ultimately shape the demand for transport.

3.5.1 Changes in everyday life conditions impacting travel needs and behaviour.

Major knowledge gaps concern changes of mobility behaviours coming from major demographic and socio economic changes. These include shift of population from rural to urban regions, increasing share of smaller households, or new distribution patterns in household income. Another field of external influence concerns new options coming along with ICT that allow remote shopping or tele-working. So far there is not enough knowledge on the huge and rapid impact of exploding online activities on travel demand, commuting patterns, freight traffic, freight fleets, land use, and new delivery business models.

3.5.2 "New" lifestyle groups creating new needs and markets.

There is much uncertainty about the behavioural impact of the large and relatively affluent cohorts of baby boomers with individualistic life styles, advancing beyond 65 years of age. The need for assisted transport, the possibility of exclusion, the new emerging mobility patterns and uneven rates of new technology adoption, cannot be derived from extrapolation of past experience. Empirical research is needed. The mobility behaviour of the younger connected generations is equally undefined and responds to complex and little studied situations of new expectations of transport combining just in time services and on-line access, more precarious job markets and high unemployment.

3.5.3 Transportation and health.

The interaction between transport and human health is manifold, and still major gaps exist concerning knowledge about this interaction. There is an urgent need to research the health effects of PM, also known as particle pollution, consisting of a complex mixture of coarse and fine air-borne droplets and particles including acids, ammonium, carbon, organic chemicals, metals, and soil. Research is also required on the effectiveness of control strategies. Importantly, the impact of noise has been identified recently as a large and significant knowledge gap. Finally, research is needed to better understand the positive health impact of soft modes and public transport that demand a measure of physical activity; more generally, the way transport systems can be designed as positive drivers for health remains unchartered.

3.5.4 Models of the human in the transport system.

In the future we will have a transport system that protects all road users equally well in the event of a crash. In order to get there, the safety of the system has to be designed and assessed with the entire population in mind. This is not currently the case. There are legislative safety tests applied all over EU that do not include women's ECE standards, and thus exclude half of the adult population from the protection tests for vehicle occupants. This also applies to the recently developed Human Body Models. Design norms need to be revisited. In the safety areas this applies to both crash test dummies and human body models.

3.5.5 Transport and climate.

More knowledge is needed on behaviours, incentives and rules required to avoid less environmentally friendly transport modes and behaviours, and to shift towards more climate friendly transport modes and behaviours. Study is needed on transport choice, and on the most effective incentives and rules that make people switch to better choices and climate friendly transport modes. The interaction of travel behaviour and health may be one important key to better address this issue. In parallel, gaps exist in the field of corporate travel about how to improve the environment and climate footprint; this should be done by a combination of more efficient mobility, revisited value added chain practices that reduce the demand for transport, and the use of more friendly transport modes and systems. In that process, the switch of freight transport towards lower carbon impact is a combination of new business models and new vehicles, where smart solutions for the "last mile" may yield large benefits.

4 Research integration

The integration issue is raised by two of the questions addressed to the Advisory Group:

- [Which transport R&I challenges] require an integrated approach across the societal challenges and leadership in enabling and industrial technologies?
- Which areas could benefit from integration of horizontal aspects such as social sciences and humanities, responsible research and innovation, gender aspects, and climate and sustainable development?

This chapter addresses these questions in two main sections:

- the first deals with the need/opportunity to collaborate (co-creation) with other (non transport) research communities in order to improve the quality and effectiveness of transport R&I, its outcome and its chances of successfully reaching the market; this includes both R&I in sectoral areas such as energy, environment, health, ICT and KETs in general, as well as the so-called "horizontal" aspects (SSH etc.), where the aim is to recognise the importance of socio-economic factors and the human in the transport R&I cycle, from its early stages (identification of priorities) to the design of transport research that incorporates the human dimension, and to the appropriate valorisation of results when they reach society.
- the second focuses on the synergies that should be sought across all or most H2020 areas to jointly and more effectively tackle common/cross cutting issues that are crucial to ensure the overall effectiveness of the R&I process and its governance.

4.1 Integration of transport research with other R&I areas

4.1.1 Collaboration with sector-specific R&I

Scientific and technological innovation in several non-transport areas will affect both the supply and the demand of transport systems and services, enhancing their performance (increasing effectiveness, ensuring better response to users' needs, increasing economic and environmental efficiency) and possibly influencing demand in both volume (through e.g. substitution) and patterns (switch to more affordable and environmental friendly modes). On the other hand, recognizing the potential market that the transport sector represents for a variety of non-transport innovative technologies will contribute to the competitiveness of other sectors, and to gaining and/or maintaining industrial leadership in strategic areas such as ICT, advanced manufacturing, energy technologies, and eco-industries in general. Research in these areas should incorporate the requirements of the transport community in the design of novel solutions.

