Consultation of the Horizon 2020 Advisory Groups

Response of the Transport Advisory Group

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This paper summarises the response of the Transport Advisory Group (TAG) to the seven questions listed in the '*Consultation of the Horizon 2020 Advisory Groups'* document. Each of the questions will be answered in sequence.

It is important to note at the outset that, for research purposes, transport can be defined in various ways, as an:

Activity	*involving the movement of people and goods*
Service sector	*comprising all the businesses directly involved in moving people and goods and indirectly providing ancillary support with, for example, ICT and vehicle maintenance*
Manufacturing industry	*composed of firms producing vehicles, vessels, aircraft and related equipment*
Management function	*responsible for logistics and business travel*
Infrastructure	*providing networks for the flow of passengers and freight*
Instrument of economic development	*at local, national and EU levels*
Academic discipline	*with its own literature, conferences, university departments etc*

In reviewing future research challenges and opportunities in this field, the Group has adopted a broad perspective on transport, spanning all of these definitions. Annex 1 contains a glossary of the technical terms used in this report.

Q1: Biggest challenges in the field of transport requiring immediate action.

(i) Need to refresh the transport research agenda for the second phase of Horizon 2020?

Much research is incremental, building on previous studies and gradually expanding knowledge. There are occasionally periods when paradigm shifts, the emergence of new disruptive technologies and changes in the external business, social or physical environment demand a more radical response from the research community. We believe that, as far as transport is concerned, we are now entering such a period and that transport research agendas will need to be modified accordingly. They will need to respond to several developments:

'Trend-breach': discontinuities in longer term trends in key transport variables. For example, 'peak mobility' appears to have been reached in some cities and regions, while some EU countries are exhibiting a decoupling of GDP and freight tonne-km growth.

New technology: technological developments occurring or anticipated that have the potential to be transformational – both internal to transport and in other activities that are likely to impact on transport. For example, cloud computing, the dual-carbon battery, the electrification of highways and 3D printing may prove disruptive technologies in the transport sector. Information and Communication Technology (ICT) is expanding at an explosive pace raising inter-connectivity between transport providers and between providers and users to a much higher level. Equipped with this technology a new generation of 'smart travellers' is emerging with higher expectations and new means of managing the available transport options.

New risk profiles: managing transport has become a more risky business. It is necessary to develop new risk detection and auditing methodologies for transport and to recalibrate risk factors such as extreme weather, cyber threats, energy crises etc. There has, for example, been a dramatic increase in the frequency, intensity and duration of extreme weather events in recent years imposing new stresses on transport infrastructure and services.

New concepts: likely to impact on the future planning and management of transport – both emerging from within the field and externally. For example, individual travellers and businesses are showing much greater willingness to collaborate and share transport assets, fundamentally changing the pattern of demand for passenger and freight services. Car sharing is rapidly expanding, while 'crowd-shipping' is extending the same principle into the logistics arena.

New policy perspectives and objectives: Shifts in transport policy at EU, national and global levels since the European Commission' 2011 Transport White Paper[1]. By the second phase of H2020, the last White Paper will be 5 years old a new Parliament and Commission will be in place and new transport policy initiatives launched. Delays in implementing White Paper policies (e.g. on carbon reduction in the transport sector) creates a new sense of urgency.

New life-styles: A complex interaction of demographic, sociological, employment and communication trends is fundamentally changing the way we live and this is having an important bearing on transport. Older age groups are representing an increasing share of the population and their mobility needs are evolving. Patterns of social interaction are changing with more people falling into the LAT category ('living apart together') and redefining the concept of locality in urban areas. E-commerce is also rapidly and drastically changing mobility patterns and last mile logistics. The desire for healthy lifestyles and, on the other hand, growth of obesity, is also reshaping transport demand. Life styles and associated travel behaviour are also being affected by the financial situation in Europe, environmental challenges and public perceptions of the need for socio-economic change.

New methodologies and data sources: altering the nature and scale of the transport research activities. For example, Big Data could well stimulate a renaissance in transport research.

The Horizon 2020 transport research programme for the period 2016-2020 will need to reflect some or all of these developments. It is the role of the TAG to suggest how this might be done.

(ii) Objectives of this reframing of the transport research agenda?

The TAG sees its role as advising the European Commission on the content of its future transport research programme, the research process and the later stages of the 'innovation chain' comprising dissemination, commercialisation and implementation.

As far as content is concerned, there is a need to ensure that the future research agenda:

[1] European Commission (2011) '*Roadmap to a single European transport area — Towards a competitive and RESOU RCE -EFFICIENT transport system*' http://ec.europa.eu/transport/themes/strategies/2011_white_paper_en.htm

- reflects the new developments outlined in 1. Above.
- maximises relevance to the main challenges facing the sector
- gains traction with the user community to ensure a high level of implementation
- recognises the outputs of previous research to promote continuity and avoid duplication
- exploits EU strengths in transport research
- is well-aligned with EU transport policy objectives
- breaks down traditional ‘silos’ both within transport research and between transport and cognate fields

The TAG’s review of past transport research activities suggests that the process of specifying, commissioning, managing and evaluating EU-funded transport research could be improved in several ways. This is discussed in our response to Question 4.

The results of EU-funded transport research could also be more fully exploited. They could be more widely and effectively disseminated and gain greater traction with industry and the public policy making process. Greater emphasis should be placed on the implementation of innovative solutions arising from transport research projects. We issue recommendations on this subject at several points in this document.

(iii) Definition of challenges in the context of transport research?

The term ‘challenge’ needs to be more clearly defined. It could be a threat or an opportunity. It could emerge from the public policy arena, from industry, civil society, the research community or some other stakeholder group. At the highest level it must be consistent with the EU’s overarching objective of achieving a sustainable, safe, efficient and inclusive society, with global leadership and competitiveness. At a sectoral level, the challenge must recognise EU transport policy targets, such as those contained in the 2011 Transport White Paper and modally-specific reports such Flightpath 2050 for the aviation sector[2]. Goals for 2050 include:

- CO_2 emissions to be reduced by 60% against a 1990 baseline
- Road transport safety to be vastly improved, with zero fatalities and serious injuries
- No more conventionally-fuelled cars in cities
- 40% use of sustainable low carbon fuels in aviation; at least 40% cut in shipping emissions.
- A 50% shift of medium distance intercity passenger from road to rail
- 90% reduction in NOx emissions and 65% drop in perceived noise from aircraft between 2000 and 2050
- more than 50% of road freight moving over 300 km to shift to other modes such as rail or waterborne transport

All of these targets will be extremely ‘challenging’ and the longer it takes to get onto the right trajectory the more difficult it will be to achieve these long term goals. Much of the transport research effort in the period 2016-2020 should be directed at getting the European transport system onto this trajectory.

