EUROPEAN
COMMISSION

Brussels, 31.5.2017
SWD(2017) 223 final

COMMISSION STAFF WORKING DOCUMENT

Towards clean, competitive and connected mobility: the contribution of Transport Research and Innovation to the Mobility package

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1. The contribution of transport R&I to the Mobility package: setting the scene

Policy background

Recent years have seen a profound economic and societal transformation pushed by the energy transition and the 4th industrial revolution, with new technologies and business models bringing disruptive change to the transport sector that allows for completely new mobility services and logistics solutions.

Europe needs a better framework for joint action on transport research and innovation if it wants to fully exploit the opportunities this radical transformation brings. Systemic solutions and the development of vehicles/vessels technology need to be better synchronised across modal silos to deliver more resource-efficient multimodal solutios for door-to-door mobility and logistics solutions increasingly based on clean energy, enabled by digitalisation and harnessing the potential of social innovation.

This Staff Working Document is being presented as part of the 2017 package for clean, competitive and connected mobility. It delivers on the European Commission's Strategy for low emission mobility adopted in July 2016 under the Energy Union3, thus complementing the "Accelerating Clean Energy Innovation" Communication and the Strategic Energy Technology Plan5.

To address the urgency, the magnitude and complexity of the transformation that the transport system is undergoing, the present document addresses current and future challenges in an integrated manner through 7 innovation roadmaps. These roadmaps reflect the 'state of the art' of technologies, identify focus areas for research and innovation and actions to enable and deliver a systemic transformation of the transport system in the short-term (2018-2020) and in the medium- to long term (towards 2030 and up to 2050).

The document also outlines a process for the implementation of the roadmaps that shall ensure the link with policy making and programming of research and innovation funding.

Innovative technologies and mobility solutions are needed…

The mobility system is facing multiple challenges. In road transport alone, 25,500 people lost their lives to accidents in 2016 and 135,000 people were seriously injured6. Transport remains largely dependent on oil which means that under current trends CO2 emissions from transport would only decline by 11.4% between 2005 and 20507, making transport the largest contributor of CO2 emissions in the EU after 2030. Air pollution caused by transport already today presents a major health problem in European cities8. Transport is also generating significant noise, affecting sleep, causing annoyance and cardiovascular diseases, with at least 10 000 premature deaths in Europe every year. Already today, the economic cost of congestion is estimated at 1 per cent of EU Gross Domestic Product (EUR 100 billion). At the same time freight and passenger traffic are expected to grow significantly.

That means that research and innovation in transport can, and must make a real difference to the daily lives of Europe's citizens.

But these challenges also present a major opportunity that the EU industry must seize. European manufacturers of transport equipment and companies developing mobility solutions are among the leaders globally. Together with the service industry, they represent one of the most important employers in the EU and employ directly around 14 million people in 2014, representing 7.2 % of the EU Gross Value Added10.

With Europe's transport system relying already to a significant extent on transport modes other than road (rail, waterborne, aviation, active mobility), the European industry has the chance to lead the transition towards the user-centric, integrated and truly multimodal transport system of the future.

… in priority areas

Throughout 2016, the European Commission consulted widely with a wide range of transport experts and stakeholders on a forward looking and focussed agenda for research and innovation in transport. The consultation led to the identification of 7 priority areas that cut across the different modes of transport. It also underlined the need to focus on the needs of users instead of existing capacity and to ensure an unprecedented and coordinated mobilisation of all transport sector players, public and private, including policy makers and the civil society

The seven priority areas are:

1. Cooperative, connected and automated transport

There is consensus that cooperative, connected and automated transport can make transport more efficient, safer, inclusive and sustainable. Focus areas for research and innovation are: the co-existence of automated and non-automated systems, user needs, social acceptance, socio-economic impact of digital technologies, their influence on behaviour, including effects on CO2 emissions and resource efficiency, human-machine interaction, new types of vehicles and issues related to the data economy.

2. Electrification

Electrification of transport, not only in road but also in other modes and as a systemic solution to decarbonise transport and energy systems, can reduce Europe's oil dependency and contribute to decreasing CO2, air pollution and noise from transport. Advanced power-train technologies and new vehicles architectures, including weight reduction, improved aerodynamics and rolling resistance and the development of components for electric vehicles are in the focus. The roadmap also addresses interfaces between vehicles and recharging infrastructure and cross-cutting issues such as new materials, advanced production systems and information and communication technologies, especially in relation to advanced energy storage systems.