4.1.1.1 ICT

Research in ICT and related technologies, as currently funded by the LEIT component of H2020, is the most obvious and prominent area where joint R&I will have a direct impact:

- 3D printing and virtual reality both have the potential of reducing the need for physically moving goods and people, which will in turn lead to rethinking and reshaping entire supply chains, and therefore the transport networks and logistic infrastructure that serve them.

- Augmented reality has the potential of changing the nature of the interaction between citizens and suppliers of goods and services. This may have positive consequences (shortening of trip length), although the change in the perceived pattern of supply may on the other hand structurally modify consumers' behaviour (rebound effect).
- Internet of things, big data and innovative data management in general will significantly contribute to an overall increase in the effectiveness and efficiency of transport systems and services, notably through the optimization of route choices and travel time, a reduction in resource consumption, the rationalisation of logistic infrastructure use. More generally, the so-called "Artificial Intelligence" (AI) has a considerable potential in many areas, notably for the smart maintenance of both vehicles and infrastructure. The development of targeted AI applications should be sought to address the specific requirements of both passengers and freight transport systems.
- As innovative data management tools develop, and the functioning of entire transport chains increasingly relies on automatic data exchange between vehicles and between vehicles and infrastructure, cybersecurity rapidly emerges as a major threat that can lead to disruptions of the transport systems and possibly the loss of lives (e.g. in air transport). Research is needed, notably in the field of Cyber-Physical Systems (CPS), to ensure the robustness and resilience of transport systems that are increasingly data-dependent and devise effective protection against cyber attacks specifically directed to the transport sector.

4.1.1.2 Nanotechnologies and advanced manufacturing

Nanotechnologies and new materials, additive manufacturing and in general innovative manufacturing technologies, processes and systems (LEIT) have the potential of significantly modifying the performance of transport system components (both vehicles and infrastructure) and of the corresponding manufacturing processes. This can generate economic and energy savings (lighter materials, leaner manufacturing processes) along with environmental as well as safety benefits.

4.1.1.3 Energy

Energy technologies (SC3 in H2020) are known to be crucial to the capability of the transport sector to reach higher sustainability levels, and extensive research collaboration has long developed. Within the decarbonisation strategy of the overall economy, transport – across modes - deserves priority attention, and its specific requirements must accordingly be high on the energy research agenda. The forceful push towards electromobility, and the corresponding, urgent need for high performance batteries and recharging infrastructure should be accompanied by an adequate transition strategy where 2nd and 3rd generation biofuels can play an important role. This is conditioned however by aligning the timing of the technological (and subsequently market) development with the expected dynamics of the transport industry, and with that of other sectors, such as agriculture (SC2), where competing end-uses of fuel crops take place, and such as new materials, where bio-based processes and products are likely to progressively replace traditional, mostly petroleum-based materials (e.g. bio-plastics). Another important area of joint R&I with the energy community regards the air transport sector, where fuel could become substantially renewable within the next decades. The production and distribution of these new fuels will have an impact on

transport and these changes are starting now, entailing a major reshaping of the current freight transport system designed for coal, gas and petroleum based fuels.

4.1.1.4 Biometrics

Biometrics (LEIT, SC7) is developing fast, with radically novel technological solutions to the sensitive issue of identification and recognition of individuals. In times of increasing overall vulnerability to terrorist and other threats, the specific security requirements of transport systems and infrastructure must trigger research that targets the development of tailored solutions meeting the needs and requirements of the transport community while reducing as much as possible the limitations to the freedom of movement and the negative impacts in terms of time costs, privacy and users' comfort.

4.1.2 The social and human dimension and its integration in Transport R&I

Transport is a "derived" activity, implying that demand (both in nature/structure and in volume) is directly affected by the dynamics of sectoral economies and of socio-economic trends in general. While the importance of integrating ("embedding" is the term often used) social sciences and humanities in thematic, technological research has been explicitly recognised, it is felt that the current setting falls short of ensuring true interdisciplinary co-creation.