[2] European Commission (2011) ‘*Flightpath 2050: Europe’s Vision for Aviation’* http://ec.europa.eu/transport/modes/air/doc/flightpath2050.pdf

It would be wrong, however, simply to define the challenge with respect to long term public policy objectives. In the short to medium term many other transport issues will need to be addressed and this will create a demand for new transport research. Researchers also have an important role to play in questioning the credibility and feasibility of the public policy objectives and targets that have been set for transport. This has long been an integral part of the policy formulation and review process, particularly in the transport sector where European, national and local controversies abound. If all these goals and issues are to be integrated into a single 'big challenge' that embraces the interests of all the various stakeholders, it will inevitably be defined in fairly general terms. We will attempt to define such a challenge but also supplement it with a series of subsidiary challenges to show the range of problems and opportunities confronting the European transport sector. This will be done within a conceptual framework outlined in the next section.

(iv) Conceptual framework for our review of the challenges.

The challenges can be defined within the following three-dimensional framework:

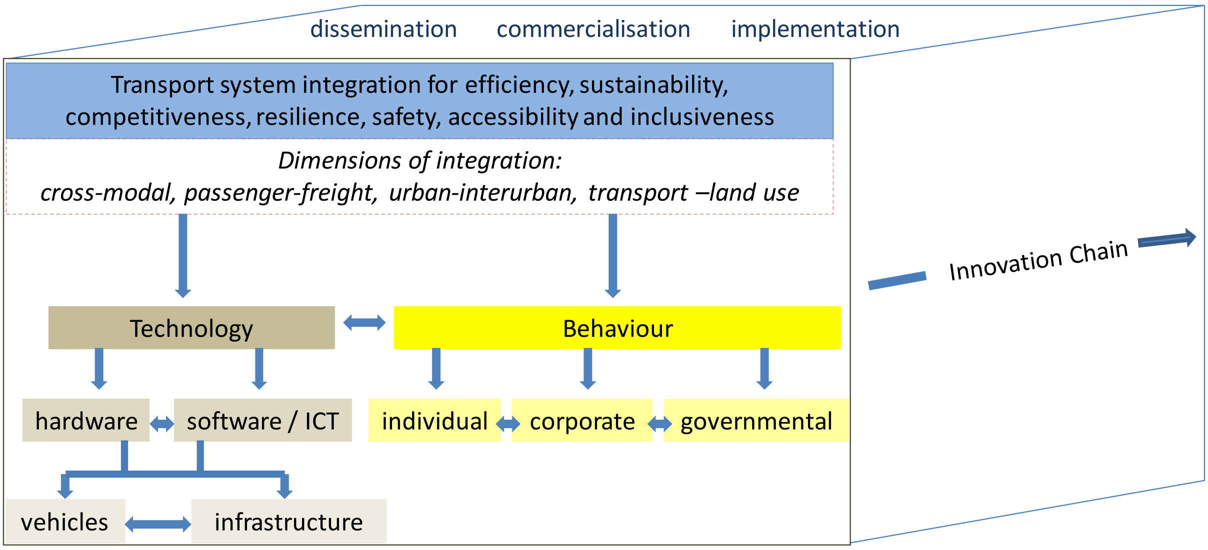

Figure 1:

In the horizontal dimension, in the blue box, is our over-riding, 'transversal' challenge which seeks to achieve greater integration across the transport sector to improve its sustainability, competitiveness, resilience, safety, accessibility and inclusiveness. The aim is to improve the integration of transport in several respects:

across transport modes: reinforcing the long term trend towards greater co-ordination of road, rail, water and air services to facilitate the transfer of people and goods between these modes. It is widely acknowledged that inefficiencies dwell at the inter-modal nodes. Optimal co-ordination of modes is also hampered by 'silo' management of each mode and the lack of integrated multi-modal information platforms. Inter-modal optimization requires a higher degree of integration with the primary goal of improving customer service.

between passenger and freight movement: recognising the interdependence between the movement of people and goods, particularly urban areas, and the need to devise more holistic models of order and service fulfilment that optimise personal and freight movement as a single system.

between urban and inter-urban transport: the interfaces between urban, inter-urban and rural transport services are often poorly planned and managed and so need to be upgraded.

between transport and land-use: despite major advances in land-use / transportation planning over the past few decades, it can still be used more effectively as an instrument of transport demand management. It should lie at the heart of future attempts to redesign urban areas, as the zoning of land uses can 'lock-in' particular patterns of personal and freight movement for the longer term.

In the vertical dimension are the developments and interventions which can help to meet the over-riding challenge. They are split into two broad categories, those with a strong technological emphasis and those relating more to the behaviour of individual travellers, businesses and the government agencies. Although presented as separate categories, the interaction of technology and behaviour is often critical. The technology category is sub-divided, initially into hardware and sortware, and, on a lower tier, by its impact on infrastructure and vehicles. Again there are important interactions among these various components.

A third dimension has been added to represent the 'innovation chain' through which ideas emerging to meet the various challenges must pass as they proceed from inception to implementation.

(v) The key challenges:

In its deliberations, the TAG has identified eleven major transport research challenges:

a) Addressing the nexus of problems affecting urban transport (including congestion, pollution, accidents and inaccessibility) and using transport as an enabler of urban renewal.

b) Achieving the required level of climate change, air pollution and noise mitigation in the transport sector

c) Managing the impact of demographic trends and, in particular, the ageing population

d) Effectively harnessing new transport -related ICT technology and data management opportunities (see Annex 2)

e) Measuring and managing uncertainty and risk in the transport system, particularly associated with high-impact low probability events.

f) Making the transport system, and in particular infrastructure, more resilient to extreme weather

g) Reducing the loss of life and adverse health effects associated with transport

h) Reducing transport's dependence on fossil fuels through improvements in energy efficiency and a switch to alternative energy sources.

i) Enhancing the competitiveness of European transport manufacturers and service providers in global markets.

j) Deploying innovative technologies, materials and processes to overhaul the system of infrastructure maintenance.

k) Maximising resource utilization across the transport sector.

These challenges have not been listed in order of importance. They are all closely inter-related, with some having a much broader scope than others. Figure 2 illustrates the inter-relationship and scopes by means of a Venn diagram. This identifies challenges e), g) and i) as all-embracing and shows how addressing transport problems at an urban scale will require research to address a series of related challenges. Research on some challenges would be mutually-reinforcing such as that on b) and h).