3. Vehicle design and manufacturing

The shift towards cleaner energy sources, connectivity and automation depends on the capacity to design and manufacture vehicles and vessels integrating these new technologies without compromising safety, comfort and affordability and minimising lifecycle impact on the environment and on energy use. Focus areas of this roadmap are shortened cycles for vehicle design, development and manufacturing, new vehicle concepts, business models and modular vehicle architecture, as well as processes for reducing the environmental impact of manufacturing and recycling and remanufacturing.

4. Low emission alternative energies for transport

Parts of aviation, waterborne and road transport may have to rely on combustion engines for the foreseeable future. This roadmap takes stock and outlines possible options for research and innovation to enable a wide-spread use of synthetic fuels, hydrogen (including fuel cells) and advanced biofuels as well as fuel blends and engine optimisation. New high efficient, low polluting combustion engines in combination with electrification and applications combining electrical, fuel cell and renewable fuels are addressed as well.

5. Network and traffic management

Digitalisation will allow for better management of traffic streams and to optimise the transport network across current modal restrictions. Focus areas are actions to help developing and testing a future transport network that enables optimal traffic mix and circumvents temporary capacity limitations. This includes improving the interfaces between systems used in specific modes and

ensuring interoperability, to make best use of existing infrastructure and accommodate changing demand and supply situations in real-time, without additional burden for users.

6. Smart mobility and services

Innovation has a strong impact on transport demand, making transport more efficient and sustainable, in particular in cities, by fostering multi-modal transport solutions and avoiding unnecessary transportation. Smart mobility services also serve the social inclusion of those who are currently limited in their mobility. Focus areas identified by the roadmaps are urban mobility, demand and land use management, moving passengers to more sustainable modes of transports, smart mobility services in passenger transport , including 'mobility as a service', as well as in freight and logistics.

7. Infrastructure

Innovative infrastructure design and operation can drastically improve the efficiency, safety and security of the transport system and reduce greenhouse gas emissions from transport operations over the entire lifecycle of the infrastructure. Focus areas of this roadmap are governance, the charging, interoperability, lifecycle optimisation and efficient operation of infrastructure.

The actions identified in the 7 priority areas are interlinked and support each other. For example, technology for cooperative, connected and automated vehicles (roadmap 1) will serve societal needs only if well integrated in concepts for sustainable smart urban mobility (roadmap 6). The safe operation of these vehicles very much depends on the right infrastructure being available (roadmap 7). Electric vehicles for different uses (private, freights, public transport, roadmap 2) can ensure sustainable mobility and a lower energy bill for Europe (roadmap 4), but this depends on improved vehicle design and manufacturing (roadmap 3) and a suitable infrastructure (roadmap 7), and is being leveraged by a better network and traffic management (roadmap 5).

Governance

More coordination of transport research and innovation efforts at national and European levels is needed to create synergies and steer joint implementation of research and innovation priorities. To this end, representatives of Member States and relevant transport stakeholders (transport related European Technology Platforms, industry, academia and civil society) will be consulted on a regular basis on the innovation roadmaps presented in this document.

This process will, *inter alia*, address the need to:

- Ensure a regular dialogue on innovative solutions for sustainable transport and mobility and discuss joint initiatives,
- Allow for synergies, economies of scale and technology transfer through an integrated, cross-modal approach,
- Focus financial support to research and innovation, linking EU funding closer to the long term objectives of EU transport policy and those of other policies, notably energy, climate and industrial policy.

A new information and monitoring tool - the Transport Research and Innovation Monitoring and Information System (TRIMIS) - will be set up to follow up transport research and innovation actions and provide feedback to policy and decision makers, including interfaces with the energy sector's corresponding tool (SETIS).

II. Transport research and innovation roadmaps (only roadmap 6 shown here)

6. Smart mobility and services

Significant changes can be observed in user behaviour and lifestyle in relation to transport that will affect the decarbonisation impacts of new service models in the transport sector. Younger generations are currently opting for reduced motorisation rates and modal shift away from daily use of the automobile and towards multi-modal shared, public and active travel modes. Overall, transport users are embracing digitalisation and the use of smart phones, mobile web applications and social media. These behavioural shifts are supporting new shared mobility and transport business models, services and markets, which collectively open new pathways to sustainable mobility. If such behavioural trends persist, they can provide a principal support factor for decarbonisation, provided that use innovations are building on decarbonised mobility systems, potential rebound effects are mitigated and expected higher mileage and faster turnover (shorter lifetime) of shared vehicles are addressed.