4.1.2.1 Understanding and anticipating the dynamics of mobility drivers.

A major area of potential R&I collaboration with other H2020 parts relates to the interfaces between transport technology and systems, social acceptability and behavioural change. Drivers that directly affect mobility systems and services, calling for interdisciplinary research that focuses on the needs and aspirations of users, also affect a very wide range of other economic sectors, as they reflect structural changes in socio-economic paradigms, societal organization and governance models, along with the introduction of new technologies from other areas, with specific reference to Key Enabling Technologies (KET), which are inherently cross-sectoral. Accordingly, the in-depth analysis of these drivers and their multifaceted impacts should be carried out in close collaboration with other research areas, and notably with Social Sciences and Humanities (SC6 in H2020). Specifically, drivers of interest include:

- Ageing and demographics in general (including migration)
- New patterns of social organization and interaction (e.g. shrinking family size, LAT - Leaving Apart Together, etc.)
- Land use, urbanization and the redefinition of the concept of locality;
- E-commerce development and the digitalisation of society in general
- Health and environment awareness (SC1, SC2)) inducing changes in consumption patterns (physical activity, diets, but also obesity and other behaviour-induced conditions that can affect the supply of mobility services).

On the other hand, research is also needed on how and at what pace effectively trigger behavioural switches while ensuring that large users' groups – notably the elderly – are not alienated or excluded.

The contribution of the transport sector to tackling global challenges, with particular attention to Climate Change (SC5), needs to be more deeply investigated in a fully

interdisciplinary context, along with the impact of Climate Change (e.g. extreme weather events) on transport infrastructures, systems and services.

The much advocated transition towards circular economy will bear considerable effects on the transport sector. Research is needed to assess the specific impact on the lifecycle of both vehicles and infrastructure (reuse-and-recycle-driven design, end-of-life regulation), as well as on the redefinition of transport needs associated to changing production processes and materials.

Finally, it is important to note that while changes in behaviour and values are crucial for individual mobility choices, they are also highly relevant for business and logistic strategies, and can play a major role in reshaping the patterns (in time and space) of demand for goods. This calls for additional research to better understand and anticipate the impacts on freight and logistics of major trends such as the increasing awareness of environmental and resource scarcity constraints, the shift of preferences towards shorter food supply chains, and of course the development of e-commerce in general.

4.1.2.2 Gender

The integration of the gender dimension in R&I concerns all parts of H2020 and encompasses both the contents of research itself and the gender balance within research teams, with the underlying ultimate goal of achieving gender equality. The challenge of questioning gender norms and stereotypes cuts across all areas of research, and deserves targeted attention in view of the acquisition of better knowledge and understanding of the factors that hinder the transition towards a better gender balance, and of the identification of the specific role and needs of women as both agents and users of transport systems and services. Changing socio-economic paradigms, family structures and employment patterns should be analysed, among others, with the specific goal of removing the barriers along the pathway towards gender equality. As a first and fundamental step, statistical data on gender balance should be systematically collected and maintained at the finest possible level of granularity to facilitate the identification of critical aspects.

A case in point is the design of safety systems that take into account the whole population. This currently not the case: legal safety tests in force in the EU do not usually include women, while the average sized woman (i.e. about 50% of the adult population) is not represented in ECE regulations on the protection of vehicle occupants

4.1.2.3 Responsible Research and Innovation

Notably within the SwafS (Science with and for Society) component of H2020, increasing emphasis is put on the value of Responsible Research and Innovation (RRI) as a means to ensure better and earlier acceptance of novel solutions based on the adoption of new and innovative technologies and systems. RRI is thus expected to contribute to the attainment of a higher degree of satisfaction of citizens and therefore to faster and more successful market diffusion of new technologies. Key to the effectiveness of RRI is the capability of engaging society as early as possible in the R&I cycle, so as to actually replace the concept of acceptance (passive) with that of ownership (active) of innovation.

Mobility needs vary considerably across the population, with age, income, family size, place of residence, and are changing rapidly within each group in the light of new employment patterns, of the dematerialization of the economy and, more generally, of the dynamics of individual and collective preferences. Responding to these changes

requires not only a better understanding of their nature but also a more effective capability of anticipating their ramifications, and therefore an earlier engagement of citizens in the design process. The reference to the TRL concept can serve as an immediate means of representation of this challenge: by and large, participatory processes aimed at securing citizens' acceptance of new technologies and products currently start around TRL 6/7, while a societal engagement towards true co-creation mandates their anticipation to lower TRL levels (2/3).