At a higher level all of these challenges can be subsumed within the transversal challenge in Figure 1 and could be partly addressed by greater integration of transport across the four dimensions listed. High-level integration can also be supported by a range of new technological and behavioural developments occurring in the vertical 'pillars' of the framework diagram. Figure 3 gives examples of fertile areas of technical innovation that could reach market deployment in 5-7 years. Most of them are transport-specific, though the transport sector is also likely to be strongly influenced technological advances in other sectors and the nature and scale of these impacts will need to be investigated.

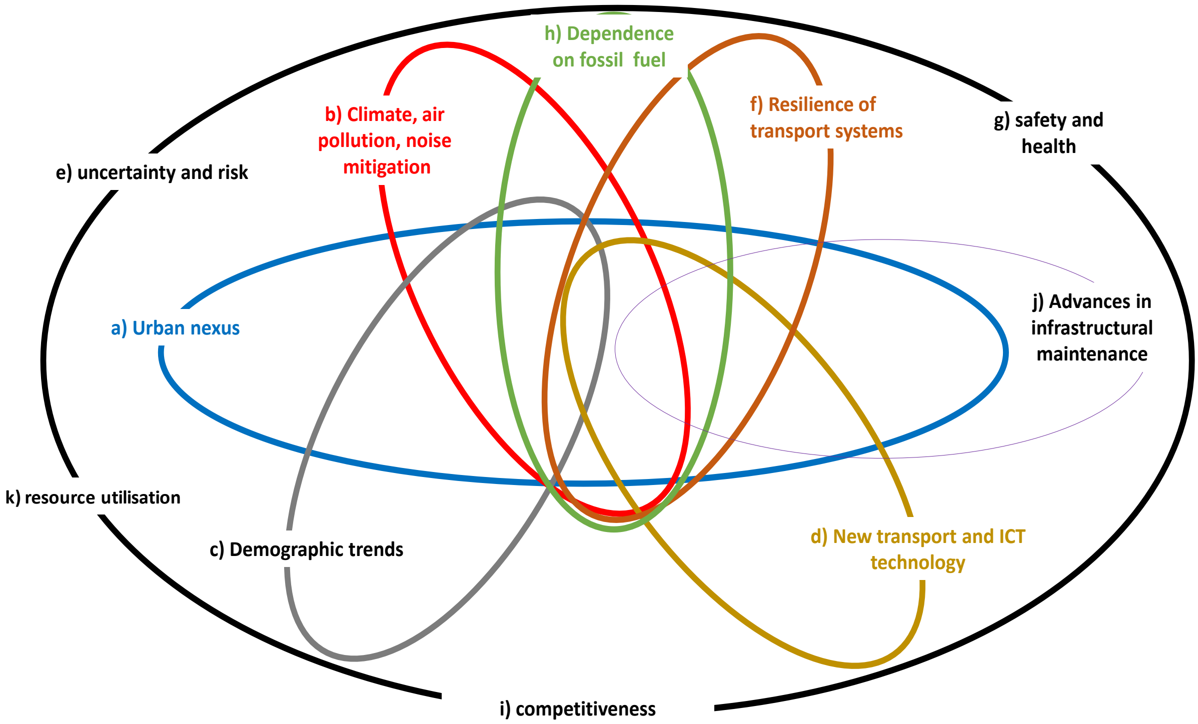

Figure 2

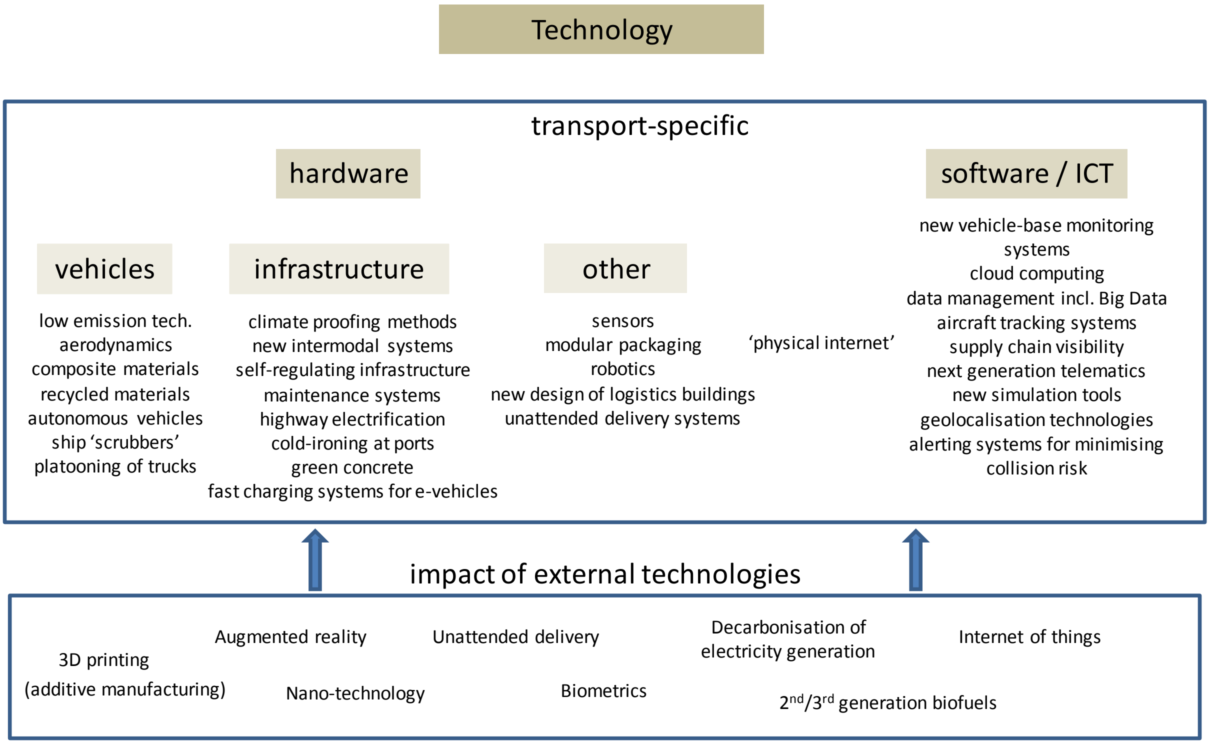

Figure 3

Figure 4 similarly provides a more detailed breakdown of major 'behavioural' challenges upon which the transport section of H2020 could usefully focus upon from 2016 onwards given their likely market impact over the next 5-7 years.