6.1. State of the technology development

Digitalisation is currently reshaping the sector. ICT-enabled web, mobile and big data applications are spawning new mobility and transport services and systems. Traditional automotive, public and private transport models are being challenged as new players are emerging with disruptive service offerings; many of the new models are blurring traditional demarcations between public transport and private mobility, including in the area of urban logistics. Mobility-as-a-Service (MaaS) will increasingly catalyse the public-private co-development and co-delivery of mobility and transport systems and services, as well as shared and open use of public space, data and infrastructure.

The potential for decarbonisation depends on a better utilisation of underused assets in transport fleets and infrastructures to accommodate passengers demand and reduce the share of unsustainable travel modes. Smart mobility systems can help to accommodate this potential and also address persistent problems of congestion and accessibility.

There is a critical link between new technologies and services and transport decarbonisation.

The potential carbon mitigation performance of emerging new technologies and services such as multi-modal, electric, autonomous, low-altitude aerial, vertical and on-demand mobility has not yet been extensively evaluated, in particular in their integrated application. They can strongly support a shift to transport decarbonisation, or further lock in unsustainable travel behaviour. A key task will be to establish empirical validation of the sectoral and systemic decarbonisation impacts of such technology, systems and services innovation, and ensure that technologies and service innovations are not taken forward for their own sake, but in view of achieving a transition to a low-carbon, efficient and accessible transport system.

6.2. Focus areas for action

- *Smart and sustainable cities*

Future transport and mobility services cannot be envisaged as stand-alone sectoral solutions. Given significant urbanisation in Europe, these will need to be embedded in wider smart and sustainable city strategies aimed at increasing urban resource efficiency and decarbonisation. Smart mobility services will need to interface with multi-sectoral and city-wide strategies for optimising the use of energy, spatial, economic and material resources. Cities should not been seen as stand-alone systems but as embedded in larger regional and European and global mobility systems. Sustainable and efficient linkages between future urban and extra-urban transport networks, including rail and air travel systems, will need to be developed. Shared electric vehicles within and across corporate and public fleets increase availability and attractiveness to the public.

- *Demand and land use management*

If individual mobility services can be integrated (in first/last mile and supplementary function) with public transport systems, the overall efficiency of urban mobility systems can be greatly enhanced and thus contribute to avoidance of unsustainable modes and efficient demand management.

With regard to urban logistics and delivery services, smart mobility services enable avoidance of unnecessary vehicle movements in urban areas by making last mile deliveries more efficient by consolidating goods flows and moving towards smaller and lighter freight vehicles (such as electric cargo bikes). A key challenge will be to develop shared data, infrastructure and logistics business models for urban goods distribution that deliver a more efficient utilisation of public transport infrastructure across both passenger and goods transport modes.

The contribution of mobility service innovations to sustainable demand and land use management is thus dependent on their embedding in an overall mobility and transport strategy for the whole city. New economic and technological trends influence land use patterns and people's lifestyles. Digitalisation, on-demand mobility, flexible and cleaner production can increase the chances of higher density development and a more balanced mix of land uses (residential, commercial, production, schools, parks), potentially reducing demand for unsustainable travel modes. Identifying and validating the positive contribution that new mobility services and systems can make to sustainable, transit-oriented urban development should be of central concern to European innovation efforts.

- *Modal shift*

A reduction of personal-use and single-occupancy vehicles requires adequate options for public transport, other shared transport, as well as cycling and walking. Across a number of European cities daily travel modes have shifted away from the automobile towards public transport or active travel (London, -12%, Berlin -8% from 1998-2013, Brussels -18% from 1999-2010).

New technologies, big data and real-time information on demand and supply will make these tools more efficient in promoting modal shift. The measures include financial measures (dynamic pricing of road-use and parking), mobility budgets, business models for mobility-as-a-service, incentivizing sustainable modes over individual car use, regulatory interventions to restrict access to sensitive areas and parking, integrated intermodal terminals and park and ride services, integrated ticketing and real-time information covering all modes.

While it is currently not realistic to expect that all car travel can be shifted to other modes, it is desirable that car travel shifts to more sustainable practices by promoting carpooling and ridesharing services together with the transition towards electric mobility and modal shift towards public transport and active modes (cycling, walking). Car-sharing and short term rental in principle do not reduce passenger/vehicle kilometre ratios and as such do not constitute modal shift, but they have the potential to decrease the overall amount of vehicles required.