4.1.2.4 Forward looking knowledge and tools

There is an increasing recognition of the potential contribution of foresight, and of forward looking exercises in general, towards the design and implementation of sustainability and other policies, across sectors. Foresight exercises are also acknowledged as a powerful means to alert regulators to future transport governance issues. With respect to previous Framework Programmes, H2020 has innovated in this regard through the inclusion of foresight topics in most thematic work programmes. On the other hand, foresight is an intrinsically transdisciplinary activity, which must inevitably rely on cross cutting research efforts and the sharing of a wide range of knowledge and tools, including new modelling platforms relying on the wealth of novel evidence that can be expected from the diffusion of Big Data, the Internet of things and in general the involvement of citizens in their capacity of data and information producers and providers. In fact, a new philosophy in the transport modelling process emerges, based on big-data collection and analysis, on-line micro-modelling, and large scale simulations. In other words, the traditional 4-stage modelling process needs to be reviewed with respect to the opportunities offered by the new technologies. With the next phase of H2020 approaching, it would be appropriate to review the legacy of recent methodological innovation and clarify the gains and avenues for progress in the next step.

There is a critical need to document the socio economic mega trends, understand them and build the knowledge to address its issues and respond to its needs with appropriate policies and incentives. Empirical evidence, elasticity measures, travel surveys, reliability measures, comfort indicators, updated real value of time, social and environmental externalities and their monetary valuation, along with the anticipation of the future dynamics of individual and corporate preferences, all these inputs to updated modelling are mostly missing or obsolete. The efficient sharing of knowledge, updating of the repository of data and promotion of its use in policy making, also constitutes a research governance agenda, which should allow to address issues such as the assessment of the effects of political inaction on the dynamics of external costs.

4.2 Cross-cutting issues and common (R&I governance) challenges

Beyond the identification of priority themes, there are several challenges related to the effectiveness and efficiency of the research process that are common to all or most thematic R&I areas, and where joint efforts to devise and experiment with new and/or improved instruments would be beneficial to the entire EU R&I community, to industry and society at large. They mostly have to do with the governance of R&I, its overarching principles and its operational instruments. Accordingly, a novel setting should be devised to ensure a dedicated venue for synergic efforts.

4.2.1 Innovative financial instruments

Exacerbated by the recent economic crisis, the scarcity of financial resources is weighing heavily on the development of infrastructure networks, not least in the transport sector. This also contributes to undermine the transition towards more sustainable modes, as for instance the capital costs of rail infrastructure are higher than for road. Innovative finance is therefore needed to ensure the level of investment required to meet the strategic goals of completing the EU transport network while promoting transport modes that are both more sustainable and safer. Similar challenges are faced by other sectors (energy, urban development, public health, water supply) that are historically depending on the availability of public funds. While each sector needs to devise new financing mechanisms that meet their specific requirements and constraints, potential exists for combined financing of sectors as well as for a higher level search for new and innovative means to e.g. leverage private capital could help creating a new financing culture that recognises the collective interest of a better targeted and more transparent finance, guaranteeing fair and proportionate returns to all concerned.

4.2.2 Public procurement

While the potential contribution of public procurement to the sustainability of the transport sector has been explored, including in dedicated European R&I projects that primarily focused on urban public transport fleets, its targeted effects on the acceleration of market uptake of new products, and on economies of scale, remain largely unseen to date. Hindering factors have been identified in the difficult balance between competition and cooperation among suppliers, and in the often found inability of public administrations to streamline the procurement process so as to ensure its ultimate effectiveness and efficiency. The experience accumulated with long term concessions is large yet the complexities of long term concessions for design, build and operate continues to grow, with the challenge of distributing the burden of the risks, responsibilities, data governance, safety and security between the mandating public sector and the private or mixed operator. Here again, the challenges, both methodological and practical, are common to many sectors, and synergies towards the design and experimentation of novel approaches would be beneficial. Particularly in the urban environment, innovative approaches are required to make the most of, and facilitate, the transition towards electromobility and automated vehicles, and the new mobility concepts (vehicle sharing replacing ownership, door-to-door services replacing a fragmented supply) these entail.