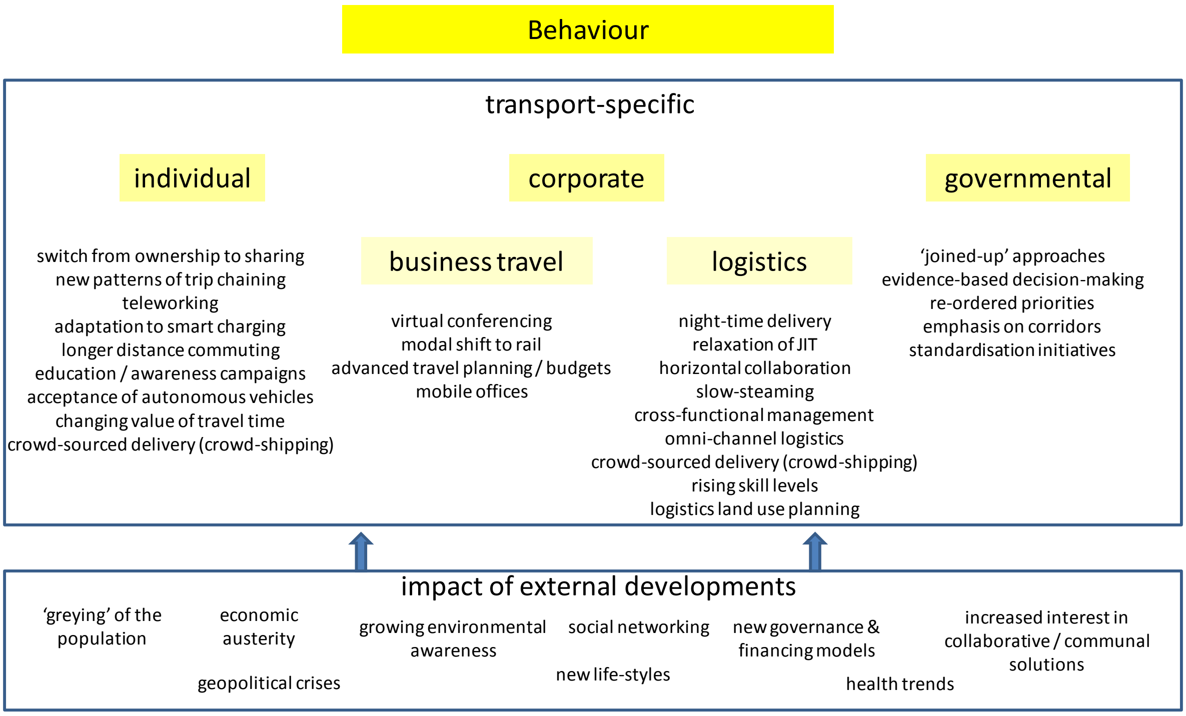

Figure 4

(vi) Types of research that will be required to address these challenges

To meet these challenges, many different types of transport research will be required. The TAG proposes the following taxonomy to illustrate the required diversity of future H2020 transport research and help the Commission to frame its future H2020 transport calls:

Technology-driven research: focused on the development and exploitation of new transport technologies and embracing many scientific disciplines. This can range from exploratory / pioneering research to the refinement of well-established technologies This category also includes studies of the impact on transport of technological developments occurring in other sectors.

Trend-breach studies: evidence of changes in key transport trends merit new investigations to explore their causes and future impacts. Transport scenarios constructed in earlier studies will need to be revised or replaced.

Issue-focused research: as the transport policy-making process evolves new issues arise which require research to establish a firm evidence base.

Methodologically-innovative studies: with the emergence of new data collection methods and / or analytical tools established fields of transport research can be re-examined in a fresh light and in greater depth.

Policy-evaluation studies: there is a constant need for research which assesses the efficacy of previous transport policy initiatives and planning measures.

Research-implementation studies: these can monitor the adoption and impact of previous research outputs, assessing the longer term worth and improving understanding of how best to exploit transport innovation.

Cross-disciplinary research: closer collaboration with researchers in cognate disciplines can help transport specialists gain new perspectives and investigate more fully the inter-relationship between transport and other socio-economic and physical phenomena. This applies particularly to interaction between transport technologies and human behaviour and the nature and scale of public adaptation to and acceptance of transport innovations.

Geographical-diffusion studies: these studies can support the dissemination of good practice in transport planning, logistics management etc across the EU by assessing its applicability in different geographical contexts. Such studies involve close co-ordination between research activities at different spatial scales.

Extra-EU collaborations: it is important to have high levels of cross-fertilisation between transport researchers in different parts of the world. Horizon 2020's transport programme must therefore be responsive to changing research agendas outside the EU and opportunities for international collaboration.

(vii) The Innovation Chain: This chain, as it relates to transport, was examined in detail for the EU's Strategic Transport Technology Plan, published in 2012[3]. It often contains weak links which prevent transport innovations achieving their full potential in commercial, social and environmental terms. Sometimes the problem lies at the start of the chain where an emphasis is placed on ideas likely to yield quick return on investment at the expense of more costly, large-scale projects which, in the longer term, could potentially prove transformational. *Ex ante* appraisal methods should therefore be critically reviewed and adapted, partly to reflect the shortage of public funds but also the need to identify and experiment with innovative financing mechanisms. Greater effort could be made to measure the Technology Readiness Level (TRL) of transport innovations, following the procedures originally devised by NASA and now widely applied in industry. All the main stakeholders, including industry, universities and other research centres should be actively involved in this process to provide realistic assessments of the likelihood of innovations progressing through the chain from inception (TRL1) to implementation (TRL9) and particularly across the so-called 'valley of death'. If subjected to such assessments, many of the technological and behavioural innovations listed in Figures 3 and 4 would probably be judged to offer good implementation potential by 2020.

Q2: Key assumptions underpinning the choice of challenges and themes

Many of these assumptions have been implicit in the TAG's discussions rather explicitly itemised. They fall into several categories:

1. *Assumptions relating to wider political, economic, social, technological, environmental and legislative (PESTEL) trends, which will strongly influence the transport sector but which the TAG has taken as given*. Transport is a derived demand, dependent on activities in other sectors. The TAG has had to make assumptions about how this demand will be affected by these external developments. Major examples of such developments are the demographic trends outlined above, a strengthening commitment to decarbonise the European economy, intensifying pressure to cut air and noise pollution and a continuing growth of online retailing.

2. *Assumptions about continuing adherence to public policy objectives relating specifically to transport and more generally to research and innovation in the EU.* These objectives can be found in official documents relating to the 2011 Transport White Paper, the Lisbon agreement and the Innovation Union.