- *Smart mobility services in public and private passenger transport*

Smart public transport services and systems can provide the backbone for future integrated smart mobility. Allowing multiple infrastructures to integrate and communicate with one-another, can pave the way for 'one stop shop' platforms that consolidate multiple forms of transport and provide 'mobility as a service'. Car-sharing schemes (both point-to-point and station-based networks) continue to grow in number throughout Europe, with automotive manufacturers and traditional rental-car companies currently dominating the market. A convergence of sharing providers and mobility services models is to be expected. Technological, socio-demographic and behavioural change are facilitating a move towards multimodal transport – combining walking, cars, buses, bikes, trains and other forms of shared transportation. Driven by the transition from "owning" to "using", Mobility as a service (MaaS) enables multimodal mobility by providing user-centric information and travel services such as navigation, location, booking, payment and access that allow the use to consume mobility as a seamless service across all existing modes of transport.

Primarily software-driven, MaaS is the precursor of specifically-designed 'Mobility on-demand' transportation hardware and services. The transformation of transport and mobility services presents a unique opportunity to develop post-fossil, user-centric, smart systems based on access to individual, public, shared and active mobility, rather than ownership of private automobiles. This in turn requires the integration of personal electric vehicles into multi-modal public transport and mobility-on-demand systems to allow users flexible and convenient access to a range of travel modes while socialising the high initial costs of switching to electric vehicle-based mobility.

Integrated Mobility-on-Demand services can contribute to modal shift to public transport and also address the spatial inefficiencies of private individual motorised transport. User-centric urban mobility systems will provide ubiquitous check-in/check-out user access to enable both inter- and multimodal mobility on demand and enhance overall transport efficiency. In future integrated and sustainable mobility-on-demand systems, electric mobility will become a component of both power and public transport infrastructure and systems. The smart integration of tariff structures, data and user interfaces as well as the disposition of rolling stock across these sectors is a central challenge, which requires new business models and scheduling, booking, navigating, ticketing and charging solutions. Autonomous electric vehicles are expected to form a significant component of 'mobility as a service' for urban transport.

- *Smart mobility services in freight and logistics*

Significant growth in small-goods and large-goods logistics activity is to be expected; by 2050, freight activity is expected to increase by as much as 250%. Strong growth in online retailing and attendant increases in freight volumes and last mile goods delivery are leading to rising carbon emissions from road-based freight distribution. Future mobility and transport services cannot be viewed in isolation from future urban logistics. The rise in urban goods traffic will lead to further conflicts and capacity constraints on the use of urban space and thus is inextricably linked with overall transport transformation.

- *Systems, freight and logistics*

The evolution of smart systems for cooperation between infrastructures (road, rail, air, shipping) aiming at seamless freight transport will be crucial in facilitating increased capacity – from the port to the last-mile. Loading and unloading cargo that is electronically tagged (thereby carrying all required information to allow for reliable international tracking and reduced border delays) onto autonomous convoys of self-driving trucks will be aided by automated robotics systems.

Wide-scale deployment of autonomous freight shipping is imminent; increased mobile internet availability, adoption of (and developments in) Differential GPS and Automatic Identification Systems and advancements in computer vision will accelerate a transition towards crewless cargo ships and fully autonomous docks. Logistics will also become increasingly smart, as artificial intelligence advancements (such as machine learning) allow for the leveraging of data collected throughout the transport chain, rapidly identifying bottlenecks, solving path optimisation problems, and coordinating efficient flows through and across infrastructures.

It is becoming increasingly likely that many of the future smart mobility services envisaged for personal transportation - electric, autonomous, shared, and connected - will initially be developed and implemented in the goods delivery sector (i.e. logistics) which is already leading innovation in many of these areas. Given health and safety, regulatory and political concerns regarding autonomous vehicles and the application of total data and user transparency, steady-state integrated and electrified mobility-on-demand systems are likely to be deployed in freight distribution first. In this report, new

freight and logistics services and systems are reviewed against the same evaluative framework as personal transport systems regarding the potential for decarbonisation.

6.3. Short term and time-horizon 2050 actions

1. *Drones and low-altitude aerial mobility*

A rapid proliferation of drone technology is taking place due a combination of forces, such as technological transfer from other industries, 'bottom-up' open innovation practices such as accessible platforms and collaborative research and significant R&D drives from large companies looking to operate commercial drones in the retail sector.