4.2.3 Risk analysis and research prioritisation

It is widely recognised that theories and methods currently available for risk assessment fall short of providing the appropriate policy and decision making support required by the increasing, and increasingly recognised complexity of transport systems, all the more so in times of radical changes of socio-economic paradigms, when risks (and benefits) need to be shared not only within the traditional community of investors, but also with citizens and society at large. Ways and means to incorporate non-financial factors such as accessibility, comfort, safety and security of transport services in the assessment of risks must be further explored, in collaboration with other sectors of the economy that face similar challenges. Specific emphasis should be placed on new issues arising from the deployment of innovative technologies to secure transport systems against terrorism threats. New knowledge is particularly needed on how to assess trade-offs between social benefits (increased security) and social costs (reduced

privacy, increased friction along the transport chain) of novel technology-based solutions and, more generally, to promote the systematic adoption of a fully-fledged Social Cost Benefit Analysis (SCBA) framework.

4.2.4 Integration of the innovation chain

This is yet another strategic concern that affects all sectors of the economy that rely on the effectiveness and efficiency of the innovation process. The journey from an R&D output ("proven science") to full commercialization ("product in the market") is extremely long, risky, and expensive. It can easily cost tens of millions of euros and take as long as ten years from the launch of a company commercializing a specific technology to the moment when the company has a finished product from which it starts generating meaningful revenues. Much of the publicly supported R&D in the EU never gets properly commercialized due to major gaps in the innovation chain, particularly when it comes to the financing of early stage companies commercializing new technologies. Overcoming this "valley of death" requires a much better adaptation of R&D grant instruments to the needs of early stage companies, in order to enlarge significantly the pool of financing that is available to them. In addition, more needs to be done to foster additional complementary instruments managed by EU agencies such as the European Investment Bank (EIB).

4.2.5 International cooperation

Notably through the International Cooperation (INCO) programme, the EC has established the framework for R&I cooperation with international partner countries at both the regional and national level. Accordingly, joint R&I priorities have been identified in many areas including transport, and targeted transport themes (e.g. biofuels with South America) have been activated. Accruing benefits at the EU level through international R&I cooperation however requires a stronger engagement on behalf of all concerned parties: the European dimension (in terms of both inputs and outputs) of international cooperation programmes and projects is not sufficiently visible, as individual Member States, as well as industry, often opt for bilateral approaches that do not allow to achieve the critical mass that is a prerequisite to successfully operate on global markets. The European leadership in areas such as transport automation, safety, energy efficiency and greening in general can only be maintained and enhanced if the governance of international cooperation in R&I recognizes the need for novel instruments (incentives, standards, multilateral policy dialogue) to promote a truly integrated European strategy.

Moreover, EU knowledge in transport technology, combined with its recognized leadership in sustainable mobility policies and practice, should be better and more systematically exploited to foster education programmes directed to the next generation of transport leaders in other regions of the world.

5 Research priorities

The main priority areas for Transport R&I that emerge from the TAG deliberations are summarized in the table below. Each finds its rationale and justification in one or more of the sections of this report. These are flagged in the last column of the table for quick reference.

	R&I priority areas Research Priorities **not in order of importance**	Mobility and access for all	Sustainable mobility	Competitivity . Leadership	Main references to report sections
1	Understanding and anticipating the dynamics of mobility drivers, accounting for the human	***	*	*	2.2; 3.5
2	Updating and enhancing the knowledge toolbox	***	***	***	2.5.1
3	Mainstreaming transport and mobility foresight	***	**	***	4.1.2.4; 5.3
4	Accelerating decarbonization with energy efficiency in all transport modes	*	***	***	2.3.2 to 2.3.4; 3.2.3
5	Supporting the shift of transport offer and mobility choices towards environment friendly transport	*	***	*	1.1; 1.2; 2.1; 2.3; 3.2.1; 3.3; 3.5.5; 4
6	Establishing health as a driver for transport, with pollution-free, less noisy transport solutions	***	***	***	2.2.6; 2.3; 3.3.1; 3.4.2; 3.5; 3.5; 4; 4.12; 4.2.1
7	Restoring maintenance as an efficient & effective management of assets in support of mobility for all, smart decarbonization, smart greening and EU leadership	**	**	***	1.2; 2.4.1; 3.2.1.3; 3.3.1; 3.3.3
8	Enhancing door to door safety for all	***	*	**	2.2.4; 2.2.5; 2.5; 3.2.1; 3.2.2; 3.5.4; 4.1.2; 4.2
9	Driving the automation and digitalization for safer and more efficient transport	***	*	***	2.2.5; 2.4.3; 3.2.1
10	Establishing the framework conditions for new business models to succeed	*	*	***	2.2.6; 2.3; 2.4.2; 2.4.6; 3.1 to 3.5
11	Developing a flexible Governance framework, including the legal and regulatory dimension, to promote ethical transport, safe mobility for all, decarbonization, innovation and competitiveness	***	*	*	2.4.4; 2.5.2; 4.2
12	Allowing the contribution of Key Enabling Technologies to drive new transport solutions	***	***	***	4.1.2
13	Advancing electromobility, including energy harvesting and storage for clean and competitive Transport	*	***	***	3.2.3; 4.1.1.3; 4.2.2
14	Proofing the transport system for Resilience and Security	***	*	***	2.2.3; 2.3.7; 2.4.2; 3.3.2
15	Establishing Big Data as a secure platform for the new Transport business model	**	***	***	2.4.1; 2.4.3; 2.5.2; 3.4; 4.1
16	Easing transition by mainstreaming ex-ante impact assessment of policies and technologies, their effectiveness and efficiency and their potential rebound / unexpected effects	***	**	**	2.2.5; 2.3; 2.4.6; 2.5.2; 3.2.1; 4.1.1; 4.1.2; 4.2.1; 4.2.2