3. *Assumptions about the effectiveness of the research and innovation 'value chain' in ensuring that a high proportion of research outputs find a practical application in transport planning, operations and policy-making.*

4. Specific assumptions about the principles governing the planning and management of transport: many of these principles are deeply embedded and unlikely to change in the foreseeable future: e.g. high degree of personal freedom in choice of transport mode and service, pursuit of inter-operability between transport modes, co-ordination of land-use and transport planning, the goal of transport planning should be to maximise access rather than mobility.

5. *Specific assumptions relating to the nature of transport research*: such as the need for inter-disciplinary perspectives and methodological diversity, continuation of the consortium-model of research funding etc.

[3] European Commission (2012) '*Scientific Assessment of Strategic Transport Technologies*' http://ec.europa.eu/transport/themes/research/sttp/

Q3a: What output can be foreseen and what will be its impact?

Presumably this is the 'output' of the research on the 'big challenges' identified in our answer to Q1 and the innovations that would flow from it. The 'output' and 'impact' will clearly depend on the nature of the research. At an aggregate level, we would expect the research to promote greater integration of transport along the axes we have described and thus make the European transport system more efficient, sustainable, competitive, safe etc. We would also expect the transport system to be on a trajectory to meet the 2030 and 2050 targets set out in the 2011 Transport White Paper. Major outputs of the research would be a series of roadmaps plotting the future course in key transport parameters such a modal split, energy efficiency, road casualties, vehicle loading etc. This could be supplemented by the construction and updating of scenarios showing the nature of transport operations in different visions of the European economy and society in 2030 and 2050.

H2020-funded research should not only project transport futures, but also seek to influence them in various ways. If research on the themes we have identified is successful it would also yield tangible outputs in new implementable technologies, information systems and business practices. Some of these outputs would be evolutionary, representing refinements to existing technologies, systems and practices, while others could be more revolutionary, in offering a step-change in performance. These will be discussed in our answer to Question 5. In addition to these 'supply-side' outputs, we would envisage the results of the research altering the 'demand-side' of European transport, by promoting changes in people's travel behaviour and the 'logistical' behaviour of companies.

A good measure of the H2020 transport programme's impact will be the extent to which practitioners and policy-makers feel that it has represented a good investment of EU funds. Assessments of this 'return on investment' will have to consider improvements both to the efficiency, quality and sustainability of transport within Europe and to the EU's standing in the world as a source of transport innovation, know-how and best-practice.

Q3b: What are the opportunities for international linkages?

In the field of transport, there is already a great deal of research collaboration both across EU member states and externally with other parts of the world. There, nevertheless, exists excellent potential to extend and deepen this collaboration. A future role for the TAG would be identify those areas of transport research where new opportunities for external collaboration are greatest and likely to be most productive. In many cases, this would involve strengthening links with research teams in countries that already have a good reputation and where there are obvious synergies. The current collaboration between the EU and US TRB, which has already promoted trans-Atlantic research interactions in the fields of city logistics and transport research implementation, provides a good illustration of how this can be achieved. In some cases, international links could be with transport research communities in non-EU countries at an earlier stage in their development, partly to provide support but also to assist the dissemination of EU know-how and commercialisable IPR.

The Transport Research Arena (TRA) conference, which is strongly supported by the European Commission, is central to EU transport research dissemination and has the potential to grow into a truly global event. This would give the results of European transport research much wider exposure and foster links with research activities outside the EU.

Q4: Bottlenecks, risks and uncertainties and how might these be addressed?

We take the word 'bottleneck' here to mean a barrier or constraint. The type of barrier will partly depend on the nature of the research: e.g.

1. *empirical research*: perennial problem of gaining access to sufficient data. This may be partly relieved by Big Data, cloud computing, use of smart phones for tracking / travel diaries and advanced telematics, though will require the owners of this data to make it available for research purposes in anonymised and aggregated form. The incompatibility of available data bases is also a barrier.

2. *vehicle technology* – where the risk associated with the development of a particular technology is too high or too difficult to quantify for industry to make the necessary investment. Gaining certification for new technologies can also be an inhibitor.

3. *simulation modelling* – again this is exposed to the risk of insufficient real-world data being available to calibrate the models, with a resulting loss of realism. This problem afflicts simulation at both the macro-level, at which transport and logistics systems are modeled, and the micro-level at which new vehicle technologies are tested. The effectiveness of the research programme in general can also be constrained in other ways: e.g.

- Its fragmentation into too many small projects
- Researchers merely 'paying lip-service' to dissemination and exploitation
- Project assessments being too narrowly focused and not always relevant
- Some outputs being too 'academic' and not sufficiently attuned to the real-world of transport
- A fundamental disconnect between research and transport decision-making processes in government and business.
- Implementation of innovative solutions can conflict with existing rules e.g. on public procurement.
- Lack of standardization and poor alignment of certification systems for new technologies
- Deficient funding mechanisms for financing the implementation of research outputs
- Gaining social and business acceptance of solutions and technologies emerging from the research.

The TAG believes that these constraints could be eased in several ways:

- Promoting regular dialogues between researchers, policy-makers and practitioners to define and review transport research agendas
- Establishing permanent focus groups, comprising researchers and the various user groups, to ensure continuing stakeholder engagement
- Creating opportunities for researchers to spend short periods in government offices and businesses thus gaining first-hand experience of the decision-making processes they seek to influence. This could be conducted on an exchange basis, with government officials / managers spending time with research groups. Similar exchanges could occur between research centres specializing in different aspects of transport.
- Reforming the process of R&I project assessment, partly to take more account of past feedback from the user community.
- Redefining the criteria used for the selection of large transport projects, recognising that the project with the greatest innovation potential need not be the cheapest.

Research is an inherently risky process for everyone involved. Research funding organisations are sometimes accused of not being sufficiently adventurous and overly risk averse. If, as the introductory section suggested, transport research is likely to undergo a significant change, both in content and process, in the second half of this decade it may be necessary to support more projects that are inherently more risky, but offer potentially greater rewards. The research challenges and themes that we have identified are exposed to several risks, such as:

- Big Data may have less impact on transport research than expected (for example, in a 2013 report the US consultancy company Gartner[4] positioned Big Data at the 'peak of inflated expectations' in its 'hype cycle' graph)

- The willingness of transport infrastructure and service providers to collaborate and co-ordinate their activities may be much lower than expected

- The growth in transport asset-sharing by individual travellers and businesses, upon which several of our suggested research themes are predicated, may prove a temporary phenomenon and not a longer-term 'gamechanger'.