The integration of vertical urban mobility into existing horizontal transport systems will add further complexity to the organisation of the urban transport and mobility services. Early evidence indicates that light-weight drone platforms can deliver both economic and energetic efficiencies in the short-range distribution of small good. Effective integration of drone-based delivery systems with other urban logistics, public transport and building services infrastructure is a promising innovation vector. Drone and low-altitude aerial mobility is now technically possible for passenger transport also and the combined demand for such on-demand vertical urban mobility solutions will require significant governance, regulation (esp. for the "U-Space") and infrastructure innovation.

2. *Establish better operating models*

Effective collaboration of cities, users, researchers and industry should be a central theme in the development of smart mobility technologies, solutions and systems. To meet the challenge of decarbonisation publicly owned and operated systems (such as backbone public rail and bus networks) must work in tandem with private services (such as shared electric and autonomous vehicles), all of which will utilize new technologies that will need to be developed with both public and private investment. New operating models are required to allow public transport and mobility services to collaborate effectively with private individual mobility providers in co-delivering sustainable mobility and transport systems. From a municipal and regional institutions perspective, this will require innovative approaches to cross-sectoral planning, public participation and procurement and the shared use of embedded physical and technical infrastructure.

3. *Development of integrated mobility systems*

A core focus should be to enable cities, users, researchers and industry to collaboratively devise multi-stakeholder solutions to the complex problem of mobility and to test and develop them at sufficient scale. It is in the interest of all stakeholders that the private and public sector collaborate not just on research, but on on-the-ground operations such as data sharing, network and infrastructure access, and the development of inclusive user interfaces. The burden of research and analysis should be shared by the private and public sectors, as each will rely on the other for effective technological advancement and sustainable use innovation.

4. *Sharing Data and Infrastructure*

Companies, governments and public entities should be equally encouraged to provide user and urban data collected on the use of public space and infrastructures wherever it is available (in such a way that protects the privacy of its citizens) so that users, cities, third party apps, operators, developers and innovators can access it to inform their decisions and innovate their applications. Smart mobility and cities will combine publically and privately developed infrastructures; only by making data such as aggregate dynamic mobile phone and traffic data, the real-time location of buses or the accurate arrival

time of trains 'open' will third parties be able to integrate it into their systems and establish truly 'cross-infrastructure' integrated mobility systems.

5. *Future interoperability*

Support in the development of EU Technical Standards for communication and interoperability of user devices, critical infrastructures, v2v and v2i will be vital. It is important that such standards can evolve and adapt with technologies to prevent innovation stagnation. This should encompass a dialogue between users, governments, science and industry (including both incumbents/long-term players in the mobility sector and startups). Multi-stakeholder standard setting will allow for the most intelligent standards to be adopted; such standards should not be too prescriptive (thus hindering innovation and technological developments), but should also facilitate robust privacy frameworks, decarbonisation and international interoperability to as great an extent as possible.

- *Carry out large-scale and city-led lighthouse demonstrations which:*

- lead to sustained integration of solutions into city operations at real scale (beyond small scale pilots) and at the spatial level of the daily urban system (DUS) to pursue long-term decarbonisation impacts;
- develop the strategic capacity of municipalities and regions to manage integrated transport systems and infrastructure;
- effectively integrate partners from government, research, industry and users in the shared development of future mobility and transport services and systems in real-world settings;
- contribute to the integration of new mobility service innovations with existing (public) transport infrastructure into an overall urban mobility system, allowing for optimal use of infrastructure for passenger and freight transport;

Develop and test deployment of innovative and robust arrangements for public-private co-design of transport and mobility services, addressing in particular:

- the shared and efficient use of existing physical transport infrastructures, (in particular backbone urban transport infrastructures, parking structures, delivery nodes and intermodal hubs), across public, private, passenger and freight sectors and modes;
- the secure collation, management and protection of user and city data in public and commercial open data platforms and public digital infrastructures;
- the enablement of real-time, informational, transactional and operational interoperability across public and private service providers, municipal operators and individual users;
- the innovative integration of access, tariff and user interface systems for public and private transport and mobility services.

Develop and test implementation of governance, regulatory, and public procurement strategies that:

- integrated indicators and urban plans to measure impact on transport decarbonisation and sustainable land use;
- strengthen the development of integrated planning tools and open, real-time data systems to allow for the validation and optimisation of integrated mobility eco-systems against overall sustainability targets (e.g. SUMPS);
- Enable integrated and strategic public procurement of open, interoperable and cross-sectoral solutions.