Before detailing the research priorities, it should however be noted that, with the next phase of H2020 approaching, it would be appropriate to review the adequacy of current methodological approaches and analytical techniques to address the broad range of research challenges identified in this report.

5.1 Understanding and anticipating the dynamics of mobility drivers, accounting for the human.

Users' aspirations and needs, and therefore their preferences, evolve as the combined result of (i) technological advancements, and (ii) changing socio-economic paradigms, including the increasing awareness of the need to engage in the transition towards sustainability. The interaction between these two (families of) drivers are complex, with multiple feedbacks: the availability of new technologies and solutions can drive behavioural changes, while at the same time evolving societal models and aspirations stimulate the identification of new solutions and of the development of technologies to enable them.

Research is needed to better understand these interactions in order to (i) identify and promote technological and organizational solutions that are the most acceptable and, at the same time, (ii) devise policies and instruments to nudge end users towards the most effective and sustainable mobility solutions.

Research in this area should be highly participatory and should devote equal and combined attention to the mobility of people and goods, thus focusing on the evolving choice mechanisms of both individuals and firms.

5.2 Updating and enhancing the knowledge toolbox

Devising the most effective transport policies relies strongly on the capability to evaluate ex ante, monitor and assess the impact (economic, environmental) of new mobility solutions (resulting from technological and/or organizational innovation). This in turn requires a robust and comprehensive set of information and of tools to simulate, assess and predict.

Research is needed in this area for several reasons:

(i) the traditional toolbox (databases, models) is now largely obsolete, as essential inputs such as e.g. values of time, elasticity measures, monetary values of social and environmental externalities have not been regularly updated and their reliability suffers from the rapid dynamics of both the transport system performance and of users' preferences

(ii) new variables play an increasingly important role, such as comfort, security, and in general indicators that measure the perceived acceptance of users. These are not adequately studied and documented

(iii) innovative techniques are becoming available that will radically improve the availability of data and information on which simulations and predictions are carried out. Big data and the internet of things, notably, have the potential of providing an abundance of micro-data that can feed directly into both medium/long term decision making and into near-to-real time assessments.

5.3 Multisector-based transport foresight for new transport technologies and solutions across markets

The complexity of transport systems calls for a concerted, inter-sectoral and intermodal policy approach. Foresight offers such a holistic, interdisciplinary approach: while technological advancements that are already on the cards will indeed play a major role in the transition towards more sustainable transport systems, there is the need to develop more normative, long term visions, from which radically new solutions can emerge, and back cast into short term R&I and policy decisions.

Research is needed to develop the transport and mobility dimension of forward looking exercises, currently represented at a level of aggregation that does not allow to effectively feed into transport policies and strategies.

5.4 Accelerating decarbonization with energy efficiency in all transport modes

Electromobility (see below priority 13) will provide a major contribution to decarbonisation. In general, research is needed to accelerate decarbonization through more energy efficient vehicles (all modes) and the adaptation of construction and maintenance standards of infrastructure and services.

Research is also needed to address current knowledge gaps in several enabling areas: (i) regulation and measure of the environmental impact of vehicles, of transport modes and systems, from the local clean air perspective and from the global climate change perspective; (ii) more broadly how transport system choices lead to different climate footprint; (iii) documenting the monitoring and reporting of performance targets, norms; (iv) the interconnection with other relevant fields such as land use, urban and regional planning, climate science and ecology, business models and value chains, technology and innovations, and health.