- Uncertainty about future public policy on transport may discourage private investment in technologies and services.

Applicants for research funding could be asked to provide more explicit risk assessments and evaluators instructed to attach greater weight to risk factors in their assessments. The level of risk must clearly be related to the TRL level and balanced against the potential rewards.

There is also a need for improved methods of assessing risk in the appraisal of transport projects and making it more visible to decision-makers. In this assessment statistically quantifiable risk can be distinguished from risk arising from so-called 'unknown unknowns' that do not lend themselves to statistical analysis. This would be a fertile area for future research in an ever-more volatile and turbulent world.

Q5: Knowledge gaps, game-changers and the role of the public sector.

The perception of transport knowledge gaps will vary between stakeholders. For instance, much university-based research is carried out on gaps that academics regard as important but may be of little interest to policy-makers and managers. As EU-funded research is more pragmatic it needs to be oriented towards gaps which if filled will yield real economic, social and / or environmental benefit.

Major knowledge gaps in the transport sector include:

- Lack of reliable forecasts of future trends in key external variables, particularly oil prices, technology adoption rates and climatic conditions
- Relationship between current social trends and the longer term demand for transport infrastructure capacity
- Absence of data on the utilisation of the available carrying capacity in freight vehicles and containers
- Poor understanding of rebound effects from efficiency improvements in the transport sector
- Lack of life-cycle analyses of energy use by and emissions from vehicles, infrastructure and transport services
- Effects of fully internalising the environmental and social costs of transport
- Role of vested interests in the shaping of transport policy at local and central government levels
- Prospects of autonomous vehicles becoming widely used and the resulting economic, social and environmental effects.
- Types of institution / governance architectures that will be required to exploit the benefits of Big Data and cloud computing in the transport sector.

[4] http://www.gartner.com/newsroom/id/2575515

Many of the changes observed in the transport sector are incremental reflecting a gradual uptake of improvements in technology and management practice. In its deliberations, however, the TAG has identified a series of potential game-changers for the transport sector. Several of the developments listed in Figures 2 and 3 would qualify for this status, such as:

- Crowd sourcing of vehicle-based traffic data for congestion management and navigation
- Application of internet principles to the movement of freight in the so-called 'physical internet'
- New business models for sharing cars, vans and bicycles in urban areas (for both people and goods)
- Application of new gain-sharing techniques to promote logistics collaboration across the supply chain
- New long-life, 'self-healing' systems for maintaining transport infrastructure
- Proliferation of reception boxes at homes, shops and offices to permit widespread unattended delivery
- More effective use of insurance pricing to incentivize the uptake of safety measures and equipment.

Many game-changing innovations relate to the supply-side of transport. One should not overlook the possibility of demand-side changes also proving transformational as personal travel behaviour and the logistical decision-making of businesses experience a period of rapid change. Major advances in ICT are inducing a combination of supply- and demand-side changes that the TAG has subsumed under the heading 'smart mobility solutions'.

<u>Smart Mobility Solutions:</u>

The development and implementation of these solutions will be a fertile field of transport research in the second half of this decade. Key components of these solutions will be:

(i) Vehicle sharing

Vehicle sharing includes car/bicycle sharing (multiple users of one vehicle, no ownership) and car pooling (sharing rides). Global membership of car sharing services is rising steeply, with 12 million people expected to be part of a car sharing system by 2020 on a global level. Car sharing not only responds to a demand for more flexibility; it also promotes a wider use of multimodal transportation and helps to ease traffic congestion. It is estimated that for every car entering the car sharing pool, four to ten cars are removed from the streets. The resulting environmental improvement would be even greater if electric car sharing were adopted. Given the large potential car sharing, this is a very promising area for future transport research, on topics such as:

- Impact of car sharing on personal vehicle ownership and use of other modes of transport
- Role of car sharing within integrated mobility programmes
- Development of models for real time multimodal travel information systems
- Impact of the growth of electric car sharing on the demand for electro mobility
- Implications for logistics of the growth of crowd-sourced deliveries / crowd-shipping.

(ii) Smart traffic / transit management

Under this heading fall several ICT-driven developments:

- Adaptive centralized traffic and transit management systems that deliver real-time visibility across the entire transport network
- Tunnel management, emergency management in sensitive areas
- Enhanced predictability of traffic information based on the analysis of Big Data
- Installation of smart street furniture

(iii) Interoperable mobility systems across Europe

Advances in ICT and wider adoption of standards are raising inter-operability to a new level:

- Tools and systems (such as smart cards for transit and bike/car sharing) operable across different European cities
- Universal mobile electronic toll systems

(iv) Dynamic allocation of resources in the transport system

This can take several forms:

- Multi-use of mass transit infrastructure (e.g. peak hours: mass transit; off peak hours: car sharing)
- Smart charging stations, V2G (Vehicle to Grid), Vehicle to Home, Vehicle to Building energy transfer systems

(v) Smart vehicle / fleet management

Innovative developments under this heading include:

- Exchange and management of vehicle performance/maintenance data from the web/cloud
- Dynamic rerouting of urban delivery vehicles using real time traffic information

Research is also required on the technical, legal and economic issues raised by the entry of new online peer-to-peer services in the taxi (e.g. Uber) and logistics (e.g. Shippies) market.

<u>Role of the public sector</u>:

The public sector comprises a huge range of organisations with widely varying involvement in transport and ability to influence the course of transport research. It is therefore difficult to generalize about its role in plugging knowledge gaps and exploiting 'game-changers'. A few points are worth highlighting, however:

- Public procurement could be used more effectively to trial transport and logistics innovations and accelerate their update
- Government agencies play a vital role in collecting transport statistics which are the life-blood of research in this field. They should be aspiring to increase the quantity and quality of such data,

taking advantage of new opportunities afforded by developments in ICT, Big Data, cloud computing etc. It may be necessary for government bodies to put new governance structures in place for the use of Big Data in publicly-funded transport research projects.

- By improving standardization and certification, public bodies can create more favourable conditions for the adoption of new transport solutions, though they must be careful not to stifle innovation with overly restrictive regulations.

Q6: Exploiting the EU knowledge-base and engaging industry and SMEs?

Several decades of EU and national government funding of transport research has established a solid 'knowledge base' in most aspects of the subject and helped EU research teams, in universities, industry and consultancies, gain world leadership in major fields

More effective leveraging of the transport knowledge-base would enhance the international competitiveness of transport-related businesses. EU transport research centres also market their services directly to non-EU clients and could expand this business, possibly by working more collaboratively. Joint research with transport specialists outside the EU can also yield valuable spinoffs through the intensification of research efforts, sharing of best practice and access to business and government networks in other countries. The EU-US (TRB) collaboration on transport research, mentioned earlier, has demonstrated the value of such external links.