5.5 Supporting the shift of transport offer and mobility choices towards environment friendly transport

Decarbonization and efficiency will provide a fundamental contribution to Climate Change mitigation, and research is needed to address the current knowledge gap concerning the costs and benefits of mitigation on local economies. This requires a system approach that notably includes the evaluation of land use and business models that affect transport demand, and synergies with other sectors.

Beyond just decarbonization, research is needed on the adaptation of construction and maintenance technologies and standards of infrastructure and services, and on how to achieve extreme weather proofing for aircrafts, ships and vessels in response to climate induced changes in temperature and in the nature and intensity of adverse meteorological conditions. In the freight sector, short term benefits should be sought through the innovation in the business models, including for production and distribution.

5.6 Establishing health as a driver for transport, with pollution-free, less noisy transport solutions

Health should be established as a driver for transport. Research in this area is needed to: (i) reduce the impact of air pollutants and noise emissions on physical or mental

health, against the background of medical science that assesses these impacts, and (ii) help to better understand and assess the (positive) health impact of soft modes use and public transport that encourages people's physical movement.

Research in this area should aim at turning what is currently a weakness (transport as a major contributor to environmental degradation and health risks), into an opportunity to assert transport as a leader for improved health, with potential economic returns at the global level.

5.7 Restoring maintenance as an efficient & effective management of assets in support of mobility for all, smart decarbonization, smart greening and EU leadership

Starting from a vision of "(near) zero maintenance infrastructure" research should go into fields that use new technologies to keep up efficient and effective maintenance of both built infrastructure and assets. This applies in particular to predictive maintenance and self-maintaining or -repairing systems which will not only make maintenance more efficient, but will also largely contribute to increase life times of infrastructure and assets of road, rail, maritime and air. There should be a strong link to research on networks for pervasive intelligence addressing the ownership and responsibility for data quality.

5.8 Enhancing door to door safety for all

Many technological and behavioural transitions are occurring simultaneously, calling for novel research. There are no complete safety standards of electro-mobility and no procedure for the safe introduction of automated vehicles, platooning and full automation of trucks, and drones. The safety of vulnerable users facing new risks needs updating, and gender is an important dimension of this transition. Safety with an aging population also continues to require research, with such knowledge gaps as driving and mental issues, or in mixed and evolving traffic. The ergonomics of dummy for safety trials urgently needs to be improved: testing with dummies representative equally of women and men, as well as of elder people must be introduced. The rapid diffusion of drones requires research on the opportunities and challenges created in all areas of safety, including maritime navigation and of aerial traffic safety. Regulation and safety for drones will also open a promising area of improved efficiency and socio economic benefits.

Huge safety improvements are expected from Driver Assistance Systems and automated vehicles. Benefits include reaching the 2020 safety goals and advancing towards the zero vision. More flexible legislation, regulations and enforcement will help to prolong the safe driving of older drivers, deriving considerable social and financial benefits. Addressing the needs of older people will also result in a better transport system for all users.

5.9 Driving the automation and digitalization for safer and more efficient transport

Automation and digitalization entering the overall transport system will create a transition phase that is not understood so far. This is true for both the passenger and the freight sector. Research should combine technical, societal and business/organizational

fields to understand requirements, needs and demands, acceptance and resistance and find the adequate and appropriate solutions that provide mobility for all, help reduce environmental effects and support EU leadership while offering system oriented solutions. Research should include testing and demonstration.

5.10 Establishing the framework conditions for new business models to succeed

As the combined effect of technological innovation (electromobility, automation, big data) and of socio-economic and cultural paradigm shifts, new actors and new business models are emerging, calling for renewed and dedicated attention to the corporate perspective and dimension in transport research, in order to sustain the transport industry capacity in EU and its competitive positioning in the global markets.

Research in new mobility concepts that integrate products and services should take up the corporate perspective to bring up new innovative business models. This also includes framework conditions to implement new business models, where specific focus is needed on data issues – quality availability, privacy.

Public research funding in this area should be used to leverage industry R&I efforts and facilitate industrial cooperation between firms and across Member States.

5.11 Developing a flexible Governance framework, including the legal and regulatory dimension, to promote ethical transport, safe mobility for all, decarbonization, innovation and competitiveness

The knowledge gap at sector level, deals with regulation supportive of innovation, and the updating of the ethics, privacy, safety, security, and social premises on which transport decisions are taken. At the project level, the technological transitions towards mixed traffics and automation also require a governance brush up for testing, market regulation and enabling new business models. Data and big data access, sharing and use related to the mobility, identity, activity, security or safety of travellers and freight require novel governance in particular on how to address situations of de facto monopolies, and ex post regulations. The development of drones, also requires urgent governance. Finally, public procurement of new products with economies of scale, needs addressing to balance competition and cooperation among suppliers, and help public administration procure with effectiveness and efficiency.

Research is also needed to address the issues of distribution of risks, responsibilities, data governance, and safety associated with long term concessions for design, build and operate. The challenges are common to many sectors and should be addressed accordingly.

Benefits would include smoother and safer technological transition, with less negative socio economic impact, faster adoption of new technologies by the public, and more new and vibrant business opportunities. Quasi monopoles would be prevented to capture abusive revenues. A clearer vision may also emerge and build a consensus on where the EU may be on matters of governance and privacy in the long run.

5.12 Allowing the contribution of Key Enabling Technologies to drive new transport solutions

Scientific and technological innovation in several non-transport areas, with specific reference to Key Enabling Technologies (KET), which are inherently cross-sectoral, is increasingly recognized as a major potential contributor to both reshaping the demand of transport systems and services (through e.g. substitution effects and modal shifts) and to enhancing the supply side performance (increasing effectiveness, ensuring better response to users' needs, increasing economic and environmental efficiency).

While research on KETs follows its own, multi-purpose and mostly technology-driven agenda, there is a need to explicitly incorporate the specific requirements of the transport community in the design of novel transport solutions.

5.13 Advancing electromobility, including energy harvesting and storage for clean and competitive Transport

Research and innovation is needed in electromobility for (i) the charging infrastructure (private, semi-public and public), including technologies to charge while running, and (ii) improvement in battery performance, i.e. batteries' capability to store electricity, (iii) energy harvesting technologies for road vehicles, (iv) energy storage and ubiquitous energy provisioning, and (v) advancing improved and alternative combustion (biofuels, electromobility).

Electromobility research will also advance the deployment of small electric vehicles in urban setting, with large health, technologic and economic potential benefits.

In addition to addressing the knowledge gaps, research is needed on how make the most of, and facilitate, the transition towards electromobility and automated vehicles, and the new mobility concepts, in cities including pedestrians and two wheelers. Learning from other sectors, such as manufacturing, and across transport modes is needed.

5.14 Proofing the transport system for Resilience and Security

Research is needed across the board on all aspects of resilience to achieve better ability to withstand disruption, recover and re-bound It needs to cover all systems, all locations, all times. Withstanding extreme events, and the ability to recover require equal attention. There, flexibility is key and demands coordination across the transport network, across transport modes, and horizontally with local governments, communities and business.

With regards to security, non-intrusive security checking that preserve efficient traffic flows, including user profiling and face screening technologies need to be advanced and adapted to all modes, abnormal behaviour recognition needs to be developed and applied. Although all modes and vehicle types need to be covered for security, drone security is an area where the knowledge gap is particularly significant.

Researching transport related cyber security is urgent and critical as it affects all dimensions of transport security for passengers and goods in the EU.

Urgent innovation should come from automated detection systems that will also be of great utility in the area of traffic management. In addition to enhancing security resilience and security research will foster new technology developments that will contribute to gaining/maintaining the EU competitive position for technology exports.

5.15 Establishing Big Data as a secure platform for the new Transport business model

Big Data is expected to be one of the key innovation area in transportation in the coming years, and research will help bring to bear the enormous benefits of efficiency, while mitigating the security and privacy risks. The potential value propositions of Big Data are multiple and relevant for all modes in personal travel as well as freight.

The first area of knowledge to be built deals with the governance, use and misuse of Big Data, guaranteeing information security and privacy of users and providers. Principles of governance and technical solutions need to be found within a narrow time frame. Research is needed on how Big Data can be used to optimise transport systems, and how it will allow the development of new business models.

5.16 Easing transition by mainstreaming ex-ante impact assessment of policies and technologies, their effectiveness and efficiency and their potential rebound / unexpected effects

Research is needed to forecast if and how the desired degree of effectiveness and efficiency of policies and technologies can be achieved addressing in particular the effects of automation and digitalization applied to improve accessibility to all modes of transport. It will be important to take into consideration rebound effects or unexpected effects that may emerge with the implementation of new technologies and services. Model based, improved forward looking activities and tools are needed to allow anticipating the uptake and the impact of novel technologies. They should (i) cover both long and short term impact, and (ii) be applicable to urban, suburban and rural areas.