Our response to Q4 suggested various ways of getting industry more closely engaged in the transport research process. Getting SMEs more actively involved can be difficult given their more limited resources, though greater effort could be made to incorporate 'micro SMEs' into research consortia.

The development of electro-mobility is creating new opportunities for SMEs manufacturing and repairing new forms of equipment, servicing vehicles and maintaining the recharging infrastructure. Future research could explore the potential for promoting regional clustering of SMEs specializing in the development, production and maintenance of electric vehicles.

Q7. Integration, cross-cutting activities, co-benefits and inter-disciplinarity.

Integration is fundamental to the major research challenges that we have proposed, in three respects. First, the core challenge of making transport more sustainable, efficient, inclusive and safer embraces the economic, social and environmental aspects of the subject. Second, this goal will only be achievable if there is greater integration <u>within</u> the transport system between modes, across traffic types, at different spatial scales, between infrastructure and services etc. The TAG discussions have confirmed that, in the field of transport, there is excellent potential for framing research in a way that tackles several related problems simultaneously. Indeed there are probably few areas of transport where improving one activity does not yield 'co-benefits' in other areas. The aim must be to define transport research themes and topics in a way that maximises these co-benefits and synergies. This might entail modifications to the metrics currently used to measure the performance of transport systems; for example, prioritising accessibility over mobility and providing a more holistic assessment of transport externalities. It might also require the development of new business models and value chains within the transport sector, as for instance in the development of electro-mobility systems in urban areas yielding a stream of economic and environmental benefits.

The third type of integration strengthens the links between transport research and research on closely related activities such as energy, ICT, materials, manufacturing, retailing and the provision of public services. In the case of energy, for example, transport is both a major consumer of fuels and critical to their exploitation, processing and delivery. The transformation of the energy supply system to cut carbon emissions and improve energy security will have a dramatic and far-reaching impact on transport. This will require much closer research collaboration between transport and energy specialists.

Transport research is intrinsically multi-disciplinary, attracting specialists from many different fields, particularly economics, engineering, mathematics / operations research, planning and management. There could, however, be greater interaction and collaboration among these various specialists in joint projects. Although they publish in the same journals and attend the same transport conferences (like TRB, TRA and WCTR), the degree of 'cross-fertilisation' is much less than it could be. Past EU transport research programmes have facilitated this interaction and this process should be continued during H2020.

Transport research can also be made more inter-disciplinary in another sense by encouraging 'mainstream' transport researchers to work more closely with specialists in cognate fields to explore the close relationship between transport and related activities; for example, with sociologists in the area of transport and social inclusion and with production management specialists in the area of freight transport scheduling. Promoting this form of inter-disciplinary co-operation can be more difficult as these groups of specialist tend not interact in the same research forums. In the latter stages of H2020 efforts should be made to get transport researchers out of their disciplinary 'comfort zones' and encourage them to form new alliances with specialists in cognate fields.

Conclusions

As a result of a number of inter-related developments the time appears to be ripe for a fundamental review of the objectives, approaches and content of transport research. This needs to be reflected in the transport programme devised for Horizon 2020 over the period 2016-2018. This document provides advice on both the structuring and delivery of this programme. It summarises many hours of stimulating discussion by members of the TAG on the questions posed in the consultation document.

The first and most important of these questions is what will be the major challenges for transport research to address in the second phase of H2020. We have devised a three-dimensional framework within which these challenges can be identified and inter-related. We have listed eleven major challenges (p.7), though do not attempt to rank them in order of importance. Any ranking would partly reflect the interest and experience of the mix of people in the TAG. Arguably of greater importance are the broader research perspectives within which these challenges can be tackled. Four deserve particular mention:

- *Need for research to focus on the interfaces between transport technology, social acceptance and behavioural change*. The technological and behavioural developments listed in Figures 3 and 4 should not be seen as two separate research domains. On the contrary, the interaction between these developments is fundamentally reshaping travel demand and the way companies plan and manage their logistics systems. This interaction is complex and not well understood. It merits a good deal of attention in the next stage of H2020. This research would be intrinsically inter-disciplinary and bridge the traditional divide between science / engineering and social science.

- *Emphasis on integration and the dismantling of the various silos that have traditionally existed in transport research*. A multi-dimensional concept of integration lies at the heart of our conceptual framework (Figure 1), promoting studies that are cross-modal and link personal and freight movement, transport and land–use and transport operations at different spatial scales. It is at the urban scale that most of the eleven challenges intersect and so we would recommend that much of the H2020 transport research in the period 2016-2018 be urban focused and holistic in its approach.

- *Exploitation of the wealth of new data likely to become available to transport researchers over the next few years*. The proliferation of sensors and smart phones, social networking, the internet of things, Big Data, advanced telematics, cloud computing etc. will all create massive new opportunities for empirical research and simulation modeling in the field of transport (Annex 2). The Horizon 2020 programme must incentivize transport researchers to take full advantage of these new opportunities.

- *Broader definition and assessment of transport externalities*. The term externality is traditionally associated with an adverse impact on the environment, and transport is undeniably the source of many such impacts. The impact currently and rightly attracting the greatest research interest in transport circles is climate change. As transport's share of total EU carbon emissions is steadily rising, climate change mitigation should remain an important transport research theme, though it needs to be complemented by more work on the impact of extreme weather on transport systems, the adaptation of these systems to climate change and the inter-relationship between mitigation and adaptation efforts in the transport sector. The wider social and environmental co-benefits accruing from climate-related measures also need to be more fully investigated in future studies. More generally, future research should not overlook the many positive externalities that result of transport developments in the form of economic growth, employment, social cohesion and international competitiveness. The traditional cost-benefit methodologies that are widely applied by transport researchers to assess all these externalities need to be re-evaluated and upgraded, particularly as they underpin much governmental and corporate decision-making in this field.

Finally, if we were to sum up our recommendations in a single headline, it would be that future transport research promotes:

Smart, integrated and sustainable transport that focuses on the needs of personal and business users

Annex 1: Glossary of terms used in the report

Augmented reality: superimposition of a computer-generated image on a person's view of the real-world.

Automotivity: Portion of the mobility and transportation that is executed by car. The overall level of automotivity results from the combination of: the land use and geographical distribution of activities and residences; the body of policies and regulations in transportation; the offer of transportation infrastructure, services and vehicles available in all modes, and; the socio economic architecture that underpins users' needs, preferences and demand.

Autonomous vehicle: a computer-controlled *vehicle that does not allow pilot/driver intervention in the management of the flight/driving.*

Big Data: data sets that are too large and complex to be manipulated and analysed with conventional data management tools

Cold-ironing: connecting ships to dock-side energy supplies in ports to enable them to shut down fuel-burning engines and thereby reduce local pollution.

Cross-modal: a research perspective which covers several transport modes

Crowd-sourced delivery: also known as 'crowd-shipping': This is where ordinary citizens, often linked through social networking sites, individually or collectively organise the delivery of parcels, usually in the normal course of their personal travel. It is another example of people sharing transport capacity, in this case for freight rather than personal movement.

Decarbonisation of Transport Reduction of the carbon footprint of transport resulting from a combination of; an improved efficiency of combustion engines used for transportation; an increased use of renewable energy, improved vehicle loading and a modal shift to lower carbon transport modes.

Electro-mobility: switch to electrically-powered vehicles.

Externalities: changes of welfare generated by a given activity without being reflected in market prices. They may be positive (benefits) or negative (costs). A cost (benefit) is external when it is not paid (enjoyed) by those who have generated it. Negative externalities from the transport sector are mainly originated by: Air pollution, Greenhouse Gas emissions, Noise emission, Accidents and Congestion. Additional negative externalities include Visual Intrusion, Severance Effects, Loss of Biodiversity. In some cases (accidents through insurance, greenhouse gases through carbon taxes, etc.), these externalities can be partly or totally internalised (by application of the "user pays" principle). Research in general, and transport research in particular, generate positive externalities (spillovers) inasmuch as the knowledge gained through research in a given area benefits other areas. In the case of transport, spillovers can happen between modes, but also between transport and other research areas.

Green concrete: concrete whose production, distribution and use meets high environmental standards.

Horizontal collaboration: collaboration among companies at a particular level in a supply chain to share vehicle and possibly warehouse capacity to improve utilization and cut costs and emissions.

Innovation Value Chain The process by which the new technology and innovation emerging from research in a research facility, are used to develop new innovative products which are effectively brought to the market where they generate new opportunities and innovative practices.

Interdisciplinarity (or cross-disciplinarity): interaction between several disciplines towards a commonly recognized objective, with each discipline following its own methods and approaches. The added value is in the cross fertilization along the process

Inter-modal services: services which allow travelers or freight to transfer between several modes during a single journey

Internet of things: connecting physical objects, such as electrical appliances, to the internet.

JIT: Just in time. Management practice through which the delivery of goods is done just in time for distribution, thereby reducing the need for inventory and warehousing, while also allowing for continue adaptation to evolving demand. JIT represents a considerable challenge for the transport sector, since it does not allow for taking into account delays, special or extreme events, reliability through robust and redundant networks, congestion avoidance, environmental concerns..

Multidisciplinarity (or pluridiscipliniarity): juxtaposition of several disciplines, each targeting its own objectives and adopting its own methods. Results are then assembled, compared and interpreted, to the extent possible, in a joint perspective

Multilocality: represents a social pattern where individuals have relationships through virtual medias and belong to social groups which are in a number of separated locations, resulting in a multilocal sense of identity and belonging.

Omni-channel logistics: logistical systems that can flexibly and cost-effectively deliver orders received through various channels to locations the customer specifies (e.g. a shop, home, workplace, collection point etc)

Physical internet: applying the principles of the internet to the movement of freight, enabling consignments to be routed more flexibly to absorb available transport and warehousing capacity.

Platooning is a method of grouping vehicles to increase the capacity of roads and reduce fuel consumption. The proposed technology of highway platooning would decrease distances between vehicles using electronic, and possibly mechanical, coupling while enhancing safety by allow vehicles of a platoon to accelerate or brake simultaneously.

Ship 'scrubbers': devices attached to vessel exhausts systems to remove noxious gases, principally sulphur dioxide.

Slow-steaming: practice of operating ships (mainly deep-sea container vessels) at speeds 15-20% below the normal speed (of around 24 knots) primarily to save fuel.

Telematics: application of advanced information and communication systems to vehicles, infrastructure and the links between them

Transdisciplinarity: integration of several disciplines at the outset. Goals are defined jointly and new methods are devised and applied based on the integration of existing (disciplinary) knowledge and experiences.

Trip-chaining: where travellers combine trips for different purposes in a single journey.

Unattended delivery: delivery of goods to an unmanned reception box at a home, office, shop etc.

User A transport user is a person, a household, any other group of people or a business constituting an economic agent, with a transport or mobility need, and performing a transport or mobility activity.

Annex 2: New Data Management Challenges in the Personal Travel Market

Ever more data gets generated and used in the transport sector. This data gives for instance valuable information about individual and collective behaviour, about the performance of specific individual transport systems, infrastructures and vehicles, travel patterns and traffic flows, incidents and disruptions.

Consumers demand and expect an increasingly flexibility for their mobility and travel. The collection and the use of data respond to this trend, enabling increased tailoring of the transport and travel service offering and of related services. Further to the fields of mobility and traffic management, information is also critical for the delivery of travel support services, in fleet and infrastructure management and for the provision of remote traveller and vehicle services.

Important challenges for data management include an appropriate access control to the generated and gathered data and the resulting benefits to society. Open data policies and open platforms, data ownership, data access costs, user acceptance, data security, data integrity, data confidentiality and data privacy are all part of efforts required to develop appropriate access control over transport data.

Access to data and open platforms: The ability to develop high quality transport offerings as well as transport related services is highly dependent on the availability and accessibility - in some cases in real time – of data. The control over both individual and aggregated data in many ways determines the control over the competitive environment, the service offer and demand. Further research should help to analyse in how far free competition in the market, consumer choice and the related societal benefits can be enhanced through open data policies and open data standards and platforms.

Data rights and obligations: Consumers and companies are generally uncertain about their rights and obligations in terms of data ownership, data collection, data storage and data processing. Research into the gathering and use of data in the transport sector should help clarify the current legal uncertainties, which are hampering the development of connectivity and further deployment of intelligent transport systems.

Data and access security: The rising connectivity in transport and the related openness of data systems and networks tend to increase the risks of unauthorised access and hacking. Considering the vulnerability of transport systems and the potential hazards that malicious entry may cause, more research should be directed at better understanding specific threats to transport systems as well as proposing and developing ways to address them, without compromising the connectivity trend and its benefits.